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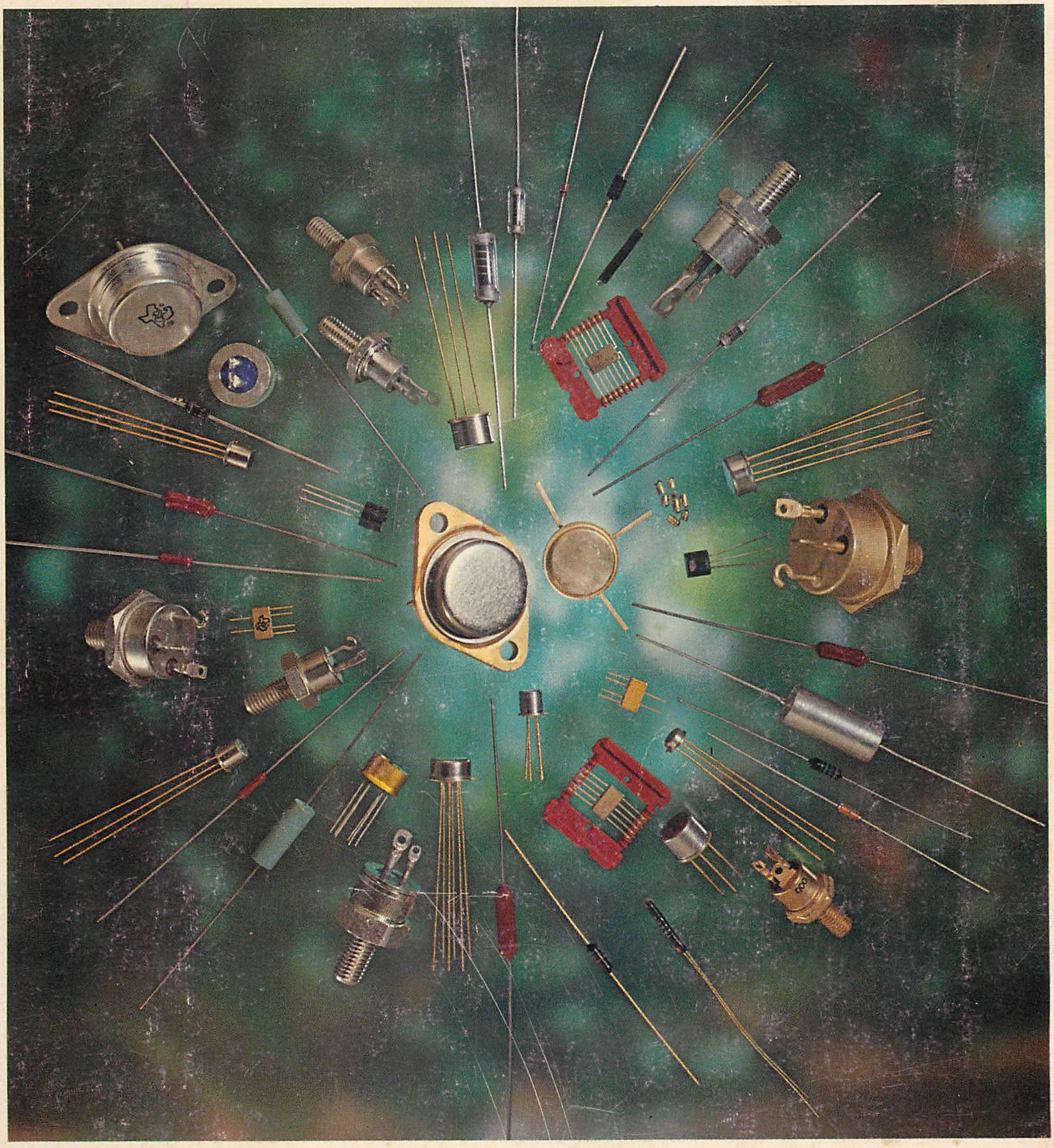
Bulletin CC101

Preferred Semiconductors and Components from Texas Instruments

a selection of popular, readily available discrete semiconductors and components for new and present circuit designs.



A TOTALLY NEW KIND OF CATALOG

Here's how to use it:

TI makes more than 14,800 different types of standard and special discrete semiconductors and passive electronic components. But this catalog includes detailed specifications on only 289.

Months of computer demand analysis reveal that these 289 types will meet the vast majority of your requirements. They are workhorse devices — customer preferred devices — all in wide use today, readily available from distributor or TI stocks, and in volume production that spells low prices. By specifying preferred TI products, you save design time, reduce purchasing costs, cut inventory requirements, and increase the certainty of on-time delivery. That makes this the most helpful semiconductor catalog you've ever used.

Preferred products are readily identifiable by their **bold numbers** at the top of the first page of each data sheet.

Holders of TI's 1967-68 Semiconductors and Components Catalog are urged to continue using their catalogs as a total index of specification data to the standard TI line. While improvement in ratings and characteristics of many devices are included in this catalog, most of the data sheets listed in the 1967-68 Semiconductors and Components Catalog are current.

A cross-reference guide between JEDEC or competitive type numbers and TI devices is presented on Pages 15-38.

Should you have interest in a device not listed as a preferred device, please check the Index to All Standard Discrete Semiconductors and Components shown on Pages 39-45. You may obtain specification data for any of these devices by writing to Inquiry Answering Service, Texas Instruments Incorporated, MS 980, P.O. Box 5621, Dallas, Texas 75222, specifying the device by type number.

Note that certain blocks of page numbers have intentionally been omitted to anticipate new products which may be added in future editions.

Preferred Semiconductors and Components from Texas Instruments

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TEXAS INSTRUMENTS
INCORPORATED
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HOW TO USE THE INDEXES

If you know only the **category of device**, look in the **Listing of Preferred Semiconductors and Components**, page **3**.

If you want a device for a **particular application**, look in the **Application Guide to Preferred Semiconductors and Components**, page **5**, also see pages **11-14** for Silicon Power devices.

If you are seeking the **TI device nearest** to a JEDEC or competitive type number, look in the **Cross-Reference Guide Between JEDEC or Competitive Type Numbers and TI Devices**, starting on page **15**.

If you know the **Texas Instruments device number**, look in the **Index to All Standard Discrete Semiconductors and Components**, page 39.

SPECIAL INFORMATION

TI Field Sales Office Addresses, page 1332

TI Microlibrary Information, page 1524

Standard Mounting Hardware for Silicon Thyristors, page 24001

IMPORTANT NOTICES

Texas Instruments reserves the right to make changes at any time in order to improve design and to supply the best product possible.

TI cannot assume any responsibility for any circuits shown or represent that they are free from patent infringement.

LISTING OF PREFERRED SEMICONDUCTORS AND COMPONENTS BY DEVICE CLASSIFICATION

LISTING OF PREFERRED SEMICONDUCTORS AND COMPONENTS BY DEVICE CLASSIFICATION (Cont'd.)

REGULATOR DIODES (Cont'd.)

1N758A	23109
1N759	23109
1N759A	23109
1N4370	23601
1N4370A	23601
1N4371	23601
1N4371A	23601
1N4372	23601
1N4372A	23601

THYRISTORS AND TRIGGER DIODES†

TIC20	24101
TIC21	24101
TIC22	24101
TIC23	24101
TI42A	24105
TI43A	24105
TIC44	24109
TIC45	24109
TIC46	24109
TIC47	24109
2N3001	24401
2N3002	24401
2N3003	24401
2N3004	24401
2N3005	24407
2N3006	24407
2N3007	24407
2N3008	24407
2N3555	24417
2N3556	24417
2N3557	24417
2N3558	24417
2N3559	24425
2N3560	24425
2N3561	24425
2N3562	24425
2N5273	24601
2N5274	24601

SILICON RECTIFIERS

1N4001	25401
1N4002	25401
1N4003	25401
1N4004	25401
1N4005	25401
1N4006	25401
1N4007	25401

OPTOELECTRONIC DEVICES

LS400	27401
LS600	27501
1N2175	27801

PRECISION FILM RESISTORS

CG1/8	28201
CG1/4	28201
CG1/2	28201
MC55	28401
MC55D	28401
MC60	28401
MC60D	28401
MC65	28401
MC65D	28401

TEMPERATURE-SENSING SILICON RESISTORS

TG1/8	29001
TM1/8	29003
TM1/4	29003

†See page 24001 for standard mounting hardware.

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS

APPLICATION	DEVICE RECOMMENDATION							
	BIPOLAR				FET			
	N-P-N		P-N-P		N-CHANNEL		P-CHANNEL	
	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.
Small-Signal Transistor Amplifier:	•TIS92	4105	•TIS93	4105	TIS88	6111	2N2386	6301
	•TIS92M	4105	•TIS93M	4105	•2N3819	6401	•2N2498	6303
	•TIS97	1047	2N404	9105	•2N3822	6405	•2N3330	6305
DC to 1 MHz	•TIS98	1047	2N1303	9205			2N3909	6413
	TIS99	1047	2N1305	9205			•2N3820	6403
	2N697	1201	2N1307	9205				
	2N718A	1201	2N1309	9205				
	2N930	1269	2N2000	9307				
	•2N997	4301	2N2605	2119				
	•2N1302	9205	•2N2905	2127				
	•2N1304	9205	•2N2907	2127				
	•2N1306	9205	•2N3486	2213				
	•2N1308	9205	•2N3495	2215				
	2N1893	1209	•2N3964	2241				
	•2N2484	1337	•2N4058-61	2301				
	2N3707	1431	•2N5447	2305				
	2N3708	1431						
	2N3709	1431						
	2N3710	1431						
	2N3711	1431						
	•2N4104	1501						
	•2N5449	1701						
1 MHz to 10 MHz	TIS63	1025	•TIS37	2001	TIS88	6111	2N2386	6301
	2N697	1201	2N404	9105	•2N3819	6401	•2N2498	6303
	2N930	1269	2N1303	9205	•2N3822	6405	•2N3330	6305
	2N1302	9205	2N1305	9205	•2N3823	6407	2N3909	6413
	2N1304	9205	2N1307	9205	•2N4416	6503	•2N3820	6403
	2N1306	9205	2N1309	9205				
	2N1308	9205	2N1377	9213				
	2N1613	1201	2N1997	9301				
	2N1893	1209	2N2605	2119				
	•2N2484	1337	•2N2905	2127				
	•2N4104	1501	•2N3495	2215				
	•2N4995	1441						
	•2N4996	1511						
10 MHz to 50 MHz	TIS56	1021	•TIS37	2001	TIS88	6111	•2N2498	6303
	•TIS63	1025	•2N3495	2215	•2N3819	6401	•2N3330	6305
	•TIS84	1033	•2N5043	14401	•2N3822	6405		
	•TIS85	1033			•2N3823	6407		
	•TIS86	1041			•2N4416	6503		
	•TIS87	1041						
	2N918	3201						
	•2N2219	1305						
	•2N2222	1305						
	•2N2243A	1301						
	2N4252	1503						
	•2N4996	1511						
50 MHz to 100 MHz	•TIS63	1025	•2N2905	2127	TIS88	6111	•2N2498	6303
	•TIS84	1033	•2N2907	2127	•2N3823	6407	•2N3330	6305
	•TIS85	1033	•2N3486	2213	•2N4416	6503		
	•TIS86	1041	•2N5043	14401				
	•TIS87	1041						
	2N918	3201						
	•2N2219	1305						
	•2N2222	1305						
	2N4252	1503						
	•2N4875	3701						
	•2N4996	1511						
100 MHz to 5 GHz	2N918	3201	•2N5043	14401	TIS88	6111		
	•2N3570	3401			•2N3823	6407		
	2N4252	1503			•2N4416	6503		
	•2N4875	3701						

• Devices especially recommended for new design.

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS (Cont'd.)

APPLICATION	DEVICE RECOMMENDATION							
	BIPOLAR				FET			
	N-P-N		P-N-P		N-CHANNEL		P-CHANNEL	
	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.
Low-Noise Amplifier:	•TIS97	1047	•TIS37	2001	TIS88	6111	•2N2498	6303
	2N930	1269	2N2605	2119	•2N3822	6405	•2N3330	6305
0 to 10 MHz	•2N2484	1337	•2N4058-61	2301	•2N4416	6503		
	2N3707	1431						
	•2N4104	1501						
10 MHz to 50 MHz	•TIS62	1025	•TIS37	2001	TIS88	6111		
	•TIS84	1033			•2N3822	6405		
	•TIS86	1041			•2N3823	6407		
	2N918	3201			•2N4416	6503		
	2N4252	1503						
	•2N4875	3701						
50 MHz to 100 MHz	•TIS62	1025	•2N5043	14401	•TIS88	6111		
	•TIS84	1033			•2N3823	6407		
	•TIS86	1041			•2N4416	6503		
	2N918	3201						
	•2N3570	3401						
	2N4252	1503						
	•2N4875	3701						
100 MHz to 1 GHz	•TIS86	1041	•2N5043	14401	•TIS88	6111		
	2N918	3201			•2N3823	6407		
	•2N3570	3401			•2N4416	6503		
	•2N4875	3701						
Mixer and Converter:	2N918	3201	•TIS37	2001	•2N3823	6407	•2N2498	6303
0 to 10 MHz	•2N4995	1441			•2N4416	6503	•2N3330	6305
10 MHz to 50 MHz	TIS56	1021	•TIS37	2001	•TIS88	6111	•2N3820	6403
	•TIS63	1025			•2N3823	6407		
	•TIS85	1033			•2N4416	6503		
	•TIS86	1041						
	2N4252	1503						
	•2N4875	3701						
	•2N4995	1441						
50 MHz to 100 MHz	•TIS63	1025	•2N5043	14401	•TIS88	6111		
	•TIS85	1033			•2N3823	6407		
	•TIS86	1041			•2N4416	6503		
	•2N3570	3401						
	2N4252	1503						
	•2N4875	3701						
100 MHz to 5 GHz	•TIS86	1041	•2N5043	14401	•TIS88	6111		
	2N918	3201			•2N3823	6407		
	•2N3570	3401			•2N4416	6503		
	2N4252	1503						
	•2N4875	3701						
Oscillator:	•TIS98	1047	•TIS38	2001	•TIS88	6111	•2N2498	6703
	2N697	1201	•2N2905	2127	•2N3819	6401	•2N3330	6305
0 to 10 MHz	2N1613	1201	•2N3486	2213	•2N3822	6405		
	•2N2484	1337	•2N3495	2215	•2N3823	6407		
	2N3711	1431			•2N4416	6503		
	•2N5449	1701						
10 MHz to 50 MHz	•TIS63	1025	•TIS38	2001	•TIS88	6111		
	•TIS98	1047	•2N2905	2127	•2N3822	6405		
	2N918	3201	•2N2907	2127	•2N3823	6407		
	•2N2219	1305	•2N3486	2213	•2N4416	6503		
	•2N2222	1305	•2N5447	2305				
	•2N4875	3701						
	•2N5449	1701						

• Devices especially recommended for new design.

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS (Cont'd.)

DEVICE RECOMMENDATION

APPLICATION	BIPOLAR N-P-N Type No.	Page No.	BIPOLAR P-N-P Type No.	Page No.	FET N-CHANNEL Type No.	Page No.	FET P-CHANNEL Type No.	Page No.
50 MHz to 100 MHz	•TIS63	1025	• 2N5043	14401	TIS88	6111		
	•TIS86	1041	• 2N5447	2305	• 2N3823	6407		
	2N918	3201			• 2N4416	6503		
	•2N4875	3701						
	•2N5449	1701						
100 MHz to 5 GHz	•TIS63	1025	• 2N5043	14401	TIS88	6111		
	•TIS86	1041			• 2N3823	6407		
	2N918	3201			• 2N4416	6503		
	•2N3570	3401						
	•2N4875	3701						
Power Oscillator:	•2N3866	3501						
Power Amplifier:								
Radio Frequency	•2N3866	3501						
	•2N4875	3701						
Audio Frequency	•TIP29	16101	• TIP30	16105	• 2N4857	6511		
	•TIP29A	16101	• TIP30A	16105				
	•TIP31	16109	• TIP32	16113				
	•TIP31A	16109	• TIP32A	16113				
	•TIP33	16117	• TIP34	16121				
	•TIP33A	16117	• TIP34A	16121				
	•TIP35	16125	• TIP36	16129				
	•TIP35A	16125	• TIP36A	16129				
	2N697	1201	2N456A	17101				
	2N718A	1201	2N1038	17201				
	2N1613	1201	• 2N2905	2127				
	2N1711	1201	• 2N2907	2127				
			TI3027	17301				
			• 2N3486	2213				
			• 2N3495	2215				

APPLICATION	BIPOLAR N-P-N Type No.	Page No.	BIPOLAR P-N-P Type No.	Page No.	OTHER DEVICES Type No.	Page No.	Classification
Switching:	2N1302	9205	2N404	9105	• 2N3980	7201	UJT
Multivibrator,	2N1304	9205	2N1303	9205	• 2N3993	6501	P-FET
Pulse Generator,	2N1306	9205	2N1305	9205	• 2N4416	6503	N-FET
Schmitt Trigger	2N1308	9205	2N1307	9205	• 2N4857	6511	N-FET
	•2N2219	1305	2N1309	9205			
	•2N2222	1305	2N1997	9301			
	•2N2369A	1315	2N2000	9307			
	•2N3010	1401	2N2635	12301			
	•2N3013	1405	• 2N2894	2125			
	•2N3725	1433	• 2N2905	2127			
	•2N4418	1519	• 2N2907	2127			
	•2N4420	1521	• 2N3829	2235			
			• 2N4423	2303			
Ring Counter/	2N930	1269	• 2N2894	2125	• TIC20-3	24101	TRIAC
Latching Amplifier	•2N2369A	1315	• 2N2905	2127	• 2N3001-4	24401	SCR
	•2N3010	1401	• 2N3250	2209	• 2N3555-8	24417	SCR
	•2N3013	1405	• 2N3304	2211	• 2N3993	6501	P-FET
	•2N4418	1519	• 2N3829	2235	• 2N4416	6503	N-FET
	•2N4420	1521	• 2N4058-61	2301	• 2N4857	6511	N-FET
	•2N5449	1701	• 2N5447	2305	• 2N5273-4	24601	TRIAC
					• TIS73	6103	N-FET
Relaxation Oscillator					•TI42A	24105	Trigger Diode
					•TI43A	24105	Trigger Diode
					2N1671B	7109	UJT
					•2N3980	7201	UJT
					•2N4891	7301	UJT

• Devices especially recommended for new design.

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS (Cont'd.)

APPLICATION	DEVICE RECOMMENDATION						
	BIPOLAR				OTHER DEVICES		
	N-P-N		P-N-P				
	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.	Classification
Pulse Amplifier	• 2N2243A	1301	2N1907	17231	• 2N3993	6501	P-FET
	• 2N2369A	1315	• 2N2894	2125	• 2N4857	6511	N-FET
			• 2N2905	2127			
			• 2N3304	2211			
			• 2N3486	2213			
			• 2N3829	2235			
			• 2N5333	16701			
			• 2N5384	16707			
			• 2N5386	16711			
Chopper	• 3N79	4101	• 3N111	4109	• 2N3993	6501	P-FET
	• 2N2432	1325	• 2N2945A	2131	• 2N4857	6511	N-FET
	• TIP29	16101	• 2N3467	2203			
	• TIP29A	16101	• TIP30	16105			
	• TIP31	16109	• TIP30A	16105			
	• TIP31A	16109	• TIP32	16113			
	• TIP33	16117	• TIP32A	16113			
	• TIP33A	16117	• TIP34	16121			
	• TIP35	16125	• TIP34A	16121			
	• TIP35A	16125	• TIP36	16129			
			• TIP36A	16129			
Computer Memory Driver	• 2N3013	1405	• 2N3467	2203	• 2N3993	6501	P-FET
	• 2N3015	1409			• 2N4857	6511	N-FET
	• 2N3725	1433			• TIS73	6103	N-FET
Power Control/ Regulator (See Selection Guide on pages 11 – 14)	• TIP29	16101	• TIP30	16105	• TIC20-3	24101	TRIAC
	• TIP29A	16101	• TIP30A	16105	• TIC44-7	24109	SCR
	• TIP31	16109	• TIP32	16113	• 2N3001-4	24401	SCR
	• TIP31A	16109	• TIP32A	16113	• 2N3005-08	24407	SCR
	• TIP33	16117	• TIP34	16121	• 2N3555-8	24417	SCR
	• TIP33A	16117	• TIP34A	16121	• 2N3559-62	24425	SCR
	• TIP35	16125	• TIP36	16129	• 2N5273-4	24601	TRIAC
	• TIP35A	16125	• TIP36A	16129			
	2N1724	16301	2N456A	17101			
	• 2N2987-94	16401	2N1539	17223			
	2N3055	16409	2N1907	17231			
	• 2N3418-21	16501	TI3027	17301			
	• 2N3551,2	16507	• 2N5333	16701			
	• 2N3713-16	16511	• 2N5384,5	16707			
	• 2N3996-9	16601	• 2N5386	16711			
	• 2N4000,1	16607					
	• 2N4002,3	16613					
	• 2N4300	16625					
	• 2N4301	16631					
	• 2N5387-9	16715					
Computer Logic Switch	2N797	12101	2N404	9105	• 2N3993	6501	P-FET
	2N1302	9205	2N964	12105	• 2N4857	6511	N-FET
	2N1304	9205	2N1303	9205	• TIS73	6103	N-FET
	2N1306	9205	2N1305	9205			
	2N1308	9205	2N1307	9205			
	• 2N2369A	1315	2N1309	9205			
	• 2N3010	1401	2N1997	9301			
	• 2N3013	1405	2N2635	12301			
	• 2N4418	1519	• 2N2894	2125			
	• 2N4420	1521	• 2N3250	2209			
			• 2N3304	2211			
			• 2N3829	2235			
			• 2N4423	2303			

• Devices especially recommended for new design

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS (Cont'd.)

APPLICATION	DEVICE RECOMMENDATION						
	BIPOLAR				OTHER DEVICES		
	N-P-N		P-N-P				
	Type No.	Page No.	Type No.	Page No.	Type No.	Page No.	Classification
Series/Shunt Register	• TIP29	16101	• TIP30	16105	• 2N3993	6501	P-FET
	• TIP29A	16101	• TIP30A	16105	• 2N4857	6511	N-FET
	• TIP31	16109	• TIP32	16113			
	• TIP31A	16109	• TIP32A	16113			
	• TIP33	16117	• TIP34	16121			
	• TIP33A	16117	• TIP34A	16121			
	• TIP35	16125	• TIP36	16129			
	• TIP35A	16125	• TIP36A	16129			
	2N1724	16301	2N456A	17101			
	• 2N2987-94	16401	2N1038	17201			
	2N3055	16409	2N1539	17223			
	• 2N3418-21	16501	2N1907	17231			
	• 2N3551,2	16507	TI3027	17301			
	• 2N3713-16	16511	• 2N5333	16701			
	• 2N3996-9	16601	• 2N5384,5	16707			
	• 2N4000,1	16607	• 2N5386	16711			
	• 2N4002,3	16613					
	• 2N4300	16625					
	• 2N4301	16631					
	• 2N5387-9	16715					
Lamp Driver (Nixie Driver) High Voltage	2N1893	1209	2N398	9101	• 2N4857	6511	N-FET
	• 2N2243A	1301	• 2N3495	2215			
Linear Application: Demodulator	• 3N79	4101	2N1907	17231	• 2N4857	6511	N-FET
	• 2N2432	1325	• 2N2945A	2131			
Differential Amplifier	• 2N2060	4401	• 2N3049	4503	• TIS69	6101	N-FET
	• 2N2642	4405	• 2N3350	4507	• 2N5045	6601	N-FET
	• 2N3043	4501	• 2N3351	4507			
	• 2N3045	4501					
	• 2N3680	4509					
	• 2N3838	4517					
Operational Amplifier	• 2N2060	4401	• 2N3049	4503	• TIS69	6101	N-FET
	• 2N2223	4401	• 2N3350	4507	• 2N4854	4701	NPN-PNP
	• 2N2642	4405	• 2N3351	4507	• 2N5045	6601	N-FET
	• 2N3043	4501					
	• 2N3045	4501					
	• 2N3680	4509					
Servo Amplifier	• 2N2060	4401	2N1038	17201	• TIS69	6101	N-FET
	• 2N2223	4401	2N1907	17231	• 2N5045	6601	N-FET
	• 2N2642	4405	• 2N3350	4507			
	• 2N3680	4509	• 2N3351	4507			
Sense Amplifier/ Comparator	• 2N2060	4401	• 2N3049	4503	TIS88	6111	N-FET
	• 2N2642	4405	• 2N3350	4507	• 2N4416	6503	N-FET
	• 2N3043	4501	• 2N3351	4507	• 2N5045	6601	N-FET
	• 2N3680	4509					
	• 2N3838	4517					
Waveform Generator/ Clipper/Compressor	2N930	1269	• 2N5447	2305	TIS88	6111	N-FET
	2N3707	1431			• 2N4416	6503	N-FET
	2N3708	1431			• 2N4857	6511	N-FET
	2N3709	1431					
	2N3711	1431					
	• 2N5449	1701					
Diodes: Mixer/Converter					1N456-8	18101	
					1N482-5	18105	
					1N914	19201	

• Devices especially recommended for new design.

APPLICATIONS GUIDE TO PREFERRED SEMICONDUCTORS AND COMPONENTS (Cont'd.)

APPLICATION	DEVICE RECOMMENDATION BIPOLAR N-P-N Type No.	Page No.	P-N-P Type No.	Page No.	OTHER DEVICES Type No.	Page No.	Classification
Detector					1N456-8	18101	
					1N914	19201	
					• 1N4148	19401	
					• 1N4448	19401	
Switch					1N914	19201	
					• 1N3064	19301	
					• 1N3070	19303	200 V
					• 1N4148	19401	
					• 1N4448	19401	
					• 1N4531	19407	
Tuning					• TIV306-08	21205	Voltage Variable
Voltage Regulator					1N746-1N759	23109	
					• 1N746A-1N759A	23109	
					1N4370	23601	
					• 1N4370A	23601	
Rectifier					1N456-1N458	18101	
					1N482-5	18105	
					• 1N645-9	18109	
					• 1N4001-7	25401	
Computer					• TID21-24	20005	8-Diode Array
					• TID25-26	20009	16-Diode Array
					• TID29-30	20013	20-Diode Array
					1N914	19201	
					• 1N3064	19301	
Transistor Biasing					• 1N746A-1N759A	23109	
TV "Color Killer"					• 1N3070	19303	
Power Supply					• 1N645-9	18109	
Logarithmic					• 1N645-9	18109	
					• 1N746A-1N759A	23109	
Light Sensor					• LS400	27401	
					• LS600	27501	
					• 1N2175	27801	

• Devices especially recommended for new design.

The following curves, arranged in ascending order of rated power dissipation, show typical h_{FE} versus collector current at 25°C case temperature. Listed above each curve are the standard open-base collector-emitter voltage ratings available from among the device types listed.

N-P-N
2N3418-2N3421
10 W
V_{CEO}: 60 V and 80 V

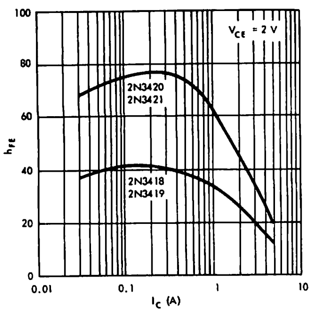

FIGURE 1

N-P-N
2N2987-2N2994
15 W
V_{CEO}: 80 V and 100 V

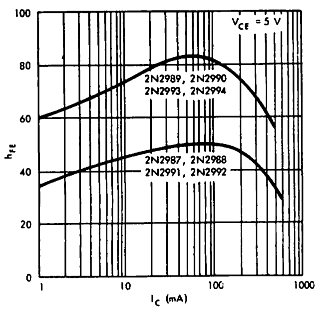

FIGURE 2

N-P-N
2N4000-2N4001
15 W
V_{CEO}: 80 V and 100 V

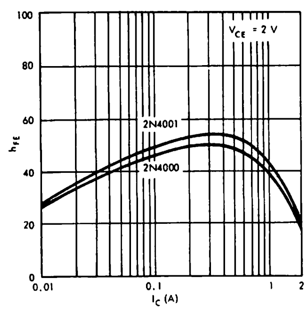

FIGURE 3

N-P-N
2N4300
15 W
V_{CEO}: 80 V

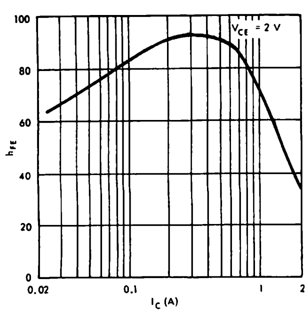

FIGURE 4

P-N-P
2N5333
15 W
V_{CEO}: 80 V

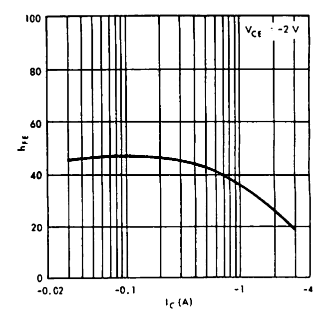

FIGURE 5

N-P-N
TIP29, TIP29A
30 W
V_{CEO}: 40 V and 60 V

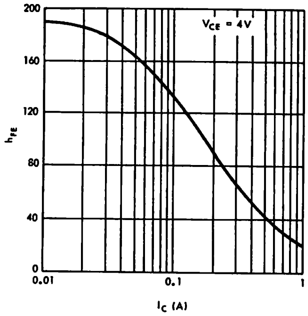

FIGURE 6

P-N-P
TIP30, TIP30A
30 W
V_{CEO}: 40 V and 60 V

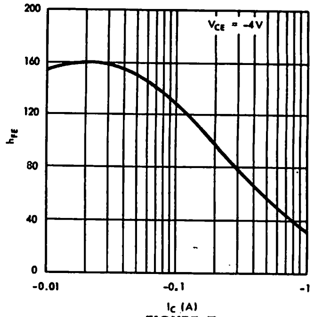

FIGURE 7

N-P-N
2N3996-2N3999
30 W
V_{CEO}: 80 V

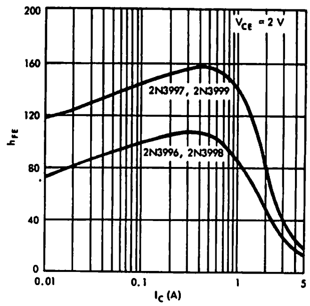

FIGURE 8

N-P-N
TIP31, TIP31A
40 W
V_{CEO}: 40 V and 60 V

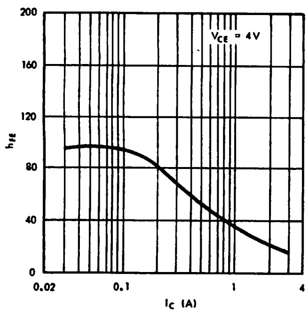

FIGURE 9

P-N-P
TIP32, TIP32A
40 W
V_{CEO}: 40 V and 60 V

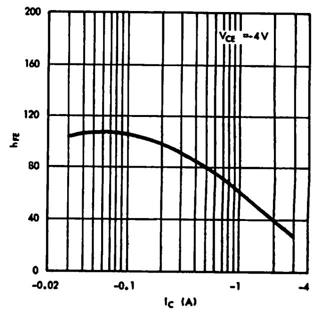

FIGURE 10

N-P-N
2N3551-2N3552
40 W
V_{CEO}: 60 V and 80 V

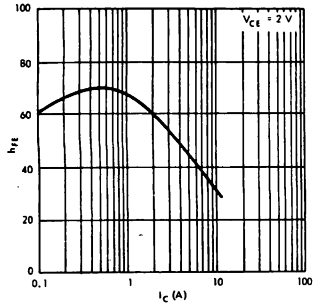

FIGURE 11

N-P-N
2N1724
50 W
V_{CEO}: 80 V

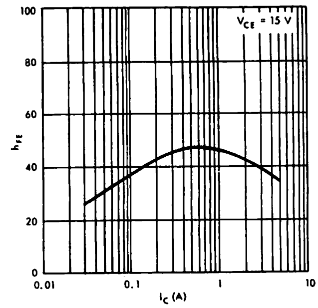

FIGURE 12

N-P-N
2N4301
50 W
V_{CEO}: 80 V

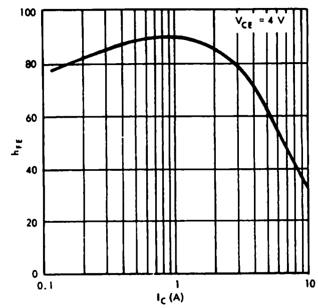

FIGURE 13

N-P-N
TIP33, TIP33A
80 W
V_{CEO}: 40 V and 60 V

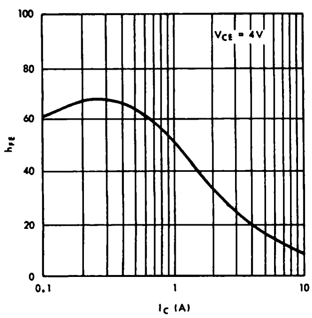

FIGURE 14

P-N-P
TIP34, TIP34A
80 W
V_{CEO}: 40 V and 60 V

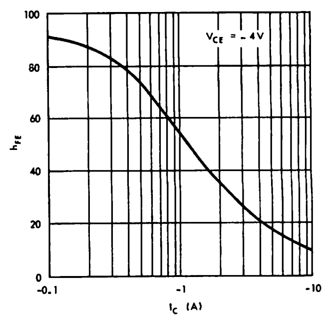

FIGURE 15

N-P-N
TIP35, TIP35A
90 W
V_{CEO}: 40 V and 60 V

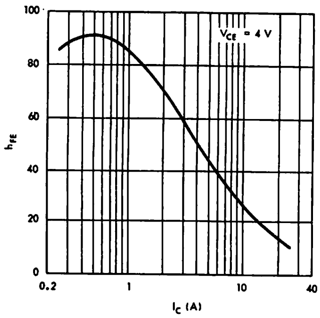

FIGURE 16

P-N-P
TIP36, TIP36A
90 W
V_{CEO}: 40 V and 60 V

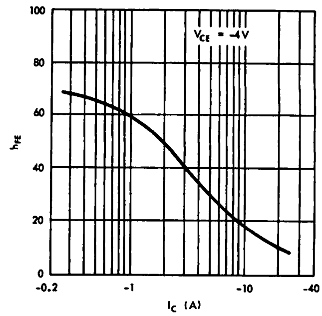

FIGURE 17

N-P-N
2N5387-2N5389
100 W
V_{CEO}: 200 V, 250 V, and 300 V

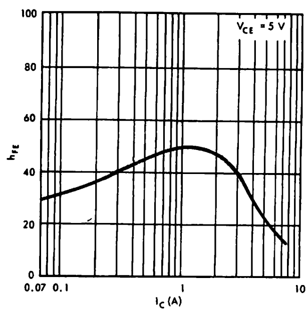

FIGURE 18

N-P-N
2N4002-2N4003
100 W
V_{CEO}: 80 V and 100 V

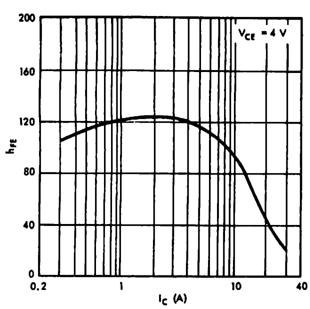

FIGURE 19

N-P-N
2N3713-2N3716
150 W
V_{CEO}: 60 V and 80 V

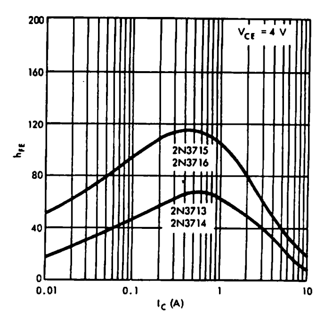

FIGURE 20

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES

Nearest TI types were selected on the basis of the general similarity of electrical characteristics. Interchangeability in particular applications is not guaranteed. Before using a substitute type, the user should compare the detailed specifications of the substitute device with the detailed specifications of the original device with emphasis on those ratings and characteristics which are actually critical. Occasionally another device on the same data sheet as the stated "Nearest TI Type" may be found to be better suited for the particular application.

TI makes no warranty as to the information furnished and Buyer assumes all risk in the use thereof. No liability is assumed for damages resulting from the use of the information contained in this list.

Type	Preferred TI Type	Nearest TI Type
1N38B	1N484	1N458A
1N39B	1N645	1N645
1N52A	1N483	1N457A
1N60	1N456	1N456
1N67A	1N484	1N458A
1N69A	1N483	1N457A
1N70A	1N484	1N458A
1N81A	1N483	1N457A
1N90	1N483	1N457A
1N91	1N645	1N484A
1N92	1N645	1N645
1N93	1N646	1N646
1N96	1N483	1N457A
1N98	1N484	1N458A
1N98A	1N484	1N458A
1N100A	1N484	1N458A
1N111	1N914B	1N663
1N112	1N914B	1N663
1N113	1N914B	1N663
1N114	1N914B	1N663
1N115	1N914B	1N663
1N118A	1N483	1N457A
1N119	1N914B	1N663
1N120	1N914B	1N663
1N126	1N483	1N547A
1N127	1N484	1N458A
1N128	1N483	1N457A
1N128A	1N457	1N457
1N137B	1N483	1N457A
1N138B	1N483	1N457A
1N144	1N914B	1N914B
1N145	1N914B	1N658
1N191	1N3070	1N663
1N193	1N914	1N251
1N194	1N914	1N251
1N194A	1N914	1N251
1N195	1N914	1N251
1N196	1N914	1N251
1N198	1N484	1N458A
1N198A	1N483	1N457A
1N198B	1N483	1N457A
1N200		1N764
1N201		1N765
1N202		1N766
1N251	1N914	1N251
1N253		1N253
1N254		1N254
1N256		1N256
1N270		TID32
1N273	1N914B	1N663
1N276	1N914B	1N915
1N277	1N914B	1N658
1N278	1N914B	1N658
1N279	1N914B	1N663
1N281	1N914B	TID29
1N282	1N456	1N456
1N283		TID33
1N294	1N457	1N457
1N294A	1N483	1N483
1N295	1N457	1N457
1N297	1N483	1N458A
1N298	1N483	1N457A
1N298A	1N483	1N457A
1N300	1N482	1N456A
1N300A	1N482	1N456A
1N301	1N483	1N457A
1N301A	1N483	1N457A
1N301B	1N483	1N457A
1N302A	1N645	1N645
*1N302B	1N645	1N645
1N303	1N484	1N484
1N303B	1N484	1N484
1N305	1N645	1N483A
1N306	1N645	1N482A
1N307	1N484	1N458A
1N315	1N4004	1N4004
1N316	1N645	1N483A
1N317	1N645	1N484A
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1N319	1N646	1N646
1N320	1N648	1N648
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1N325	1N645	1N645
1N326	1N646	1N646
1N327	1N648	1N648
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1N331	1N456	1N456
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1N418	1N914B	1N663
1N419	1N914B	1N663
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1N432A	1N482	1N457A
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1N433A	1N485	1N458A
1N434	1N485	1N459A
1N434A	1N485	1N459A
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1N440B	1N4002	1N440B
1N441	1N4003	1N2069
1N441B	1N4003	1N441B
1N442	1N4004	1N2070
1N442B	1N4004	1N442B
1N443	1N4004	1N2070
1N443B	1N4004	1N443B
1N444	1N4005	1N2071
1N444B	1N4005	1N444B
1N445	1N4005	1N2071
1N445B	1N4005	1N445B
1N447	1N482	1N461A
1N448	1N484	1N458A
1N449	1N482	1N461A
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1N451	1N484	1N458A
1N452	1N482	1N461A
1N453	1N484	1N458A
1N454	1N482	1N461A
1N455	1N482	1N461A
1N456	1N456	1N456
1N456A	1N482	1N456A
1N457	1N457	1N457
1N457A	1N483	1N457A

*Denotes 1N- or 2N- numbers not JEDEC registered through September 1968.

Type	Preferred TI Type	Nearest TI Type
1N458	1N458	1N458
1N458A	1N484	1N458A
1N459	1N485	1N459
1N459A	1N485	1N459A
1N460	1N484	1N458A
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1N461A	1N482	1N461A
1N462	1N483	1N462
1N462A	1N483	1N483
1N463	1N485	1N463
1N463A	1N485	1N485
1N464	1N484	1N464
1N464A	1N484	1N484
1N465A	1N4370A	1N702A
1N466A	1N747A	650C0
1N467A	1N749A	650
1N468A	1N750A	651
1N469A	1N752A	652
1N470A	1N754A	653
1N471A	1N747A	650C0
1N472A	1N749A	650
1N473A	1N750A	651
1N474A	1N752A	652
1N475A	1N754A	653
1N481	1N645	1N645
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1N482B	1N482	1N482B
1N483	1N483	1N483
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1N483B	1N483	1N483B
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1N484B	1N484	1N484B
1N485	1N485	1N485
1N485A	1N485	1N485A
1N485B	1N485	1N485B
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1N488B	1N647	1N647
1N490	1N914	1N462
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1N500	1N914B	TID32
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1N628	1N3070	1N628
1N629	1N3070	1N629
1N631	1N914B	1N915
1N632	1N914	1N914
1N633	1N3070	TID32
1N634	1N3070	1N3070
1N635	1N3070	1N3070
1N636	1N4448	1N916B
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1N643A	1N3070	1N643
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1N645A	1N645	1N645A
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1N658		1N658
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1N659A	1N914	1N659
1N660		1N660
1N660A	1N914B	1N660
1N661		1N661
1N661A	1N3070	1N661
1N662	1N914	1N662
1N663	1N914B	1N663
1N664	1N756A	1N712
1N665	1N759	1N716
1N674	1N750A	1N705A
1N675	1N753A	1N709A
1N676	1N645	1N484A
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1N682	1N646	1N646
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1N692	1N645	1N645
1N693	1N645	1N645
1N695A	1N914B	1N663
1N696	1N914	1N914
1N699	1N914B	1N663
1N701	1N758A	1N714A
1N702		1N702
1N702A	1N4370A	1N702A
1N703		1N703
1N703A	1N746A	1N703A
1N704		1N704
1N704A	1N749A	1N704A
1N705		1N705
1N705A	1N750A	1N705A
1N706		1N706
1N706A	1N752A	1N706A
1N707		1N707
1N707A	1N755A	1N707A
1N708		1N708
1N708A	1N752A	1N708A

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES (Cont'd.)

Type	Preferred TI Type	Nearest TI Type
1N709		1N709
1N709A	1N753A	1N709A
1N710		1N710
1N710A	1N754A	1N710A
1N711		1N711
1N711A	1N755A	1N711A
1N712		1N712
1N712A	1N756A	1N712A
1N713		1N713
1N713A	1N757A	1N713A
1N714		1N714
1N714A	1N758A	1N714A
1N715		1N715
1N715A	1N758A	1N715A
1N716		1N716
1N716A	1N759A	1N716A
1N746	1N746	1N746
1N746A	1N746A	1N746A
1N747	1N747	1N747
1N747A	1N747A	1N747A
1N748	1N748	1N748
1N748A	1N748A	1N748A
1N749	1N749	1N749
1N749A	1N749A	1N749A
1N750	1N750	1N750
1N750A	1N750A	1N750A
1N751	1N751	1N751
1N751A	1N751A	1N751A
1N752	1N752	1N752
1N752A	1N752A	1N752A
1N753	1N753	1N753
1N753A	1N753A	1N753A
1N754	1N754	1N754
1N754A	1N754A	1N754A
1N755	1N755	1N755
1N755A	1N755A	1N755A
1N756	1N756	1N756
1N756A	1N756A	1N756A
1N757	1N757	1N757
1N757A	1N757A	1N757A
1N758	1N758	1N758
1N758A	1N758A	1N758A
1N759	1N759	1N759
1N759A	1N759A	1N759A
1N761	1N751	1N761
1N762	1N752	1N762
1N763	1N755	1N763
1N764	1N756	1N764
1N765	1N758	1N765
1N766	1N759	1N766
1N771	1N914B	TID37
1N771A	1N645	TID31
1N772	1N914B	TID37
1N772A	1N645	TID31
1N773	1N914B	TID37
1N773A	1N645	TID31
1N774	1N914B	TID37
1N774A	1N645	TID31
1N775	1N914B	TID37
1N776	1N645	1N915
1N777	1N914B	TID37
1N778	1N914	1N643
1N779	1N3070	1N643
1N781	1N914	TI72
1N789	1N914	TI72
1N790	1N914	TI72
1N791	1N914B	TI75
1N792	1N914B	TID29
1N793	1N914	1N662
1N794	1N914	1N662
1N795	1N914B	1N915
1N796	1N914B	1N658
1N797	1N3070	TID42
1N798	1N3070	TID42
1N799	1N3070	1N658
1N800	1N3070	1N658
1N801	1N3070	TID42
1N802	1N3070	1N3070
1N806	1N914	1N628
1N807	1N3070	1N643
1N808	1N3070	1N663
1N810	1N914	1N4151
1N811	1N914	1N251
1N812	1N914	1N251
1N813	1N914	1N251
1N814	1N914	1N625
1N815	1N914B	1N658
1N817	1N3070	1N643

Type	Preferred TI Type	Nearest TI Type
1N818	1N914B	1N916B
1N890	1N914	1N4447
1N891	1N914B	1N915
1N892	1N3070	1N658
1N897	1N4148	1N660
1N898	1N914B	1N4444
1N899	1N914	1N662
1N900	1N914B	1N658
1N901	1N914B	1N658
1N902	1N3070	1N643
1N903A	1N914B	1N4446
1N904A	1N914B	1N4446
1N905A	1N914B	1N4446
1N906A	1N914B	1N4446
1N907A	1N914B	1N4446
1N908A	1N914B	1N4446
1N912	1N759A	1N759
1N913	1N759A	1N759
1N914	1N914	1N914
1N914A	1N914B	1N914A
1N914B	1N914B	1N914B
1N915	1N914B	1N915
1N916	1N914	1N916
1N916A	1N914B	1N916A
1N916B	1N914B	1N916B
1N917	1N914	1N917
1N919	1N3070	TID32
1N920	1N645	1N645
1N921	1N645	1N645
1N922	1N645	1N645
1N923	1N645	1N645
1N925	1N914	1N251
1N926	1N914	1N251
1N927	1N914	1N916
1N928	1N3070	1N643
1N929	1N914B	1N4446
1N930	1N914B	1N4446
1N931	1N914B	TID40
1N932	1N914B	TID40
1N934	1N914B	1N916B
1N947	1N649	1N649
1N957		1N957
1N957A		1N957A
1N957B		1N957B
1N958		1N958
1N958A		1N958A
1N958B		1N958B
1N959		1N959
1N959A		1N959A
1N959B		1N959B
1N960		1N960
1N960A		1N960A
1N960B		1N960B
1N961		1N961
1N961A		1N961A
1N961B		1N961B
1N993	1N914	1N914
1N994	1N914	1N914
1N995	1N914	1N914
1N996	1N914B	1N915
1N997	1N914	1N914
1N999	1N914B	1N914B
1N1095	1N4005	1N1095
1N1096	1N4005	1N1096
1N1100		1N1100
1N1101		1N1101
1N1102		1N1102
1N1103		1N1103
1N1104		1N1104
1N1105		1N1105
1N1115		1N1115
1N1116		1N1116
1N1117		1N1117
1N1118		1N1118
1N1119		1N1119
1N1120		1N1120
1N1124A		1N1124A
1N1125A		1N1125A
1N1126A		1N1126A
1N1127A		1N1127A
1N1128A		1N1128A
1N1415	1N4004	1N4004
1N1440	1N4003	1N4003
1N1441	1N4004	1N4004
1N1442	1N4004	1N4004
1N1487	1N4002	1N1487
1N1488	1N4003	1N1488

Type	Preferred TI Type	Nearest TI Type
1N1489	1N4004	1N1489
1N1490	1N4004	1N1490
1N1491	1N4005	1N1491
1N1492	1N4005	1N1492
1N1581		1N1581
1N1582		1N1582
1N1583		1N1583
1N1584		1N1584
1N1585		1N1585
1N1586		1N1586
1N1587		1N1587
1N1612		1N1612
1N1613		1N1613
1N1614		1N1614
1N1615		1N1615
1N1616		1N1616
1N1692	1N4002	1N1692
1N1693	1N4003	1N1693
1N1694	1N4004	1N1694
1N1695	1N4004	1N1695
1N1696		1N1696
1N1697		1N1697
1N1701	1N4001	1N4001
1N1702	1N4002	1N4002
1N1703	1N4003	1N4003
1N1704	1N4004	1N4004
1N1705	1N4004	1N4004
1N1706	1N4005	1N4005
1N1816		1N1816
1N1816A		1N1816A
1N1816C		1N1816C
1N1816CA		1N1816CA
1N1817		1N1817
1N1817A		1N1817A
1N1817C		1N1817C
1N1817CA		1N1817CA
1N1818		1N1818
1N1818A		1N1818A
1N1818C		1N1818C
1N1818CA		1N1818CA
1N1819		1N1819
1N1819A		1N1819A
1N1819C		1N1819C
1N1819CA		1N1819CA
1N1820		1N1820
1N1820A		1N1820A
1N1820C		1N1820C
1N1820CA		1N1820CA
1N1821		1N1821
1N1821A		1N1821A
1N1821C		1N1821C
1N1821CA		1N1821CA
1N1822		1N1822
1N1822A		1N1822A
1N1822C		1N1822C
1N1822CA		1N1822CA
1N1823		1N1823
1N1823A		1N1823A
1N1823C		1N1823C
1N1823CA		1N1823CA
1N1824		1N1824
1N1824A		1N1824A
1N1824C		1N1824C
1N1824CA		1N1824CA
1N1825		1N1825
1N1825A		1N1825A
1N1825C		1N1825C
1N1825CA		1N1825CA
1N1826		1N1826
1N1826A		1N1826A
1N1826C		1N1826C
1N1826CA		1N1826CA
1N1827		1N1827
1N1827A		1N1827A
1N1827C		1N1827C
1N1827CA		1N1827CA
1N1828		1N1828
1N1828A		1N1828A
1N1828C		1N1828C
1N1828CA		1N1828CA
1N1829		1N1829
1N1829A		1N1829A
1N1829C		1N1829C
1N1829CA		1N1829CA
1N1830		1N1830
1N1830A		1N1830A
1N1830C		1N1830C
1N1830CA		1N1830CA

Type	Preferred TI Type	Nearest TI Type
1N1831		1N1831
1N1831A		1N1831A
1N1831C		1N1831C
1N1831CA		1N1831CA
1N1832		1N1832
1N1832A		1N1832A
1N1832C		1N1832C
1N1832CA		1N1832CA
1N1833		1N1833
1N1833A		1N1833A
1N1833C		1N1833C
1N1833CA		1N1833CA
1N1834		1N1834
1N1834A		1N1834A
1N1834C		1N1834C
1N1834CA		1N1834CA
1N1835		1N1835
1N1835A		1N1835A
1N1835C		1N1835C
1N1835CA		1N1835CA
1N1836		1N1836
1N1836A		1N1836A
1N1836C		1N1836C
1N1836CA		1N1836CA
1N2008		1N2008
1N2008A		1N2008A
1N2008C		1N2008C
1N2008CA		1N2008CA
1N2009		1N2009
1N2009A		1N2009A
1N2009C		1N2009C
1N2009CA		1N2009CA
1N2010		1N2010
1N2010A		1N2010A
1N2010C		1N2010C
1N2010CA		1N2010CA
1N2011		1N2011
1N2011A		1N2011A
1N2011C		1N2011C
1N2011CA		1N2011CA
1N2012		1N2012
1N2012A		1N2012A
1N2012C		1N2012C
1N2012CA		1N2012CA
1N2069	1N4003	1N2069
1N2069A	1N4003	1N2069A
1N2070	1N4004	1N2070
1N2070A	1N4004	1N2070A
1N2071	1N4005	1N2071
1N2071A	1N4005	1N2071A
1N2072	1N4001	1N4001
1N2073	1N4002	1N4002
1N2074	1N4003	1N4003
1N2075	1N4003	1N4003
1N2076	1N4004	1N4004
1N2077	1N4004	1N4004
1N2078	1N4004	1N4004
1N2079	1N4005	1N4005
1N2080	1N4001	1N4001
1N2081	1N4002	1N4002
1N2082	1N4003	1N4003
1N2083	1N4004	1N4004
1N2084	1N4004	1N4004
1N2085	1N4005	1N4005
1N2086	1N4005	1N4005
1N2088	1N4005	1N4005
1N2089	1N4005	1N4005
1N2116	1N4004	1N4004
1N2117	1N4006	1N4006
1N2175	1N2175	1N2175
1N2372	1N4007	1N4007
1N2482	1N4003	1N4003
1N2483	1N4004	1N4004
1N2484	1N4005	1N4005
1N2485	1N4003	1N4003
1N2486	1N4004	1N4004
1N2487	1N4004	1N4004
1N2488	1N4005	1N4005
1N2489	1N4005	1N4005
1N3062	1N914B	1N914B
1N3063	1N3064	1N3064
1N3064	1N3064	1N3064
1N3065	1N914B	1N914B
1N3066	1N3064	1N3064
1N3067	1N3064	1N3064
1N3068	1N3064	1N3064
1N3069	1N914B	1N914B
1N3070	1N3070	1N3070

Type	Preferred TI Type	Nearest TI Type
1N3071	1N3070	1N3070
1N3146	1N914B	1N4444
1N3179	1N4003	1N4003
1N3192	1N645	1N645
1N3215	1N914	1N914
1N3223	1N3070	1N3070
1N3477	1N4370	1N702
1N3477A	1N4372A	1N702A
1N3478	1N645	1N645
1N3479	1N647	1N647
1N3480	1N649	1N649
1N3485	1N3070	1N643
1N3506		1N3506
1N3507		1N3507
1N3508		1N3508
1N3509		1N3509
1N3510		1N3510
1N3511		1N3511
1N3512		1N3512
1N3513		1N3513
1N3514		1N3514
1N3515		1N3515
1N3516		1N3516
1N3517		1N3517
1N3518		1N3518
1N3519		1N3519
1N3520		1N3520
1N3535	1N645	1N645
1N3536	1N457	1N457
1N3550	1N3070	1N3070
1N3568	1N914B	1N4446
1N3593	1N4531	1N4531
1N3594	1N4531	1N4531
1N3596	1N3070	1N3070
1N3598	1N914	1N914
1N3599	1N3070	1N3070
1N3601	1N3070	1N3070
1N3602	1N3070	1N3070
1N3603	1N3070	1N3070
1N3604	1N914B	1N914B
1N3607	1N914B	1N914B
1N3656	1N4003	1N4003
1N3657	1N4004	1N4004
1N3658	1N4005	1N4005
1N3668	1N914	1N914
1N3722	1N914B	1N4446
1N3728	1N649	1N649
1N3731	1N914B	1N914B
1N3753	1N645	1N483A
1N3866	1N4003	1N4003
1N3867	1N4004	1N4004
1N3868	1N4005	1N4005
1N3873	1N914B	1N914B
1N3894	1N648	1N648
1N3895	1N648	1N648
1N3956	1N914B	1N4534
1N4001	1N4001	1N4001
1N4002	1N4002	1N4002
1N4003	1N4003	1N4003
1N4004	1N4004	1N4004
1N4005	1N4005	1N4005
1N4006	1N4006	1N4006
1N4007	1N4007	1N4007
1N4043	1N914B	1N914B
1N4087	1N914B	1N914B
1N4099		1N4099
1N4100		1N4100
1N4101		1N4101
1N4102		1N4102
1N4103		1N4103
1N4104		1N4104
1N4105		1N4105
1N4106		1N4106
1N4147	1N914B	1N914B
1N4148	1N4148	1N4148
1N4149	1N4148	1N4149
1N4150	1N914B	1N4444
1N4151	1N4448	1N4151
1N4152	1N4448	1N4152
1N4153	1N4448	1N4153
1N4154	1N4448	1N4154
1N4244	1N914B	1N4446
1N4305	1N4148	1N4305
1N4360	1N4370	1N4360
1N4362	1N645	1N484A
1N4370	1N4370	1N4370
1N4370A	1N4370A	1N4370A
1N4371	1N4371	1N4371
1N4371A	1N4371A	1N4371A
1N4372	1N4372	1N4372
1N4372A	1N4372A	1N4372A
1N4373	1N914	1N4373
1N4375	1N914B	1N4446
1N4378	LS400	LS400
1N4444	1N914B	1N4444
1N4446	1N4448	1N4446
1N4447	1N4448	1N4447
1N4448	1N4448	1N4448
1N4449	1N4448	1N4449
1N4450	1N914B	1N4444
1N4451	1N914B	1N4444
1N4453	1N4448	1N4448
1N4454	1N4454	1N4454
1N4523	1N4448	1N4448
1N4531	1N4531	1N4531
1N4532	1N4531	1N4532
1N4533	1N4531	1N4533
1N4534	1N4531	1N4534
1N4536	1N4531	1N4536
1N4541	1N645	1N645
1N4542	1N647	1N647
1N4543	1N649	1N649
1N4544	1N649	1N649
1N4545	1N649	1N649
1N4548	1N914B	1N4448
1N4606		1N4606
1N4718	1N4001	1N4001
1N4726	1N4148	1N4148
1N4727	1N4148	1N4727
1N4827	1N914	1N915
1N4828	1N914B	1N914B
1N4861	1N483	1N483
1N4862	1N483	1N483
1N4863	1N914B	1N914B
1N4938	1N3070	1N4938
2N34	2N404	2N404
2N34A	2N404	2N404
2N35	2N404	2N404
2N36	2N404	2N404
2N37	2N404	2N404
2N38	2N404	2N404
2N41	2N404	2N404
2N42	2N404	2N404
2N45	2N404	2N404
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2N53	2N404	2N404
2N54	2N404	2N404
2N55	2N404	2N404
2N56	2N404	2N404
2N57	TI3027	TI3027
2N59	2N404	2N404
2N60	2N404	2N404
2N61	2N404	2N404
2N62	2N404	2N404
2N63	2N404	2N404
2N64	2N404	2N404
2N65	2N404	2N404
2N66	TI3027	TI3027
2N68	TI3027	TI3027
2N71	2N404	2N404
2N73	2N404	2N404
2N74	2N404	2N404
2N75	2N404	2N404
2N76	2N404	2N404
2N77	2N404	2N404
2N78	2N1302	2N1302
2N78A	2N1302	2N1302
2N79	2N404	2N404
2N80	2N404	2N404
2N81	2N404	2N404
2N82	2N404	2N404

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES (Cont'd.)

Type	Preferred TI Type	Nearest TI Type
2N94	2N1304	2N1304
2N96	2N404	2N404
2N97	2N1302	2N1302
2N98	2N1304	2N1304
2N99	2N1306	2N1306
2N100	2N1306	2N1306
2N101	2N404	2N404
2N102	2N1302	2N1302
2N103	2N1302	2N1302
2N104	2N404	2N404
2N105	2N404	2N404
2N106	2N404	2N404
2N107	2N404	2N404
2N108	2N404	2N404
2N109	2N404	2N404
2N111	2N404	2N404
2N112	2N404	2N404
2N115	2N404	2N404
2N116	2N404	2N404
2N117		2N117
2N118		2N118
2N118A		2N118A
2N119		2N119
2N120		2N120
2N122		2N122
2N123	2N1303	2N1303
2N124	2N1302	2N1302
2N125	2N1304	2N1304
2N126	2N1304	2N1304
2N127	2N1304	2N1304
2N128	2N404	2N404
2N129	2N404	2N404
2N130	2N404	2N404
2N131	2N404	2N404
2N132	2N404	2N404
2N133	2N404	2N404
2N135	2N404	2N404
2N136	2N404	2N404
2N137	2N404	2N404
2N138	2N404	2N404
2N139	2N404	2N404
2N140	2N404	2N404
2N141	2N1038	2N1038
2N143	2N1038	2N1038
2N145	2N1302	2N1302
2N146	2N1302	2N1302
2N147	2N1302	2N1302
2N148	2N1302	2N1302
2N149	2N1302	2N1302
2N150	2N1302	2N1302
2N155	TI3027	TI3027
2N156	TI3027	TI156
2N157	2N1038	2N1038
2N158	TI3027	TI158
2N158A	TI3027	TI158A
*2N164	2N1302	2N1302
*2N165	2N1302	2N1302
2N166	2N1304	2N1304
2N167	2N1306	2N1306
2N168	2N1306	2N1306
2N169	2N1308	2N1308
2N170	2N1308	2N1308
2N173	TI3027	TI3027
2N174	TI3027	TI3027
2N174A	TI3027	TI3027
2N175	2N404	2N404
2N176	TI3027	TI3027
2N178	TI3027	TI3027
2N179	TI3027	TI3027
2N180	2N404	2N404
2N181	2N404	2N404
2N182	2N1302	2N1302
2N183	2N1302	2N1302
2N184	2N1306	2N1306
2N185	2N404	2N404
2N186	2N404	2N404
2N186A	2N404	2N404
2N193	2N1302	2N1302
2N194	2N1302	2N1302

Type	Preferred TI Type	Nearest TI Type
*2N204	2N1377	2N1373
*2N205	2N1377	2N1372
2N206	2N1377	2N1372
2N207	2N1377	2N1372
2N211	2N1302	2N1302
2N212	2N1302	2N1302
2N213	2N1304	2N1304
2N214	2N1304	2N1304
2N215	2N404	2N404
2N216	2N1302	2N1302
2N217	2N404	2N404
2N218	2N404	2N404
2N219	2N404	2N404
2N220	2N404	2N404
2N223	2N404	2N404
2N224	2N404	2N404
2N225	2N404	2N404
2N226	2N404	2N404
2N227	2N404	2N404
2N228	2N1302	2N1302
2N229	2N1302	2N1302
2N231	2N404	2N404
2N232	2N404	2N404
2N233	2N1306	2N1306
2N234	TI3027	TI3027
2N234A	TI3027	TI3027
2N235	TI3027	TI3027
2N235A	TI3027	TI3027
2N235B	TI3027	TI3027
2N236	TI3027	TI3027
2N236A	TI3027	TI3028
2N236B	TI3027	TI3028
2N237	2N404	2N404
2N238	2N404	2N404
2N240	2N404	2N404
2N241	2N404	2N404
2N242	TI3027	TI3029
2N243		2N243
2N244		2N244
2N247		2N2188
2N248		2N2188
2N249	2N404	2N404
2N250	2N456A	2N250
2N250A	2N456A	2N250A
2N251	2N456A	2N251
2N251A	2N456A	2N251A
2N252		2N2188
2N253	2N1302	2N1302
2N254	2N1302	2N1302
2N255	TI3027	TI3027
2N255A	TI3027	TI3027
2N256	TI3027	TI3027
2N256A	TI3027	TI3027
2N257	TI3027	TI3027
*2N257B	TI3027	TI3027
2N263		2N263
2N264		2N264
2N265	2N404	2N404
2N266	2N404	2N404
2N267		2N2188
2N268	TI3027	TI3027
2N268A	TI3027	TI3030
2N269	2N1303	2N1303
2N270	2N404	2N404
2N271	2N404	2N404
2N272	2N404	2N404
2N273	2N404	2N404
2N274		2N2188
2N279	2N404	2N404
2N280	2N404	2N404
2N281	2N404	2N404
2N282	2N404	2N404
2N283	2N404	2N404
2N284	2N404	2N404
2N285	TI3027	TI3027
2N285A	TI3027	TI3027
*2N285B	TI3027	TI3027
2N291	2N404	2N404
2N292	2N1302	2N1302
2N293	2N1304	2N1304

*Denotes 1N- or 2N- numbers not JEDEC registered through September 1968.

Type	Preferred TI Type	Nearest TI Type
2N296	2N456A	2N3146
2N297	TI3027	TI3028
2N297A		TI3028
2N299		2N2188
2N300		2N2188
2N301	TI3027	TI3027
2N301A	TI3027	TI3028
2N302	2N1303	2N1303
2N303	2N1303	2N1303
2N306	2N1302	2N1302
2N307	TI3027	TI3027
2N307A	TI3027	TI3027
2N308	2N1377	2N1375
2N309	2N1377	2N1375
2N310	2N1377	2N1375
2N311	2N404	2N404
2N312	2N1304	2N1304
2N315		2N315A
2N315A		2N315A
2N316	2N404	2N404
2N317		2N317A
2N317A		2N317A
2N325	TI3027	TI3027
2N326	TI3027	TI3027
2N327A		2N327A
2N328A		2N328A
2N329A		2N329A
2N331	2N404	2N404
2N332		2N332
2N332A		2N332A
2N333		2N333
2N333A		2N333A
2N334		2N334
2N334A		2N334A
2N335		2N335
2N335A		2N335A
2N336		2N336
2N336A		2N336A
2N337		2N337
2N338		2N338
2N339		2N339
2N340		2N340
2N341		2N341
2N342		2N342
2N342A		2N342A
2N343		2N343
2N344	2N404	2N404
2N345	2N404	2N404
2N346	2N404	2N404
2N350	TI3027	TI3028
2N350A	TI3027	TI3028
2N351	TI3027	TI3028
2N351A	TI3027	TI3028
2N352	TI3027	TI3027
2N353	TI3027	TI3027
2N356	2N1302	2N1302
2N356A	2N1302	2N1302
2N357	2N1302	2N1302
2N357A	2N1302	2N1302
2N358	2N1304	2N1304
2N358A	2N1304	2N1304
2N359	2N404	2N404
2N360	2N404	2N404
2N361	2N404	2N404
2N362	2N404	2N404
2N363	2N404	2N404
2N364	2N1306	2N1306
2N365	2N1306	2N1306
2N366	2N1306	2N1306
2N367	2N404	2N404
2N370		2N2188
2N371		2N2188
2N372		2N2188
2N373		2N2188
2N374		2N2188
2N375	TI3027	TI3031
2N376	TI3027	TI3028
2N377	2N1302	2N377
2N377A	2N1302	2N377
2N378	TI3027	TI3027
2N379	TI3027	TI3029
2N380	TI3027	TI3030
2N384		2N2189
2N385	2N1304	2N1304
2N385A	2N1304	2N1304
2N386	TI3027	TI3027
2N387	TI3027	TI3027

Type	Preferred TI Type	Nearest TI Type
2N388	2N1306	2N388
2N388A	2N1306	2N388A
2N389		2N389
2N389A		2N389A
2N392	TI3027	TI3027
2N393		2N2189
2N394	2N404	2N404
2N395	2N1308	2N395
2N396	2N1305	2N396
2N396A	2N1307	2N397
2N397	2N1307	2N397
2N398	2N398	2N398
2N398A	2N398	2N398A
2N398B	2N398	2N398B
2N399	TI3027	TI3028
2N400	TI3027	TI3028
2N401	TI3027	TI3028
2N402	2N404	2N404
2N403	2N404	2N404
2N404	2N404	2N404
2N404A	2N404	2N404A
2N405	2N404	2N404
2N406	2N404	2N404
2N407	2N404	2N404
2N408	2N404	2N404
2N409	2N404	2N404
2N410	2N404	2N404
2N411	2N404	2N404
2N412	2N404	2N404
2N413	2N404	2N404
2N414	2N404	2N404
2N415	2N404	2N404
2N416	2N404	2N404
2N417	2N404	2N404
2N418	2N456A	2N3146
2N419	TI3027	TI3029
2N420	TI3027	TI3029
2N420A	2N456A	2N3146
2N424		2N424
2N424A		2N424A
2N425	2N404	2N404
2N426	2N404	2N426
2N427	2N404	2N427
2N428	2N404	2N428
2N428A	2N404	2N428
2N438	2N1304	2N438
2N438A	2N1304	2N438A
2N439	2N1304	2N439
2N439A	2N1304	2N439
2N440	2N1304	2N440
2N444	2N1304	2N1304
2N444A	2N1304	2N1304
2N445	2N1304	2N1304
2N445A	2N1304	2N1304
2N446A	2N1304	2N1304
2N447A	2N1304	2N1304
2N448	2N1307	2N1307
2N449	2N1306	2N1306
2N450	2N1302	2N1302
2N456	2N456A	2N456A
2N456A	2N456A	2N456A
2N456B	2N456A	2N456B
2N457	2N456A	2N457A
2N457A	2N456A	2N457A
2N457B	2N456A	2N457B
2N458	2N456A	2N458A
2N458A	2N456A	2N458A
2N458B	2N456A	2N458B
2N459	2N456A	2N3146
2N459A	TI3027	TI3031
2N462		2N1319
2N464	2N404	2N404
2N465	2N404	2N404
2N466	2N404	2N404
2N467	2N404	2N404
2N470		2N470
2N471		2N471
2N472		2N472
2N473		2N473
2N474		2N474
2N475		2N475
2N476		2N476
2N477		2N477
2N478		2N478
2N479		2N479
2N480		2N480
2N481		2N2188

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES (Cont'd.)

Type	Preferred TI Type	Nearest TI Type
2N482		2N2189
2N483		2N2189
2N484		2N2189
2N485		2N2190
2N486		2N2191
2N487		2N2191
2N489	2N491A	2N489
2N489A	2N491A	2N489A
2N489B	2N491A	2N489B
2N490	2N491A	2N490
2N490A	2N491A	2N490A
2N490B	2N491A	2N490B
2N491	2N491A	2N491
2N491A	2N491A	2N491A
2N491B	2N491A	2N491B
2N492	2N491A	2N492
2N492A	2N491A	2N492A
2N492B	2N491A	2N492B
2N492C	2N491A	2N492B
2N493	2N491A	2N493
2N493A	2N491A	2N493A
2N493B	2N491A	2N493B
2N494	2N491A	2N494
2N494A	2N491A	2N494A
2N494B	2N491A	2N494B
2N494C	2N491A	2N494C
2N495	2N2945A	2N2944
2N496	2N2945A	2N2944
2N497		2N497
2N497A		2N497A
2N498		2N498
2N498A		2N498A
2N499		2N2188
2N500		2N2189
2N501		2N2189
2N502		2N2189
2N503		2N2189
2N504		2N2189
2N508		2N508
2N511	2N456A	2N511
2N511A	2N456A	2N511A
2N511B	2N456A	2N511B
2N512	2N456A	2N512
2N512A	2N456A	2N512A
2N512B	2N456A	2N512B
2N513	2N456A	2N513
2N513A	2N456A	2N513A
2N513B	2N456A	2N513B
2N514	2N456A	2N514
2N514A	2N456A	2N514A
2N514B	2N456A	2N514B
2N515		2N1304
2N516		2N1304
2N517	2N1306	2N1306
2N518	2N404	2N404
2N519	2N404	2N404
2N520	2N404	2N520
2N520A	2N404	2N520A
2N521	2N1377	2N1377
2N522		2N522A
2N522A		2N522A
2N523	2N1377	2N1377
2N524		2N524
2N525		2N525
2N526		2N526
2N527		2N527
2N534	2N404	2N404
2N535	2N404	2N404
2N536	2N404	2N404
2N538	TI3027	TI3031
2N538A	TI3027	TI3031
2N539	TI3027	TI3031
2N539A	TI3027	TI3031
2N540	TI3027	TI3031
2N540A	TI3027	TI3031
2N541		2N541
2N541A		2N541
2N542		2N542
2N542A		2N542
2N543		2N543
2N543A		2N543
2N544		2N2188
2N549	2N1893	2N1893
2N550	2N1893	2N1893
2N551	2N1893	2N1893
2N552	2N1893	2N1893
2N554	TI3027	TI3027

Type	Preferred TI Type	Nearest TI Type
2N555	TI3027	TI3027
2N556	2N1302	2N1302
2N557	2N1304	2N1304
2N558	2N1306	2N1306
2N560	2N3015	2N2537
2N561	2N456A	2N3146
2N574	2N456A	2N1022A
2N574A	2N456A	2N3146
2N576	2N1304	2N1304
2N578	2N404	2N404
2N579	2N404	2N404
2N580	2N404	2N404
2N581	2N404	2N581
2N582	2N404	2N582
2N583	2N404	2N404
2N584	2N404	2N404
2N585	2N1304	2N1304
2N586	2N404	2N404
2N587	2N1304	2N587
2N588		2N2189
2N591	2N404	2N404
2N594		2N594
2N595		2N595
2N596		2N596
2N597	2N1997	2N1997
2N598	2N1997	2N1998
2N599	2N1997	2N1999
2N600	2N1997	2N1998
2N601	2N1997	2N1999
2N602	2N2635	2N2635
2N603	2N2635	2N2635
2N604	2N2635	2N2635
2N605	2N2635	2N2635
2N606	2N2635	2N2635
2N607	2N2635	2N2635
2N608	2N2635	2N2635
2N609	2N404	2N404
2N610	2N404	2N404
2N611	2N404	2N404
2N612	2N404	2N404
2N613	2N404	2N404
2N614	2N404	2N404
2N615	2N404	2N404
2N617	2N404	2N404
2N618	TI3027	TI3030
2N622	2N2432	2N2432
2N624		2N2188
2N625	2N1308	2N1308
2N627	TI3027	TI3027
2N628	TI3027	TI3028
2N629	TI3027	TI3030
2N630	TI3027	TI3031
2N631	2N404	2N404
2N632	2N404	2N404
2N633	2N404	2N404
2N634	2N1304	2N634A
2N634A	2N1304	2N634A
2N635	2N1304	2N635A
2N635A	2N1304	2N635A
2N636	2N1304	2N636A
2N636A	2N1304	2N636A
2N637	TI3027	TI3027
2N637A	TI3027	TI3031
2N637B	2N456A	2N3146
2N638	TI3027	TI3027
2N638A	TI3027	TI3028
2N638B	2N456A	2N3146
2N639	TI3027	TI3028
2N639A	2N456A	2N3146
2N639B	2N456A	2N3146
2N640		2N2188
2N641		2N2188
2N642		2N2188
2N643	2N2635	2N2635
2N644	2N2635	2N2635
2N645	2N2635	2N2635
2N647	2N1306	2N1306
2N649	2N1308	2N1308
2N650	2N1997	2N650A
2N650A	2N1997	2N650A
2N651	2N1997	2N651A
2N651A	2N1997	2N651A
2N652	2N1997	2N652A
2N652A	2N1997	2N652A
2N653	2N1997	2N1997
2N654	2N1997	2N1997
2N655	2N1997	2N1997
2N656		2N656

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES (Cont'd.)

Type	Preferred TI Type	Nearest TI Type
2N656A		2N656A
2N657		2N657
2N657A		2N657A
2N658	2N2000	2N658
2N659	2N2000	2N659
2N660	2N2000	2N660
2N661	2N2000	2N661
2N662	2N2000	2N662
2N663	TI3027	TI3027
2N665	TI3027	TI3028
2N669	TI3027	TI3027
2N670	2N1038	2N1038
2N671	2N1038	2N1038
2N672	2N1038	2N1038
2N673	2N1038	2N1038
2N674	2N1038	2N1038
2N677	2N456A	2N456A
2N677A	2N456A	2N456B
2N677B	2N456A	2N3146
2N677C	2N456A	2N3146
2N678	2N456A	2N513
2N678A	2N456A	2N513
2N678B	2N456A	2N513A
2N678C	2N456A	2N513B
2N679	2N1304	2N1304
2N680	2N404	2N404
2N681		2N681
2N681A		2N681A
2N682		2N682
2N682A		2N682A
2N683		2N683
2N683A		2N683A
2N684		2N684
2N684A		2N684A
2N685		2N685
2N685A		2N685A
2N686		2N686
2N686A		2N686A
2N687		2N687
2N687A		2N687A
2N688		2N688
2N688A		2N688A
2N689		2N689
2N689A		2N689A
2N694	2N2635	2N2635
2N695	2N2635	2N2635
2N696	2N697	2N696
2N697	2N697	2N697
2N698	2N1893	2N698
2N699	2N1893	2N699
2N699A	2N1893	2N699
2N699B	2N1893	2N699
2N700	2N5043	2N2415
2N700A	2N5043	2N2415
2N702		2N702
2N703		2N703
2N705	2N964	2N705
2N705A	2N964	2N705
2N706		2N706
2N706A		2N706A
2N706B		2N706B
2N706C		2N706B
2N707	2N2484	2N2483
2N707A	2N2484	2N2484
2N708		2N708
2N708A		2N708
2N709	2N3010	2N709
2N709A	2N3010	2N709
2N710	2N964	2N710
2N710A	2N964	2N710
2N711	2N964	2N711
2N711A	2N964	2N711A
2N711B	2N964	2N711B
2N715	2N4875	2N4875
2N716	2N4875	2N4875
2N717	2N718A	2N717
2N718	2N718A	2N718
2N718A	2N718A	2N718A
2N719	2N720A	2N719
2N719A	2N720A	2N719A
2N720	2N720A	2N720
2N720A	2N720A	2N720A
2N721	2N2907	2N721
2N721A	2N2907	2N721
2N722	2N2907	2N722
2N722A	2N2907	2N722
2N725	2N2635	2N2635
2N726		2N726

Type	Preferred TI Type	Nearest TI Type
2N727		2N727
2N728	2N2219	2N2217
2N729	2N2219	2N2217
2N730	2N718A	2N730
2N731	2N718A	2N731
2N734		2N734
2N735		2N735
2N735A		2N735
2N736		2N736
2N736A		2N736A
2N736B		2N736A
2N738		2N738
2N739		2N739
2N739A		2N739
2N740		2N740
2N740A		2N740
2N741	2N5043	2N2996
2N741A	2N5043	2N2997
2N742	2N2219	2N2217
2N742A	2N2219	2N2217
2N743		2N743
2N743A		2N743
2N744		2N744
2N744A		2N744
2N745		2N337
2N746		2N338
2N747		2N337
2N748		2N337
2N749	2N697	2N696
2N751	2N697	2N697
2N752		2N736
2N753		2N753
2N754	2N1893	2N1893
2N755	2N1893	2N1893
2N756		2N734
2N757		2N734
2N757A		2N734
2N758		2N734
2N758A		2N734
2N758B		2N734
2N759		2N759
2N759A		2N759A
2N759B		2N759A
2N760		2N760
2N760A		2N760A
2N760B		2N760A
2N768	2N964	2N961
2N769	2N964	2N964
2N773		2N734
2N774		2N734
2N775		2N735
2N776		2N734
2N777		2N734
2N778		2N735
2N779	2N964	2N964
2N779A	2N964	2N964
2N780		2N780
2N781	2N2635	2N2635
2N782	2N2635	2N2635
2N783	2N3010	2N3010
2N784	2N3010	2N3010
2N784A	2N3010	2N3010
2N789		2N332
2N790		2N333
2N791		2N334
2N792		2N335
2N793		2N336
2N794	2N2635	2N2635
2N795	2N2635	2N2635
2N796	2N2635	2N2635
2N797	2N797	2N797
2N799	2N1309	2N1309
2N800	2N404	2N404
2N801	2N404	2N404
2N802	2N404	2N404
2N803	2N404	2N404
2N804	2N404	2N404
2N805	2N404	2N404
2N806	2N404	2N404
2N807	2N404	2N404
2N808	2N404	2N404
2N809	2N404	2N404
2N810	2N404	2N404
2N812	2N404	2N404
2N813	2N404	2N404
2N814	2N404	2N404
2N815	2N404	2N404
2N816	2N404	2N404

Type	Preferred TI Type	Nearest TI Type
2N817	2N404	2N404
2N818	2N404	2N404
2N819	2N404	2N404
2N820	2N404	2N404
2N821	2N404	2N404
2N822	2N404	2N404
2N823	2N404	2N404
2N824	2N404	2N404
2N825	2N404	2N404
2N826	2N404	2N404
2N834		2N3014
2N834A		2N3014
2N835		2N3014
2N838	2N2635	2N2635
2N839	2N930	2N929
2N840	2N930	2N929
2N841	2N930	2N929
2N842	2N4252	2N4253
2N843	2N4252	2N4253
2N844	2N1893	2N1893
2N845	2N1893	2N1893
2N846	2N964	2N964
2N846A	2N964	2N964
2N846B	2N964	2N964
2N849		2N849
2N850		2N850
2N851		2N851
2N852		2N852
2N858	2N2945A	2N2945
2N859	2N2945A	2N2945
2N860	2N2945A	2N2945
2N861	2N2945A	2N2944
2N862	2N2945A	2N2944
2N863	2N2945A	2N2944
2N864	2N2905	2N2904
2N864A	2N2905	2N2904
2N865	2N2905	2N2904
2N865A	2N2905	2N2904
2N869	2N2905	2N2904
2N869A	2N2894	2N3576
2N870	2N720A	2N870
2N871	2N720A	2N871
2N876		2N876
2N877		2N877
2N878		2N878
2N879		2N879
2N880		2N880
2N881		2N881
2N884		2N884
2N885		2N885
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2N887		2N887
2N888		2N888
2N889		2N889
2N902		2N332
2N903		2N333
2N904		2N334
2N905		2N335
2N906		2N336
2N907	2N3015	2N2537
2N908	2N3015	2N2537
2N909	2N2243A	2N2192
2N910	2N720A	2N910
2N911	2N720A	2N911
2N912	2N720A	2N912
2N914		2N914
2N914A		2N914
2N915		2N915
2N915A		2N915
2N916		2N916
2N916A		2N916
2N916B		2N916
2N917	2N918	2N917
2N917A	2N918	2N917
2N918	2N918	2N918
2N919		2N706
2N920		2N706
2N923	2N2605	2N2604
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2N925	2N2605	2N2604
2N926	2N2605	2N2604
2N927	2N2605	2N2604
2N928	2N2605	2N2604
2N929	2N930	2N929
2N929A	2N930	2N929A
2N930	2N930	2N930
2N930A	2N930	2N930A
2N930B	2N930	2N930A
2N934	2N2635	2N2635
2N935	2N2945A	2N2944
2N936	2N2945A	2N2944
2N937	2N2945A	2N2944
2N938	2N2945A	2N2944
2N939	2N2945A	2N2944
2N940	2N2945A	2N2944
2N941	2N2945A	2N2944
2N942	2N2945A	2N2944
2N943	2N2945A	2N2944
2N944	2N2945A	2N2944
2N945	2N2945A	2N2944
2N946	2N2945A	2N2944
2N947		2N706
2N955	2N797	2N797
2N955A	2N797	2N797
2N956	2N718A	2N956
2N957	2N2484	2N2484
2N958		2N706
2N959		2N706
2N960	2N964	2N960
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2N962	2N964	2N962
2N963	2N964	2N963
2N964	2N964	2N964
2N964A	2N964	2N964A
2N965	2N964	2N965
2N966	2N964	2N966
2N967	2N964	2N967
2N968	2N964	2N968
2N969	2N964	2N969
2N970	2N964	2N970
2N971	2N964	2N971
2N972	2N964	2N972
2N973	2N964	2N973
2N974	2N964	2N974
2N975	2N964	2N975
2N976	2N964	2N961
2N977	2N964	2N985
2N978	2N2907	2N721
2N979	2N2635	2N2635
2N980	2N2635	2N2635
2N982	2N964	2N985
2N983	2N964	2N985
2N984	2N964	2N985
2N985	2N964	2N985
2N986	LS600	LS600
2N987	2N2635	2N2635
2N988		2N706
2N989		2N706
2N990	2N2635	2N2635
2N991	2N2635	2N2635
2N992	2N2635	2N2635
2N993	2N2635	2N2635
2N995		2N995
2N995A		2N995
2N996	2N2907	2N2906
2N997	2N997	2N997
2N998	2N997	2N997
2N999	2N997	2N997
2N1000	2N404	2N404A
2N1010	2N1302	2N1302
2N1011	TI3027	TI3028
2N1012	2N1306	2N388A
2N1014	2N456A	2N1021
2N1017	2N404	2N582
2N1018	2N404	2N582
2N1021	2N456A	2N1021
2N1021A	2N456A	2N1021A
2N1022	2N456A	2N1022
2N1022A	2N456A	2N1022A
2N1023	2N2635	2N2635
2N1024	2N2945A	2N2944
2N1025	2N2945A	2N2944
2N1026	2N2945A	2N2944
2N1027	2N2945A	2N2944
2N1028	2N2945A	2N2944
2N1029	TI3027	TI3027
2N1029A	TI3027	TI3027
2N1029B	TI3027	TI3031
2N1029C	2N456A	2N3146
2N1030	2N456A	2N514A
2N1030A	2N456A	2N514B
2N1031	TI3027	TI3027
2N1031A	TI3027	TI3027
2N1031B	TI3027	TI3031
2N1031C	2N456A	2N3146
2N1032	2N456A	2N514A

Type	Preferred TI Type	Nearest TI Type
2N1032A	2N456A	2N514B
2N1034	2N2945A	2N2944
2N1035	2N2945A	2N2944
2N1036	2N2945A	2N2944
2N1037	2N2945A	2N2944
2N1038	2N1038	2N1038
2N1038-1	2N1038	2N2552
2N1038-2	2N1038	2N2556
2N1039	2N1038	2N1039
2N1039-1	2N1038	2N2553
2N1039-2	2N1038	2N2557
2N1040	2N1038	2N1040
2N1040-1	2N1038	2N2554
2N1040-2	2N1038	2N2558
2N1041	2N1038	2N1041
2N1041-1	2N1038	2N2555
2N1041-2	2N1038	2N2559
2N1042	2N1038	2N1042
2N1042-1	2N1038	2N2560
2N1042-2	2N1038	2N2564
2N1043	2N1038	2N1043
2N1043-1	2N1038	2N2561
2N1043-2	2N1038	2N2565
2N1044	2N1038	2N1044
2N1044-1	2N1038	2N2562
2N1044-2	2N1038	2N2566
2N1045	2N1038	2N1045
2N1045-1	2N1038	2N2563
2N1045-2	2N1038	2N2567
2N1046	2N1907	2N1046
2N1046A	2N1907	2N1046
2N1046B	2N1907	2N1046
2N1047		2N1047
2N1047A		2N1047A
2N1047B		2N1047B
2N1048		2N1048
2N1048A		2N1048A
2N1048B		2N1048B
2N1049		2N1049
2N1049A		2N1049A
2N1049B		2N1049B
2N1050		2N1050
2N1050A		2N1050A
2N1050B		2N1050B
2N1051	2N2219	2N2217
2N1052		2N5058
2N1054		2N5059
2N1058	2N404	2N404
2N1059	2N404	2N404
2N1060	2N2219	2N2217
2N1065		2N2188
2N1066		2N2189
2N1074		2N328A
2N1075		2N328A
2N1076		2N328A
2N1078	2N404	2N404
2N1081	2N3725	2N3724
2N1082	2N2219	2N2217
2N1086	2N1308	2N1308
2N1086A	2N1308	2N1308
2N1087	2N1308	2N1308
2N1090	2N1304	2N1605
2N1091	2N1304	2N1605
2N1093	2N1305	2N1305
2N1094	2N1308	2N1308
2N1101	2N1302	2N1302
2N1102	2N1306	2N1306
2N1107		2N2188
2N1108		2N2188
2N1109		2N2188
2N1110		2N2188
2N1111		2N2188
*2N1111A		2N2188
*2N1111B		2N2188
2N1116	2N2243A	2N2243
2N1117	2N2243A	2N2193
2N1118	2N2605	2N2604
2N1118A	2N2605	2N2604
2N1119	2N2605	2N2604
2N1120	TI3027	TI3031
2N1121	2N1306	2N1306
2N1122	2N964	2N964
2N1122A	2N964	2N964
2N1123	2N1997	2N1997
2N1124	2N1377	2N1375
2N1125	2N2000	2N2000
2N1128	2N1377	2N1377
2N1129	2N1377	2N1379

Type	Preferred TI Type	Nearest TI Type
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2N1131	2N2905	2N1131
2N1131A	2N2905	2N1131
2N1132	2N2905	2N1132
2N1132B	2N2905	2N1132
2N1136	TI3027	TI3027
2N1136A	TI3027	TI3028
2N1136B	2N456A	2N3146
2N1137	2N456A	2N456A
2N1137A	2N456A	2N1022A
2N1137B	2N456A	2N3146
2N1138	TI3027	TI3029
2N1138A	2N456A	2N3146
2N1138B	2N456A	2N3146
2N1141		2N1141
2N1141A		2N1141A
2N1142		2N1142
2N1142A		2N1142A
2N1143		2N1143
2N1143A		2N1143A
2N1144	2N1303	2N1303
2N1145	2N1303	2N1303
2N1146	2N456A	2N456A
2N1146A	2N456A	2N456B
2N1146B	2N456A	2N1021A
2N1146C	2N456A	2N3146
2N1147	2N456A	2N456A
2N1147A	2N456A	2N456B
2N1147B	2N456A	2N1021A
2N1147C	2N456A	2N3146
2N1149		2N1149
2N1150		2N1150
2N1151		2N1151
2N1152		2N1152
2N1153		2N1153
2N1154		2N1154
2N1155		2N1155
2N1156		2N1156
2N1158	2N5043	2N2996
2N1159	2N456A	2N3146
2N1160	2N456A	2N3146
2N1162	2N456A	2N514A
2N1162A	2N456A	2N514A
2N1163	2N456A	2N514A
2N1163A	2N456A	2N514A
2N1168	TI3027	TI3027
2N1169		2N1995
2N1170		2N1996
2N1171	2N404	2N404
2N1172	TI3027	TI3028
2N1173	2N1304	2N1605
2N1174	2N404	2N404A
2N1176	2N1038	2N1038
*2N1176A	2N1038	2N1038
*2N1176B	2N1038	2N1041
2N1177		2N2188
2N1178		2N2188
2N1179		2N2188
2N1180		2N2188
2N1183	2N1038	2N1038
2N1183A	2N1038	2N1038
2N1183B	2N1038	2N1039
2N1184	2N1038	2N2564
2N1184A	2N1038	2N2564
2N1184B	2N1038	2N2565
2N1185	2N1377	2N1375
2N1186	2N1377	2N1375
2N1187	2N1377	2N1376
2N1188	2N1377	2N1376
2N1189	2N1377	2N1377
2N1190	2N1377	2N1377
2N1191	2N404	2N404
2N1192	2N404	2N404
2N1193	2N404	2N404
2N1194	2N404	2N404
2N1195	2N404	2N1195
2N1198	2N1304	2N1304
2N1200	2N4252	2N4252
2N1201	2N4252	2N4252
2N1202	2N456A	2N3146
2N1203	2N456A	2N3146
2N1206		2N5059
2N1207		2N5059
2N1209	2N1724	2N1724
2N1210		2N1722
2N1211		2N1722
2N1212	2N1724	2N1724
2N1217	2N1308	2N1308

*Denotes 1N- or 2N- numbers not JEDEC registered through September 1968.

Type	Preferred TI Type	Nearest TI Type
2N1220	2N2905	2N2904
2N1221	2N2905	2N2904
2N1222	2N2905	2N2904
2N1223	2N2905	2N2904
2N1224	2N2635	2N2635
2N1225	2N2635	2N2635
2N1226	2N2635	2N2635
2N1227	TI3027	TI3027
2N1235		2N1235
2N1245	2N404	2N404
2N1246	2N404	2N404
2N1249		2N1248
2N1251	2N1304	2N1304
2N1252		2N1252
2N1252A		2N1252
2N1253		2N1253
2N1253A		2N1253
2N1254	2N2907	2N722
2N1255	2N2907	2N722
2N1256	2N2907	2N722
2N1257	2N2907	2N722
2N1258	2N2907	2N722
2N1259	2N2907	2N722
2N1260		2N1260
2N1261	TI3027	TI3030
2N1262	TI3027	TI3030
2N1263	TI3027	TI3030
2N1265	2N404	2N404
2N1266	2N404	2N404
2N1267	2N4252	2N4253
2N1268	2N4252	2N4253
2N1269	2N4252	2N4253
2N1270	2N4252	2N4253
2N1271	2N4252	2N4253
2N1272	2N4252	2N4253
2N1273	2N404	2N1273
2N1274	2N404	2N1274
2N1275	2N2945A	2N2944
2N1276		2N1276
2N1277		2N1277
2N1278		2N1278
2N1279		2N1279
2N1280	2N1305	2N1305
2N1281	2N1305	2N1305
2N1282	2N1305	2N1305
2N1284	2N1305	2N1305
2N1285		2N2188
2N1287	2N1303	2N1303
2N1287A	2N1305	2N1305
2N1291	TI3027	TI3027
2N1293	TI3027	TI3028
2N1295	2N456A	2N3146
2N1297	2N456A	2N3146
2N1298	2N1302	2N1302
2N1299	2N1306	2N1306
2N1300	2N2635	2N2635
2N1301	2N2635	2N2635
2N1302	2N1302	2N1302
2N1303	2N1303	2N1303
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2N1307	2N1307	2N1307
2N1308	2N1308	2N1308
2N1309	2N1309	2N1309
2N1314	TI3027	TI3027
2N1316	2N1997	2N1999
2N1317	2N1997	2N1999
2N1318	2N1997	2N1998
2N1319		2N1319
2N1320	2N1038	2N1038
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2N1326	2N1038	2N1041
2N1328	2N1038	2N1038
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*2N1350	2N404	2N404
*2N1351	2N404	2N404
2N1353	2N404	2N404
2N1354	2N404	2N404
2N1355	2N404	2N404

Type	Preferred TI Type	Nearest TI Type
2N1356	2N404	2N404
2N1357	2N404	2N404
2N1359	TI3027	TI3027
2N1360	TI3027	TI3027
2N1362	2N456A	2N3146
2N1363	2N456A	2N3146
2N1364	2N456A	2N3146
2N1365	2N456A	2N3146
2N1366	2N1302	2N1302
2N1367	2N1304	2N1304
2N1370	2N1377	2N1370
2N1371	2N1377	2N1371
2N1372	2N1377	2N1372
2N1373	2N1377	2N1373
2N1374	2N1377	2N1374
2N1375	2N1377	2N1375
2N1376	2N1377	2N1376
2N1377	2N1377	2N1377
2N1378	2N1377	2N1378
2N1379	2N1377	2N1379
2N1380	2N1377	2N1380
2N1381	2N1377	2N1381
2N1382	2N1377	2N1382
2N1383	2N1377	2N1383
2N1384	2N2635	2N2635
2N1385		2N1385
2N1391	2N1302	2N1302
2N1395		2N2188
2N1396		2N2191
2N1397		2N2191
2N1398		2N2996
2N1399		2N2996
2N1400		2N2996
2N1401		2N2996
2N1402		2N2996
2N1403		2N2996
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2N1404A	2N1303	2N1404
2N1405		2N2996
2N1406		2N2996
2N1407		2N2996
2N1408	2N2000	2N2000
2N1411		2N2188
2N1413		2N1413
2N1414		2N1414
2N1415		2N1415
2N1416	2N404	2N404
2N1420	2N1893	2N1420
2N1420A	2N1893	2N1420
2N1425		2N2188
2N1426		2N2188
2N1427	2N2635	2N2635
2N1428	2N2905	2N1132
2N1429	2N2905	2N1132
2N1431	2N1302	2N1302
2N1432		2N2189
2N1437	2N456A	2N3146
2N1438	2N456A	2N3146
2N1439	2N2945A	2N2946
2N1440	2N2945A	2N2946
2N1441	2N2945A	2N2946
2N1442	2N2945A	2N2946
2N1443	2N2945A	2N2946
2N1444		2N3252
2N1445		2N1445
2N1446	2N1377	2N1373
2N1447	2N1377	2N1373
2N1448	2N1377	2N1373
2N1449	2N1377	2N1375
2N1450		2N1143
2N1451	2N1377	2N1375
2N1452	2N1377	2N1375
2N1465	2N456A	2N3146
2N1466	2N456A	2N3146
2N1469	2N2945A	2N2944
2N1471	2N1309	2N1309
2N1472	2N3015	2N2537
2N1473	2N2000	2N2000
2N1474	2N2945A	2N2944
2N1474A	2N2945A	2N2944
2N1475	2N2945A	2N2944
2N1476	2N2945A	2N2944
2N1477	2N2945A	2N2944
2N1478	2N1997	2N1997
2N1479	2N2987	2N2987
2N1480	2N2988	2N2988
2N1481	2N2989	2N2989
2N1482	2N2990	2N2990

*Denotes 1N- or 2N- numbers not JEDEC registered through September 1968.

Type	Preferred TI Type	Nearest TI Type
2N1499	2N964	2N964
2N1499A	2N964	2N964
2N1499B	2N964	2N964
2N1500	2N964	2N964
2N1501	TI3027	TI3028
2N1502	TI3027	TI3028
2N1504	2N456A	2N3146
2N1505	2N2219	2N2217
2N1506	2N2219	2N2217
2N1507	2N1893	2N1507
*2N1515		2N2191
2N1516		2N2189
*2N1517		2N2189
2N1524	TIS37	2N2188
2N1525	TIS37	2N2188
2N1526	TIS37	2N2189
2N1527	TIS37	2N2189
2N1529		2N1529
2N1530		2N1530
2N1531		2N1531
2N1532		2N1532
2N1533		2N1533
2N1534		2N1534
2N1534A		2N1534
2N1535		2N1535
2N1535A		2N1535
2N1536		2N1536
2N1536A		2N1536
2N1537		2N1537
2N1537A		2N1537
2N1538		2N1538
2N1539	2N1539	2N1539
2N1540		2N1540
2N1540A		2N1540
2N1541		2N1541
2N1541A		2N1541
2N1542		2N1542
2N1542A		2N1542
2N1543		2N1543
2N1544		2N1544
2N1544A		2N1544
2N1545		2N1545
2N1545A		2N1545
2N1546		2N1546
2N1546A		2N1546
2N1547		2N1547
2N1547A		2N1547
2N1548		2N1548
2N1549	TI3027	TI3027
2N1549A	TI3027	TI3027
2N1550		TI3028
2N1550A		TI3028
2N1551		2N458B
2N1551A		2N458B
2N1552		2N1021A
2N1552A		2N1021A
2N1553	TI3027	TI3027
2N1553A	TI3027	TI3027
2N1554		TI3028
2N1554A		TI3028
2N1555		2N458B
2N1555A		2N458B
2N1556		2N1021A
2N1556A		2N1021A
2N1557	2N456A	2N514
2N1557A	2N456A	2N514
2N1558		2N514A
2N1558A		2N514A
2N1559		2N514B
2N1559A		2N514B
2N1560		2N1021A
2N1560A		2N1021A
2N1564		2N1564
2N1565		2N1565
2N1566		2N1566
2N1566A		2N1566A
2N1572		2N1572
2N1573		2N1573
2N1574		2N1574
2N1586		2N1586
2N1587		2N1587
2N1588		2N1588
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2N1592		2N1592
2N1593		2N1593
2N1594		2N1594
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2N1602		2N1602
2N1603		2N1603
2N1604		2N1604
2N1605	2N1304	2N1605
2N1605A	2N1304	2N1605
2N1613	2N1613	2N1613
2N1614	2N2000	2N2001
2N1616	2N1724	2N1724
2N1617	2N1724	2N1724
2N1618	2N1724	2N1724
2N1620	2N1724	2N1724
2N1624	2N1308	2N1308
2N1631	2N2635	2N2635
2N1632	2N2635	2N2635
2N1633	2N2635	2N2635
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2N1636	2N2635	2N2635
2N1637	2N2635	2N2635
2N1638	2N2635	2N2635
2N1639	2N2635	2N2635
2N1640	2N2945A	2N2946
2N1641	2N2945A	2N2946
2N1642	2N2945A	2N2946
2N1643	2N2945A	2N2944
2N1644	2N1893	2N1893
2N1647		2N2150
2N1648		2N2151
2N1649		2N2150
2N1650		2N2151
2N1654	2N2945A	2N2944
2N1655	2N2945A	2N2944
2N1656	2N2945A	2N2944
2N1660		2N1722
2N1661		2N1722
2N1662		2N1722
2N1663	2N2369A	2N3011
2N1666	TI3027	TI3027
2N1667	TI3027	TI3027
2N1668	TI3027	TI3027
2N1669	TI3027	TI3027
2N1670	2N398	2N398A
2N1671	2N1671B	2N1671
2N1671A	2N1671B	2N1671A
2N1671B	2N1671B	2N1671B
2N1671C	2N1671B	2N1671B
2N1672	2N1302	2N1302
2N1672A	2N1304	2N1304
2N1673	2N404	2N404
2N1676	2N2945A	2N2944
2N1677	2N2945A	2N2944
2N1678		2N2191
2N1682	2N2219	2N2217
2N1683	2N2635	2N2635
2N1690		2N1690
2N1691		2N1691
2N1694	2N1302	2N1302
2N1704	2N1893	2N1893
2N1708		2N743
2N1708A		2N743
2N1711	2N1711	2N1711
2N1711A	2N1711	2N1711
2N1711B	2N1711	2N1711
2N1714		2N1714
2N1715		2N1715
2N1716		2N1716

*Denotes 1N- or 2N- numbers not JEDEC registered through September 1968.

Type	Preferred TI Type	Nearest TI Type
2N1717		2N1717
2N1718		2N1718
2N1719		2N1719
2N1720		2N1720
2N1721		2N1721
2N1722		2N1722
2N1722A		2N1722A
2N1724	2N1724	2N1724
2N1724A		2N1724A
2N1725		2N1725
2N1726		2N2996
2N1727		2N2996
2N1728		2N2996
2N1729	2N1303	2N1729
2N1730	2N1302	2N1730
2N1731	2N1303	2N1731
2N1732	2N1302	2N1732
2N1742		2N2996
2N1743		2N2996
2N1744		2N2996
2N1745		2N2996
2N1746		2N2996
2N1747		2N2996
2N1748		2N2996
2N1748A		2N2997
2N1749		2N2996
2N1750		2N2996
2N1752		2N2996
2N1754		2N2996
2N1755	2N1038	2N2552
2N1756	2N1038	2N2554
2N1757	2N1038	2N2555
2N1758	2N1038	2N2555
2N1759	2N1038	2N2564
2N1760	2N1038	2N2566
2N1761	2N1038	2N2567
2N1762	2N1038	2N2567
2N1763		2N3014
2N1764	2N2369A	2N3011
2N1768		2N1050
2N1769		2N1050
2N1770		2N1770
2N1770A		2N1770A
2N1771		2N1771
2N1771A		2N1771A
2N1772		2N1772
2N1772A		2N1772A
2N1773		2N1773
2N1773A		2N1773A
2N1774		2N1774
2N1774A		2N1774A
2N1775		2N1775
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2N1776		2N1776
2N1776A		2N1776A
2N1777		2N1777
2N1777A		2N1777A
2N1778		2N1778
2N1785		2N2996
2N1786		2N2996
2N1787		2N2996
2N1788		2N2996
2N1789		2N2996
2N1790		2N2996
2N1808	2N1302	2N1808
2N1842B		2N1842B
2N1843B		2N1843B
2N1844B		2N1844B
2N1845B		2N1845B
2N1846B		2N1846B
2N1847B		2N1847B
2N1848B		2N1848B
2N1849B		2N1849B
2N1850B		2N1850B
2N1853	2N2635	2N2635
2N1854	2N2635	2N2635
2N1864		2N2997
2N1865		2N2997
2N1866		2N2997
2N1867		2N2997
2N1868		2N2997
2N1869	2N3559	2N3559
2N1870	2N3559	2N3559
2N1871	2N3560	2N3560
2N1872	2N3561	2N3561
2N1873	2N3562	2N3562
2N1874	2N3562	2N3562
2N1875	2N3555	2N3555

Type	Preferred TI Type	Nearest TI Type
2N1876	2N3555	2N3555
2N1877	2N3556	2N3556
2N1878	2N3557	2N3557
2N1879	2N3558	2N3558
2N1880	2N3558	2N3558
2N1886		2N2151
2N1889	2N1893	2N1889
2N1890	2N1893	2N1890
2N1891		2N1891
2N1892	2N1303	2N1892
2N1893	2N1893	2N1893
2N1899	2N4002	2N4002
2N1901	2N4002	2N4002
2N1905		2N1046
2N1906	2N1907	2N1907
2N1907	2N1907	2N1907
2N1907A	2N1907	2N1907
2N1908	2N1907	2N1908
2N1908A	2N1907	2N1908
2N1917	2N2945A	2N2944
2N1918	2N2945A	2N2944
2N1919	2N2945A	2N2944
2N1920	2N2945A	2N2944
2N1921	2N2945A	2N2944
2N1922	2N2945A	2N2944
2N1924		2N1924
2N1925		2N1925
2N1926		2N1926
2N1936		2N3846
2N1937		2N3846
2N1940	TI3027	TI3027
2N1943	2N1893	2N1893
2N1944	2N1893	2N1893
2N1945	2N1893	2N1893
2N1946	2N1893	2N1893
2N1954	2N2000	2N2000
2N1955	2N2000	2N2000
2N1956	2N2000	2N2000
2N1957	2N2000	2N2000
2N1960	2N964	2N964
2N1961	2N964	2N964
2N1962	2N2369A	2N3011
2N1963	2N2369A	2N3011
2N1964	2N3015	2N2537
2N1965	2N3015	2N2537
2N1968		2N2997
2N1969		2N2996
2N1972	2N2243A	2N2192
2N1973	2N1893	2N1973
2N1974	2N1893	2N1974
2N1975	2N1893	2N1975
2N1986	2N697	2N696
2N1988	2N1893	2N1893
2N1989	2N1893	2N1893
2N1990	2N697	2N696
2N1991	2N2905	2N1131
2N1992	2N2369A	2N3011
2N1993	2N1302	2N1993
2N1994		2N1994
2N1995		2N1995
2N1996		2N1996
2N1997	2N1997	2N1997
2N1998	2N1997	2N1998
2N1999	2N1997	2N1999
2N2000	2N2000	2N2000
2N2001	2N2000	2N2001
2N2002	2N2945A	2N2944
2N2003	2N2945A	2N2944
2N2004	2N2945A	2N2944
2N2005	2N2945A	2N2944
2N2006	2N2945A	2N2944
2N2007	2N2945A	2N2944
2N2008	2N2990	2N2990
2N2018	2N3996	2N3996
2N2019	2N3996	2N3996
2N2033	2N3420	2N3420
2N2034	2N3421	2N3421
2N2048	2N2635	2N2635
2N2049	2N1711	2N1711
2N2060	2N2060	2N2060
2N2060A	2N2060	2N2060
2N2060B	2N2060	2N2060
2N2061A	TI3027	TI3027
2N2062A	TI3027	TI3027
2N2063A	TI3027	TI3027
2N2064A	TI3027	TI3027
2N2065A	TI3027	TI3030
2N2066A	TI3027	TI3030

Type	Preferred TI Type	Nearest TI Type
2N2067	2N1038	2N2553
2N2068	2N1038	2N2555
2N2084		2N2189
2N2085	2N1304	2N1304
2N2086	2N2243A	2N2243
2N2087	2N2243A	2N2243
2N2089		2N2188
2N2090		2N2188
2N2091		2N2188
2N2092		2N2189
2N2095		2N2999
2N2096		2N2997
2N2097		2N2997
2N2098		2N2999
2N2099		2N2997
2N2100		2N2997
2N2102		2N2102
2N2102A		2N2102A
2N2104	2N2905	2N2904A
2N2105	2N2905	2N2904A
2N2106	2N2987	2N2987
2N2107	2N2987	2N2987
2N2108	2N2989	2N2989
2N2109		2N3846
2N2110		2N3846
2N2111		2N3846
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2N2113		2N3846
2N2114		2N3846
2N2116		2N3846
2N2117		2N3846
2N2118		2N3846
2N2119		2N3846
2N2123	2N4002	2N4002
2N2124	2N4002	2N4002
2N2125	2N4002	2N4002
2N2126	2N4002	2N4002
2N2130	2N4002	2N4002
2N2131	2N4002	2N4002
2N2132	2N4002	2N4002
2N2133	2N4002	2N4002
2N2137	2N1038	2N2552
2N2138	2N1038	2N2552
2N2138A	2N1038	2N2552
2N2139	2N1038	2N2554
2N2139A	2N1038	2N2554
2N2140	2N1038	2N2555
2N2140A	2N1038	2N2555
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2N2141A	2N1038	2N2555
2N2147	2N1907	2N1907
2N2148	2N1907	2N1908
2N2150		2N2150
2N2151		2N2151
2N2160	2N1671B	2N2160
2N2162	2N2945A	2N2946
2N2163	2N2945A	2N2944
2N2164	2N2945A	2N2944
2N2165	2N2945A	2N2946
2N2166	2N2945A	2N2944
2N2167	2N2945A	2N2944
2N2168		2N2997
2N2169		2N2996
2N2170		2N2996
2N2171	2N1377	2N1376
2N2172	2N1377	2N1376
2N2173		2N2173
2N2175	2N2945A	2N2944
2N2176	2N2945A	2N2944
2N2177	2N2945A	2N2944
2N2178	2N2945A	2N2944
2N2180	2N2635	2N2635
2N2181	2N2945A	2N2944
2N2182	3N111	3N108
2N2183	2N2945A	2N2944
2N2184	3N111	3N108
2N2185	2N2945A	2N2944
2N2186	3N111	3N108
2N2187	3N111	3N108
2N2188		2N2188
2N2189		2N2189
2N2190		2N2190
2N2191		2N2191
2N2192	2N2243A	2N2192
2N2192A	2N2243A	2N2192A
2N2192B	2N2243A	2N2192A
2N2193	2N2243A	2N2193
2N2193A	2N2243A	2N2193A

Type	Preferred TI Type	Nearest TI Type
2N2193B	2N2243A	2N2193A
2N2194	2N2243A	2N2194
2N2194A	2N2243A	2N2194A
2N2194B	2N2243A	2N2194A
2N2195	2N2219	2N2217
2N2195A	2N2219	2N2218
2N2195B	2N2219	2N2218
2N2197	2N2989	2N2989
2N2205		2N706
2N2206	2N3015	2N2410
2N2214		2N706
2N2216		2N3114
2N2217	2N2219	2N2217
2N2218	2N2219	2N2218
2N2218A	2N2219	2N2218A
2N2219	2N2219	2N2219
2N2219A		2N2219A
2N2220	2N2222	2N2220
2N2221	2N2222	2N2221
2N2221A	2N2222	2N2221A
2N2222	2N2222	2N2222
2N2222A	2N2222	2N2222A
2N2222B	2N2222	2N2222
2N2223	2N2223	2N2223
2N2223A	2N2223	2N2223A
2N2224	2N2219	2N2218
2N2225		2N1143
2N2236	2N2243A	2N2193
2N2237	2N2243A	2N2192
2N2240	2N1893	2N699
2N2241	2N1893	2N1890
2N2242	2N2369A	2N2369
2N2243	2N2243A	2N2243
2N2243A	2N2243A	2N2243A
2N2244	2N930	2N929
2N2245	2N930	2N929
2N2246	2N930	2N929
2N2247	2N930	2N929
2N2248	2N930	2N929
2N2249	2N930	2N929
2N2250	2N930	2N929
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2N2253	2N930	2N929
2N2254	2N930	2N929
2N2255	2N930	2N929
2N2258	2N964	2N972
2N2259	2N964	2N972
2N2270	2N2243A	2N2270
2N2271	2N404	2N404
2N2272		2N914
2N2274	2N2945A	2N2944
2N2288	2N1907	2N1046
2N2291	2N1907	2N1907
2N2294	2N1907	2N1907
2N2297	2N2243A	2N2243A
2N2303		2N2303
2N2307		2N1671
2N2309	2N697	2N696
2N2310	2N1893	2N698
2N2311	2N1893	2N698
2N2312	2N1893	2N699
2N2313	2N1893	2N1889
2N2314	2N1893	2N698
2N2315	2N1893	2N699
2N2316	2N1893	2N1893
2N2317	2N1613	2N1613
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2N2320		2N3014
2N2322		2N2322
2N2323		2N2323
2N2324		2N2324
2N2325		2N2325
2N2326		2N2326
2N2330	2N2432	2N2432
2N2331	2N2432	2N2432
2N2332	2N2945A	2N2944
2N2333	2N2945A	2N2944
2N2334	2N2945A	2N2944
2N2335	2N2945A	2N2944
2N2336	2N2945A	2N2944
2N2337	2N2945A	2N2944
2N2339		2N1049
2N2349		TI495
2N2350	2N2243A	2N2192
2N2350A	2N2243A	2N2192
2N2351	2N2243A	2N2193

Type	Preferred TI Type	Nearest TI Type
2N2351A	2N2243A	2N2193A
2N2352	2N2243A	2N2194
2N2352A	2N2243A	2N2194A
2N2353	2N2243A	2N2243
2N2353A	2N2243A	2N2243A
2N2354	2N1302	2N1302
2N2356	3N79	3N76
2N2356A	3N79	3N74
2N2360		2N2997
2N2361		2N2997
2N2363		2N2997
2N2364	2N2243A	2N2243A
2N2364A	2N2243A	2N2243A
2N2368	2N2369A	2N2368
2N2369	2N2369A	2N2369
2N2369A	2N2369A	2N2369A
2N2370	2N2945A	2N2944
2N2371	2N2945A	2N2944
2N2372	2N2945A	2N2944
2N2373	2N2945A	2N2944
2N2374	2N404	2N404
2N2375	2N404	2N404
2N2376	2N404	2N404
2N2377	2N2945A	2N2944
2N2378	2N2945A	2N2944
2N2380	2N1893	2N1893
2N2380A	2N2219	2N2217
2N2386	2N2386	2N2386
2N2386A		2N2386A
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2N2613	2N404	2N404
2N2614	2N404	2N404
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2N2617	2N2945A	2N2944
2N2632	2N3421	2N3421
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Type	Preferred TI Type	Nearest TI Type
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2N3083	3N79	3N74
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2N3109	2N697	2N697
2N3110	2N2243A	2N2243A
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2N3116	2N2222	2N2221
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2N3147	2N456A	2N3147
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2N3394	TIS98	TIS98
2N3395	TIS98	TIS98
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2N3398	TIS98	TIS98
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2N3483	2N3980	2N3980
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2N3486A	2N3486	2N3486A
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2N3496	2N3495	2N3496
2N3497	2N3495	2N3497
2N3498	2N697	2N698
2N3499		2N5058
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2N3501	2N2243A	2N2243
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2N3505	2N2907	2N3505
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2N3513	2N2639	2N2640
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2N3518	2N3043	2N3046
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2N3521	2N2643	2N2643
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2N3527	2N2945A	2N2944
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2N3576	2N2894	2N3576
2N3578	2N3330	2N3329
2N3579	2N2605	2N2604
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2N3581	2N2605	2N2605
2N3582	2N2605	2N2605
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Type	Preferred TI Type	Nearest TI Type
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2N3614	TI3027	TI3028
2N3615	TI3027	TI3031
2N3616	2N456A	2N3146
2N3617	TI3027	TI3030
2N3618	2N456A	2N3146
2N3632		2N3632
2N3638	2N5447	2N5447
2N3638A	2N5447	2N5447
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2N3642	2N5449	2N5449
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2N3647		2N3303
2N3648		2N3303
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2N3672	2N2905	2N2905
2N3673	2N2905	2N2905
2N3677	2N2945A	2N2944
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2N3681	2N3570	2N3570
2N3682	2N918	2N918
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2N3685	2N3822	2N3821
2N3686	2N3822	2N3821
2N3687	2N3822	2N3821
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2N3692	TIS98	TIS98
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2N3772		2N3772
2N3783	2N5043	TIXM101
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2N3798	2N2605	2N3798
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Type	Preferred TI Type	Nearest TI Type
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2N3805A	2N3350	2N3350
2N3806	2N3351	2N3806
2N3807	2N3351	2N3807
2N3808	2N3350	2N3808
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2N3840	2N2945A	2N2946
2N3841	2N2945A	2N2946
2N3842	2N2945A	2N2946
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2N3850	2N3998	2N3998
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2N3857	2N2945A	2N2944
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2N3858A	TIS98	TIS98
2N3859	TIS98	TIS98
2N3860	TIS98	TIS98
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2N3867	2N5333	2N5333
2N3868	2N5333	2N5333
2N3877	TIS98	TIS98
2N3877A	TIS98	TIS98
2N3900	TIS98	TIS98
2N3900A	TIS98	TIS98
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2N3912	2N2945A	2N2944
2N3913	2N2945A	2N2944
2N3914	2N2945A	2N2944
2N3915	2N2945A	2N2944
2N3921	2N5045	TIS25
2N3922	2N5045	TIS25
2N3930	2N3495	2N3497
2N3934	2N5045	TIS25
2N3935	2N5045	TIS25
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2N3946	2N2219	2N2217
2N3947	2N2219	2N2217
2N3954	2N5045	TIS25
2N3955	2N5045	TIS25
2N3956	2N5045	TIS25
2N3957	2N5045	TIS25
2N3958	2N5045	TIS25
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Type	Preferred TI Type	Nearest TI Type
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2N3972	2N4857	2N3972
2N3973	2N5449	2N5449
2N3974	2N5449	2N5449
2N3975	2N5449	2N5449
2N3976	2N5449	2N5449
2N3977	2N2945A	2N2944
2N3978	2N2945A	2N2944
2N3979	2N2945A	2N2944
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2N3983	TIS62	TI407
2N3984	TIS63	TI408
2N3985	TIS63	TI409
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2N4001	2N4001	2N4001
2N4002	2N4002	2N4002
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2N4008	2N2945A	2N2944
2N4014	2N2219	2N2219A
2N4015	2N3350	2N3350
2N4016	2N3350	2N3350
2N4017	2N3351	2N3352
2N4018	2N3351	2N3352
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2N4021	2N3350	2N3350
2N4022	2N3350	2N3350
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2N4025	2N3350	2N3350
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2N4046		2N3252
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2N4059	2N4059	2N4059
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2N4061	2N4061	2N4061
2N4062	2N4062	2N4062
2N4065		3N160
2N4066		3N160
2N4072		2N2863
2N4073		2N2863
2N4075	2N3996	2N3996
2N4076	2N3996	2N3996
2N4081	2N4252	2N4252
2N4082	2N5045	TIS25
2N4083	2N5045	TIS25
2N4084	2N5045	TIS25
2N4085	2N5045	TIS25
2N4086	TIS98	TIS98
2N4087	TIS97	TIS97
2N4091	2N4857	2N4091
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2N4093	2N4857	2N4093
2N4099	2N3680	2N3680
2N4104	2N4104	2N4104
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2N4116	2N3996	2N3996

Type	Preferred TI Type	Nearest TI Type
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2N4119A	2N3822	2N3821
2N4120		3N160
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2N4122	2N4423	2N4423
2N4123	TIS99	TIS99
2N4124	TIS98	TIS98
2N4125	2N5447	2N5447
2N4126	2N4061	2N4061
2N4138	2N2432	2N4138
2N4139	2N3823	2N3823
2N4150	2N3421	2N3421
2N4210	2N4002	2N4002
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2N4224	2N3819	2N3819
2N4235	2N5333	2N5333
2N4236	2N5333	2N5333
2N4241	TI3027	TI3027
2N4242	TI3027	TI3028
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2N4244	TI3027	TI3028
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2N4246	TI3027	TI3028
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2N4248	2N4058	2N4058
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2N4254		2N4254
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2N4267		3N160
2N4268		3N160
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2N4274	2N4418	2N4419
2N4275	2N4418	2N4418
2N4284	2N4060	2N4060
2N4285	2N4060	2N4060
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2N4287	TIS98	TIS98
2N4288	2N4062	2N4062
2N4289	2N4062	2N4062
2N4290	2N5447	2N3702
2N4291	2N5447	2N3702
2N4292	TIS62	TIS62
2N4293	TIS62	TIS62
2N4300	2N4300	2N4300
2N4301	2N4301	2N4301
2N4302	TIS88	2N5246
2N4303	TIS88	2N5245
2N4304	2N3819	2N3819
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2N4360	2N3820	2N3820
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2N4382	2N3330	2N3331
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2N4391	2N4857	2N4391
2N4392	2N4857	2N4392
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2N4403	2N2905	2N2905
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Type	Preferred TI Type	Nearest TI Type
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2N4857	2N4857	2N4857
2N4857A	2N4857	2N4857A
2N4858	2N4857	2N4858
2N4858A	2N4857	2N4858A
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2N4859A	2N4857	2N4859A
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2N4867A	2N3822	2N3821
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2N4891	2N4891	2N4891
2N4892	2N4891	2N4892
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2N4894	2N4891	2N4894
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2N4914		2N4914
2N4915		2N4915
2N4934	2N4252	2N4252
2N4935	2N4252	2N4252
2N4936	2N4252	2N4252
2N4944	2N5449	2N5449
2N4946	2N5449	2N5449
2N4947	2N3980	2N4947
2N4948	2N3980	2N4948
2N4949	2N3980	2N4949
2N4951	2N5450	2N3705
2N4952	2N5499	2N3704
2N4954	2N5449	2N5449
2N4964	2N4060	2N4060
2N4965	2N4058	2N4058
2N4966	TIS99	TIS99
2N4967	TIS99	TIS99
2N4968	TIS99	TIS99
2N4976	2N4875	TIS39
2N4977	2N4857	2N4856A
2N4978	2N4857	2N4856A
2N4979	2N4857	2N4856A
2N4994		2N4994
2N4995	2N4995	2N4995
2N4996	2N4996	2N4996
2N4997		2N4997
2N5020	2N2386	2N2386A
2N5021	2N2386	2N2386A
2N5022	2N2386	2N2386A
2N5023	2N2386	2N2386A
2N5043	2N5043	2N5043
2N5044		2N5044
2N5045	2N5045	2N5045
2N5046	2N5045	2N5046
2N5047	2N5045	2N5047
2N5053	2N918	2N918
2N5054	2N918	2N918
2N5055	2N3829	2N3829
2N5056	2N3829	2N3829
2N5057	2N3829	2N3829
2N5058		2N5058
2N5059		2N5059
2N5066	2N2432	2N2432
2N5078	2N4416	2N4416
2N5086	2N4058	2N4058
2N5103	2N4416	2N4416
2N5104	2N4416	2N4416
2N5105	2N4416	2N4416
2N5106		2N5399
2N5107		2N5399
2N5126	TIS98	TIS98

Type	Preferred TI Type	Nearest TI Type
2N5127	TIS98	TIS98
2N5128	2N5451	2N5451
2N5129	2N5451	2N5451
2N5130	2N5450	2N5450
2N5131	2N5451	2N5451
2N5132	2N5451	2N5451
2N5133	2N5449	2N5449
2N5134	2N4420	2N4420
2N5138	2N4061	2N4061
2N5139	2N3250	2N3250
2N5140	2N3250	2N3250
2N5141	2N3829	2N3829
2N5142	2N3829	2N3829
2N5143	2N3829	2N3829
2N5196	2N5045	2N5545
2N5197	2N5045	2N5545
2N5198	2N5045	2N5546
2N5199	2N5045	2N5547
2N5245	TIS88	2N5245
2N5246	TIS88	2N5246
2N5247	TIS88	2N5247
2N5248	2N3819	2N5248
2N5273	2N5273	2N5273
2N5274	2N5274	2N5274
2N5275		2N5275
2N5312	2N5386	2N5386
2N5313	2N5386	2N5386
2N5314	2N5386	2N5386
2N5316	2N5384	2N5384
2N5317	2N5384	2N5384
2N5318	2N5384	2N5384
2N5332		2N5332
2N5333	2N5333	2N5333
2N5384	2N5384	2N5384
2N5385	2N5385	2N5385
2N5386	2N5386	2N5386
2N5387	2N5387	2N5387
2N5388	2N5388	2N5388
2N5389	2N5389	2N5389
2N5390		2N5390
2N5399		2N5399
*2N5404	2N5384	2N5384
*2N5405	2N5384	2N5384
*2N5406	2N5384	2N5384
*2N5407	2N5384	2N5384
2N5413		2N5413
2N5414		2N5414
2N5417		2N5417
*2N5441	2N5273	2N5273
*2N5442	2N5274	2N5274
*2N5444	2N5273	2N5273
*2N5445	2N5274	2N5274
2N5447	2N5447	2N5447
2N5448	2N5448	2N5448
2N5449	2N5449	2N5449
2N5450	2N5450	2N5450
2N5451	2N5451	2N5451
3N34		3N34
3N35		3N35
3N62	3N79	3N79
3N63	3N79	3N78
3N64	3N79	3N77
3N65	3N79	3N79
3N66	3N79	3N78
3N67	3N79	3N77
3N68	3N79	3N79
3N68A	3N79	3N108
3N69	3N79	3N78
3N70	3N79	3N77
3N71	3N79	3N77
3N72	3N79	3N78
3N73	3N79	3N79
3N74	3N79	3N74
3N75	3N79	3N75
3N76	3N79	3N76
3N77	3N79	3N77
3N78	3N79	3N78
3N79	3N79	3N79
3N87	3N79	3N77
3N88	3N79	3N78
3N90	3N111	3N110
3N91	3N111	3N110
3N92	3N111	3N111
3N93	3N111	3N108

CROSS-REFERENCE GUIDE BETWEEN JEDEC OR COMPETITIVE TYPE NUMBERS AND TI DEVICES (Cont'd.)

Type	Preferred TI Type	Nearest TI Type
3N94	3N111	3N108
3N95	3N111	3N109
3N100	3N111	3N108
3N101	3N111	3N108
3N102	3N111	3N108
3N103	3N111	3N108
3N104	3N111	3N108
3N105	3N111	3N108
3N106	3N111	3N108
3N107	3N111	3N108
3N108	3N111	3N108
3N109	3N111	3N109
3N110	3N111	3N110
3N111	3N111	3N111
3N112	3N111	3N108
3N113	3N111	3N108
3N114	3N111	3N110
3N115	3N111	3N110
3N116	3N111	3N111
3N117	3N111	3N110
3N118	3N111	3N110
3N119	3N111	3N110
3N120	3N111	3N111
3N121	3N111	3N111
3N123	3N111	3N111
3N124		TIXS80
3N125		TIXS80
3N126		TIXS80
3N127	3N79	3N79
3N129	3N111	3N108
3N130	3N111	3N108
3N131	3N111	3N108
3N132	3N111	3N108
3N133	3N111	3N108
3N134	3N111	3N108
3N135	3N111	3N108
3N136	3N111	3N108

Type	Manufacturer	Preferred TI Type	Nearest TI Type
3RC2	INR		2N1600
3RC5	INR		2N1600
3RC10	INR		2N1601
3RC15	INR		2N1602
3RC20	INR		2N1602
3RC25	INR		2N1603
3RC30	INR		2N1603
3RC40	INR		2N1604
5RC2	INR		2N1770
5RC5	INR		2N1771
5RC10	INR		2N1772
5RC15	INR		2N1773
5RC20	INR		2N1774
5RC25	INR		2N1775
5RC30	INR		2N1776
5RC40	INR		2N1777
5RC50	INR		2N1778
5RCL2	INR		TI40A0
5RCL5	INR		TI40A0
5RCL10	INR		TI40A1
5RCL15	INR		TI40A2
5RCL20	INR		TI40A2
5RCL25	INR		TI40A3
5RCL30	INR		TI40A3
5RCL40	INR		TI40A4
10RC2	INR		2N1842B
10RC5	INR		2N1843B
10RC10	INR		2N1844B
10RC15	INR		2N1845B
10RC20	INR		2N1846B
10RC25			2N1847B
10RC30	INR		2N1848B
10RC40	INR		2N1849B
10RC50	INR		2N1850B
10RCL2	INR		2N1842B
10RCL5	INR		2N1843B
10RCL10	INR		2N1844B
10RCL15	INR		2N1845B
10RCL20	INR		2N1846B
10RCL30	INR		2N1848B
10RCL40	INR		2N1849B
16RC2	INR		2N1842B
16RC5	INR		2N1843B
16RC10	INR		2N1844B
16RC15	INR		2N1845B
16RL20	INR		2N1846B
16RL25	INR		2N1847B
16RL30	INR		2N1848B
16RL40	INR		2N1849B
16RL50	INR		2N1850B
40598	RCA		TIXL09
C5A	GE		2N2324
C5B	GE		2N2326
C5F	GE		2N2323
C5G	GE		2N2325
C5U	GE		2N2322
C6A	GE	2N3561	2N3561
C6B	GE	2N3562	2N3562
C6F	GE	2N3560	2N3560
C6G	GE	2N3562	2N3562
C6U	GE	2N3559	2N3559
C7A	GE	2N3557	2N3557
C7B	GE	2N3558	2N3558
C7F	GE	2N3556	2N3556
C7G	GE	2N3558	2N3558
C7U	GE	2N3555	2N3555
C10A	GE		2N1772A
C10B	GE		2N1774A
C10C	GE		2N1776A
C10D	GE		2N1777A
C10F	GE		2N1771A
C10G	GE		2N1773A
C10H	GE		2N1775A
C10U	GE		2N1770A
C11A	GE		2N1772
C11B	GE		2N1774
C11C	GE		2N1776
C11D	GE		2N1777
C11E	GE		2N1778
C11F	GE		2N1771
C11G	GE		2N1773
C11H	GE		2N1775
C11U	GE		2N1770
C12A	GE		2N3936
C12B	GE		2N3937
C12C	GE		2N3938
C12D	GE		2N3939
C12F	GE		2N3936
C12G	GE		2N3937
C12H	GE		2N3938
C12U	GE		2N3936
C15A	GE		TI40A1
C15B	GE		TI40A2
C15C	GE		TI40A3
C15D	GE		TI40A4
C15F	GE		TI40A0
C15G	GE		TI40A2
C15U	GE		TI40A0
C20A	GE		TI40A1
C20B	GE		TI40A2
C20C	GE		TI40A3
C20D	GE		TI40A4
C20F	GE		TI40A0
C20U	GE		TI40A0
C36A	GE		2N1844B
C36B	GE		2N1846B

KEY TO MANUFACTURERS

ECC — Electronic Control Corporation
FSC — Fairchild Semiconductor Corporation
GE — General Electric Company
GSI — General Sensors, Incorporated
HPA — Hewlett-Packard Associates
HUDSON — Hudson Electronics
INR — International Rectifier Corporation
MOTA — Motorola Semiconductor Products, Incorporated
RAYN — Raytheon Semiconductor Division
RCA — Radio Corporation of America
SOD — Solitron Devices, Incorporated
TEC — Transitron Electronic Corporation

CROSS REFERENCE GUIDE BETWEEN COMPETITIVE DEVICES AND TI DEVICES (Cont'd.)

Type	Manu-facturer	Preferred TI Type	Nearest TI Type
C36C	GE		2N1848B
C36D	GE		2N1849B
C36E	GE		2N1850B
C36F	GE		2N1843B
C36G	GE		2N1845B
C36H	GE		2N1847B
C36U	GE		2N1842B
C37A	GE		2N1844B
C37B	GE		2N1846B
C37C	GE		2N1848B
C37D	GE		2N1849B
C37E	GE		2N1850B
C37F	GE		2N1843B
C37U	GE		2N1842B
ER900	TEC	TI43A	TI43A
FK918	FSC		A3T918
FK2484	FSC		A3T2484
FLB100	FSC		TIL01
FPD100	FSC	LS600	LS600
FPM100	FSC	LS600	LS600
FPM200	FSC	1N2175	1N2175
FPT100	FSC	LS600	LS600
FV918	FSC		A3T918
FV2484	FSC		A3T2484
FV2894	FSC		A3T2894
FW2484	FSC		A3T2484
GA1	RAYN		TIXL03
GA2	RAYN		TIXL03
GS600	GSI	LS600	LS600
HI6820	HUDSON	LS400	LS400
HP4107	HPA		TIL01
HP4120	HPA		TIXL10
HP4205	HPA		LSX900
HP4220	HPA		TIXL51-2
HP4309	HPA		TIXL101
HP4310	HPA		TIXL102-3
MHM2001-2017	SOD		2N5390
MHM2101-2117	SOD		2N5390
MHM2201-2217	SOD		2N5390
MHT4551-4583	SOD		2N2151
MHT5501-5508	SOD	2N4300	2N4300
MHT6408-6416	SOD	2N4301	2N3996
MHT7011-7019	SOD	2N3996	2N4301
MHT7401-7419	SOD	2N3421	2N3421
MHT7801-7809	SOD	2N5387	2N5387
MHT8002-8304	SOD	2N4002	2N4002
MHT9001-9012	SOD	2N4002	2N4002
MPS918	MOTA	TIS62	TIS62
MPS2923	MOTA	TIS99	TIS99
MPS2924	MOTA	TIS98	TIS98
MPS2925	MOTA	TIS98	TIS98
MPS3563	MOTA	TIS62	TIS62
MPS6506	MOTA	TIS86	2N4996
MPS6507	MOTA	TIS86	2N4996
MPS6508	MOTA	TIS86	2N4996
MPS6509	MOTA	TIS84	TIS84
MPS6510	MOTA	TIS84	TIS84
MPS6511	MOTA	TIS87	TIS87
MPS6512	MOTA	TIS99	TIS99
MPS6513	MOTA	TIS99	TIS99
MPS6514	MOTA	TIS98	TIS98
MPS6515	MOTA	TIS97	TIS97
MPS6516	MOTA	2N5447	2N5447
MPS6517	MOTA	2N5447	2N5447
MPS6518	MOTA	2N5447	2N5447
MPS6519	MOTA	2N5447	2N5447
MPS6520	MOTA	TIS98	TIS98
MPS6521	MOTA	TIS97	TIS97
MPS6522	MOTA	2N5447	2N5447
MPS6523	MOTA	2N5447	2N5447
MPS6528	MOTA	TIS84	TIS84
MPS6529	MOTA	TIS85	TIS85
MPS6530	MOTA	TIS92	TIS92
MPS6531	MOTA	TIS92	TIS92
MPS6532	MOTA	TIS92	TIS92
MPS6533	MOTA	TIS93	TIS93
MPS6534	MOTA	TIS93	TIS93
MPS6535	MOTA	TIS93	TIS93
MPS6541	MOTA	TIS86	2N4996
MPS6542	MOTA	TIS62	TIS62
MPS6543	MOTA	TIS86	TIS86
MPS6544	MOTA	TIS87	TIS87
MPS6545	MOTA	TIS87	TIS87
MPS6546	MOTA	TIS86	TIS86
MPS6547	MOTA	TIS86	TIS86
MPS6552	MOTA	TIS98	TIS98
MPS6553	MOTA	TIS97	TIS97
MPS6554	MOTA	TIS97	TIS97
MPS6555	MOTA	TIS97	TIS97
MPS6560	MOTA	TIS92	TIS92
MPS6561	MOTA	TIS92	TIS92
MPS6562	MOTA	TIS93	TIS93
MPS6563	MOTA	TIS93	TIS93
MPS6564	MOTA		2N4994
MPS6565	MOTA	TIS99	TIS99
MPS6566	MOTA	TIS98	TIS98
MPS6567	MOTA	TIS86	TIS86
MPS6579	MOTA	TIS37	TIS37
MRD200	MOTA	LS600	LS600
MRD300	MOTA	LS600	LS600
Q2040	ECC	2N5273	2N5273
Q3040	ECC	2N5274	2N5274
Q4040	ECC	2N5274	2N5274
Q6040	ECC		2N5275
Q6540	ECC		2N5275
SDT6905-6908	SOD	2N3421	2N3421
SDT8105-8116	SOD		2N4004
SDT8801-8805	SOD		2N3846
SDT9901-9904	SOD	2N4301	2N4301
SE1001	FSC		2N4994
SE1002	FSC		2N4995
SE2001	FSC	TIS98	TIS98
SE2002	FSC	2N5449	2N5449
SE3001	FSC	TIS62	TI62
SE3002	FSC	TIS62	TIS62
SE4001	FSC	TIS97	TIS97
SE4002	FSC	TIS97	TIS97
SE4010	FSC	TIS97	TIS97
SE5020	FSC	TIS84	TIS84
SE5021	FSC	TIS85	TIS85
SE5022	FSC	TIS85	TIS85
SE5023	FSC	TIS85	TIS85
SE5024	FSC	TIS85	TIS85
SE7001	FSC		TIXS100
SE7002	FSC		TIXS100
ST2	GE	TI43A	TI43A
TA2314	RCA		2N3847
TCR3	TEC		2N1600
TCR8	TEC		TI40A0
TCR13	TEC		2N1601
TCR18	TEC		TI40A1
TCR23	TEC		2N1602
TCR28	TEC		TI40A2
TCR33	TEC		2N1603
TCR35C	TEC		TI145A0
TCR38	TEC		TI40A3
TCR40C	TEC	2N3559	2N3559
TCR41C	TEC	2N3559	2N3559
TCR42C	TEC	2N3560	2N3560
TCR43	TEC		2N1604
TCR43C	TEC	2N3561	2N3561
TCR44C	TEC	2N3562	2N3562
TCR45C	TEC	2N3562	2N3562
TCR48	TEC		TI40A4
TCR65C	TEC		TI145A0
TCR105C	TEC		TI145A1
TCR205C	TEC		TI145A2
TCR305C	TEC		TI145A3
TCR405C	TEC		TI145A4
TCR730	TEC		TI40A0
TCR731	TEC		TI40A1
TCR732	TEC		TI40A2
TCR733	TEC		TI40A3
TCR734	TEC		TI40A4
TT500	TEC	2N3560	2N3560
TT501	TEC	2N3561	2N3561
TT502	TEC	2N3562	2N3562

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INDEX TO ALL STANDARD DISCRETE SEMICONDUCTORS AND COMPONENTS MANUFACTURED BY TEXAS INSTRUMENTS

(Preferred Devices in Bold Type)

Devices shown below represent the entire line of TI standard discrete semiconductors arranged in strict numerical order disregarding prefix.

Example: LSX900
A905-A908 (A900) (parentheses indicate first device listed on data sheet)
2N910-2N912
1N914-1N917

DEVICE TYPE	PAGE/CODE	DEVICE TYPE	PAGE/CODE
CD 1/8 R	SCC	TID31-TID37	SCC
CG 1/8	**28201**	**TIP31**	**16109**
CR 1/8	SCC	**TIP31A** (TIP31)	**16109**
TC 1/8 (TM 1/8)	29003	**TIP32**	**16113**
TG 1/8	**29001**	**TIP32A** (TIP32)	**16113**
TM 1/8	**29003**	**TIP33**	**16117**
CD 1/4 R (CD 1/8 R)	SCC	**TIP33A** (TIP33)	**16117**
CG 1/4 (CG 1/8)	**28201**	TIXS33	NR
CR 1/4 (CR 1/8)	SCC	3N34	SCC
TM 1/4 (TM 1/8)	**29003**	**TIP34**	**16121**
CD 1/2 MR (CD 1/8 R)	SCC	**TIP34A** (TIP34)	**16121**
CD 1/2 PR (CD 1/8 R)	SCC	TIS34	SCC
CD 1/2 SR (CD 1/8 R)	SCC	3N35	SCC
CG 1/2 (CG 1/8)	**28201**	H35 (H11)	SCC
CR 1/2 (CR 1/8)	SCC	**TIP35**	**16125**
CD 1 R (CD 1/8 R)	SCC	**TIP35A** (TIP35)	**16125**
G01	CSO	TIXS35-TIXS36	SCC
TIL01	SCC	**TIP36**	**16129**
TIXV01-TIXV04	SCC	**TIP36A** (TIP36)	**16129**
CD 2 R (CD 1/8 R)	SCC	**TIS37-TIS38**	**2001**
G02	CSO	H38 (H11)	SCC
TIXL02	NR	TIS39 (Same as TIXS39)	SCC
TIXL03	SCC	TIXS39	SCC
TIS05	NR	TI40A0-TI40A4	SCC
TIXL05-TIXL06	SCC	TID40-TID44	SCC
TIXV05-TIXV07	SCC	**TI42A-TI43A**	**24105**
TIXL08	SCC	TIS42	SCC
TIXV08-TIXV19	SCC	TIS43	SCC
TIXL09	SCC	**TIC44-TIC47**	**24109**
TIXL10	SCC	TIS44(706)	SCC
H11	SCC	TIS45(708)	SCC
TIXM12	SCC	TIS46(914)	SCC
TIXS12-TIXS13	SCC	TIS47(2368)-TIS48(2369)	SCC
TIS14	SCC	TIS49(2369A)	SCC
TIXM14-TIXM17	SCC	TIS50(2894)	SCC
TID17-TID20	SCC	TI51-TI60	SCC
TIS18	SCC	TIS51(3011)	SCC
TIC20-TIC23	**24101**	TIXL51-TIXL53	SCC
TID21-TID24	**20005**	TIS52(3014)	SCC
TIS22-TIS24	SCC	TIS53(3639)-TIS54(3640)	SCC
TID25-TID26	**20009**	TIC54-TIC57 (TI42A)	24105
TIS25-TIS27	SCC	TIXL54	SCC
TID29-TID30	**20013**	**MC55**	**28401**
TIP29	**16101**	**MC55D** (MC55)	**28401**
TIP29A (TIP29)	**16101**	TIS55(3646)	SCC
TIP30	**16105**	TIXL55-TIXL56	SCC
TIP30A (TIP30)	**16105**	**TIS56**-TIS57	**1021**

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DEVICE TYPE	PAGE/CODE	DEVICE TYPE	PAGE/CODE
TIXL57	SCC	**300**	
TIS58-TIS59	SCC	TIXM301	SCC
H60-H62 (H11)	SCC	TIXV304	SCC
MC60 (MC55)	**28401**	TIV305	SCC
MC60D (MC55)	**28401**	**TIV306-TIV308**	**21205**
MM60	SCC	2N315A	CSO
TIS60-TIS61	SCC	2N317A	CSO
TIS60M-TIS61M (TIS60)	SCC	2N327A-2N329A	SCC
TIS62, TIS63, TIS64	**1025**	1N332-1N349	CSO
MC65 (MC55)	**28401**	2N332	SCC
MC65D (MC55)	**28401**	2N332A	CSO
MM65 (MM60)	SCC	2N333	SCC
TIXS67	SCC	2N333A	CSO
TIS68, **TIS69**, TIS70	**6101**	2N334	SCC
MM70 (MM60)	SCC	2N334A	CSO
TI71-TI75	CSO	2N335	SCC
TIS71-TIS72	SCC	2N335A	CSO
TIS73-TIS75	**6103**	2N336	SCC
3N74-**3N79**	**4101**	2N336A	CSO
TIS78-TIS79	SCC	2N337	SCC
TIXS80-TIXS81	SCC	2N338	SCC
TIS82	SCC	2N339-2N343	SCC
TIS83	SCC	2N342A (2N339)	SCC
TIS84-TIS85	**1033**	TI363-TI364	NR
TIS86-TIS87	**1041**	TI365	CSO
TIS88	**6111**	2N377	CSO
TIS90, TIS91,**TIS92, TIS93**	**4105**	2N388	SCC
TIS90M, TIS91M, **TIS92M,**		2N388A (2N388)	SCC
TIS93M (TIS90)	**4105**	TI388-TI391	CSO
TIS94, TIS95, TIS96, **TIS97,**		2N389	SCC
TIS98, TIS99	**1047**	2N389A	CSO
100		2N395-2N397	NR
P100 Probe (TM 1/8)	29003	TI395	CSO
TIXS100-TIXS101	CSO	TI397-TI398	CSO
TIXL101	SCC	**2N398**	**9101**
TIXM101	SCC	2N398A (2N398)	9101
TIXL102-TIXL103	SCC	2N398B (2N398)	9101
TIXS102-TIXS103	CSO	TI399	CSO
TIXM103-TIXM104	SCC	**400**	
TIXL104-TIXL106	CSO	**LS400**	**27401**
TIXM105-TIXM106	SCC	TI400-TI403	SCC
TIXM107-TIXM108	SCC	**2N404**	**9105**
3N108-**3N111**	**4109**	2N404A (2N404)	9105
2N117	SCC	TI407-TI409	SCC
2N118	SCC	2N424 (2N389)	SCC
2N118A	SCC	2N424A	CSO
2N119	SCC	2N426-2N428	SCC
2N120	SCC	2N438	CSO
2N122	SCC	2N438A	CSO
G129	SCC	2N439-2N440	CSO
G130	SCC	1N440B-1N445B	CSO
TI145A0-TI145A4	SCC	**1N456, 1N457, 1N458,** 1N459	**18101**
TI156	SCC	1N456A-1N459A	CSO
TI156L (TI156)	SCC	**2N456A-2N458A**	**17101**
TI158 (TI156)	SCC	2N456B-2N458B	SCC
TI158A (TI156)	SCC	1N461-1N464	SCC
TI158AL (TI156)	SCC	1N461A	CSO
TI158L (TI156)	SCC	2N470-2N480	CSO
TI159-TI162	SCC	TI480-TI481	SCC
200		**1N482-1N485**	**18105**
2N243-2N244	SCC	1N482A-1N485A	CSO
2N250	NR	1N482B-1N485B	CSO
2N250A-2N251A	SCC	TI482	SCC
1N251	SCC	TI483-TI484	SCC
2N251	NR	TI485	CSO
1N253-1N256	CSO	TI486-TI487	SCC
2N263-2N264	CSO	2N489-2N494	7101

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DEVICE TYPE	PAGE/CODE
2N489A, 2N490A, **2N491A**, 2N492A, 2N493A, 2N494A (2N489)	**7101**
2N489B-2N494B (2N489)	7101
TI492	SCC
TI493-TI495	SCC
2N494C	CSO
TI496	SCC
2N497-2N498	SCC
2N497A-2N498A	CSO
500	
LS500	CSO
XD500-XD502	SCC
2N508	CSO
2N511	SCC
2N511A (2N511)	SCC
2N511B (2N511)	SCC
2N512	SCC
2N512A (2N512)	SCC
2N512B (2N512)	SCC
2N513	SCC
2N513A (2N513)	SCC
2N513B (2N513)	SCC
2N514	SCC
2N514A (2N514)	SCC
2N514B (2N514)	SCC
A516-A517	SCC
2N520	CSO
2N520A	CSO
2N522A	CSO
2N524-2N527	SCC
1N530-1N540	CSO
TI539-TI540	NR
A543	CSO
2N541-2N543	CSO
1N547	CSO
1N550-1N555	CSO
TI550-TI551	SCC
2N581-2N582	CSO
2N587	CSO
2N594-2N596	NR
1N599	CSO
1N599A	CSO
600	
600C-601C	SCC
1N600-1N606	CSO
1N600A-1N606A	CSO
A600-A602	SCC
LS600	**27501**
604C (600C)	SCC
606C (600C)	SCC
1N607-1N614	CSO
1N607A-1N614A	CSO
608C (600C)	SCC
610C (600C)	SCC
A610-A612	SCC
612C (600C)	SCC
614C (600C)	SCC
616C (600C)	SCC
618C (600C)	SCC
620C (600C)	SCC
622C (600C)	SCC
624C (600C)	SCC
1N625-1N629	SCC
2N634A-2N636A	CSO
1N643	SCC
1N645-1N649	**18109**
1N645A (1N645)	18109
2N650A-2N652A	NR
650-653	SCC
650C0-650C7 (650)	SCC
651C0-651C9 (650)	SCC
652C0-652C9 (650)	SCC
653C0-653C9 (650)	SCC
654C9 (650)	SCC
655C9 (650)	SCC
2N656-2N657 (2N497)	SCC
2N656A-2N657A	CSO
1N658	CSO
2N658-2N662	NR
1N659-1N661	SCC
1N662-1N663	SCC
2N681-2N688	SCC
2N681A-2N689A	SCC
2N689	CSO
2N696-**2N697**	**1201**
2N698-2N699	1209
700	
1N702-1N707	SCC
1N702A 1N707A (1N702)	SCC
2N702	NR
2N703	NR
2N705	NR
A706-A713	SCC
2N706	CSO
2N706A	SCC
2N706B	CSO
1N708-1N716	SCC
1N708A-1N716A (1N708)	SCC
2N708	SCC
2N709	SCC
2N710	CSO
2N711	NR
2N711A	SCC
2N711B (2N711A)	SCC
2N715-2N716	CSO
2N717-2N718 (2N696)	1201
2N718A (2N696)	**1201**
2N719-2N720 (2N698)	1209
2N719A-**2N720A** (2N698)	**1209**
2N721-2N722	CSO
2N726-2N727	SCC
2N730-2N731 (2N696)	1201
2N734	CSO
2N735	SCC
2N736	SCC
2N736A	SCC
2N738	NR
2N739	SCC
2N740	SCC
2N743-2N744	SCC
1N746-1N759	**23109**
1N746A-1N759A (1N746)	**23109**
2N753 (2N706A)	SCC
2N759	SCC
2N759A (2N759)	SCC
2N760	SCC
2N760A (2N760)	SCC
1N761-1N766	SCC
2N780	SCC
2N797	**12101**
800	
2N849-2N850	SCC
2N851-2N852	SCC

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DEVICE TYPE	PAGE/CODE
2N870-2N871 (2N698)	1209
2N876-2N881	SCC
2N884-2N888	SCC
2N889	CSO
900	
A900-A903	SCC
LSX900	SCC
A905-A908 (A900)	SCC
2N910-2N912	SCC
1N914-1N917	**19201**
2N914	SCC
1N914A (1N914)	19201
1N914B (1N914)	**19201**
2N915	SCC
2N916	SCC
1N916A (1N914)	19201
1N916B (1N914)	19201
2N917	SCC
2N918	**3201**
A3T918	CSO
2N929-**2N930**	**1269**
A3T929-A3T930	CSO
2N929A-2N930A	CSO
2N956 (2N696)	1201
1N957-1N961	CSO
1N957A-1N961A	CSO
1N957B-1N961B	CSO
2N960-2N962	12105
2N963	SCC
2N964-2N966 (2N960)	**12105**
2N967 (2N963)	SCC
2N968-2N975	SCC
2N985	SCC
2N995	SCC
2N997	**4301**
1000	
NP1000-NP1001 (Solar Cells)	SCC
2N1021-2N1022 (2N456A)	17101
2N1021A-2N1022A (2N456B)	SCC
2N1038-2N1041	**17201**
2N1042-2N1045	SCC
2N1046	SCC
2N1047-2N1050	SCC
2N1047A-2N1050A	CSO
2N1047B-2N1050B	SCC
1N1095-1N1096	CSO
1100	
1N1100-1N1105	CSO
1N1115-1N1120	CSO
TI1121-TI1126	SCC
1N1124A-1N1128A	CSO
2N1131-2N1132	SCC
TI1131-TI1136	SCC
2N1141-2N1143	SCC
2N1141A-2N1143A	CSO
TI1141-TI1146	SCC
2N1149-2N1153	SCC
TI1151-TI1156	SCC
2N1154-2N1156	SCC
2N1195	CSO
1200	
2N1235	CSO
2N1252	SCC
2N1253	SCC
2N1260	CSO
2N1273-2N1274	SCC
2N1276-2N1279	CSO
1300	
2N1302-2N1309	**9205**
2N1319	CSO
2N1370-2N1371 (2N1273)	SCC
2N1372-**2N1377**	**9213**
2N1378-2N1381 (2N1372)	9213
2N1382-2N1383	NR
2N1385	CSO
1400	
2N1404	CSO
2N1413-2N1415	SCC
2N1420 (2N696)	1201
2N1445	CSO
1N1487-1N1492	CSO
1500	
2N1507 (2N696)	1201
2N1529-2N1538	CSO
2N1539-2N1543	**17223**
2N1544-2N1548	CSO
2N1564	NR
2N1565	SCC
2N1566	SCC
2N1566A (2N736A)	SCC
2N1572	NR
2N1573	SCC
2N1574	SCC
1N1581-1N1587	CSO
2N1586-2N1594	CSO
2N1595-2N1599	SCC
1600	
2N1600-2N1604	SCC
2N1605	SCC
1N1612-1N1616	CSO
2N1613 (2N696)	**1201**
2N1671	7109
2N1671A (2N1671)	7109
2N1671B (2N1671)	**7109**
2N1690-2N1691	CSO
1N1692-1N1697	CSO
1700	
2N1711 (2N696)	**1201**
2N1714-2N1721	SCC
2N1722	16301
2N1722A	SCC
2N1723	SCC
2N1724 (2N1722)	**16301**
2N1724A (2N1722A)	SCC
2N1725 (2N1723)	SCC
2N1729-2N1732	CSO
2N1770-2N1778	SCC
2N1770A-2N1777A	SCC
1800	
2N1808 (2N1605)	SCC
1N1816-1N1836	CSO
1N1816A-1N1836A	CSO
1N1816C-1N1836C	CSO
1N1816CA-1N1836CA	CSO
2N1842B-2N1850B	SCC
2N1889-2N1890 (2N698)	1209
2N1891-2N1892	CSO
2N1893 (2N698)	**1209**
1900	
2N1907-2N1908	**17231**
2N1924-2N1926	SCC
2N1973-2N1975 (2N910)	SCC
2N1993	CSO
2N1994-2N1996	SCC

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DEVICE TYPE	PAGE/CODE
3300	
2N3303	SCC
2N3304	**2211**
2N3328	NR
2N3329,**2N3330**, 2N3331, 2N3332	**6305**
2N3333-2N3336	SCC
2N3347-**2N3350**	**4507**
2N3351-2N3352 (2N3347)	4507
2N3371	SCC
2N3375	SCC
3400	
2N3418-2N3421	**16501**
2N3444	SCC
2N3449	CSO
2N3467-2N3468 (2N3244)	**2203**
2N3485-**2N3486**	**2213**
2N3485A-2N3486A (2N3485)	2213
2N3494, **2N3495**, 2N3496, 2N3497	**2215**
3500	
2N3502-2N3505	SCC
1N3506-1N3520	CSO
2N3551-2N3552	**16507**
2N3553	CSO
2N3554	SCC
2N3555-2N3558	**24417**
2N3559-2N3562	**24425**
2N3570-2N3572	**3401**
2N3573-2N3575	CSO
2N3576	SCC
3600	
2N3632	SCC
2N3680	**4509**
3700	
2N3702-2N3703	SCC
2N3704-2N3706	SCC
2N3707-2N3711	**1431**
2N3712	NR
2N3713-2N3716	**16511**
2N3724-**2N3725**	**1433**
2N3724A-2N3725A (2N3724)	1433
2N3733	CSO
2N3771-2N3772	CSO
2N3798-2N3799	SCC
3800	
2N3806-2N3811	SCC
2N3819	**6401**
2N3820	**6403**
2N3821-**2N3822**	**6405**
A3T3821-A3T3823	CSO
2N3823	**6407**
2N3824	SCC
2N3826-2N3827	1441
2N3828	NR
2N3829	**2235**
2N3830-2N3831	SCC
2N3832	SCC
2N3833-2N3835	SCC
2N3838	**4517**
2N3846-2N3847	CSO
2N3866	**3501**
3900	
2N3909	**6413**
2N3909A	CSO
2N3936-2N3940	SCC
2N3962-**2N3964**	**2241**
2N3965 (2N3962)	2241
2N3970-2N3972	SCC

DEVICE TYPE	PAGE/CODE
2N3980	**7201**
2N3993-2N3994	**6501**
2N3995	SCC
2N3996-2N3999	**16601**
4000	
2N4000-2N4001	**16607**
1N4001-1N4007	**25401**
2N4002-2N4003	**16613**
2N4004-2N4005	SCC
2N4030-2N4033	CSO
2N4040-2N4041	CSO
2N4058-2N4060	**2301**
2N4061-2N4062 (2N4058)	**2301**
2N4091-2N4093	SCC
1N4099	SCC
4100	
1N4100-1N4106	SCC
2N4104	**1501**
2N4138 (2N2432)	1325
1N4148-1N4149	**19401**
1N4151-1N4154	SCC
4200	
2N4252-2N4253	**1503**
2N4254-**2N4255**	**1511**
4300	
2N4300	**16625**
2N4301	**16631**
1N4305	19405
1N4360	CSO
1N4370-1N4372	**23601**
1N4370A-1N4372A (1N4370)	**23601**
1N4373	CSO
1N4378	CSO
2N4391-2N4393	SCC
4400	
2N4416	**6503**
2N4416A (2N4416)	6503
2N4418-2N4419	**1519**
2N4420-2N4421	**1521**
2N4422	SCC
2N4423	**2303**
1N4444 (1N4305)	19405
1N4446, 1N4447, **1N4448**, 1N4449 (1N4148)	**19401**
1N4454 (1N4305)	**19405**
4500	
1N4531-1N4534	**19407**
1N4536 (1N4531)	19407
4600	
1N4606	SCC
4700	
1N4727	SCC
4800	
2N4854-2N4855	**4701**
2N4856-**2N4857**	**6511**
2N4858-2N4861 (2N4856)	6511
2N4856A-2N4861A	SCC
2N4874, **2N4875**, 2N4876	**3701**
2N4891-2N4894	**7301**
4900	
2N4913-2N4915	CSO
1N4938	CSO
2N4947-2N4949 (2N3980)	7201
2N4994-**2N4995** (2N3826)	**1441**
2N4996-2N4997 (2N4254)	**1511**
5000	
2N5043-2N5044	**14401**

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DEVICE TYPE	PAGE/CODE
2N5045-2N5047	6601
2N5058-2N5059	SCC
5200	
2N5245-2N5247	CSO
2N5248	CSO
2N5273, 2N5274,2N5275	24601
5300	
2N5332	CSO
2N5333	16701
2N5384-2N5385	16707
2N5386	16711
2N5387-2N5389	16715
2N5390	SCC
2N5399	CSO
5400	
2N5413-2N5414	CSO
2N5417	CSO
2N5447-2N5448	2305
2N5449-2N5451	1701
MISC.	
ECM	SCC
N on P Silicon Solar Cells	SCC
SCM	30201
XMST	SCC

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MILITARY DEVICES AVAILABLE FROM TEXAS INSTRUMENTS

This table lists available TI device types manufactured and tested in accordance with appropriate military specification requirements. Note that, except for items with an asterisk, only the latest specification revision and type number prefix (as of July 1, 1968) are listed. In certain cases, however, previous prefix types meeting superseded issues of the specifications can be supplied if desired.

Copies of the current military specification issues may be ordered from: Commanding Officer, U. S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa., 19120.

DIODES

JAN 1N251	MIL-S-19500/188A
JAN 1N457, 1N458, 1N459	MIL-S-19500/193A
JAN 1N483B	MIL-S-19500/118C
JAN TX1N483B	MIL-S-19500/118C
JAN 1N485B, 1N486B	MIL-S-19500/118C
JAN TX1N485B, TX1N486B	MIL-S-19500/188C
JAN 1N643	MIL-S-19500/256B
JAN 1N645	MIL-S-19500/240B w/Amend.-1
JAN TX1N645	MIL-S-19500/240B w/Amend.-1
JAN 1N662, 1N663	MIL-S-19500/256B
JAN 1N746A thru 1N759A	MIL-S-19500/127D (NAVY) w/Amend.-2
JAN TX1N746A thru TX1N759A	MIL-S-19500/127D (NAVY) w/Amend.-2
JAN 1N914	MIL-S-19500/116E
JAN TX1N914	MIL-S-19500/116E
JAN 1N3064	MIL-S-19500/144E
JAN TX1N3064	MIL-S-19500/144E
JAN 1N3070	MIL-S-19500/169E
JAN TX1N3070	MIL-S-19500/169E
JAN 1N4148	MIL-S-19500/116E
JAN TX1N4148	MIL-S-19500/116E
JAN 1N4153	MIL-S-19500/337A (NAVY)
JAN 1N4370A, 1N4371A, 1N4372A	MIL-S-19500/127D (NAVY) w/Amend.-2
JAN TX1N4370A, TX1N4371A, TX1N4372A	MIL-S-19500/127D (NAVY) w/Amend.-2
JAN 1N4454	MIL-S-19500/144E
JAN TX1N4454	MIL-S-19500/144E
JAN 1N4938	MIL-S-19500/169E
JAN TX1N4938	MIL-S-19500/169E

TRANSISTORS

JAN 2N117	MIL-S-19500/35B (NAVY)
JAN 2N118	MIL-S-19500/2A
JAN 2N119	MIL-S-19500/35B (NAVY)
USN 2N332	*MIL-T-19500/37A (NAVY)
JAN 2N333	MIL-S-19500/37C w/Amend.-1
USN 2N334	*MIL-T-19500/37A (NAVY)
JAN 2N335, 2N336	MIL-S-19500/37C w/Amend.-1
JAN 2N337, 2N338	MIL-S-19500/69D w/Amend.-1
JAN 2N341	MIL-S-19500/31B
JAN 2N342, 2N343	MIL-S-19500/16E
JAN 2N358A	MIL-S-19500/63C
JAN2N388	MIL-S-19500/65A
JAN 2N389	MIL-S-19500/173A
JAN 2N404	MIL-S-19500/20B w/Amend.-1
JAN 2N404A	MIL-S-19500/20B w/Amend.-1
JAN 2N416	MIL-T-19500/56A (SigC) w/Amend.-1
JAN 2N417	MIL-T-19500/57A (SigC) w/Amend.-1
JAN 2N424	MIL-S-19500/173A
JAN 2N427	MIL-S-19500/41B (EL) w/Amend.-1
JAN 2N428M	MIL-S-19500/44C w/Amend.-2
JAN 2N456B, 2N457B, 2N458B	MIL-S-19500/217A
JAN 2N489A thru 2N494A	MIL-S-19500/75B w/Amend.-1
JAN TX2N489A thru TX2N494A	MIL-S-19500/75B w/Amend.-1
USAF 2N489 thru 2N494	*MIL-T-19500/75 (USAF)
JAN 2N497, 2N498	MIL-S-19500/74E
JAN 2N502A, 2N502B	MIL-S-19500/112C (EL)
JAN 2N656, 2N657	MIL-S-19500/74E
JAN 2N696, 2N697	MIL-S-19500/99E w/Amend.-1
JAN 2N702, 2N703	MIL-S-19500/153B (EL)
JAN 2N705	MIL-S-19500/86A w/Amend.-1
JAN 2N706	MIL-S-19500/120B w/Amend.-1
JAN 2N718A	MIL-S-19500/181C w/Amend.-1
JAN TX2N718A	MIL-S-19500/181C w/Amend.-1
JAN 2N720A	MIL-S-19500/182C
JAN TX2N720A	MIL-S-19500/182C
JAN 2N744	MIL-S-19500/273A (NAVY)
JAN 2N759A, 2N760A	MIL-S-19500/218A
JAN 2N869A	MIL-S-19500/283A (NAVY) w/Amend.-2
JAN 2N910, 2N911, 2N912	MIL-S-19500/274A (EL)
JAN 2N916	MIL-S-19500/271A (NAVY) w/Amend.-2
JAN 2N918	MIL-S-19500/301A w/Amend.-1
JAN TX2N918	MIL-S-19500/301A w/Amend.-1
JAN 2N929, 2N930	MIL-S-19500/253B
JAN TX2N929, TX2N930	MIL-S-19500/253B
JAN 2N962	MIL-S-19500/258A (NAVY) w/Amend.-3
JAN 2N964	MIL-S-19500/258A (NAVY) w/Amend.-3
JAN 2N1021A, 2N1022A	MIL-S-19500/217A
JAN 2N1039	MIL-S-19500/89C w/Amend.-1
JAN 2N1041	MIL-S-19500/89C w/Amend.-1
JAN 2N1042 thru 2N1045	MIL-S-19500/137B
JAN 2N1046	MIL-S-19500/88 (NAVY) w/Amend.-1
JAN 2N1049A, 2N1050A	MIL-S-19500/176A w/Amend.-1
JAN 2N1131, 2N1132	MIL-S-19500/177C
JAN 2N1142	MIL-S-19500/87A
JAN 2N1302 thru 2N1309	MIL-S-19500/126B
JAN 2N1613	MIL-S-19500/181C w/Amend.-1
JAN TX2N1613	MIL-S-19500/181C w/Amend.-1
JAN 2N1711	MIL-S-19500/225D
JAN TX2N1711	MIL-S-19500/225D
JAN 2N1714 thru 2N1717	MIL-S-19500/263A (EL) w/Amend.-2
JAN 2N1722	MIL-S-19500/262E w/Amend.-1
JAN TX2N1722	MIL-S-19500/262E w/Amend.-1
JAN 2N1724	MIL-S-19500/262E w/Amend.-1
JAN TX2N1724	MIL-S-19500/262E w/Amend.-1
JAN 2N1890	MIL-S-19500/225D
JAN TX2N1890	MIL-S-19500/225D
JAN 2N1893	MIL-S-19500/182C
JAN TX2N1893	MIL-S-19500/182C
JAN 2N2060	MIL-S-19500/270B (NAVY) w/Amend.-2
JAN TX2N2060	MIL-S-19500/270B (NAVY) w/Amend.-2
JAN 2N2218, 2N2218A	MIL-S-19500/251E w/Amend.-1
JAN TX2N2218, TX2N2218A	MIL-S-19500/251E w/Amend.-1
JAN 2N2219, 2N2219A	MIL-S-19500/251E w/Amend.-1
JAN TX2N2219, TX2N2219A	MIL-S-19500/251E w/Amend.-1
JAN 2N2221, 2N2221A	MIL-S-19500/255E w/Amend.-1
JAN TX2N2221, TX2N2221A	MIL-S-19500/255E w/Amend.-1
JAN 2N2222, 2N2222A	MIL-S-19500/255E w/Amend.-1
JAN TX2N2222, TX2N2222A	MIL-S-19500/255E w/Amend.-1
JAN 2N2369A	MIL-S-19500/317D
JAN TX2N2369A	MIL-S-19500/317D
JAN 2N2432	MIL-S-19500/313A
JAN TX2N2432	MIL-S-19500/313A
JAN 2N2481	MIL-S-19500/268B (NAVY) w/Amend.-1
JAN TX2N2481	MIL-S-19500/268B (NAVY) w/Amend.-1
JAN 2N2553	MIL-S-19500/89C w/Amend.-1
JAN 2N2555	MIL-S-19500/89C w/Amend.-1
JAN 2N2557	MIL-S-19500/89C w/Amend.-1
JAN 2N2559	MIL-S-19500/89C w/Amend.-1
JAN 2N2904, 2N2904A	MIL-S-19500/290B w/Amend.-1
JAN TX2N2904, TX2N2904A	MIL-S-19500/290B w/Amend.-1
JAN 2N2905, 2N2905A	MIL-S-19500/290B w/Amend.-1
JAN TX2N2905, TX2N2905A	MIL-S-19500/290B w/Amend.-1
JAN 2N2906, 2N2906A	MIL-S-19500/291B w/Amend.-1
JAN TX2N2906, TX2N2906A	MIL-S-19500/291B w/Amend.-1
JAN 2N2907, 2N2907A	MIL-S-19500/291B w/Amend.-1
JAN TX2N2907, TX2N2907A	MIL-S-19500/291B w/Amend.-1
JAN 2N3013	MIL-S-19500/287 (NAVY) w/Amend.-2
JAN 2N3251A	MIL-S-19500/323 (NAVY) w/Amend.-1
JAN 2N3253	MIL-S-19500/347 (NAVY)
JAN 2N3449	MIL-S-19500/338 (USAF)
JAN 2N3467	MIL-S-19500/348 (NAVY)
JAN 2N3810	MIL-S-19500/336 (NAVY) w/Amend.-2
JAN 3N35	MIL-S-19500/80D
JAN 3N108	MIL-S-19500/361 (NAVY)

RESISTORS

RN55 C,D,E,G	MIL-R-10509/7B
RN60 C,D,E,G	MIL-R-10509/1E
RN65 C,D,E,F,G	MIL-R-10509/2C
RN70 C,D,E	MIL-R-10509/3D
RN55 . . . TX C,D,E,G	MIL-R-10509/007D (USAF)
RN60 . . . TX C,D,E,G	MIL-R-10509/001G (USAF)
RN65 . . . TX C,D,E,F,G	MIL-R-10509/002D (USAF)
RN70 . . . TX C,D,E	MIL-R-10509/003E (USAF)

CAPACITORS

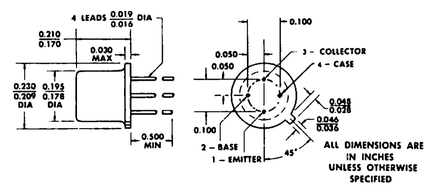
CS 12	*MIL-C-26655/2D
CS 13	*MIL-C-26655/2D
CSR 13	MIL-C-39003/1A

TYPES TIS56 AND TIS57
BULLETIN NO. DL-S 668628, APRIL 1966

ESPECIALLY DESIGNED FOR TELEVISION AND VHF COMMUNICATIONS APPLICATIONS REQUIRING HIGH GAIN AND FORWARD AGC

- **Low Capacitance . . . 0.32 pF Max**
- **AGC Operation Guaranteed at 45 Mc/s and 200 Mc/s**

mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	20 V
Emitter-Base Voltage	3 V
Continuous Collector Current	30 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	200 mW
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 1.33 mW/deg.

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$	30			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 2$ mA, $I_B = 0$, See Note 3	20			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$	3			V
I_{CBO}	Collector-Cutoff Current	$V_{CB} = 10$ V, $I_E = 0$			50	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA	20			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ mA, $I_C = 10$ mA		1	3	V
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 100 Mc/s	5	9	14	
		$V_{CE} = 10$ V, $I_C = 4$ mA, f = 45 Mc/s		20		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 Mc/s, See Note 4	0	0.2	0.32	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -4$ mA, f = 79.8 Mc/s		6	12	ps

NOTES: 3. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. Collector-Base Capacitance is measured using three-terminal measurement techniques with the case and emitter guarded.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TIS56			TIS57			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 3$ mA, $R_G = 50\ \Omega$, f = 200 Mc/s		2.8	3.3				dB
		$V_{CE} = 10$ V, $I_C = 3$ mA, $R_G = 50\ \Omega$, f = 45 Mc/s					3	6	dB
G_{pe}	Unneutralized Small-Signal Common-Emitter Insertion Power Gain	$V_{CC} = 12$ V, $I_C \approx 2.5$ mA, $V_{BB} = 2.1$ V, $R'_G = 150\ \Omega$, $R'_L = 1\ k\Omega$, f = 200 Mc/s, See Figure 2	12	16	18				dB
		$V_{CC} = 12$ V, $I_C \approx 4.5$ mA, $V_{BB} = 3.1$ V, $R'_G = 500\ \Omega$, $R'_L = 250\ \Omega$, f = 45 Mc/s, See Figure 2				25	30	33	dB
$V_{BB(GC)}$	Gain-Control Base-Supply Voltage	$V_{CC} = 12$ V, $I_C \approx 2.5$ mA, $\Delta G_{pe} = -30$ dB, $R'_G = 150\ \Omega$, $R'_L = 1\ k\Omega$, f = 200 Mc/s, See Figure 2	3.7		4.6				V
		$V_{CC} = 12$ V, $I_C \approx 4.5$ mA, $\Delta G_{pe} = -30$ dB, $R'_G = 500\ \Omega$, $R'_L = 250\ \Omega$, f = 45 Mc/s, See Figure 2				3.7		4.6	V

†The fourth lead (case) is grounded for all measurements except C_{cb}.

THERMAL INFORMATION

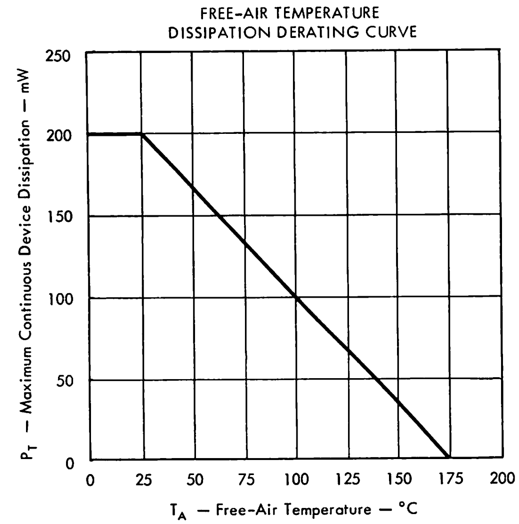
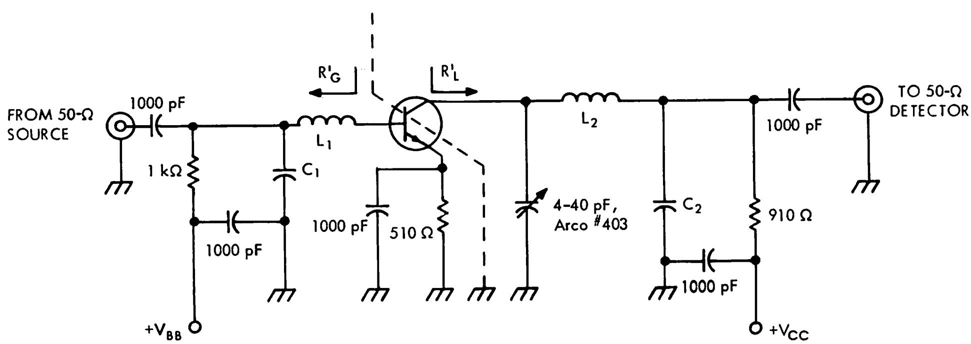


FIGURE 1

PARAMETER MEASUREMENT INFORMATION



COMPONENTS FOR f = 45 Mc/s

C_1: 36 pF
C_2: 47 pF
L_1: 8T #20 enameled copper wire, close-wound on ¼″ diameter form
L_2: 10T #20 enameled copper wire, close-wound on ¼″ diameter form

COMPONENTS FOR f = 200 Mc/s

C_1: 18 pF
C_2: 270 pF
L_1: 2T #20 enameled copper wire, ⅛″ pitch, wound on 7/32″ diameter form
L_2: 2T #14 enameled copper wire, ⅛″ pitch, wound on 7/32″ diameter form

FIGURE 2 — POWER-GAIN AND GAIN-CONTROL-VOLTAGE TEST CIRCUIT

TYPICAL CHARACTERISTICS

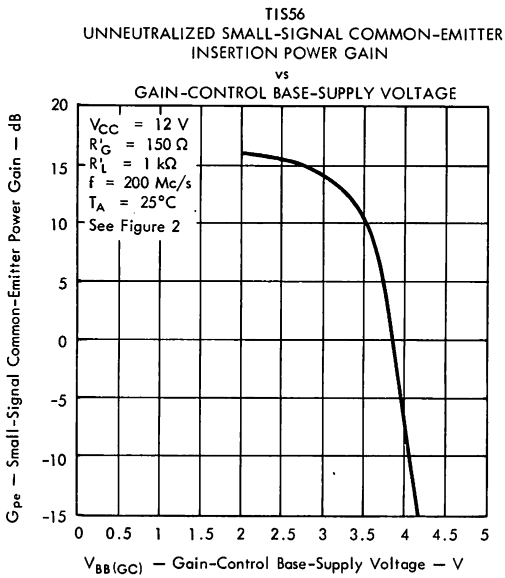


FIGURE 3

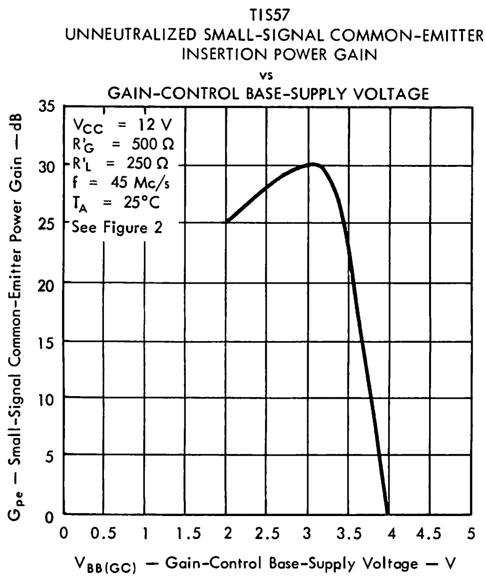


FIGURE 4

TYPES TIS62, TIS63, TIS64
BULLETIN NO. DL-S 689443, DECEMBER 1966
REVISED MAY 1968

SILECT† TRANSISTORS

Electrical Equivalents of TI407, TI408, and TI409

Encapsulated in Plastic for Application in

AM-FM Receivers and General-Purpose High-Frequency Amplifiers

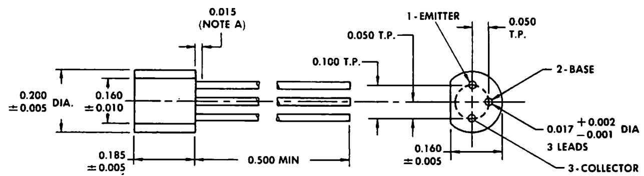
TIS62 Features:

- f_T . . . 500 MHz min
- Low $r_b'C_c$ . . . . 20 ps max
- NF . . . 6 dB max at 100 MHz

Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	12 V
Emitter-Base Voltage	3 V
Continuous Collector Current	30 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2 mW/deg.

†Trademark of Texas Instruments
‡Patent Pending

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIS62, TIS63, TIS64
N-P-N PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS62 MIN	TIS62 MAX	TIS63 MIN	TIS63 MAX	TIS64 MIN	TIS64 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$	30		30		30		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 4$ mA, $I_B = 0$	12		12		12		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$	3		3		3		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 10$ V, $I_E = 0$		100		100		100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA	30		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 455 kHz			27				dB
		$V_{CE} = 10$ V, $I_C = 4$ mA, f = 10 MHz			27				
		$V_{CE} = 10$ V, $I_C = 4$ mA, f = 100 MHz	5	18	4	18	3	18	
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz, See Note 3	0.7	1.6	0.7	1.6	0.7	2.2	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -4$ mA, f = 79.8 MHz		20		26		32	ps

NOTE 3: This parameter is measured using three-terminal measurement techniques with the emitter guarded.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS62 TYP	TIS62 MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 2$ mA, $R_G = 300\ \Omega$, f = 100 MHz	4	6	dB

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

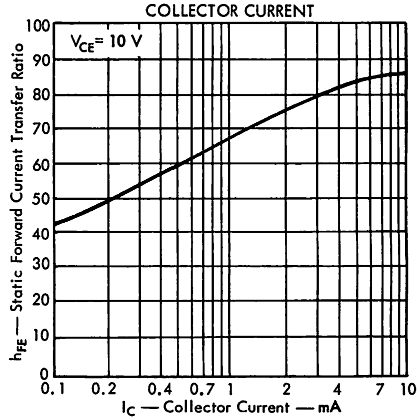
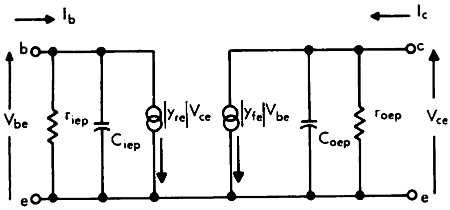


FIGURE 1

COMMON-EMITTER EQUIVALENT CIRCUIT USING SHORT-CIRCUIT "y" PARAMETERS



$$I_b = |y_{ie}|V_{be} + |y_{re}|V_{ce}$$
$$I_c = |y_{fe}|V_{be} + |y_{oe}|V_{ce}$$

$$|y_{ie}| = \left.\frac{I_b}{V_{be}}\right|_{V_{ce}=0} = \frac{1}{r_{iep}} + j\omega C_{iep} \qquad |y_{fe}| = \left.\frac{I_c}{V_{be}}\right|_{V_{ce}=0}$$

$$|y_{re}| = \left.\frac{I_b}{V_{ce}}\right|_{V_{be}=0} \qquad |y_{oe}| = \left.\frac{I_c}{V_{ce}}\right|_{V_{be}=0} = \frac{1}{r_{oep}} + j\omega C_{oep}$$

TYPICAL CHARACTERISTICS AT 455 kHz, $T_A = 25°C$

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

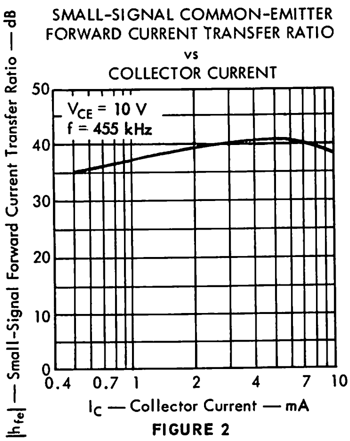


FIGURE 2

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

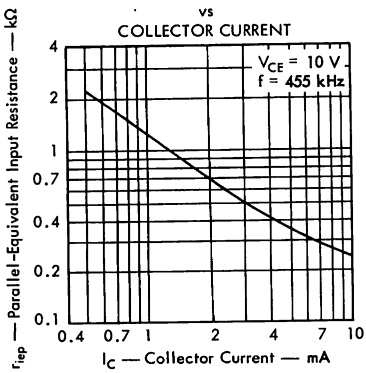


FIGURE 3

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

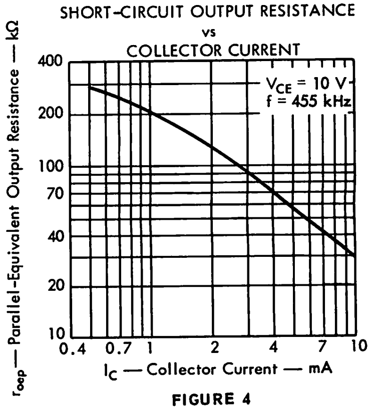


FIGURE 4

TYPICAL CHARACTERISTICS AT 10 MHz, $T_A = 25°C$

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT CAPACITANCE
vs
COLLECTOR-CURRENT

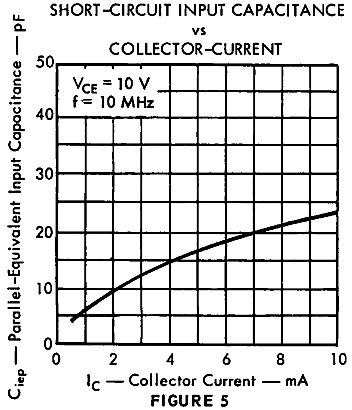


FIGURE 5

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR CURRENT

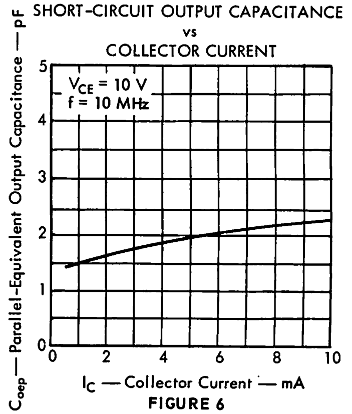


FIGURE 6

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

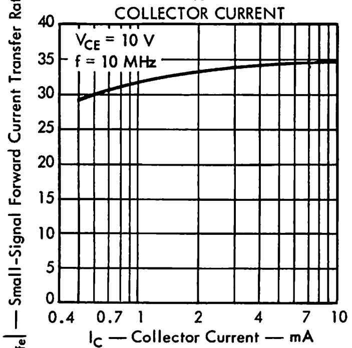


FIGURE 7

SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

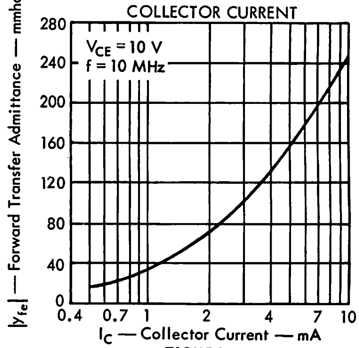


FIGURE 8

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

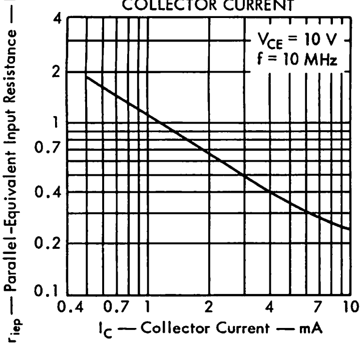


FIGURE 9

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

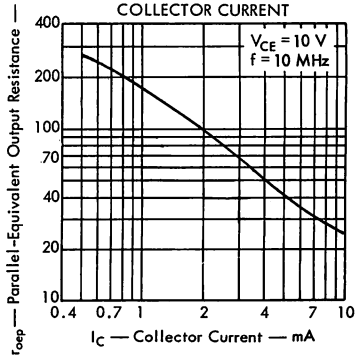


FIGURE 10

TYPICAL CHARACTERISTICS AT 100 MHz, $T_A = 25°C$

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT CAPACITANCE
vs
COLLECTOR CURRENT

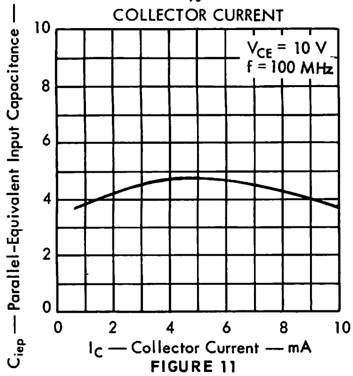


FIGURE 11

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR CURRENT

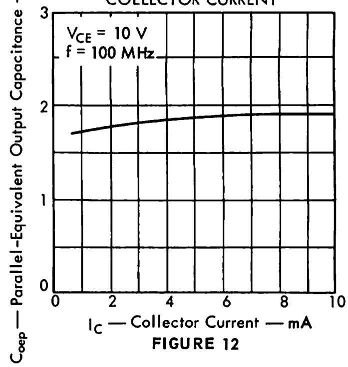


FIGURE 12

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

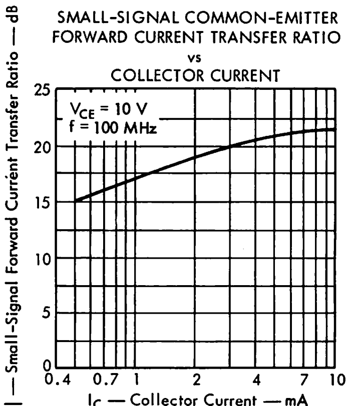


FIGURE 13

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

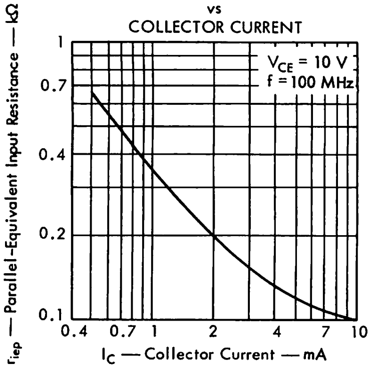


FIGURE 14

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

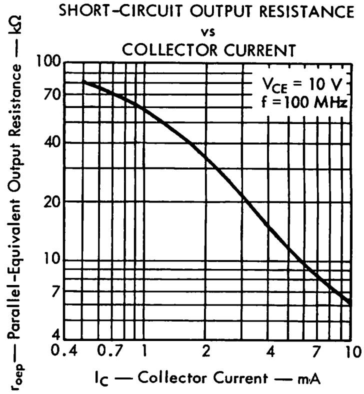
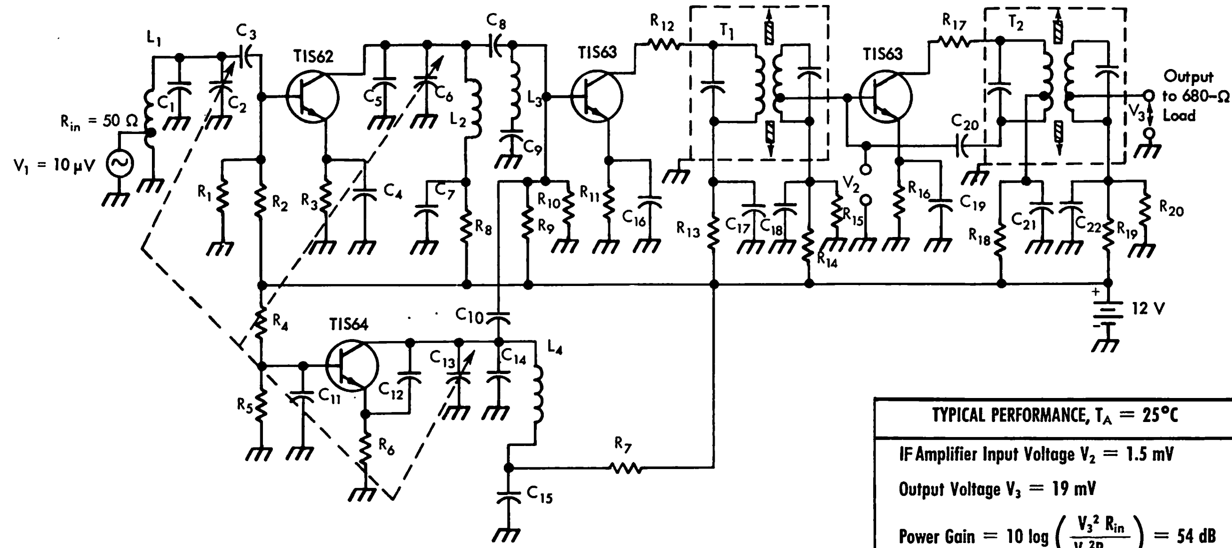


FIGURE 15

TYPICAL APPLICATION DATA

TYPICAL FM TUNER WITH IF AMPLIFIER STAGE



TYPICAL PERFORMANCE, $T_A = 25°C$
IF Amplifier Input Voltage $V_2 = 1.5$ mV
Output Voltage $V_3 = 19$ mV
Power Gain $= 10 \log \left(\frac{V_3^2 R_{in}}{V_1^2 R_{load}} \right) = 54$ dB
Image Rejection at 98 MHz = 50 dB

CIRCUIT COMPONENT INFORMATION

TRANSFORMERS

T_1: Radio Industries #18300 (or equivalent)
T_2: Radio Industries #18301 (or equivalent)

COILS

L_1: 4 T #18 bus, 5/16" ID, 3/4" length, Turns Ratio ≈ 1/2 to 4.
L_2: 4 T #18 bus, 5/16" ID, 3/4" length,
L_3: 1 μH
L_4: 3 T #18 bus, 5/16" ID, 3/4" length

RESISTORS

R_1:	8.2 kΩ	R_{11}:	1 kΩ
R_2:	33 kΩ	R_{12}:	120 Ω
R_3:	1 kΩ	R_{13}:	330 Ω
R_4:	12 kΩ	R_{14}:	10 kΩ
R_5:	2.7 kΩ	R_{15}:	3.9 kΩ
R_6:	1 kΩ	R_{16}:	1.2 kΩ
R_7:	330 Ω	R_{17}:	120 Ω
R_8:	330 Ω	R_{18}:	330 Ω
R_9:	15 kΩ	R_{19}:	10 kΩ
R_{10}:	2.7 kΩ	R_{20}:	3.9 kΩ

All resistors 1/2 W, ten percent tolerance.

CAPACITORS

C_1:	10 pF	C_{12}:	3.3 pF
C_2:	30-45 pF	C_{13}:	30-45 pF
C_3:	3.3 pF	C_{14}:	10 pF
C_4:	0.001 μF	C_{15}:	0.001 μF
C_5:	10 pF	C_{16}:	0.01 μF
C_6:	30-45 pF	C_{17}:	0.01 μF
C_7:	0.001 μF	C_{18}:	0.01 μF
C_8:	3.3 pF	C_{19}:	0.01 μF
C_9:	240 pF	C_{20}:	2.2 pF
C_{10}:	0.82 pF	C_{21}:	0.01 μF
C_{11}:	0.001 μF	C_{22}:	0.01 μF

TYPES TIS84, TIS85
BULLETIN NO. DL-S 6710195, JUNE 1967

SILECT† HIGH-FREQUENCY TRANSISTORS DESIGNED FOR TV TUNER AND IF APPLICATIONS

Featuring Low-Feedback Capacitance and Forward-AGC Characteristics

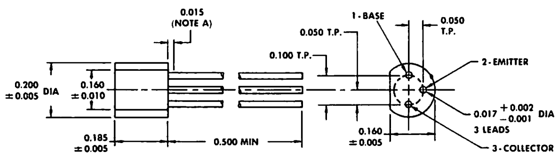
- **TIS84 for Tuner RF Amplifiers**
- **TIS85 for IF Amplifiers**

Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle

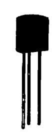
mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

Feedback capacitance is minimized by placing the emitter terminal between the base and collector terminals, thus optimizing compatability with advanced high-frequency design.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	40 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Base Voltage	4 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TIS84			TIS85			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$		40			40			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10\ mA$, $I_B = 0$,	See Note 3	30			30			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 10\ V$, $I_E = 0$				50			50	nA
		$V_{CB} = 10\ V$, $I_E = 0$,	$T_A = 85°C$			5			5	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 4\ V$, $I_C = 0$				10			10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10\ V$, $I_C = 4\ mA$		30			25			
V_{BE}	Base-Emitter Voltage	$V_{CE} = 10\ V$, $I_C = 4\ mA$				0.84			0.84	V

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2 mW/deg.
3. This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

†Trademark of Texas Instruments
‡Patent pending

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS84 MIN	TIS84 TYP	TIS84 MAX	TIS85 MIN	TIS85 TYP	TIS85 MAX	UNIT
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 4 mA, f = 100 MHz	3.5	6.5		3.5	6.5		
$\|y_{fe}\|$	Small-Signal Common-Emitter Forward Transfer Admittance	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz	60	80					mmho
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz				80	105		
ϕ_{yfe}	Phase Angle of Small-Signal Common-Emitter Forward Transfer Admittance	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz	–50°	–60°	–80°				
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz				–10°	–18°	–25°	
C_{ies}	Parallel-Equivalent Common-Emitter Short-Circuit Input Capacitance†	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz		11					pF
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz					18		
C_{res}	Common-Emitter Short-Circuit Reverse Transfer Capacitance†	V_{CE} = 10 V, I_C = 1 mA, f = 0.1 MHz to 1 MHz		0.32	0.4		0.32	0.4	pF
C_{oes}	Parallel-Equivalent Common-Emitter Short-Circuit Output Capacitance†	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz		1.1					pF
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz					1.1		
$Re(h_{ie})$	Real Part of Small-Signal Common-Emitter Input Impedance	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz		25	60				Ω
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz					50	80	
$Re(y_{ie})$	Real Part of Small-Signal Common-Emitter Input Admittance	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz		14	40				mmho
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz					3	6	
$Re(y_{oe})$	Real Part of Small-Signal Common-Emitter Output Admittance	V_{CE} = 10 V, I_C = 4 mA, f = 200 MHz		0.2	0.5				mmho
		V_{CE} = 10 V, I_C = 4 mA, f = 45 MHz					0.05	0.2	

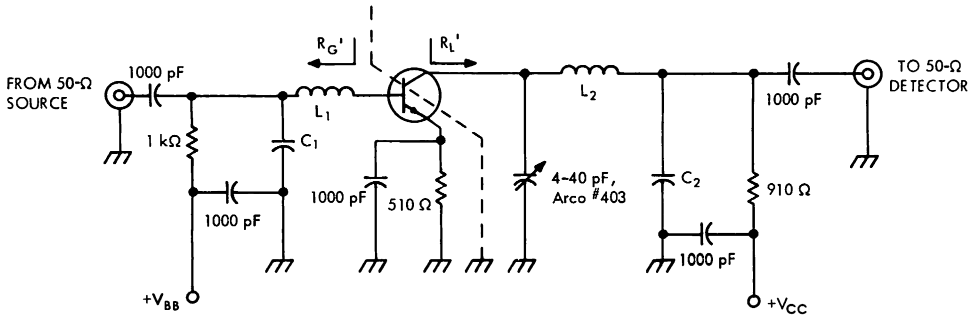
† C_{ies}, C_{res}, and C_{oes} are defined as the imaginary parts of the small-signal, common-emitter, short-circuit admittances divided by $2\pi f$.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS84 MIN	TIS84 TYP	TIS84 MAX	TIS85 MIN	TIS85 TYP	TIS85 MAX	UNIT
NF	Spot Noise Figure	V_{CE} = 10 V, I_C = 3 mA, R_G = 50 Ω, f = 200 MHz		2.8	3.3				dB
		V_{CE} = 10 V, I_C = 3 mA, R_G = 50 Ω, f = 45 MHz					3	6	dB
G_{pe}	Unneutralized Small-Signal Common-Emitter Insertion Power Gain	V_{CC} = 12 V, $I_C \approx$ 2.5 mA, V_{BB} = 2.1 V, R_G' = 150 Ω, R_L' = 1 kΩ, f = 200 MHz, See Figure 1	12	16	18				dB
		V_{CC} = 12 V, $I_C \approx$ 4.5 mA, V_{BB} = 3.1 V, R_G' = 500 Ω, R_L' = 250 Ω, f = 45 MHz, See Figure 1				25	30	33	dB
$V_{BB(GC)}$	Gain-Control Base-Supply Voltage	V_{CC} = 12 V, R_G' = 150 Ω, R_L' = 1 kΩ, ΔG_{pe} = –30 dB‡, f = 200 MHz, See Figure 1	3.7		4.6				V
		V_{CC} = 12 V, R_G' = 500 Ω, R_L' = 250 Ω, ΔG_{pe} = –30 dB‡, f = 45 MHz, See Figure 1				3.7		4.6	V

‡ΔG_{pe} is defined as the change in G_{pe} from the value at V_{BB} = 2.1 V at 200 MHz or from the value at V_{BB} = 3.1 V at 45 MHz.

PARAMETER MEASUREMENT INFORMATION



COMPONENTS FOR f = 45 MHz

C_1: 36 pF
C_2: 47 pF
L_1: 8 T #20 enameled copper wire, close-wound on ¼″ diameter form
L_2: 10 T #20 enameled copper wire, close-wound on ¼″ diameter form

COMPONENTS FOR f = 200 MHz

C_1: 18 pF
C_2: 270 pF
L_1: 2 T #20 enameled copper wire, ⅛″ pitch, wound on 7⁄32″ diameter form
L_2: 2 T #14 enameled copper wire, ⅛″ pitch, wound on 7⁄32″ diameter form

FIGURE 1 — POWER-GAIN AND GAIN-CONTROL-VOLTAGE TEST CIRCUIT

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

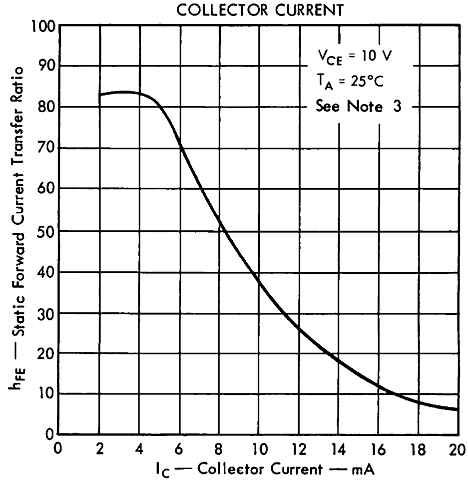


FIGURE 2

NOTE 3: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle = 10%.

TYPICAL CHARACTERISTICS

TIS84

SMALL-SIGNAL COMMON-EMITTER INPUT ADMITTANCE
vs
COLLECTOR CURRENT

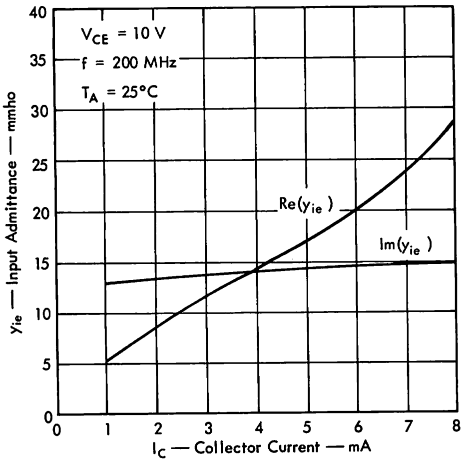


FIGURE 3

TIS84

SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

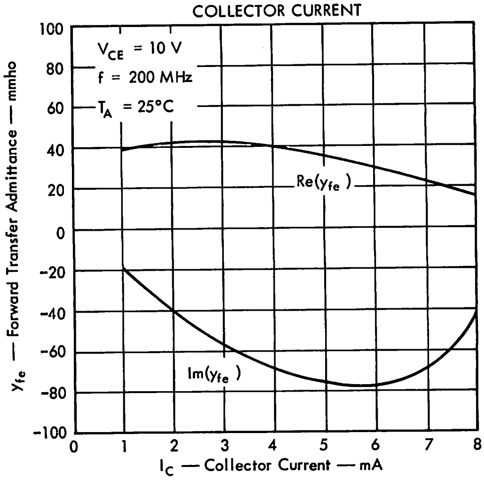


FIGURE 4

TIS84

SMALL-SIGNAL COMMON-EMITTER OUTPUT ADMITTANCE
vs
COLLECTOR CURRENT

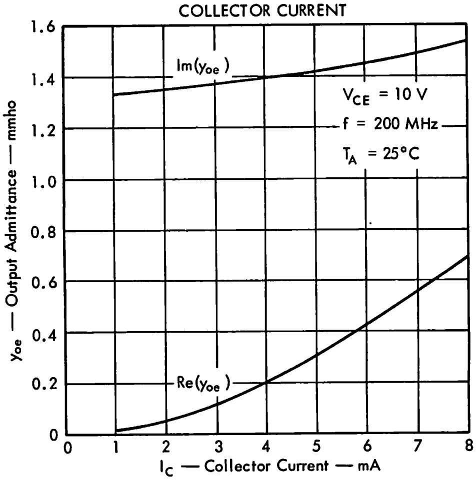


FIGURE 5

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TYPICAL CHARACTERISTICS

TIS85
SMALL-SIGNAL COMMON-EMITTER INPUT ADMITTANCE
vs
COLLECTOR CURRENT

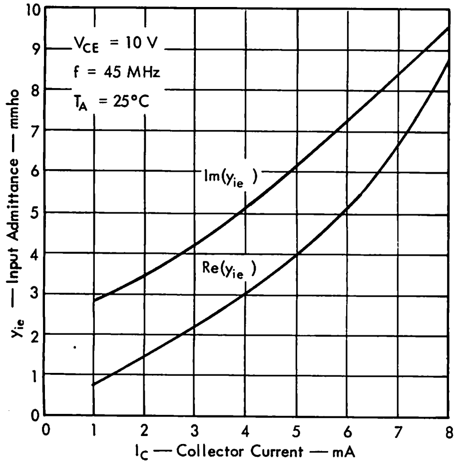

FIGURE 6

TIS85
SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

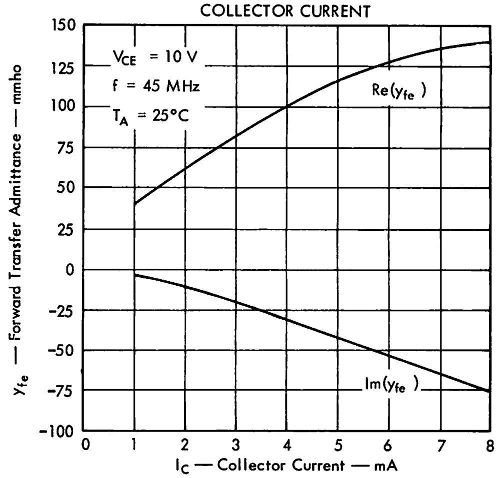

FIGURE 7

TIS85
SMALL-SIGNAL COMMON-EMITTER OUTPUT ADMITTANCE
vs
COLLECTOR CURRENT

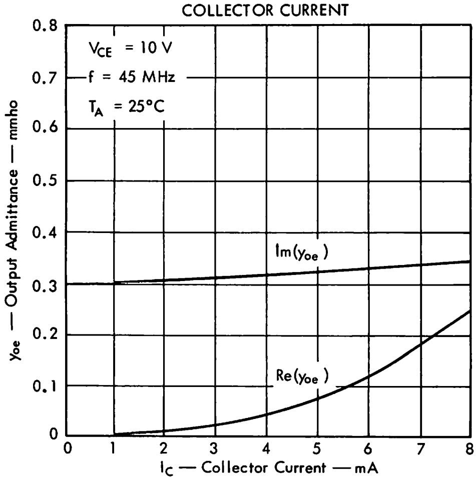

FIGURE 8

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TYPICAL CHARACTERISTICS

TIS84
SPOT NOISE FIGURE
vs
COLLECTOR CURRENT

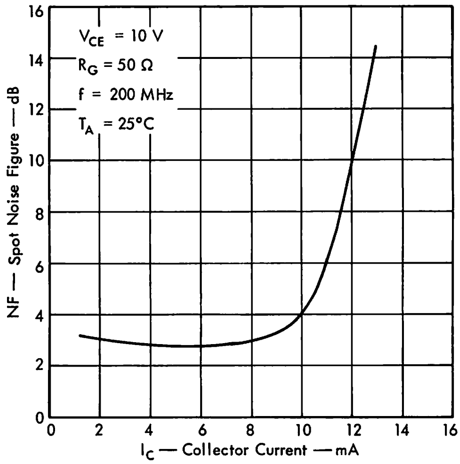


FIGURE 9

TIS84
RELATIVE SMALL-SIGNAL COMMON-EMITTER POWER GAIN
vs
GAIN-CONTROL BASE-SUPPLY VOLTAGE

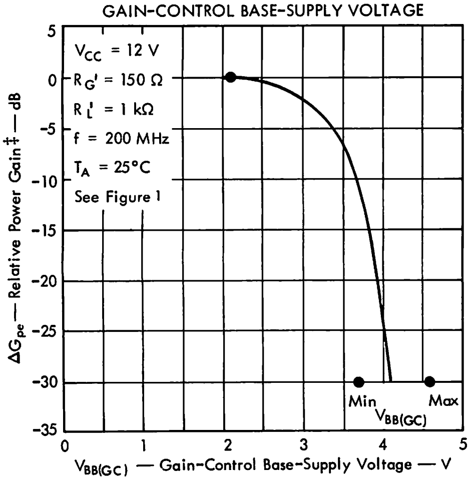


FIGURE 10

TIS85
RELATIVE SMALL-SIGNAL COMMON-EMITTER POWER GAIN
vs
GAIN-CONTROL BASE-SUPPLY VOLTAGE

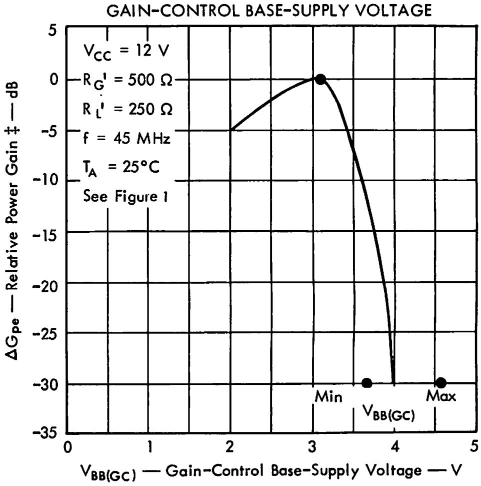
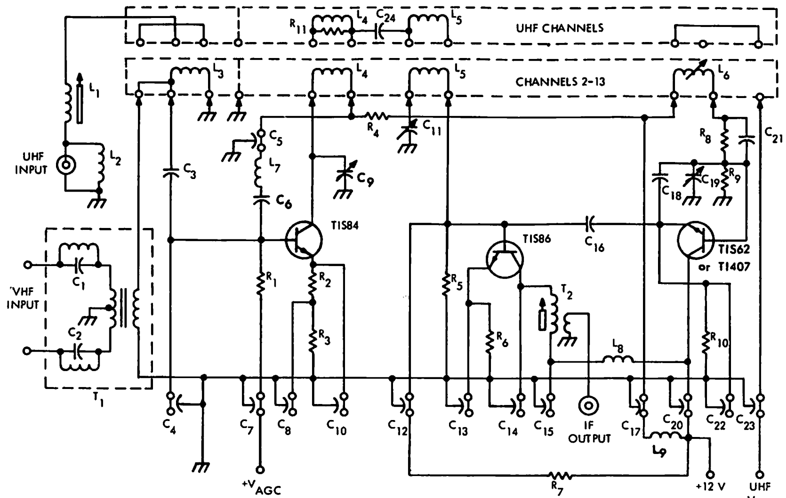


FIGURE 11

‡ΔG_{pe} is defined as the change in G_{pe} from the value at V_{BB} = 2.1 V at 200 MHz or from the value at V_{BB} = 3.1 V at 45 MHz.

TYPICAL APPLICATION DATA

TYPICAL TV VHF TUNER



CIRCUIT COMPONENT INFORMATION

CAPACITORS

C_1: 47 pF
C_2: 47 pF
C_3: 8.2 pF
C_4: 18 pF feed-thru
C_5: 30 pF feed-thru
C_6: 0.68 pF
C_7: 1000 pF feed-thru
C_8: 1000 pF feed-thru
C_9: 2-8 pF air trimmer
C_{10}: 39 pF feed-thru
C_{11}: 2-8 pF air trimmer
C_{12}: 30 pF feed-thru
C_{13}: 1000 pF feed-thru
C_{14}: 10 pF feed-thru
C_{15}: 1000 pF feed-thru
C_{16}: 3.6 pF
C_{17}: 1000 pF feed-thru
C_{18}: 5.6 pF
C_{19}: 0.5-3 pF air trimmer
C_{20}: 1000 pF feed-thru
C_{21}: 5.6 pF
C_{22}: 2.5 pF feed-thru
C_{23}: 1000 pF feed-thru
C_{24}: 5.6 pF

RESISTORS (1/2 W, ten percent)

R_1: 1 kΩ
R_2: 15 Ω
R_3: 560 Ω
R_4: 390 Ω
R_5: 1.2 kΩ
R_6: 220 Ω
R_7: 10 kΩ
R_8: 5.6 kΩ
R_9: 10 kΩ
R_{10}: 1 kΩ
R_{11}: 10 kΩ

INDUCTORS

L_1: UHF matching coil
L_2: UHF matching coil
L_3: as required per channel
L_4: as required per channel
L_5: as required per channel
L_6: as required per channel
L_7: neutralizing coil
L_8: RFC
L_9: RFC

TRANSFORMERS

T_1: balun assembly, including IF traps
T_2: IF output transformer

FIGURE 12 — TYPICAL TV VHF TUNER

TYPICAL TV VHF TUNER PERFORMANCE

CHANNEL	POWER GAIN	NOISE FIGURE	IF REJECT	IMAGE REJECT	UNIT
2	39	5.5	55	70	dB
3	38	5.2	55	77	dB
4	38	5.7	57	82	dB
5	36	5.5	59	88	dB
6	38	6.0	63	75	dB
7	37	5.5	72	68	dB
8	35	6.1	71	72	dB
9	36	5.5	72	66	dB
10	34	5.5	84	78	dB
11	35	6.2	79	79	dB
12	35	6.2	76	79	dB
13	35	6.1	65	70	dB

POWER SUPPLY INFORMATION

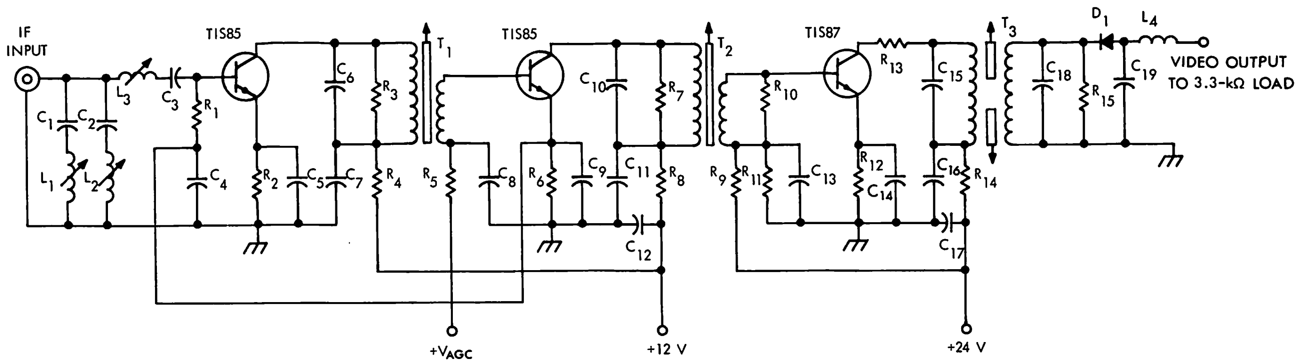
	MAXIMUM GAIN	MINIMUM GAIN
Power Supply	12 V at 19.5 mA	12 V at 34 mA
V_{AGC} Supply	1.8 V at 0.1 mA	8 V at 2.85 mA

TYPICAL TUNER AND IF AMPLIFIER (SEE FIG. 13) COMBINED PERFORMANCE

CHANNEL	$V_{in(rf)}$ (μV)
2	3.5
3	3.5
4	3.5
5	4.5
6	3.5
7	11.0
8	10.0
9	9.0
10	13.0
11	12.0
12	9.5
13	11.0

Frequency Rejection:
39.75 MHz: down 13.5 dB
41.25 MHz: down 13.5 dB
41.80 MHz: down 6 dB
45.75 MHz: down 6 dB
47.25 MHz: down 46.5 dB

TYPICAL APPLICATION DATA



CIRCUIT COMPONENT INFORMATION

RESISTORS (1/2 W, TEN PERCENT)

R_1: 20 Ω	R_6: 680 Ω	R_{11}: 4.7 kΩ
R_2: 470 Ω	R_7: 1 kΩ	R_{12}: 510 Ω
R_3: 1 kΩ	R_8: 270 Ω	R_{13}: 56 Ω
R_4: 270 Ω	R_9: 15 kΩ	R_{14}: 220 Ω
R_5: 1 kΩ	R_{10}: 20 Ω	R_{15}: 5.6 kΩ

CAPACITORS

C_1: 8.2 pF	C_6: 15 pF	C_{11}: 0.002 μF	C_{16}: 0.002 μF
C_2: 10 pF	C_7: 0.002 μF	C_{12}: 0.002 μF	C_{17}: 0.002 μF
C_3: 18 pF	C_8: 0.002 μF	C_{13}: 0.002 μF	C_{18}: 18 pF
C_4: 0.002 μF	C_9: 0.002 μF	C_{14}: 0.002 μF	C_{19}: 10 pF
C_5: 0.002 μF	C_{10}: 10 pF	C_{15}: 15 pF	

DIODE

D_1: 1N60

INDUCTORS

L_1: self sound, 14 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_2: adjacent sound, 10 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_3: series inductor, 6 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_4: filter inductor, 10 μH, Delevan RFC

TRANSFORMERS

T_1: pri.: 6T, sec.: 2 T, #27 enameled, close-wound, bifilar, 9/32" OD form, Arnold Eng. core type "J"
T_2: pri.: 8T, sec.: 2 T, #27 enameled, close-wound, bifilar, 9/32" OD form, Arnold Eng. core type "J"
T_3: pri.: 9T, sec.: 8 T, #25 enameled, close-wound, pri. and sec. spacing: 0.18", 9/32" OD form, Arnold Eng. core type "J"

POWER SUPPLY INFORMATION		
	MAXIMUM GAIN	MINIMUM GAIN
Power Supply	12 V at 9 mA	12 V at 20 mA
	24 V at 10 mA	24 V at 10 mA
V_{AGC} Supply	4 V at 0 mA	7.5 V at 0.5 mA

TYPICAL TV IF AMPLIFIER PERFORMANCE

Sensitivity: $V_{in(if)} = 100\ \mu V$ for $V_{OUT(DC)} = 1\ V$

Frequency Rejection:

39.75 MHz: down 17 dB
41.25 MHz: down 20 dB
45.75 MHz: down 3 dB
47.25 MHz: down 18 dB

FIGURE 13 — TYPICAL TV IF AMPLIFIER

TYPES TIS86, TIS87
BULLETIN NO. DL-S 6810225, JUNE 1967
REVISED MAY 1968

SILECT† HIGH-FREQUENCY TRANSISTORS DESIGNED FOR TV MIXER AND NON-AGC IF STAGES

Featuring Low Feedback Capacitance and
Full Characterization to Simplify Circuit Design

- **TIS86 for Mixer**
- **TIS87 for Non-AGC IF Amplifier**

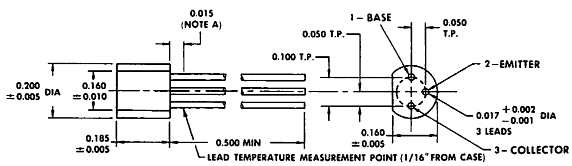
Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

High thermal-conductivity leads allow operation at unusually high dissipation levels.

Feedback capacitance is minimized by placing the emitter terminal between the base and collector terminals, thus optimizing compatibility with advanced high-frequency design.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	TIS86	TIS87
Collector-Base Voltage	30 V	45 V
Collector-Emitter Voltage (See Note 1)	30 V	45 V
Emitter-Base Voltage	4 V	4 V
Continuous Collector Current	←— 50 mA —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←—400 mW—→	
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 3)	←—700 mW—→	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←— 260°C —→	

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 3.2 mW/deg.
3. Derate linearly to 150°C lead temperature at the rate of 5.6 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.

†Trademark of Texas Instruments
‡Patent pending

TEXAS INSTRUMENTS
INCORPORATED
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TYPES TIS86, TIS87
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIS86 MIN	TIS86 TYP	TIS86 MAX	TIS87 MIN	TIS87 TYP	TIS87 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	30			45			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 4	30			45			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V, $I_E = 0$			100			100	nA
		$V_{CB} = 15$ V, $I_E = 0$, $T_A = 85°C$			10			10	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 4$ V, $I_C = 0$			10			10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA	40		200				
		$V_{CE} = 12$ V, $I_C = 12$ mA				30		150	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 12$ V, $I_C = 15$ mA			0.87			0.87	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1.5$ mA, $I_C = 15$ mA						0.5	V
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 100 MHz	5						
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 100 MHz				5			
$\lvert y_{fe} \rvert$	Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 45 MHz	90	115					mmho
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz				130	200		mmho
ϕ_{yfe}	Phase Angle of Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 45 MHz	–7°	–15°	–20°				
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz				–18°	–25°	–35°	
C_{ies}	Parallel-Equivalent Common-Emitter Short-Circuit Input Capacitance†	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 200 MHz		9					pF
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz					25		pF
C_{res}	Common-Emitter Short-Circuit Reverse Transfer Capacitance†	$V_{CE} = 10$ V, $I_C = 1$ mA, f = 0.1 MHz to 1 MHz		0.33	0.45		0.33	0.45	pF
C_{oes}	Parallel-Equivalent Common-Emitter Short-Circuit Output Capacitance†	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 45 MHz		1.1					pF
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz					1.1		pF
$Re(h_{ie})$	Real Part of Small-Signal Common-Emitter Input Impedance	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 200 MHz		32	60				Ω
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz					55	100	Ω
$Re(y_{ie})$	Real Part of Small-Signal Common-Emitter Input Admittance	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 200 MHz		8.5	30				mmho
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz					5	12	mmho
$Re(y_{oe})$	Real Part of Small-Signal Common-Emitter Output Admittance	$V_{CE} = 10$ V, $I_C = 4$ mA, f = 45 MHz		0.02	0.15				mmho
		$V_{CE} = 12$ V, $I_C = 12$ mA, f = 45 MHz					0.07	0.2	mmho

NOTE 4: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

†C_{ies}, C_{res}, and C_{oes} are defined as the imaginary parts of the small-signal, common-emitter, short-circuit admittances divided by $2\pi f$.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS86 TYP	TIS86 MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 4$ mA, $R_G = 50\ \Omega$, f = 200 MHz	2.5	5	dB

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

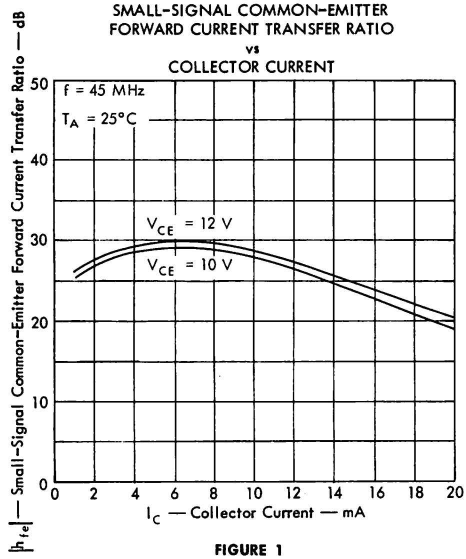


FIGURE 1

COMMON-EMITTER SHORT-CIRCUIT REVERSE TRANSFER CAPACITANCE
vs
COLLECTOR-EMITTER VOLTAGE

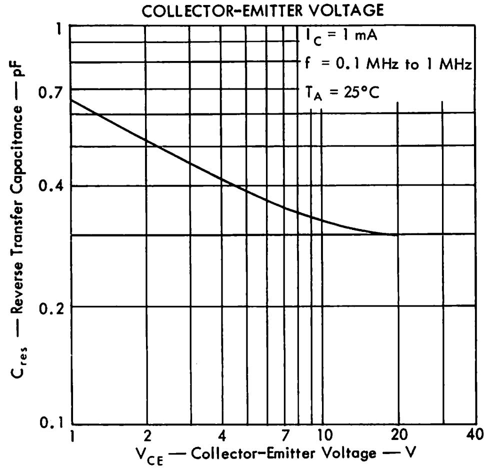


FIGURE 2

TYPICAL CHARACTERISTICS

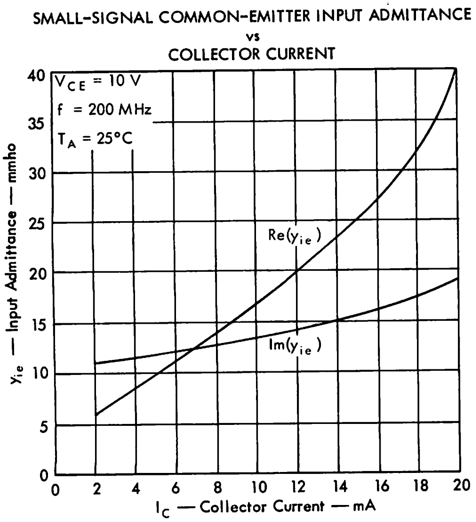


FIGURE 3

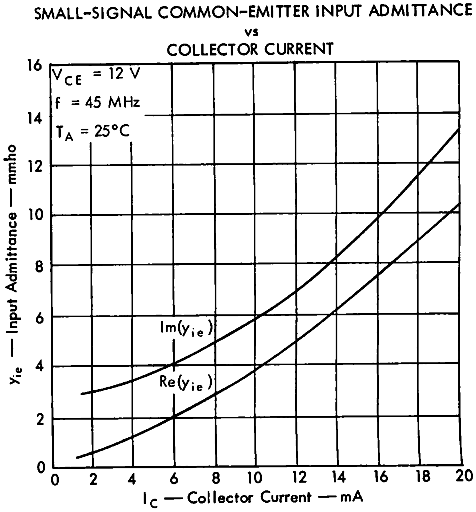


FIGURE 4

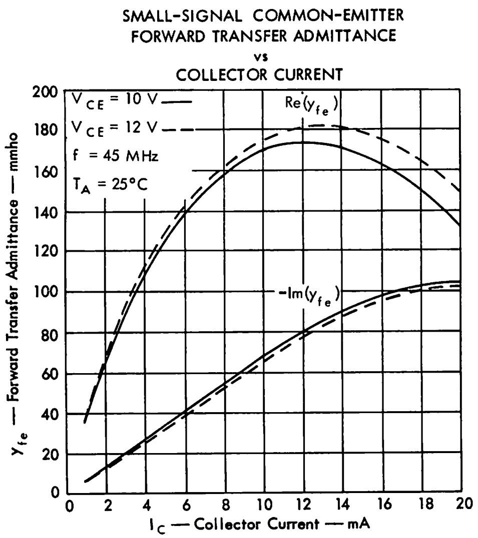


FIGURE 5

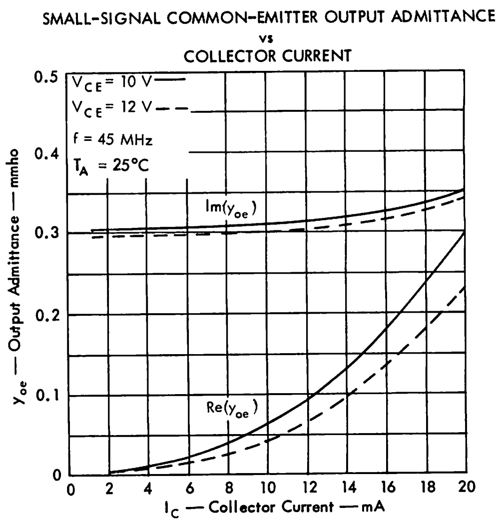
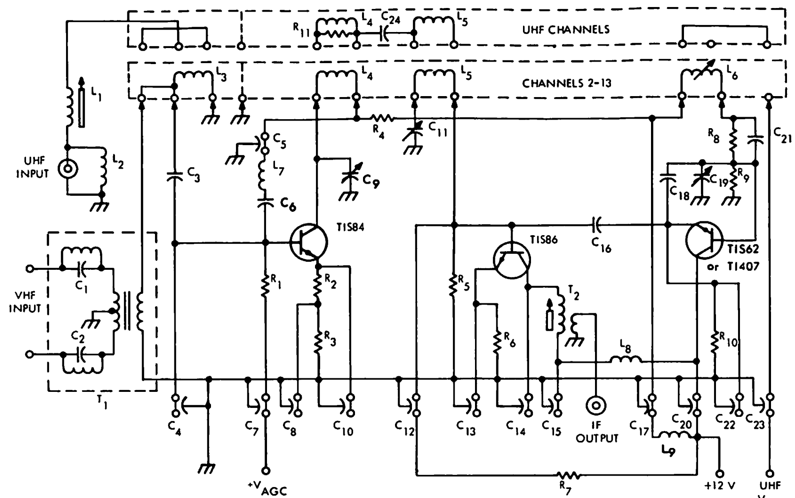


FIGURE 6

TYPICAL APPLICATION DATA

TYPICAL TV VHF TUNER



CIRCUIT COMPONENT INFORMATION

CAPACITORS

C_1: 47 pF
C_2: 47 pF
C_3: 8.2 pF
C_4: 18 pF feed-thru
C_5: 30 pF feed-thru
C_6: 0.68 pF
C_7: 1000 pF feed-thru
C_8: 1000 pF feed-thru
C_9: 2-8 pF air trimmer
C_{10}: 39 pF feed-thru
C_{11}: 2-8 pF air trimmer
C_{12}: 30 pF feed-thru
C_{13}: 1000 pF feed-thru
C_{14}: 10 pF feed-thru
C_{15}: 1000 pF feed-thru
C_{16}: 3.6 pF
C_{17}: 1000 pF feed-thru
C_{18}: 5.6 pF
C_{19}: 0.5-3 pF air trimmer
C_{20}: 1000 pF feed-thru
C_{21}: 5.6 pF
C_{22}: 2.5 pF feed-thru
C_{23}: 1000 pF feed-thru
C_{24}: 5.6 pF

RESISTORS (1/2 W, ten percent)

R_1: 1 kΩ
R_2: 15 Ω
R_3: 560 Ω
R_4: 390 Ω
R_5: 1.2 kΩ
R_6: 220 Ω
R_7: 10 kΩ
R_8: 5.6 kΩ
R_9: 10 kΩ
R_{10}: 1 kΩ
R_{11}: 10 kΩ

INDUCTORS

L_1: UHF matching coil
L_2: UHF matching coil
L_3: as required per channel
L_4: as required per channel
L_5: as required per channel
L_6: as required per channel
L_7: neutralizing coil
L_8: RFC
L_9: RFC

TRANSFORMERS

T_1: balun assembly, including IF traps
T_2: IF output transformer

FIGURE 12 — TYPICAL TV VHF TUNER

TYPICAL TV VHF TUNER PERFORMANCE

CHANNEL	POWER GAIN	NOISE FIGURE	IF REJECT	IMAGE REJECT	UNIT
2	39	5.5	55	70	dB
3	38	5.2	55	77	dB
4	38	5.7	57	82	dB
5	36	5.5	59	88	dB
6	38	6.0	63	75	dB
7	37	5.5	72	68	dB
8	35	6.1	71	72	dB
9	36	5.5	72	66	dB
10	34	5.5	84	78	dB
11	35	6.2	79	79	dB
12	35	6.2	76	79	dB
13	35	6.1	65	70	dB

POWER SUPPLY INFORMATION

	MAXIMUM GAIN	MINIMUM GAIN
Power Supply	12 V at 19.5 mA	12 V at 34 mA
V_{AGC} Supply	1.8 V at 0.1 mA	8 V at 2.85 mA

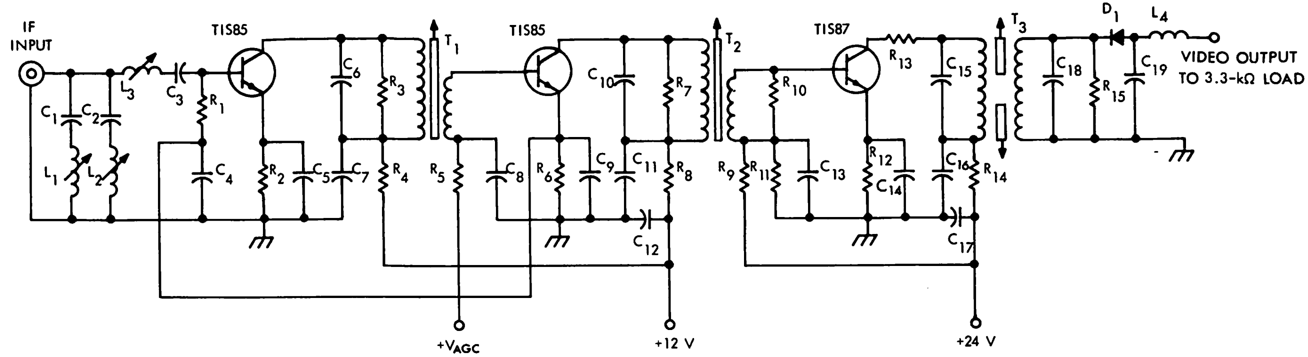
TYPICAL TUNER AND IF AMPLIFIER (SEE FIG. 13) COMBINED PERFORMANCE

CHANNEL	$V_{in(rf)}$ (μV)
2	3.5
3	3.5
4	3.5
5	4.5
6	3.5
7	11.0
8	10.0
9	9.0
10	13.0
11	12.0
12	9.5
13	11.0

Frequency Rejection:
39.75 MHz: down 13.5 dB
41.25 MHz: down 13.5 dB
41.80 MHz: down 6 dB
45.75 MHz: down 6 dB
47.25 MHz: down 46.5 dB

TYPES TIS86, TIS87
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPICAL APPLICATION DATA



CIRCUIT COMPONENT INFORMATION

RESISTORS (1/2 W, TEN PERCENT)

R_1: 20 Ω
R_2: 470 Ω
R_3: 1 kΩ
R_4: 270 Ω
R_5: 1 kΩ
R_6: 680 Ω
R_7: 1 kΩ
R_8: 270 Ω
R_9: 15 kΩ
R_{10}: 20 Ω
R_{11}: 4.7 kΩ
R_{12}: 510 Ω
R_{13}: 56 Ω
R_{14}: 220 Ω
R_{15}: 5.6 kΩ

CAPACITORS

C_1: 8.2 pF
C_2: 10 pF
C_3: 18 pF
C_4: 0.002 μF
C_5: 0.002 μF
C_6: 15 pF
C_7: 0.002 μF
C_8: 0.002 μF
C_9: 0.002 μF
C_{10}: 10 pF
C_{11}: 0.002 μF
C_{12}: 0.002 μF
C_{13}: 0.002 μF
C_{14}: 0.002 μF
C_{15}: 15 pF
C_{16}: 0.002 μF
C_{17}: 0.002 μF
C_{18}: 18 pF
C_{19}: 10 pF

DIODE

D_1: 1N60

INDUCTORS

L_1: self sound, 14 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_2: adjacent sound, 10 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_3: series inductor, 6 T, #27 enameled, close-wound, 9/32" OD form, Arnold Eng. core type "J"
L_4: filter inductor, 10 μH, Delevan RFC

TRANSFORMERS

T_1: pri.: 6T, sec.: 2 T, #27 enameled, close-wound, bifilar, 9/32" OD form, Arnold Eng. core type "J"
T_2: pri.: 8T, sec.: 2 T, #27 enameled, close-wound, bifilar, 9/32" OD form, Arnold Eng. core type "J"
T_3: pri.: 9T, sec.: 8 T, #25 enameled, close-wound, pri. and sec. spacing: 0.18", 9/32" OD form, Arnold Eng. core type "J"

POWER SUPPLY INFORMATION

	MAXIMUM GAIN	MINIMUM GAIN
Power Supply	12 V at 9 mA	12 V at 20 mA
	24 V at 10 mA	24 V at 10 mA
V_{AGC} Supply	4 V at 0 mA	7.5 V at 0.5 mA

TYPICAL TV IF AMPLIFIER PERFORMANCE

Sensitivity: $V_{in(if)} = 100\ \mu V$ for $V_{OUT(DC)} = 1\ V$

Frequency Rejection:

39.75 MHz: down 17 dB
41.25 MHz: down 20 dB
45.75 MHz: down 3 dB
47.25 MHz: down 18 dB

FIGURE 13 — TYPICAL TV IF AMPLIFIER

TYPES TIS94 THRU TIS99
BULLETIN NO. DL-S 6710187, JUNE 1967

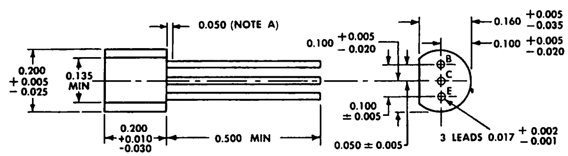
A COMPLETE FAMILY OF LOW-NOISE, LOW- TO MEDIUM-CURRENT SILECT† TRANSISTORS FOR USE IN HI-FI AUDIO AMPLIFIERS AND GENERAL PURPOSE LOW-FREQUENCY APPLICATIONS

- **High $V_{(BR)CEO}$ . . . 65 V Min (TIS96 and TIS99)**
- **Excellent h_{FE} Linearity to 100 mA**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

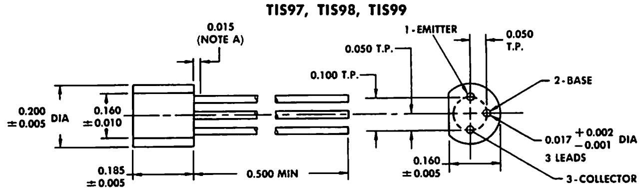
TIS94, TIS95, TIS96



ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES: A. Lead diameter is not controlled in this area.
B. All dimensions are in inches.

TIS97, TIS98, TIS99



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	TIS94 TIS97	TIS95 TIS98	TIS96 TIS99
Collector-Base Voltage	60 V	80 V	80 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	65 V
Emitter-Base Voltage	6 V	6 V	6 V
Continuous Collector Current	←200 mA→		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←360 mW→		
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 3)	←500 mW→		
Storage Temperature Range	←−65°C to 150°C→		
Lead Temperature 1/16 Inch from Case for 10 Seconds	←260°C→		

NOTES: 1. These values apply between 0 and 10 mA collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
3. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.

†Trademark of Texas Instruments
‡Patent pending

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TYPES TIS94 THRU TIS99
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		TIS94 TIS97 MIN	TIS94 TIS97 TYP	TIS94 TIS97 MAX	TIS95 TIS98 MIN	TIS95 TIS98 TYP	TIS95 TIS98 MAX	TIS96 TIS99 MIN	TIS96 TIS99 TYP	TIS96 TIS99 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$,	See Note 4	40			60			65			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 40$ V, $I_E = 0$				10			10			10	nA
		$V_{CB} = 60$ V, $I_E = 0$				10							μA
		$V_{CB} = 80$ V, $I_E = 0$							10			10	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 6$ V, $I_C = 0$				20			20			20	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 100$ μA		250	340	700							
		$V_{CE} = 5$ V, $I_C = 1$ mA					100	200	300				
		$V_{CE} = 5$ V, $I_C = 10$ mA,	See Note 4							60	125		
		$V_{CE} = 5$ V, $I_C = 100$ mA,	See Note 4							55	110	300	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ V, $I_C = 100$ μA		0.45		0.65							V
		$V_{CE} = 5$ V, $I_C = 1$ mA					0.5		0.7				V
		$V_{CE} = 5$ V, $I_C = 10$ mA,	See Note 4							0.6		0.8	V
V_{CE}	Collector-Emitter Voltage	$I_B = 0.1$ mA, $I_C = 10$ mA,	See Note 4						1				V
		$I_B = 2$ mA, $I_C = 100$ mA,	See Note 4									2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ mA, $I_C = 100$ mA,	See Note 4						0.5			0.5	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 5$ V, $I_C = 100$ μA	$f = 1$ kHz		115								kΩ
		$V_{CE} = 5$ V, $I_C = 1$ mA						6.4					
		$V_{CE} = 5$ V, $I_C = 10$ mA									0.5		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 100$ μA	$f = 1$ kHz	250	440	800							
		$V_{CE} = 5$ V, $I_C = 1$ mA					100	240	400				
		$V_{CE} = 5$ V, $I_C = 10$ mA								60	130	500	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio	$V_{CE} = 5$ V, $I_C = 100$ μA	$f = 1$ kHz		30×10^{-4}								
		$V_{CE} = 5$ V, $I_C = 1$ mA						1.5×10^{-4}					
		$V_{CE} = 5$ V, $I_C = 10$ mA									0.9×10^{-4}		
h_{oe}	Small-Signal Common-Emitter Output Admittance	$V_{CE} = 5$ V, $I_C = 100$ μA	$f = 1$ kHz		11								μmho
		$V_{CE} = 5$ V, $I_C = 1$ mA						6					
		$V_{CE} = 5$ V, $I_C = 10$ mA									50		
y_{fe}	Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = 5$ V, $I_C = 100$ μA	$f = 1$ kHz		3.8								mmho
		$V_{CE} = 5$ V, $I_C = 1$ mA					30	38					
		$V_{CE} = 5$ V, $I_C = 10$ mA									260		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 10$ mA,	$f = 100$ MHz	2			2			2			
C_{cb}	Collector-Base Capacitance	$V_{CB} = 5$ V, $I_E = 0$,	$f = 1$ MHz, See Note 5	1		4	1		4	1		4	pF
C_{eb}	Emitter-Base Capacitance	$V_{EB} = 0.5$ V, $I_C = 0$,	$f = 1$ MHz, See Note 5			16			16			16	pF

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS94, TIS97 MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = 5$ V, $I_C = 30$ μA, $R_G = 10$ kΩ, $f = 1$ kHz, Noise Bandwidth $= 100$ Hz	2	dB
$\overline{NF}$	Average Noise Figure	$V_{CE} = 5$ V, $I_C = 100$ μA, $R_G = 10$ kΩ, Noise Bandwidth $= 15.7$ kHz, See Note 6	3	dB

NOTES: 4. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.
5. C_{cb} and C_{eb} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded.
6. Average Noise Figure is measured in an amplifier with response down 3 dB at 10 Hz and 10 kHz and a high-frequency rolloff of 6 dB/octave.

PARAMETER COLOR-CODE INFORMATION

The TIS96 and TIS99 are furnished in three color-coded h_{FE} brackets, each having a 2-to-1 spread as shown in the table below. No h_{FE}-bracket distribution is implied by this coding system.

COLOR CODE	h_{FE} BRACKET $V_{CE} = 5$ V, $I_C = 100$ mA
red	55—110
orange	90—180
yellow	150—300

TABLE 1 — TIS96, TIS99 h_{FE} BRACKETS

TYPICAL CHARACTERISTICS

TIS94, TIS97

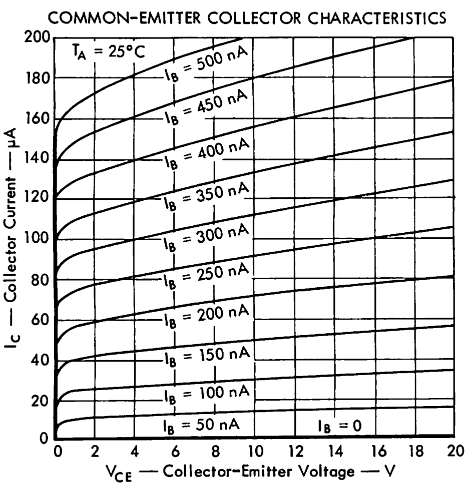

FIGURE 1

TIS96, TIS99

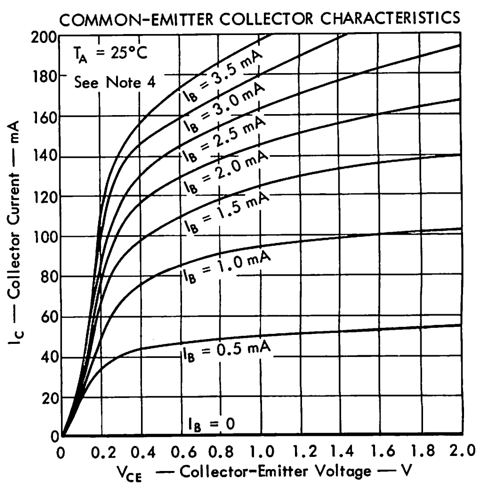

FIGURE 2

NOTE 4: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

TYPICAL CHARACTERISTICS

NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

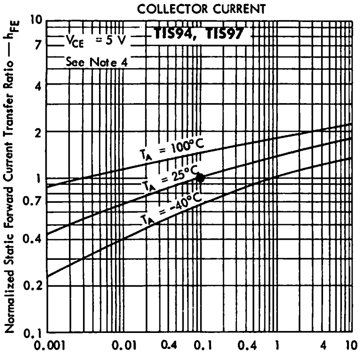

FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

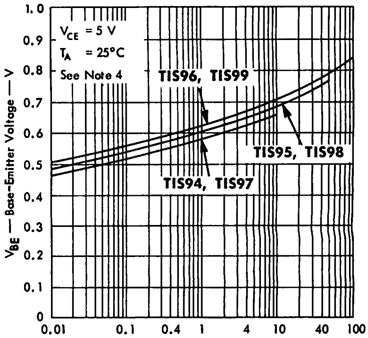

FIGURE 4

NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

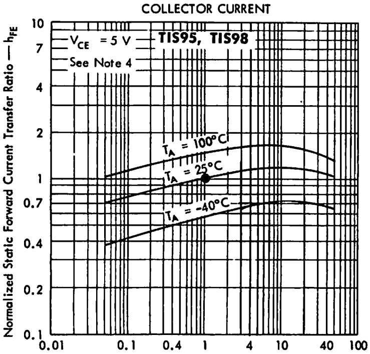

FIGURE 5

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

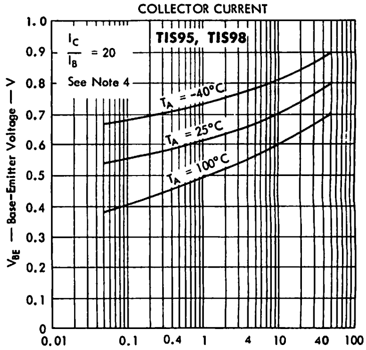

FIGURE 6

NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

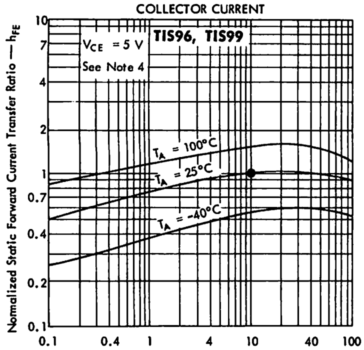

FIGURE 7

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

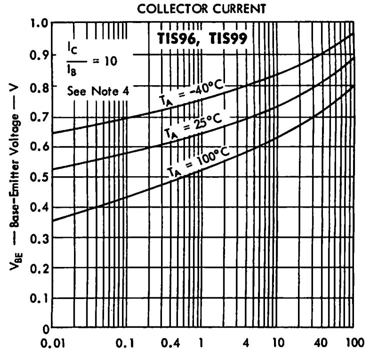

FIGURE 8

NOTE 4: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

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TYPICAL CHARACTERISTICS

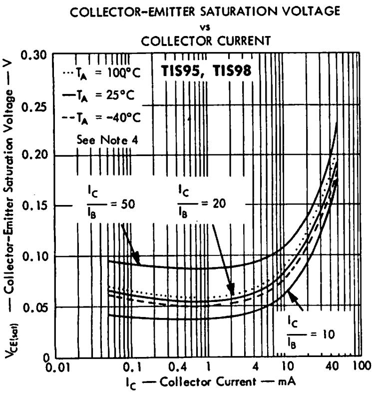


FIGURE 9

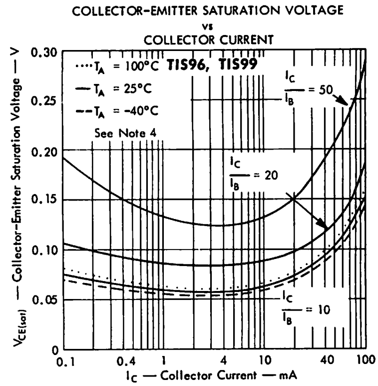


FIGURE 10

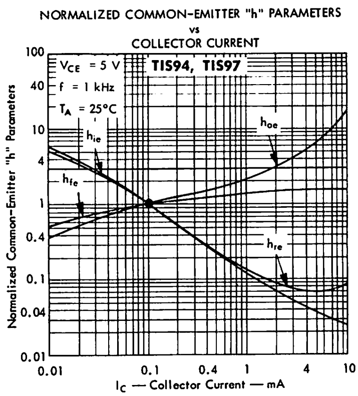


FIGURE 11

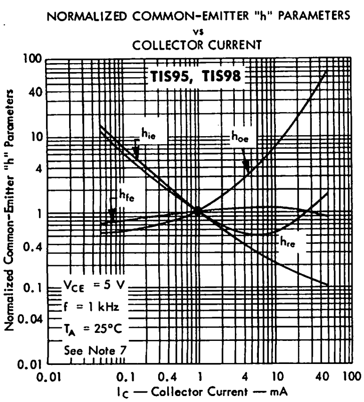


FIGURE 12

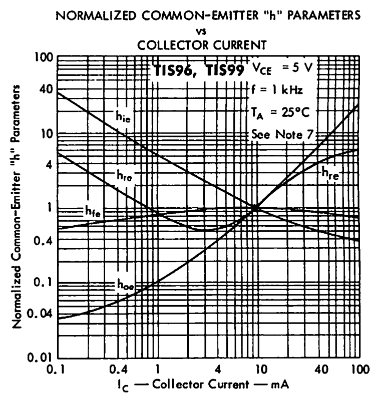


FIGURE 13

NOTES: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.
7. These parameters are measured with bias voltages applied for less than five seconds to avoid overheating the transistor.

TYPICAL CHARACTERISTICS

TIS96, TIS99

COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

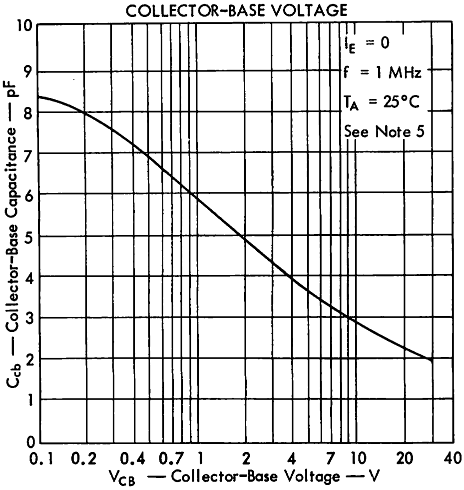


FIGURE 14

TIS94, TIS97

EMITTER-BASE CAPACITANCE
vs
EMITTER-BASE VOLTAGE

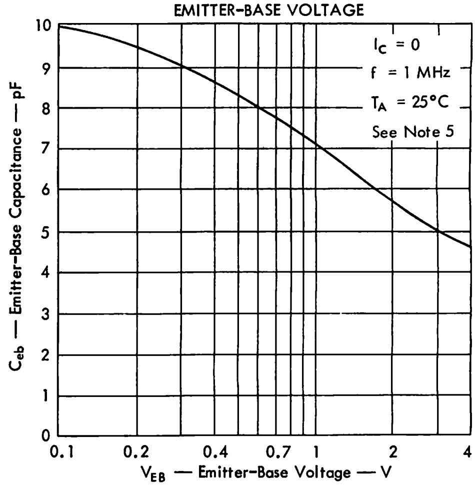


FIGURE 15

TIS94, TIS97

AVERAGE NOISE FIGURE
vs
GENERATOR RESISTANCE

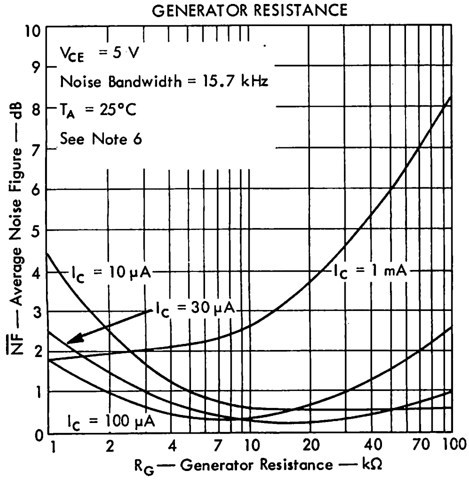


FIGURE 16

TIS94, TIS97

SPOT NOISE FIGURE
vs
FREQUENCY

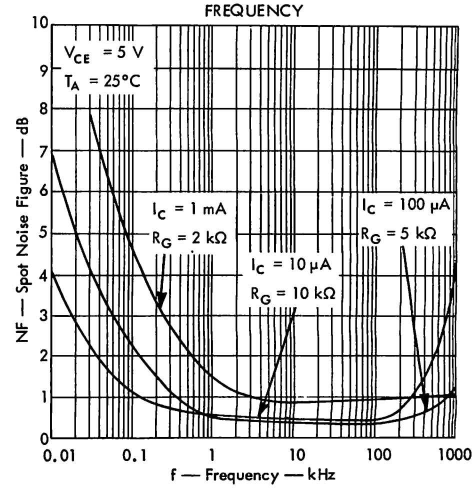


FIGURE 17

NOTES: 5. C_{cb} and C_{eb} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded.
6. Average Noise Figure is measured in an amplifier with response down 3 dB at 10 Hz and 10 kHz and a high-frequency rolloff of 6 dB/octave.

TYPICAL CHARACTERISTICS

TIS94, TIS97

CONTOURS OF CONSTANT SPOT NOISE FIGURE

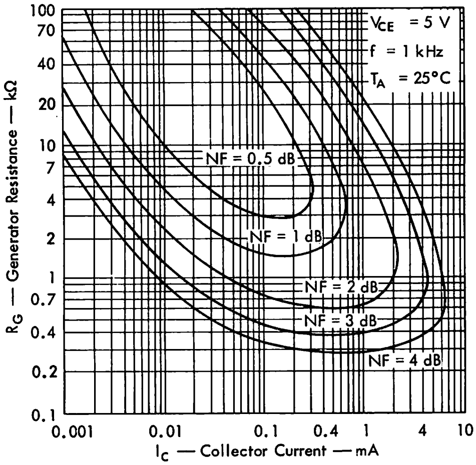


FIGURE 18

TIS94, TIS97

CONTOURS OF CONSTANT SPOT NOISE FIGURE

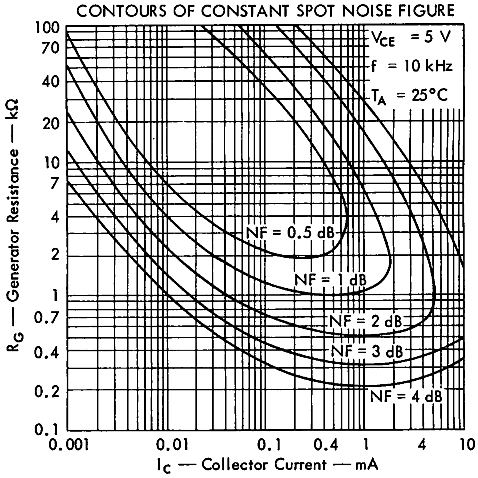
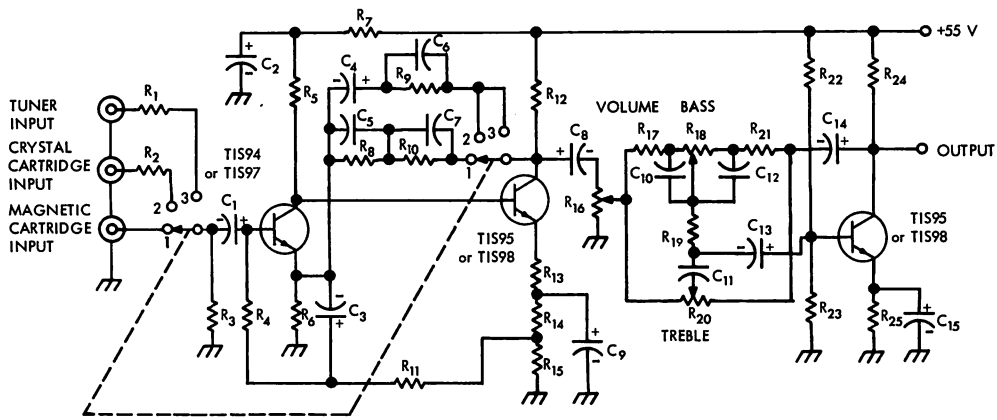


FIGURE 19

TYPICAL APPLICATION DATA



CIRCUIT COMPONENT INFORMATION

RESISTORS

R_1: 1 MΩ	R_{10}: 56 kΩ	R_{18}: 0–1 MΩ
R_2: 2.7 MΩ	R_{11}: 100 kΩ	R_{19}: 47 kΩ
R_3: 47 kΩ	R_{12}: 33 kΩ	R_{20}: 0–500 kΩ
R_4: 100 kΩ	R_{13}: 270 Ω	R_{21}: 82 kΩ
R_5: 150 kΩ	R_{14}: 2.2 kΩ	R_{22}: 470 kΩ
R_6: 330 Ω	R_{15}: 1 kΩ	R_{23}: 56 kΩ
R_7: 15 kΩ	R_{16}: 0–100 kΩ	R_{24}: 39 kΩ
R_8: 1.2 MΩ	R_{17}: 82 kΩ	R_{25}: 4.7 kΩ
R_9: 75 kΩ		

All resistors ½ W, ten percent tolerance

CAPACITORS

C_1: 10 μF, 3 V, electrolytic	C_9 : 50 μF, 6 V, electrolytic
C_2: 2 μF, 50 V, electrolytic	C_{10}: 0.003 μF
C_3: 50 μF, 3 V, electrolytic	C_{11}: 470 pF
C_4: 20 μF, 25 V, electrolytic	C_{12}: 0.003 μF
C_5: 0.0033 μF	C_{13}: 5 μF, 6 V, electrolytic
C_6: 47 pF	C_{14}: 1 μF, 25 V, electrolytic
C_7: 1200 pF	C_{15}: 20 μF, 6 V, electrolytic
C_8: 1 μF, 50 V, electrolytic	

TYPICAL PERFORMANCE AT RATED OUTPUT
V_{out}=1 V, R_L=22 kΩ, f=1 kHz (unless otherwise noted), T_A=25°C

Sensitivity:		Overload Capability:	
Magnetic Cartridge Input	4 mV	Magnetic Cartridge Input	35 to 50 mV†
Crystal Cartridge Input	220 mV	Crystal Cartridge Input	2 to 2.8 V†
Tuner Input	100 mV	Tuner Input	0.9 to 1.3 V†
Total Harmonic Distortion:		Input Impedance:	
Magnetic Cartridge Input	0.06%	Magnetic Cartridge Input	47 kΩ
Crystal and Tuner Inputs	0.14%	Crystal Cartridge Input	2.7 MΩ
		Tuner Input	1 MΩ
Unweighted Noise Below 1 V rms With Grounded Input	72 dB	RIAA Compensation (Magnetic Input Only) Within ±1 dB of Ideal Curve from 20 Hz to 20 kHz	
Frequency Response: Crystal and Tuner Inputs 20 Hz to 20 kHz	±1 dB		

†Value dependent on volume control setting

FIGURE 20 — TYPICAL AUDIO PREAMPLIFIER

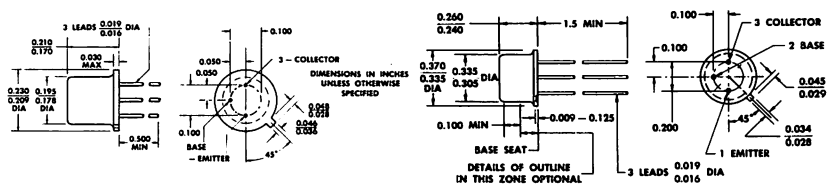
TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

Highly Reliable, Versatile Devices Designed for Amplifier, Switching and Oscillator Applications from <0.1 ma to >150 ma, dc to 30 mc

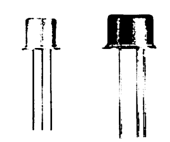
- **High Voltage** • **Low Leakage**
- **Useful h_{FE} Over Wide Current Range**

*mechanical data

Device types 2N717, 2N718, 2N718A, 2N730, 2N731, and 2N956 are in JEDEC TO-18 packages.
Device types 2N696, 2N697, 2N1420, 2N1507, 2N1613, and 2N1711 are in JEDEC TO-5 packages.



TO-18 THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE TO-5



TO-18 TO-5

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N696 2N697	2N717 2N718	2N718A	2N730 2N731	2N956	2N1420 2N1507	2N1613	2N1711	UNIT
Collector-Base Voltage	60	60	75	60	75	60	75	75	v
Collector-Emitter Voltage (See Note 1)	40	40	50	40	50	30	50	50	v
Collector-Emitter Voltage (See Note 2)			32						v
Emitter-Base Voltage	5	5	7	5	7	5	7	7	v
Collector Current				1.0		1.0		1.0	a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note Indicated in Parentheses) →	0.6 † (3)	0.4 †† (5)	0.5 (7)	0.5 †† (9)	0.5 (7)	0.6 † (3)	0.8 (10)	0.8 (10)	w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note Indicated in Parentheses) →	2.0 † (4)	1.5 †† (6)	1.8 (8)	1.5 †† (6)	1.8 (8)	2.0 † (4)	3.0 (11)	3.0 (11)	w
Total Device Dissipation at 100°C Case Temperature	1.0 †	0.75 ††	1.0	0.75 ††	1.0	1.0 †	1.7	1.7	w
Operating Collector Junction Temperature	175†	175††	200	175††	200	175†	200	200	°C
Storage Temperature Range	—65°C to 200°C								

NOTES:
1. This value applies when the base-emitter resistance (R_{BE}) is equal to or less than 10 ohms.
2. This value applies when the base-emitter diode is open-circuited.
3. Derate linearly to 175°C free-air temperature at the rate of 4.0 mw/C°.
4. Derate linearly to 175°C case temperature at the rate of 13.3 mw/C°.
5. Derate linearly to 175°C free-air temperature at the rate of 2.67 mw/C°.
6. Derate linearly to 175°C case temperature at the rate of 10.0 mw/C°.
7. Derate linearly to 200°C free-air temperature at the rate of 2.86 mw/C°.
8. Derate linearly to 200°C case temperature at the rate of 10.3 mw/C°.
9. Derate linearly to 175°C free-air temperature at the rate of 3.33 mw/C°.
10. Derate linearly to 200°C free-air temperature at the rate of 4.56 mw/C°.
11. Derate linearly to 200°C case temperature at the rate of 17.2 mw/C°.

*Indicates JEDEC registered data.

†Texas Instruments guarantees its types 2N696, 2N697, 2N1420, and 2N1507 to be capable of the same dissipation as registered and shown for types 2N1613 and 2N1711 with appropriate derating factors shown in Notes 10 and 11. See derating curves, page 8.

††Texas Instruments guarantees its types 2N717, 2N718, 2N730, and 2N731 to be capable of the same dissipation as registered and shown for types 2N718A and 2N956 with appropriate derating factors shown in Notes 7 and 8. See derating curves, page 8.

TEXAS INSTRUMENTS
INCORPORATED
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TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS TO-18 → / TO-5 →		2N696		2N697		2N717 2N730		2N718 2N731	UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	60		60		60		60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 12									v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = 100$ ma, $R_{BE} = 10\ \Omega$, See Note 12	40		40		40		40		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$ Except 2N717,2N718: $I_E = 1$ ma	5		5		5		5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_E = 0$		1.0		1.0		1.0		1.0	μa
		$V_{CB} = 30$ v, $I_E = 0$, $T_A = 150°C$		100		100		100		100	μa
		$V_{CB} = 60$ v, $I_E = 0$									μa
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$									μa
I_{CER}	Collector Cutoff Current	$V_{CE} = 20$ v, $R_{BE} = 100\ k\Omega$									μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$									μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 10\ \mu a$									
		$V_{CE} = 10$ v, $I_C = 100\ \mu a$									
		$V_{CE} = 10$ v, $I_C = 10$ ma, See Note 12									
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$ See Note 12									
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 12	20	60	40	120	20	60	40	120	
		$V_{CE} = 10$ v, $I_C = 500$ ma, See Note 12									
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 12		1.3		1.3		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 12		1.5		1.5		1.5		1.5	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc									ohm
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc									ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc									
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc									
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc									μmho
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc									μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc									
		$V_{CE} = 10$ v, $I_C = 5$ ma, $f = 1$ kc									
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, $f = 20$ mc	2.0		2.5		2.0		2.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ mc		35		35		35		35	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, $f = 1$ mc						80		80	pf

NOTE 12: These parameters must be measured using pulse techniques. PW $\leq 300\ \mu$sec, Duty Cycle $\leq 2\%$. Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.

*Indicates JEDEC registered data

TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TO-18→ 2N718A / TO-5→ 2N1613		2N1420		2N1507		2N956 / 2N1711		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a, I_E = 0$	75		60		60		75		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 12					25				v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = 100$ ma, $R_{BE} = 10\ \Omega$, See Note 12	50		30		30		50		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a, I_C = 0$	7						7		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_E = 0$				1.0		1.0			μa
		$V_{CB} = 30$ v, $I_E = 0$, $T_A = 150°C$				100		50			μa
		$V_{CB} = 60$ v, $I_E = 0$		0.010						0.010	μa
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$		10						10	μa
I_{CER}	Collector Cutoff Current	$V_{CE} = 20$ v, $R_{BE} = 100\ k\Omega$						10			μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		0.01				100		0.005	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 10\ \mu a$							20		
		$V_{CE} = 10$ v, $I_C = 100\ \mu a$	20						35		
		$V_{CE} = 10$ v, $I_C = 10$ ma, See Note 12	35						75		
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$, See Note 12	20						35		
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 12	40	120	100	300	100	300	100	300	
		$V_{CE} = 10$ v, $I_C = 500$ ma, See Note 12	20						40		
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 12		1.3		1.3		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 12		1.5		1.5		1.5		1.5	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_C = 1$ ma, f = 1 kc	24	34					24	34	ohm
		$V_{CB} = 10$ v, $I_C = 5$ ma, f = 1 kc	4	8					4	8	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_C = 1$ ma, f = 1 kc		3×10^{-4}						5×10^{-4}	
		$V_{CB} = 10$ v, $I_C = 5$ ma, f = 1 kc		3×10^{-4}						5×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_C = 1$ ma, f = 1 kc	0.1	0.5					0.1	0.5	μmho
		$V_{CB} = 10$ v, $I_C = 5$ ma, f = 1 kc	0.1	1.0					0.1	1.0	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, f = 1 kc	30	100					50	200	
		$V_{CE} = 10$ v, $I_C = 5$ ma, f = 1 kc	35	150					70	300	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, f = 20 mc	3.0		2.5		2.5		3.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 mc		25		35		35		25	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, f = 1 mc		80						80	pf

See operating and switching characteristics for types 2N718A, 2N956, 2N1613, and 2N1711 on page 4.

NOTE 12: These parameters must be measured using pulse techniques. PW ≤ 300 μsec, Duty Cycle ≤ 2%. Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.

*Indicates JEDEC registered data

*operating characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	TO-18 → 2N956 TYP	TO-18 → 2N956 MAX	TO-18 → 2N718A TYP	TO-18 → 2N718A MAX	UNIT
	TO-5 →	2N1711		2N1613		
NF Spot Noise Figure	$V_{CE} = 10$ v, $I_C = 300\ \mu a$, $R_G = 510\ \Omega$, f = 1 kc	5	8	6	12	db

* switching characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	TO-18 → 2N718A TYP	TO-18 → 2N718A MAX	UNIT
	TO-5 →	2N1613		
t_T Total Switching Time	See Figure 1	20	30	nsec

*PARAMETER MEASUREMENT INFORMATION

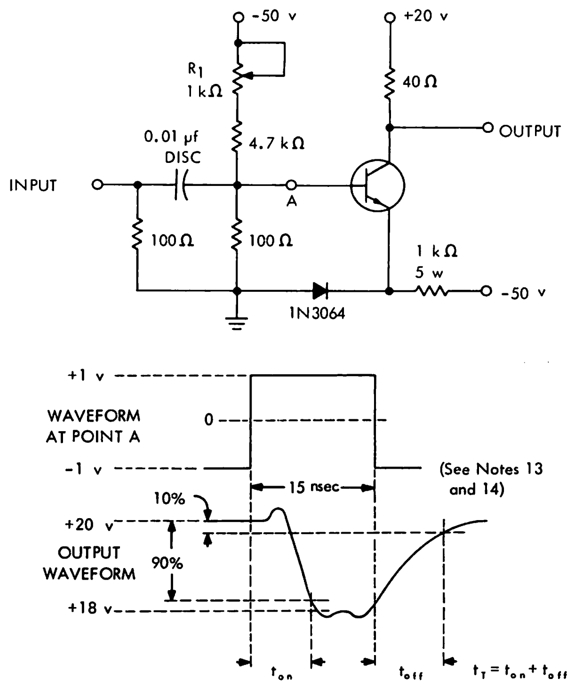


FIGURE 1 — SWITCHING TIME MEASUREMENT CIRCUIT FOR 2N718A AND 2N1613

NOTES: 13. The input waveform is supplied by a mercury relay pulse generator with the following characteristics: $t_r \leq 1$ nsec, $t_f \leq 1$ nsec, PW = 15 nsec. Adjust R_1 and the input pulse amplitude to obtain the specified voltage levels at Point A.

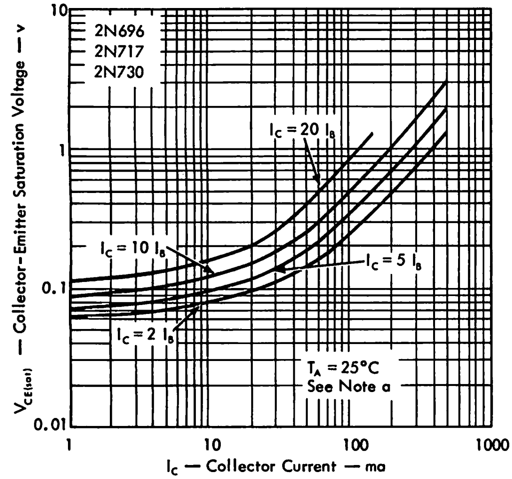
14. Waveforms are monitored on a sampling oscilloscope ($t_r \leq 0.4$ nsec) using a 2000 Ω probe.

*Indicates JEDEC registered data (typical data excluded)

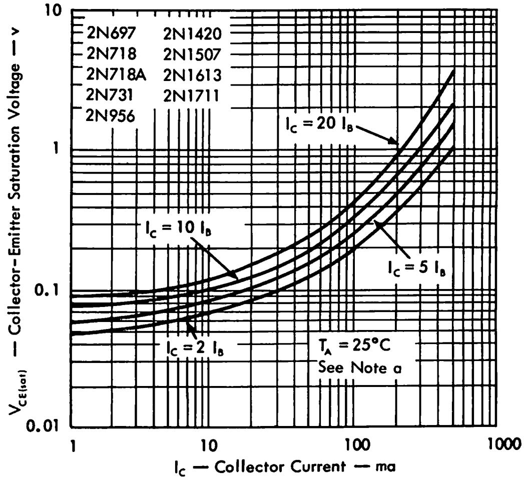
TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

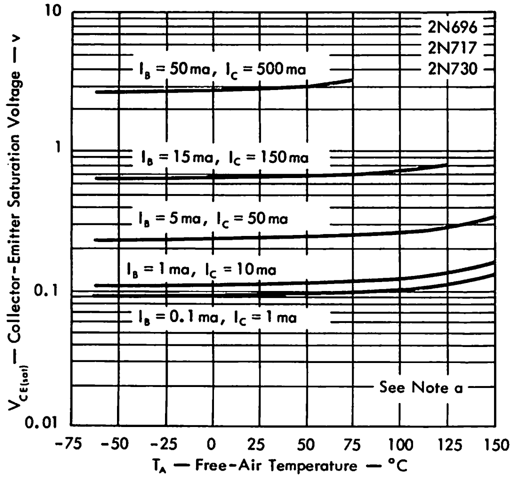
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT



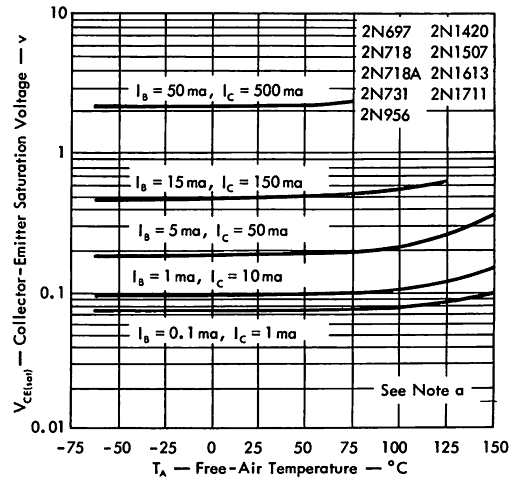
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT



COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE

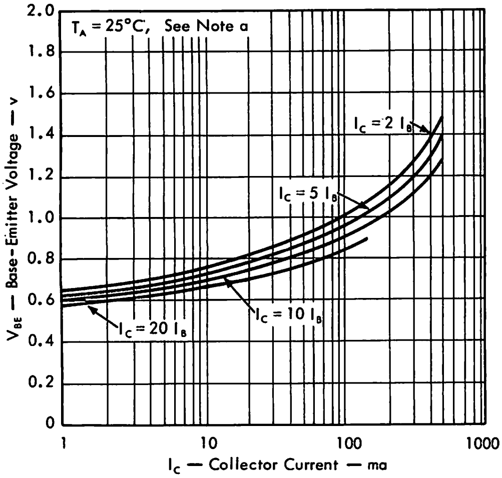


NOTE a: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

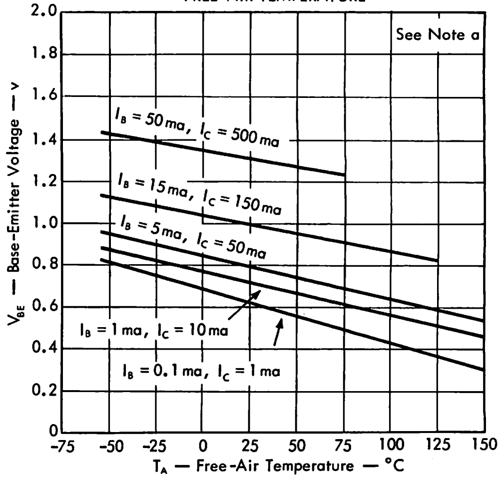
TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711 N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

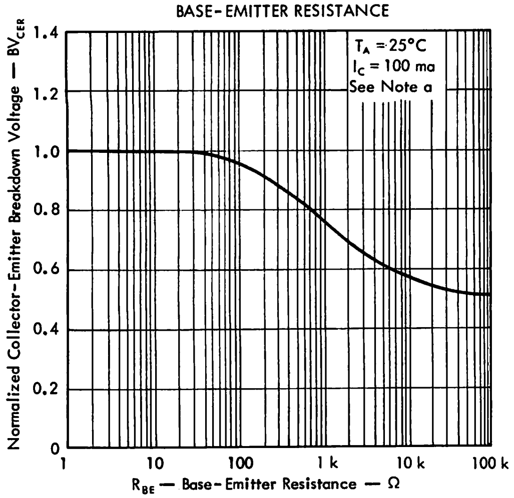
BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT



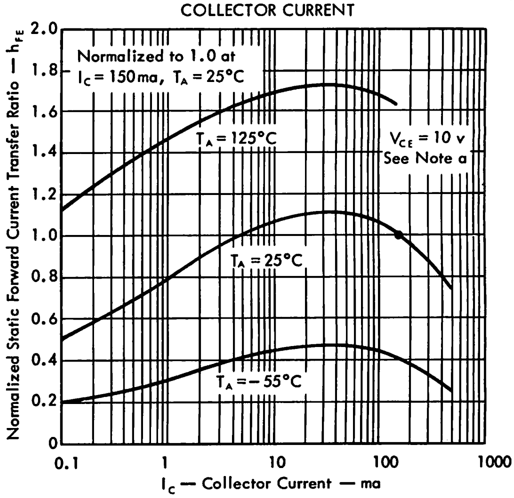
BASE-EMITTER VOLTAGE vs FREE-AIR TEMPERATURE



NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE



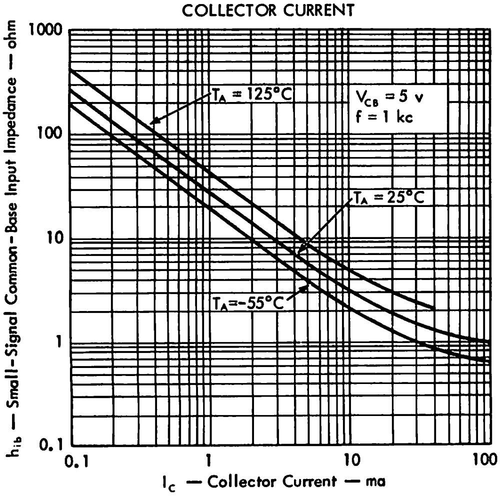
NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT



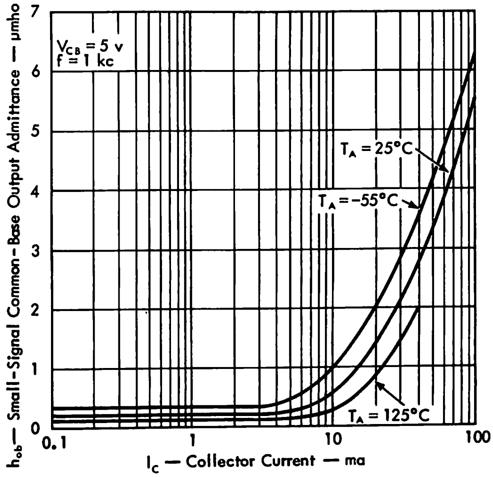
NOTE a: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

TYPICAL CHARACTERISTICS

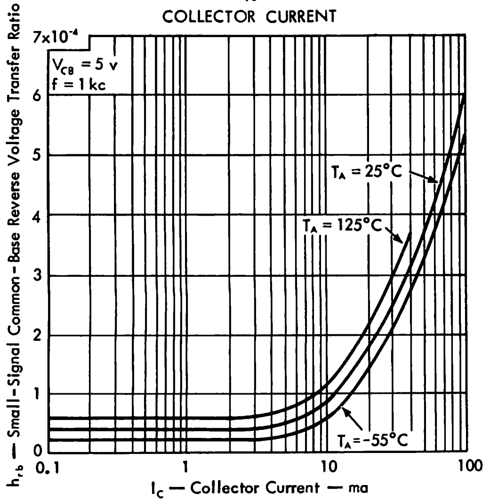
SMALL-SIGNAL COMMON-BASE INPUT IMPEDANCE
vs
COLLECTOR CURRENT



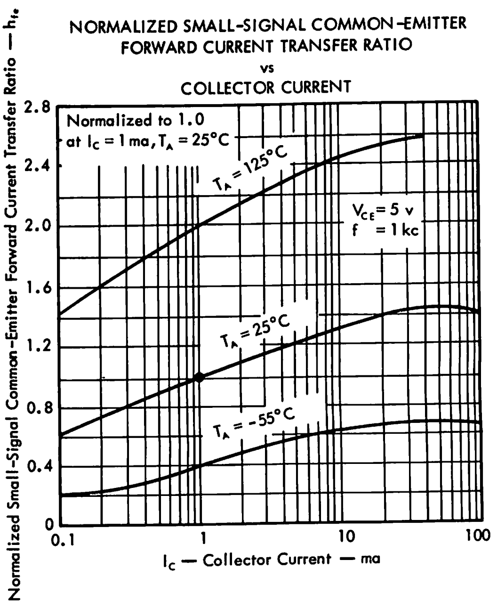
SMALL-SIGNAL COMMON-BASE OUTPUT ADMITTANCE
vs
COLLECTOR CURRENT



SMALL-SIGNAL COMMON-BASE
REVERSE VOLTAGE TRANSFER RATIO
vs
COLLECTOR CURRENT



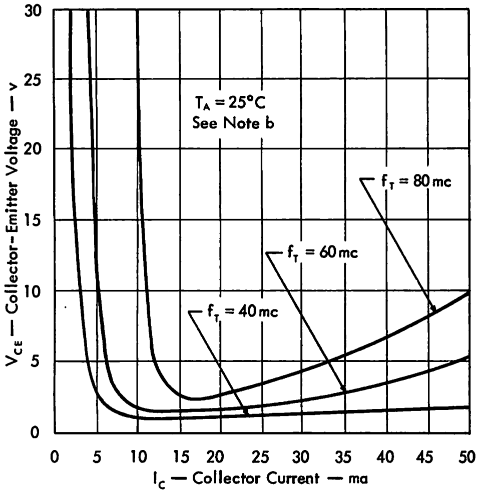
NORMALIZED SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



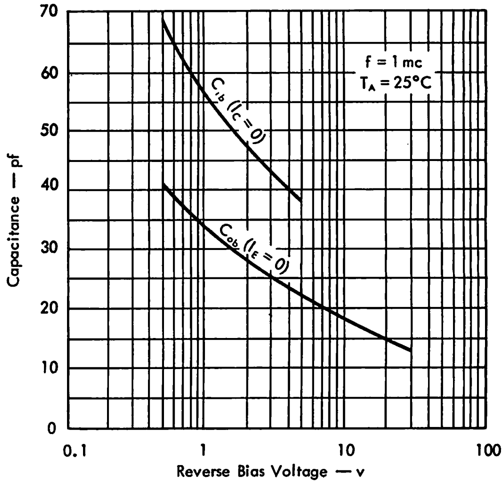
TYPES 2N696, 2N697, 2N717, 2N718, 2N718A, 2N730, 2N731, 2N956, 2N1420, 2N1507, 2N1613, 2N1711
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

CONTOURS OF CONSTANT TRANSITION FREQUENCY, f_T



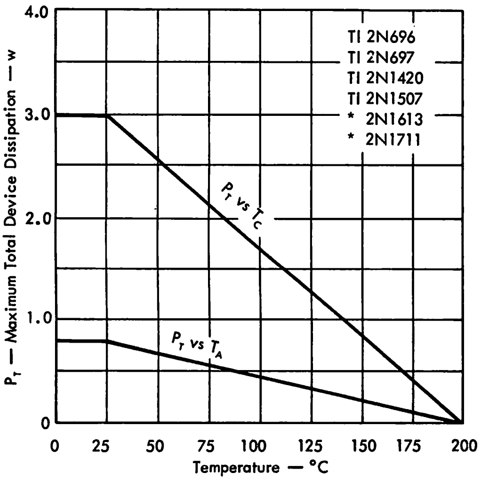
COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE



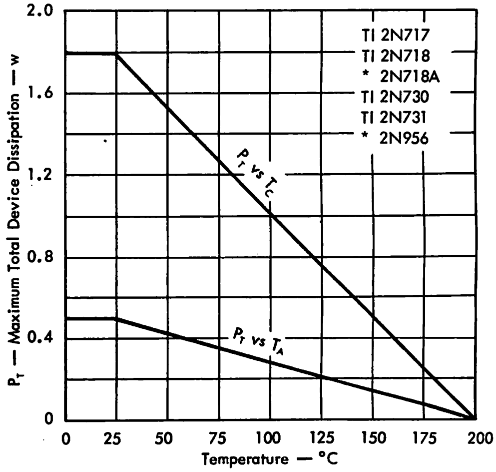
NOTE b: To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at the rate of −6 db per octave from f = 20 mc to the frequency at which $|h_{fe}| = 1$.

THERMAL CHARACTERISTICS

DISSIPATION DERATING CURVES FOR TO-5 TYPES



DISSIPATION DERATING CURVES FOR TO-18 TYPES



*Indicates JEDEC registered data

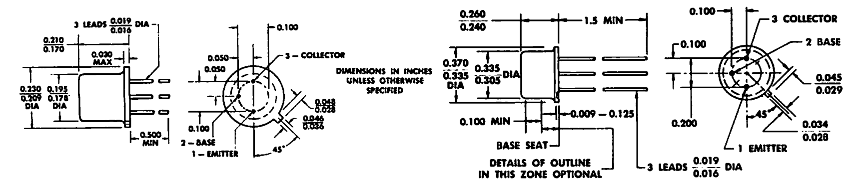
TYPES 2N698, 2N699, 2N719, 2N719A, 2N720 2N720A, 2N870, 2N871, 2N1889, 2N1890, 2N1893 N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

Highly Reliable, Versatile Devices Designed for Amplifier, Switching and Oscillator Applications from <0.1 ma to >150 ma, dc to 30 mc

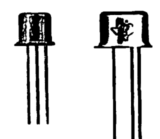
- **High Voltage** • **Low Leakage**
- **Useful h_{FE} Over Wide Current Range**

*mechanical data

Device types 2N719, 2N719A, 2N720, 2N720A, 2N870 and 2N871 are in JEDEC TO-18 packages.
Device types 2N698, 2N699, 2N1889, 2N1890, and 2N1893 are in JEDEC TO-5 packages.



TO-18 THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE TO-5



TO-18 TO-5

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N698	2N699	2N719 2N720	2N719A	2N720A	2N870 2N871	2N1889 2N1890	2N1893	UNIT
Collector-Base Voltage	120	120	120	120	120	100	100	120	v
Collector-Emitter Voltage (See Note 1)	80	80	80	80	100	80	80	100	v
Collector-Emitter Voltage (See Note 2)	60			60	80	60	60	80	v
Emitter-Base Voltage	7	5	5	7	7	7	7	7	v
Collector Current				1.0				0.5	a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note Indicated in Parentheses) →	0.8 (3)	0.6 † (5)	0.4 †† (7)	0.5 (9)	0.5 (9)	0.5 (9)	0.8 (3)	0.8 (3)	w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note Indicated in Parentheses) →	3.0 (4)	2.0 † (6)	1.5 †† (8)	1.8 (10)	1.8 (10)	1.8 (10)	3.0 (4)	3.0 (4)	w
Total Device Dissipation at 100°C Case Temperature	1.7	1.0 †	0.75 ††	1.0	1.0	1.0	1.7	1.7	w
Operating Collector Junction Temperature	200	175†	175††	200	200	200	200	200	°C
Storage Temperature Range	—65°C to 200°C								

NOTES: 1. This values applies when the base-emitter resistance (R_{BE}) is equal to or less than 10 ohms.
2. This values applies when the base-emitter diode is open-circuited.
3. Derate linearly to 200°C free-air temperature at the rate of 4.56 mw/C°.
4. Derate linearly to 200°C case temperature at the rate of 17.2 mw/C°.
5. Derate linearly to 175°C free-air temperature at the rate of 4.0 mw/C°.
6. Derate linearly to 175°C case temperature at the rate of 13.3 mw/C°.
7. Derate linearly to 175°C free-air temperature at the rate of 2.67 mw/C°.
8. Derate linearly to 175°C case temperature at the rate of 10.0 mw/C°.
9. Derate linearly to 200°C free-air temperature at the rate of 2.86 mw/C°.
10. Derate linearly to 200°C case temperature at the rate of 10.3 mw/C°.

*Indicates JEDEC registered data.

†Texas Instruments guarantees its type 2N699 to be capable of the same dissipation as registered and shown for types 2N698, 2N1889, 2N1890, and 2N1893 with appropriate derating factors shown in Notes 3 and 4. See derating curves, page 6.

††Texas Instruments guarantees its types 2N719 and 2N720 to be capable of the same dissipation as registered and shown for types 2N719A, 2N720A, 2N870, and 2N871 with appropriate derating factors shown in Notes 9 and 10. See derating curves, page 6.

TEXAS INSTRUMENTS
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TYPES 2N698, 2N699, 2N719, 2N719A, 2N720
2N720A, 2N870, 2N871, 2N1889, 2N1890, 2N1893
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	2N698 MIN	2N698 MAX	2N699 MIN	2N699 MAX	2N719 MIN	2N719 MAX	2N719A MIN	2N719A MAX	UNIT
		TO-18→					2N719		2N719A		
		TO-5→	2N698		2N699						
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	120				120		120		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 11	60						60		v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = 100$ ma, $R_{BE} = 10\ \Omega$, See Note 11	80		80		80		80		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	7						7		v
		$I_E = 1$ ma, $I_C = 0$					5				v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ v, $I_E = 0$				2		2			μa
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$						200			μa
		$V_{CB} = 75$ v, $I_E = 0$		0.005						0.010	μa
		$V_{CB} = 75$ v, $I_E = 0$, $T_A = 150°C$		15						15	μa
		$V_{CB} = 90$ v, $I_E = 0$									μa
		$V_{CB} = 90$ v, $I_E = 0$, $T_A = 150°C$									μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 2$ v, $I_C = 0$				100					μa
		$V_{EB} = 5$ v, $I_C = 0$		0.010						0.010	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\ \mu a$									
		$V_{CE} = 10$ v, $I_C = 10$ ma, See Note 11									
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$, See Note 11									
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 11	20	60	40	120	20	60	20	60	
V_{BE}	Base-Emitter Voltage	$I_B = 5$ ma, $I_C = 50$ ma, See Note 11		0.9						0.9	v
		$I_B = 15$ ma, $I_C = 150$ ma, See Note 11		1.3		1.3		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ ma, $I_C = 50$ ma, See Note 11		1.2						1.2	v
		$I_B = 15$ ma, $I_C = 150$ ma, See Note 11		5		5		5		5	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	20	35	20	30	20	35	20	35	ohm
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		10		10		10		10	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc		2.5×10^{-4}		2.5×10^{-4}		2.5×10^{-4}		2.5×10^{-4}	
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		5×10^{-4}		3×10^{-4}		5×10^{-4}		5×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc		0.5	0.1	0.5	0.1	0.5	0.1	0.5	μmho
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		1.0		1.0		1.0		1.0	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	15		35	100	15		15		
		$V_{CE} = 10$ v, $I_C = 5$ ma, $f = 1$ kc	25		45		25		25		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, $f = 20$ mc	2.0		2.5		2.0		2.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ mc; Except 2N719: $f = 140$ kc		15		20		20		15	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, $f = 1$ mc; Except 2N719: $f = 140$ kc		85				85		85	pf

NOTE 11: These parameters must be measured using pulse techniques. PW $\leq 300\ \mu$sec., Duty cycle $\leq 2\%$. Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.

*Indicates JEDEC registered data.

TYPES 2N698, 2N699, 2N719, 2N719A, 2N720
2N720A, 2N870, 2N871, 2N1889, 2N1890, 2N1893
N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS (TO-18 → / TO-5 →)	2N720 MIN	2N720 MAX	2N720A / 2N1893 MIN	2N720A / 2N1893 MAX	2N870 / 2N1889 MIN	2N870 / 2N1889 MAX	2N871 / 2N1890 MIN	2N871 / 2N1890 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	120		120		100		100		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 11			80		60		60		v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = 100$ ma, $R_{BE} = 10\ \Omega$, See Note 11	80		100		80		80		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$			7		7		7		v
		$I_E = 1$ ma, $I_C = 0$	5								v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ v, $I_E = 0$		2							μa
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$		200							μa
		$V_{CB} = 75$ v, $I_E = 0$						0.010		0.010	μa
		$V_{CB} = 75$ v, $I_E = 0$, $T_A = 150°C$						15		15	μa
		$V_{CB} = 90$ v, $I_E = 0$				0.010					μa
		$V_{CB} = 90$ v, $I_E = 0$, $T_A = 150°C$				15					μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 2$ v, $I_C = 0$									μa
		$V_{EB} = 5$ v, $I_C = 0$				0.010		0.010		0.010	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\ \mu a$			20		20				
		$V_{CE} = 10$ v, $I_C = 10$ ma, See Note 11			35		35				
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$, See Note 11			20		20				
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 11	40	120	40	120	40	120	100	300	
V_{BE}	Base-Emitter Voltage	$I_B = 5$ ma, $I_C = 50$ ma, See Note 11				0.9		0.9		0.9	v
		$I_B = 15$ ma, $I_C = 150$ ma, See Note 11		1.3		1.3		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ ma, $I_C = 50$ ma, See Note 11				1.2		1.2		1.2	v
		$I_B = 15$ ma, $I_C = 150$ ma, See Note 11		5		5		5		5	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	20	30	20	30	20	30	20	30	ohm
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		10	4	8	4	8	4	8	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc		2.5×10^{-4}		1.25×10^{-4}		1.25×10^{-4}		1.5×10^{-4}	
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		3×10^{-4}		1.5×10^{-4}		1.5×10^{-4}		1.5×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	0.1	0.5		0.5		0.5		0.3	μmho
		$V_{CB} = 10$ v, $I_C = 5$ ma, $f = 1$ kc		1.0		0.5		0.5		0.3	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	35	100	30	100	30	100	50	200	
		$V_{CE} = 10$ v, $I_C = 5$ ma, $f = 1$ kc	45		45		45	150	70	300	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, $f = 20$ mc	2.5		2.5		2.5		3.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ mc; Except 2N720: $f = 140$ kc		20		15		15		15	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, $f = 1$ mc; Except 2N720: $f = 140$ kc		85		85		85		85	pf

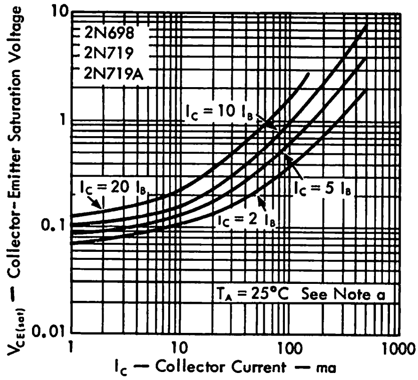
NOTE 11: These parameters must be measured using pulse techniques. PW $\leq 300\ \mu$sec., Duty cycle $\leq 2\%$. Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.

*Indicates JEDEC registered data.

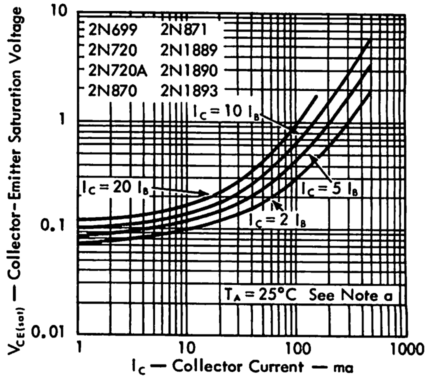
TYPES 2N698, 2N699, 2N719, 2N719A, 2N720 2N720A, 2N870, 2N871, 2N1889, 2N1890, 2N1893 N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

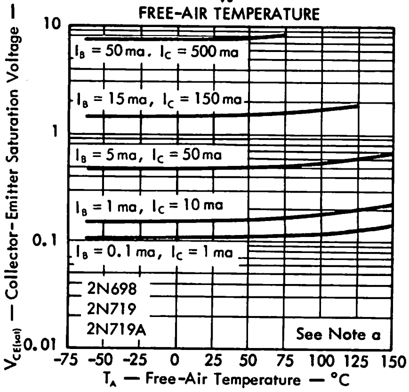
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT



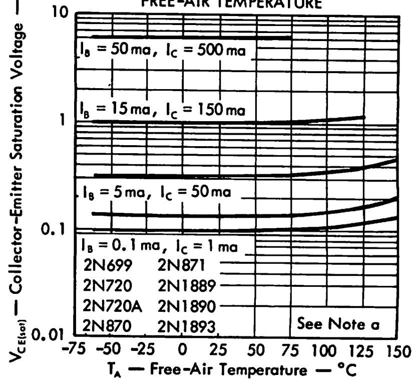
COLLECTOR-EMITTER SAUTRATION VOLTAGE
vs
COLLECTOR CURRENT



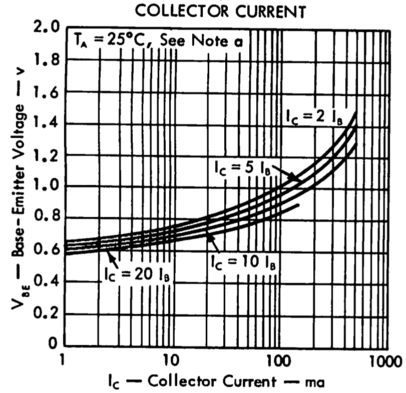
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



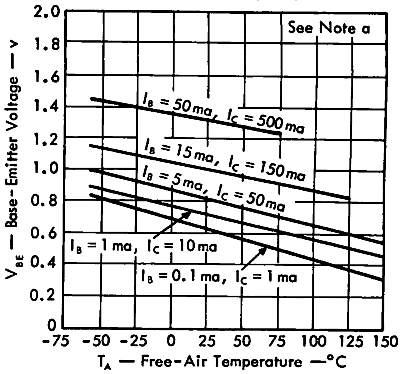
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT



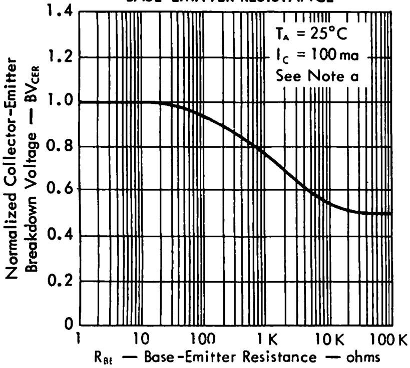
BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE



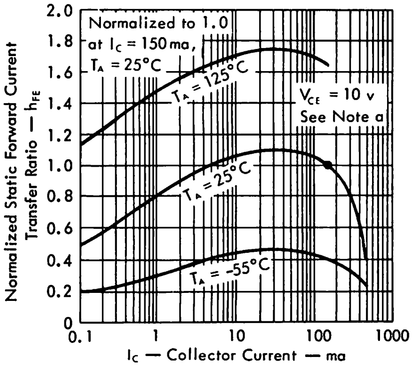
NOTE a: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle 2%.

TYPICAL CHARACTERISTICS

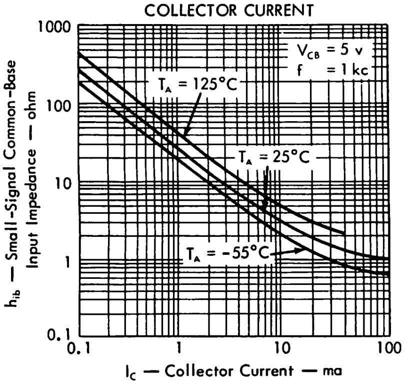
NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE



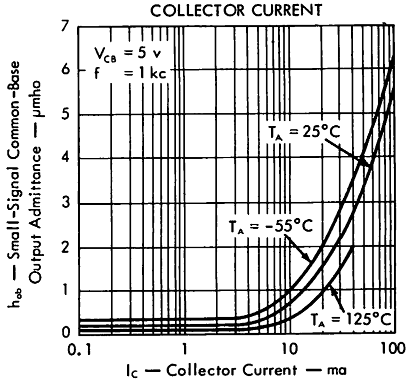
NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



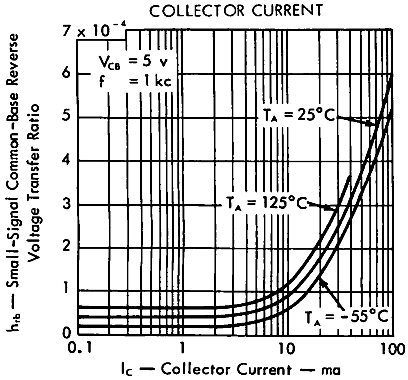
SMALL-SIGNAL COMMON-BASE INPUT IMPEDANCE
vs
COLLECTOR CURRENT



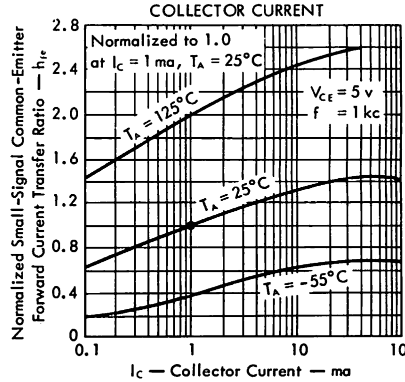
SMALL-SIGNAL COMMON-BASE OUTPUT ADMITTANCE
vs
COLLECTOR CURRENT



SMALL-SIGNAL COMMON-BASE REVERSE
VOLTAGE TRANSFER RATIO
vs
COLLECTOR CURRENT



NORMALIZED SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

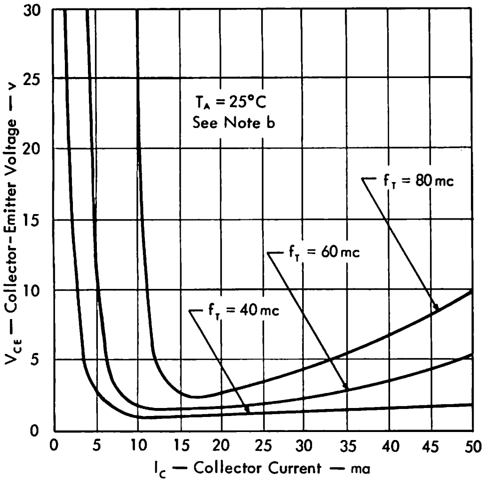


NOTE a: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

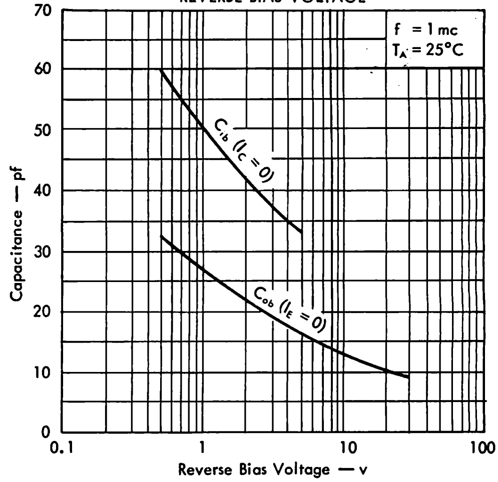
TYPES 2N698, 2N699, 2N719, 2N719A, 2N720 2N720A, 2N870, 2N871, 2N1889, 2N1890, 2N1893 N-P-N DOUBLE-DIFFUSED PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

CONTOURS OF CONSTANT TRANSITION FREQUENCY, f_T



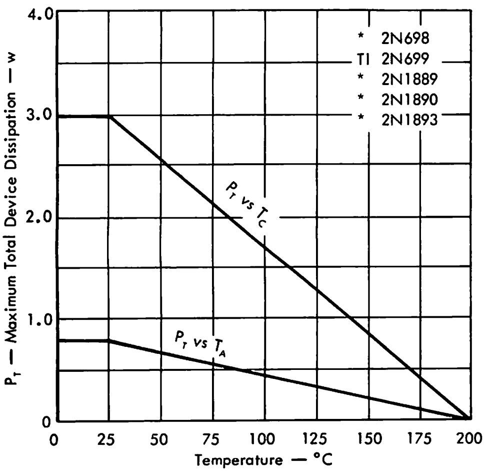
COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE



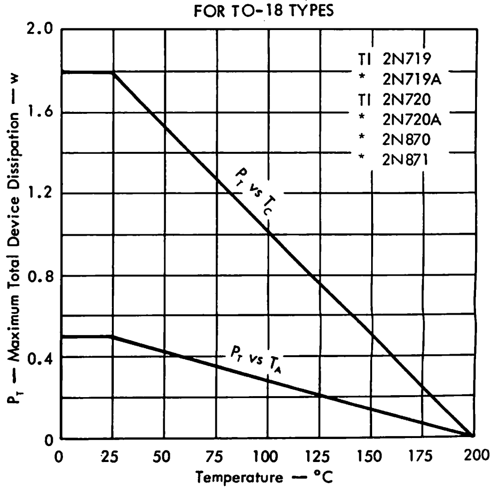
NOTE b: To obtain f_T, the h_{fe} response with frequency is extrapolated at the rate of −6 db per octave from f = 20 mc to the frequency at which $|h_{fe}| = 1$.

THERMAL CHARACTERISTICS

DISSIPATION DERATING CURVES FOR TO-5 TYPES



DISSIPATION DERATING CURVES FOR TO-18 TYPES



*Indicates JEDEC registered data.

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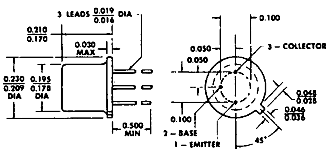
TEXAS INSTRUMENTS RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME IN ORDER TO IMPROVE DESIGN AND TO SUPPLY THE BEST PRODUCT POSSIBLE.

TYPES 2N929, 2N930
BULLETIN NO. DL-S-633553 MAY 1963
REVISED SEPTEMBER 1965

FOR EXTREMELY LOW-LEVEL, LOW-NOISE, HIGH-GAIN, SMALL-SIGNAL AMPLIFIER APPLICATIONS

- **Guaranteed h_{FE} at 10 μa, $T_A = -55°C$ and 25°C**
- **Guaranteed Low-Noise Characteristics at 10 μa**
- **Usable at Collector Currents as Low as 1 μa**
- **Very High Reliability**
- **2N929 and 2N930 Also Are Available to MIL-S-19500/253 (Sig C)**

*mechanical data



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	45 v
Collector-Emitter Voltage (See Note 1)	45 v
Emitter-Base Voltage	5 v
Collector Current	30 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	300 mw
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	600 mw
Operating Collector Junction Temperature	175°C
Storage Temperature Range	−65°C to +200°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 2.0 mw/C°.
3. Derate linearly to 175°C case temperature at the rate of 4.0 mw/C°.

*Indicates JEDEC registered data

TYPES 2N929, 2N930
N-P-N PLANAR SILICON TRANSISTOR

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	2N929 MIN	2N929 MAX	2N930 MIN	2N930 MAX	UNIT
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, (See Note 4)	45		45		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10$ na $I_C = 0$	5		5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 45$ v, $I_E = 0$		10		10	na
I_{CES}	Collector Cutoff Current (See Note 5)	$V_{CE} = 45$ v, $V_{BE} = 0$		10		10	na
		$V_{CE} = 45$ v, $V_{BE} = 0$, $T_A = 170°C$		10		10	μa
I_{CEO}	Collector Cutoff Current	$V_{CE} = 5$ v, $I_B = 0$		2		2	na
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		10		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu a$	40	120	100	300	
		$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_A = -55°C$	10		20		
		$V_{CE} = 5$ v, $I_C = 500\ \mu a$	60		150		
		$V_{CE} = 5$ v, $I_C = 10$ ma, (See Note 4)		350		600	
V_{BE}	Base-Emitter Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma, (See Note 4)	0.6	1.0	0.6	1.0	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma, (See Note 4)		1.0		1.0	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_E = -1$ ma, $f = 1$ kc	25	32	25	32	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_E = -1$ ma, $f = 1$ kc	0	6.0×10^{-4}	0	6.0×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_E = -1$ ma, $f = 1$ kc	0	1.0	0	1.0	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	60	350	150	600	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 500\ \mu a$, $f = 30$ mc	1.0		1.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, $f = 1$ mc		8		8	pf

***operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N929 MAX	2N930 MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $R_G = 10\ k\Omega$ Noise Bandwidth 10 cps to 15.7 kc	4	3	db

NOTES: 4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

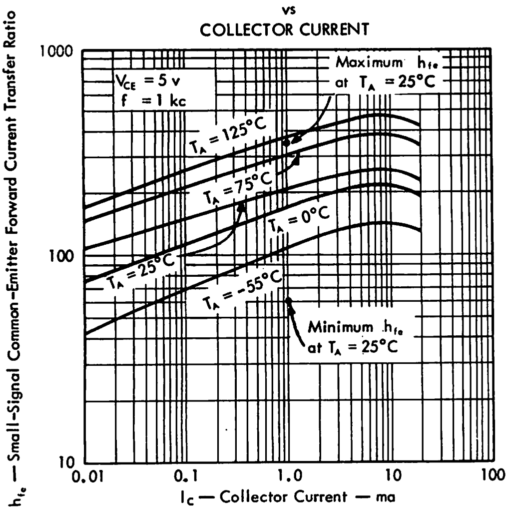
5. I_{CES} may be used in place of I_{CBO} for circuit stability calculations.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

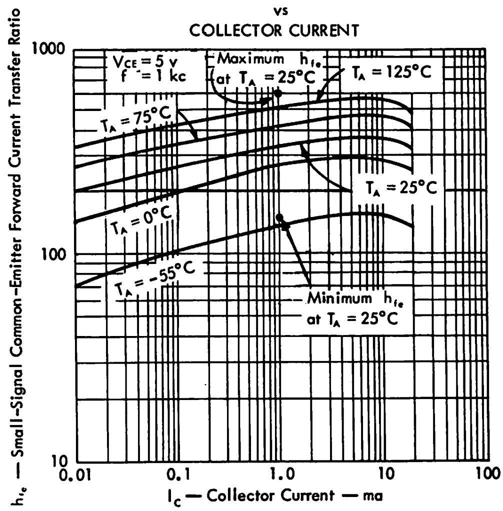
2N929

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



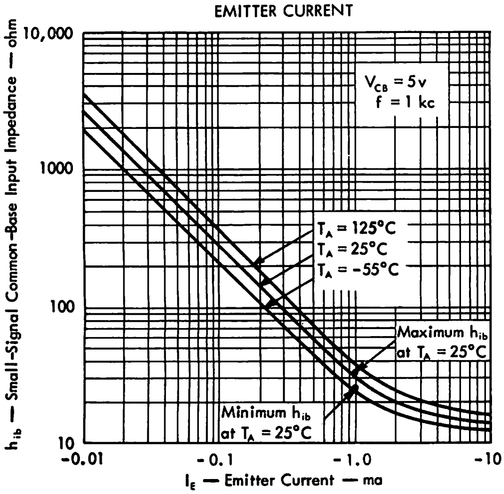
2N930

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



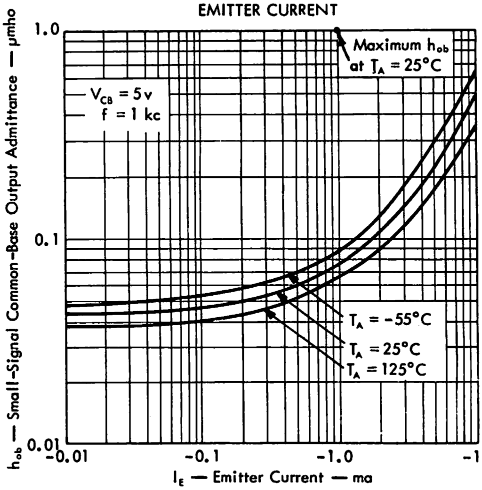
2N929 2N930

SMALL-SIGNAL COMMON-BASE INPUT IMPEDANCE
vs
EMITTER CURRENT



2N929 2N930

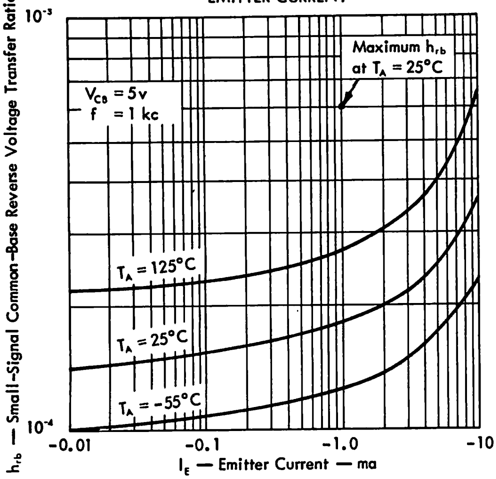
SMALL-SIGNAL COMMON-BASE OUTPUT ADMITTANCE
vs
EMITTER CURRENT



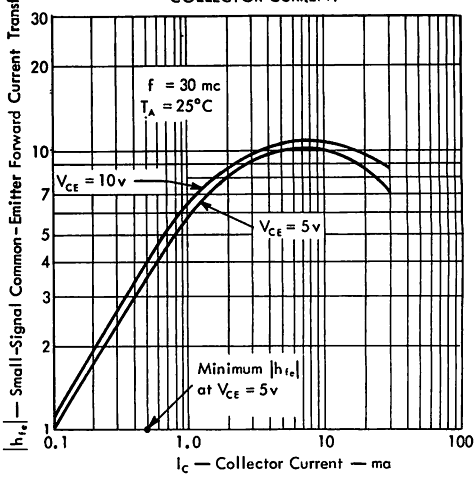
TYPES 2N929, 2N930
N-P-N PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

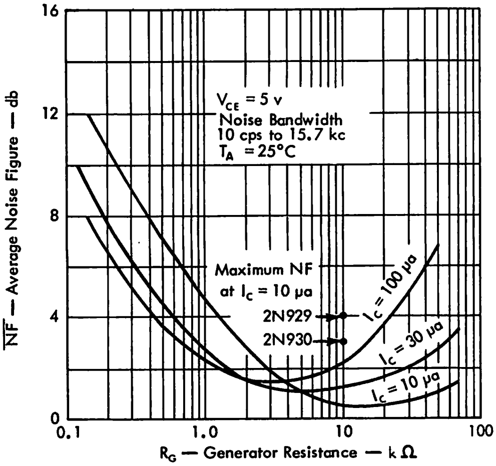
SMALL-SIGNAL COMMON-BASE REVERSE VOLTAGE TRANSFER RATIO
vs
EMITTER CURRENT



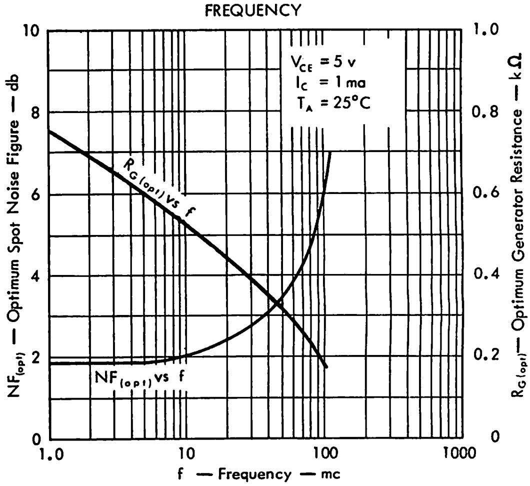
SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



AVERAGE NOISE FIGURE
vs
GENERATOR RESISTANCE



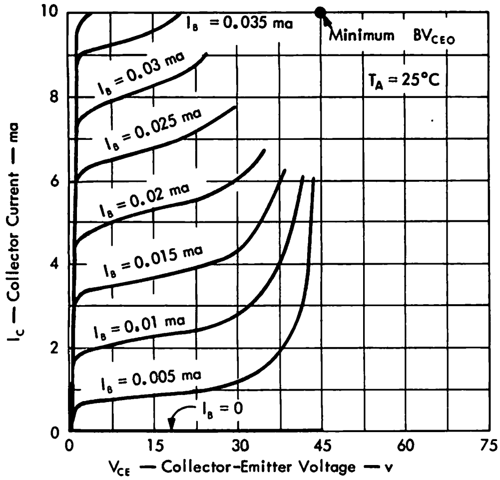
OPTIMUM SPOT NOISE FIGURE AND OPTIMUM GENERATOR RESISTANCE
vs
FREQUENCY



TYPICAL CHARACTERISTICS

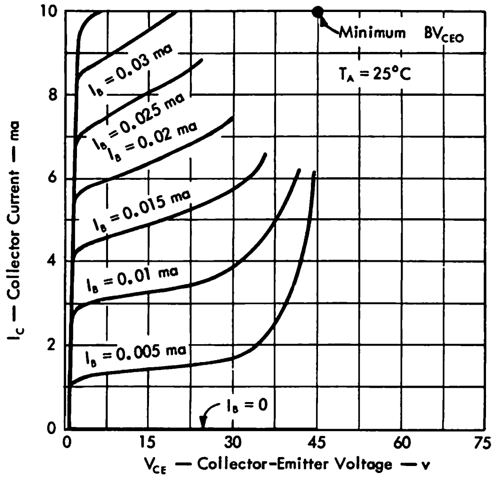
2N929

COMMON-EMITTER COLLECTOR CHARACTERISTICS



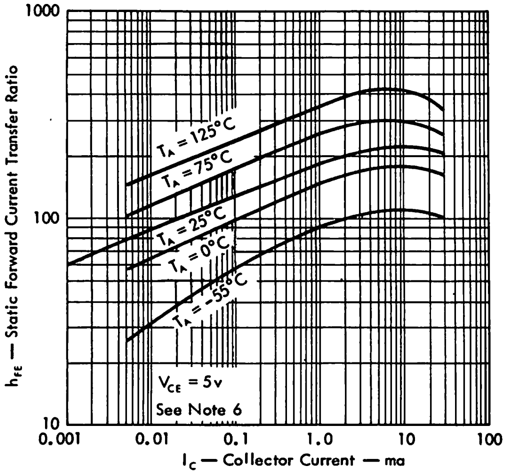
2N930

COMMON-EMITTER COLLECTOR CHARACTERISTICS



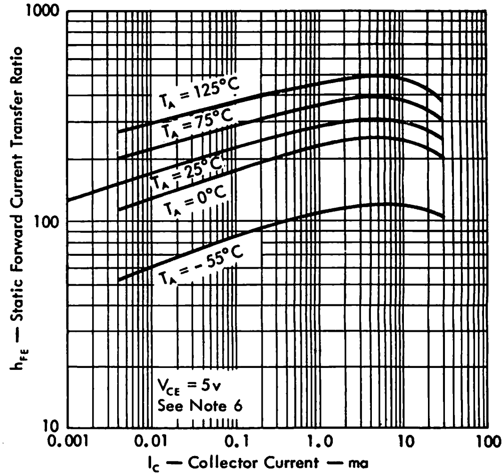
2N929

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



2N930

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

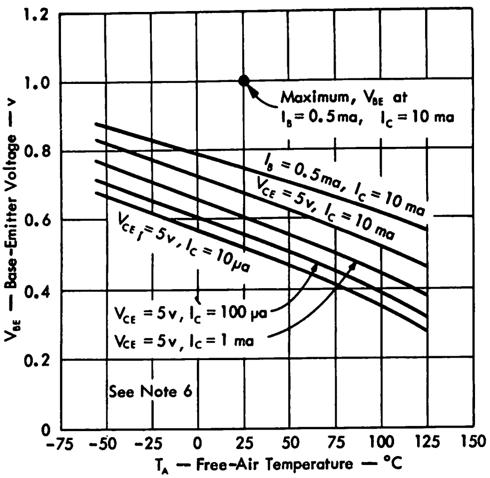


NOTE 6: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS

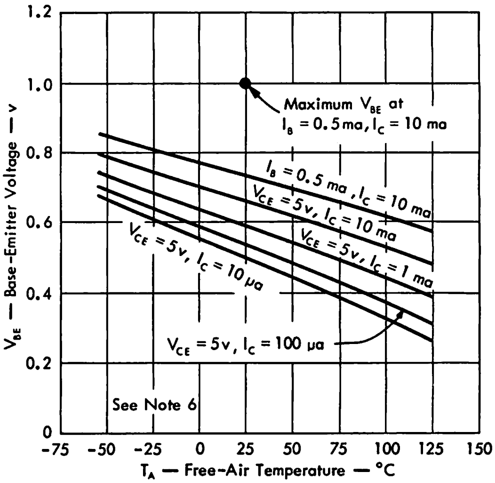
2N929

BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE



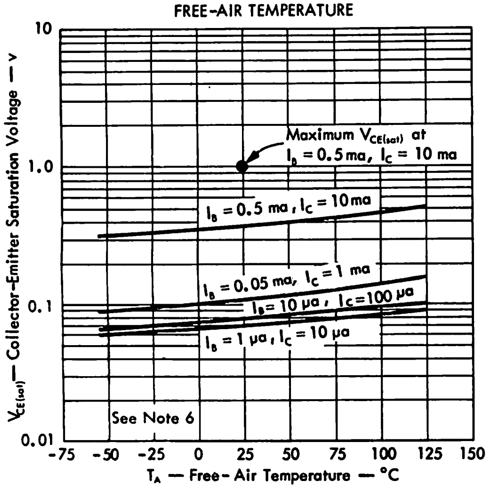
2N930

BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE



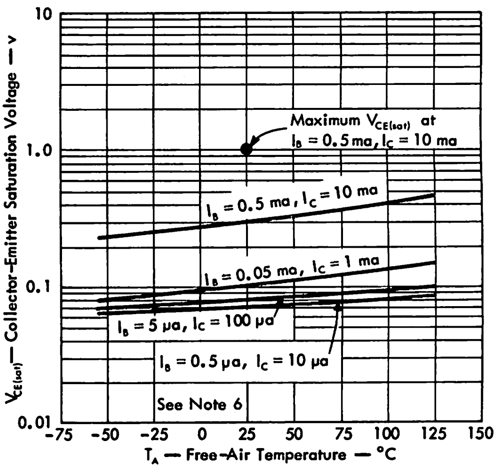
2N929

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



2N930

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



NOTE 6: These parameters were measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

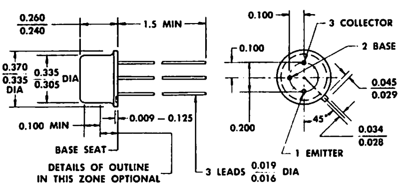
TYPES 2N2192, 2N2192A, 2N2193, 2N2193A, 2N2194, 2N2194A, 2N2243, 2N2243A N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N2192 THRU 2N2194, 2N2192A THRU 2N2194A, 2N2243, 2N2243A
BULLETIN NO. DL-S 683571, MARCH 1963
REVISED MAY 1968

FOR MEDIUM-POWER, HIGH-SPEED SWITCHING AND AMPLIFIER APPLICATIONS

- **High Breakdown Voltage Combined with Very Low Saturation Voltage**
- **h_{FE} — Guaranteed from 100 μa to 1 amp**

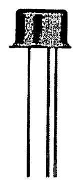
*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N2192 2N2192A	2N2193 2N2193A	2N2194 2N2194A	2N2243 2N2243A	UNIT
Collector-Base Voltage	60	80	60	120	v
Collector-Emitter Voltage (See Note 1)	40	50	40	80	v
Emitter-Base Voltage	5	8	5	7	v
Collector Current	1	1	1	1	a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.8	0.8	0.8	0.8	w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	2.8	2.8	2.8	2.8	w
Total Device Dissipation at 100°C Case Temperature	1.6	1.6	1.6	1.6	w
Operating Collector Junction Temperature Range	−65°C to 200°C				
Storage Temperature Range	−65°C to 200°C				
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C				

NOTES: 1. This value applies when the emitter-base diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 4.6 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 16 mw/C°.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
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TYPES 2N2192, 2N2192A, 2N2193, 2N2193A, 2N2194, 2N2194A, 2N2243, 2N2243A
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	2N2192 2N2192A		2N2193 2N2193A		2N2194 2N2194A		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\,\mu a, I_E = 0$	60		80		60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 25$ ma, $I_B = 0$, See Note 4	40		50		40		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\,\mu a$, $I_C = 0$	5		8		5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_E = 0$		10				10	na
		$V_{CB} = 30$ v, $I_E = 0$, $T_A = 150°C$		15				25	μa
		$V_{CB} = 60$ v, $I_E = 0$				10			na
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$				25			μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ v, $I_C = 0$		50				50	na
		$V_{EB} = 5$ v, $I_C = 0$				50			na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\,\mu a$	15		15				
		$V_{CE} = 10$ v, $I_C = 10$ ma	75		30		15		
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$	35		20				
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 4	100	300	40	120	20	60	
		$V_{CE} = 10$ v, $I_C = 500$ ma, See Note 4	35		20		12		
		$V_{CE} = 10$ v, $I_C = 1$ a, See Note 4	15		15				
		$V_{CE} = 1$ v, $I_C = 150$ ma, See Note 4	70		30		15		
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma		1.3		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma — 2N2192–2N2194		0.35		0.35		0.35	v
		$I_B = 15$ ma, $I_C = 150$ ma — 2N2192A–2N2194A		0.25		0.25		0.25	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, f = 20 mc	2.5		2.5		2.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 mc		20		20		20	pf

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N2192 2N2192A 2N2193 2N2193A 2N2194 2N2194A	UNIT
			MAX	
t_r	Rise Time	See Figure 1	70	nsec
t_s	Storage Time		150	nsec
t_f	Fall Time		50	nsec

NOTE 4: These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	2N2243 MIN	2N2243 MAX	2N2243A MIN	2N2243A MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	120		120		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 25$ ma, $I_B = 0$, See Note 4	80		80		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	7		7		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ v, $I_E = 0$		10		10	na
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$		15		15	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		50		50	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\ \mu a$	15		15		
		$V_{CE} = 10$ v, $I_C = 10$ ma	30		30		
		$V_{CE} = 10$ v, $I_C = 10$ ma, $T_A = -55°C$	20		20		
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 4	40	120	40	120	
		$V_{CE} = 10$ v, $I_C = 500$ ma, See Note 4	15		15		
		$V_{CE} = 1$ v, $I_C = 150$ ma, See Note 4	30		30		
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma		1.3		1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma		0.35		0.25	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, f = 20 mc	2.5		2.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 mc		15		15	pf

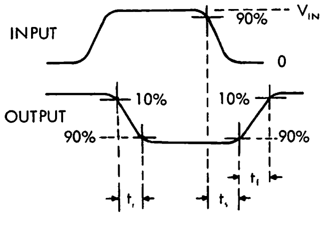
*switching characteristics at 25°C free-air temperature

	PARAMETER	TEST CONDITIONS	2N2243 2N2243A MAX	UNIT
τ_b	Stored-Charge Time Constant	See Figure 2	2.1	μsec

NOTE 4: These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

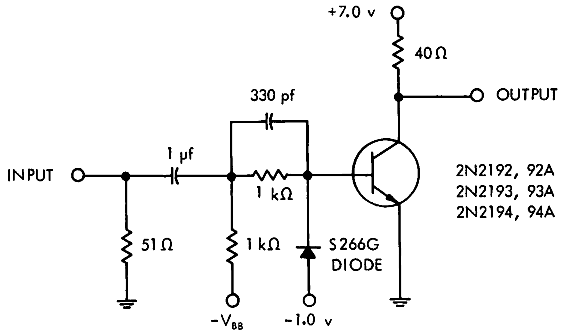
*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



See Notes a and b

VOLTAGE WAVEFORMS

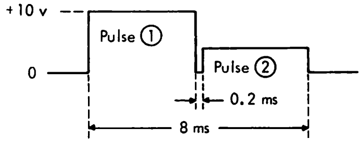


TEST CIRCUIT

CIRCUIT CONDITIONS

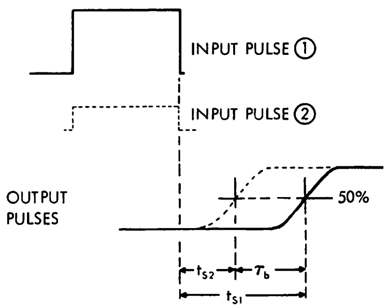
	2N2192, 92A	2N2193, 93A 2N2194, 94A
V_{IN}	7.5 v	15 v
V_{BB}	7.5 v	15 v

***FIGURE 1 — SWITCHING TIMES — t_r, t_f, t_s**

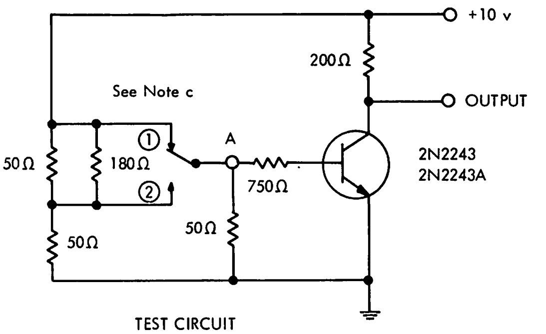


See Note c

INPUT PULSES AT POINT A



VOLTAGE WAVEFORMS



TEST CIRCUIT

***FIGURE 2 — STORED-CHARGE TIME CONSTANT — τ_b**

NOTES: a. The input waveform in Figure 1 is supplied by a generator with the following characteristics: t_r = 20 nsec, t_f = 20 nsec, Z_{out} = 50 Ω, PW = 10 μsec, PRR = 5 kc.

b. Waveforms in Figure 1 and Figure 2 are monitored on an oscilloscope with the following characteristics: $t_r \leq$ 14 nsec, R_{in} = 10 MΩ, C_{in} = 11.5 pf.

c. The relay in Figure 2 is Clare HG 1005 (or equivalent).

*Indicates JEDEC registered data

TYPES 2N2217, 2N2218, 2N2219, 2N2220, 2N2221, 2N2222
BULLETIN NO. DL-S 633544, MARCH 1963
REVISED OCTOBER 1965

DESIGNED FOR HIGH-SPEED, MEDIUM-POWER SWITCHING AND GENERAL PURPOSE AMPLIFIER APPLICATIONS

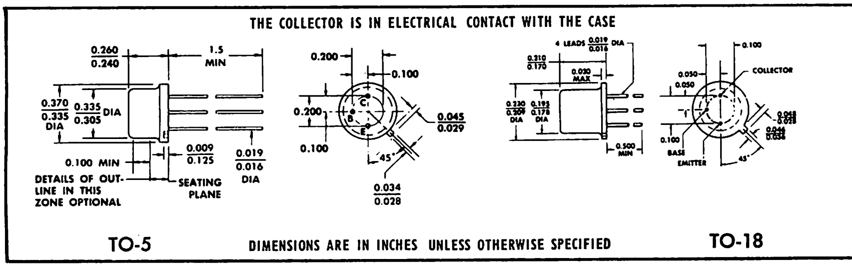
- **DC Beta — Guaranteed from 100μa to 500 ma**
- **High f_T — 250 mc min at 20v, 20 ma**

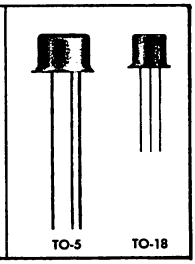
environmental tests

To ensure maximum integrity, stability, and long life, all finished transistors are subjected to sustained acceleration at a minimum of 35,000 G and verification of hermetic seal by helium leak testing.

*mechanical data

Device types 2N2217, 2N2218, and 2N2219 are in JEDEC TO-5 packages.
Device types 2N2220, 2N2221, and 2N2222 are in JEDEC TO-18 packages.





*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N2217 2N2218 2N2219	2N2220 2N2221 2N2222
Collector-Base Voltage	60 v	60 v
Collector-Emitter Voltage (See Note 1)	30 v	30 v
Emitter-Base Voltage	5 v	5 v
Collector Current	0.8 a	0.8 a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Notes 2 and 3)	0.8 w	0.5 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Notes 4 and 5)	3 w	1.8 w
Operating Collector Junction Temperature Range	−65°C to + 175°C	
Storage Temperature Range	−65°C to + 200°C	

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate 2N2217, 2N2218, and 2N2219 linearly to 175°C free-air temperature at the rate of 5.33 mw/C°.
3. Derate 2N2220, 2N2221, and 2N2222 linearly to 175°C free-air temperature at the rate of 3.33 mw/C°.
4. Derate 2N2217, 2N2218, and 2N2219 linearly to 175°C case temperature at the rate of 20.0 mw/C°.
5. Derate 2N2220, 2N2221, and 2N2222 linearly to 175°C case temperature at the rate of 12.0 mw/C°.

*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS (TO-5 →)	2N2217			2N2218			2N2219			UNIT
		(TO-18 →)	2N2220			2N2221			2N2222			
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10\ \mu a,\ I_E = 0$	60			60			60			v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$	30			30			30			v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a,\ I_C = 0$	5			5			5			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 50$ v, $I_E = 0$			10			10			10	na
		$V_{CB} = 50$ v, $I_E = 0$, $T_A = 150°C$			10			10			10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ v, $I_C = 0$			10			10			10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\ \mu a$				20			35			
		$V_{CE} = 10$ v, $I_C = 1$ ma	12			25			50			
		$V_{CE} = 10$ v, $I_C = 10$ ma	17			35			75			
		$V_{CE} = 10$ v, $I_C = 150$ ma, (See Note 6)	20		60	40		120	100		300	
		$V_{CE} = 10$ v, $I_C = 500$ ma, (See Note 6)				20			30			
		$V_{CE} = 1$ v, $I_C = 150$ ma, (See Note 6)	10			20			50			
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma, (See Note 6)		0.9	1.3		0.9	1.3		0.9	1.3	v
		$I_B = 50$ ma, $I_C = 500$ ma, (See Note 6)		1.2			1.2	2.6		1.2	2.6	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma, (See Note 6)		0.2	0.4		0.2	0.4		0.2	0.4	v
		$I_B = 50$ ma, $I_C = 500$ ma, (See Note 6)		0.5			0.4	1.6		0.4	1.6	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 20$ v, $I_C = 20$ ma, f = 100 mc	2.5	2.8		2.5	3.0		2.5	3.5		
f_T	Transition Frequency	$V_{CE} = 20$ v, $I_C = 20$ ma, (See Note 7)	250	280		250	300		250	350		mc
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 mc		5	8		5	8		5	8	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, f = 1 mc		23			23			23		pf
$Re(h_{ie})$	Real Part of Small-Signal Common-Emitter Input Impedance	$V_{CE} = 20$ v, $I_C = 20$ ma, f = 300 mc		15	60		15	60		15	60	ohm

NOTES: 6. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

7. To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at the rate of −6db per octave from f = 100 mc to the frequency at which $|h_{fe}| = 1$.

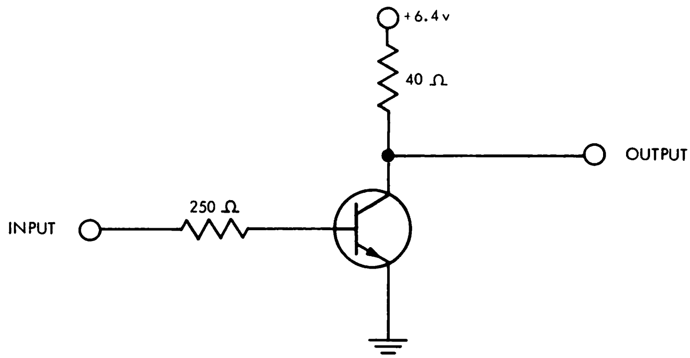
*Indicates JEDEC registered data (typical data excluded)

switching characteristics at 25°C free-air temperature

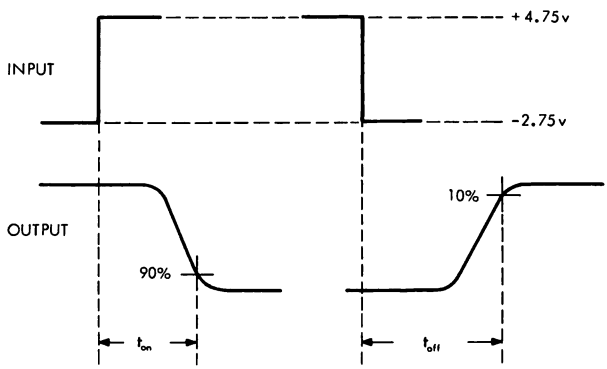
PARAMETER		TEST CONDITIONS††	TO-5 → 2N2217 / TO-18 → 2N2220	2N2218 / 2N2221	2N2219 / 2N2222	UNIT
			TYPICAL			
t_{on}	Turn-On Time	$I_C = 150$ ma, $I_{B(1)} = 15$ ma, $I_{B(2)} = -15$ ma	25	25	25	nsec
t_{off}	Turn-Off Time	$V_{BE(off)} = -2.75$ v, $R_L = 40\ \Omega$, (See Figure 1)	150	175	200	nsec
t_T	Total Switching Time	See Figure 2	9	9	9	nsec

††Voltage and current values shown are nominal; exact values vary slightly with device parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS (See Notes a and b)

FIGURE 1 - SATURATED SWITCHING CIRCUIT FOR TURN-ON AND TURN-OFF TIMES

NOTES: a. The input waveforms in Figure 1 have the following characteristics: $t_r \leq 1$ nsec, PW ≥ 300 nsec.

b. All waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 4$ nsec, $R_{in} \geq 100$ KΩ, $C_{in} \leq 12$ pf.

PARAMETER MEASUREMENT INFORMATION

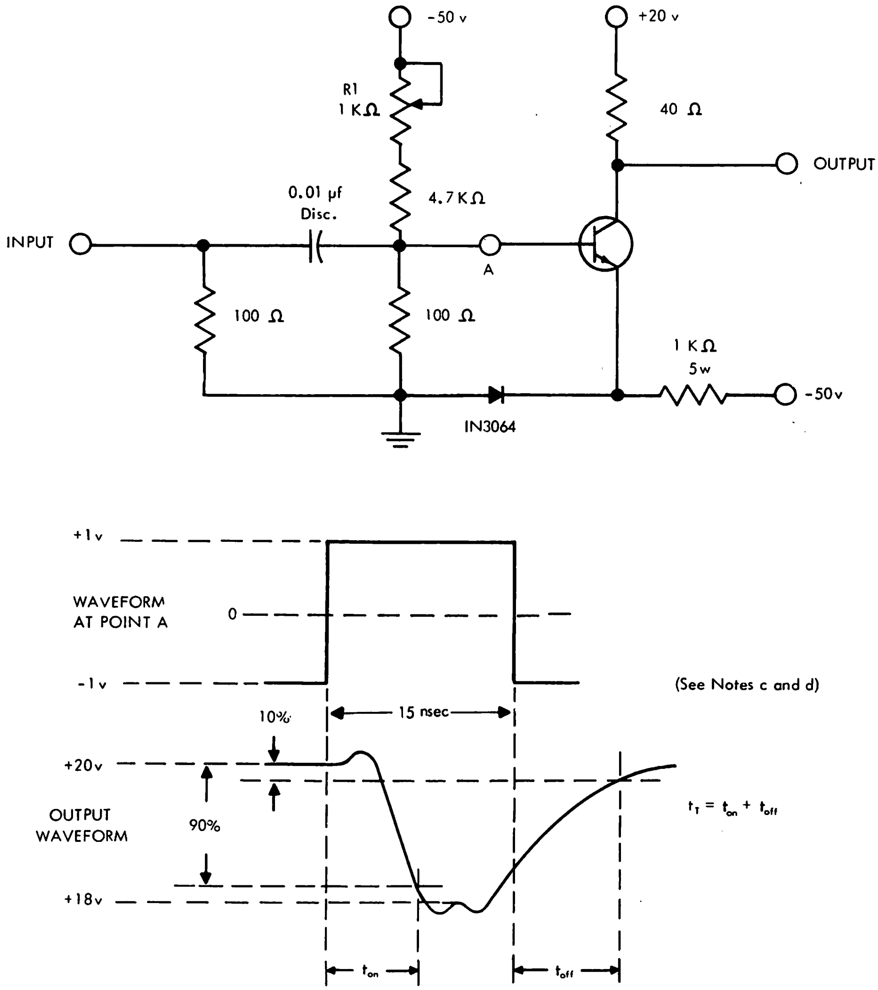


FIGURE 2. NON-SATURATED SWITCHING TIME MEASUREMENT CIRCUIT

NOTES: c. The input waveform is supplied by a mercury relay pulse generator with the following characteristics: $t_r \leq 1$ nsec, $t_f \leq 1$ nsec, PW = 15 nsec. Adjust R1 and the input pulse amplitude to obtain the specified voltage levels at Point A.

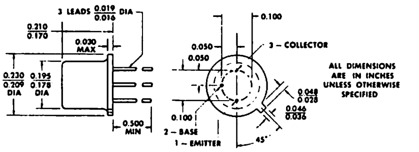
d. Waveforms are monitored on a sampling oscilloscope ($t_r \leq 0.8$ nsec) using a 2000Ω probe.

TYPE 2N2369A
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N2369A
BULLETIN NO. DL-S 658082, SEPTEMBER 1965
REPLACES BULLETIN NO. DL-S 645609 JUNE 1964

DESIGNED FOR VERY-HIGH-SPEED SWITCHING APPLICATIONS

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	40 v
Collector-Emitter Voltage (See Note 1)	40 v
Collector-Emitter Voltage (See Note 2)	15 v
Emitter-Base Voltage	4.5 v
Continuous Collector Current	200 ma
Peak Collector Current (See Note 3)	500 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	0.36 w
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 5)	1.2 w
Continuous Device Dissipation at 100°C Case Temperature	0.68 w
Operating Collector Junction Temperature	200°C
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 60 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu a$, $I_E = 0$	40		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 6	15		v
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = 10\ \mu a$, $V_{BE} = 0$	40		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	4.5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20$ v, $I_E = 0$, $T_A = 150°C$		30	μa
I_{CES}	Collector Cutoff Current	$V_{CE} = 20$ v, $V_{BE} = 0$		0.4	μa
I_B	Base Current	$V_{CE} = 20$ v, $V_{BE} = 0$		−0.4	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 0.35$ v, $I_C = 10$ ma, See Note 6	40		
		$V_{CE} = 1$ v, $I_C = 10$ ma, See Note 6		120	
		$V_{CE} = 0.4$ v, $I_C = 30$ ma, See Note 6	30		
		$V_{CE} = 1$ v, $I_C = 100$ ma, See Note 6	20		
		$V_{CE} = 0.35$ v, $I_C = 10$ ma, $T_A = -55°C$, See Note 6	20		
V_{BE}	Base-Emitter Voltage	$I_B = 1$ ma, $I_C = 10$ ma	0.7	0.85	v
		$I_B = 3$ ma, $I_C = 30$ ma		1.15	v
		$I_B = 10$ ma, $I_C = 100$ ma		1.6	v
		$I_B = 1$ ma, $I_C = 10$ ma, $T_A = 125°C$	0.59		v
		$I_B = 1$ ma, $I_C = 10$ ma, $T_A = -55°C$		1.02	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ ma, $I_C = 10$ ma,		0.2	v
		$I_B = 3$ ma, $I_C = 30$ ma,		0.25	v
		$I_B = 10$ ma, $I_C = 100$ ma,		0.5	v
		$I_B = 1$ ma, $I_C = 10$ ma, $T_A = 125°C$		0.3	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 20$ ma, f = 100 Mc	5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 140 kc		4	pf

NOTES: 1. This value applies when the base-emitter diode is short-circuited.
2. This value applies between 10 μa and 10 ma collector current when the base-emitter diode is open-circuited.
3. This value applies for PW $\leq$ 10 μsec.
4. Derate linearly to 200°C free-air temperature at the rate of 2.06 mw/C°.
5. Derate linearly to 200°C case temperature at the rate of 6.85 mw/C°.
6. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

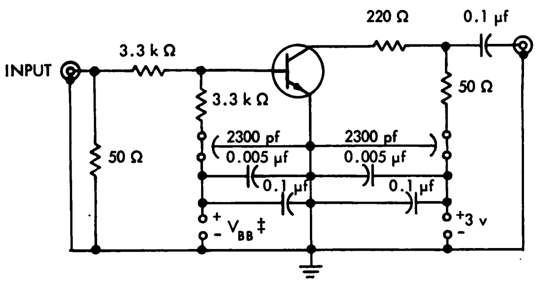
*Indicates JEDEC registered data

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†			MAX	UNIT
t_{on}	Turn-On Time	$I_C = 10$ ma,	$I_{B(1)} = 3$ ma,	$I_{B(2)} = -1.5$ ma,	12	nsec
t_{off}	Turn-Off Time	$V_{BE(off)} = -1.5$ v,	$R_L = 250\ \Omega$,	See Figure 1	18	nsec
t_s	Storage Time	$I_C = I_{B(1)} = 10$ ma,	$I_{B(2)} = -10$ ma,	See Figure 2	13	nsec

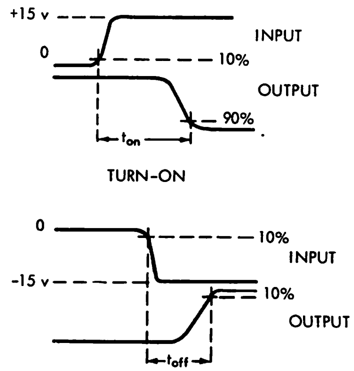
†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



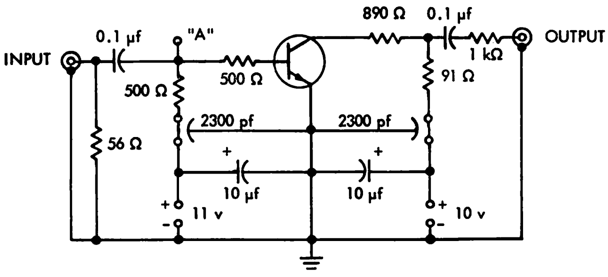
‡ V_{BB} = -3 v for t_{on}, +12 v for t_{off}.

TEST CIRCUIT

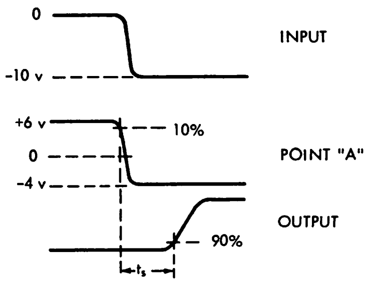


VOLTAGE WAVEFORMS

FIGURE 1 — TURN-ON AND TURN-OFF TIMES



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 2 — STORAGE TIME

NOTES: a. The input waveforms are supplied by a pulse generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, PW > 300 nsec. Duty Cycle $\leq 2\%$.

b. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $Z_{in} = 50\ \Omega$.

*Indicates JEDEC registered data

TYPES 2N2432, 2N2432A, 2N4138
BULLETIN NO. DL-S 669079, OCTOBER 1966, REVISED JANUARY 1968
REPLACES BULLETINS NO. DL-S 622467, MARCH 1962
AND DL-S 668381, MARCH 1966

FOR LOW-LEVEL, HIGH-SPEED CHOPPER APPLICATIONS IN INVERTED CONNECTION

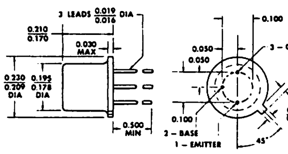
- Low Offset Voltage . . . 0.4 mV Max (2N2432A)
- Low I_{ECS} . . . 2 nA Max
- High Rated V_{ECO} for Inverted Connection

ALSO USEFUL FOR LOW-LEVEL AMPLIFIER APPLICATIONS

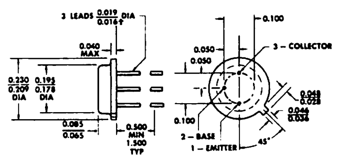
- h_{FE} . . . 30 Min at 10 μA

*mechanical data

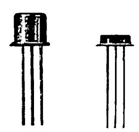
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



2N2432 AND 2N2432A
ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.



2N4138
ALL JEDEC TO-46 DIMENSIONS AND NOTES ARE APPLICABLE.



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

†TI guaranteed minimum. The JEDEC registered minimum lead diameter for the TO-46 is 0.012.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N2432 2N4138	2N2432A
Collector-Base Voltage	30 V	45 V
Collector-Emitter Voltage (See Note 1)	30 V	45 V
Emitter-Collector Voltage (See Note 2)	15 V	18 V
Emitter-Base Voltage	15 V	18 V
Continuous Collector Current	← 100 mA →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 300 mW →	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 4)	← 600 mW →	
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 300°C →	

NOTES: 1. This value applies between 0 and 10 mA collector current when the emitter-base diode is open-circuited.
2. This value applies between 0 and 100 μA emitter current when the collector-base diode is open-circuited.
3. Derate linearly to 175°C free-air temperature at the rate of 2 mW/deg.
4. Derate linearly to 175°C case temperature at the rate of 4 mW/deg.

*Indicates JEDEC registered data.

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*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2432 2N4138 MIN	2N2432 2N4138 MAX	2N2432A MIN	2N2432A MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A, I_E = 0$	30		45		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 5	30		45		V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A, I_B = 0$	15		18		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 25$ V, $I_E = 0$		10			nA
		$V_{CB} = 40$ V, $I_E = 0$				10	nA
I_{CES}	Collector Cutoff Current	$V_{CE} = 25$ V, $V_{BE} = 0$		10			nA
		$V_{CE} = 25$ V, $V_{BE} = 0$, $T_A = 125°C$		250			nA
		$V_{CE} = 40$ V, $V_{BE} = 0$				10	nA
		$V_{CE} = 40$ V, $V_{BE} = 0$, $T_A = 125°C$				250	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 15$ V, $I_C = 0$		2		2	nA
I_{ECS}	Emitter Cutoff Current	$V_{EC} = 15$ V, $V_{BC} = 0$		2		2	nA
		$V_{EC} = 15$ V, $V_{BC} = 0$, $T_A = 125°C$		200		200	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 10\ \mu A$	30		30		
		$V_{CE} = 5$ V, $I_C = 1$ mA	50		50		
$h_{FE(inv)}$	Static Forward Current Transfer Ratio (Inverted Connection)	$V_{EC} = 5$ V, $I_E = 0.2$ mA	2		3		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ mA, $I_C = 10$ mA		0.15		0.15	V
$V_{EC(ofs)}$	Offset Voltage (Inverted Connection)	$I_B = 200\ \mu A$, $I_E = 0$, See Figure 1		0.5		0.4	mV
		$I_B = 1$ mA, $I_E = 0$, See Figure 1		1		0.7	mV
$r_{ec(on)}$	Small-Signal Emitter-Collector On-State Resistance	$I_B = 1$ mA, $I_E = 0$, $I_e = 100\ \mu A$, f = 1 kHz, See Figure 2		20		15	Ω
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ mA, f = 20 MHz	1		1		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 0$, $I_E = 0$, f = 140 kHz		12		12	pF
C_{cb}	Collector-Base Capacitance	$V_{CB} = 0$, $I_E = 0$, f = 1 MHz, See Note 6		12		12	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0$, $I_C = 0$, f = 140 kHz		12		12	pF
C_{eb}	Emitter-Base Capacitance	$V_{EB} = 0$, $I_C = 0$, f = 1 MHz, See Note 6		12		12	pF

NOTES: 5. This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. C_{cb} and C_{eb} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded.

PARAMETER MEASUREMENT INFORMATION

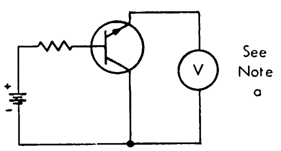
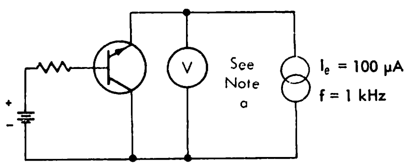


FIGURE 1

MEASUREMENT CIRCUIT FOR OFFSET VOLTAGE



$$r_{ec(on)} = \frac{V_{ec}}{I_e}$$

FIGURE 2

MEASUREMENT CIRCUIT FOR EMITTER-COLLECTOR ON-STATE RESISTANCE

NOTE a: The voltmeter must have high enough impedance that halving the value of the voltmeter impedance does not change the measured value.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

2N2432, 2N4138

EMITTER-COLLECTOR VOLTAGE vs BASE CURRENT

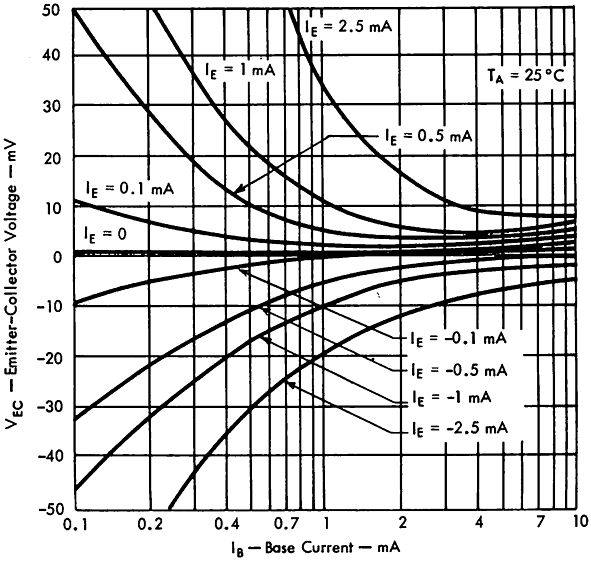


FIGURE 3

2N2432A

EMITTER-COLLECTOR VOLTAGE vs BASE CURRENT

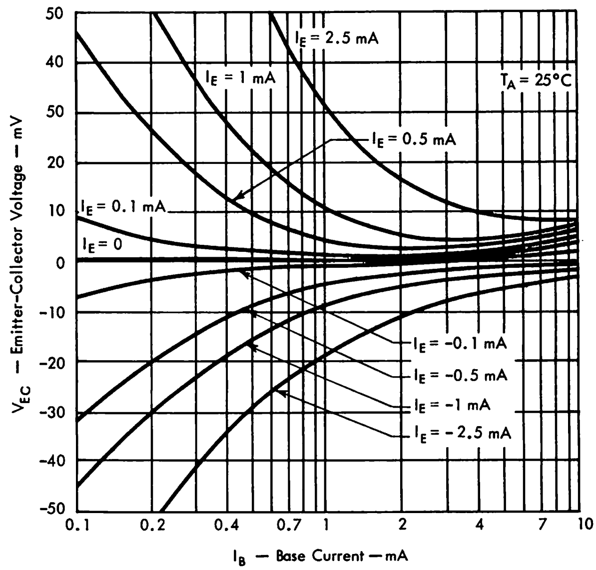


FIGURE 4

TYPICAL CHARACTERISTICS

2N2432, 2N4138
EMITTER-COLLECTOR OFFSET VOLTAGE
vs
BASE CURRENT

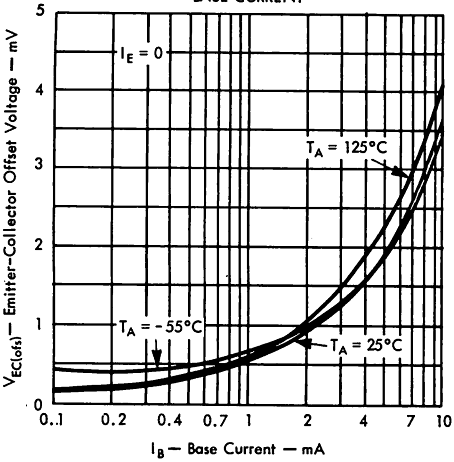


FIGURE 5

2N2432A
EMITTER-COLLECTOR OFFSET VOLTAGE
vs
BASE CURRENT

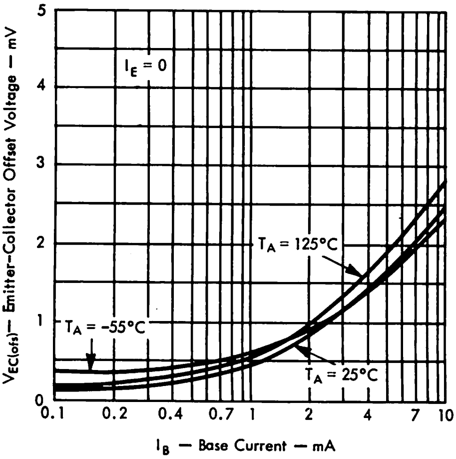


FIGURE 6

2N2432A
COLLECTOR-EMITTER CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

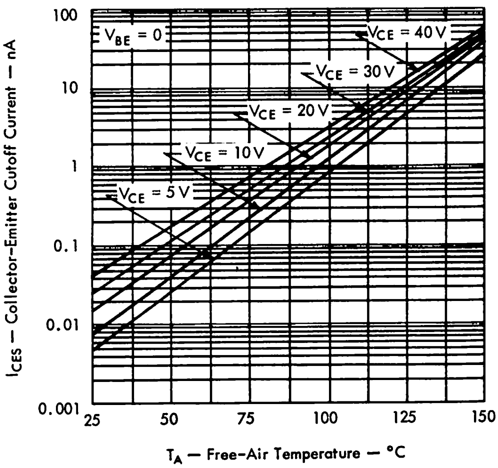


FIGURE 7

2N2432, 2N2432A, 2N4138
EMITTER-COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

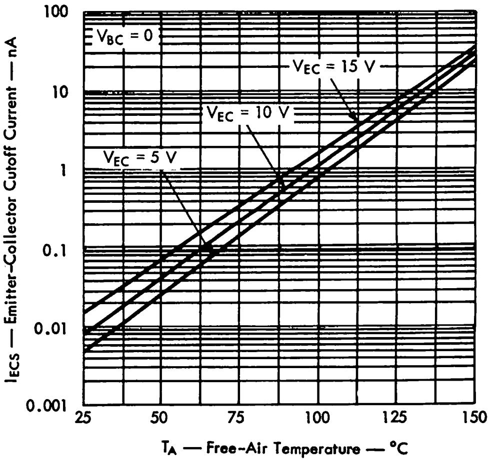


FIGURE 8

TYPICAL CHARACTERISTICS

2N2432, 2N2432A, 2N4138
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

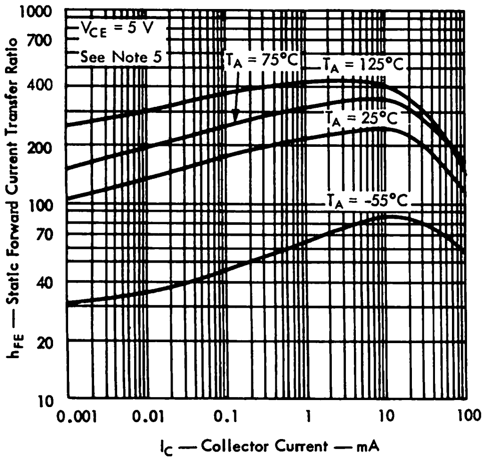


FIGURE 9

2N2432, 2N2432A, 2N4138
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

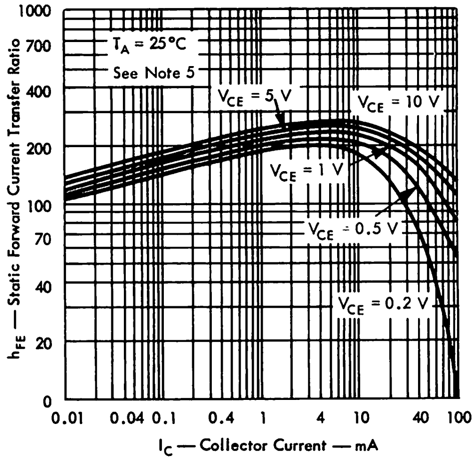


FIGURE 10

2N2432, 2N4138
STATIC FORWARD CURRENT TRANSFER RATIO
(INVERTED CONNECTION)
vs
EMITTER CURRENT

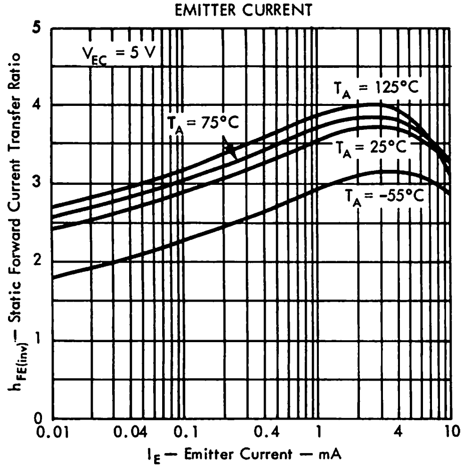


FIGURE 11

2N2432A
STATIC FORWARD CURRENT TRANSFER RATIO
(INVERTED CONNECTION)
vs
EMITTER CURRENT

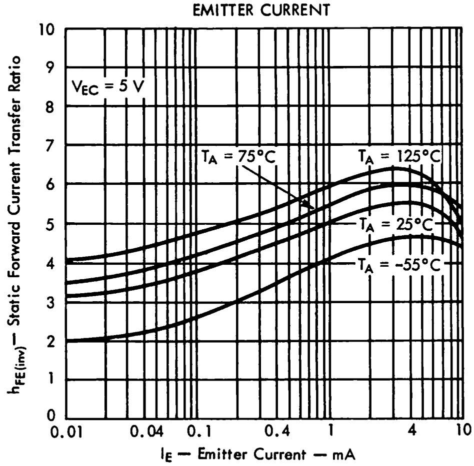


FIGURE 12

NOTE 5: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS

2N2432, 2N2432A, 2N4138

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

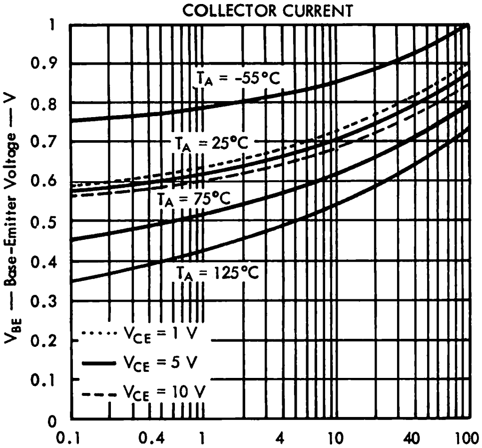


FIGURE 13

2N2432, 2N2432A, 2N4138

BASE-COLLECTOR VOLTAGE
vs
EMITTER CURRENT

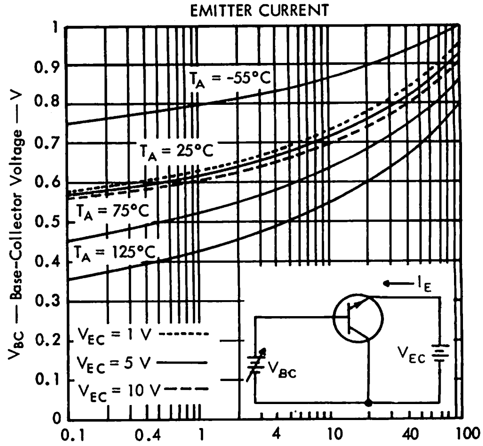


FIGURE 14

2N2432A

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

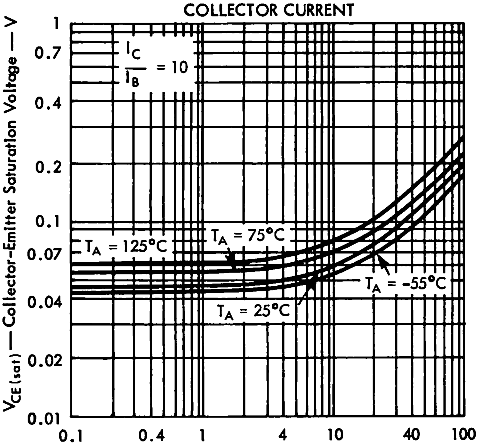


FIGURE 15

2N2432A

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

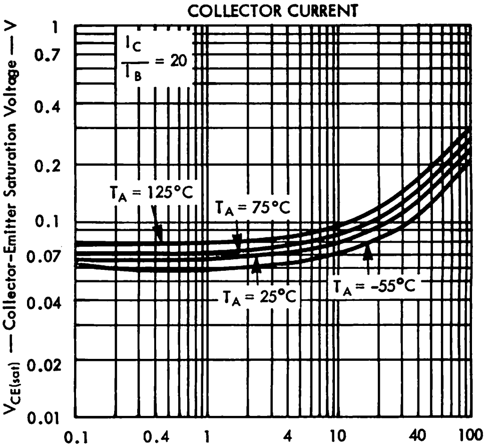


FIGURE 16

TYPICAL CHARACTERISTICS

2N2432, 2N4138

SMALL-SIGNAL EMITTER-COLLECTOR ON-STATE RESISTANCE vs BASE CURRENT

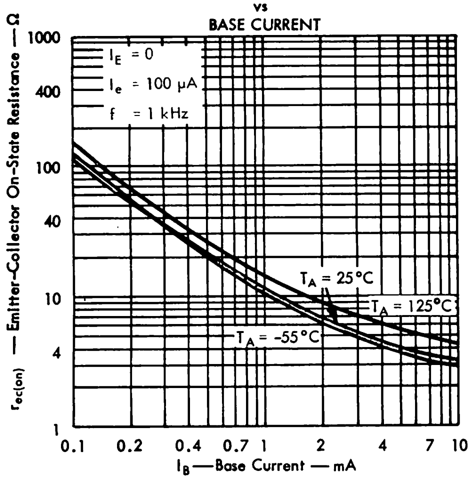


FIGURE 17

2N2432A

SMALL-SIGNAL EMITTER-COLLECTOR ON-STATE RESISTANCE vs BASE CURRENT

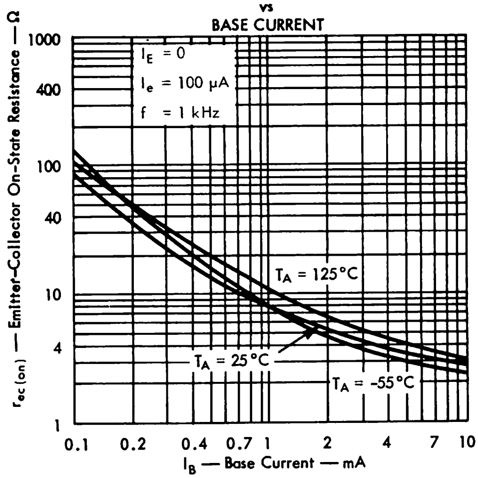


FIGURE 18

2N2432, 2N2432A, 2N4138

EMITTER-BASE CAPACITANCE vs EMITTER-BASE VOLTAGE

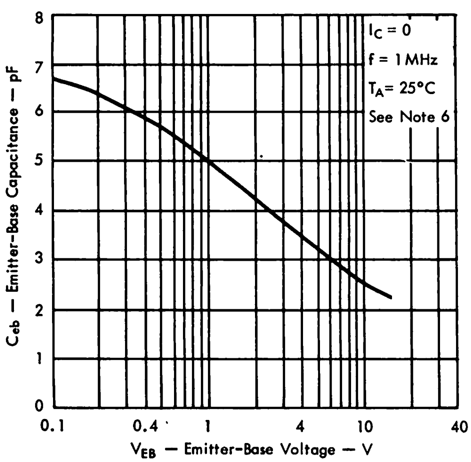


FIGURE 19

2N2432, 2N2432A, 2N4138

COLLECTOR BASE CAPACITANCE vs COLLECTOR-BASE VOLTAGE

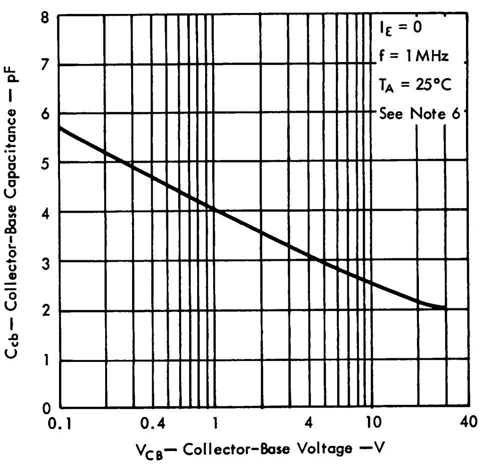


FIGURE 20

NOTE 6: C_{cb} and C_{eb} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded.

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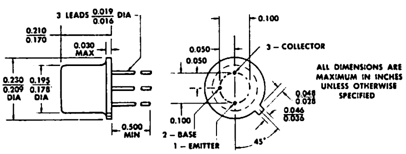
TYPES 2N2483, 2N2484
BULLETIN NO. DL-S 6710300, SEPTEMBER 1967
REPLACES BULLETIN NO. DL-S 645729. REVISED OCTOBER 1965

FOR LOW-LEVEL, LOW-NOISE, HIGH-GAIN, AMPLIFIER APPLICATIONS

- **Guaranteed Low-Noise Characteristics at 100 Hz, 1 kHz, and 10 kHz**
- **High $V_{(BR)CEO}$ . . . 60 V Min**
- **D-C Beta Guaranteed at $I_C = 1\ \mu A$ (2N2484)**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 V
Collector-Emitter Voltage (See Note 1)	60 V
Emitter-Base Voltage	6 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.36 W
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	1.2 W
Continuous Device Dissipation at 100°C Case Temperature	0.68 W
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.06 mW/deg.
3. Derate linearly to 200°C case temperature at the rate of 6.85 mW/deg.

*Indicates JEDEC registered data

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TYPES 2N2483, 2N2484
N-P-N PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2483 MIN	2N2483 MAX	2N2484 MIN	2N2484 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 10 μA, I_E = 0	60		60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 10 mA, I_B = 0, See Note 4	60		60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 μA, I_C = 0	6		6		V
I_{CBO}	Collector Cutoff Current	V_{CB} = 45 V, I_E = 0		10		10	nA
		V_{CB} = 45 V, I_E = 0, T_A = 150°C		10		10	μA
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		10		10	nA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 μA			30		
		V_{CE} = 5 V, I_C = 10 μA	40	120	100	500	
		V_{CE} = 5 V, I_C = 10 μA, T_A = −55°C	10		20		
		V_{CE} = 5 V, I_C = 100 μA	75		175		
		V_{CE} = 5 V, I_C = 500 μA	100		200		
		V_{CE} = 5 V, I_C = 1 mA	175		250		
		V_{CE} = 5 V, I_C = 10 mA, See Note 4		500		800	
V_{BE}	Base-Emitter Voltage	V_{CE} = 5 V, I_C = 100 μA	0.5	0.7	0.5	0.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 100 μA, I_C = 1 mA		0.35		0.35	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	V_{CE} = 5 V, I_C = 1 mA, f = 1 kHz	1.5	13	3.5	24	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio		80	450	150	900	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio			8×10^{-4}		8×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance			30		40	μmho
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 50 μA, f = 5 MHz	2.4		3		
		V_{CE} = 5 V, I_C = 500 μA, f = 30 MHz	2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 5 V, I_E = 0, f = 140 kHz		6		6	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	V_{EB} = 0.5 V, I_C = 0, f = 140 kHz		6		6	pF

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N2483 MAX	2N2484 MAX	UNIT
$\overline{NF}$	Average Noise Figure	V_{CE} = 5 V, I_C = 10 μA, R_G = 10 kΩ, Noise Bandwidth = 15.7 kHz, See Note 5	4	3	dB
NF	Spot Noise Figure	V_{CE} = 5 V, I_C = 10 μA, R_G = 10 kΩ, f = 100 Hz, Noise Bandwidth = 20 Hz	15	10	dB
		V_{CE} = 5 V, I_C = 10 μA, R_G = 10 kΩ, f = 1 kHz, Noise Bandwidth = 200 Hz	4	3	dB
		V_{CE} = 5 V, I_C = 10 μA, R_G = 10 kΩ, f = 10 kHz, Noise Bandwidth = 2 kHz	3	2	dB

NOTES: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 1%.

5. Average Noise Figure is measured in an amplifier with response down 3 dB at 10 Hz and 10 kHz and a high-frequency rolloff at 6 dB/octave.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

2N2483 2N2484
COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

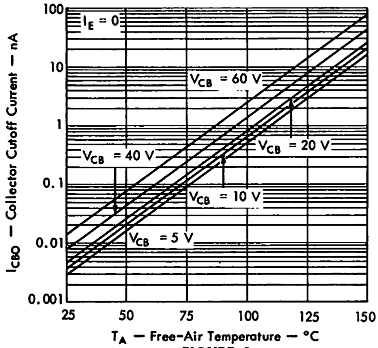


FIGURE 1

2N2484
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

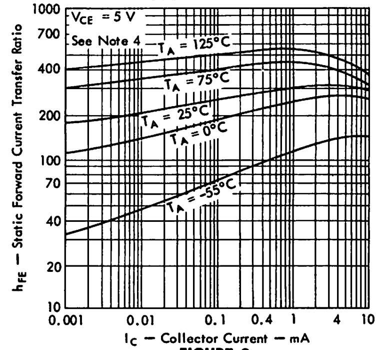


FIGURE 2

2N2484
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

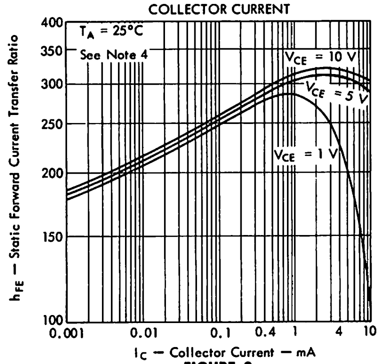


FIGURE 3

2N2483, 2N2484
BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE

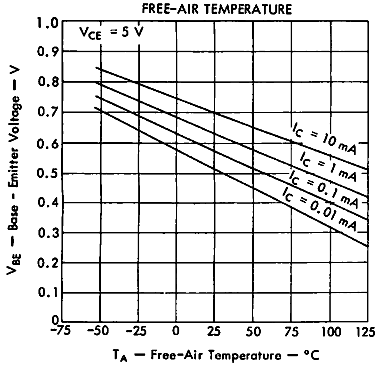


FIGURE 4

2N2483, 2N2484
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE

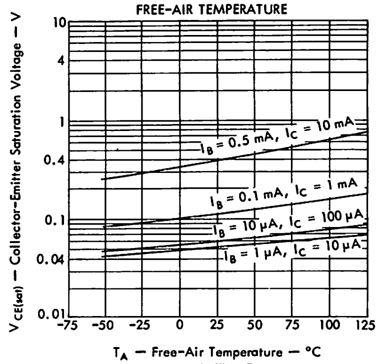


FIGURE 5

TYPICAL CHARACTERISTICS

2N2484

SMALL-SIGNAL COMMON-EMITTER
INPUT IMPEDANCE
vs
COLLECTOR CURRENT

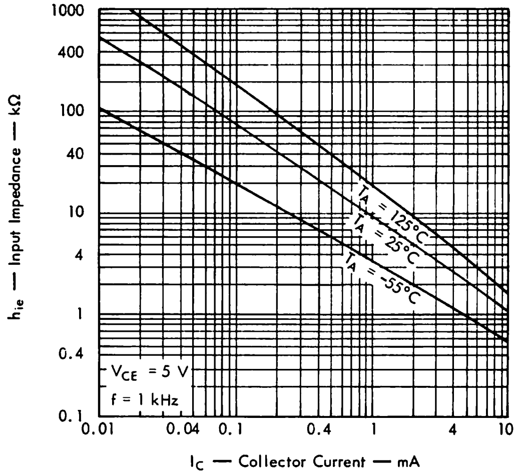


FIGURE 6

2N2484

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

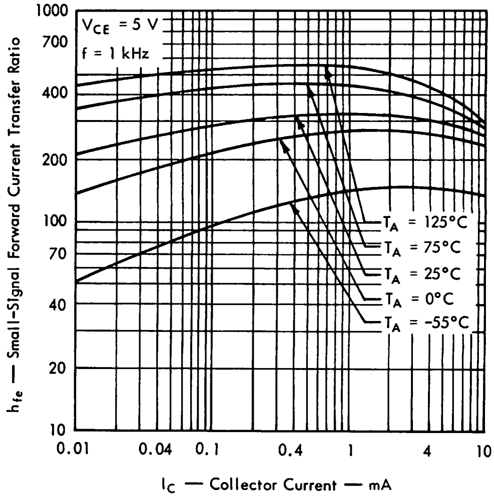


FIGURE 7

2N2484

SMALL-SIGNAL COMMON-EMITTER
REVERSE VOLTAGE TRANSFER RATIO
vs
COLLECTOR CURRENT

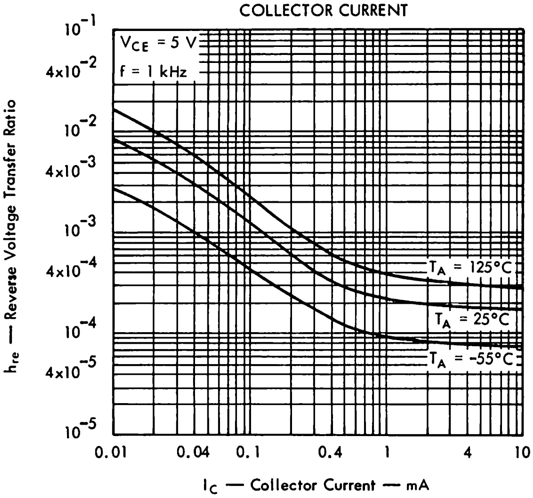


FIGURE 8

2N2484

SMALL-SIGNAL COMMON-EMITTER
OUTPUT ADMITTANCE
vs
COLLECTOR CURRENT

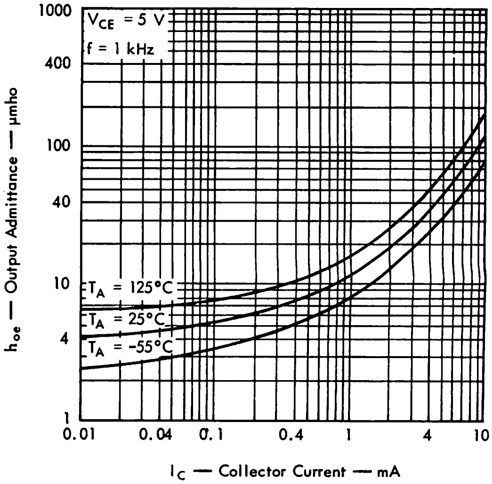


FIGURE 9

TYPICAL CHARACTERISTICS

2N2484

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

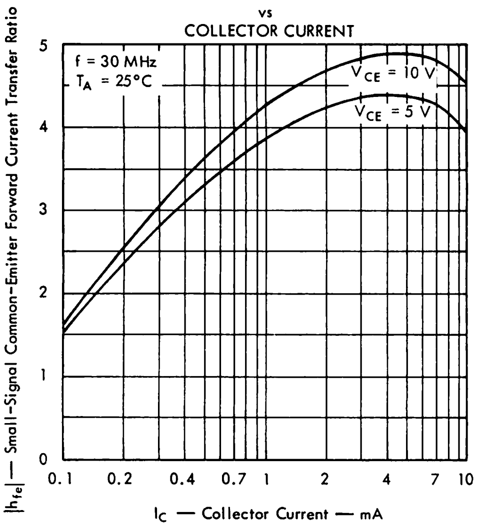


FIGURE 10

2N2483, 2N2484

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE AND COLLECTOR-BASE CAPACITANCE vs COLLECTOR-BASE VOLTAGE

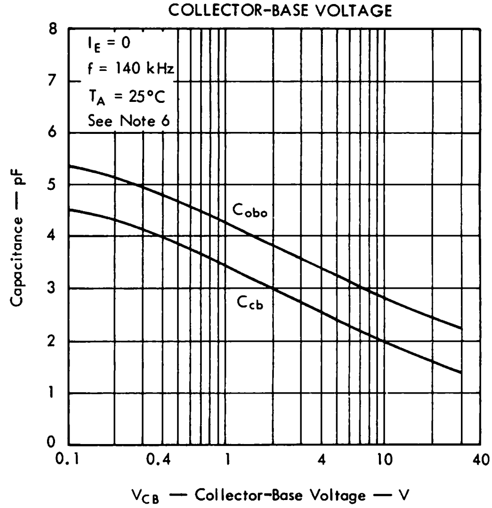


FIGURE 11

2N2483, 2N2484

COMMON-BASE OPEN-CIRCUIT INPUT CAPACITANCE AND EMITTER-BASE CAPACITANCE vs EMITTER-BASE VOLTAGE

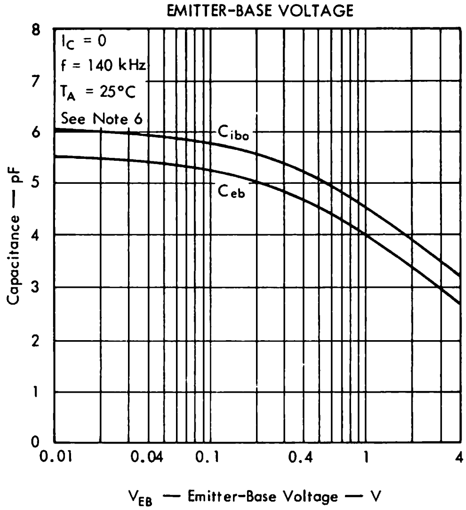


FIGURE 12

NOTE 6: C_{cb} and C_{eb} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded. C_{obo} and C_{ibo} are measured with the third terminal floating.

TYPICAL CHARACTERISTICS

2N2484
AVERAGE NOISE FIGURE
vs
GENERATOR RESISTANCE

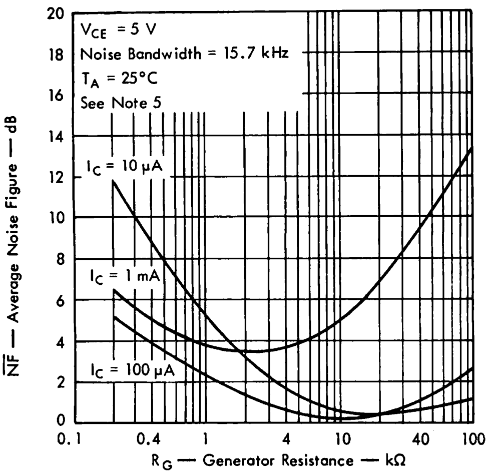


FIGURE 13

2N2484
SPOT NOISE FIGURE
vs
FREQUENCY

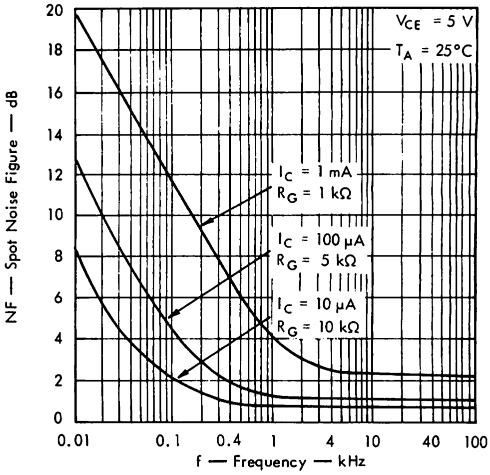


FIGURE 14

NOTE 5: Average Noise Figure is measured in an amplifier with response down 3 dB at 10 Hz and 10 kHz and a high-frequency rolloff at 6 dB/octave.

THERMAL INFORMATION

CONTINUOUS DEVICE DISSIPATION
vs
FREE-AIR TEMPERATURE

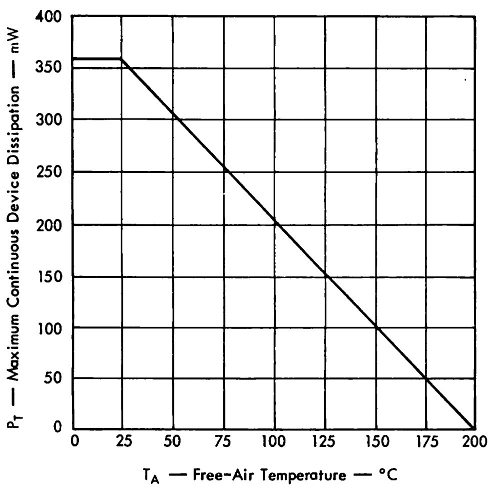


FIGURE 15

CONTINUOUS DEVICE DISSIPATION
vs
CASE TEMPERATURE

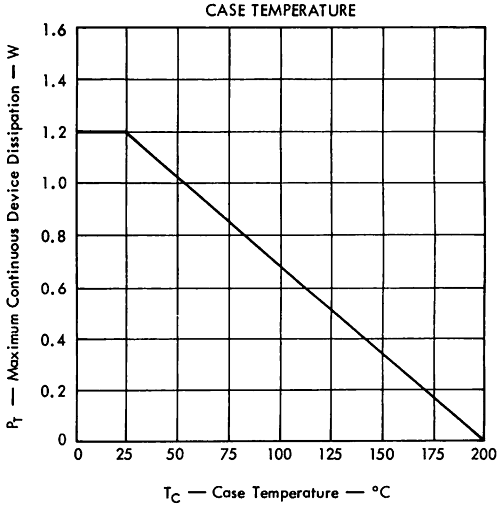


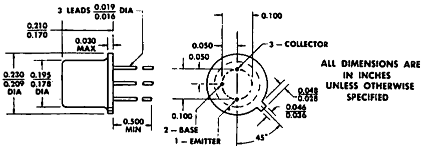
FIGURE 16

TYPE 2N3010
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3010
BULLETIN NO. DL-S 645022, MARCH 1964

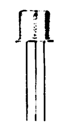
DESIGNED FOR EXTREMELY HIGH-SPEED SWITCHING APPLICATIONS

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	15 v
Collector-Emitter Voltage (See Note 1)	11 v
Collector-Emitter Voltage (See Note 2)	6 v
Emitter-Base Voltage	4 v
Collector Current	50 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	0.3 w
Operating Collector Junction Temperature	200°C
Storage Temperature Range	–65°C to +200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10\mu a$, $I_E = 0$	15		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 4	6		v
BV_{CES}	Collector-Emitter Breakdown Voltage	$I_C = 10\mu a$, $V_{BE} = 0$	11		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	4		v
I_{CES}	Collector Cutoff Current	$V_{CE} = 11$ v, $V_{BE} = 0$		10	μa
		$V_{CE} = 5$ v, $V_{BE} = 0$		100	na
		$V_{CE} = 5$ v, $V_{BE} = 0$, $T_A = 85°C$		5	μa
I_B	Base Current	$V_{CE} = 11$ v, $V_{BE} = 0$		–10	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 0.4$ v, $I_C = 1$ ma, See Note 4	15		
		$V_{CE} = 0.4$ v, $I_C = 10$ ma, See Note 4	25	125	
		$V_{CE} = 0.4$ v, $I_C = 30$ ma, See Note 4	15		
V_{BE}	Base-Emitter Voltage	$I_B = 0.1$ ma, $I_C = 1$ ma, See Note 4	0.68	0.85	v
		$I_B = 1$ ma, $I_C = 10$ ma, See Note 4	0.75	0.95	v
		$I_B = 3$ ma, $I_C = 30$ ma, See Note 4		1.30	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.1$ ma, $I_C = 1$ ma, See Note 4		0.25	v
		$I_B = 1$ ma, $I_C = 10$ ma, See Note 4		0.25	v
		$I_B = 3$ ma, $I_C = 30$ ma, See Note 4		0.38	v
		$I_B = 1$ ma, $I_C = 10$ ma, $T_A = 85°C$, See Note 4		0.40	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ v, $I_C = 10$ ma, f = 100 Mc	6.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 140 kc		3.0	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, f = 140 kc		2.0	pf

NOTES: 1. This value applies when the base-emitter diode is short-circuited.

2. This value applies between 10 μa and 10 ma collector current when the base-emitter diode is open-circuited.

3. Derate linearly to 200°C free-air temperature at the rate of 1.71 mw/C°.

4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data.

TYPE 2N3010
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-on Time	$I_C = 10$ ma, $I_{B(1)} = 2$ ma, $V_{BE(off)} = -1$ v, $R_L = 84\ \Omega$, See Figure 1	12	nsec
t_{off}	Turn-off Time	$I_C = 10$ ma, $I_{B(1)} = 1$ ma, $I_{B(2)} = -1$ ma, $R_L = 84\ \Omega$, See Figure 1	12	nsec
t_s	Storage Time	$I_C = 6$ ma, $I_{B(1)} = 5$ ma, $I_{B(2)} = -5$ ma, See Figure 2	6	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

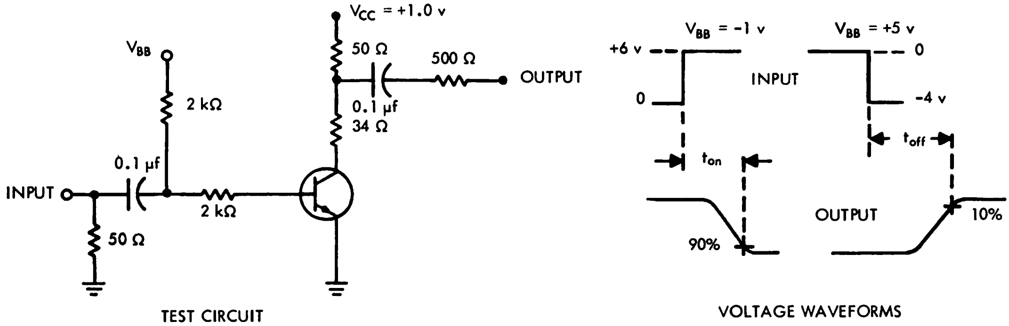


FIGURE 1 — TURN-ON AND TURN-OFF TIMES

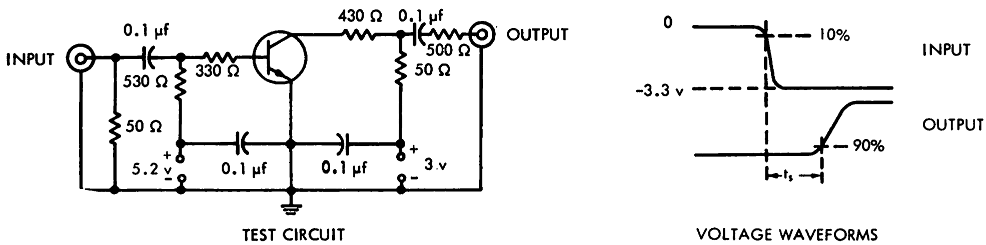


FIGURE 2 — STORAGE TIMES

NOTES: a. The input waveforms are supplied by a pulse generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, PW ≥ 100 nsec.

b. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 0.4$ nsec, $Z_{in} = 50\ \Omega$.

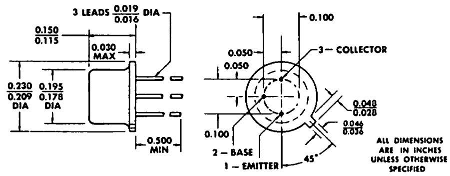
*Indicates JEDEC registered data.

TYPE 2N3013
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3013
BULLETIN NO. DL-S 645019, MARCH 1964

DESIGNED FOR VERY-HIGH-SPEED, HIGH-CURRENT SWITCHING APPLICATIONS

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-52 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	40 v
Collector-Emitter Voltage (See Note 1)	40 v
Collector-Emitter Voltage (See Note 2)	15 v
Emitter-Base Voltage	5 v
Collector Current, Continuous	200 ma
Collector Current, Peak (See Note 3)	500 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	0.36 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 5)	1.2 w
Total Device Dissipation at 100°C Case Temperature	0.68 w
Operating Collector Junction Temperature	200°C
Storage Temperature Range	−65°C to +200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	40		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 6	15		v
BV_{CES}	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu a$, $V_{BE} = 0$	40		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	5		v
I_{CES}	Collector Cutoff Current	$V_{CE} = 20$ v, $V_{BE} = 0$		0.3	μa
		$V_{CE} = 20$ v, $V_{BE} = 0$, $T_A = 125°C$		40	μa
I_B	Base Current	$V_{CE} = 20$ v, $V_{BE} = 0$		−0.3	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 0.4$ v, $I_C = 30$ ma, See Note 6	30	120	
		$V_{CE} = 0.5$ v, $I_C = 100$ ma, See Note 6	25		
		$V_{CE} = 1$ v, $I_C = 300$ ma, See Note 6	15		
		$V_{CE} = 0.4$ v, $I_C = 30$ ma, $T_A = -55°C$, See Note 6	12		
V_{BE}	Base-Emitter Voltage	$I_B = 3$ ma, $I_C = 30$ ma, See Note 6	0.75	0.95	v
		$I_B = 10$ ma, $I_C = 100$ ma, See Note 6		1.20	v
		$I_B = 30$ ma, $I_C = 300$ ma, See Note 6		1.70	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 3$ ma, $I_C = 30$ ma, See Note 6		0.18	v
		$I_B = 10$ ma, $I_C = 100$ ma, See Note 6		0.28	v
		$I_B = 30$ ma, $I_C = 300$ ma, See Note 6		0.50	v
		$I_B = 3$ ma, $I_C = 30$ ma, $T_A = 125°C$, See Note 6		0.25	v
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 30$ ma, f = 100 Mc	3.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 140 kc		5.0	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, f = 140 kc		8.0	pf

NOTES:
1. This value applies when the base-emitter diode is short-circuited.
2. This value applies between 10 μa and 10 ma collector current when the base-emitter diode is open-circuited.
3. This value applies for PW $\leq$ 10 μsec.
4. Derate linearly to 200°C free-air temperature at the rate of 2.06 mw/C°.
5. Derate linearly to 200°C case temperature at the rate of 6.85 mw/C°.
6. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-on Time	$I_C = 300$ ma, $I_{B(1)} = 30$ ma, $I_{B(2)} = -35$ ma	15	nsec
t_{off}	Turn-off Time	$V_{BE(off)} = -5$ v, $R_L = 50\ \Omega$, See Figure 1	25	nsec
t_s	Storage Time	$I_C = I_{B(1)} = -I_{B(2)} = 10$ ma, See Figure 2	18	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

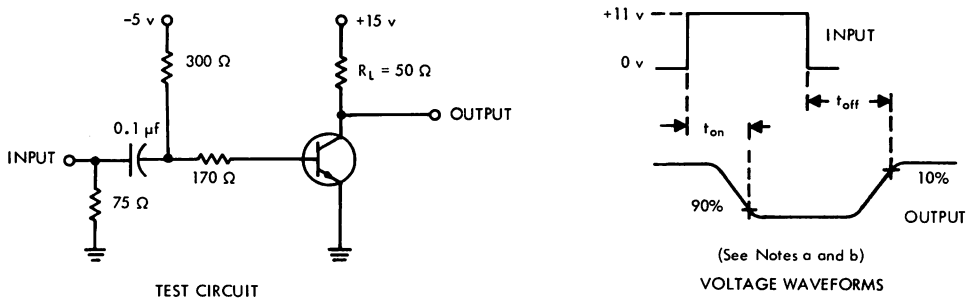


FIGURE 1 — TURN-ON AND TURN-OFF TIMES

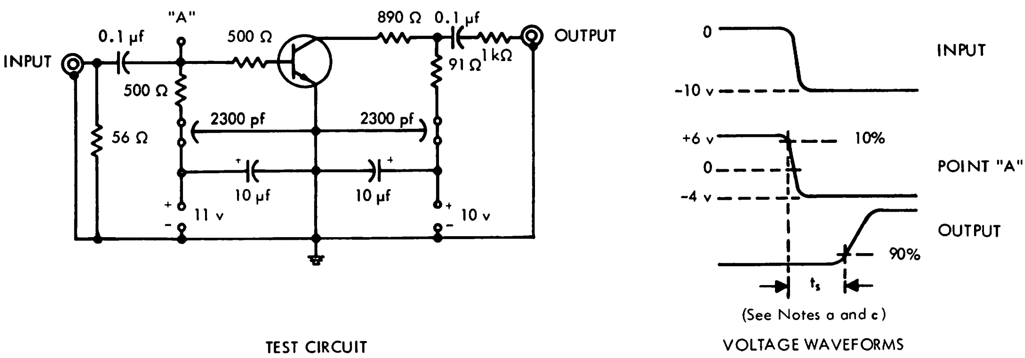


FIGURE 2 — STORAGE TIMES

NOTES: a. The input waveforms are supplied by a pulse generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, $t_f \leq 1$ nsec, PW $\geq$ 300 nsec, Duty Cycle $\leq$ 2%.

b. Waveforms of figure 1 are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100$ kΩ.

c. Output waveform of figure 2 is monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $Z_{in} = 50\Omega$.

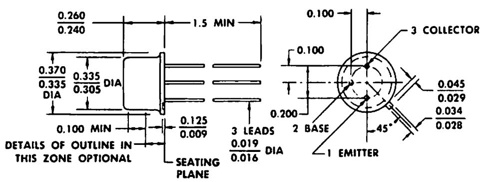
*Indicates JEDEC registered data.

TYPE 2N3015
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3015
BULLETIN NO. DL-S 645017, MARCH 1964

DESIGNED FOR HIGH-SPEED, HIGH-CURRENT SWITCHING APPLICATIONS

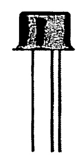
***mechani al data**



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 v
Collector-Emitter Voltage (See Note 1)	30 v
Emitter-Base Voltage	5 v
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.8 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	3.0 w
Operating Collector Junction Temperature	200°C
Storage Temperature Range	−65°C to +200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 4	30		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	5		v
I_{CES}	Collector Cutoff Current	$V_{CE} = 30$ v, $V_{BE} = 0$		0.2	μa
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_E = 0$, $T_A = 125°C$		200	μa
I_B	Base Current	$V_{CE} = 20$ v, $V_{BE} = 0$		−0.2	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 4	30	120	
		$V_{CE} = 0.7$ v, $I_C = 300$ ma, See Note 4	10		
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 4		1.2	v
		$I_B = 50$ ma, $I_C = 500$ ma, See Note 4		1.6	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 4		0.4	v
		$I_B = 50$ ma, $I_C = 500$ ma, See Note 4		1.0	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, f = 100 Mc	2.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 140 kc		8.0	pf

NOTES: 1. This value applies between 1 ma and 30 ma collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 4.6 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 17.2 mw/C°.
4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

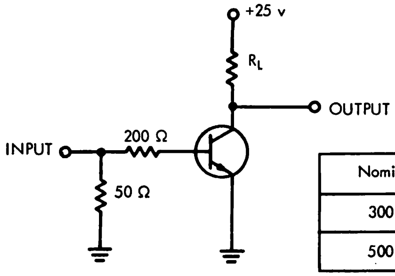
*Indicates JEDEC registered data.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-on Time	I_C = 300 ma, $I_{B(1)}$ = 30 ma, $V_{BE(off)}$ = 0, R_L = 80 Ω, See Figure 1	40	nsec
		I_C = 500 ma, $I_{B(1)}$ = 50 ma, $V_{BE(off)}$ = 0, R_L = 48 Ω, See Figure 1	40	nsec
t_{off}	Turn-off Time	I_C = 300 ma, $I_{B(1)}$ = 30 ma, $I_{B(2)}$ = −35 ma, R_L = 80 Ω, See Figure 2	60	nsec
		I_C = 500 ma, $I_{B(1)}$ = 50 ma, $I_{B(2)}$ = −55 ma, R_L = 48 Ω, See Figure 2	60	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

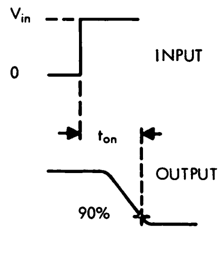
*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

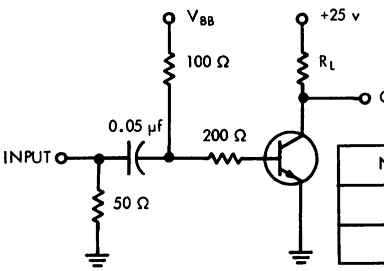
Nominal I_C	R_L	V_{in}
300 ma	80 Ω	+7 v
500 ma	48 Ω	+11 v

CIRCUIT CONDITIONS



VOLTAGE WAVEFORMS

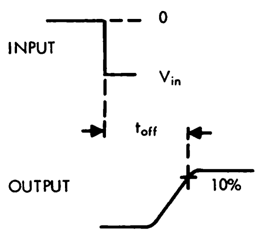
FIGURE 1 — TURN-ON TIMES



TEST CIRCUIT

Nominal I_C	R_L	V_{BB}	V_{in}
300 ma	80 Ω	+10 v	-13 v
500 ma	48 Ω	+16 v	-21 v

CIRCUIT CONDITIONS



VOLTAGE WAVEFORMS

FIGURE 2 — TURN-OFF TIMES

NOTES: a. The input waveforms are supplied by a pulse generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq$ 2 nsec, PW = 200 nsec.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq$ 1 nsec, $R_{in} \geq$ 100 kΩ.

*Indicates JEDEC registered data.

TYPES 2N3707, 2N3708, 2N3709, 2N3710, 2N3711
N-P-N PLANAR SILICON TRANSISTORS

TYPES 2N3707, 2N3708, 2N3709, 2N3710, 2N3711
BULLETIN NO. DL-S 687584, APRIL 1965
REPLACES BULLETIN NO. DL-S 657334, FEBRUARY 1965
REVISED JANUARY 1968

SILECT† TRANSISTORS

- **ENCAPSULATED IN PLASTIC**
- **INSENSITIVE TO LIGHT**
- **HIGHLY MOISTURE RESISTANT**

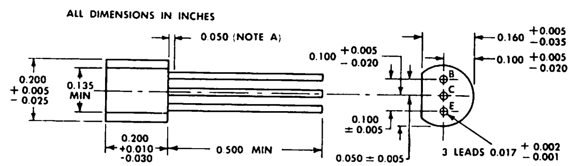
2N3707 (Formerly TI415) For Low-Level, Low-Noise Applications

2N3708 (Formerly TI416)
2N3709
2N3710 (Formerly TI417)
2N3711 (Formerly TI418)
For General-Purpose, Low-Level, High-Gain Applications

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTE A: Lead diameter is not controlled in this area.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 v
Collector-Emitter Voltage (See Note 1)	30 v
Emitter-Base Voltage	6 v
Collector Current	30 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	360 mw
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mw/C°.

*Indicates JEDEC registered data (typical data excluded).
†Trademark of Texas Instruments Incorporated
‡Patent Pending

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***electrical characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N3707		2N3708		2N3709		2N3710		2N3711		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1$ ma, $I_B = 0$	30		30		30		30		30		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20$ v, $I_E = 0$		100		100		100		100		100	na
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 6$ v, $I_C = 0$		100		100		100		100		100	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 100\ \mu a$	100	400									
		$V_{CE} = 5$ v, $I_C = 1$ ma			45	660	45	165	90	330	180	660	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ v, $I_C = 1$ ma	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma		1		1		1		1		1	v
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 100\ \mu a$, f = 1 kc	100	550									
		$V_{CE} = 5$ v, $I_C = 1$ ma, f = 1 kc			45	800	45	250	90	450	180	800	

***operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N3707		UNIT
			TYP	MAX	
$\overline{NF}$	Average Noise Figure	$V_{CE} = 5$ v, $I_C = 100\ \mu a$, $R_G = 5\ k\Omega$, Noise Bandwidth = 15.7 kc, See Note 3	1.9	5	db

NOTE 3: Average Noise Figure is measured in an amplifier with low-frequency response down 3 db at 10 cps.

*Indicates JEDEC registered data (typical data excluded).

PARAMETER DISTRIBUTION INFORMATION

The 2N3708 is furnished in seven color-coded h_{FE} brackets, each having less than 2-to-1 spread. In lots of 1000 (or more) pieces they are shipped in the percentages shown below.

COLOR CODE	h_{FE} BRACKET $V_{CE} = 5$ v, $I_C = 1$ ma	CONTENT
brown	45-85	0-5%
red	65-110	5-15%
orange	90-165	25-35%
yellow	135-220	15-25%
green	180-330	15-25%
blue	270-440	0-10%
violet	360-660	0-5%

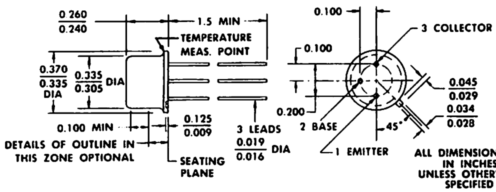
Table 1 — 2N3708 h_{FE} DISTRIBUTION

TYPES 2N3724, 2N3724A, 2N3725, 2N3725A
BULLETIN NO. DL-S 6710081, JUNE 1967
REPLACES BULLETIN NO. DL-S 679713, MARCH 1967
AND BULLETIN NO. DL-S 679871, JANUARY 1967

FAST, HIGH-VOLTAGE, HIGH-CURRENT CORE DRIVERS

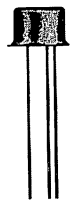
- h_{FE} Guaranteed from 10 mA to 1.5 A
- Made with TRI-REL† Redundant Stabilization (Field-Relief Electrode‡, Special Oxide Passivation, Annular Guard Ring§)
- Guaranteed Switching Times at One Ampere (2N3724A, 2N3725A)

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3724	2N3724A	2N3725	2N3725A	UNIT
Collector-Base Voltage	50		80		V
Collector-Emitter Voltage (See Note 1)	30		50		V
Emitter-Base Voltage	6		6		V
Continuous Collector Current	0.5	1.2	0.5	1.2	A
Peak Collector Current (See Note 2)		1.75		1.75	A
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	0.8	1	0.8	1	W
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 4)	3.5	5	3.5	5	W
Storage Temperature Range	−65 to 200		−65 to 200		°C
Lead Temperature 1/16 Inch from Case for 60 Seconds	300		300		°C

NOTES: 1. These values apply between 0.01 mA and 500 mA collector current when the base-emitter diode is open-circuited.
2. This value applies for square-wave pulses. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
3. For the 2N3724 and 2N3725 derate linearly to 200°C free-air temperature at the rate of 4.6 mW/deg. For the 2N3724A and 2N3725A derate linearly to 200°C free-air temperature at the rate of 5.71 mW/deg.
4. For the 2N3724 and 2N3725 derate linearly to 200°C case temperature at the rate of 20 mW/deg. For the 2N3724A and 2N3725A derate linearly to 200°C case temperature at the rate of 28.6 mW/deg.

†Trademark of Texas Instruments
‡Patent pending
§Patented by Texas Instruments
*Indicates JEDEC registered data

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TYPES 2N3724, 2N3724A, 2N3725, 2N3725A
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		2N3724 MIN	2N3724 MAX	2N3724A MIN	2N3724A MAX	2N3725 MIN	2N3725 MAX	2N3725A MIN	2N3725A MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$		50		50		80		80		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$,	See Note 5	30		30		50		50		V
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = 10\ \mu A$, $V_{BE} = 0$		50		50		80		80		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$		6		6		6		6		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 40$ V, $I_E = 0$			1.7		0.5					μA
		$V_{CB} = 40$ V, $I_E = 0$, $T_A = 100°C$			120		50					μA
		$V_{CB} = 60$ V, $I_E = 0$							1.7		0.5	μA
		$V_{CB} = 60$ V, $I_E = 0$, $T_A = 100°C$							120		50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 50$ V, $V_{BE} = 0$			10		10					μA
		$V_{CE} = 80$ V, $V_{BE} = 0$							10		10	μA
I_B	Base Current	$V_{CE} = 50$ V, $V_{BE} = 0$			–10		–10					μA
		$V_{CE} = 80$ V, $V_{BE} = 0$							–10		–10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 1$ V, $I_C = 10$ mA	See Note 5	30		30		30		30		
		$V_{CE} = 1$ V, $I_C = 100$ mA		60	150	60	150	60	150	60	150	
		$V_{CE} = 1$ V, $I_C = 100$ mA, $T_A = -55°C$		30		30		30		30		
		$V_{CE} = 1$ V, $I_C = 300$ mA		40		40		40		40		
		$V_{CE} = 1$ V, $I_C = 500$ mA		35		35		35		35		
		$V_{CE} = 1$ V, $I_C = 500$ mA, $T_A = -55°C$		20		20		20		20		
		$V_{CE} = 2$ V, $I_C = 800$ mA		25		30		20		25		
		$V_{CE} = 5$ V, $I_C = 1$ A		30		30		25		25		
		$V_{CE} = 5$ V, $I_C = 1.5$ A				25				20		
V_{BE}	Base-Emitter Voltage	$I_B = 1$ mA, $I_C = 10$ mA	See Note 5		0.76		0.76		0.76		0.76	V
		$I_B = 10$ mA, $I_C = 100$ mA			0.86		0.86		0.86		0.86	V
		$I_B = 30$ mA, $I_C = 300$ mA			1.1		1.1		1.1		1.1	V
		$I_B = 50$ mA, $I_C = 500$ mA		0.9	1.2	0.9	1.2	0.9	1.2	0.9	1.2	V
		$I_B = 80$ mA, $I_C = 800$ mA			1.5		1.3		1.5		1.3	V
		$I_B = 100$ mA, $I_C = 1$ A			1.7	0.9	1.4		1.7	0.9	1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ mA, $I_C = 10$ mA	See Note 5		0.25		0.25		0.25		0.25	V
		$I_B = 10$ mA, $I_C = 100$ mA			0.2		0.2		0.26		0.26	V
		$I_B = 30$ mA, $I_C = 300$ mA			0.32		0.32		0.4		0.4	V
		$I_B = 50$ mA, $I_C = 500$ mA			0.42		0.42		0.52		0.52	V
		$I_B = 80$ mA, $I_C = 800$ mA			0.65		0.65		0.8		0.8	V
		$I_B = 100$ mA, $I_C = 1$ A			0.75		0.75		0.95		0.9	V
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 50$ mA, $f = 100$ MHz		3		3		3		3		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz			12		12		10		10	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ V, $I_C = 0$, $f = 1$ MHz			55		55		55		55	pF

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 1\%$.

*Indicates JEDEC registered data

*switching characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS†	2N3724 MAX	2N3724A MAX	2N3725 MAX	2N3725A MAX	UNIT
t_d Delay Time	I_C = 500 mA,	10	10	10	10	ns
t_r Rise Time	$I_{B(1)}$ = 50 mA, $V_{BE(off)}$ = −3.8 V,	30	30	30	30	ns
t_{on} Turn-On Time	R_L = 58 Ω, See Figure 1	35	35	35	35	ns
t_s Storage Time	I_C = 500 mA,	50	50	50	50	ns
t_f Fall Time	$I_{B(1)}$ = 50 mA, $I_{B(2)}$ = −50 mA,	25	25	30	30	ns
t_{off} Turn-Off Time	R_L = 58 Ω, See Figure 1	60	60	60	60	ns
t_{on} Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $V_{BE(off)}$ = −2 V, R_L = 30 Ω, See Figure 2		30		30	ns
t_{off} Turn-Off Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA, R_L = 30 Ω, See Figure 3		50		50	ns

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

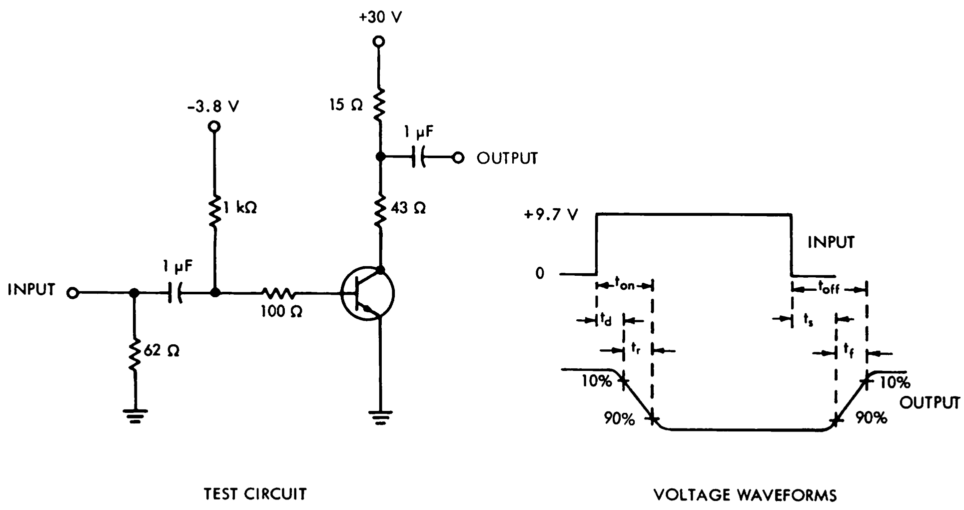
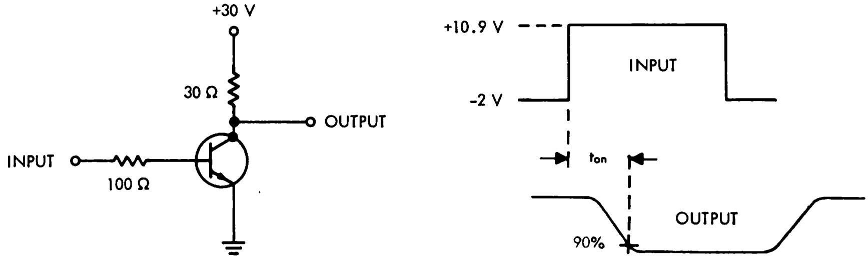


FIGURE 1 — 500-mA SWITCHING TIMES

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq 1$ ns, $t_f \leq 1$ ns, $t_p \approx 1$ μs, duty cycle ≤ 2%.
b. The output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 7$ pF.

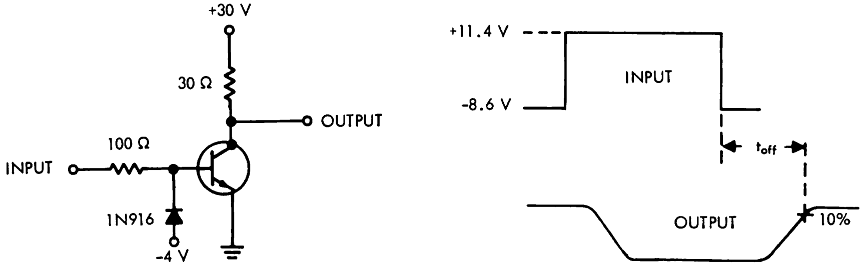
*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 2 — 1-AMPERE TURN-ON TIME (2N3724A AND 2N3725A)



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 3 — 1-AMPERE TURN-OFF TIME (2N3724A AND 2N3725A)

NOTES: a. The input waveforms have the following characteristics:
For measuring turn-on time: $t_r \leq 2$ ns, $t_p = 200$ ns, duty cycle $\leq 2\%$.
For measuring turn-off time: $t_f \leq 3$ ns, $t_p = 200$ ns to 10 μs, duty cycle $= 2\%$.

b. The output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 7$ pF.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

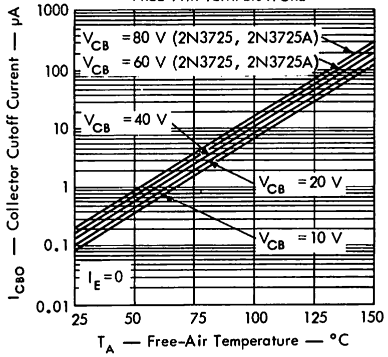


FIGURE 4

TYPICAL CHARACTERISTICS

2N3724A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

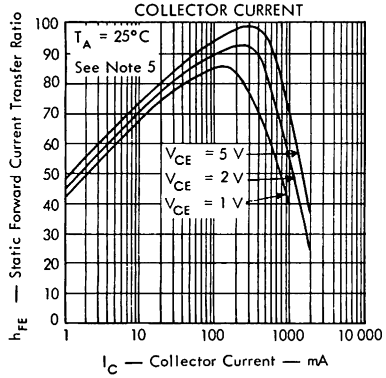


FIGURE 5

2N3725A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

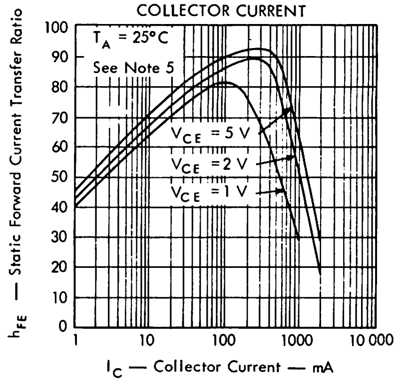


FIGURE 6

2N3724A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

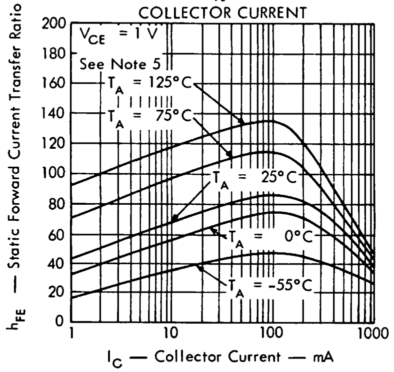


FIGURE 7

2N3725A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

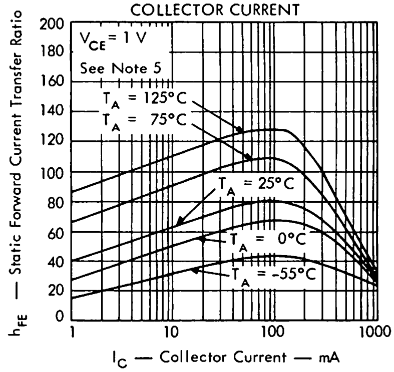


FIGURE 8

2N3724A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

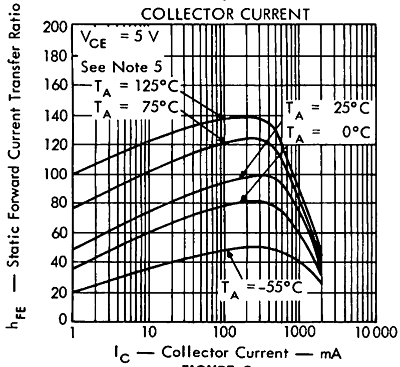


FIGURE 9

2N3725A

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

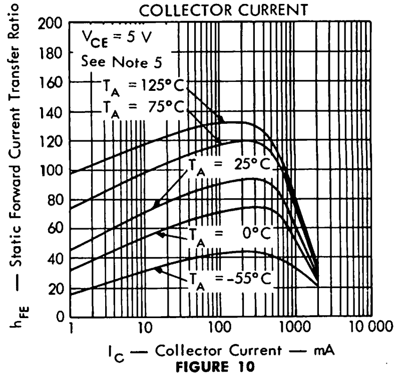


FIGURE 10

TYPICAL CHARACTERISTICS

BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT

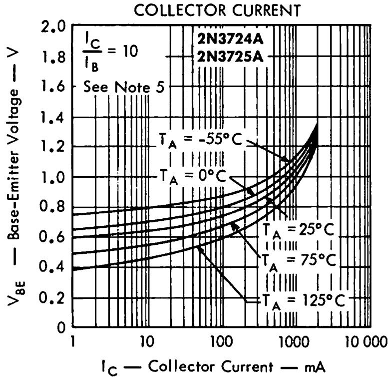


FIGURE 11

COLLECTOR-EMITTER SATURATION VOLTAGE vs COLLECTOR CURRENT

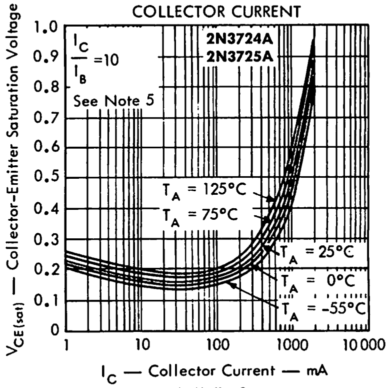


FIGURE 12

COMMON-BASE OPEN-CIRCUIT INPUT CAPACITANCE vs EMITTER-BASE VOLTAGE

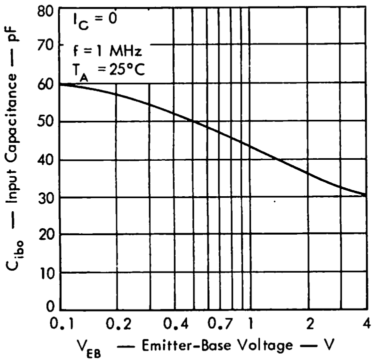


FIGURE 13

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE vs COLLECTOR-BASE VOLTAGE

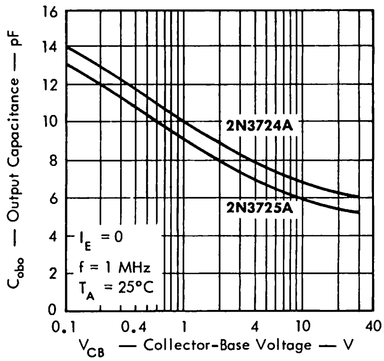


FIGURE 14

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

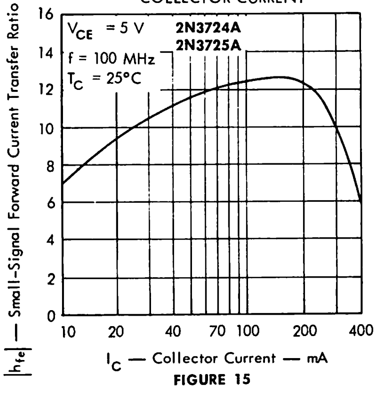


FIGURE 15

TYPICAL CHARACTERISTICS

2N3724A
2N3725A

CONTOURS OF CONSTANT
DELAY TIME, t_d

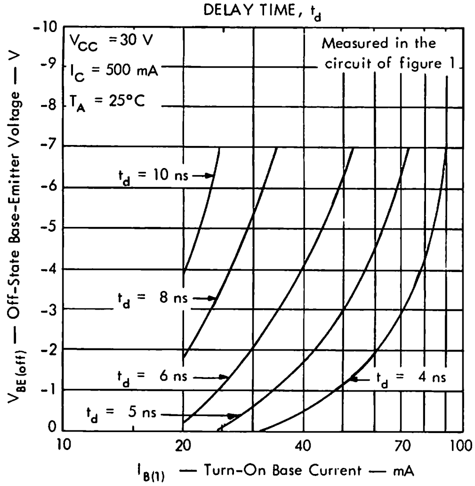


FIGURE 16

2N3724A
2N3725A

CONTOURS OF CONSTANT
RISE TIME, t_r

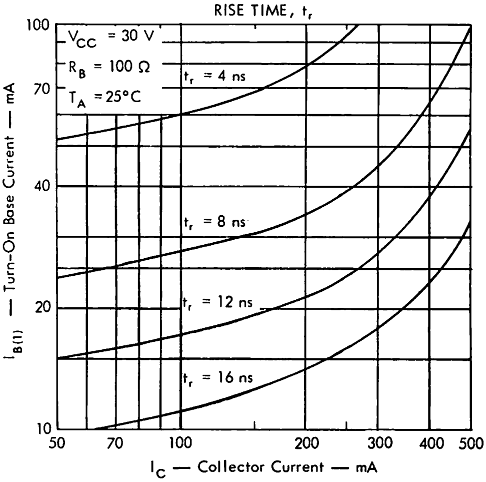


FIGURE 17

2N3724A
2N3725A

CONTOURS OF CONSTANT
STORAGE TIME, t_s

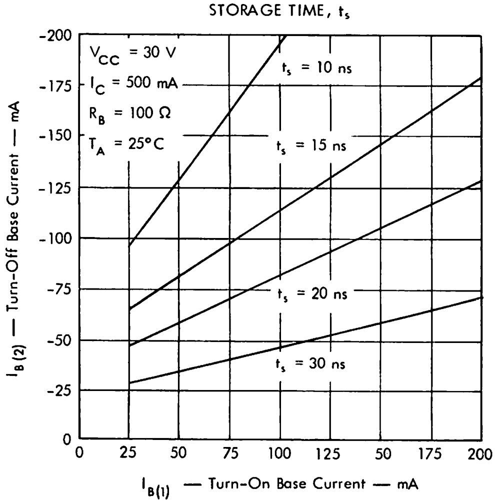


FIGURE 18

2N3724A
2N3725A

CONTOURS OF CONSTANT
FALL TIME, t_f

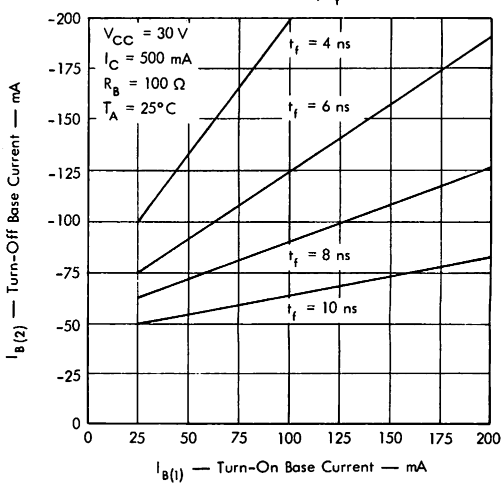


FIGURE 19

TYPICAL CHARACTERISTICS

2N3724A
2N3725A

SWITCHING TIME
vs
COLLECTOR CURRENT

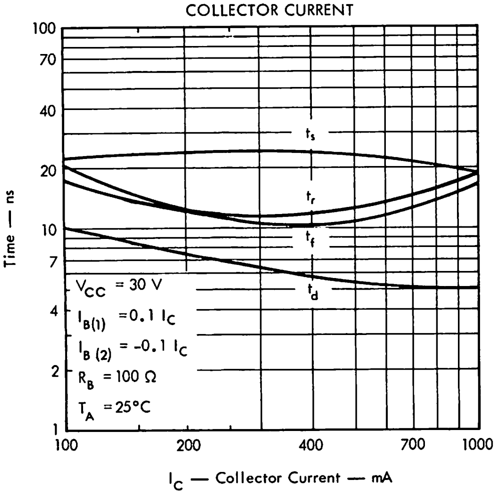


FIGURE 20

2N3724A
2N3725A

SWITCHING TIME
vs
FREE-AIR TEMPERATURE

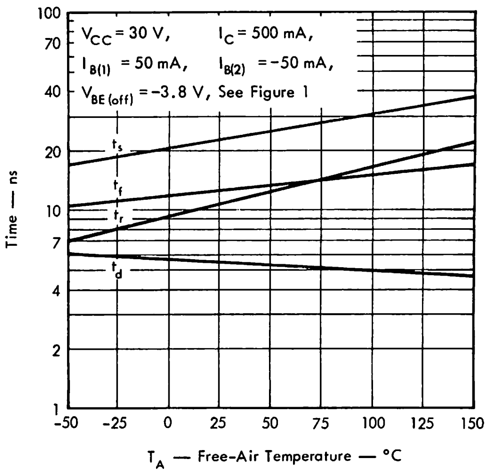


FIGURE 21

THERMAL INFORMATION

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

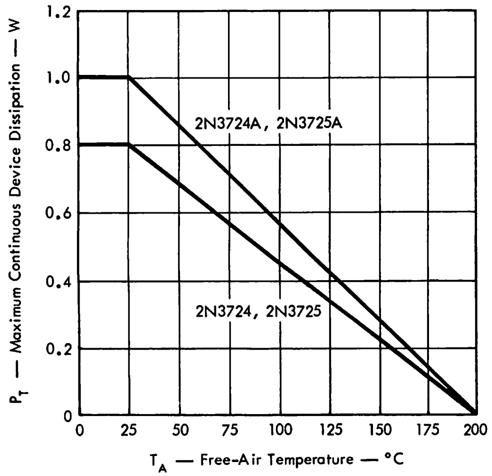


FIGURE 22

CASE TEMPERATURE
DISSIPATION DERATING CURVE

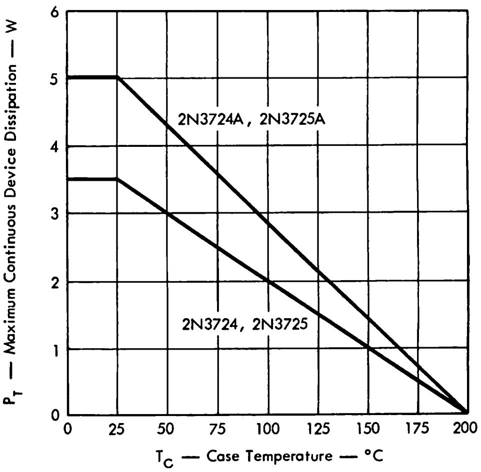


FIGURE 23

TYPES 2N3826, 2N3827, 2N4994, AND 2N4995
N-P-N PLANAR SILICON TRANSISTORS

TYPES 2N3826, 2N3827, 2N4994, AND 2N4995
BULLETIN NO. DL-S 679606, OCTOBER 1967
REPLACES BULLETIN NO. DL-S 657503, MARCH 1965

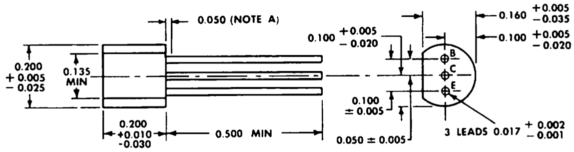
HIGH-FREQUENCY SILECT† TRANSISTORS

For Applications as

- **AM-FM IF Amplifiers**
- **AM RF Amplifiers and Oscillators**
- **FM Oscillators and Mixers**

mechanical data

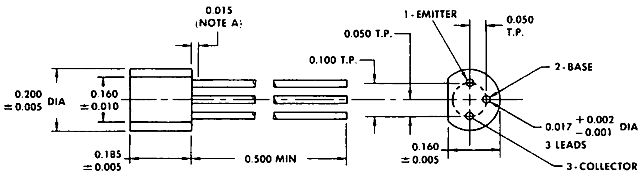
These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.



2N3826 AND 2N3827 CASE OUTLINE

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES: A. Lead diameter is not controlled in this area.
B. All dimensions are in inches.



*2N4994 AND 2N4995 CASE OUTLINE

NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 V
Collector-Emitter Voltage (See Note 1)	45 V
Emitter-Base Voltage	4 V
Continuous Collector Current	30 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	360 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

†Trademark of Texas Instruments
‡Patent Pending
*Indicates JEDEC registered data (typical data excluded)

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3826, 2N4994 MIN	TYP	MAX	2N3827, 2N4995 MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$	60			60			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 3	45			45			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$	4			4			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ V, $I_E = 0$			100			100	nA
		$V_{CB} = 30$ V, $I_E = 0$, $T_A = 85°C$			5			5	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 10$ mA, See Note 3	40		160	100		400	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 10$ mA, f = 455 kHz		42			45		dB
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 10$ mA, f = 100 MHz	2	3	8	2	3	8	
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz		2.5	3.5		2.5	3.5	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -10$ mA, f = 79.8 MHz		45	100		45	100	ps

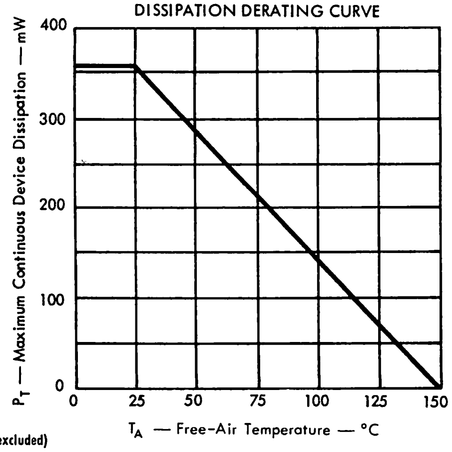
NOTE 3: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
MAG	Maximum Available Gain	$V_{CE} = 10$ V, $I_C = 10$ mA, f = 10.7 MHz, See Note 4	34	dB

NOTE 4: Maximum Available Gain, MAG, at frequency f in the higher frequency portion of the spectrum, is calculated from the formula MAG $\approx 4\ \alpha_o f_T \times 10^4 \div f^2 r_b' C_c$ where f and f_T are in megahertz, $r_b'C_c$ is in picoseconds, and α_o is the low-frequency alpha, which for most practical design can be taken as unity. To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at the rate of −6 dB/octave from f = 100 MHz to the frequency at which $|h_{fe}| = 1$.

THERMAL CHARACTERISTICS



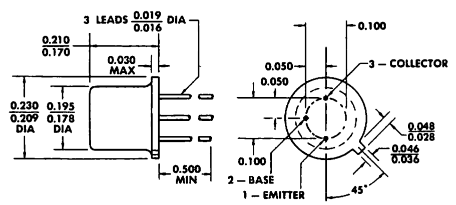
*Indicates JEDEC registered data (typical data excluded)

TYPE 2N4104
BULLETIN NO. DL-S 668315, JANUARY 1966

DESIGNED FOR USE IN LOW-LEVEL, LOW-NOISE AMPLIFIERS

- **Guaranteed Low-Noise Characteristics at 10 c/s, 100 c/s, 1 kc/s, and 10 kc/s**
- **Very High Guaranteed h_{FE} at $I_C = 10\ \mu A$: 400 Minimum**
- **High Rated V_{EBO} : 10 V**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 V
Collector-Emitter Voltage (See Note 1)	60 V
Emitter-Base Voltage	10 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.3 W
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	1.2 W
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTES: 1. This value applies between 0 and 10 mA when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 2 mW/deg.
3. Derate linearly to 175°C case temperature at the rate of 8 mW/deg.

*Indicates JEDEC registered data.

TEXAS INSTRUMENTS
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TYPE 2N4104
N-P-N PLANAR SILICON TRANSISTOR

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 4	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$	10		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 45$ V, $I_E = 0$		10	nA
		$V_{CB} = 45$ V, $I_E = 0$, $T_A = 150°C$		10	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		10	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1\ \mu A$	150		
		$V_{CE} = 5$ V, $I_C = 10\ \mu A$	400	800	
		$V_{CE} = 5$ V, $I_C = 100\ \mu A$	450		
		$V_{CE} = 5$ V, $I_C = 1$ mA	500		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ V, $I_C = 100\ \mu A$		0.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.1$ mA, $I_C = 1$ mA		0.3	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 5$ V, $I_C = 1$ mA, $f = 1$ kc/s	12	42	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio		500	1400	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio			8×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance		8	60	μmho
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ mA, $f = 30$ Mc/s	3	18	
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ V, $I_E = 0$, $f = 1$ Mc/s		4.5	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ V, $I_C = 0$, $f = 1$ Mc/s		6	pF

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = 5$ V, $I_C = 30\ \mu A$, $R_G = 10$ kΩ, $f = 10$ c/s		15	dB
		$V_{CE} = 5$ V, $I_C = 30\ \mu A$, $R_G = 10$ kΩ, $f = 100$ c/s		4	dB
		$V_{CE} = 5$ V, $I_C = 5\ \mu A$, $R_G = 50$ kΩ, $f = 1$ kc/s		1	dB
		$V_{CE} = 5$ V, $I_C = 5\ \mu A$, $R_G = 50$ kΩ, $f = 10$ kc/s		1	dB

NOTE 4: This parameter must be measured using pulse techniques: $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

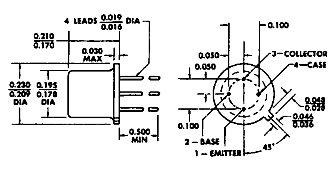
*Indicates JEDEC registered data.

TYPES 2N4252 AND 2N4253
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N4252 AND 2N4253
BULLETIN NO. DL-S 668575, APRIL 1966

HIGH-FREQUENCY TRANSISTORS FOR TUNER AND IF-AMPLIFIER STAGES IN FM AND AM/FM STEREO-MULTIPLEX RECEIVERS

*mechanical data



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	18 V
Emitter-Base Voltage	4 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	200 mW
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	2N4252			2N4253			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	30			30			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 2$ mA, $I_B = 0$, See Note 3	18			18			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$	4			4			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V, $I_E = 0$			50			50	nA
		$V_{CB} = 15$ V, $I_E = 0$, $T_A = 85°C$			5			5	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 2$ mA	50			30		150	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 2$ mA, f = 100 MHz	6		14	6		14	
$\lvert y_{fe} \rvert$	Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = 10$ V, $I_C = 2$ mA, f = 10 MHz					70		mmho
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz, See Note 4	0.1		0.45	0.1		0.45	pF
r_{oep}	Parallel-Equivalent Common-Emitter Short-Circuit Output Resistance	$V_{CE} = 10$ V, $I_C = 2$ mA, f = 10 MHz				50			kΩ
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -2$ mA, f = 79.8 MHz		8	12		8	12	ps

NOTES: 1. This value applies when base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 1.33 mW/deg.
3. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. Collector-Base Capacitance is measured using three-terminal measurement techniques with the case and emitter guarded.

*Indicates JEDEC registered data (typical data excluded).

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operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N4252 TYP	UNIT
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 2$ mA, $R_G = 100\ \Omega$, f = 100 MHz	2.5	dB

TYPICAL CHARACTERISTICS

2N4253
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

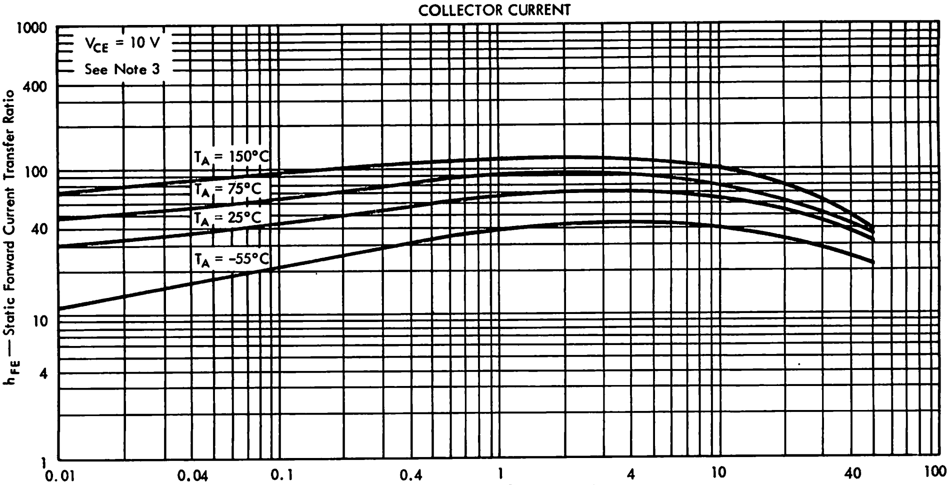


FIGURE 1

2N4252, 2N4253
BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE

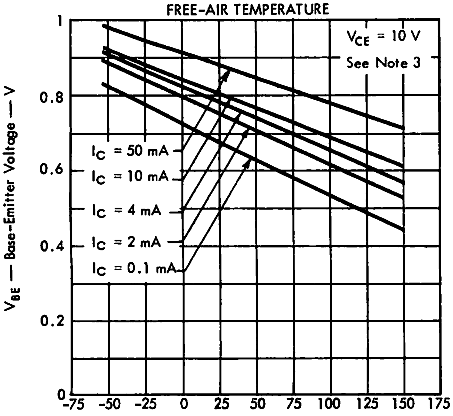


FIGURE 2

2N4252, 2N4253
COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

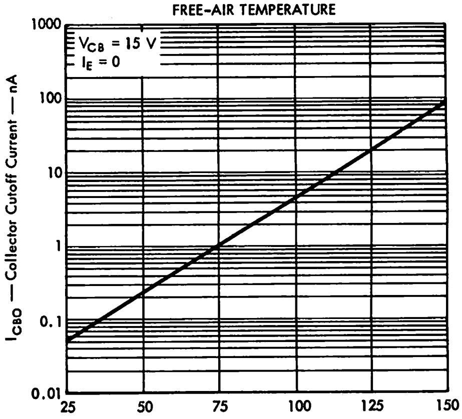


FIGURE 3

NOTE 3: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

2N4253

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

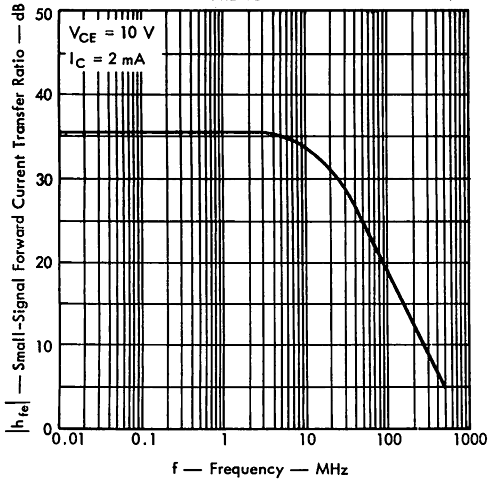


FIGURE 4

2N4252, 2N4253

COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

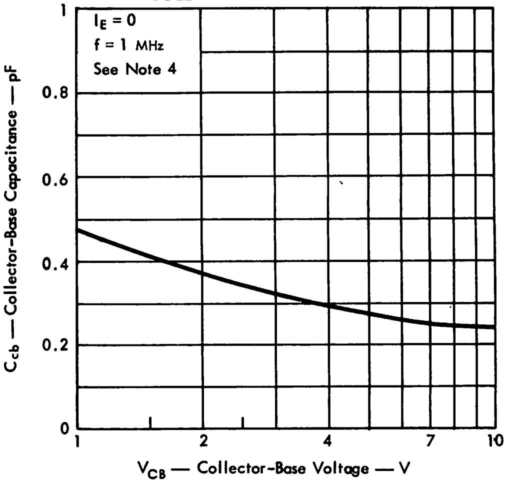


FIGURE 5

2N4252

SPOT NOISE FIGURE
vs
FREQUENCY

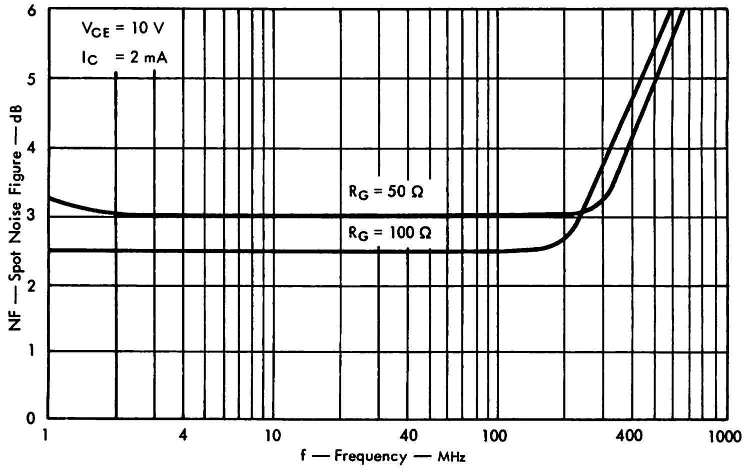


FIGURE 6

NOTE 4: Collector-Base Capacitance is measured using three-terminal measurement techniques with the case and emitter guarded.

TYPES 2N4252 AND 2N4253
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPICAL CHARACTERISTICS AT 455 kHz, $T_A = 25°C$

2N4253
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

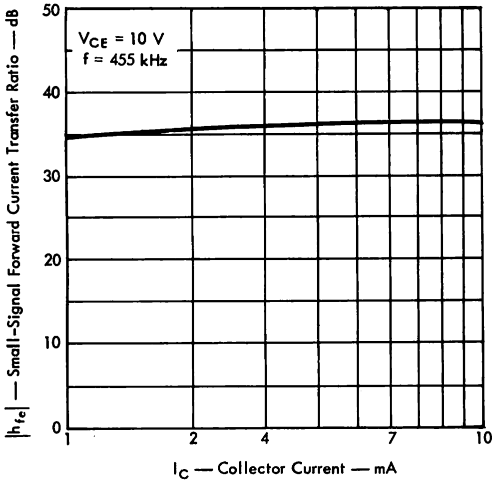


FIGURE 7

2N4253
SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

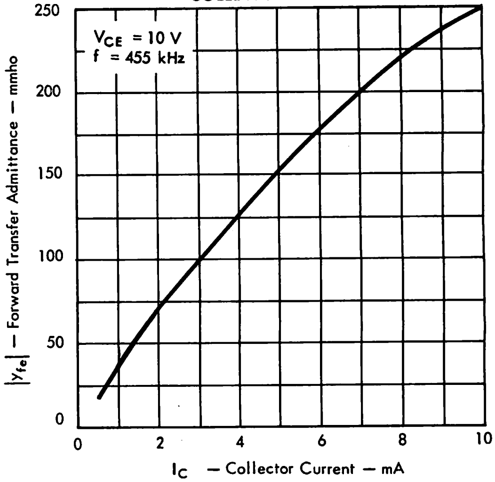


FIGURE 8

2N4253
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

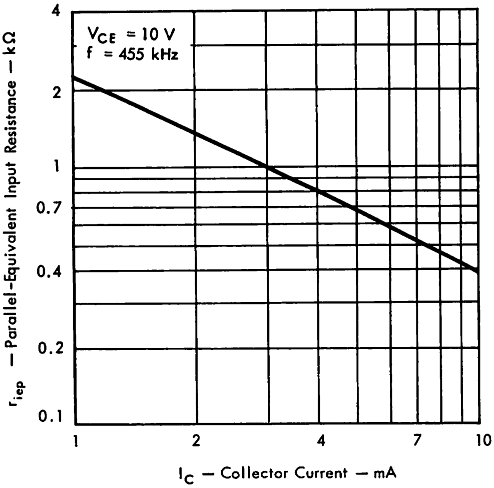


FIGURE 9

2N4253
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

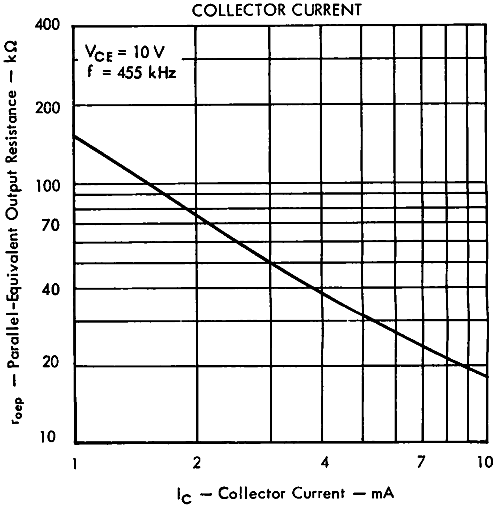


FIGURE 10

TYPICAL CHARACTERISTICS AT 10 MHz, $T_A = 25°C$

2N4253
SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

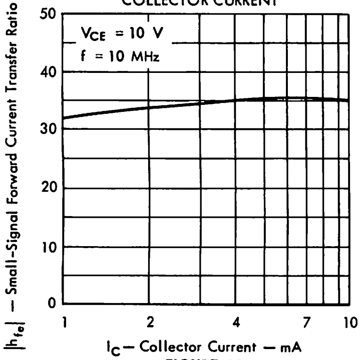


FIGURE 11

2N4253
SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs COLLECTOR-EMITTER VOLTAGE

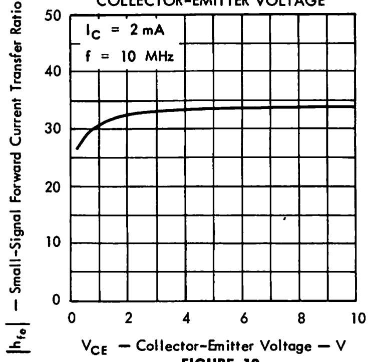


FIGURE 12

2N4253
SMALL-SIGNAL COMMON-EMITTER FORWARD TRANSFER ADMITTANCE vs COLLECTOR CURRENT

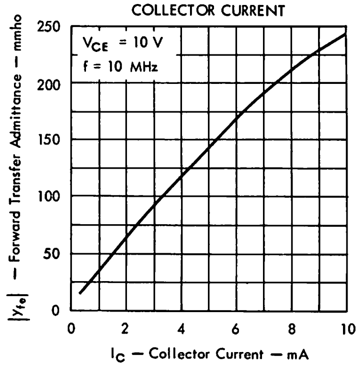


FIGURE 13

2N4253
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT INPUT RESISTANCE vs COLLECTOR CURRENT

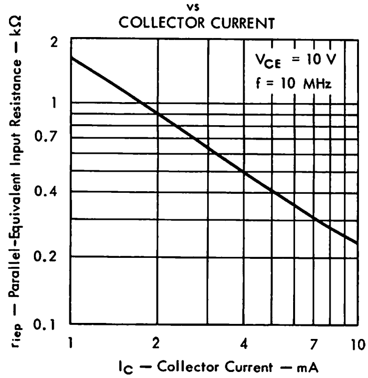


FIGURE 14

2N4253
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT OUTPUT RESISTANCE vs COLLECTOR CURRENT

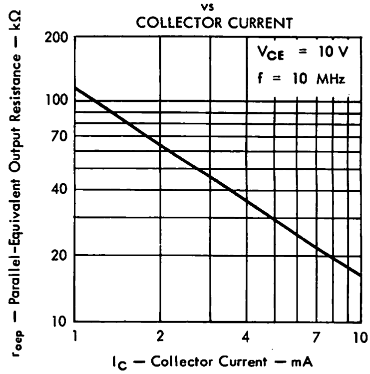


FIGURE 15

TYPICAL CHARACTERISTICS AT 100 MHz, $T_A = 25°C$

2N4252
SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

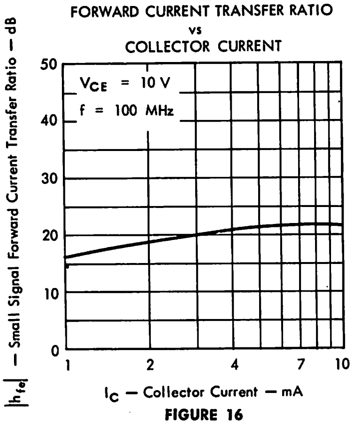


FIGURE 16

2N4252
SMALL-SIGNAL COMMON-EMITTER FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

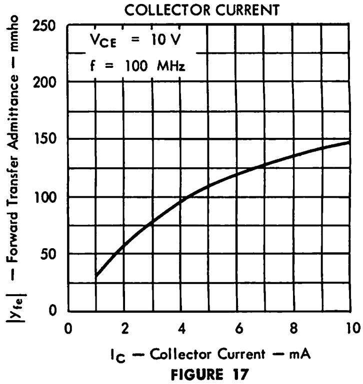


FIGURE 17

2N4252
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

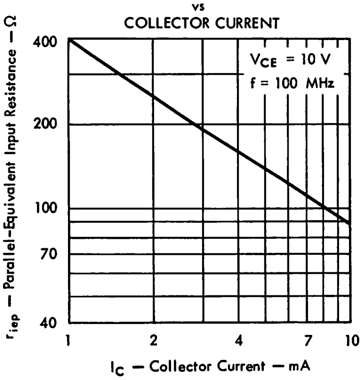


FIGURE 18

2N4252
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

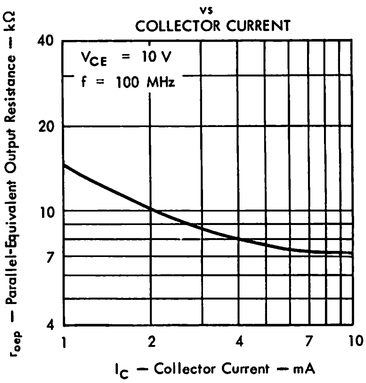
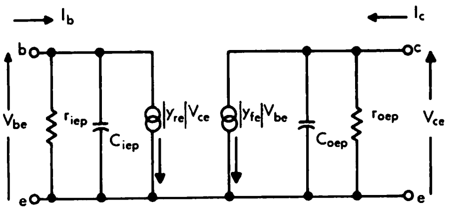


FIGURE 19

COMMON-EMITTER EQUIVALENT CIRCUIT USING SHORT-CIRCUIT "y" PARAMETERS



$$I_b = |y_{ie}|V_{be} + |y_{re}|V_{ce}$$

$$I_c = |y_{fe}|V_{be} + |y_{oe}|V_{ce}$$

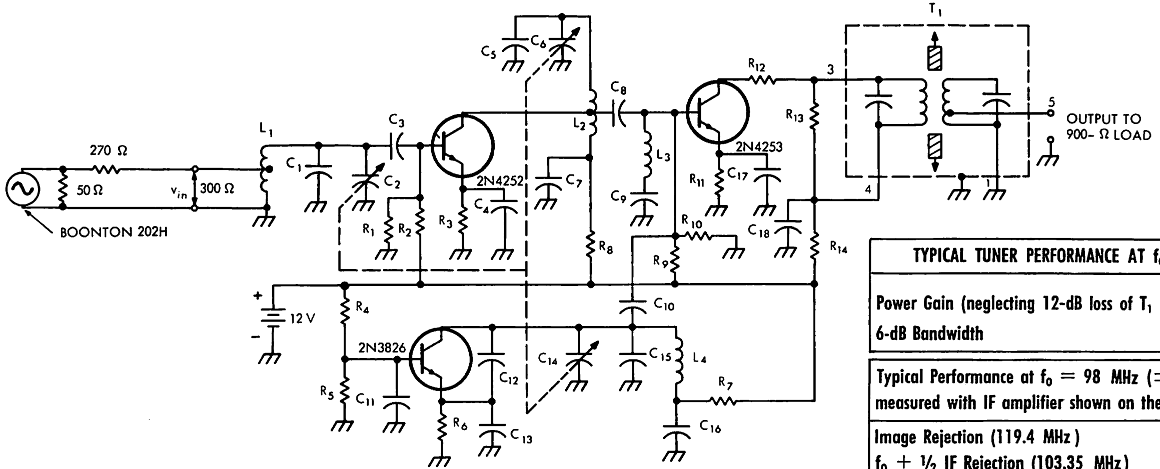
$$|y_{ie}| = \frac{I_b}{V_{be}}\bigg|_{V_{ce}=0} = \frac{1}{r_{iep}} + j\omega C_{iep} \qquad |y_{fe}| = \frac{I_c}{V_{be}}\bigg|_{V_{ce}=0}$$

$$|y_{re}| = \frac{I_b}{V_{ce}}\bigg|_{V_{be}=0} \qquad |y_{oe}| = \frac{I_c}{V_{ce}}\bigg|_{V_{be}=0} = \frac{1}{r_{oep}} + j\omega C_{oep}$$

FIGURE 20

TYPICAL APPLICATION DATA

TYPICAL FM TUNER



TYPICAL TUNER PERFORMANCE AT $f_0 = 98$ MHz	
Power Gain (neglecting 12-dB loss of T_1 secondary)	30 dB
6-dB Bandwidth	475 kHz
Typical Performance at $f_0 = 98$ MHz (± 22.5 kHz deviation) measured with IF amplifier shown on the next page	
Image Rejection (119.4 MHz)	56 dB
$f_0 + \frac{1}{2}$ IF Rejection (103.35 MHz)	71 dB
3-dB Limiting Level	13-μV input
Sensitivity for 30-dB $\frac{S+N}{N}$	3.5 μV
Overall 6-dB Bandwidth	270 kHz

CIRCUIT COMPONENT INFORMATION

TRANSFORMER

T_1: TRW #21160-R1 (or equivalent)

COILS

L_1: 4T #18 bus, 1/4″ ID, 1/2″ length, Turns Ratio 2.7:1

L_2: 4T #18 bus, 1/4″ ID, 1/2″ length, Turns Ratio 2.7:1

L_3: 1 μH

L_4: 3T #18 bus, 5/16″ ID, 5/8″ length

RESISTORS

R_1:	1 kΩ	R_8:	330 Ω
R_2:	4.7 kΩ	R_9:	10 kΩ
R_3:	1 kΩ	R_{10}:	2.7 kΩ
R_4:	9.1 kΩ	R_{11}:	820 Ω
R_5:	2.7 kΩ	R_{12}:	470 Ω
R_6:	1 kΩ	R_{13}:	9.1 kΩ
R_7:	330 Ω	R_{14}:	330 Ω

All resistors 1/2 W, ten percent tolerance

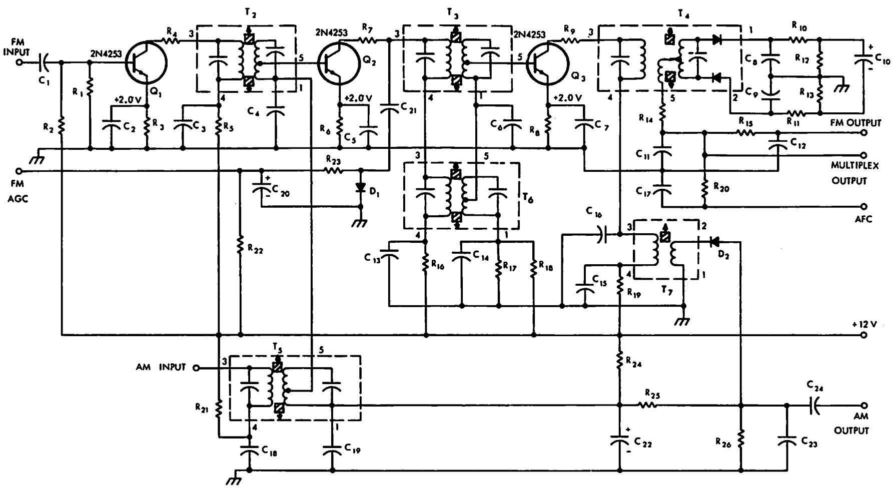
CAPACITORS

C_1:	10 pF	C_{10}:	1.2 pF
C_2:	†	C_{11}:	0.001 μF
C_3:	3.3 pF	C_{12}:	6.8 pF
C_4:	0.001 μF	C_{13}:	4.7 pF
C_5:	10 pF	C_{14}:	†
C_6:	†	C_{15}:	10 pF
C_7:	0.001 μF	C_{16}:	0.001 μF
C_8:	12 pF	C_{17}:	0.01 μF
C_9:	240 pF Dura Mica	C_{18}:	0.01 μF

† C_2, C_6, C_{14}: TRW #V0693, Model 57-3A, or equivalent

TYPICAL APPLICATION DATA

TYPICAL AM/FM IF AMPLIFIER



TYPICAL FM PERFORMANCE	
Data Taken with input on base of transistor Q_1	
IF frequency = 10.7 MHz	
1. Overall 6-dB Bandwidth (measured on base of Q_3)	300 kHz
2. Average Power Gain per Stage	26 dB
3. FM 3-dB Limiting Level	180 μV input
4. AM Rejection at 3-dB Limiting Level	> 30 dB
5. Maximum Audio Recovery (Full Limiting)	
$\pm$22.5 kHz Deviation	175 mV
$\pm$75 kHz Deviation	570 mV
6. Peak-to-Peak Separation of Ratio Detector	700 kHz

TYPICAL AM PERFORMANCE	
Data taken using Measurements Corporation signal generator model 65-B with a 0.05 μF capacitor and an 82 kΩ resistor in series with generator output.	
IF frequency = 455 kHz	
1. Overall 6-dB Bandwidth	10.6 kHz
2. Overall 20-dB Bandwidth	18.6 kHz
3. Maximum Audio Output (30% Modulation)	350 mV
4. AM Sensitivity at Pin 3 of T_5 for 20 mV Output (30% Modulation)	0.3 mV
5. AGC Figure-of-Merit	42 dB

CIRCUIT COMPONENT INFORMATION

TRANSFORMERS

T_1: Output Transformer of FM Tuner
T_2: TRW #21161-R1 (or equivalent)
T_3: TRW #21162-R1 (or equivalent)
T_4: TRW #20061-R1 (or equivalent)
T_5: TRW #21205-R1 (or equivalent)
T_6: TRW #21204-R1 (or equivalent)
T_7: TRW #18304-R1 (or equivalent)

DIODES

D_1: 1N4531
D_2: 1N295

RESISTORS

R_1:	10 kΩ	R_{14}:	68 Ω
R_2:	33 kΩ	R_{15}:	7.5 kΩ
R_3:	1 kΩ	R_{16}:	330 Ω
R_4:	220 Ω	R_{17}:	2.7 kΩ
R_5:	330 Ω	R_{18}:	8.2 kΩ
R_6:	1 kΩ	R_{19}:	330 Ω
R_7:	220 Ω	R_{20}:	200 kΩ
R_8:	1 kΩ	R_{21}:	330 Ω
R_9:	470 Ω	R_{22}:	33 kΩ
R_{10}:	1.5 kΩ	R_{23}:	4.7 kΩ
R_{11}:	1 kΩ	R_{24}:	82 kΩ
R_{12}:	8.2 kΩ	R_{25}:	27 kΩ
R_{13}:	8.2 kΩ	R_{26}:	3.3 kΩ

All resistors 1/2 W, ten percent tolerance

CAPACITORS

C_1:	0.02 μF	C_{13}:	0.05 μF
C_2:	0.01 μF	C_{14}:	0.05 μF
C_3:	0.01 μF	C_{15}:	0.05 μF
C_4:	0.001 μF	C_{16}:	0.0015 μF
C_5:	0.05 μF	C_{17}:	0.05 μF
C_6:	0.001 μF	C_{18}:	0.05 μF
C_7:	0.05 μF	C_{19}:	0.05 μF
C_8:	330 pF	C_{20}:	5 μF, 10 V, electrolytic
C_9:	330 pF	C_{21}:	6.8 pF
C_{10}:	2 μF, 10 V, electrolytic	C_{22}:	5 μF, 10 V, electrolytic
C_{11}:	330 pF	C_{23}:	0.05 μF
C_{12}:	0.01 μF	C_{24}:	5 μF, 15 V, electrolytic, Polarity determined by following stage

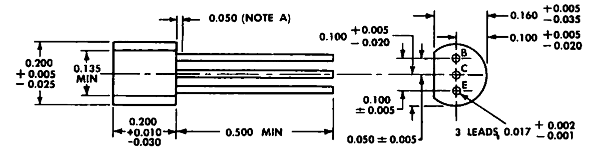
TYPES 2N4254, 2N4255, 2N4996, AND 2N4997
BULLETIN NO. DL-S 679593, OCTOBER 1967
REPLACES BULLETIN NO. DL-S 668495, MAY 1966

SILECT† HIGH-FREQUENCY TRANSISTORS FOR TUNER AND IF-AMPLIFIER STAGES IN FM AND AM/FM STEREO-MULTIPLEX RECEIVERS

- **Rugged, One-Piece Construction with In-Line Lead Configuration (2N4254, 2N4255) or Standard TO-18 100-mil Pin-Circle Configuration (2N4996, 2N4997)**

mechanical data

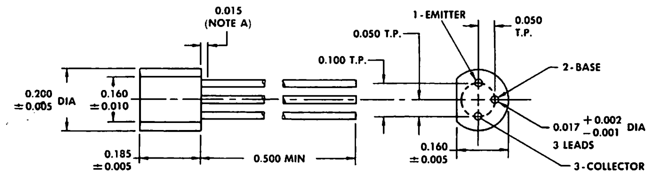
These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.



2N4254 AND 2N4255 CASE OUTLINE

***ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE**

NOTES: A. Lead diameter is not controlled in this area.
B. All dimensions are in inches.



***2N4996 AND 2N4997 CASE OUTLINE**

NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 V
Collector-Emitter Voltage (See Note 1)	18 V
Emitter-Base Voltage	4 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2 mW/deg.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent Pending

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N4254, 2N4255, 2N4996, AND 2N4997
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4254, 2N4996 MIN	TYP	MAX	2N4255, 2N4997 MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	30			30			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 2$ mA, $I_B = 0$, See Note 3	18			18			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$	4			4			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V, $I_E = 0$			100			100	nA
		$V_{CB} = 15$ V, $I_E = 0$, $T_A = 85°C$			10			10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 2$ mA	50			30		150	
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 2$ mA, $f = 100$ MHz	6		14	6		14	
$\lvert y_{fe}\rvert$	Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = 10$ V, $I_C = 2$ mA, $f = 10$ MHz					70		mmho
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz, See Note 4	0.1		0.65	0.1		0.65	pF
r_{oep}	Parallel-Equivalent Common-Emitter Short-Circuit Output Resistance	$V_{CE} = 10$ V, $I_C = 2$ mA, $f = 10$ MHz				50			kΩ
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -2$ mA, $f = 79.8$ MHz		14	20		14	20	ps

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N4254, 2N4996 TYP	UNIT
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 2$ mA, $R_G = 100\ \Omega$, $f = 100$ MHz	2.5	dB

*Indicates JEDEC registered data (typical data excluded)

TYPICAL CHARACTERISTICS

2N4255, 2N4997
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

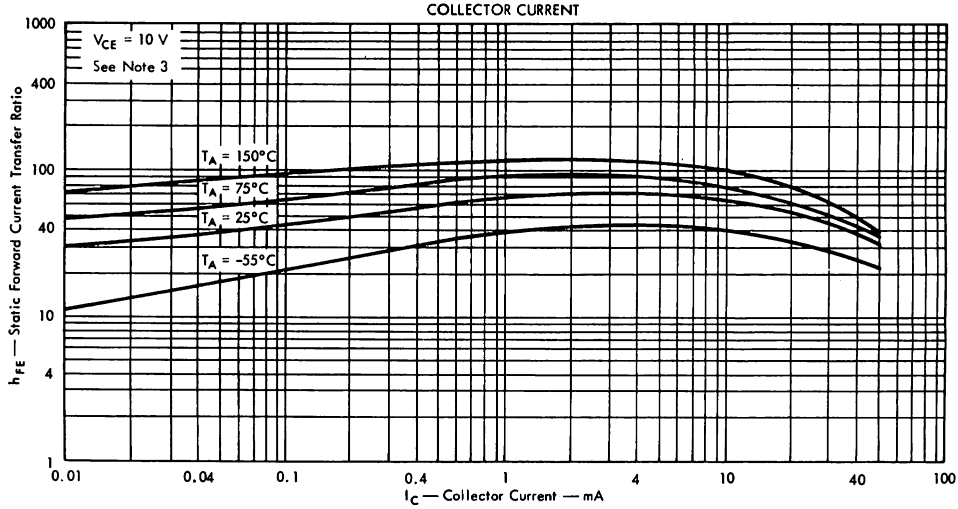


FIGURE 1

NOTES: 3. This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. Collector-Base Capacitance is measured using three-terminal measurement techniques with the emitter guarded.

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

2N4254, 2N4255
2N4996, 2N4997

BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE

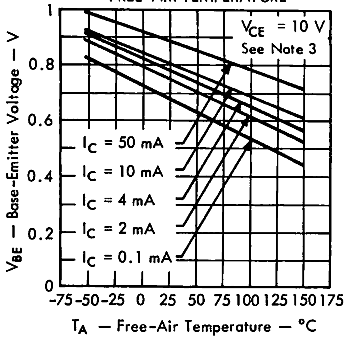


FIGURE 2

2N4254, 2N4255
2N4996, 2N4997

COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

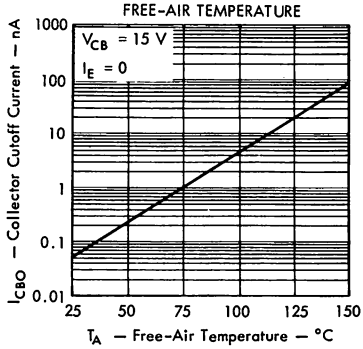


FIGURE 3

2N4255, 2N4997

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

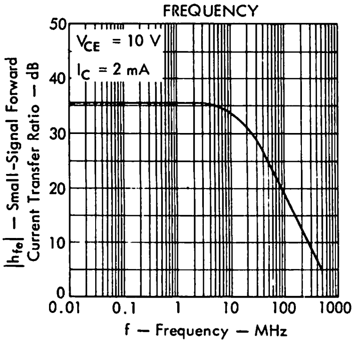


FIGURE 4

2N4254, 2N4255
2N4996, 2N4997

COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

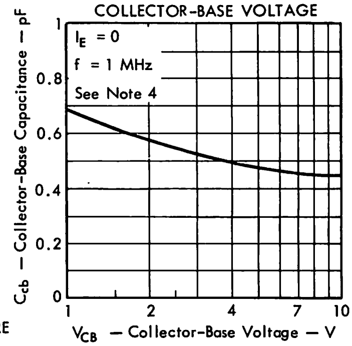


FIGURE 5

2N4254, 2N4996

SPOT NOISE FIGURE
vs
FREQUENCY

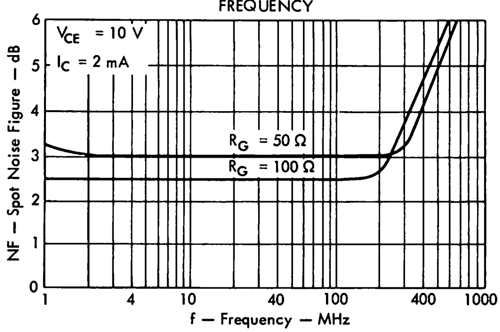


FIGURE 6

NOTES: 3. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. Collector-Base Capacitance is measured using three-terminal measurement techniques with the case and emitter guarded.

TYPICAL CHARACTERISTICS AT 455 kHz, $T_A = 25°C$

2N4255, 2N4997
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

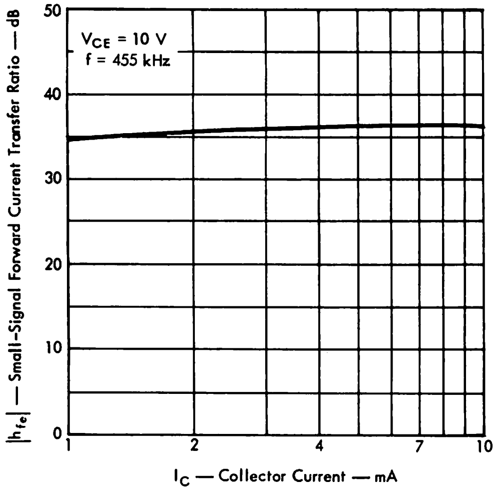


FIGURE 7

2N4255, 2N4997
SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

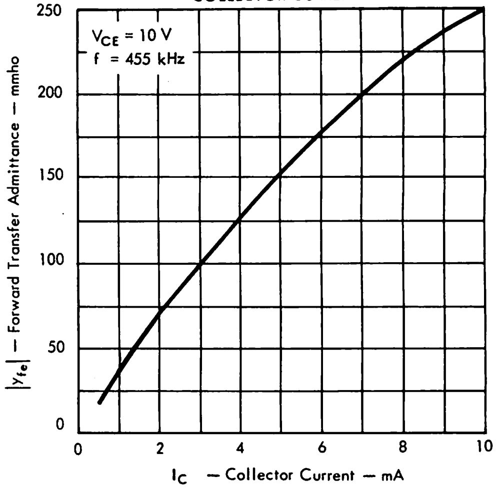


FIGURE 8

2N4255, 2N4997
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

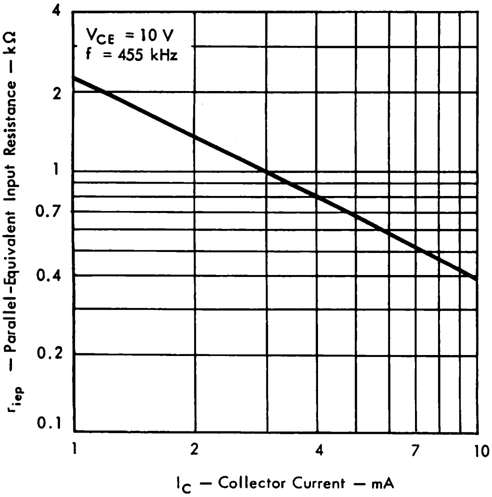


FIGURE 9

2N4255, 2N4997
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

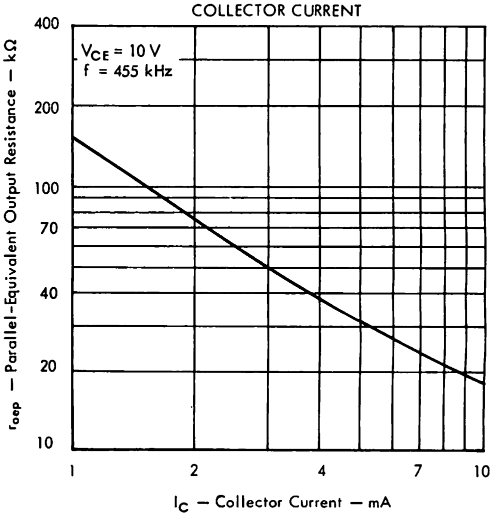


FIGURE 10

TYPICAL CHARACTERISTICS AT 10 MHz, $T_A = 25°C$

2N4255, 2N4997
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

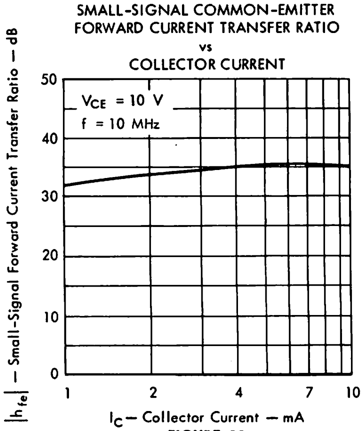


FIGURE 11

2N4255, 2N4997
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR-EMITTER VOLTAGE

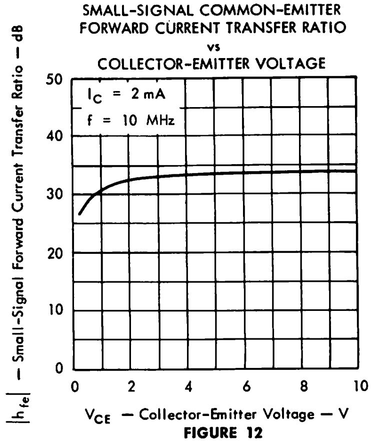


FIGURE 12

2N4255, 2N4997
SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

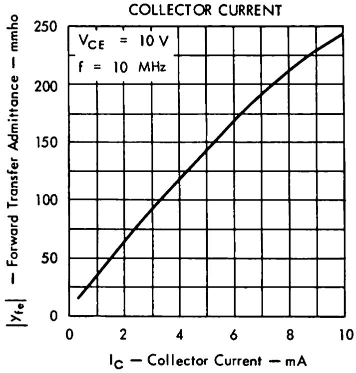


FIGURE 13

2N4255, 2N4997
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

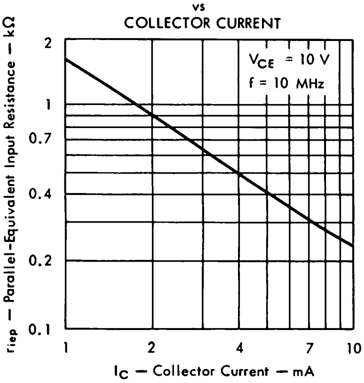


FIGURE 14

2N4255, 2N4997
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

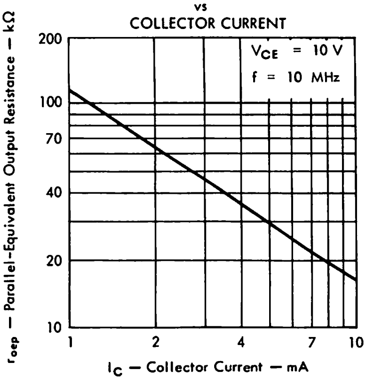


FIGURE 15

TYPICAL CHARACTERISTICS AT 100 MHz, $T_A = 25°C$

2N4254, 2N4996

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

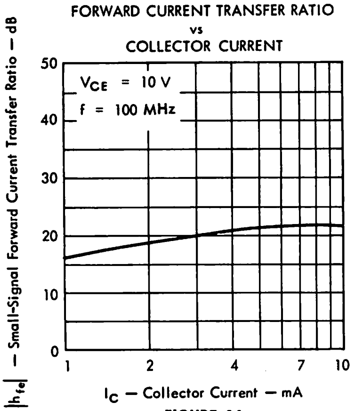


FIGURE 16

2N4254, 2N4996

SMALL-SIGNAL COMMON-EMITTER FORWARD TRANSFER ADMITTANCE vs COLLECTOR CURRENT

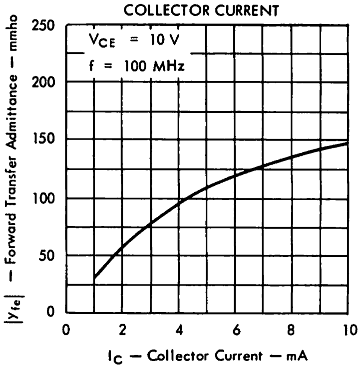


FIGURE 17

2N4254, 2N4996

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT INPUT RESISTANCE vs COLLECTOR CURRENT

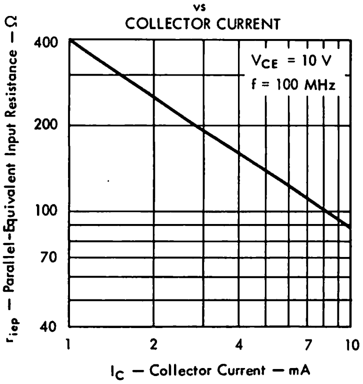


FIGURE 18

2N4254, 2N4996

PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER SHORT-CIRCUIT OUTPUT RESISTANCE vs COLLECTOR CURRENT

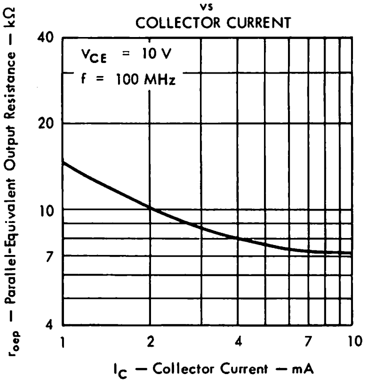
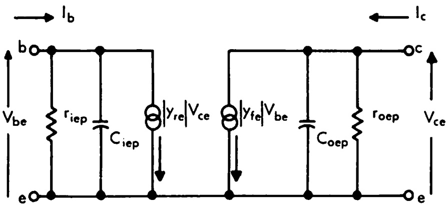


FIGURE 19

COMMON-EMITTER EQUIVALENT CIRCUIT USING SHORT-CIRCUIT "y" PARAMETERS



$$I_b = |y_{ie}| V_{be} + |y_{re}| V_{ce}$$
$$I_c = |y_{fe}| V_{be} + |y_{oe}| V_{ce}$$

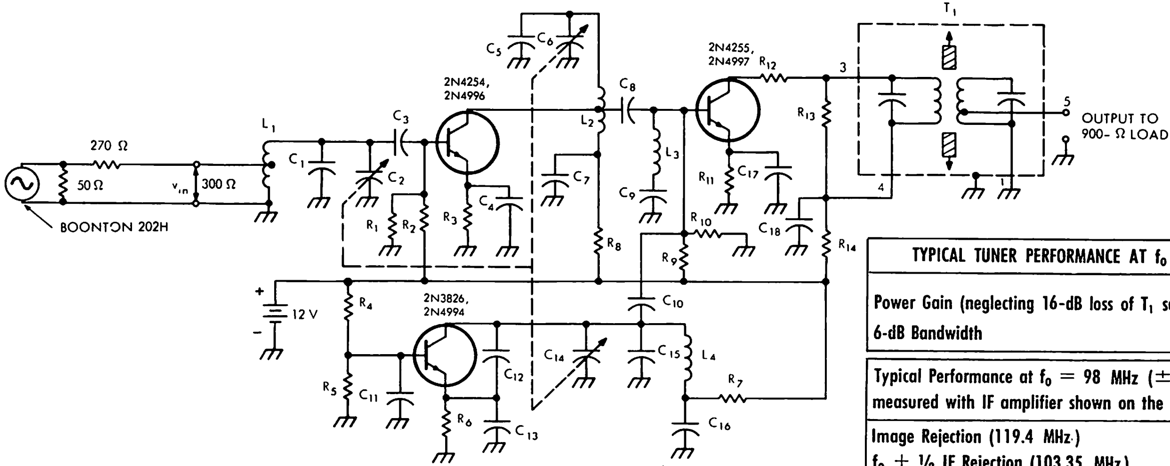
$$|y_{ie}| = \frac{I_b}{V_{be}}\bigg|_{V_{ce}=0} = \frac{1}{r_{iep}} + j\omega C_{iep} \qquad |y_{fe}| = \frac{I_c}{V_{be}}\bigg|_{V_{ce}=0}$$

$$|y_{re}| = \frac{I_b}{V_{ce}}\bigg|_{V_{be}=0} \qquad |y_{oe}| = \frac{I_c}{V_{ce}}\bigg|_{V_{be}=0} = \frac{1}{r_{oep}} + j\omega C_{oep}$$

FIGURE 20

TYPICAL APPLICATION DATA

TYPICAL FM TUNER



TYPICAL TUNER PERFORMANCE AT $f_0 = 98$ MHz	
Power Gain (neglecting 16-dB loss of T_1 secondary)	25 dB
6-dB Bandwidth	425 kHz

Typical Performance at $f_0 = 98$ MHz (± 22.5 kHz deviation) measured with IF amplifier shown on the next page	
Image Rejection (119.4 MHz)	56 dB
$f_0 + \frac{1}{2}$ IF Rejection (103.35 MHz)	71 dB
3-dB Limiting Level	43-μV input
Sensitivity for 30-dB $\frac{S+N}{N}$	3.5 μV
Overall 6-dB Bandwidth	260 kHz

CIRCUIT COMPONENT INFORMATION

TRANSFORMER

T_1: TRW #21157-R1 (or equivalent)

COILS

L_1: 4T #18 bus, 1/4″ ID, 1/2″ length, Turns Ratio 2.7:1

L_2: 4T #18 bus, 1/4″ ID, 1/2″ length, Turns Ratio 2.7:1

L_3: 1 μH

L_4: 3T #18 bus, 5/16″ ID, 5/8″ length

RESISTORS

R_1:	1 kΩ	R_8:	330 Ω
R_2:	4.7 kΩ	R_9:	10 kΩ
R_3:	1 kΩ	R_{10}:	2.7 kΩ
R_4:	9.1 kΩ	R_{11}:	820 Ω
R_5:	2.7 kΩ	R_{12}:	470 Ω
R_6:	1 kΩ	R_{13}:	9.1 kΩ
R_7:	330 Ω	R_{14}:	330 Ω

All resistors 1/2 W, ten percent tolerance

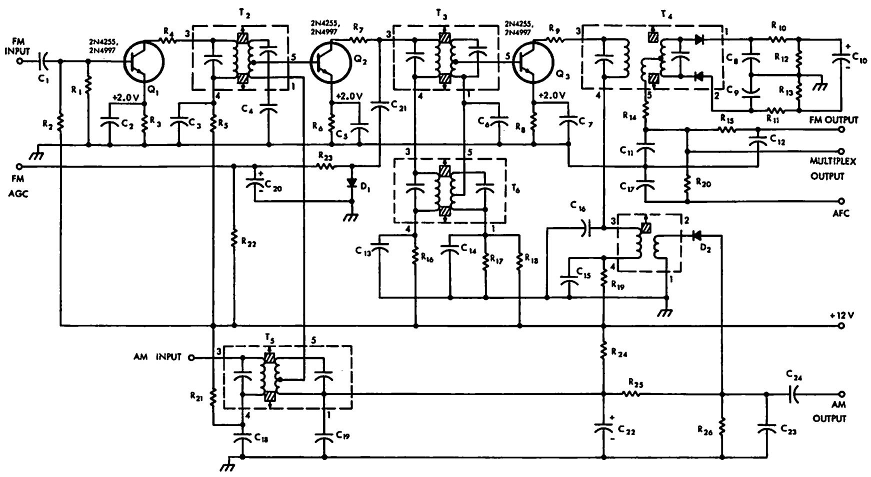
CAPACITORS

C_1:	10 pF	C_{10}:	1.2 pF
C_2:	†	C_{11}:	0.001 μF
C_3:	3.3 pF	C_{12}:	6.8 pF
C_4:	0.001 μF	C_{13}:	4.7 pF
C_5:	10 pF	C_{14}:	†
C_6:	†	C_{15}:	10 pF
C_7:	0.001 μF	C_{16}:	0.001 μF
C_8:	12 pF	C_{17}:	0.01 μF
C_9:	240 pF Dura Mica	C_{18}:	0.01 μF

† C_2, C_6, C_{14}: TRW #V0693, Model 57-3A, or equivalent

TYPICAL APPLICATION DATA

TYPICAL AM/FM IF AMPLIFIER



TYPICAL FM PERFORMANCE	
Data taken with input on base of transistor Q_1	
IF frequency = 10.7 MHz	
1. Overall 6-dB Bandwidth (measured on base of Q_3)	300 kHz
2. Average Power Gain per Stage	23 dB
3. FM 3-dB Limiting Level	350 μV input
4. AM Rejection at 3-dB Limiting Level	> 30 dB
5. Maximum Audio Recovery (Full Limiting)	
±22.5 kHz Deviation	175 mV
±75 kHz Deviation	570 mV
6. Peak-to-Peak Separation of Ratio Detector	700 kHz

TYPICAL AM PERFORMANCE	
Data taken using Measurements Corporation signal generator model 65-B with a 0.05-μF capacitor and an 82-kΩ resistor in series with generator output.	
IF frequency = 455 kHz	
1. Overall 6-dB Bandwidth	10.6 kHz
2. Overall 20-dB Bandwidth	18.6 kHz
3. Maximum Audio Output (30% Modulation)	350 mV
4. AM Sensitivity at Pin 3 of T_5 for 20-mV Output (30% Modulation)	0.3 mV
5. AGC Figure-of-Merit	42 dB

CIRCUIT COMPONENT INFORMATION

TRANSFORMERS

T_1: Output Transformer of FM Tuner
T_2: TRW #21158-R1 (or equivalent)
T_3: TRW #21159-R1 (or equivalent)
T_4: TRW #20061-R1 (or equivalent)
T_5: TRW #21205-R1 (or equivalent)
T_6: TRW #21204-R1 (or equivalent)
T_7: TRW #18304-R1 (or equivalent)

DIODES

D_1: 1N4531
D_2: 1N295

RESISTORS

R_1:	10 kΩ	R_{14}:	68 Ω
R_2:	33 kΩ	R_{15}:	7.5 kΩ
R_3:	1 kΩ	R_{16}:	330 Ω
R_4:	220 Ω	R_{17}:	2.7 kΩ
R_5:	330 Ω	R_{18}:	8.2 kΩ
R_6:	1 kΩ	R_{19}:	330 Ω
R_7:	220 Ω	R_{20}:	200 kΩ
R_8:	1 kΩ	R_{21}:	330 Ω
R_9:	470 Ω	R_{22}:	33 kΩ
R_{10}:	1.5 kΩ	R_{23}:	4.7 kΩ
R_{11}:	1 kΩ	R_{24}:	82 kΩ
R_{12}:	8.2 kΩ	R_{25}:	27 kΩ
R_{13}:	8.2 kΩ	R_{26}:	3.3 kΩ

All resistors 1/2 W, ten percent tolerance

CAPACITORS

C_1:	0.02 μF	C_{13}:	0.05 μF
C_2:	0.01 μF	C_{14}:	0.05 μF
C_3:	0.01 μF	C_{15}:	0.05 μF
C_4:	0.001 μF	C_{16}:	0.0015 μF
C_5:	0.05 μF	C_{17}:	0.05 μF
C_6:	0.001 μF	C_{18}:	0.05 μF
C_7:	0.05 μF	C_{19}:	0.05 μF
C_8:	330 pF	C_{20}:	5 μF, 10 V, electrolytic
C_9:	330 pF	C_{21}:	6.8 pF
C_{10}:	2 μF, 10 V, electrolytic	C_{22}:	5 μF, 10 V, electrolytic
C_{11}:	330 pF	C_{23}:	0.05 μF
C_{12}:	0.01 μF	C_{24}:	5 μF, 15 V, electrolytic, Polarity determined by following stage

TYPES 2N4418 AND 2N4419
BULLETIN NO. DL-S 689126, SEPTEMBER 1965
REVISED MAY 1968

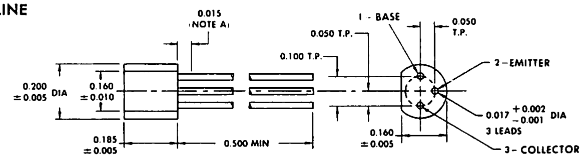
SILECT† TRANSISTORS FOR HIGH-SPEED SWITCHING APPLICATIONS

- **2N4418 Electrically Similar to the 2N2369**
- **Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N4418	2N4419
Collector-Base Voltage	40 V	30 V
Collector-Emitter Voltage (See Note 1)	40 V	30 V
Collector-Emitter Voltage (See Note 2)	15 V	12 V
Emitter-Base Voltage	4.5 V	4.5 V
Continuous Collector Current	← 200 mA →	
Peak Collector Current (See Note 3)	← 500 mA →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 360 mW →	
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 5)	← 500 mW →	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 260°C →	

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4418 MIN	2N4418 MAX	2N4419 MIN	2N4419 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	40		30		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 6	15		12		V
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = 10\ \mu A$, $V_{BE} = 0$	40		30		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$	4.5		4.5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20$ V, $I_E = 0$		0.4		0.4	μA
		$V_{CB} = 20$ V, $I_E = 0$, $T_A = 70°C$		3		3	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$		20		25	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 1$ V, $I_C = 10$ mA, See Note 6	40	120	30		
		$V_{CE} = 2$ V, $I_C = 100$ mA, See Note 6	20				
V_{BE}	Base-Emitter Voltage	$I_B = 1$ mA, $I_C = 10$ mA	0.72	0.87	0.72	0.87	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ mA, $I_C = 10$ mA		0.25		0.25	V
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 10$ mA, f = 100 MHz	5		4		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 5$ V, $I_E = 0$, f = 1 MHz, See Note 7		4		4	pF

NOTES:
1. This value applies when the base-emitter diode is short-circuited.
2. These values apply between 0 and 200 mA collector current when the base-emitter diode is open-circuited. Maximum rated voltage and 200 mA collector current may be simultaneously applied provided the time of application is 10 μs or less and the duty cycle is 2% or less.
3. This value applies for $t_p \leq 10\ \mu s$ and duty cycle $\leq 2\%$.
4. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
5. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.
6. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
7. C_{cb} is measured using three-terminal measurement techniques with the emitter guarded.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent Pending

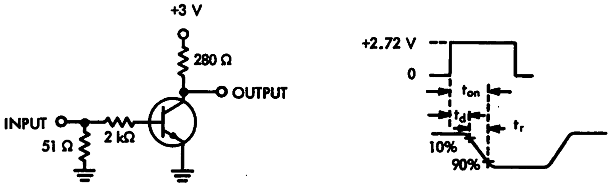
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	2N4418 MAX	2N4419 MAX	UNIT
t_d	Delay Time	$I_C = 10$ mA, $I_{B(1)} = 1$ mA, $V_{BE(off)} = 0$, $R_L = 280\ \Omega$, See Figure 1	10	10	ns
t_r	Rise Time		12	14	ns
t_{on}	Turn-on Time		20	22	ns
t_s	Storage Time	$I_C = 10$ mA, $I_{B(1)} = 1$ mA, $I_{B(2)} = -1$ mA, $R_L = 280\ \Omega$, See Figure 2	12	14	ns
t_f	Fall Time		14	16	ns
t_{off}	Turn-off Time		22	28	ns
t_s	Storage Time	$I_C = 10$ mA, $I_{B(1)} = 10$ mA, $I_{B(2)} = -10$ mA, See Figure 3	18	20	ns

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

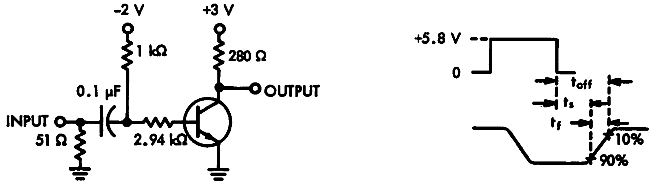
*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

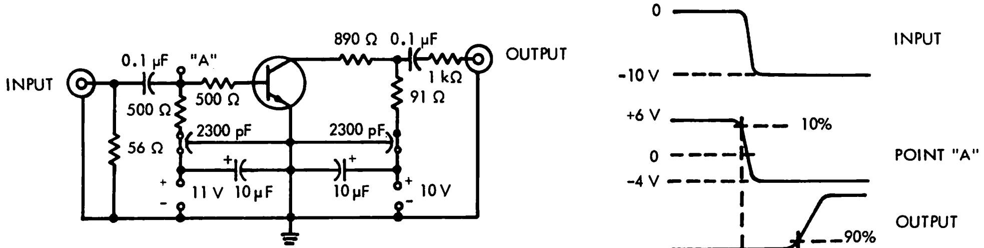
FIGURE 1



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 2



TEST CIRCUIT

(See Notes a and c)
VOLTAGE WAVEFORMS

FIGURE 3

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ ns, $t_p \geq 200$ ns, duty cycle $\leq 2\%$.

b. Waveforms of figures 1 and 2 are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 10$ pF.

c. Output waveform of figure 3 is monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $Z_{in} = 50\ \Omega$.

*Indicates JEDEC registered data

N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N4420, 2N4421
BULLETIN NO. DL-S 689132,
REVISED MAY 1968

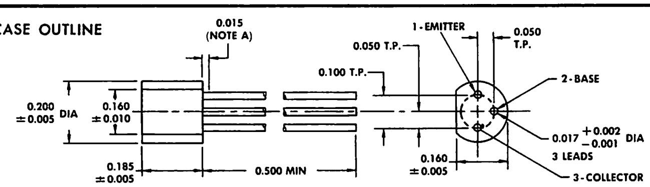
SILECT† TRANSISTORS FOR HIGH-SPEED SWITCHING APPLICATIONS

- **2N4420 Electrically Similar to the 2N3014**
- **Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N4420	2N4421
Collector-Base Voltage	40 V	30 V
Collector-Emitter Voltage (See Note 1)	40 V	30 V
Collector-Emitter Voltage (See Note 2)	20 V	12 V
Emitter-Base Voltage	5 V	5 V
Continuous Collector Current	←— 200 mA —→	
Peak Collector Current (See Note 3)	←— 500 mA —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←— 360 mW —→	
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 5)	←— 500 mW —→	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←— 260°C —→	

NOTES: 1. This value applies when the base-emitter diode is short-circuited.
2. This value applies between 0 and 200 mA collector current when the base-emitter diode is open-circuited. Maximum rated voltage and 200 mA collector current may be simultaneously applied provided the time of application is 10 μs or less and the duty cycle is 2% or less.
3. This value applies for $t_p \leq 10$ μs and duty cycle $\leq 2\%$.
4. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
5. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent Pending

TEXAS INSTRUMENTS
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TYPES 2N4420, 2N4421
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N4420 MIN	2N4420 MAX	2N4421 MIN	2N4421 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$		40		30		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$,	See Note 6	20		12		V
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $V_{BE} = 0$		40		30		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$		5		5		V
I_{CES}	Collector Cutoff Current	$V_{CE} = 20$ V, $V_{BE} = 0$			0.5		0.5	μA
		$V_{CE} = 20$ V, $V_{BE} = 0$, $T_A = 70°C$			4		4	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$			20		100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 0.4$ V, $I_C = 10$ mA	See Note 6	25				
		$V_{CE} = 0.4$ V, $I_C = 30$ mA		30	120	25		
		$V_{CE} = 1$ V, $I_C = 100$ mA		25				
V_{BE}	Base-Emitter Voltage	$I_B = 1$ mA, $I_C = 10$ mA	See Note 6	0.7	0.8			V
		$I_B = 3$ mA, $I_C = 30$ mA		0.75	0.95	0.75	0.95	V
		$I_B = 10$ mA, $I_C = 100$ mA			1.2			V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ mA, $I_C = 10$ mA	See Note 6		0.2			V
		$I_B = 3$ mA, $I_C = 30$ mA			0.2		0.2	V
		$I_B = 10$ mA, $I_C = 100$ mA			0.35			V
		$I_B = 3$ mA, $I_C = 30$ mA, $T_A = 70°C$			0.25			V
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 30$ mA, $f = 100$ MHz		3.5		3		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 5$ V, $I_E = 0$,	$f = 1$ MHz, See Note 7		5		5	pF
C_{eb}	Emitter-Base Capacitance	$V_{EB} = 0.5$ V, $I_C = 0$,	$f = 1$ MHz, See Note 7		8		8	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
7. C_{cb} and C_{ob} are measured using three-terminal measurement techniques with the third electrode (emitter or collector respectively) guarded.

*Indicates JEDEC registered data

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†			2N4420 MAX	2N4421 MAX	UNIT
t_d	Delay Time	$I_C = 30$ mA,	$I_{B(1)} = 3$ mA, $R_L = 93\ \Omega$,	$V_{BE(off)} = 0$, See Figure 1	8	10	ns
t_r	Rise Time				10	12	ns
t_{on}	Turn-on Time				16	18	ns
t_s	Storage Time	$I_C = 30$ mA,	$I_{B(1)} = 3$ mA, $R_L = 93\ \Omega$,	$I_{B(2)} = -3$ mA, See Figure 2	15	18	ns
t_f	Fall Time				10	12	ns
t_{off}	Turn-off Time				20	24	ns
t_s	Storage Time	$I_C = 10$ mA,	$I_{B(1)} = 10$ mA,	$I_{B(2)} = -10$ mA, See Figure 3	20		ns

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

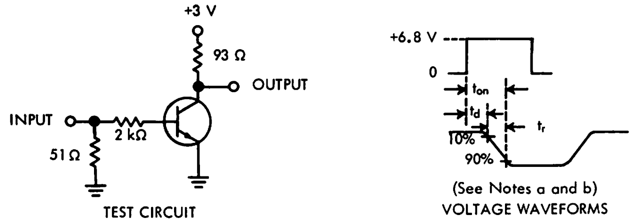


FIGURE 1

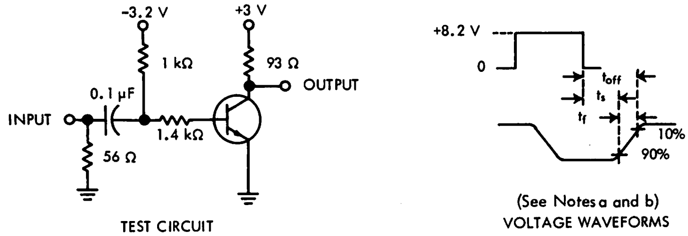


FIGURE 2

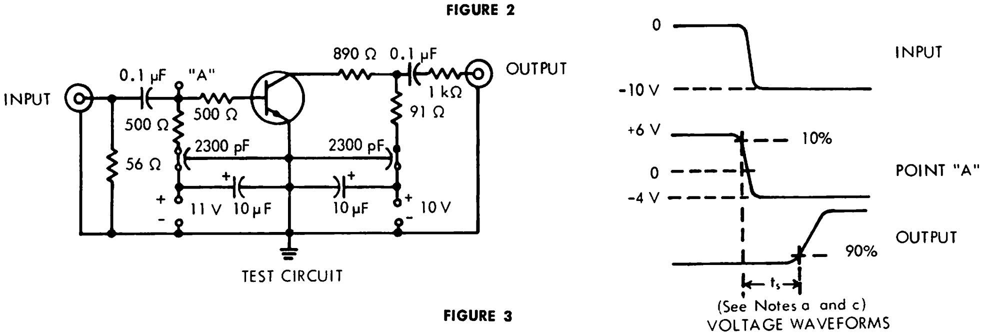


FIGURE 3

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ ns, $t_p \geq 200$ ns, duty cycle $\leq 2\%$.

b. Waveforms of figures 1 and 2 are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 10$ pF.

c. Output waveform of figure 3 is monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $Z_{in} = 50\ \Omega$.

*Indicates JEDEC registered data

TYPES 2N5449, 2N5450, 2N5451
BULLETIN NO. DL-S 6810924 MAY 1968

SILECT† TRANSISTORS

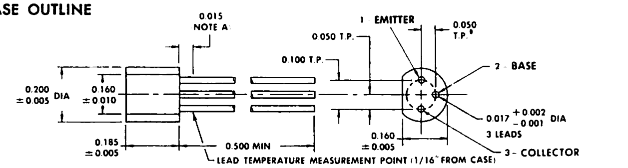
Encapsulated in Plastic for Such Applications as Medium-Power Amplifiers, Class B Audio Outputs, and Hi-Fi Drivers

- **Electrically Equivalent to 2N3704, 2N3705, and 2N3706**
- **For Complementary Use with 2N5447 and 2N5448**
- **Rugged, One-Piece Construction Features Standard 100-mil TO-18 Pin Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N5449 2N5450	2N5451
Collector-Base Voltage	50 V	40 V
Collector-Emitter Voltage (See Note 1)	30 V	20 V
Emitter-Base Voltage	5 V	5 V
Continuous Collector Current	←800 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←360 mW→	
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 3)	←500 mW→	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←260°C→	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
3. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.

†Trademark of Texas Instruments
‡Patent pending
*Indicates JEDEC registered data

TYPES 2N5449, 2N5450, 2N5451
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature**

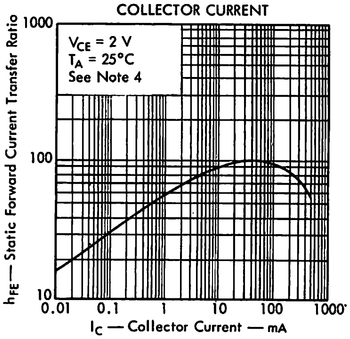
PARAMETER		TEST CONDITIONS	2N5449		2N5450		2N5451		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A, I_E = 0$	50		50		40		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 4	30		30		20		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A, I_C = 0$	5		5		5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20$ V, $I_E = 0$		100		100		100	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$		100		100		100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA, See Note 4	100	300	50	150	30	600	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V, $I_C = 100$ mA, See Note 4	0.5	1	0.5	1	0.5	1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ mA, $I_C = 100$ mA, See Note 4		0.6		0.8		1	V
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA, f = 20 MHz	5		5		5		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz, See Note 5		12		12		12	pF

NOTES: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
5. C_{cb} is measured using three-terminal measurement techniques with the emitter guarded.

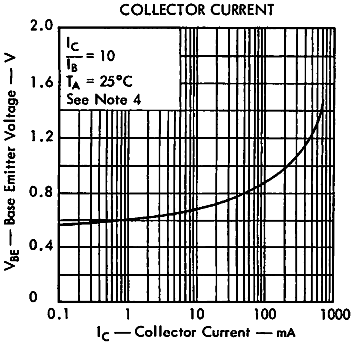
*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

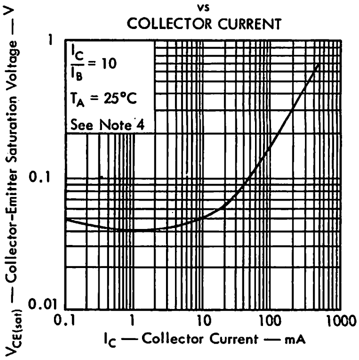
2N5450
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

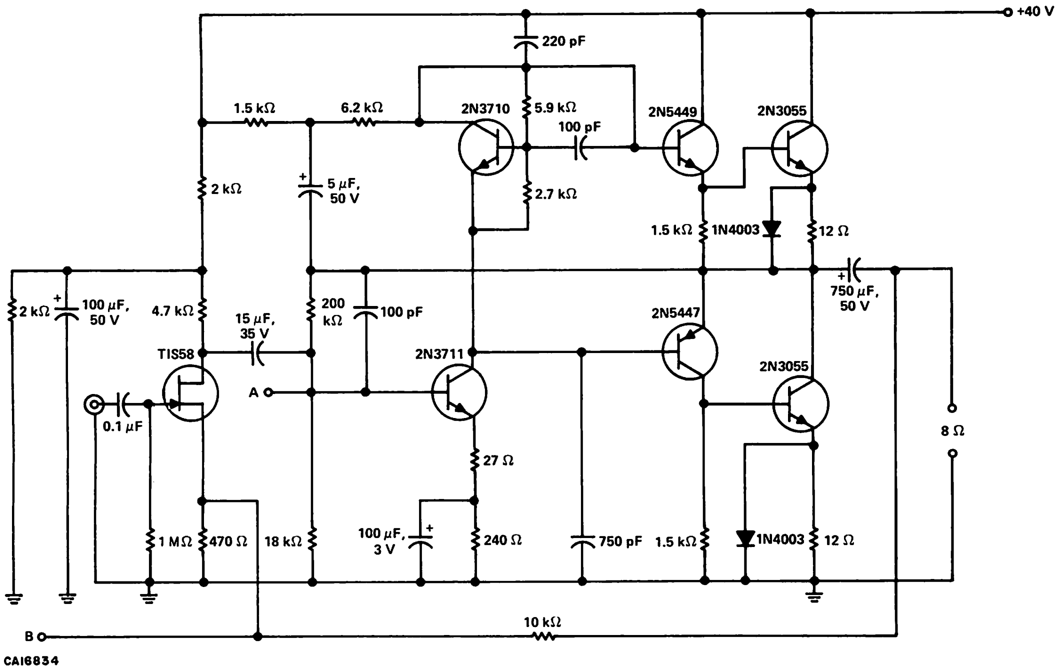


COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT



TYPICAL APPLICATION DATA

SILICON 15-WATT QUASI-COMPLEMENTARY POWER AMPLIFIER



TYPICAL PERFORMANCE SPECIFICATIONS	
Continuous Output Power	15 W @ 0.15% THD
Power Bandwidth @ 7.5 W	20 Hz – 20 kHz
Frequency Response ± 0.5 dB	10 Hz – 50 kHz
Total Harmonic Distortion @ 7.5 W	0.06%
Intermodulation Distortion @ 7.5 W	0.15%
Sensitivity @ 15 W	850 mV
Input Impedance	1 MΩ
Hum and Noise: "C" Weighting	
Input Shorted	−95 dB
Input Open	−85 dB
Damping Factor	48

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TYPES TIS37 AND TIS38
BULLETIN NO. DL-S 688535, APRIL 1966
REVISED MAY 1968

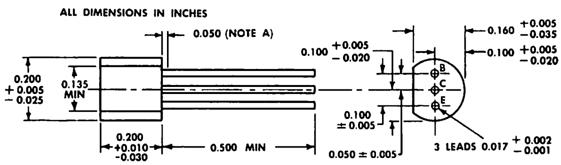
SILECT† TRANSISTORS
RECOMMENDED AS DESIGN REPLACEMENTS FOR GERMANIUM DRIFT TRANSISTORS IN:

- **AM Automobile Radio RF and IF Converter Applications**
- **Portable AM Radios**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTE A: Lead diameter is not controlled in this area.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	TIS37	TIS38
Collector-Base Voltage	−35 V	−35 V
Collector-Emitter Voltage (See Note 1)	−32 V	−32 V
Emitter-Base Voltage	−6 V	−4 V
Continuous Collector Current	←−50 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←360 mW→	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←260°C→	

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

†Trademark of Texas Instruments
‡Patent Pending

TYPES TIS37 AND TIS38
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS37 MIN	TIS37 TYP	TIS37 MAX	TIS38 MIN	TIS38 TYP	TIS38 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$, $I_E = 0$	−35			−35			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -1$ mA, $I_B = 0$, See Note 3	−32			−32			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$, $I_C = 0$	−6			−4			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -10$ V, $I_E = 0$			−100			−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -9$ V, $I_C = -1$ mA	45			25			
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -9$ V, $I_C = -1$ mA, f = 455 kHz	35		45	30		40	dB
		$V_{CE} = -9$ V, $I_C = -1$ mA, f = 10 MHz	18		30	14		26	dB
$\lvert y_{fe}\rvert$	Small-Signal Common-Emitter Forward Transfer Admittance	$V_{CE} = -9$ V, $I_C = -1$ mA, f = 455 kHz	32	35		32	35		mmho
f_T	Transition Frequency	$V_{CE} = -9$ V, $I_C = -1$ mA, See Note 4	80		320	50		200	MHz
C_{cb}	Collector-Base Capacitance	$V_{CB} = -9$ V, $I_E = 0$, f = 1 MHz, See Note 5	0.5	1.1	1.7	0.5	1.1	1.7	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = -9$ V, $I_E = 1$ mA, f = 79.8 MHz		30	70		30	70	ps

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS37 TYP	UNIT
NF	Spot Noise Figure	$V_{CE} = -9$ V, $I_C = -1$ mA, $R_G = 75\ \Omega$, f = 1 MHz	2.5	dB
		$V_{CE} = -9$ V, $I_C = -1$ mA, $R_G = 1\ k\Omega$, f = 1 MHz	1	dB

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

TIS37
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

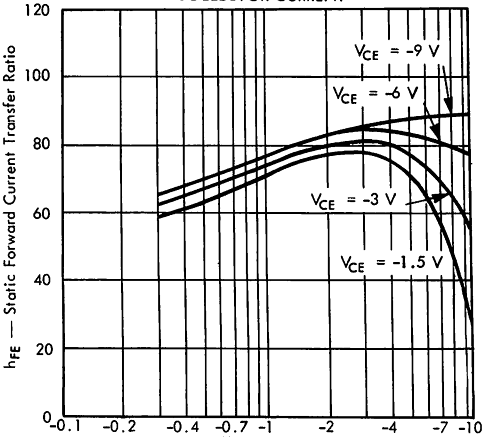


FIGURE 1

TIS37
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR-EMITTER VOLTAGE

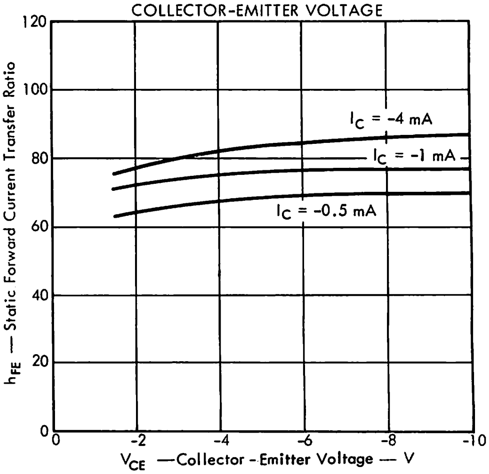


FIGURE 2

NOTES: 3. This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. To obtain f_T, the $\lvert h_{fe}\rvert$ response with frequency is extrapolated at the rate of −6 dB per octave from f = 10 MHz to the frequency at which $\lvert h_{fe}\rvert = 1$.
5. C_{cb} is measured using three-terminal measurement techniques with the emitter guarded.

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

TIS37
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

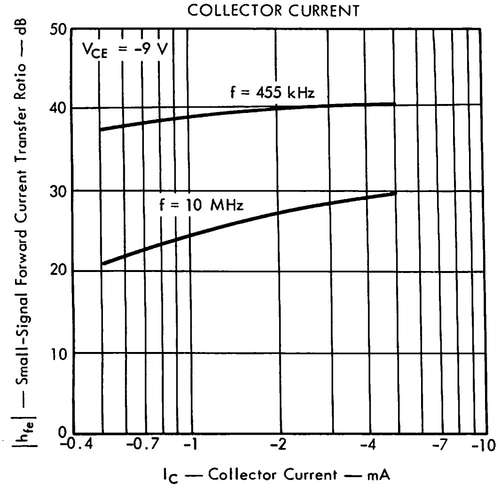


FIGURE 3

TIS37 TIS38
SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
COLLECTOR CURRENT

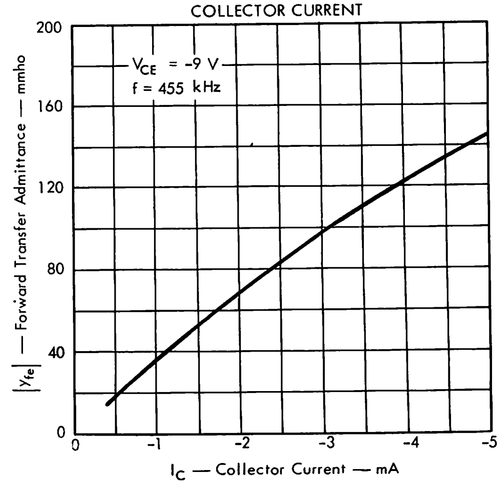


FIGURE 4

TIS38
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT INPUT RESISTANCE
vs
COLLECTOR CURRENT

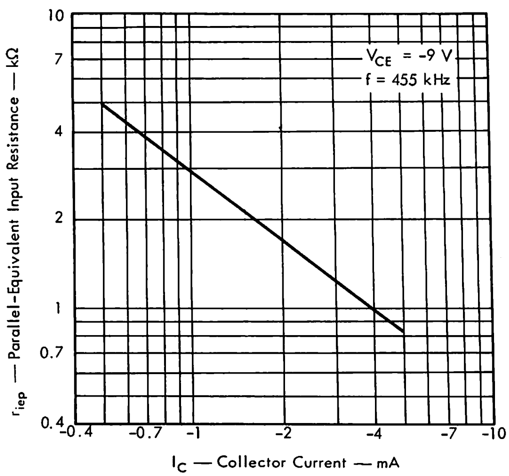


FIGURE 5

TIS38
PARALLEL-EQUIVALENT SMALL-SIGNAL COMMON-EMITTER
SHORT-CIRCUIT OUTPUT RESISTANCE
vs
COLLECTOR CURRENT

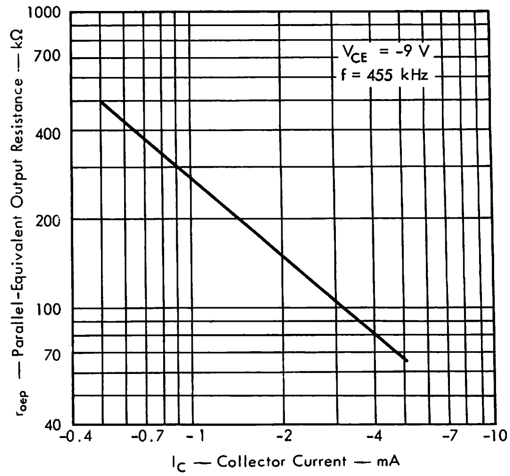


FIGURE 6

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

TIS37 TIS38
COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

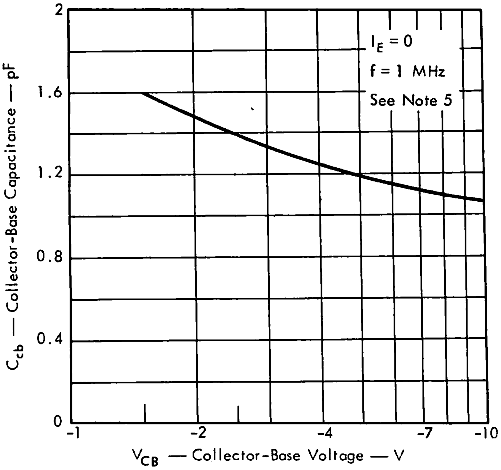


FIGURE 7

TIS37 TIS38
COLLECTOR-BASE TIME CONSTANT
vs
EMITTER CURRENT

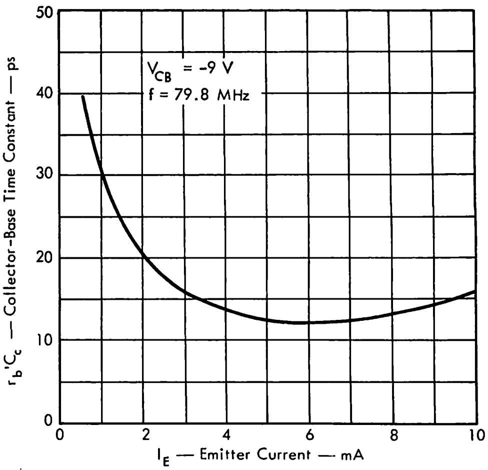


FIGURE 8

TIS37
NOISE FIGURE
vs
COLLECTOR CURRENT

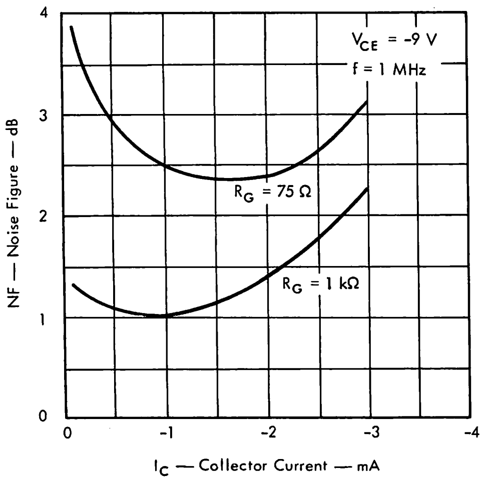


FIGURE 9

TIS37
NOISE FIGURE
vs
GENERATOR RESISTANCE

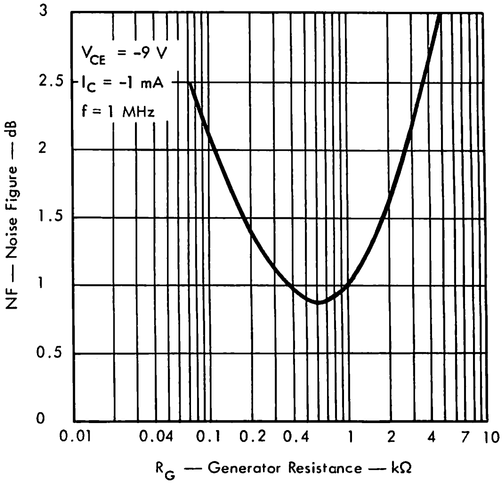
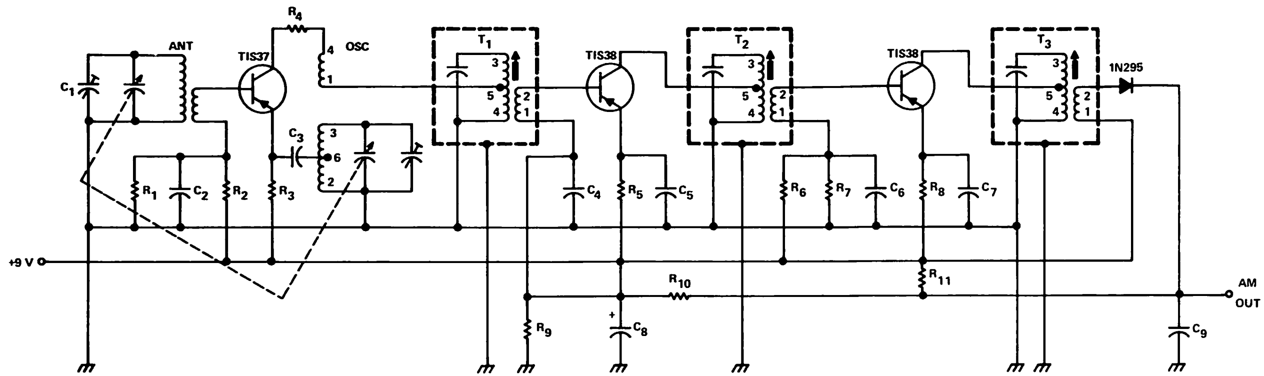


FIGURE 10

NOTE 5: C_{cb} is measured using three-terminal measurement techniques with emitter guarded.

TYPICAL APPLICATION DATA

AM CONVERTER WITH TWO-STAGE IF AMPLIFIER



CA16835

TYPICAL PERFORMANCE CHARACTERISTICS (Output Terminated with 5 kΩ)	
Sensitivity for 10 dB (S+N)/N	85 μV/m
Audio Output at 10 dB (S+N)/N level	1.0 mV
Sensitivity for 20 dB (S+N)/N	250 μv/m
Audio Output at 20 dB (S+N)/N level	6.0 mV
RF Overload for 30% Modulation	170 mV/m
Modulation Overload at 80% Modulation	100 mV/m
−10 kHz Adjacent Channel Rejection	14.0 dB
+10 kHz Adjacent Channel Rejection	16.0 dB
AGC Figure of Merit	41 dB
Image Rejection at 600 kHz	43 dB
6-dB Bandwidth at 600 kHz	7.2 kHz

CIRCUIT COMPONENT INFORMATION

CAPACITORS

C_1: TRW #V0916 (Type 42-2a) or equivalent
C_2: 0.05 μF
C_3: 0.01 μF
C_4: 0.05 μF
C_5: 0.05 μF
C_6: 0.05 μF
C_7: 0.05 μF
C_8: 5 μF, 12 V electrolytic
C_9: 0.1 μF

RESISTORS

R_1: 33 kΩ
R_2: 4.7 kΩ
R_3: 2.7 kΩ
R_4: 220 Ω
R_5: 680 Ω
R_6: 1.2 kΩ
R_7: 18 kΩ
R_8: 680 Ω
R_9: 68 kΩ
R_{10}: 6.8 kΩ
R_{11}: 1.5 kΩ

TRANSFORMERS

Antenna: TRW #19029 or equivalent
Oscillator: TRW #18908-R1 or equivalent
T_1: TRW #21484 or equivalent
T_2: TRW #21485 or equivalent
T_3: TRW #21486 or equivalent

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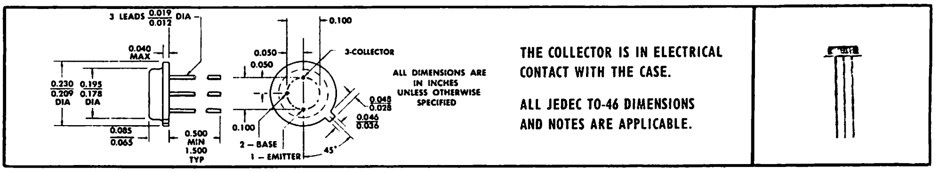
TYPES 2N2604, 2N2605
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N2604, 2N2605
BULLETIN NO. DL-S 644057, FEBRUARY 1964
REVISED SEPTEMBER 1965

FOR EXTREMELY LOW-LEVEL, LOW-NOISE, HIGH-GAIN, SMALL-SIGNAL AMPLIFIER APPLICATIONS

- **Recommended for Complementary Use With TI 2N929, 2N930, and 2N2586 N-P-N Transistors**
- **Guaranteed h_{FE} at 10 μa, T_A = −55°C and 25°C**
- **Guaranteed Low-Noise Characteristics**
- **Usable at Collector Currents as Low as 1 μa**

*mechanical data



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 v
Collector-Emitter Voltage (See Note 1)	45 v
Emitter-Base Voltage	6 v
Collector Current	30 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	400 mw
Storage Temperature Range	−65°C to + 200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2604 MIN	2N2604 MAX	2N2605 MIN	2N2605 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -10\ \mu a$, $I_E = 0$	−60		−60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 3	−45		−45		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu a$, $I_C = 0$	−6		−6		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -45$ v, $I_E = 0$		−10		−10	na
I_{CES}	Collector Cutoff Current	$V_{CE} = -45$ v, $V_{BE} = 0$		−10		−10	na
		$V_{CE} = -45$ v, $V_{BE} = 0$, $T_A = 170°C$		−10		−10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ v, $I_C = 0$		−2		−2	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -10\ \mu a$	40	120	100	300	
		$V_{CE} = -5$ v, $I_C = -10\ \mu a$, $T_A = -55°C$	10		20		
		$V_{CE} = -5$ v, $I_C = -500\ \mu a$	60		150		
		$V_{CE} = -5$ v, $I_C = -10$ ma		350		600	
V_{BE}	Base-Emitter Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma	−0.7	−0.9	−0.7	−0.9	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma		−0.5		−0.5	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc	25	35	25	35	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc		10×10^{-4}		10×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc		1.0		1.0	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc	60	350	150	600	
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -500\ \mu a$, f = 30 Mc	1.0		1.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 Mc		6		6	pf
$Re(h_{ie})$	Real Part of Small-Signal Common-Emitter Input Impedance	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 100 Mc		200		200	ohm

NOTES: 1. This value applies between 0 and 10 ma collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.28 mw/C°.
3. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≈ 2%.

*Indicates JEDEC registered data.

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N2604 MAX	2N2605 MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CE} = -5$ v, $I_C = -10$ μa, $R_G = 10$ kΩ Noise Bandwidth = 15.7 kc, (See Note 4)	4.0	3.0	db

NOTE 4. Average Noise Figure is measured in an amplifier with low-frequency-response down 3 db at 10 cps.

PARAMETER MEASUREMENT INFORMATION

A PROCEDURE FOR MEASURING AVERAGE NOISE FIGURE OF 2N2604 AND 2N2605

1. Connect audio oscillator to true RMS vacuum-tube voltmeter and adjust V_S for 0.81 mv.
2. Connect equipment as shown in block diagram, Figure 1.
3. Adjust d-c biases.
4. Adjust potentiometer for full scale deflection (10 db) on the voltmeter using the highest suitable range. The output is monitored on the oscilloscope to insure that clipping does not occur and that there is no extraneous pickup (e.g. 60 cps).
5. Remove V_S.
6. For a noiseless transistor the output would drop 20 db when the signal is removed from the input. Anything less than a 20 db drop is the noise figure of the transistor (e.g. — for a 17 db drop, NF = 3 db).

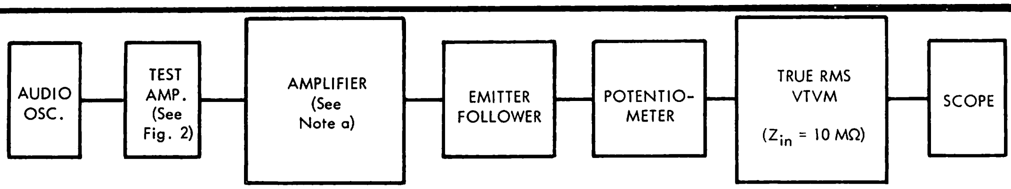


FIGURE 1 — BLOCK DIAGRAM

Note a: The amplifier has the following specifications: A_V, 100 maximum; Frequency Response, down 3 db at 10 cps and 10 kc with a high-frequency roll-off of 6 db/octave; Equivalent Input Noise, 1.5 μv RMS maximum for 10 kc bandwidth and 4 μv RMS maximum for 100 kc bandwidth between 10 cps and 1 mc; Z_{in}, 8 MΩ in parallel with 30 pf; Z_{out}, 600 Ω in series with 8 μf.

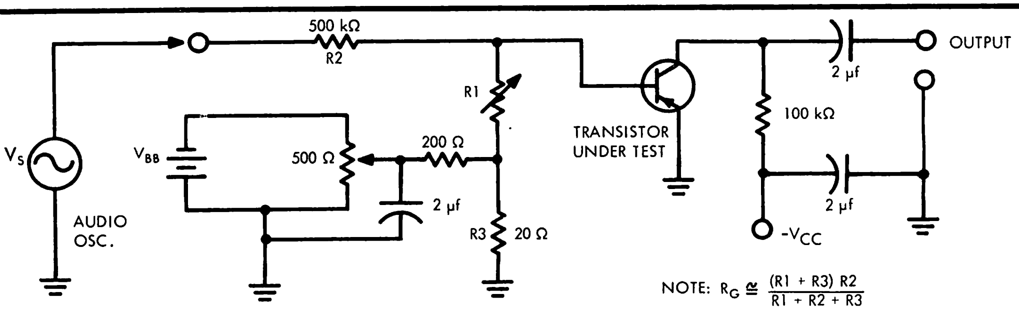


FIGURE 2 — TEST AMPLIFIER

*Indicates JEDEC registered data.

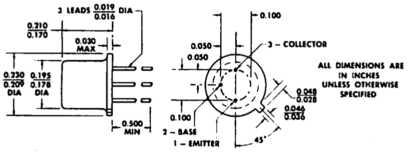
TYPES 2N2894, 2N3012
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N2894 AND 2N3012
BULLETIN NO. DL-S 645051, AUGUST 1964

DESIGNED FOR HIGH-SPEED SWITCHING APPLICATIONS

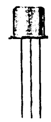
- **Guaranteed $V_{CE(sat)}$ — 0.5 v Max at 100 ma**
- **High f_T — 400 Mc Min**
- **Recommended for Complementary Use With 2N2368 and 2N3011**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−12 v
Collector-Emitter Voltage (See Note 1)	−12 v
Emitter-Base Voltage	−4 v
Collector Current	−200 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.36 w
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	1.2 w
Operating Collector Junction Temperature	200°C
Storage Temperature Range	−65°C to +200°C
Lead Temperature 1/16 Inch from Case For 60 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2894 MIN	2N2894 MAX	2N3012 MIN	2N3012 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -10\ \mu a$, $I_E = 0$	−12		−12		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 4	−12		−12		v
BV_{CES}	Collector-Emitter Breakdown Voltage	$I_C = -10\ \mu a$, $V_{BE} = 0$	−12		−12		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−4		−4		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -6$ v, $I_E = 0$, $T_A = 125°C$		−10			μa
I_{CES}	Collector Cutoff Current	$V_{CE} = -6$ v, $V_{BE} = 0$		−80		−80	na
		$V_{CE} = -6$ v, $V_{BE} = 0$, $T_A = 85°C$				−5	μa
I_B	Base Current	$V_{CE} = -6$ v, $V_{BE} = 0$		80		30	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.3$ v, $I_C = -10$ ma, See Note 4	30		25		
		$V_{CE} = -0.5$ v, $I_C = -30$ ma, See Note 4	40	150	30	120	
		$V_{CE} = -1$ v, $I_C = -100$ ma, See Note 4	25		20		
		$V_{CE} = -0.5$ v, $I_C = -30$ ma, $T_A = -55°C$, See Note 4	17				
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ ma, $I_C = -10$ ma, See Note 4		−0.15		−0.15	v
		$I_B = -3$ ma, $I_C = -30$ ma, See Note 4		−0.20		−0.20	v
		$I_B = -10$ ma, $I_C = -100$ ma, See Note 4		−0.50		−0.50	v
		$I_B = -3$ ma, $I_C = -30$ ma, $T_A = 85°C$, See Note 4				−0.40	v
V_{BE}	Base-Emitter Voltage	$I_B = -1$ ma, $I_C = -10$ ma, See Note 4	−0.78	−0.98	−0.78	−0.98	v
		$I_B = -3$ ma, $I_C = -30$ ma, See Note 4	−0.85	−1.2	−0.85	−1.2	v
		$I_B = -10$ ma, $I_C = -100$ ma, See Note 4		−1.7		−1.7	v

NOTES: 1. This value applies between 10 μa and 10 ma collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.06 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 6.85 mw/C°.
4. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle = 1%.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C free-air temperature

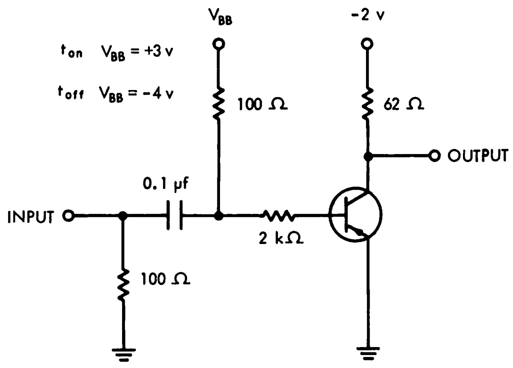
PARAMETER		TEST CONDITIONS	2N2894 MIN	2N2894 MAX	2N3012 MIN	2N3012 MAX	UNIT
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ v, $I_C = -30$ ma, f = 100 Mc	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 140 kc		6		6	pf
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ v, $I_C = 0$, f = 140 kc		6		6	pf

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	2N2894 MAX	2N3012 MAX	UNIT
t_{on}	Turn-On Time	$I_C = -30$ ma, $I_{B(1)} = -1.5$ ma, $V_{BE(off)} = 3$ v, $R_L = 62\ \Omega$, See Figure 1	60	60	nsec
t_{off}	Turn-Off Time	$I_C = -30$ ma, $I_{B(1)} = -1.5$ ma, $I_{B(2)} = 1.5$ ma, $R_L = 62\ \Omega$, See Figure 1	90	75	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



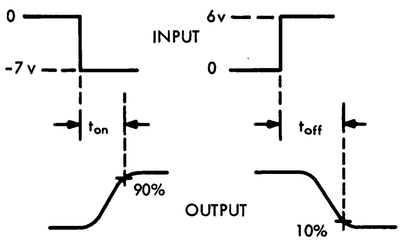


FIGURE 1 — TURN-ON AND TURN-OFF TIMES

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, PW > 200 nsec.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100$ kΩ.

*Indicates JEDEC registered data.

TYPES 2N2904, 2N2905, 2N2906, 2N2907
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N2904, 2N2905, 2N2906, 2N2907
BULLETIN NO. DL-S 645045, MARCH 1964
REVISED SEPTEMBER 1965

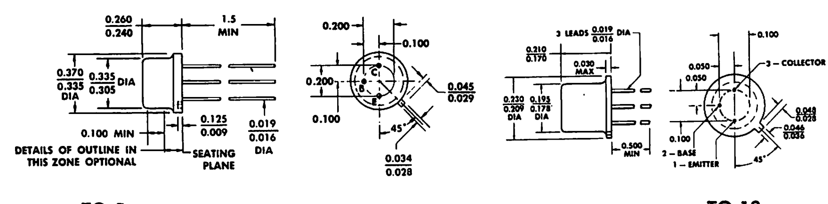
DESIGNED FOR HIGH-SPEED, MEDIUM-POWER SWITCHING AND GENERAL PURPOSE AMPLIFIER APPLICATIONS

- **High Breakdown Voltage Combined With Very-Low Saturation Voltage**
- **DC Beta — Guaranteed From 100 μa to 500 ma**

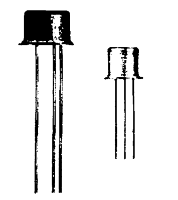
***mechanical data**

Device types 2N2904 and 2N2905 are in JEDEC TO-5 packages.
Device types 2N2906 and 2N2907 are in JEDEC TO-18 packages.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



TO-5 DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED TO-18



TO-5 TO-18

***absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)**

	2N2904 2N2905	2N2906 2N2907
Collector-Base Voltage	−60 v	−60 v
Collector-Emitter Voltage (See Note 1)	−40 v	−40 v
Emitter-Base Voltage	−5 v	−5 v
Collector Current	−0.6 a	−0.6 a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Notes 2 and 3)	0.6 w	0.4 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Notes 4 and 5)	3 w	1.8 w
Storage Temperature Range	−65°C to +200°C	

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

	PARAMETER	TEST CONDITIONS	2N2904 2N2906 MIN	2N2904 2N2906 MAX	2N2905 2N2907 MIN	2N2905 2N2907 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -10\ \mu a$, $I_E = 0$	−60		−60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 6	−40		−40		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu a$, $I_C = 0$	−5		−5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -50$ v, $I_E = 0$		−20		−20	na
		$V_{CB} = -50$ v, $I_E = 0$, $T_A = 150°C$		−20		−20	μa
I_{CEX}	Collector Cutoff Current	$V_{CE} = -30$ v, $V_{BE} = 0.5$ v		−50		−50	na
I_B	Base Current	$V_{CE} = -30$ v, $V_{BE} = 0.5$ v		50		50	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -10$ v, $I_C = -100\ \mu a$	20		35		
		$V_{CE} = -10$ v, $I_C = -1$ ma	25		50		
		$V_{CE} = -10$ v, $I_C = -10$ ma	35		75		
		$V_{CE} = -10$ v, $I_C = -150$ ma, See Note 6	40	120	100	300	
		$V_{CE} = -10$ v, $I_C = -500$ ma, See Note 6	20		30		
V_{BE}	Base-Emitter Voltage	$I_B = -15$ ma, $I_C = -150$ ma, See Note 6		−1.3		−1.3	v
		$I_B = -50$ ma, $I_C = -500$ ma, See Note 6		−2.6		−2.6	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -15$ ma, $I_C = -150$ ma, See Note 6		−0.4		−0.4	v
		$I_B = -50$ ma, $I_C = -500$ ma, See Note 6		−1.6		−1.6	v

NOTES: 1. This value applies between 0 and 100 ma collector current when the base-emitter diode is open-circuited.
2. Derate 2N2904 and 2N2905 linearly to 200°C free-air temperature at the rate of 3.43 mw/C°.
3. Derate 2N2906 and 2N2907 linearly to 200°C free-air temperature at the rate of 2.28 mw/C°.
4. Derate 2N2904 and 2N2905 linearly to 200°C case temperature at the rate of 17.3 mw/C°.
5. Derate 2N2906 and 2N2907 linearly to 200°C case temperature at the rate of 10.3 mw/C°.
6. These parameters must be measured using pulse techniques. PW $\leq$ 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS			ALL MIN	ALL MAX	UNIT
C_{ob}	Common-Base Open Circuit Output Capacitance	$V_{CB} = -10$ v,	$I_E = 0$,	f = 100 kc		8.0	pf
C_{ib}	Common-Base Open Circuit Input Capacitance	$V_{EB} = -2$ v,	$I_C = 0$,	f = 100 kc		30	pf
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -20$ v,	$I_C = -50$ ma,	f = 100 Mc	2.0		

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_d	Delay Time	$I_C = -150$ ma, $I_{B(1)} = -15$ ma, $V_{BE(off)} = 0$, $R_L = 200\ \Omega$, See Figure 1	10	nsec
t_r	Rise Time		40	nsec
t_{on}	Turn-On Time		45	nsec
t_s	Storage Time	$I_C = -150$ ma, $I_{B(1)} = -13$ ma, $I_{B(2)} = 17$ ma, $R_L = 37\ \Omega$, See Figure 2	80	nsec
t_f	Fall Time		30	nsec
t_{off}	Turn-Off Time		100	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

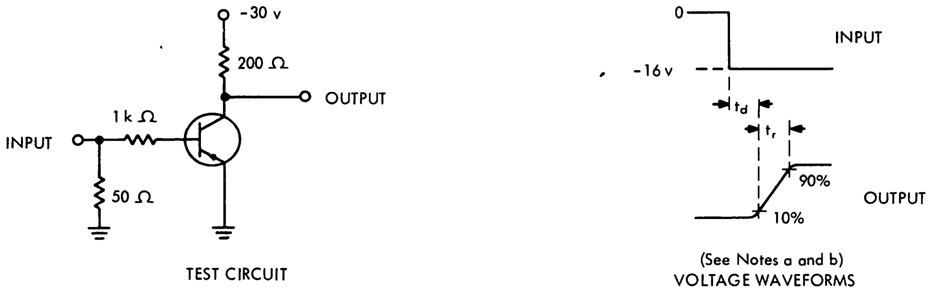


FIGURE 1

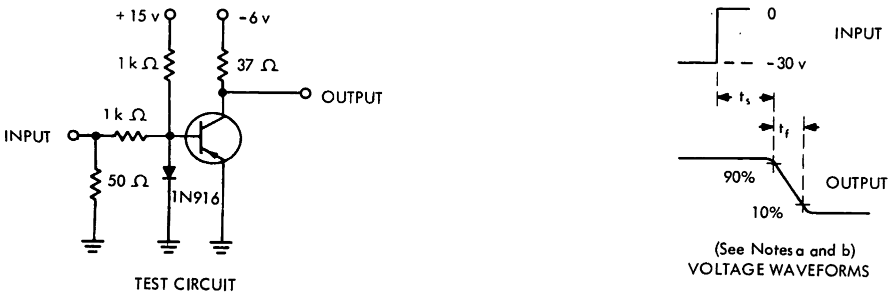


FIGURE 2

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 2$ nsec, $t_f \leq 2$ nsec, PW = 200 nsec, PRR = 150 pps.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ nsec, $R_{in} = 10\ M\Omega$.

*Indicates JEDEC registered data.

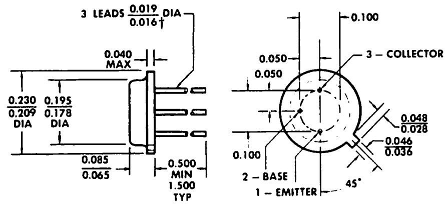
TYPES 2N2944, 2N2945, 2N2946, 2N2944A, 2N2945A, 2N2946A
P-N-P EPITAXIAL-BASE PLANAR SILICON TRANSISTORS

TYPES 2N2944 THRU 2N2946, 2N2944A THRU 2N2946A
BULLETIN NO. DL-S 679561, MARCH 1967
REPLACES BULLETIN NO. DL-S 645138, AUGUST 1964

FOR LOW-LEVEL, HIGH-SPEED CHOPPER APPLICATIONS IN INVERTED CONNECTION

- **Low Guaranteed Offset Voltage**
- **High Emitter-Base Breakdown Voltage**
- **Greatly Improved $h_{FE(inv)}$...50 Min at $I_B = 200\ \mu A$ (2N2944A)**
- **Extremely Low $r_{ec(on)}$...4 Ω Max (2N2944A)**
- **Recommended For Complementary Use with 2N2432A**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-46 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

†TI guaranteed minimum. The JEDEC registered minimum lead diameter for the TO-46 is 0.012.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N2944 2N2944A	2N2945 2N2945A	2N2946 2N2946A
Collector-Base Voltage, V_{CB}	−15 V	−25 V	−40 V
Emitter-Collector Voltage, V_{ECO} (See Note 1)	−10 V	−20 V	−35 V
Emitter-Base Voltage, V_{EB}	−15 V	−25 V	−40 V
Continuous Collector Current	←	−100 mA	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←	0.4 W	→
Storage Temperature Range	←	−65°C to 200°C	→
Lead Temperature 1/16 Inch from Case for 10 Seconds	←	240°C	→

NOTES: 1. This value applies when the collector-base diode is open-circuited.

2. Derate linearly to 200°C free-air temperature at the rate of 2.3 mW/deg.

*Indicates JEDEC registered data

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N2944 MIN	2N2944 MAX	2N2945 MIN	2N2945 MAX	2N2946 MIN	2N2946 MAX	UNIT
I_{CBO}	Collector Cutoff Current	V_{CB} = Rated V_{CB}, $I_E = 0$			−0.1*		−0.2*		−0.5*	nA
		V_{CB} = Rated V_{CB}, $I_E = 0$, $T_A = 100°C$			−10		−20		−25	nA
I_{EBO}	Emitter Cutoff Current	V_{EB} = Rated V_{EB}, $I_C = 0$			−0.1*		−0.2*		−0.5*	nA
		V_{EB} = Rated V_{EB}, $I_C = 0$, $T_A = 100°C$			−10		−15		−20	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ V, $I_C = -1$ mA		80*		40*		30*		
$h_{FE(inv)}$	Static Forward Current Transfer Ratio (Inverted Connection)	$V_{EC} = -0.5$ V, $I_B = -200$ μA		6		4		3		
$V_{EC(ofs)}$	Emitter-Collector Offset Voltage	$I_B = -200$ μA, $I_E = 0$	See Figure 1		−0.3		−0.5		−0.8	mV
		$I_B = -1$ mA, $I_E = 0$			−0.6*		−1*		−2*	mV
		$I_B = -2$ mA, $I_E = 0$			−1		−1.6		−2.5	mV
$r_{ec(on)}$	Small-Signal Emitter-Collector On-State Resistance	$I_B = -1$ mA, $I_E = 0$, $I_e = 100$ μA, f = 1 kHz, See Figure 2			20*		35*		45*	Ω
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -6$ V, $I_C = -1$ mA, f = 1 MHz		10*		5*		3*		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -6$ V, $I_E = 0$, f = 500 kHz			10*		10*		10*	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -6$ V, $I_C = 0$, f = 500 kHz			6*		6*		6*	pF

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N2944A MIN	2N2944A MAX	2N2945A MIN	2N2945A MAX	2N2946A MIN	2N2946A MAX	UNIT
I_{CBO}	Collector Cutoff Current	V_{CB} = Rated V_{CB}, $I_E = 0$			−0.1*		−0.2*		−0.5*	nA
		V_{CB} = Rated V_{CB}, $I_E = 0$, $T_A = 100°C$			−10*		−20*		−25*	nA
I_{EBO}	Emitter Cutoff Current	V_{EB} = Rated V_{EB}, $I_C = 0$			−0.1*		−0.2*		−0.5*	nA
		V_{EB} = Rated V_{EB}, $I_C = 0$, $T_A = 100°C$			−10*		−15*		−20*	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ V, $I_C = -1$ mA		100*		70*		50*		
$h_{FE(inv)}$	Static Forward Current Transfer Ratio (Inverted Connection)	$V_{EC} = -0.5$ V, $I_B = -200$ μA		50*		30*		20*		
$V_{EC(ofs)}$	Emitter-Collector Offset Voltage	$I_B = -200$ μA, $I_E = 0$	See Figure 1		−0.3*		−0.5*		−0.8*	mV
		$I_B = -1$ mA, $I_E = 0$			−0.6*		−1*		−2*	mV
		$I_B = -2$ mA, $I_E = 0$			−1*		−1.6*		−2.5*	mV
$r_{ec(on)}$	Small-Signal Emitter-Collector On-State Resistance	$I_B = -1$ mA, $I_E = 0$, $I_e = 100$ μA, f = 1 kHz, See Figure 2			4*		6*		8*	Ω
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -6$ V, $I_C = -1$ mA, f = 1 MHz		15*		10*		5*		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -6$ V, $I_E = 0$, f = 0.1 MHz to 1 MHz			10*		10*		10*	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -6$ V, $I_C = 0$, f = 0.1 MHz to 1 MHz			6*		6*		6*	pF

PARAMETER MEASUREMENT INFORMATION

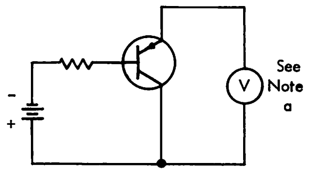


FIGURE 1

MEASUREMENT CIRCUIT FOR OFFSET VOLTAGE

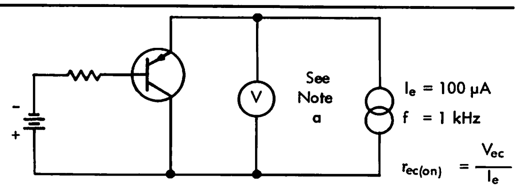


FIGURE 2

MEASUREMENT CIRCUIT FOR EMITTER-COLLECTOR ON-STATE RESISTANCE

NOTE a: The voltmeter must have high enough impedance that halving the value of the voltmeter impedance does not change the measured value.
*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

2N2944A

EMITTER-COLLECTOR VOLTAGE
vs
BASE CURRENT

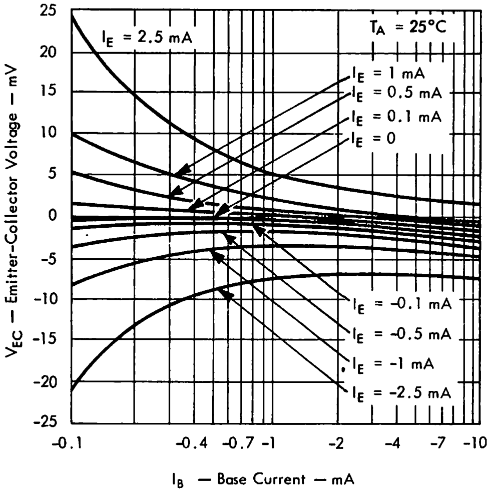


FIGURE 3

2N2945A

EMITTER-COLLECTOR VOLTAGE
vs
BASE CURRENT

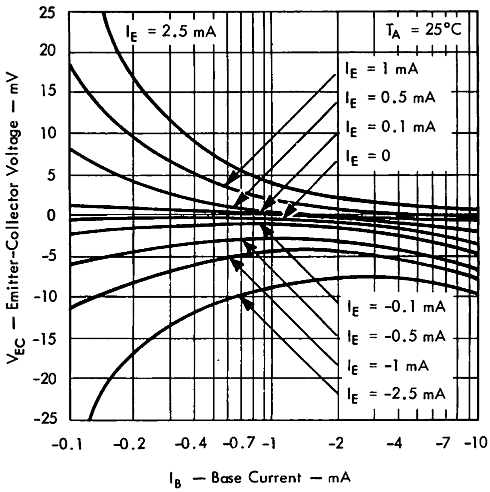


FIGURE 4

2N2946A

EMITTER-COLLECTOR VOLTAGE
vs
BASE CURRENT

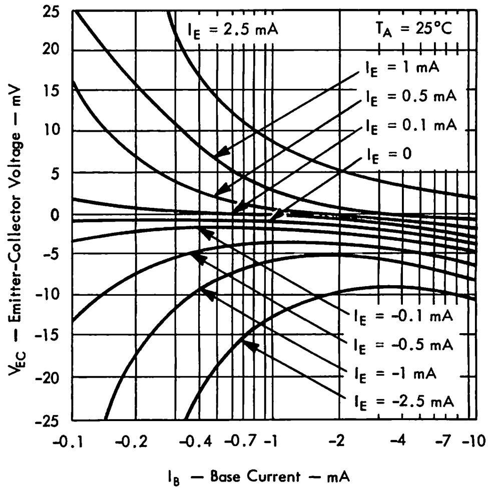


FIGURE 5

TYPICAL CHARACTERISTICS

2N2944, 2N2944A
EMITTER-COLLECTOR OFFSET VOLTAGE
vs
BASE CURRENT

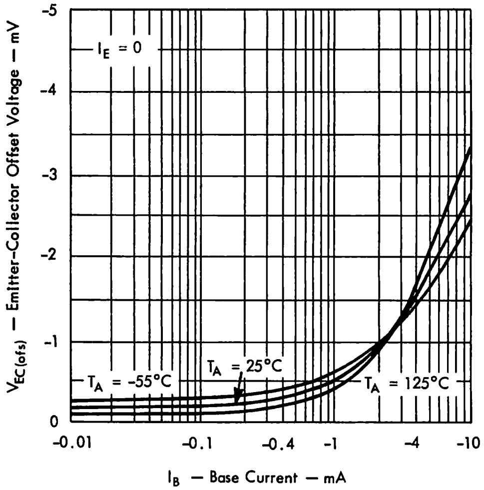


FIGURE 6

2N2945, 2N2945A
EMITTER-COLLECTOR OFFSET VOLTAGE
vs
BASE CURRENT

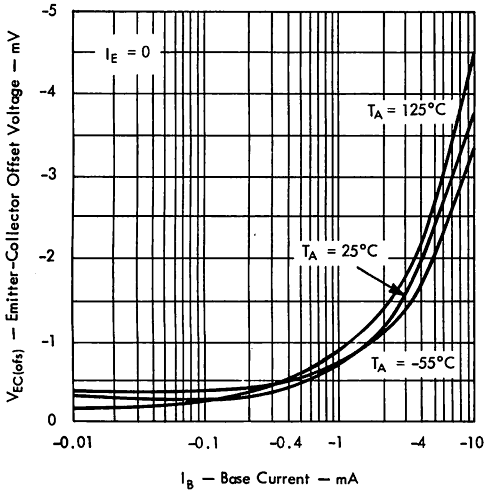


FIGURE 7

2N2946, 2N2946A
EMITTER-COLLECTOR OFFSET VOLTAGE
vs
BASE CURRENT

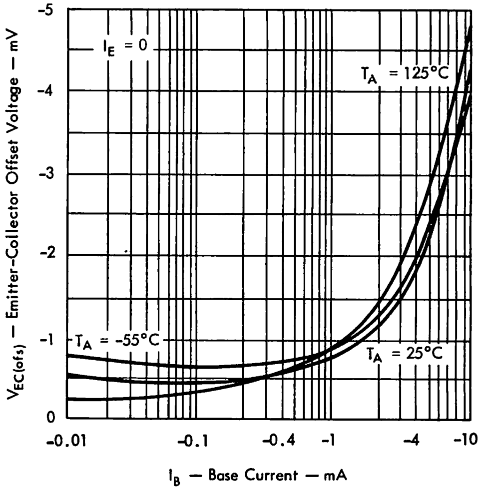


FIGURE 8

TYPICAL CHARACTERISTICS

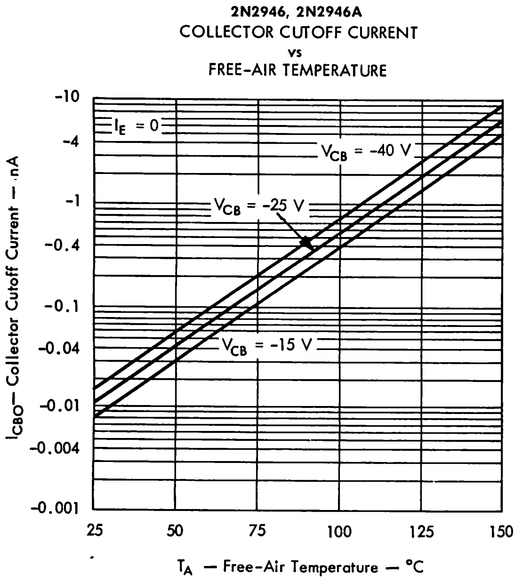


FIGURE 9

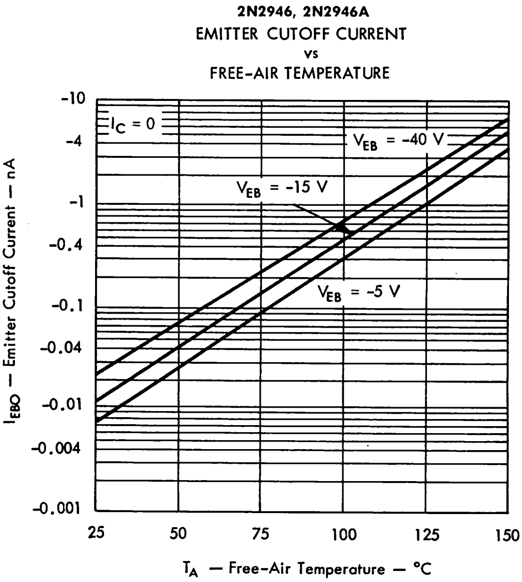


FIGURE 10

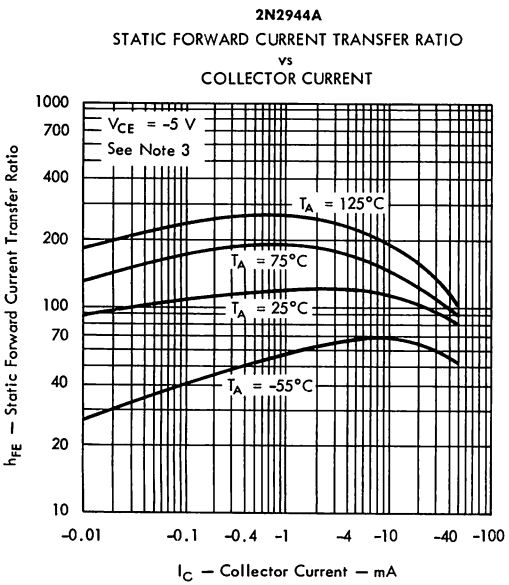


FIGURE 11

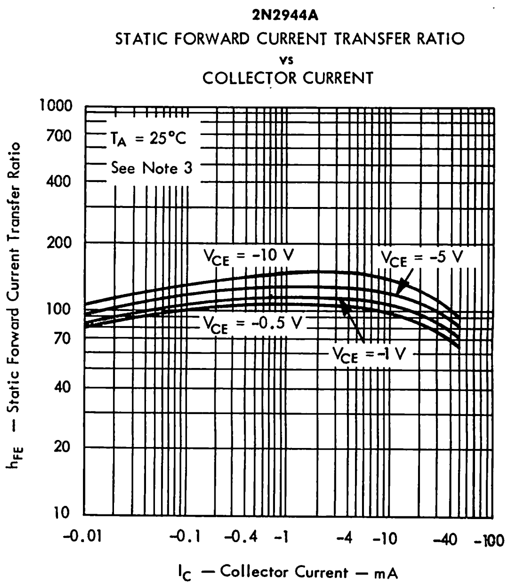


FIGURE 12

NOTE 3: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

2N2944A

STATIC FORWARD CURRENT TRANSFER RATIO
(INVERTED CONNECTION)
vs
EMITTER CURRENT

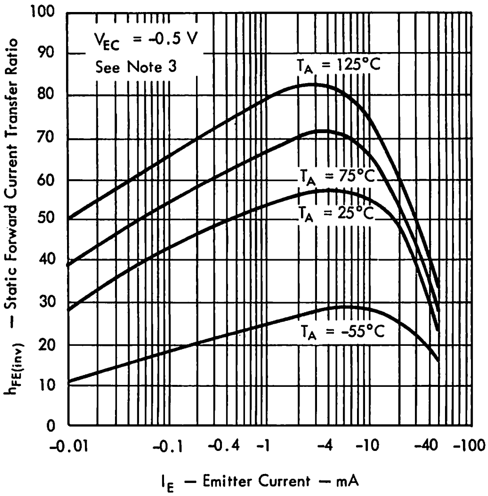


FIGURE 13

2N2945A

STATIC FORWARD CURRENT TRANSFER RATIO
(INVERTED CONNECTION)
vs
EMITTER CURRENT

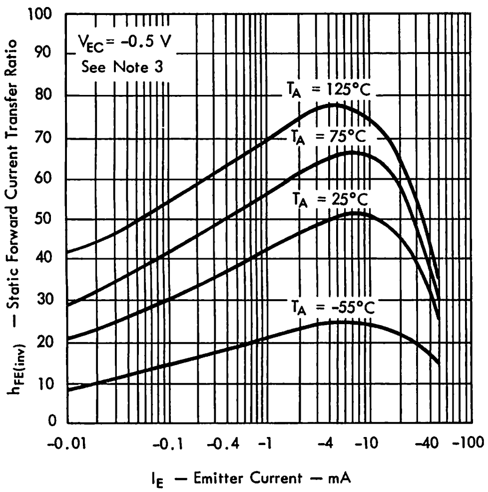


FIGURE 14

2N2946A

STATIC FORWARD CURRENT TRANSFER RATIO
(INVERTED CONNECTION)
vs
EMITTER CURRENT

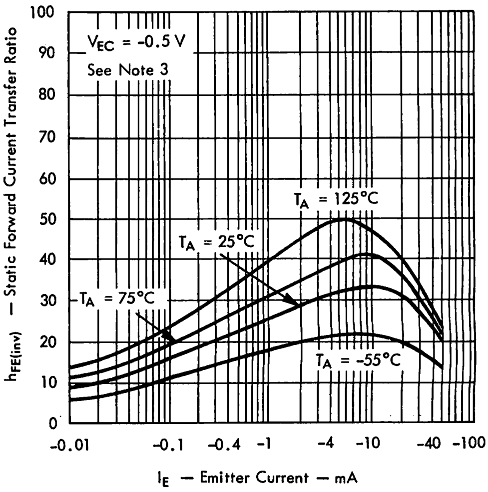


FIGURE 15

NOTE 3: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

ALL TYPES
BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

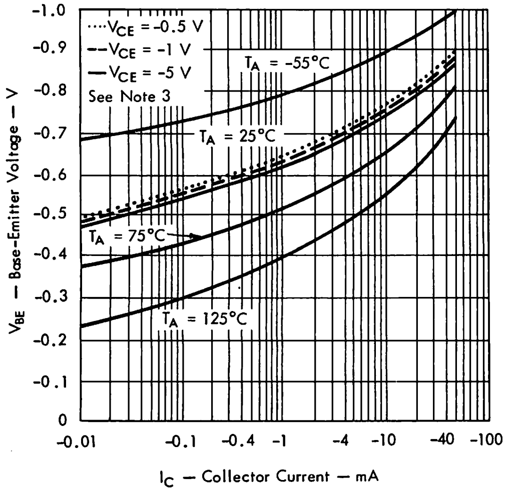


FIGURE 16

ALL TYPES
BASE-COLLECTOR VOLTAGE
vs
EMITTER CURRENT

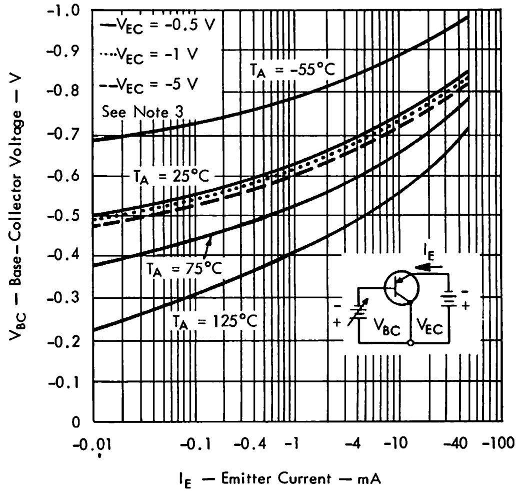


FIGURE 17

2N2944A
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

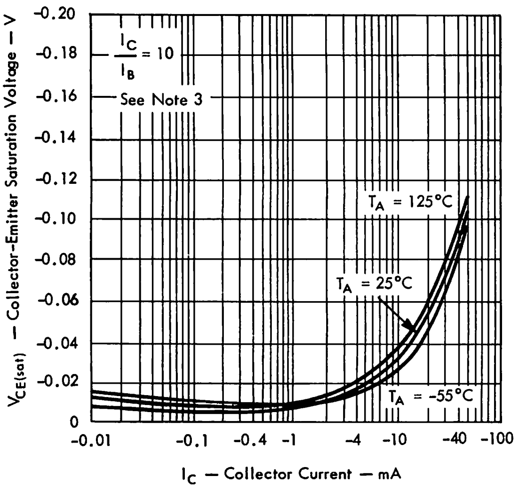


FIGURE 18

2N2944A
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

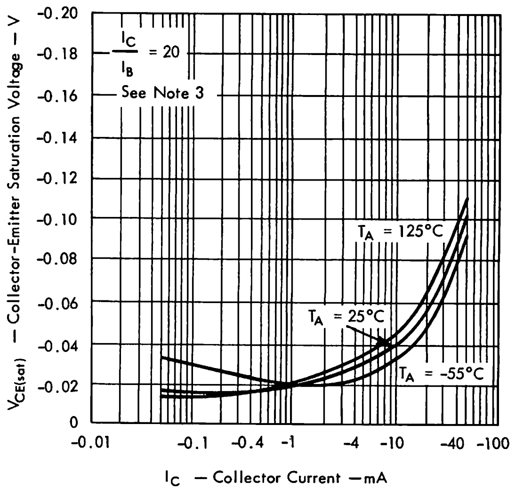


FIGURE 19

NOTE 3: These parameters must be measured using pulse techniques. $t_p \approx 300$ ms, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

2N2944A

SMALL-SIGNAL EMITTER-COLLECTOR ON-STATE RESISTANCE
vs
BASE CURRENT

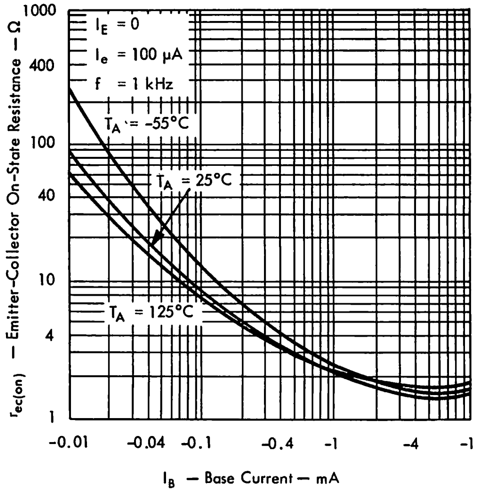


FIGURE 20

ALL TYPES

COMMON-BASE OPEN-CIRCUIT INPUT CAPACITANCE
vs
EMITTER-BASE VOLTAGE

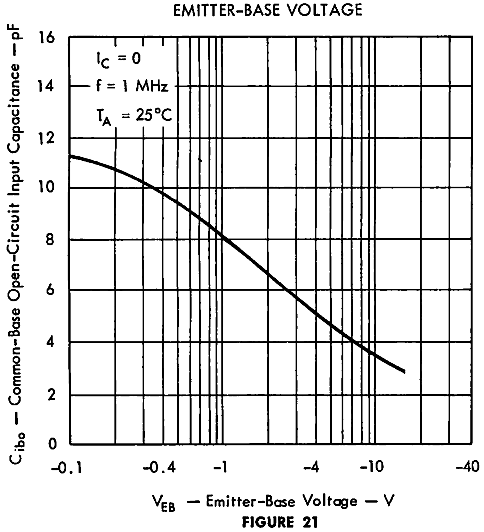


FIGURE 21

ALL TYPES

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

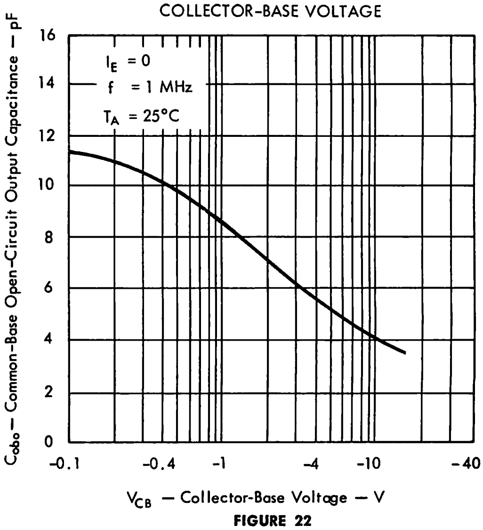


FIGURE 22

TYPES 2N3244, 2N3245, 2N3467, 2N3468
BULLETIN NO. DL-S 6810576, MAY 1968
REPLACES BULLETIN NO. DL-S 668358, FEBRUARY 1966

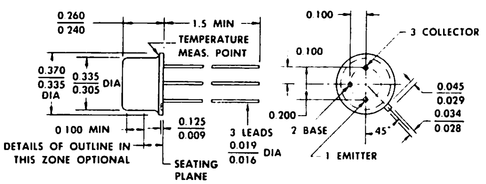
MADE WITH TRI-REL† REDUNDANT STABILIZATION

- **Field-Relief Electrode‡**
- **Special Oxide Passivation**
- **Annular Guard Ring‡**

DESIGNED FOR HIGH-SPEED CORE-DRIVER APPLICATIONS

- **High Dissipation Capability . . . 10 Watts at 25°C Case Temperature**
- **High $V_{(BR)CEO}$ . . . 50 V Min (2N3245, 2N3468)**
- **High Speed . . . 60 ns Max t_s at 500 mA (2N3467, 2N3468)**
- **High Collector Current Rating . . . 1 A**

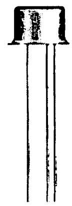
*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3244	2N3245	2N3467	2N3468	UNIT
Collector-Base Voltage	−40*	−50*	−40*	−50*	V
Collector-Emitter Voltage (See Note 1)	−40*	−50*	−40*	−50*	V
Emitter-Base Voltage	−5*	−5*	−5*	−5*	V
Continuous Collector Current	−1*	−1*	−1*	−1*	A
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	1*	1*	1*	1*	W
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	10§ 5*	10§ 5*	10	10	W
Storage Temperature Range	−65 to 200*				°C
Lead Temperature 1/16 Inch from Case for 10 Seconds			230*		°C
Lead Temperature 1/16 Inch from Case for 60 Seconds	300*		300§		°C

NOTES: 1. This value applies between 0 and 1 A collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 5.71 mW/deg.
3. Derate the 10-watt TI value linearly to 200°C case temperature at the rate of 57.1 mW/deg.
Derate the 5-watt JEDEC value linearly to 200°C case temperature at the rate of 28.6 mW/deg.

† Trademark of Texas Instruments

‡ Patented by Texas Instruments

* Indicates JEDEC registered data

§ This value is guaranteed by Texas Instruments in addition to the JEDEC registered value which is also shown.

TEXAS INSTRUMENTS
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*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3244 MIN	2N3244 MAX	2N3245 MIN	2N3245 MAX	2N3467 MIN	2N3467 MAX	2N3468 MIN	2N3468 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu A$, $I_E = 0$	–40		–50		–40		–50		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ mA, $I_B = 0$, See Note 4	–40		–50		–40		–50		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu A$, $I_C = 0$	–5		–5		–5		–5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -30$ V, $I_E = 0$		–50				–100		–100	nA
		$V_{CB} = -30$ V, $I_E = 0$, $T_A = 100°C$						–15		–15	µA
		$V_{CB} = -50$ V, $I_E = 0$				–50					nA
I_{CEV}	Collector Cutoff Current	$V_{CE} = -30$ V, $V_{BE} = 3$ V		–50		–50		–100		–100	nA
I_{BEV}	Base Cutoff Current	$V_{CE} = -30$ V, $V_{BE} = 3$ V		80		80		120		120	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		–30		–30					nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -1$ V, $I_C = -150$ mA, See Note 4	60		35		40		25		
		$V_{CE} = -1$ V, $I_C = -500$ mA, See Note 4	50	150	30	90	40	120	25	75	
		$V_{CE} = -5$ V, $I_C = -750$ mA, See Note 4	25								
		$V_{CE} = -5$ V, $I_C = -1$ A, See Note 4			20		40		20		
V_{BE}	Base-Emitter Voltage	$I_B = -15$ mA, $I_C = -150$ mA, See Note 4		–1.1		–1.1		–1		–1	V
		$I_B = -50$ mA, $I_C = -500$ mA, See Note 4	–0.75	–1.5	–0.75	–1.5	–0.8	–1.2	–0.8	–1.2	V
		$I_B = -75$ mA, $I_C = -750$ mA, See Note 4		–2							V
		$I_B = -100$ mA, $I_C = -1$ A, See Note 4				–2		–1.6		–1.6	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -15$ mA, $I_C = -150$ mA, See Note 4		–0.3		–0.35		–0.3		–0.35	V
		$I_B = -50$ mA, $I_C = -500$ mA, See Note 4		–0.5		–0.6		–0.5		–0.6	V
		$I_B = -100$ mA, $I_C = -1$ A, See Note 4		–1		–1.2		–1		–1.2	V
f_T	Transition Frequency	$V_{CE} = -10$ V, $I_C = -50$ mA, See Note 5	175		150		175		150		MHz
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, $f = 100$ kHz		25		25		25		25	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ V, $I_C = 0$, $f = 100$ kHz		100		100		100		100	pF

NOTES: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

5. To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at the rate of –6 dB per octave from f = 100 MHz to the frequency at which $|h_{fe}| = 1$.

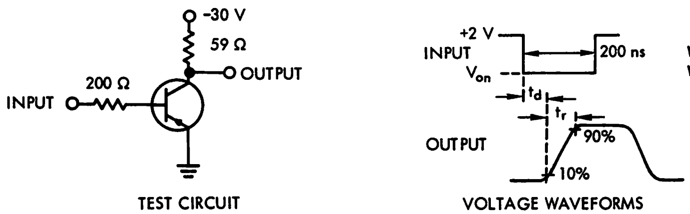
*Indicates JEDEC registered data

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	2N3244 MAX	2N3245 MAX	2N3467 MAX	2N3468 MAX	UNIT
t_d	Delay Time	$I_C = -500$ mA, $I_{B(1)} = -50$ mA, $V_{BE(off)} = 2$ V,	15	15	10	10	ns
t_r	Rise Time	$R_L = 59\ \Omega$, See Figure 1	35	40	30	30	ns
t_s	Storage Time	$I_C = -500$ mA, $I_{B(1)} = -50$ mA, $I_{B(2)} = 50$ mA,	140	120	60	60	ns
t_f	Fall Time	$R_L = 59\ \Omega$, See Figure 2	45	45	30	30	ns
Q_T	Total Control Charge	$I_C = -500$ mA, $I_B = -50$ mA, See Figure 3	14	12	6	6	nC

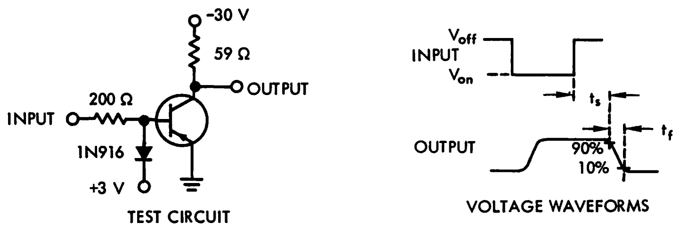
†Voltages and current values shown are nominal, exact values vary slightly with transistor parameters. Nominal base current for delay and rise times is calculated using the minimum values of V_{BE}. Nominal base currents for storage and fall times are calculated using the maximum value of V_{BE}.

*PARAMETER MEASUREMENT INFORMATION



$V_{on} = -10.75$ V for 2N3244, 2N3245
$V_{on} = -10.8$ V for 2N3467, 2N3468

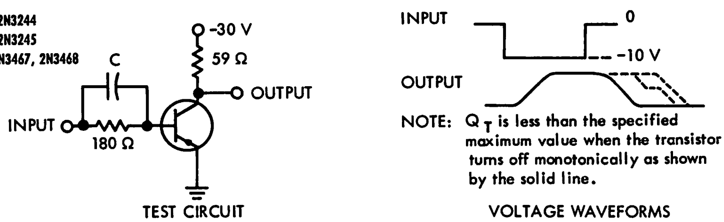
FIGURE 1 — DELAY AND RISE TIMES



$V_{off} = 8.5$ V for 2N3244, 2N3245
$V_{off} = 8.8$ V for 2N3467, 2N3468
$V_{on} = -11.5$ V for 2N3244, 2N3245
$V_{on} = -11.2$ V for 2N3467, 2N3468

FIGURE 2 — STORAGE AND FALL TIMES

C = 1400 pF for 2N3244
C = 1200 pF for 2N3245
C = 600 pF for 2N3467, 2N3468



NOTE: Q_T is less than the specified maximum value when the transistor turns off monotonically as shown by the solid line.

FIGURE 3 — TOTAL CONTROL CHARGE

NOTES: a. The input waveforms have the following characteristics:
For measuring delay and rise times: $t_r \leq 2$ ns, $t_p = 200$ ns, duty cycle = 2%.
For measuring storage and fall times: $t_f \leq 5$ ns, $t_p = 2$ to 500 μs, duty cycle = 2%.
For measuring Q_T: $t_f \leq 10$ ns, $t_p = 10$ μs, duty cycle = 2%.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 7$ pF.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

ALL TYPES

COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

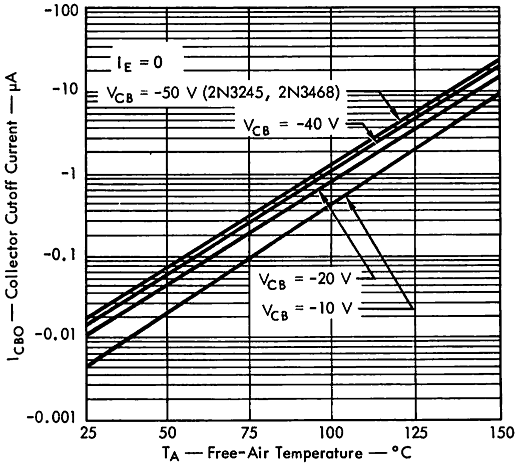


FIGURE 4

2N3467
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

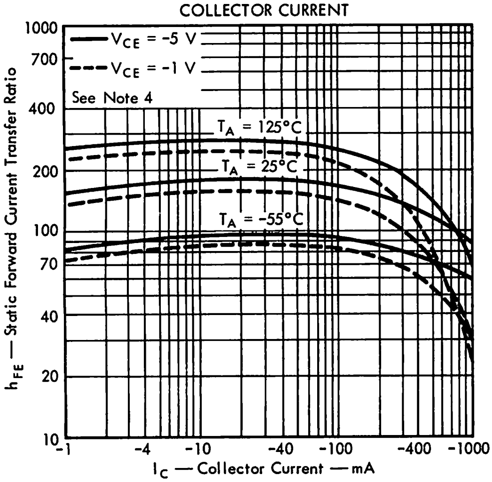


FIGURE 5

2N3468
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

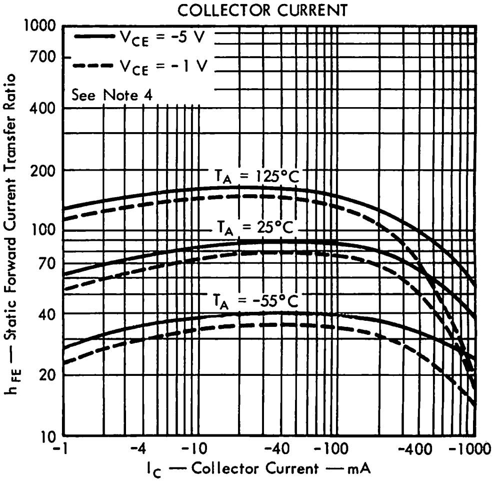


FIGURE 6

NOTE 4: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

ALL TYPES
BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

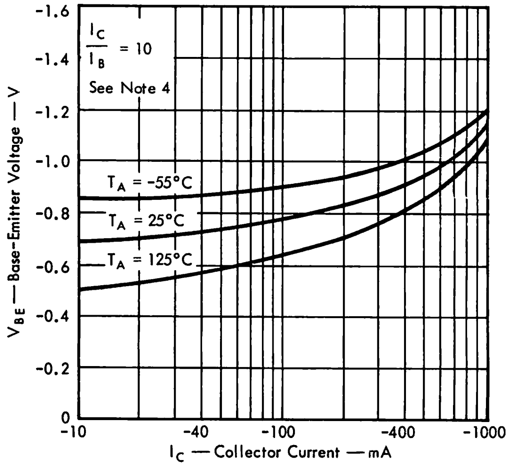


FIGURE 7

2N3244, 2N3467
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

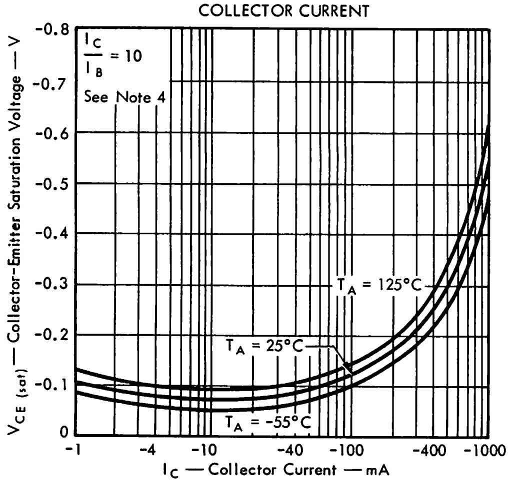


FIGURE 8

2N3245, 2N3468
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

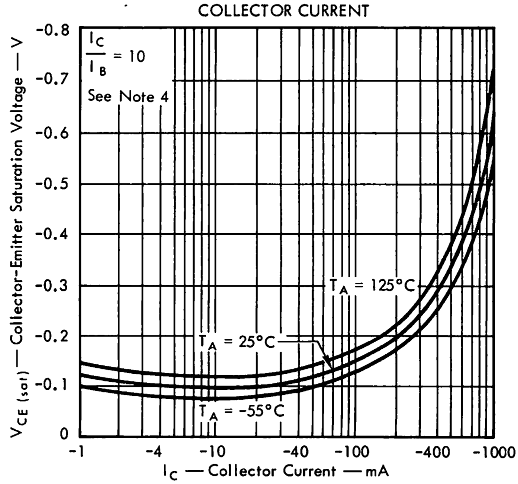


FIGURE 9

NOTE 4: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

2N3467, 2N3468
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

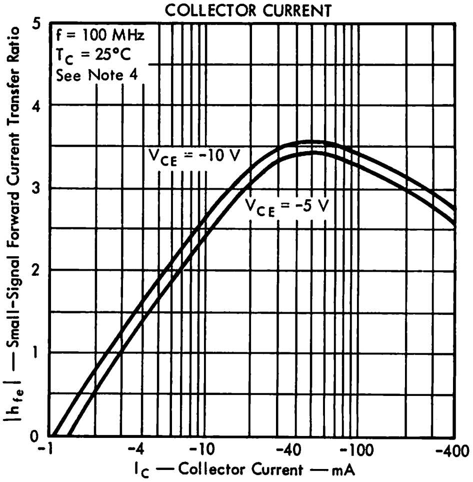


FIGURE 10

ALL TYPES
COMMON-BASE OPEN-CIRCUIT INPUT CAPACITANCE
AND EMITTER-BASE CAPACITANCE
vs
EMITTER-BASE VOLTAGE

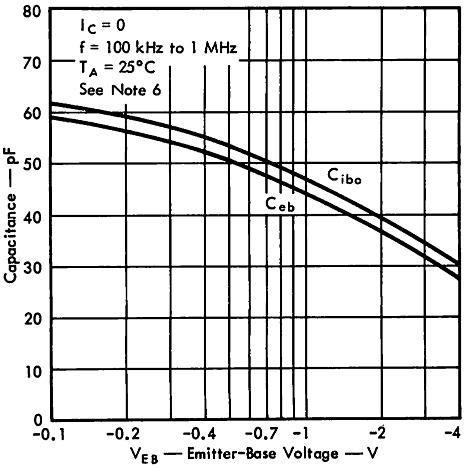


FIGURE 11

2N3467, 2N3468
COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
AND COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

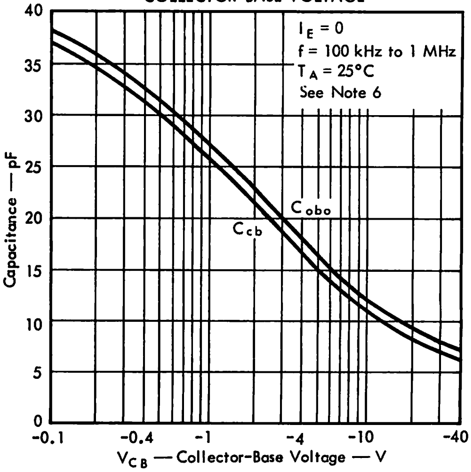


FIGURE 12

NOTES: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

6. C_{cb} and C_{eb} measurements employ a three-terminal capacitance bridge incorporating a guard circuit. The third electrode (emitter or collector, respectively) is connected to the guard terminal of the bridge. C_{obo} and C_{ibo} are measured with the third electrode floating.

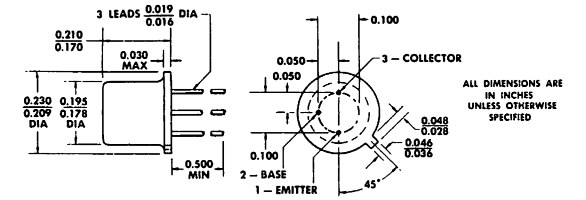
TYPES 2N3250, 2N3250A, 2N3251, 2N3251A
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N3250, 2N3250A, 2N3251, 2N3251A
BULLETIN NO. DL-S 679650, MARCH 1967
REPLACES BULLETIN NO. DL-S 657970, AUGUST 1965

DESIGNED FOR LOW-POWER SATURATED-SWITCHING AND AMPLIFIER APPLICATIONS

- **Low-Level h_{FE}: 80 Min at 100 μA (2N3251 and 2N3251A)**
- **Made with TRI-REL† Redundant Stabilization (Field-Relief Electrode‡, Special Oxide Passivation, Annular Guard Ring§)**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3250 2N3251	2N3250A 2N3251A
Collector-Base Voltage	–50 V	–60 V
Collector-Emitter Voltage (See Note 1)	–40 V	–60 V
Emitter-Base Voltage	–5 V	–5 V
Continuous Collector Current	←–200 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	← 0.36 W →	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 1.2 W →	
Storage Temperature Range	–65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 60 Seconds	← 300°C →	

*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		2N3250 MIN	2N3250 MAX	2N3250A MIN	2N3250A MAX	2N3251 MIN	2N3251 MAX	2N3251A MIN	2N3251A MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu A$, $I_E = 0$		–50		–60		–50		–60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ mA, $I_B = 0$,	See Note 4	–40		–60		–40		–60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu A$, $I_C = 0$		–5		–5		–5		–5		V
I_{CEV}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 3$ V			–20		–20		–20		–20	nA
I_{BEV}	Base Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 3$ V			50		50		50		50	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -1$ V, $I_C = -0.1$ mA	See Note 4	40		40		80		80		
		$V_{CE} = -1$ V, $I_C = -1$ mA		45		45		90		90		
		$V_{CE} = -1$ V, $I_C = -10$ mA		50	150	50	150	100	300	100	300	
		$V_{CE} = -1$ V, $I_C = -50$ mA		15		15		30		30		
V_{BE}	Base-Emitter Voltage	$I_B = -1$ mA, $I_C = -10$ mA	See Note 4	–0.6	–0.9	–0.6	–0.9	–0.6	–0.9	–0.6	–0.9	V
		$I_B = -5$ mA, $I_C = -50$ mA			–1.2		–1.2		–1.2		–1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ mA, $I_C = -10$ mA			–0.25		–0.25		–0.25		–0.25	V
		$I_B = -5$ mA, $I_C = -50$ mA			–0.5		–0.5		–0.5		–0.5	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = -10$ V, $I_C = -1$ mA, $f = 1$ kHz		1	6	1	6	2	12	2	12	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio			50	200	50	200	100	400	100	400	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio				10×10^{-4}		10×10^{-4}		20×10^{-4}		20×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance			4	40	4	40	10	60	10	60	μmho

NOTES: 1. These values apply between 0 and 200 mA collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.06 mW/deg.
3. Derate linearly to 200°C case temperature at the rate of 6.9 mW/deg.
4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

† Trademark of Texas Instruments
‡ Patent Pending
§ Patented by Texas Instruments
*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (continued)

PARAMETER		TEST CONDITIONS	2N3250 2N3250A MIN	2N3250 2N3250A MAX	2N3251 2N3251A MIN	2N3251 2N3251A MAX	UNIT
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -20$ V, $I_C = -10$ mA, f = 100 MHz	2.5		3		
f_T	Transition Frequency	$V_{CE} = -20$ V, $I_C = -10$ mA, See Note 5	250		300		MHz
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, f = 100 kHz		6		6	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -1$ V, $I_C = 0$, f = 100 kHz		8		8	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CE} = -20$ V, $I_C = -10$ mA, f = 31.8 MHz		250		250	ps

NOTE 5: To obtain f_T, the $\lvert h_{fe} \rvert$ response with frequency is extrapolated at the rate of −6 dB per octave from f = 100 MHz to the frequency at which $\lvert h_{fe} \rvert = 1$.

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N3250 2N3250A MAX	2N3251 2N3251A MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = -5$ V, $I_C = -100\ \mu$A, $R_G = 1$ kΩ, f = 100 Hz	6	6	dB

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	2N3250 2N3250A MAX	2N3251 2N3251A MAX	UNIT
t_d	Delay Time	$I_C = -10$ mA, $I_{B(1)} = -1$ mA, $V_{BE(off)} = 0.5$ V,	35	35	ns
t_r	Rise Time	$R_L = 275\ \Omega$, See Figure 1	35	35	ns
t_s	Storage Time	$I_C = -10$ mA, $I_{B(1)} = -1$ mA, $I_{B(2)} = 1$ mA,	175	200	ns
t_f	Fall Time	$R_L = 275\ \Omega$, See Figure 2	50	50	ns

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters. Nominal base current for delay and rise times is calculated using the minimum value of V_{BE}. Nominal base currents for storage and fall times are calculated using the maximum value of V_{BE}.

*PARAMETER MEASUREMENT INFORMATION

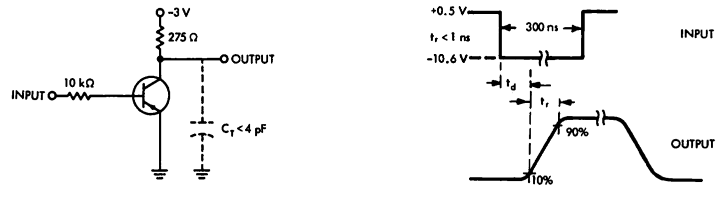


FIGURE 1—DELAY AND RISE TIMES

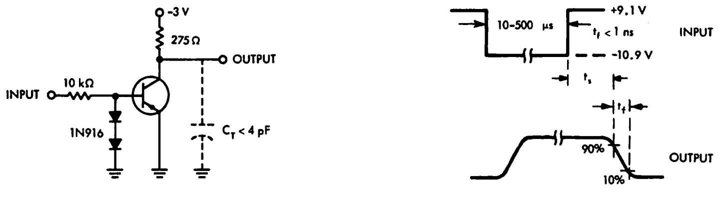


FIGURE 2 — STORAGE AND FALL TIMES

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, duty cycle = 2%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ.

*Indicates JEDEC registered data

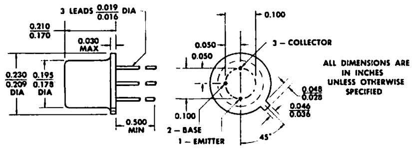
P-N-P EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3304
BULLETIN NO. DL-S 657508, MARCH 1965

DESIGNED FOR HIGH-SPEED SWITCHING APPLICATIONS

- **High f_T — 500 Mc Min**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−6 v
Collector-Emitter Voltage (See Note 1)	−6 v
Emitter-Base Voltage	−4 v
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.3 w
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	0.5 w
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 60 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$	−6		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 4	−6		v
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = -100\ \mu a$, $V_{BE} = 0$	−6		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−4		v
I_{CES}	Collector Cutoff Current	$V_{CE} = -3$ v, $V_{BE} = 0$		−10	na
		$V_{CE} = -3$ v, $V_{BE} = 0$, $T_A = 125°C$		−10	μa
I_B	Base Current	$V_{CE} = -3$ v, $V_{BE} = 0$		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ v, $I_C = -1$ ma	15		
		$V_{CE} = -0.3$ v, $I_C = -10$ ma	30	120	
		$V_{CE} = -0.3$ v, $I_C = -10$ ma, $T_A = -55°C$	12		
		$V_{CE} = -1$ v, $I_C = -50$ ma, See Note 4	20		
V_{BE}	Base-Emitter Voltage	$I_B = -100\ \mu a$, $I_C = -1$ ma	−0.7	−0.8	v
		$I_B = -1$ ma, $I_C = -10$ ma	−0.8	−1	v
		$I_B = -5$ ma, $I_C = -50$ ma, See Note 4		−1.5	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100\ \mu a$, $I_C = -1$ ma		−0.15	v
		$I_B = -1$ ma, $I_C = -10$ ma		−0.16	v
		$I_B = -1$ ma, $I_C = -10$ ma, $T_A = 125°C$		−0.23	v
		$I_B = -5$ ma, $I_C = -50$ ma, See Note 4		−0.5	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -10$ ma, f = 100 Mc	5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 140 kc		3.5	pf
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ v, $I_C = 0$, f = 140 kc		3.5	pf

NOTES: 1. This value applies between 10 na and 10 ma collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 1.72 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 5 mw/C°.
4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

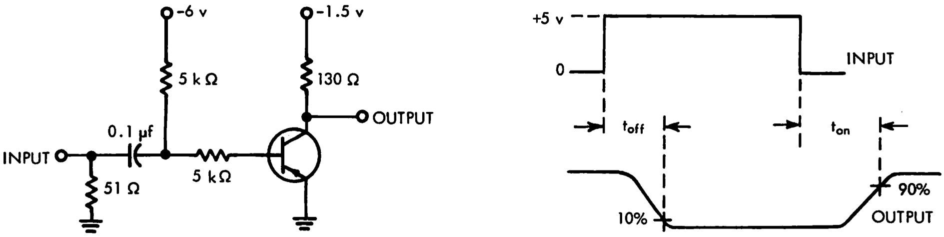
TYPE 2N3304
P-N-P EPITAXIAL PLANAR SILICON TRANSISTOR

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	$I_C = -10$ ma, $I_{B(1)} = -0.5$ ma, $I_{B(2)} = 0.5$ ma, $V_{BE(off)} = 1.5$ v,	60	nsec
t_{off}	Turn-Off Time	$R_L = 130\ \Omega$, See Figure 1	60	nsec
t_s	Storage Time	$I_C = -10$ ma, $I_{B(1)} = -10$ ma, $I_{B(2)} = 14$ ma, See Figure 2	30	nsec

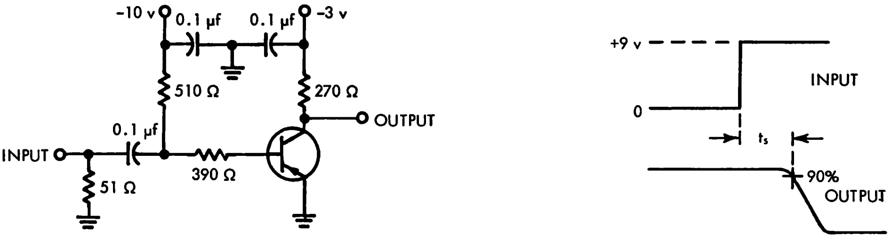
†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 1 — TURN-ON AND TURN-OFF TIMES



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 2 — STORAGE TIME

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, t_r, $t_f \leq 1$ nsec, PW $>$ 100 nsec.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100\ k\Omega$, $C_{in} \leq 5$ pf.

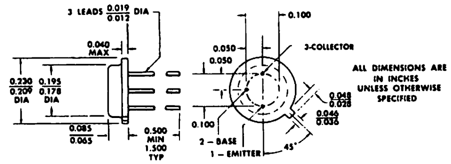
*Indicates JEDEC registered data

TYPES 2N3485, 2N3485A, 2N3486, 2N3486A
BULLETIN NO. DL-S 657885, JULY 1965

DESIGNED FOR HIGH-SPEED, MEDIUM-POWER SWITCHING AND GENERAL PURPOSE AMPLIFIER APPLICATIONS

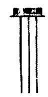
- **Electrically Identical to 2N2906, 2N2906A, 2N2907, and 2N2907A in Space-Saving TO-46 Package**
- **High Breakdown Voltage Combined With Very Low Saturation Voltage**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-46 DIMENSIONS AND NOTES ARE APPLICABLE.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3485 2N3486	2N3485A 2N3486A
*Collector-Base Voltage	−60 v	−60 v
*Collector-Emitter Voltage (See Note 1)	−40 v	−60 v
*Emitter-Base Voltage	−5 v	−5 v
*Collector Current	← 0.6 a →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	← 0.4 w →	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 2 w →	
*Storage Temperature Range	−65°C to +200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 300°C →	

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N3485 MIN	2N3485 MAX	2N3486 MIN	2N3486 MAX	2N3485A MIN	2N3485A MAX	2N3486A MIN	2N3486A MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu a$, $I_E = 0$		−60		−60		−60		−60		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$,	See Note 4	−40		−40		−60		−60		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu a$, $I_C = 0$		−5		−5		−5		−5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -50$ v, $I_E = 0$			−20		−20		−10		−10	na
		$V_{CB} = -50$ v, $I_E = 0$,	$T_A = 150°C$		−20		−20		−10		−10	μa
I_{CEV}	Collector Cutoff Current	$V_{CE} = -30$ v, $V_{BE} = 0.5$ v			−50		−50		−50		−50	na
I_{BEV}	Base Cutoff Current	$V_{CE} = -30$ v, $V_{BE} = 0.5$ v			50		50		50		50	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -10$ v, $I_C = -100\ \mu a$		20		35		40		75		
		$V_{CE} = -10$ v, $I_C = -1$ ma		25		50		40		100		
		$V_{CE} = -10$ v, $I_C = -10$ ma		35		75		40		100		
		$V_{CE} = -10$ v, $I_C = -150$ ma		40	120	100	300	40	120	100	300	
		$V_{CE} = -10$ v, $I_C = -500$ ma		20		30		40		50		
		$V_{CE} = -1$ v, $I_C = -150$ ma	See Note 4	20		50		20		50		
V_{BE}	Base-Emitter Voltage	$I_B = -15$ ma, $I_C = -150$ ma			−1.3		−1.3		−1.3		−1.3	v
		$I_B = -50$ ma, $I_C = -500$ ma			−2.6		−2.6		−2.6		−2.6	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -15$ ma, $I_C = -150$ ma			−0.4		−0.4		−0.4		−0.4	v
		$I_B = -50$ ma, $I_C = -500$ ma			−1.6		−1.6		−1.6		−1.6	v

NOTES: 1. This value applies between 0 and 100 ma collector current when the base-emitter diode is open circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.28 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 11.43 mw/C°.
4. These parameters must be measured using pulse techniques. PW ≤ 300 μsec, Duty Cycle ≤ 2%.

*Indicates JEDEC registered data.

TYPES 2N3485, 2N3485A, 2N3486, 2N3486A
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature

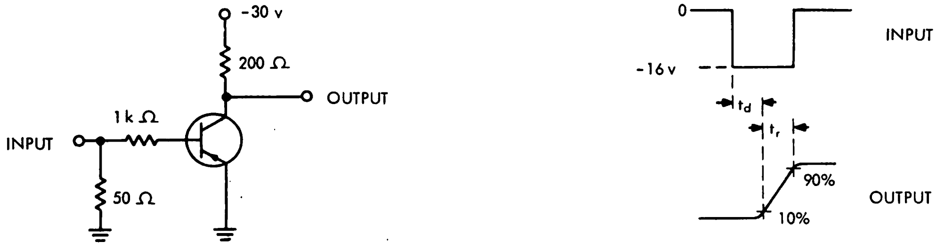
PARAMETER		TEST CONDITIONS	ALL TYPES MIN	ALL TYPES MAX	UNIT
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -20$ v, $I_C = -50$ ma, f = 100 Mc	2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ v, $I_E = 0$, f = 100 kc		8	pf
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -2$ v, $I_C = 0$, f = 100 kc		30	pf

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	ALL TYPES MAX	UNIT
t_d	Delay Time	$I_C = -150$ ma, $I_{B(1)} = -15$ ma, $V_{BE(off)} = 0$,	10	nsec
t_r	Rise Time	$R_L = 200\ \Omega$, See Figure 1	40	nsec
t_s	Storage Time	$I_C = -150$ ma, $I_{B(1)} = -13$ ma, $I_{B(2)} = 17$ ma,	80	nsec
t_f	Fall Time	$R_L = 37\ \Omega$, See Figure 2	30	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

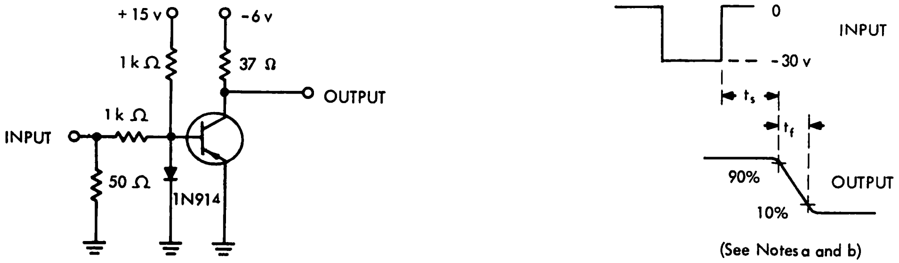
*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

(See Notes a and b)
VOLTAGE WAVEFORMS

FIGURE 1—DELAY AND RISE TIMES



TEST CIRCUIT

(See Notes a and b)
VOLTAGE WAVEFORMS

FIGURE 2—STORAGE AND FALL TIMES

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 2$ nsec, $t_f \leq 2$ nsec, PW = 200 nsec, PRR = 150 pps.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ nsec, $R_{in} = 10\ M\Omega$.

*Indicates JEDEC registered data.

TYPES 2N3494, 2N3495, 2N3496, 2N3497
BULLETIN NO. DL-S 679668, MARCH 1967

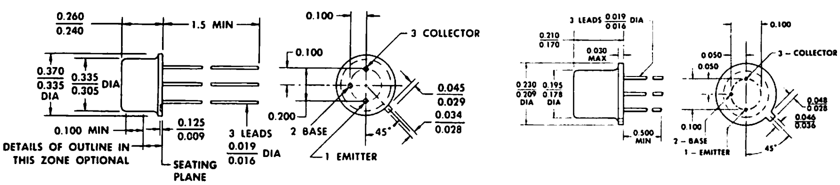
HIGH-VOLTAGE TRANSISTORS
FULLY CHARACTERIZED FOR HIGH-SPEED, LOW-NOISE, MEDIUM-POWER SWITCHING AND GENERAL-PURPOSE AMPLIFIER APPLICATIONS

- **h_{FE} Guaranteed from 100 μA to 100 mA**
- **Made with TRI-REL† Redundant Stabilization (Field-Relief Electrode‡, Special Oxide Passivation, Annular Guard Ring§)**

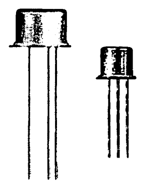
*mechanical data

Device types 2N3494 and 2N3495 are in JEDEC TO-5 packages.
Device types 2N3496 and 2N3497 are in JEDEC TO-18 packages.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



TO-5 DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED TO-18



TO-5 TO-18

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3494	2N3495	2N3496	2N3497	UNIT
Collector-Base Voltage	−80	−120	−80	−120	V
Collector-Emitter Voltage (See Note 1)	−80	−120	−80	−120	V
Emitter-Base Voltage	−4.5	−4.5	−4.5	−4.5	V
Continuous Collector Current	−100	−100	−100	−100	mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Notes 2 and 3)	0.6	0.6	0.4	0.4	W
Storage Temperature Range	−65 to 200				°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300				°C

NOTES: 1. These values apply between 0 and 100 mA collector current when the base-emitter diode is open-circuited.
2. Derate 2N3494 and 2N3495 linearly to 200°C free-air temperature at the rate of 3.43 mW/deg. See Figure 3.
3. Derate 2N3496 and 2N3497 linearly to 200°C free-air temperature at the rate of 2.28 mW/deg. See Figure 4.

†Trademark of Texas Instruments
‡Patent Pending
§Patented by Texas Instruments
*Indicates JEDEC registered data

TYPES 2N3494, 2N3495, 2N3496, 2N3497
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		TO-5 → 2N3494 / TO-18 → 2N3496 MIN	MAX	TO-5 → 2N3495 / TO-18 → 2N3497 MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu A$, $I_E = 0$		−80		−120		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ mA, $I_B = 0$,	See Note 4	−80		−120		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu A$, $I_C = 0$		−4.5		−4.5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -50$ V, $I_E = 0$			−0.1			μA
		$V_{CB} = -90$ V, $I_E = 0$					−0.1	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -3$ V, $I_C = 0$			−25		−25	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -100\ \mu A$	See Note 4	35		35		
		$V_{CE} = -10$ V, $I_C = -1$ mA		40		40		
		$V_{CE} = -10$ V, $I_C = -10$ mA		40		40		
		$V_{CE} = -10$ V, $I_C = -50$ mA		40		40		
		$V_{CE} = -10$ V, $I_C = -100$ mA		35				
V_{BE}	Base-Emitter Voltage	$I_B = -1$ mA, $I_C = -10$ mA,	See Note 4	−0.6	−0.9	−0.6	−0.9	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ mA, $I_C = -10$ mA,	See Note 4		−0.3		−0.35	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = -10$ V, $I_C = -10$ mA,	f = 1 kHz	0.1	1.2	0.1	1.2	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio			40	300	40	300	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio				2×10^{-4}		2×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance				300		300	μmho
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -20$ mA,	f = 100 MHz	2		1.5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$,	f = 100 kHz		7		6	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -2$ V, $I_C = 0$,	f = 100 kHz		30		30	pF
$Re(h_{ie})$	Small-Signal Common-Emitter Input Resistance	$V_{CE} = -10$ V, $I_C = -20$ mA,	f = 300 MHz		30		30	Ω

NOTE 4: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	$I_C = -10$ mA, $I_{B(1)} = -1$ mA, $V_{BE(off)} = 0$, $R_L = 3\ k\Omega$, See Figure 1	300	ns
t_{off}	Turn-Off Time	$I_C = -10$ mA, $I_{B(1)} = -1$ mA, $I_{B(2)} = 1$ mA, $R_L = 3\ k\Omega$, See Figure 2	1	μs

*Indicates JEDEC registered data

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters. Nominal base current for turn-on time is calculated using a minimum value of V_{BE}. Nominal base currents for turn-off times are calculated using the maximum value of V_{BE}.

*PARAMETER MEASUREMENT INFORMATION

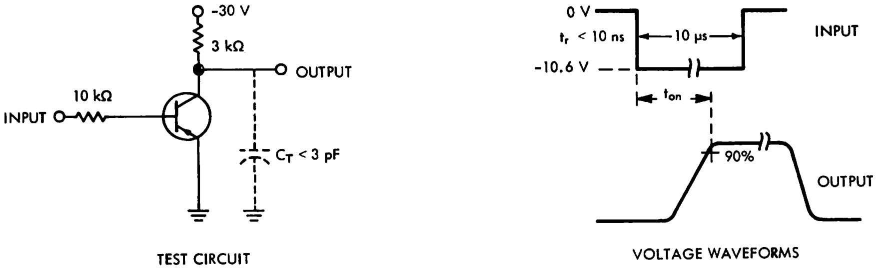


FIGURE 1 — TURN-ON TIME

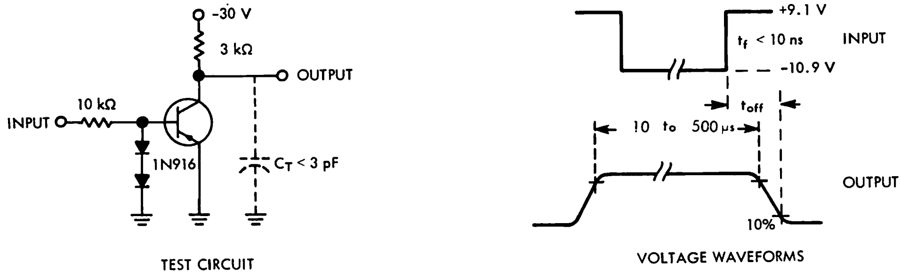
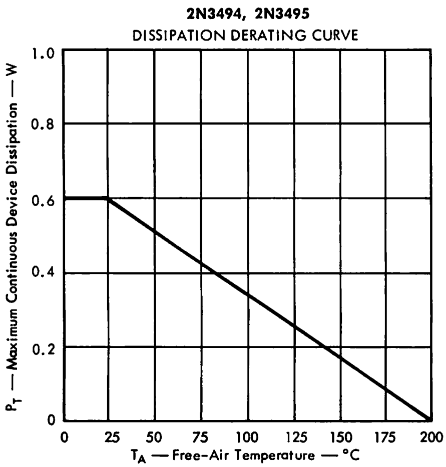


FIGURE 2 — TURN-OFF TIME

NOTES: a. The input waveforms are supplied by a generator with $Z_{out} = 50\ \Omega$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 10$ ns, $R_{in} \geq 100$ kΩ.

*Indicates JEDEC registered data

THERMAL INFORMATION



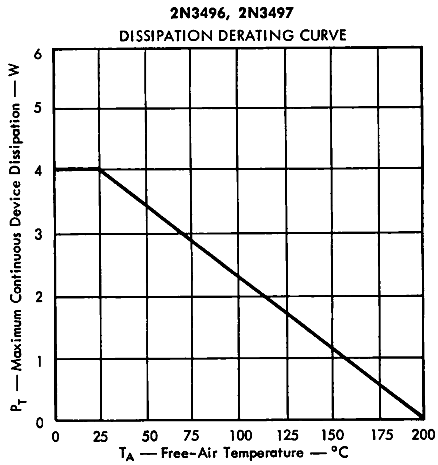


FIGURE 3

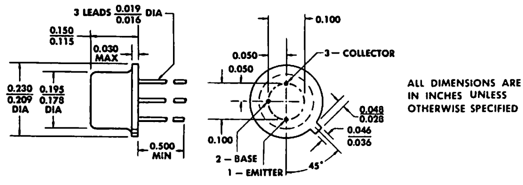
TYPE 2N3829
P-N-P EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3829
BULLETIN NO. DL-S 657455, MARCH 1965

DESIGNED FOR HIGH-SPEED SWITCHING APPLICATIONS

- **Recommended for Complementary Use With 2N3014**
- **High f_T: 350 Mc min at 10 v, 30 ma**
- **Low Guaranteed $V_{CE(sat)}$: 0.18 v at 30 ma**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-52 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−35 v
Collector-Emitter Voltage (See Note 1)	−35 v
Collector-Emitter Voltage (See Note 2)	−20 v
Emitter-Base Voltage	−5 v
Continuous Collector Current	−200 ma
Peak Collector Current (See Note 3)	−500 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	360 mw
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 5)	1.2 w
Storage Temperature Range	−65°C to +200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$		−35		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$,	See Note 6	−20		v
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = -100\ \mu a$, $V_{BE} = 0$		−35		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$		−5		v
I_{CES}	Collector Cutoff Current	$V_{CE} = -20$ v, $V_{BE} = 0$			−0.3	μa
		$V_{CE} = -20$ v, $V_{BE} = 0$,	$T_A = 125°C$		−40	μa
I_B	Base Current	$V_{CE} = -20$ v, $V_{BE} = 0$			0.3	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.4$ v, $I_C = -10$ ma	See Note 6	25		
		$V_{CE} = -0.4$ v, $I_C = -30$ ma		30	120	
		$V_{CE} = -1$ v, $I_C = -100$ ma		25		
		$V_{CE} = -0.4$ v, $I_C = -30$ ma, $T_A = -55°C$		12		
V_{BE}	Base-Emitter Voltage	$I_B = -1$ ma, $I_C = -10$ ma	See Note 6	−0.75	−0.85	v
		$I_B = -3$ ma, $I_C = -30$ ma		−0.75	−0.95	v
		$I_B = -10$ ma, $I_C = -100$ ma			−1.20	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ ma, $I_C = -10$ ma	See Note 6		−0.18	v
		$I_B = -3$ ma, $I_C = -30$ ma			−0.18	v
		$I_B = -10$ ma, $I_C = -100$ ma			−0.35	v
		$I_B = -3$ ma, $I_C = -30$ ma, $T_A = 125°C$			−0.25	v

NOTES: 1. This value applies when the base-emitter diode is short-circuited.
2. This value applies between 0 and 10 ma collector current when the base-emitter diode is open-circuited.
3. This value applies for PW $\leq$ 10 μsec, Duty Cycle $\leq$ 40%.
4. Derate linearly to 175°C free-air temperature at the rate of 2.4 mw/C°.
5. Derate linearly to 175°C case temperature at the rate of 8 mw/C°.
6. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

*Indicates JEDEC registered data.

TYPE 2N3829
P-N-P EPITAXIAL PLANAR SILICON TRANSISTOR

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ v, $I_C = -30$ ma, f = 100 Mc	3.5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 140 kc		6	pf
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ v, $I_C = 0$, f = 140 kc		10	pf

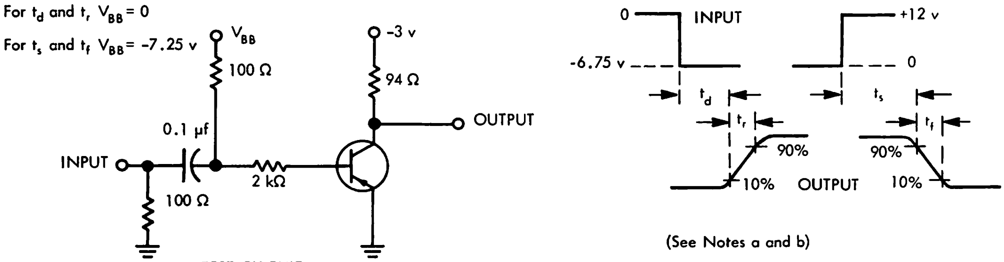
***operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_d	Delay Time	$I_C = -30$ ma, $I_{B(1)} = -3$ ma, $V_{BE(off)} = 0$,		10	nsec
t_r	Rise Time	$R_L = 94\ \Omega$, See Figure 1		15	nsec
t_s	Storage Time	$I_C = -30$ ma, $I_{B(1)} = -I_{B(2)} = -3$ ma,		50	nsec
t_f	Fall Time	$R_L = 94\ \Omega$, See Figure 1		15	nsec
$V_{CEO(NL)}$‡	Collector-Emitter Nonlatching Voltage	$I_{C(on)} = -200$ ma, $I_{B(on)} = -20$ ma, $I_{B(off)} = 0$, See Figure 2	−20		v

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

‡This characteristic is the highest value of collector supply voltage which may be safely used with a resistive-load switching circuit in which the collector current approaches −200 ma.

*PARAMETER MEASUREMENT INFORMATION

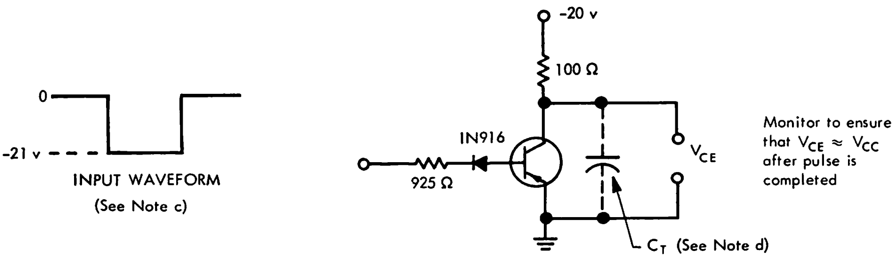


TEST CIRCUIT

(See Notes a and b)

VOLTAGE WAVEFORMS

FIGURE 1



INPUT WAVEFORM

(See Note c)

FIGURE 2 — COLLECTOR-EMITTER NONLATCHING VOLTAGE TEST CIRCUIT

NOTES: a. The input waveforms in Figure 1 are supplied by a pulse generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, PW $\geq$ 300 nsec, Duty Cycle $\leq 2\%$.
b. Waveforms of Figure 1 are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100$ kΩ, $C_{in} \leq 5$ pf.
c. The input waveform in Figure 2 has the following characteristics: PW = ≤ 10 μsec, Duty Cycle $\leq 2\%$.
d. Total collector shunt capacitance $C_T \leq 15$ pf.

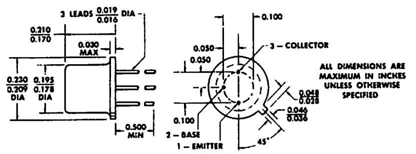
*Indicates JEDEC registered data.

TYPES 2N3962 THRU 2N3965
BULLETIN NO. DL-S 679563, FEBRUARY 1967

FOR EXTREMELY LOW-LEVEL, LOW-NOISE, HIGH-GAIN, SMALL-SIGNAL AMPLIFIER APPLICATIONS

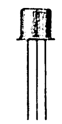
- **Guaranteed h_{FE} at 10 μA, T_A = −55°C and 25°C**
- **Guaranteed Low-Noise Characteristics at 20 μA**
- **Made with TRI-REL† Redundant Stabilization (Field-Relief Electrode‡, Special Oxide Passivation, Annular Guard Ring§)**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3962 2N3965	2N3963	2N3964
Collector-Base Voltage	−60 V	−80 V	−45 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−45 V
Emitter-Base Voltage	−6 V	−6 V	−6 V
Continuous Collector Current	←	−200 mA	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←	360 mW	→
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←	1.2 W	→
Storage Temperature Range	←	−65°C to 200°C	→
Lead Temperature 1/16 Inch from Case for 60 Seconds	←	300°C	→

NOTES: 1. These values apply between 10 μA and 5 mA collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 2.06 mW/deg. See Figure 1.
3. Derate linearly to 200°C case temperature at the rate of 6.85 mW/deg. See Figure 2.

†Trademark of Texas Instruments
‡Patent Pending
§Patented by Texas Instruments
*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3962 MIN	2N3962 MAX	2N3963 MIN	2N3963 MAX	2N3964 MIN	2N3964 MAX	2N3965 MIN	2N3965 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu A$, $I_E = 0$	−60		−80		−45		−60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -5$ mA, $I_B = 0$, See Note 4	−60		−80		−45		−60		V
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = -10\ \mu A$, $I_B = 0$	−60		−80		−45		−60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu A$, $I_C = 0$	−6		−6		−6		−6		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -40$ V, $I_E = 0$						−10			nA
		$V_{CB} = -50$ V, $I_E = 0$		−10						−10	nA
		$V_{CB} = -70$ V, $I_E = 0$				−10					nA
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{EB} = 0$						−10			nA
		$V_{CE} = -50$ V, $V_{EB} = 0$		−10						−10	nA
		$V_{CE} = -70$ V, $V_{EB} = 0$				−10					nA
		$V_{CE} = -40$ V, $V_{EB} = 0$, $T_A = 150°C$						−10			µA
		$V_{CE} = -50$ V, $V_{EB} = 0$, $T_A = 150°C$		−10						−10	µA
		$V_{CE} = -70$ V, $V_{EB} = 0$, $T_A = 150°C$				−10					µA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−10		−10		−10		−10	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -1\ \mu A$	60		60		180		180		
		$V_{CE} = -5$ V, $I_C = -10\ \mu A$	100	300	100	300	250	500	250	500	
		$V_{CE} = -5$ V, $I_C = -10\ \mu A$, $T_A = -55°C$	40		40		100		100		
		$V_{CE} = -5$ V, $I_C = -100\ \mu A$	100		100		250		250		
		$V_{CE} = -5$ V, $I_C = -1$ mA	100	450	100	450	250	600	250	600	
		$V_{CE} = -5$ V, $I_C = -1$ mA, $T_A = 100°C$		600		600		800		800	
		$V_{CE} = -5$ V, $I_C = -10$ mA, See Note 4	100		100		200		200		
		$V_{CE} = -5$ V, $I_C = -50$ mA, See Note 4	90		90		180		180		
		$V_{CE} = -5$ V, $I_C = -50$ mA, $T_A = -55°C$, See Note 4	45		45		90		90		
V_{BE}	Base-Emitter Voltage	$I_C = -10$ mA, $I_B = -0.5$ mA		−0.9		−0.9		−0.9		−0.9	V
		$I_C = -50$ mA, $I_B = -5$ mA, See Note 4		−0.95		−0.95		−0.95		−0.95	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = -10$ mA, $I_B = -0.5$ mA		−0.25		−0.25		−0.25		−0.25	V
		$I_C = -50$ mA, $I_B = -5$ mA, See Note 4		−0.4		−0.4		−0.4		−0.4	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = -5$ V, $I_C = -1$ mA, $f = 1$ kHz	2.5	17	2.5	17	6	20	6	20	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio		100	550	100	550	250	700	250	700	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio			10×10^{-4}		10×10^{-4}		10×10^{-4}		10×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance		5	40	5	40	5	50	5	50	µmho
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ mA, $f = 20$ MHz	2	8	2	8	2.5	8	2.5	8	
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ V, $I_E = 0$, $f = 1$ MHz		6		6		6		6	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ V, $I_C = 0$, $f = 1$ MHz		15		15		15		15	pF

NOTE 4: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 1\%$.

*Indicates JEDEC registered data

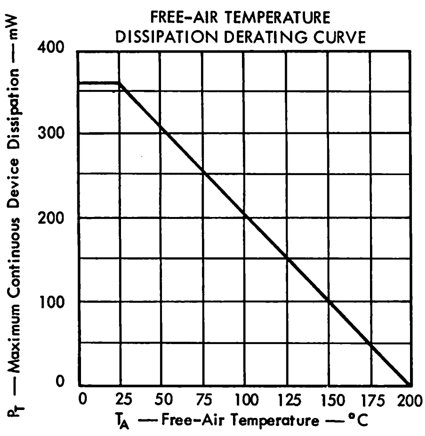
***operating characteristics at 25°C free-air temperature**

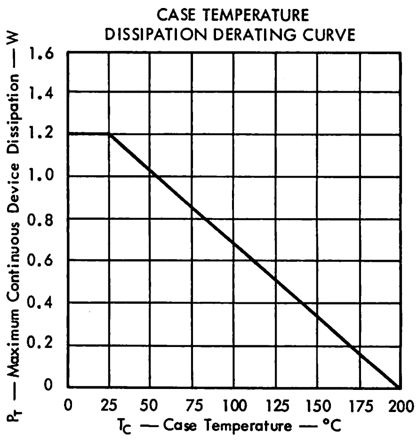
PARAMETER	TEST CONDITIONS	2N3962 2N3963 MAX	2N3964 2N3965 MAX	UNIT
NF Spot Noise Figure	$V_{CE} = -5$ V, $I_C = -20$ μA, $R_G = 10$ kΩ, f = 10 Hz, Noise Bandwidth = 2 Hz		8	dB
	$V_{CE} = -5$ V, $I_C = -20$ μA, $R_G = 10$ kΩ, f = 100 Hz, Noise Bandwidth = 15 Hz	10	4	dB
	$V_{CE} = -5$ V, $I_C = -20$ μA, $R_G = 10$ kΩ, f = 1 kHz, Noise Bandwidth = 150 Hz	3	2	dB
	$V_{CE} = -5$ V, $I_C = -20$ μA, $R_G = 10$ kΩ, f = 10 kHz, Noise Bandwidth = 1.5 kHz	3	2	dB
$\overline{NF}$ Average Noise Figure	$V_{CE} = -5$ V, $I_C = -20$ μA, $R_G = 10$ kΩ, Noise Bandwidth = 15.7 kHz, See Note 5	3	2	dB

NOTE 5: Average Noise Figure is measured in an amplifier with low-frequency response down 3 dB at 10 Hz.

*Indicates JEDEC registered data

THERMAL INFORMATION





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TYPES 2N4058 THRU 2N4062
BULLETIN NO. DL-S 688216, APRIL 1966
REVISED MAY 1968

SILECT† TRANSISTORS

- ENCAPSULATED IN PLASTIC
- INSENSITIVE TO LIGHT
- HIGHLY MOISTURE RESISTANT

Recommended For Complementary Use With 2N3707 thru 2N3711

2N4058 For Low-Level, Low-Noise Applications

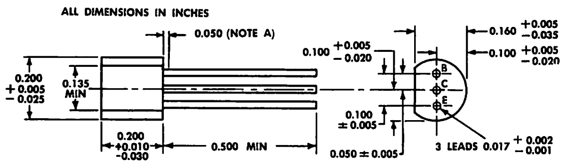
2N4059, 2N4060, 2N4061, 2N4062 For General-Purpose, Low-Level, High-Gain Applications

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE

ALL DIMENSIONS IN INCHES



NOTE A: Lead diameter is not controlled in this area.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−30 V
Collector-Emitter Voltage (See Note 1)	−30 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−30 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	360 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

* Indicates JEDEC registered data (typical data excluded).

†Trademark of Texas Instruments

‡Patent Pending

*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N4058 MIN	2N4058 MAX	2N4059 MIN	2N4059 MAX	2N4060 MIN	2N4060 MAX	2N4061 MIN	2N4061 MAX	2N4062 MIN	2N4062 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -1$ mA, $I_B = 0$	−30		−30		−30		−30		−30		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -20$ V, $I_E = 0$		−100		−100		−100		−100		−100	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -6$ V, $I_C = 0$		−100		−100		−100		−100		−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -100\ \mu$A	100	400									
		$V_{CE} = -5$ V, $I_C = -1$ mA			45	660	45	165	90	330	180	660	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -5$ V, $I_C = -1$ mA	−0.5	−1	−0.5	−1	−0.5	−1	−0.5	−1	−0.5	−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ mA, $I_C = -10$ mA		−0.7		−0.7		−0.7		−0.7		−0.7	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -100\ \mu$A, f = 1 kHz	100	550									
		$V_{CE} = -5$ V, $I_C = -1$ mA, f = 1 kHz			45	800	45	250	90	450	180	800	

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N4058 TYP	2N4058 MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CE} = -5$ V, $I_C = -100\ \mu$A, $R_G = 5\ k\Omega$, Noise Bandwidth = 15.7 kHz, See Note 3	1.7	5	dB

NOTE 3: Average Noise Figure is measured in an amplifier with low-frequency response down 3 dB at 10 c/s.

*Indicates JEDEC registered data (typical data excluded).

THERMAL INFORMATION

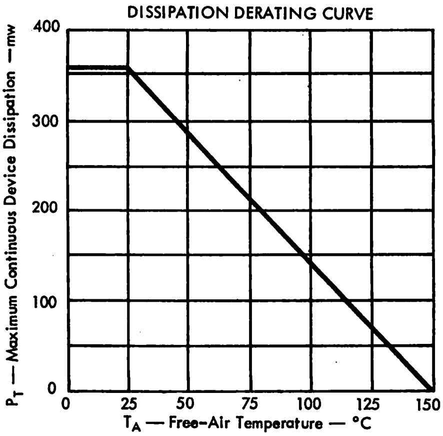


FIGURE 1

TYPE 2N4423
P-N-P EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N4423
BULLETIN NO. DL-S 689124, AUGUST 1966
REVISED MAY 1968

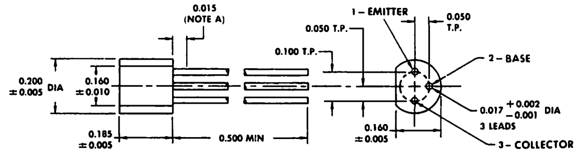
SILECT† TRANSISTOR FOR HIGH-SPEED SWITCHING APPLICATIONS

- **Electrically Similar to the 2N2894**
- **Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle**

mechanical data

This transistor is encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. This device exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C method 106B. The transistor is insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−12 V
Collector-Emitter Voltage (See Note 1)	−12 V
Collector-Emitter Voltage (See Note 2)	−12 V
Emitter-Base Voltage	−4 V
Continuous Collector Current	−200 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	360 mW
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 4)	500 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -10\ \mu A$,	$I_E = 0$		−12		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ mA,	$I_B = 0$,	See Note 5	−12		V
$V_{(BR)CES}$	Collector-Emitter Breakdown Voltage	$I_C = -10\ \mu A$,	$V_{BE} = 0$		−12		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$,	$I_C = 0$		−4		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -6$ V,	$I_E = 0$,	$T_A = 70°C$		−1	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -6$ V,	$V_{BE} = 0$			−80	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -3$ V,	$I_C = 0$			−20	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.3$ V,	$I_C = -10$ mA	See Note 5	30		
		$V_{CE} = -0.5$ V,	$I_C = -30$ mA		40	150	
		$V_{CE} = -1$ V,	$I_C = -100$ mA		20		
V_{BE}	Base-Emitter Voltage	$I_B = -1$ mA,	$I_C = -10$ mA	See Note 5	−0.76	−0.98	V
		$I_B = -3$ mA,	$I_C = -30$ mA		−0.82	−1.2	V
		$I_B = -10$ mA,	$I_C = -100$ mA			−1.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ mA,	$I_C = -10$ mA	See Note 5		−0.15	V
		$I_B = -3$ mA,	$I_C = -30$ mA			−0.2	V
		$I_B = -10$ mA,	$I_C = -100$ mA			−0.5	V

NOTES: 1. This value applies when the base-emitter diode is short-circuited.
2. This value applies between 0 and 200 mA collector current when the base-emitter diode is open-circuited. Maximum rated voltage and 200 mA collector current may be simultaneously applied provided the time of application is 10 μs or less and the duty cycle is 2% or less.
3. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
4. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.
5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent Pending

TEXAS INSTRUMENTS
INCORPORATED
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*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -30$ mA, $f = 100$ MHz	4		
C_{cb}	Collector-Base Capacitance	$V_{CB} = -5$ V, $I_E = 0$, $f = 1$ MHz, See Note 6		6	pF
C_{eb}	Emitter-Base Capacitance	$V_{EB} = -0.5$ V, $I_C = 0$, $f = 1$ MHz, See Note 6		6	pF

NOTE 6: C_{cb} and C_{eb} are measured using three-terminal measurement techniques with th third electrode (emitter or collector respectively) guarded.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_d	Delay Time	$I_C = -30$ mA, $I_{B(1)} = -3$ mA, $V_{BE(off)} = 0$, $R_L = 93\ \Omega$, See Figure 1	15	ns
t_r	Rise Time		30	ns
t_{on}	Turn-On Time		40	ns
t_s	Storage Time	$I_C = -30$ mA, $I_{B(1)} = -3$ mA, $I_{B(2)} = 3$ mA, $R_L = 93\ \Omega$, See Figure 2	40	ns
t_f	Fall Time		15	ns
t_{off}	Turn-Off Time		50	ns

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

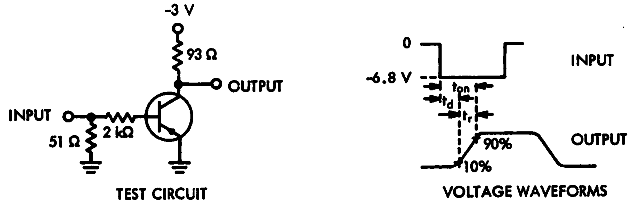


FIGURE 1

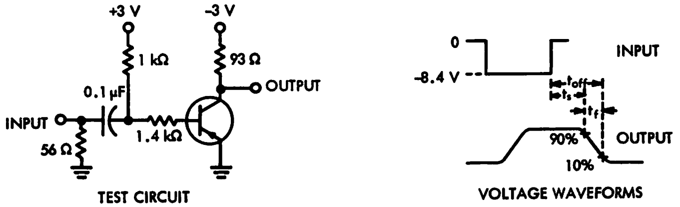


FIGURE 2

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 1$ ns, $t_p \geq 200$ ns, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ ns, $R_{in} \geq 100$ kΩ, $C_{in} \leq 10$ pF.

*Indicates JEDEC registered data

TYPES 2N5447, 2N5448
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

SILECT† TRANSISTORS

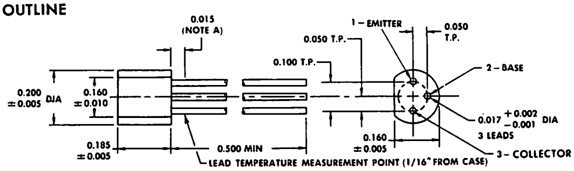
**Encapsulated in Plastic for Such Applications as
Medium-Power Amplifiers, Class B Audio Outputs, and Hi-Fi Drivers**

- **Electrically Equivalent to 2N3702 and 2N3703**
- **For Complementary Use with 2N5449, 2N5450, and 2N5451**
- **Rugged, One-Piece Construction Features Standard 100-mil TO-18 Pin Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N5447	2N5448
Collector-Base Voltage	−40 V	−50 V
Collector-Emitter Voltage (See Note 1)	−25 V	−30 V
Emitter-Base Voltage	−5 V	−5 V
Continuous Collector Current	←−200 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←360 mW→	
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 3)	← 500 mW →	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.
3. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent pending

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INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N5447, 2N5448
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N5447 MIN	2N5447 MAX	2N5448 MIN	2N5448 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$, $I_E = 0$	−40		−50		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ mA, $I_B = 0$, See Note 4	−25		−30		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$, $I_C = 0$	−5		−5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -20$ V, $I_E = 0$		−100		−100	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -3$ V, $I_C = 0$		−100		−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -50$ mA, See Note 4	60	300	30	150	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -5$ V, $I_C = -50$ mA, See Note 4	−0.6	−1	−0.6	−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -5$ mA, $I_C = -50$ mA, See Note 4		−0.25		−0.25	V
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -50$ mA, $f = 20$ MHz	5		5		
C_{cb}	Collector-Base Capacitance	$V_{CB} = -10$ V, $I_E = 0$, $f = 1$ MHz, See Note 5		12		12	pF

NOTES: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
5. C_{cb} is measured using three-terminal measurement techniques with the emitter guarded.

*Indicates JEDEC registered data

THERMAL INFORMATION

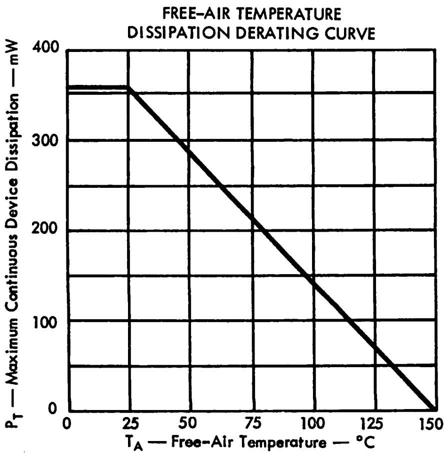


FIGURE 1

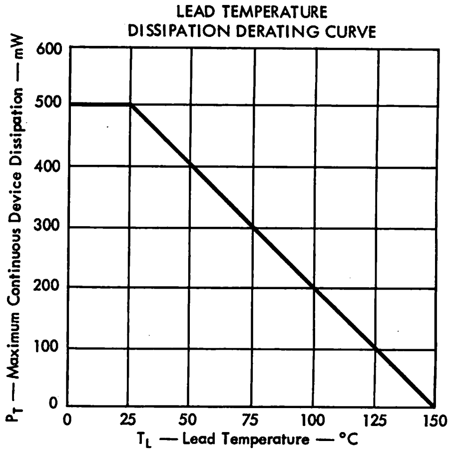
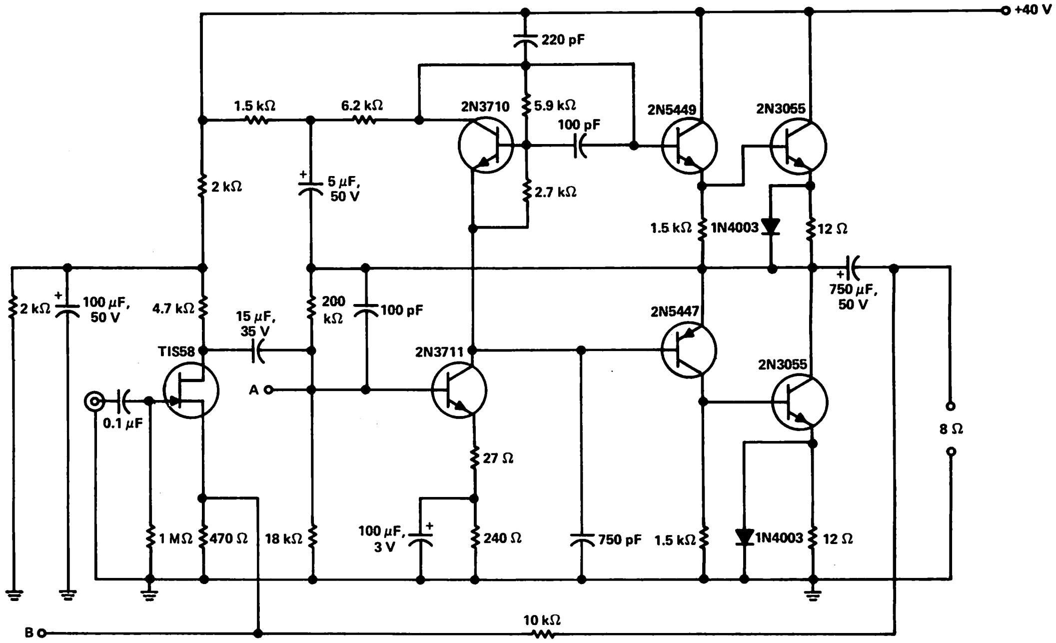


FIGURE 2

TYPICAL APPLICATION DATA

SILICON 15-WATT QUASI-COMPLEMENTARY POWER AMPLIFIER



CAI6834

TYPICAL PERFORMANCE SPECIFICATIONS	
Continuous Output Power	15 W @ 0.15% THD
Power Bandwidth @ 7.5 W	20 Hz – 20 kHz
Frequency Response ± 0.5 dB	10 Hz – 50 kHz
Total Harmonic Distortion @ 7.5 W	0.06%
Intermodulation Distortion @ 7.5 W	0.15%
Sensitivity @ 15 W	850 mV
Input Impedance	1 MΩ
Hum and Noise: "C" Weighting	
Input Shorted	−95 dB
Input Open	−85 dB
Damping Factor	48

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No. 59, 2-chome, Nagata-cho
Chiyoda-du, Tokyo, Japan

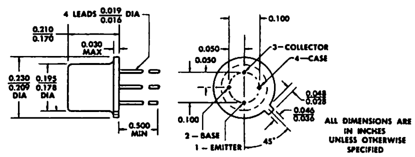
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N918
BULLETIN NO. DL-S 633996, AUGUST 1963
REVISED OCTOBER 1966

DESIGNED FOR USE IN VHF AND UHF AMPLIFIER AND OSCILLATOR APPLICATIONS TO THE KILOMEGACYCLE REGION

- **Low Noise Figure — 3 db typ at 60 mc**
- **High Neutralized Power Gain — 18 db typ at 200 mc**
- **High Oscillator Power Output — 50 mw typ at 500 mc**
- **Low Collector-Base Time Constant — 8 psec typ**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	30 v
Collector-Emitter Voltage (See Note 1)	15 v
Emitter-Base Voltage	3 v
Collector Current	50 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	200 mw
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	300 mw
Operating Collector Junction Temperature	200°C
Storage Temperature Range	−65°C to + 200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 1\ \mu a$, $I_E = 0$	30			v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 3$ ma, $I_B = 0$	15			v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	3			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ v, $I_E = 0$			10	na
		$V_{CB} = 15$ v, $I_E = 0$, $T_A = 150°C$			1	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 1$ v, $I_C = 3$ ma	20			
V_{BE}	Base-Emitter Voltage	$I_B = 1$ ma, $I_C = 10$ ma			1.0	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ ma, $I_C = 10$ ma			0.4	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 4$ ma, f = 100 mc	6.0	9.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 140 kc			1.7	pf
		$V_{CB} = 0$, $I_E = 0$, f = 140 kc			3.0	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, f = 140 kc			2.0	pf
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ v, $I_E = -4$ ma, f = 79.8 mc		8		psec

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. Derate linearly to 200°C free-air temperature at the rate of 1.14 mw/C°.

3. Derate linearly to 200°C case temperature at the rate of 1.71 mw/C°.

†The fourth lead (case) is floating for all measurements except Power Gain. For this parameter the fourth lead is grounded.

*Indicates JEDEC registered data (typical data excluded).

TYPE 2N918
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

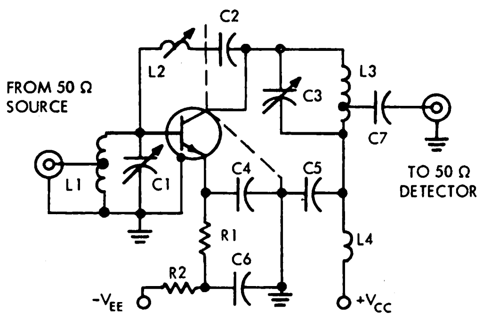
***operating characteristics at 25°C free-air temperature**

	PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT
NF	Spot Noise Figure	$V_{CE} = 6$ v, $I_C = 1$ ma, $R_G = 400\ \Omega$, f = 60 mc		3	6	db
G_{pe}	Neutralized Small-Signal Common-Emitter Insertion Power Gain	$V_{CB} = 12$ v, $I_C = 6$ ma, f = 200 mc (See Figure 1)	15	18		db
P_o	Oscillator Power Output	$V_{CB} = 15$ v, $I_C = 8$ ma, f = 500 mc	30	50		mw
η	Collector Efficiency	(See Figure 2)	25%	42%		

†The fourth lead (case) is floating for all measurements except Power Gain. For this parameter the fourth lead is grounded.

PARAMETER MEASUREMENT INFORMATION

***CIRCUIT SCHEMATIC**



NEUTRALIZATION ADJUSTMENT PROCEDURE

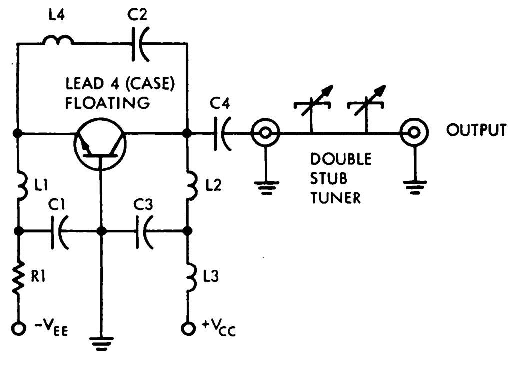
After tuning amplifier as for normal gain measurement, reverse input and output connections and tune L2 for minimum indication on detector. This sequence is repeated until optimum settings are obtained for all variables.

*** CIRCUIT COMPONENT INFORMATION**

C1: 3 — 12 pf
C2 and C7: 1000 pf
C3: 1.5 — 7.5 pf
C4 and C5: 0.01 μf
C6: 0.05 μf
R1: 100 Ω
R2: 1 kΩ
L1: 3½ T #16 AWG, 5/16" ID, 7/16" length
Turns Ratio ≈ 2 to 1
L2: 0.4 — 0.65μh, Miller #4303 (or equivalent).
L3: 8 T #16 AWG, ⅛" ID, ⅞" length,
Turns Ratio ≈ 8 to 1
L4: 200 mc RFC

FIGURE 1 — NEUTRALIZED 200 mc INSERTION POWER GAIN

CIRCUIT SCHEMATIC



CIRCUIT COMPONENT INFORMATION

C1 and C3: 1000 pf
C2: 50 pf
C4: 75 pf
R1: 2.2 kΩ
L1, L3, and L4: 0.2 μh, Ohmite Z460 (or equivalent).
L2: 2 T #16 AWG, ⅜" OD, 1¼" length
Double Stub Tuner consists of the following plumbing (or equivalent):
- 2 GR Type 874 TEE
- 1 GR Type 874-D20 Adjustable Stub
- 1 GR Type 874-LA Adjustable Line
- 1 GR Type 874-WN3 Short-Circuit Termination

*** FIGURE 2 — 500 mc OSCILLATOR POWER OUTPUT**

*Indicates JEDEC registered data (typical data excluded).

TYPES 2N3570, 2N3571, 2N3572
N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N3570, 2N3571, 2N3572
BULLETIN NO. DL-S 645937, AUGUST 1964
REPLACES BULLETIN NO. DL-S 644729, JANUARY 1964

FOR APPLICATIONS REQUIRING LOW NOISE FIGURE AND SUPERIOR SMALL-SIGNAL PERFORMANCE FROM VHF TO 1.5 GIGACYCLES

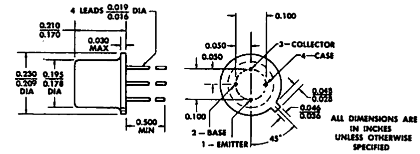
2N3570 (Formerly TIX3015) Features:

- **Guaranteed Noise Figure — 7.0 db max at 1 Gc**
- **Guaranteed Gain-Bandwidth Product — 1.5 Gc**
- **Guaranteed $r_b'C_c$ — 8 psec max**

description

These transistors are ideally suited for such applications as amplifiers, oscillators, and mixers. The guaranteed minimum gain-bandwidth products range from 1 to 1.5 Gc. Guaranteed minimum calculated f_{max} ranges from 1.7 to 2.7 Gc. These features coupled with low noise figures insure VHF through L-band amplifier and oscillator capability.

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N3570	2N3571	2N3572
Collector-Base Voltage	30 v	25 v	25 v
Collector-Emitter Voltage (See Note 1)	15 v	15 v	13 v
Emitter-Base Voltage	3 v	3 v	3 v
Collector Current	←	50 ma	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←	200 mw	→
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←	350 mw	→
Storage Temperature Range	−65°C to +200°C		
Lead Temperature 1/16 Inch from Case for 10 Seconds	←	300°C	→

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	2N3570 MIN	2N3570 TYP	2N3570 MAX	2N3571 MIN	2N3571 MAX	2N3572 MIN	2N3572 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 1\ \mu a$, $I_E = 0$	30			25		25		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 2$ ma, $I_B = 0$, See Note 4	15			15		13		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	3			3		3		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 6$ v, $I_E = 0$			10		10		10	na
		$V_{CB} = 6$ v, $I_E = 0$, $T_A = 150°C$			1		1		1	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 6$ v, $I_C = 5$ ma	20		150	20	200	20	300	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 6$ v, $I_C = 5$ ma, f = 1 kc	20		200	20	250	20	350	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 6$ v, $I_C = 5$ ma, f = 400 Mc	3.75	4.25	6	3	6	2.5	6	
C_{cb}	Collector-Base Capacitance	$V_{CB} = 6$ v, $I_E = 0$, f = 1 Mc, See Note 5		0.60	0.75		0.85		0.85	pf
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 6$ v, $I_E = -5$ ma, f = 79.8 Mc	1	5	8	1	10	1	13	psec

NOTES:
1. This value applies between 0 and 15 ma collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 1.14 mw/C°.
3. Derate linearly to 200°C case temperature at the rate of 2 mw/C°.
4. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.
5. C_{cb} is measured using three-terminal measurement techniques with case and emitter guarded.

†The fourth lead (case) is grounded for all measurements except C_{cb} and Oscillator Power Output.

*Indicates JEDEC registered data (typical data excluded).

***operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS†	2N3570 TYP	2N3570 MAX	2N3571 TYP	2N3571 MAX	2N3572 TYP	2N3572 MAX	UNIT
NF	Spot Noise Figure	$V_{CB} = 6$ v, $I_E = -2$ ma, $R_G = 50\ \Omega$, f = 1 Gc, See Note 6	6	7					db
		$V_{CB} = 6$ v, $I_E = -2$ ma, $R_G = 100\ \Omega$, f = 450 Mc				4		6	db

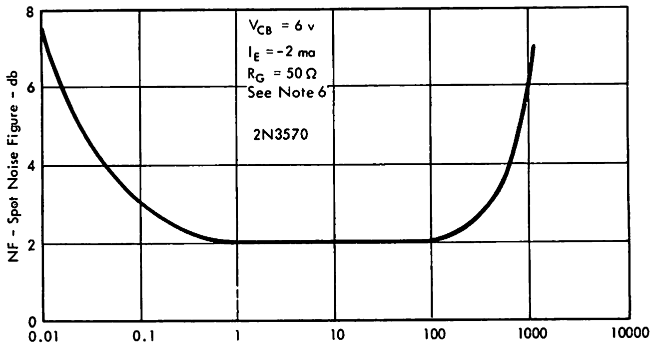
†The fourth lead (case) is grounded for all measurements except C_{cb} and Oscillator Power Output.

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	2N3570 MIN	2N3570 TYP	2N3570 MAX	UNIT
P_o	Oscillator Power Output	$V_{CC} = 20$ v, $I_C = 15$ ma, f = 1 Gc, See Figure 1 and Note 7		60		mw

TYPICAL CHARACTERISTICS AT $T_A = 25°C$

SPOT NOISE FIGURE vs FREQUENCY



NOTE 6: For detailed information on measurement technique, write for "Transistor Noise Figure Measurement at 1 Gc", referring to publication SC-4461.

PARAMETER MEASUREMENT INFORMATION

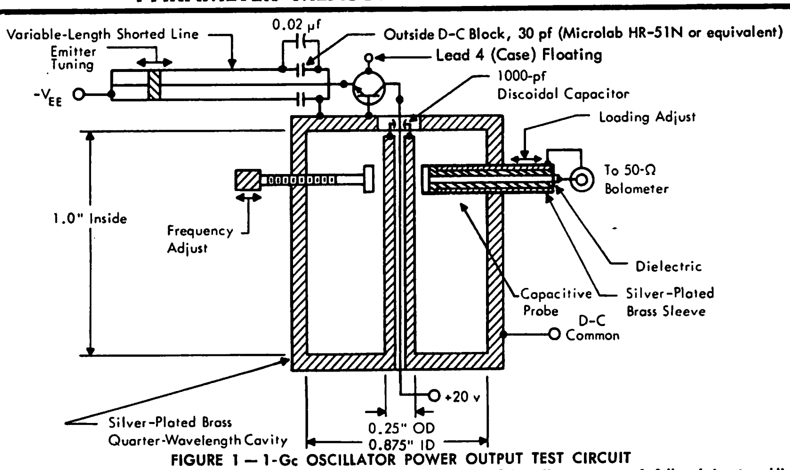


FIGURE 1 — 1-Gc OSCILLATOR POWER OUTPUT TEST CIRCUIT

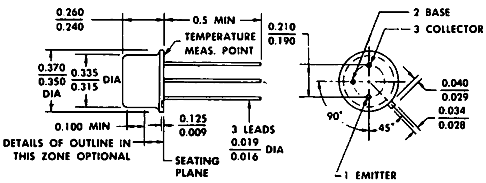
NOTE 7: For detailed information on measurement technique, write for "Transistor Oscillator Power Output Measurement at 1 Gc", refering to publication SC-4730.
*Indicates JEDEC registered data.

TYPE 2N3866
N-P-N EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3866
BULLETIN NO. DL-S 6710439, NOVEMBER 1967

- **Ideal Broadband Amplifier for CATV Line Amplifiers (50 MHz to 250 MHz)**
- **High Power Gain . . . 10 dB Min at 400 MHz**
- **High Collector Efficiency . . . 45% Min**
- **High f_T . . . 500 MHz Min**
- **High $V_{(BR)CEO}$ . . . 30 V Min**
- **Applications in Military, Commercial, and Citizens Band Radio Equipment**

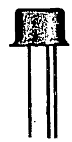
*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-39‡ DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



‡TO-39 is similar to TO-5 except for minimum lead length.

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	55 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Base Voltage	3.5 V
Continuous Collector Current	400 mA
Continuous Base Current	400 mA
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	5 W
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C case temperature at the rate of 28.6 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 5$ mA,	$I_B = 0$,	See Note 3	30			V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	$I_C = 5$ mA,	$R_{BE} = 10\ \Omega$,	See Note 3	55			V
I_{CEV}	Collector Cutoff Current	$V_{CE} = 55$ V,	$V_{BE} = -1.5$ V				0.1	mA
		$V_{CE} = 30$ V,	$V_{BE} = -1.5$ V,	$T_C = 200°C$			5	mA
I_{CEO}	Collector Cutoff Current	$V_{CE} = 28$ V,	$I_B = 0$				20	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3.5$ V,	$I_C = 0$				0.1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 360$ mA,	See Note 3	5			
		$V_{CE} = 5$ V,	$I_C = 50$ mA,	See Note 3	10	35	200	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 20$ mA,	$I_C = 100$ mA,	See Note 3			1	V
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 15$ V,	$I_C = 50$ mA,	f = 200 MHz	2.5			
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 28$ V,	$I_E = 0$,	f = 1 MHz			3	pF

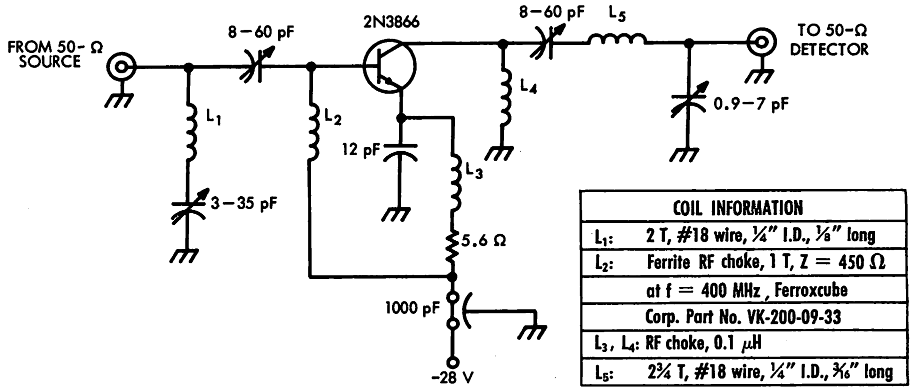
NOTE 3: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
P_{IE}	Large-Signal Common-Emitter Input Power	$P_{OE} = 1$ W, f = 400 MHz, See Figure 1		0.1	W
η	Collector Efficiency		45%		

*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



COIL INFORMATION	
L_1:	2 T, #18 wire, ¼" I.D., ⅛" long
L_2:	Ferrite RF choke, 1 T, Z = 450 Ω at f = 400 MHz, Ferroxcube Corp. Part No. VK-200-09-33
L_3, L_4:	RF choke, 0.1 μH
L_5:	2¾ T, #18 wire, ¼" I.D., 3/16" long

FIGURE 1 — 400-MHz INPUT POWER AND COLLECTOR EFFICIENCY TEST CIRCUIT

N-P-N EPITAXIAL PLANAR SILICON TRANSISTORS

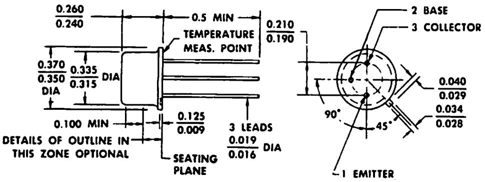
TYPES 2N4874 THRU 2N4876
BULLETIN NO. DL-S 679722, JANUARY 1967

DESIGNED FOR VHF THRU MICROWAVE APPLICATIONS

- **Ideal Broad-Band Amplifiers for CATV Line Amplifiers (50 MHz to 250 MHz)**
- **Linear Amplifiers for Single-Sideband Applications**

Calculated f_{max}† . . . 1.9 GHz Min (2N4874)

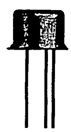
*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-39‡ DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



‡TO-39 is similar to TO-5 except for minimum lead length.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N4874	2N4875	2N4876
Collector-Base Voltage	30 V	40 V	40 V
Collector-Emitter Voltage (See Note 1)	20 V	25 V	30 V
Emitter-Base Voltage	2 V	2 V	2 V
Continuous Collector Current	←	200 mA	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←	720 mW	→
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←	6 W	→
Storage Temperature Range	←	−65°C to 200°C	→
Lead Temperature 1/16 Inch from Case for 10 Seconds	←	300°C	→

NOTES: 1. This value applies between 0 and 100 mA collector current when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 4.8 mW/deg.
3. Derate linearly to 175°C case temperature at the rate of 40 mW/deg.

*Indicates JEDEC registered data.

†Maximum Frequency of Oscillation may be calculated from the equation: $f_{max}\ (\text{MHz}) = 200 \sqrt{\dfrac{|h_{fe}| \times f_{meas}\ (\text{MHz})}{r_b' C_c\ (\text{ps})}}$

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

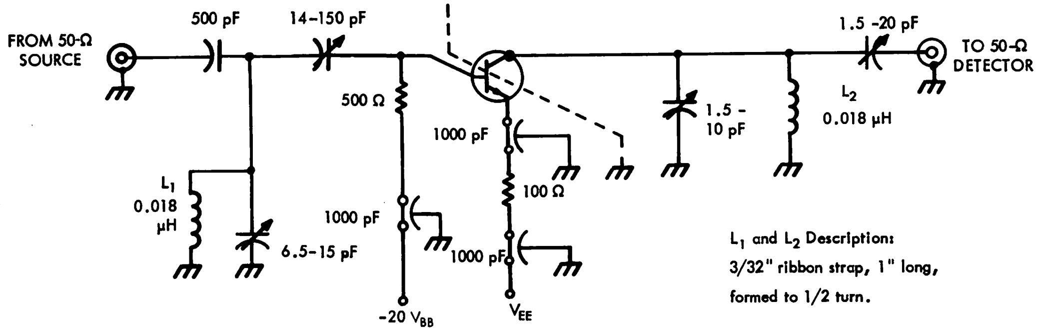
PARAMETER		TEST CONDITIONS	2N4874 MIN	2N4874 MAX	2N4875 MIN	2N4875 MAX	2N4876 MIN	2N4876 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$	30		40		40		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 4	20		25		30		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V, $I_E = 0$		0.5		0.5		0.5	μA
		$V_{CB} = 15$ V, $I_E = 0$, $T_A = 150°C$		0.5		0.5		0.5	mA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 2$ V, $I_C = 0$		10		10		10	μA
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 50$ mA, f = 1 kHz	20	200	20	200	20	200	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 20$ mA, f = 100 MHz	7	24	6	24			
		$V_{CE} = 10$ V, $I_C = 50$ mA, f = 100 MHz	9	25	8	25	6.5		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz, See Note 5		3.5		3.5		3.5	pF
$r_b'C_c$	Collector-Base Time Constant	$V_{CB} = 10$ V, $I_E = -50$ mA, f = 79.8 MHz		10		10		10	ps

NOTES: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
5. Collector-Base Capacitance is measured using three-terminal measurement techniques with the emitter guarded.

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N4874 MIN	2N4875 MIN	2N4876 MIN	UNIT
G_{PE}	Large-Signal Common-Emitter Insertion Power Gain	$V_{BB} = 20$ V, $I_E = -100$ mA, $P_{IE} = 0.1$ W, f = 400 MHz, See Figure 1	10	9.5	8.5	dB

*PARAMETER MEASUREMENT INFORMATION



*Indicates JEDEC registered data

FIGURE 1 — 400-MHz INSERTION-POWER-GAIN TEST CIRCUIT

TYPICAL CHARACTERISTICS

COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

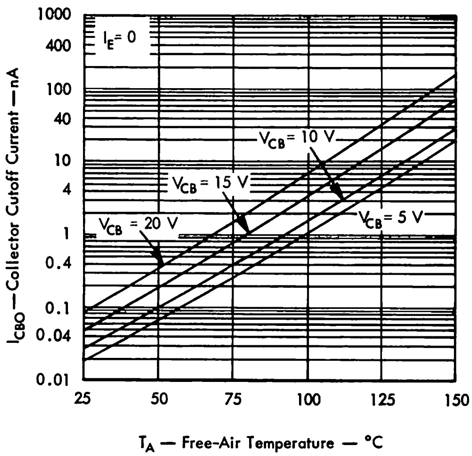


FIGURE 2

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

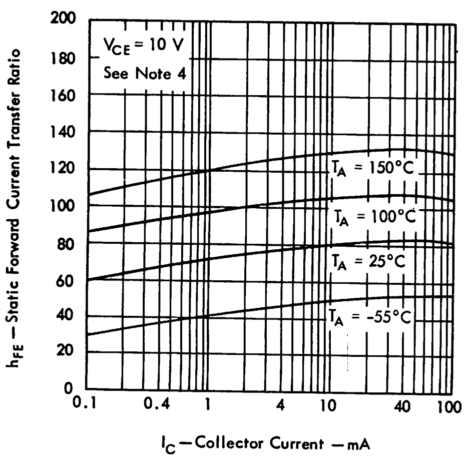


FIGURE 3

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR-EMITTER VOLTAGE

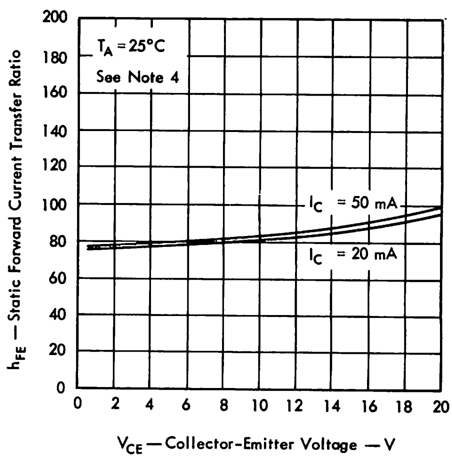


FIGURE 4

NOTE 4: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

FORWARD BASE CURRENT
vs
BASE-SUPPLY VOLTAGE

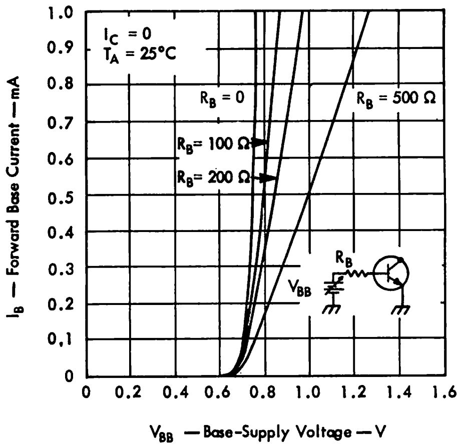


FIGURE 5

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

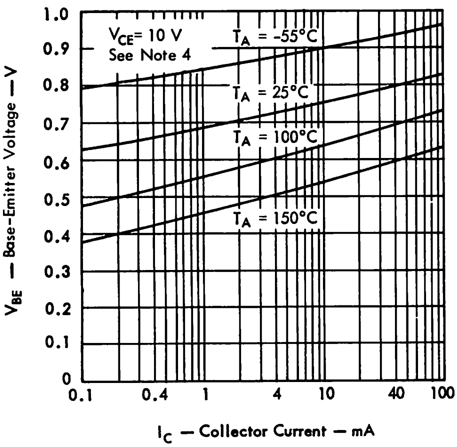


FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

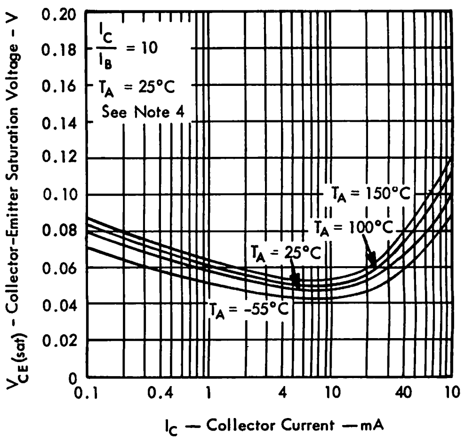


FIGURE 7

NOTE 4: These parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

TYPICAL CHARACTERISTICS

MAGNITUDE OF SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

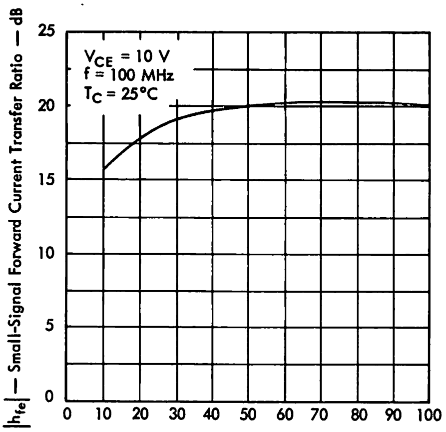


FIGURE 8

MAGNITUDE OF SMALL-SIGNAL
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

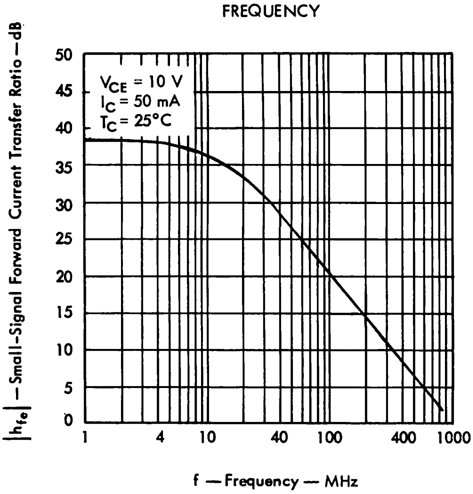


FIGURE 9

CONTOURS OF CONSTANT MAGNITUDE
OF SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO — $|h_{fe}|$

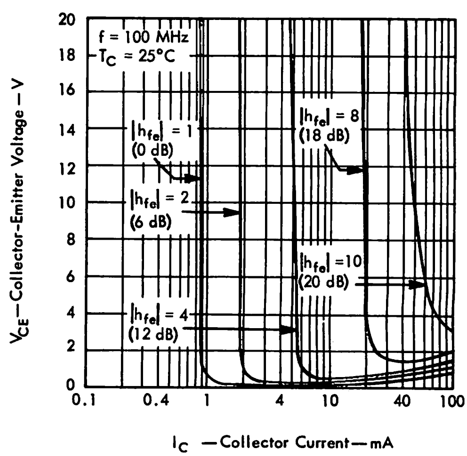


FIGURE 10

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-EMITTER INPUT ADMITTANCE
vs
FREQUENCY

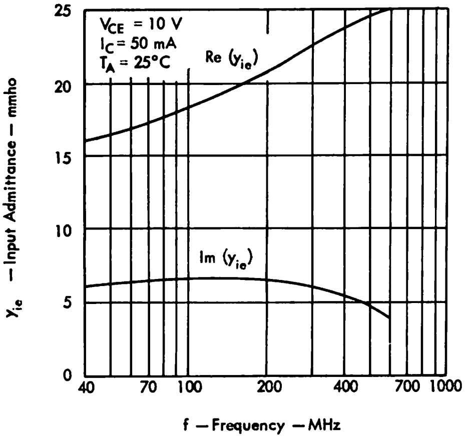


FIGURE 11

SMALL-SIGNAL COMMON-EMITTER
FORWARD TRANSFER ADMITTANCE
vs
FREQUENCY

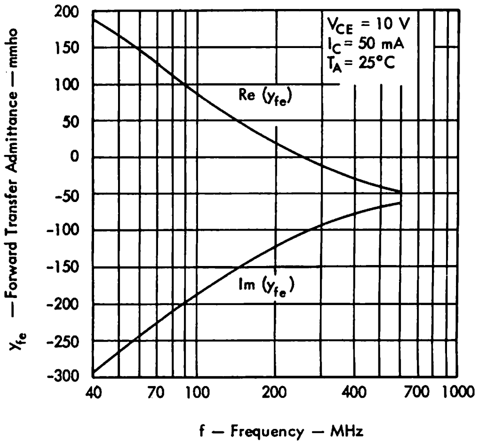


FIGURE 12

SMALL-SIGNAL COMMON-EMITTER
REVERSE TRANSFER ADMITTANCE
vs
FREQUENCY

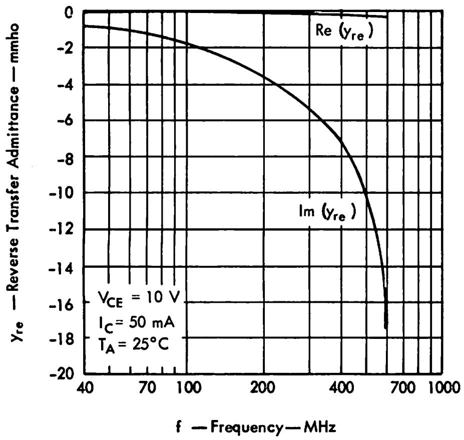


FIGURE 13

SMALL-SIGNAL COMMON-EMITTER
OUTPUT ADMITTANCE
vs
FREQUENCY

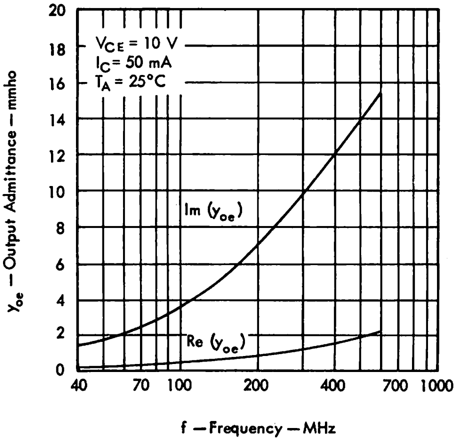


FIGURE 14

TYPICAL CHARACTERISTICS

COLLECTOR-BASE CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

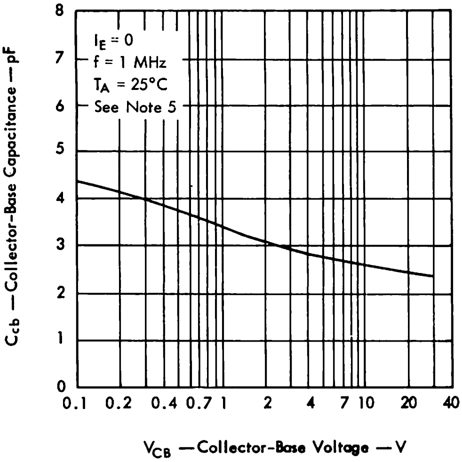


FIGURE 15

SPOT NOISE FIGURE
vs
FREQUENCY

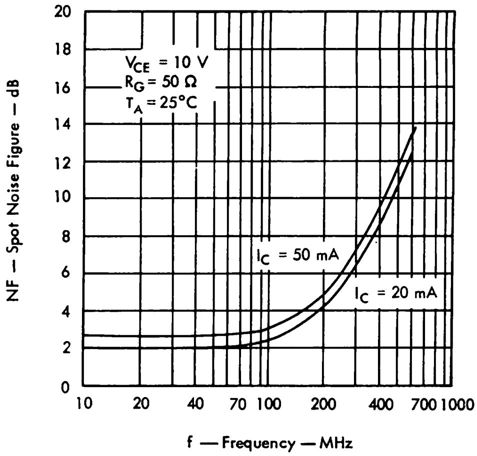


FIGURE 16

CROSS-MODULATION DISTORTION
vs
UNDESIRED-SIGNAL INPUT VOLTAGE

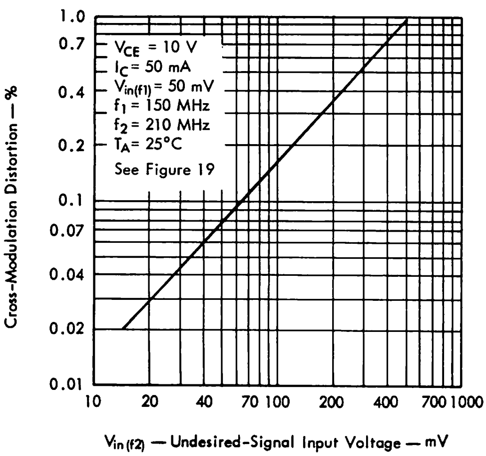


FIGURE 17

UNDESIRED-SIGNAL INPUT VOLTAGE
vs
COLLECTOR CURRENT

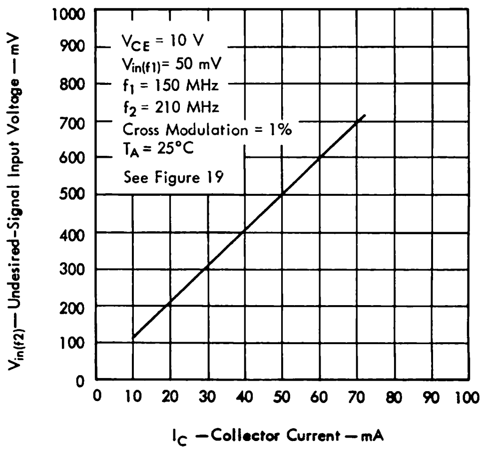
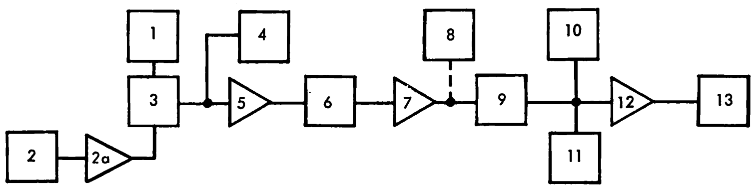


FIGURE 18

NOTE 5: Collector-Base Capacitance is measured using three-terminal measurement techniques with the emitter guarded.

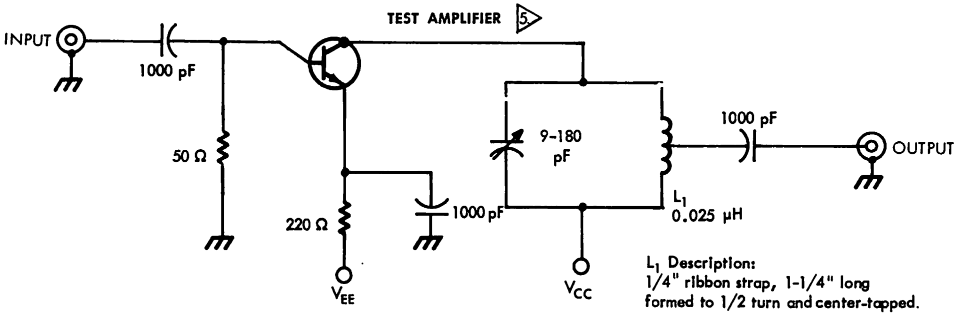
PARAMETER MEASUREMENT INFORMATION



BLOCK DIAGRAM

1. HP 608D Signal Generator
2. HP 608D Signal Generator
2a. Boonton 230A Power Amplifier
3. Power Divider
4. Boonton Model 91D RF Voltmeter
5. Test Amplifier Shown Below
6. HP Variable Attenuator (0-120 dB)
7. Boonton 230A Power Amplifier
8. Boonton Model 91D RF Voltmeter
9. Telonic RF Detector
10. HP 412A D-C Voltmeter
11. HP 130A Oscilloscope
12. 1-kHz Variable-Gain Amplifier
13. HP 400H RMS Voltmeter

TEST AMPLIFIER 5▷



L_1 Description:
1/4" ribbon strap, 1-1/4" long
formed to 1/2 turn and center-tapped.

CALIBRATING AND OPERATING INSTRUCTIONS

1. Set up equipment as shown in Block Diagram
2. Calibration
   A. Set signal generator $\boxed{1}$ to desired-signal frequency (f_1 = 150 MHz).
   B. Tune Boonton VHF Amplifier 7▷ to 150 MHz.
   C. Set desired-signal level for 50 mV at input of test amplifier 5▷.
   D. Modulate desired signal 20% with 1 kHz.
   E. Adjust variable attenuator $\boxed{6}$ to give 0.45 V at input of RF Detector $\boxed{9}$.
   F. Adjust gain of 1-kHz amplifier 12▷ for zero-dB reference on HP 400H $\boxed{13}$.
   G. Set signal generator $\boxed{2}$ to undesired-signal frequency (f_2 = 210 MHz).
   H. Modulate undesired signal 30% with 1 kHz.
3. Measurement
   A. Remove modulation from signal generator $\boxed{1}$.
   B. Increase the 30%-modulated undesired signal until a specified percentage of cross-modulation of the desired signal is indicated on the HP 400H $\boxed{13}$.
   C. Record the undesired-signal voltage at the input of test amplifier 5▷ with desired signal turned off.
4. This reading is the modulated undesired-signal voltage required to cause a specified percentage of cross-modulation on the desired-signal carrier.

FIGURE 19 — MEASUREMENT OF CROSS-MODULATION DISTORTION

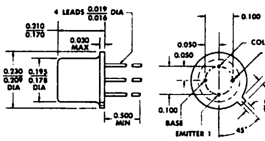
TYPES 3N74, 3N75, 3N76, 3N77, 3N78, 3N79
BULLETIN NO. DL-S 683659 MARCH 1963
REVISED MAY 1968

DOUBLE-EMITTER PLANAR TRANSISTORS DESIGNED FOR CHOPPER APPLICATIONS

- Low Offset Voltage
- Excellent Thermal Stability
- Very Low Leakage — 2 na max at 15 v (3N74, 3N75, 3N76)
- High Breakdown Voltage — 18 v min (3N74, 3N75, 3N76)

*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

ALL JEDEC TO-72 DIMENSIONS AND NOTES ARE APPLICABLE

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	3N74 3N75 3N76	3N77 3N78 3N79
Collector-Base Voltage	50 v	40 v
Emitter-One—Collector Voltage (See Note 1)	18 v	12 v
Emitter-Two—Collector Voltage (See Note 1)	18 v	12 v
Emitter-One—Emitter-Two Voltage (See Note 2)	18 v	12 v
Emitter-One—Base Voltage (See Note 3)	18 v	12 v
Emitter-Two—Base Voltage (See Note 3)	18 v	12 v
Collector Current	← 20 ma →	
Base Current	← 20 ma →	
Emitter-One Current	← 10 ma →	
Emitter-Two Current	← 10 ma →	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 300 mw →	
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 5)	← 600 mw →	
Storage Temperature Range	−65°C to +200°C	

NOTES: 1. This value applies when the base and alternate emitter are open-circuited.
2. This value applies when the collector is short-circuited to the base but open-circuited with respect to the emitters.
3. This value applies when the collector and alternate emitter are open-circuited.
4. Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.
5. Derate linearly to 175°C case temperature at the rate of 4 mw/C°.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	3N74		3N75		3N76		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_{E1} = I_{E2} = 0$	50		50		50		v
BV_{E1BO}, BV_{E2BO}	Emitter-Base Breakdown Voltage	I_{E1} (or I_{E2}) $= 10\ \mu a$ I_{E2} (or I_{E1}) $= 0$, $I_C = 0$	18		18		18		v
BV_{E1E2}	Emitter-Emitter Breakdown Voltage	$I_{E1} = \pm 10\ \mu a$, $V_{CB} = 0$ (See Note 6)	±18		±18		±18		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_{E1} = I_{E2} = 0$		10		10		10	na
I_{E1BO}, I_{E2BO}	Emitter Cutoff Current	V_{E1B} (or V_{E2B}) $= 15$ v I_{E2} (or I_{E1}) $= I_C = 0$		2		2		2	na
I_{E1E2}	Emitter Cutoff Current	$V_{E1E2} = \pm 15$ v, $V_{CB} = 0$ (See Note 6)		±2		±2		±2	na
		$V_{E1E2} = \pm 15$ v, $V_{CB} = 0$ $T_A = 100°C$, (See Note 6)		±100		±100		±100	na
$\|V_{E1E2}\|$	Offset Voltage	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$ $T_A = -25°C$, $+25°C$, and $+100°C$ (See Figure 1)		50		100		200	μv
$\|\Delta V_{E1E2}\|_{\Delta I_B}$	Offset Voltage Change With Base Current†	$I_{B(1)} = 1.5$ ma, $I_{B(2)} = 0.5$ ma $I_{E1} = I_{E2} = 0$		25		25		50	μv
$\|\Delta V_{E1E2}\|_{\Delta T_A}$	Offset Voltage Change With Temperature†	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$ $T_{A(1)} = 100°C$, $T_{A(2)} = -25°C$		75		125		175	μv
$\|h_{fe1}\|$, $\|h_{fe2}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE1} (or V_{CE2}) $= 5$ v, I_{E2} (or I_{E1}) $= 0$ $I_C = 1$ ma, $f = 20$ mc	1.5		1.5		1.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_{E1} = I_{E2} = 0$ $f = 140$ kc		8		8		8	pf
C_{e1b}, C_{e2b}	Common-Base Open-Circuit Input Capacitance	V_{E1B} (or V_{E2B}) $= 5$ v I_{E2} (or I_{E1}) $= 0$ $I_C = 0$, $f = 140$ kc		5		5		5	pf
r_{e1e2}	Dynamic On Series Resistance	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$ $I_{e1} = 100\ \mu a$, $f = 1$ kc (See Figure 2)	10	40	10	40	10	50	ohm

6. These parameters must be measured with the collector short-circuited to the base but open-circuited with respect to the emitters.

† Offset Voltage Change is defined as the magnitude of the algebraic difference between the offset voltage at the higher base current (or temperature) and the offset voltage at the lower base current (or temperature).

*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	3N77		3N78		3N79		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_{E1} = I_{E2} = 0$	40		40		40		v
BV_{E1BO}, BV_{E2BO}	Emitter-Base Breakdown Voltage	I_{E1} (or I_{E2}) $= 10\ \mu a$, I_{E2} (or I_{E1}) $= 0$, $I_C = 0$	12		12		12		v
BV_{E1E2}	Emitter-Emitter Breakdown Voltage	$I_{E1} = \pm 10\ \mu a$, $V_{CB} = 0$ (See Note 6)	±12		±12		±12		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ v, $I_{E1} = I_{E2} = 0$		10		10		20	na
I_{E1BO}, I_{E2BO}	Emitter Cutoff Current	V_{E1B} (or V_{E2B}) $= 5$ v, I_{E2} (or I_{E1}) $= I_C = 0$		5		5		10	na
I_{E1E2}	Emitter Cutoff Current	$V_{E1E2} = \pm 5$ v, $V_{CB} = 0$ (See Note 6)		±5		±5		±10	na
		$V_{E1E2} = \pm 5$ v, $V_{CB} = 0$, $T_A = 100°C$, (See Note 6)		±100		±100		±200	na
$\lvert V_{E1E2} \rvert$	Offset Voltage	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$, $T_A = -25°C$, $+25°C$, and $+100°C$ (See Figure 1)		50		100		200	μv
$\lvert \Delta V_{E1E2} \rvert_{\Delta I_B}$	Offset Voltage Change With Base Current†	$I_{B(1)} = 1.5$ ma, $I_{B(2)} = 0.5$ ma, $I_{E1} = I_{E2} = 0$		25		50		75	μv
$\lvert \Delta V_{E1E2} \rvert_{\Delta T_A}$	Offset Voltage Change With Temperature†	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$, $T_{A(1)} = 100°C$, $T_{A(2)} = -25°C$		75		125		175	μv
$\lvert h_{fe1} \rvert$, $\lvert h_{fe2} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE1} (or V_{CE2}) $= 5$ v, I_{E2} (or I_{E1}) $= 0$, $I_C = 1$ ma, $f = 20$ mc	1.5		1.5		1.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_{E1} = I_{E2} = 0$, $f = 140$ kc		8		8		10	pf
C_{e1b}, C_{e2b}	Common-Base Open-Circuit Input Capacitance	V_{E1B} (or V_{E2B}) $= 5$ v, I_{E2} (or I_{E1}) $= 0$, $I_C = 0$, $f = 140$ kc		5		5		6	pf
r_{e1e2}	Dynamic On Series Resistance	$I_B = 1$ ma, $I_{E1} = I_{E2} = 0$, $I_{e1} = 100\ \mu a$, $f = 1$ kc (See Figure 2)	10	50	10	50	10	60	ohm

6. These parameters must be measured with the collector short-circuited to the base but open-circuited with respect to the emitters.

† Offset Voltage Change is defined as the magnitude of the algebraic difference between the offset voltage at the higher base current (or temperature) and the offset voltage at the lower base current (or temperature).

*Indicates JEDEC registered data

TYPES 3N74, 3N75, 3N76, 3N77, 3N78, 3N79
N-P-N PLANAR SILICON TRANSISTORS

*PARAMETER MEASUREMENT INFORMATION

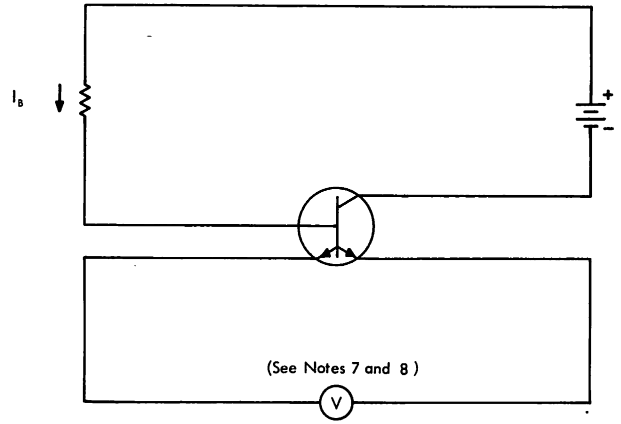


FIGURE 1 — OFFSET VOLTAGE TEST CIRCUIT

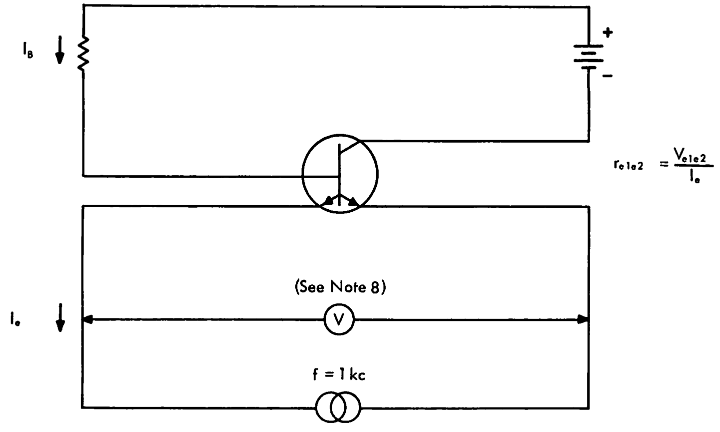


FIGURE 2 — ON SERIES RESISTANCE TEST CIRCUIT

NOTES: 7. Care must be taken to avoid error due to thermocouple action.

8. The voltmeter impedance must be high enough that halving it does not change the measured value.

*Indicates JEDEC registered data

N-P-N TYPES TIS90, TIS90M, TIS92, TIS92M
P-N-P TYPES TIS91, TIS91M, TIS93, TIS93M
COMPLEMENTARY EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES TIS90 THRU TIS93, TIS90M THRU TIS93M
BULLETIN NO. DL-S 671024, JULY 1967

SILECT† COMPLEMENTARY TRANSISTORS

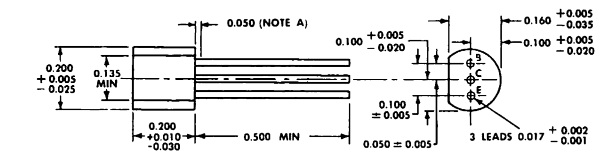
Available in Matched Complementary Pairs (TIS90M thru TIS93M)
for Complementary-Symmetry or Other Class-B Audio-Amplifier Applications

- **Supplied in Color-Coded h_{FE} Brackets of 3-dB-Maximum Range**
- **1.6-W Rating at 25°C Case Temperature**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

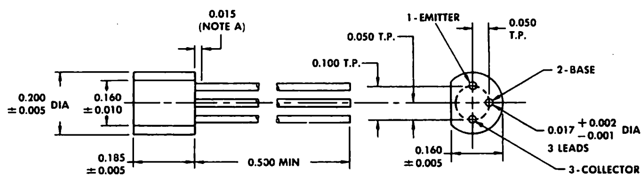
High-thermal-conductivity leads allow operation at unusually high dissipation levels.



TIS90, TIS90M, TIS91, TIS91M

ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES: A. Lead diameter is not controlled in this area.
B. All dimensions are in inches.



TIS92, TIS92M, TIS93, TIS93M

NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)§

Collector-Base Voltage	40 V
Collector-Emitter Voltage (See Note 1)	40 V
Emitter-Base Voltage	5 V
Continuous Collector Current	400 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	625 mW
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 3)	1.25 W
Continuous Device Dissipation at (or below) 25°C Case-and-Lead Temperature (See Note 4)	1.6 W
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C free-air temperature at the rate of 5 mW/deg.
3. Derate linearly to 150°C lead temperature at the rate of 10 mW/deg. Lead temperature is measured on the collector lead 1/16 inch from the case.
4. This rating applies with the entire case (including the leads) maintained at 25°C. Derate linearly to 150°C case-and-lead temperature at the rate of 12.8 mW/deg.

†Trademark of Texas Instruments
‡Patent pending
§Voltages and currents apply to the n-p-n transistors. For the p-n-p transistors the values are the same, but the polarities are reversed.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

N-P-N TYPES TIS90, TIS90M, TIS92, TIS92M
P-N-P TYPES TIS91, TIS91M, TIS93, TIS93M
COMPLEMENTARY EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	N-P-N TIS90, TIS90M TIS92, TIS92M MIN	TYP	MAX	P-N-P TIS91, TIS91M TIS93, TIS93M MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$	40			−40			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 5	40			−40			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$	5			−5			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20$ V, $I_E = 0$			100			−100	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$			100			−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA, See Note 5	100	160	300	100	160	300	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V, $I_C = 50$ mA, See Note 5	0.6	0.77	1	−0.6	−0.76	−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ mA, $I_C = 50$ mA, See Note 5		0.04	0.25		−0.06	−0.25	V
		$I_B = 20$ mA, $I_C = 200$ mA, See Note 5		0.17			−0.23		V

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

†Test condition voltages and currents apply to the n-p-n transistors. For the p-n-p transistors the values are the same, but the polarities are reversed.

PARAMETER COLOR-CODE INFORMATION

To facilitate matching and identification these transistors are color-coded in h_{FE} brackets, each having a maximum spread of 3 dB as shown in the table below. No guarantee is made as to distribution of h_{FE} values, except that equal numbers of n-p-n and p-n-p devices will be shipped in any given bracket when matched complementary pairs are ordered. To order from specific brackets, contact a TI sales office or distributor.

COLOR CODE	YELLOW	GREEN	BLUE	VIOLET	GRAY
h_{FE} Range, $\lvert V_{CE}\rvert = 2$ V, $\lvert I_C\rvert = 50$ mA	100 - 125	115 - 150	140 - 190	170 - 235	215 - 300

ORDERING INFORMATION — To order matched complementary pairs, order the same quantity each of TIS90M and TIS91M or TIS92M and TIS93M. Devices may be ordered separately by specifying TIS90, TIS91, TIS92, or TIS93.

THERMAL INFORMATION

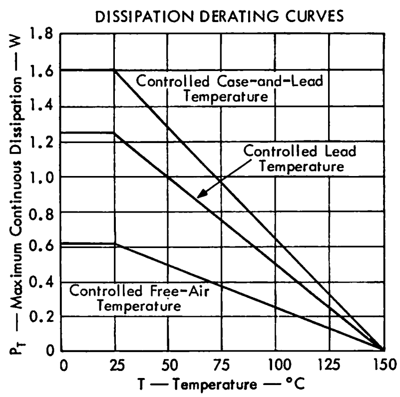


FIGURE 1

TYPICAL CHARACTERISTICS

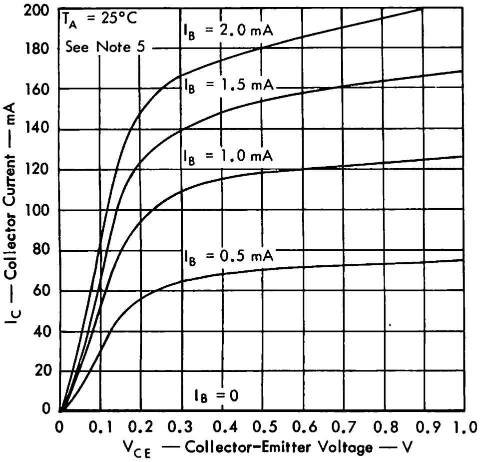


FIGURE 2

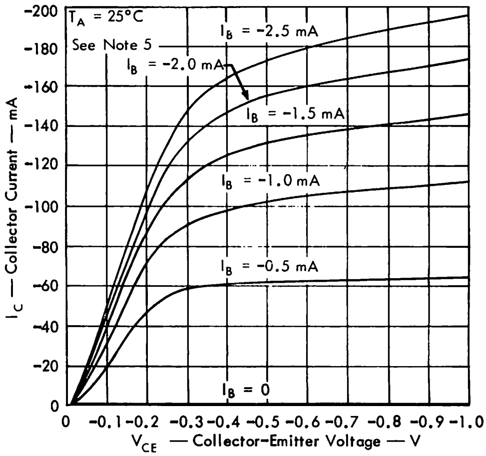


FIGURE 3

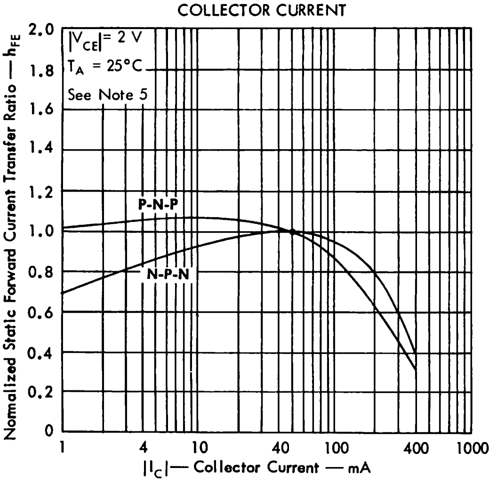


FIGURE 4

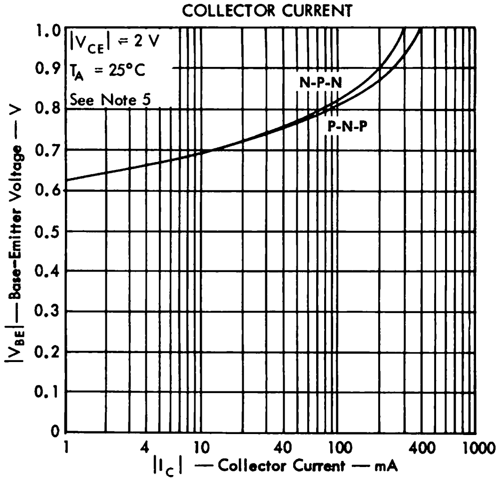
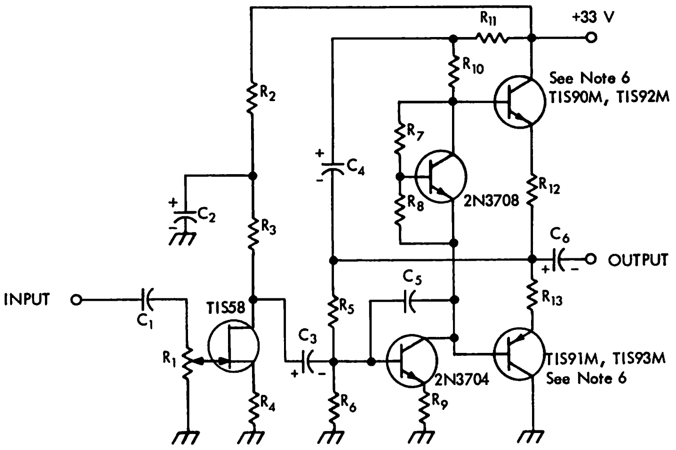


FIGURE 5

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL APPLICATION DATA



CIRCUIT COMPONENT INFORMATION

RESISTORS

R_1: 1 MΩ	R_6: 1.3 kΩ	R_{11}: 300 Ω
R_2: 2 kΩ	R_7: 200 Ω	R_{12}: 3.9 Ω
R_3: 2 kΩ	R_8: 360 Ω	R_{13}: 3.9 Ω
R_4: 100 Ω	R_9: 10 Ω	
R_5: 24 kΩ	R_{10}: 1.2 kΩ	

All resistors ½ W, ten percent tolerance

CAPACITORS

C_1: 0.05 μF
C_2: 50 μF, 30 V, electrolytic
C_3: 5 μF, 30 V, electrolytic
C_4: 20 μF, 20 V, electrolytic
C_5: 330 pF
C_6: 100 μF, 35 V, electrolytic

TYPICAL PERFORMANCE, R_L = 40 Ω, f = 1 kHz, T_A = 25°C (EXCEPT WHERE NOTED)	
Sensitivity at 1-W Output	100 mV
Input Impedance	1 MΩ
Total Harmonic Distortion at 2-W Output	3.7%
Total Harmonic Distortion at 1-W Output	1.2%
Total Harmonic Distortion at 50-mW Output	0.15%
Frequency Response	Down 3 dB at 63 Hz and 17 kHz
Power Supply Drain at Zero Signal	15 mA
Power Supply Drain at Rated Output	115 mA

NOTE 6: Heat sink the collector lead.

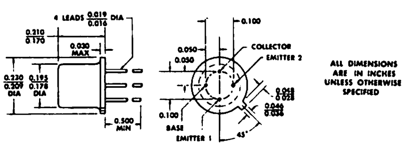
FIGURE 6 — TYPICAL 2-WATT COMPLEMENTARY AMPLIFIER

TYPES 3N108, 3N109, 3N110, 3N111
BULLETIN NO. DL-S 6810485, MAY 1968
REPLACES BULLETIN NO. DL-S 657302, MARCH 1965

HIGH-VOLTAGE DOUBLE-EMITTER PLANAR TRANSISTORS DESIGNED FOR LOW-LEVEL, HIGH-SPEED CHOPPER APPLICATIONS REQUIRING VERY LOW OFFSET VOLTAGE

- **May be Used in Some Circuits Designed for N-P-N Types by Reversing Collector and Base Terminations**
- **High Breakdown Voltages . . . 50 V Min (3N108, 3N109)**
- **Low Offset-Voltage/Temperature Sensitivity**
- **Extremely Low Leakage . . . 0.1 nA Max at 25 V (3N108, 3N109)**
- **Military Version (JAN3N108) Available**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	3N108 3N109	3N110 3N111
Collector-Base Voltage	–50 V	–50 V
Emitter-One—Collector Voltage (See Note 1)	–50 V	–30 V
Emitter-Two—Collector Voltage (See Note 1)	–50 V	–30 V
Emitter-One—Emitter-Two Voltage (See Note 2)	±50 V	±30 V
Emitter-One—Base Voltage	–50 V	–30 V
Emitter-Two—Base Voltage	–50 V	–30 V
Continuous Collector Current	←±20 mA→	
Continuous Base Current	←±20 mA→	
Continuous Emitter-One Current	←±10 mA→	
Continuous Emitter-Two Current	←±10 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	←300 mW→	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 4)	←600 mW→	
Storage Temperature Range	–65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←300°C→	

NOTES: 1. This value applies between 0 and 10 mA collector current when the base and alternate emitter are open-circuited.
2. This value applies when the collector is short-circuited to the base but open-circuited with respect to the emitters.
3. Derate linearly to 200°C free-air temperature at the rate of 1.71 mW/deg.
4. Derate linearly to 200°C case temperature at the rate of 3.43 mW/deg.

*Indicates JEDEC registered data

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TYPES 3N108, 3N109, 3N110, 3N111
P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	3N108 MIN	3N108 MAX	3N109 MIN	3N109 MAX	3N110 MIN	3N110 MAX	3N111 MIN	3N111 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -1\ \mu A$, $I_{E1} = I_{E2} = 0$	−50		−50		−50		−50		V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = -1\ \mu A$, $I_B = 0$, See Note 5	−50		−50		−30		−30		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -1\ \mu A$, $I_C = 0$, See Note 5	−50		−50		−30		−30		V
$V_{(BR)E1-E2}$	Emitter-Emitter Breakdown Voltage	$I_{E1} = \pm 1\ \mu A$, $V_{CB} = 0$, See Note 6	±50		±50		±30		±30		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -30\ V$, $I_{E1} = I_{E2} = 0$		−0.25		−0.25		−0.5		−0.5	nA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -25\ V$, $I_C = 0$, See Note 5		−0.1		−0.1		−0.5		−0.5	nA
$I_{E1-E2(off)}$	Emitter Cutoff Current	$V_{E1-E2} = \pm 25\ V$, $V_{CB} = 0$, See Note 6		±0.1		±0.1		±0.5		±0.5	nA
		$V_{E1-E2} = \pm 25\ V$, $V_{CB} = 0$, $T_A = 100°C$, See Note 6		±10		±10		±50		±50	nA
$\lvert V_{E1-E2(ofs)} \rvert$	Emitter-Emitter Offset Voltage	$I_B = -1\ mA$, $I_{E1} = I_{E2} = 0$, See Figure 1, $T_A = -25°C, 25°C$, and $100°C$		30		150		30		150	µV
$\lvert \Delta V_{E1-E2(ofs)} \rvert_{\Delta I_B}$	Offset Voltage Change With Base Current†	$I_{B(1)} = -1.5\ mA$, $I_{B(2)} = -0.5\ mA$, $I_{E1} = I_{E2} = 0$		20		50		20		50	µV
$\lvert \Delta V_{E1-E2(ofs)} \rvert_{\Delta T_A}$	Offset Voltage Change With Temperature†	$I_B = -1\ mA$, $I_{E1} = I_{E2} = 0$, $T_{A(1)} = 100°C$, $T_{A(2)} = -25°C$		50		150		50		150	µV
$r_{e1-e2(on)}$	Small-Signal Emitter-Emitter On-State Resistance	$I_B = -1\ mA$, $I_{E1} = I_{E2} = 0$, $I_e = 100\ \mu A$, $f = 1\ kHz$, See Figure 2	10	50	10	50	10	50	10	50	Ω
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -6\ V$, $I_C = -1\ mA$, $f = 4\ MHz$, See Note 5	3		3		3		3		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -6\ V$, $I_{E1} = I_{E2} = 0$, $f = 1\ MHz$		10		10		10		10	pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -6\ V$, $I_C = 0$, $f = 1\ MHz$, See Note 5		3		3		3		3	pF

NOTES: 5. These limits apply separately for each emitter with the alternate emitter open-circuited.

6. These parameters must be measured with the collector short-circuited to the base but open-circuited with respect to the emitters. The limits apply to both polarities of emitter-to-emitter voltage.

†Offset Voltage Change is defined as the magnitude of the algebraic difference between the offset voltages at two specified base currents or temperatures.

*PARAMETER MEASUREMENT INFORMATION

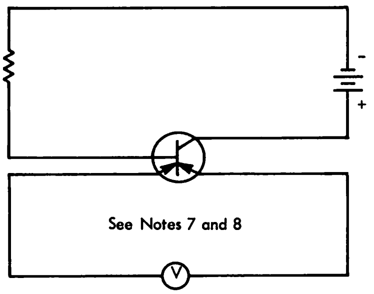


FIGURE 1 — OFFSET VOLTAGE TEST CIRCUIT

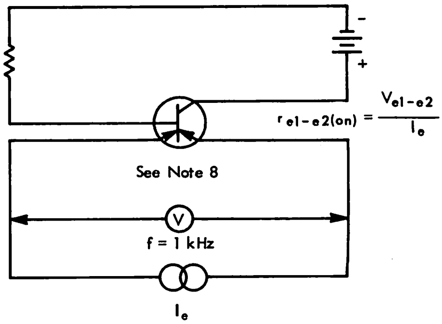


FIGURE 2 — SMALL-SIGNAL EMITTER-EMITTER ON-STATE RESISTANCE TEST CIRCUIT

NOTES: 7. Care must be taken to avoid error due to thermocouple action.

8. The voltmeter impedance must be high enough that halving it does not change the measured value.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

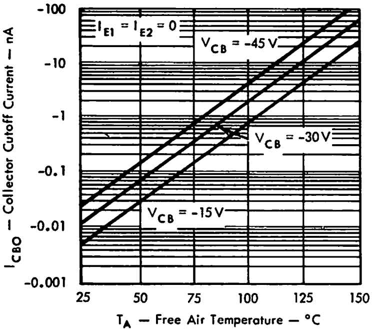


FIGURE 3

EMITTER CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

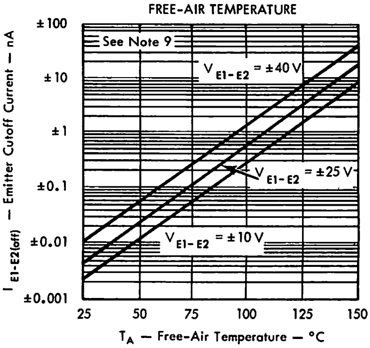


FIGURE 4

EMITTER CURRENT
vs
EMITTER-ONE—EMITTER-TWO VOLTAGE

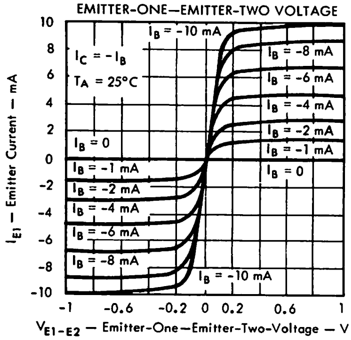


FIGURE 5

BASE-COLLECTOR VOLTAGE
vs
BASE CURRENT

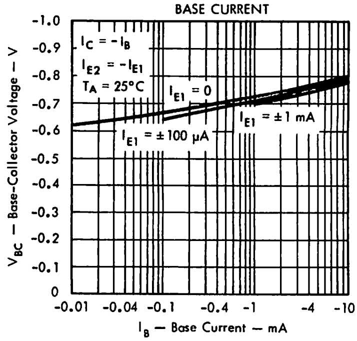


FIGURE 6

3N108, 3N110
EMITTER-EMITTER OFFSET VOLTAGE
vs
FREE-AIR TEMPERATURE

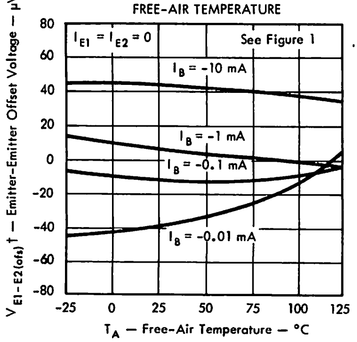


FIGURE 7

3N108, 3N110
EMITTER-EMITTER OFFSET VOLTAGE
vs
BASE CURRENT

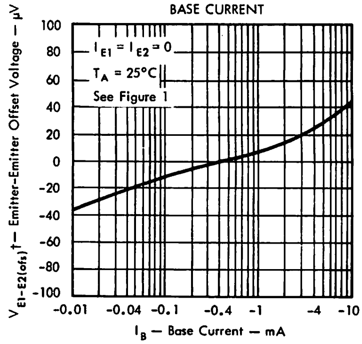


FIGURE 8

NOTE 9: This parameter is measured with the collectors short-circuited to the base but open-circuited with respect to the emitters.

†The polarity of the offset voltage at $T_A = 25°C$ and $I_B = -1$ mA is arbitrarily assumed to be positive.

TYPICAL CHARACTERISTICS

COMMON-BASE OPEN-CIRCUIT INPUT CAPACITANCE
vs
EMITTER-BASE VOLTAGE

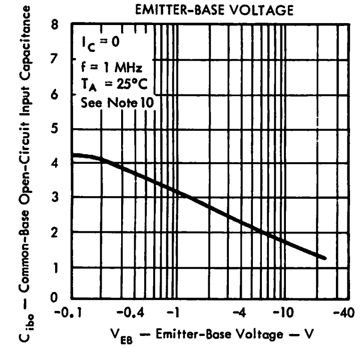


FIGURE 9

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

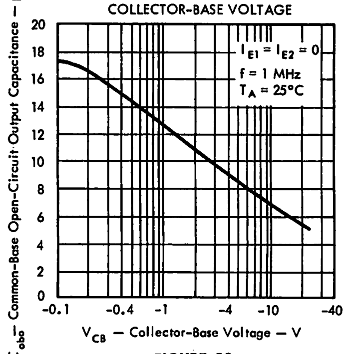


FIGURE 10

DYNAMIC ON-STATE RESISTANCE
vs
BASE CURRENT

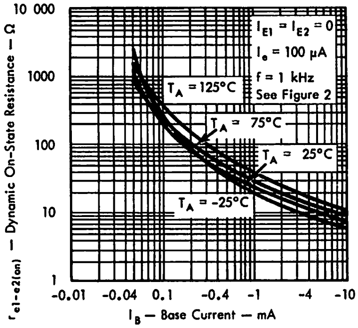


FIGURE 11

NOTE 10: This curve applies separately for each emitter with the alternate emitter open-circuited.

THERMAL INFORMATION

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

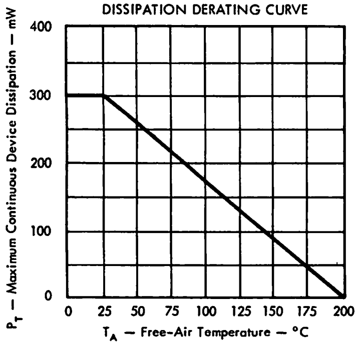


FIGURE 12

CASE TEMPERATURE
DISSIPATION DERATING CURVE

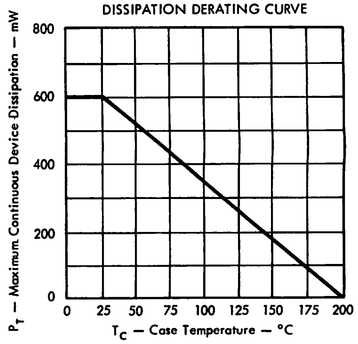


FIGURE 13

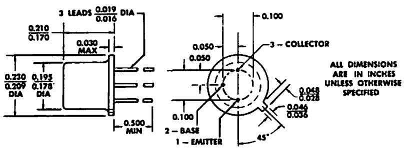
N-P-N PLANAR SILICON TRANSISTOR

TYPE 2N997
BULLETIN NO. DL-S 683526, FEBRUARY, 1963
REVISED MAY 1968

TWO TRIODES INTERNALLY CONNECTED IN DARLINGTON CONFIGURATION

- **Very High Gain — 1000 min at 100 μa**
- **Low Leakage — 10 na max at 60 v**
- **Rugged Internal Connections**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	75 v
Collector-Emitter Voltage (See Note 1)	40 v
Emitter-Base Voltage	7 v
Collector Current	300 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.5 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	1.5 w
Storage Temperature Range	−65°C to 200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	75		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, See Note 4	40		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	7		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ v, $I_E = 0$		10	na
		$V_{CB} = 60$ v, $I_E = 0$, $T_A = 150°C$		10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100\ \mu a$	1000		
		$V_{CE} = 10$ v, $I_C = 10$ ma	4000		
		$V_{CE} = 10$ v, $I_C = 100$ ma, See Note 4	7000	70 000	
		$V_{CE} = 10$ v, $I_C = 100$ ma, $T_A = -55°C$, See Note 4	1000		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 10$ v, $I_C = 100$ ma, See Note 4	0.9	1.8	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ ma, $I_C = 100$ ma, See Note 4		1.6	v
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ mc		35	pf

NOTES: 1. This value applies when the emitter-base diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 3.33 mw/C°.
3. Derate linearly to 175°C case temperature at the rate of 10.0 mw/C°.
4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

*Indicates JEDEC registered data

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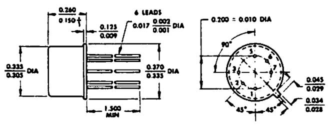
DUAL N-P-N PLANAR SILICON TRANSISTORS

TYPES 2N2060, 2N2223, 2N2223A
BULLETIN NO. DL-S 663514, MARCH 1963
REVISED OCTOBER 1965
2ND REVISION OCTOBER 1966

TWO TRANSISTORS IN ONE PACKAGE
FOR DIFFERENTIAL AMPLIFIER APPLICATIONS

- **Medium Power**
- **High Operating Voltage**

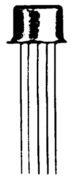
*mechanical data



1 COLLECTOR 1
2 BASE 1
3 EMITTER 1
5 EMITTER 2
6 BASE 2
7 COLLECTOR 2

ALL LEADS INSULATED FROM CASE

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



† Applicable to 2N2223 and 2N2223A only. Registered minimum dimension for 2N2060 is 0.140.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N2060		2N2223 2N2223A		UNIT
	EACH TRIODE	TOTAL DEVICE	EACH TRIODE	TOTAL DEVICE	
Collector-Base Voltage	100		100		v
Collector-Emitter Voltage (See Note 1)	80		80		v
Collector-Emitter Voltage (See Note 2)	60		60		v
Emitter-Base Voltage	7.0		7.0		v
Collector Current	500		500		ma
Total Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	0.5	0.6	0.5	0.6	w
Total Dissipation at (or below) 25°C Case Temperature (See Notes 4 and 5)	1.5	3.0	1.6	3.0	w
Total Dissipation at 100°C Case Temperature	0.86	1.7	0.91	1.7	w
Operating Collector Junction Temperature	200		200		°C
Storage Temperature Range	−65°C to +200°C				
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C				

NOTES: 1. This value applies when the base-emitter resistance (R_{BE}) is equal to or less than 10 ohms.
2. This value applies when the base-emitter diode is open-circuited.
3. Derate linearly to 200°C free-air temperature at the rate of 2.86 mw/C° for each triode and 3.43 mw/C° for total device.
4. Derate 2N2060 linearly to 200°C case temperature at the rate of 8.6 mw/C° for each triode and 17.2 mw/C° for total device.
5. Derate 2N2223 and 2N2223A linearly to 200°C case temperature at the rate of 9.1 mw/C° for each triode and 17.2 mw/C° for total device.
6. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.
7. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 1%.
8. The lower of the two h_{FE} readings is taken as h_{FE1}.
9. This parameter is measured in an amplifier with response down 3db at 25 cps and 10 kc and a high frequency rolloff of 6 db/octave.

*Indicates JEDEC registered data.

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

* individual triode characteristics (see note 6)

PARAMETER		TEST CONDITIONS	2N2060 MIN	2N2060 MAX	2N2223 2N2223A MIN	2N2223 2N2223A MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	100		100		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$ (See Note 7)	60		60		v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = 100$ ma, $R_{BE} = 10\ \Omega$ (See Note 7)	80		80		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	7.0		7.0		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 80$ v, $I_E = 0$		2		10	na
		$V_{CB} = 80$ v, $I_E = 0$, $T_A = 150°C$		10		15	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		2		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu a$	25	75	15		
		$V_{CE} = 5$ v, $I_C = 100\ \mu a$	30	90	25	150	
		$V_{CE} = 5$ v, $I_C = 1$ ma	40	120			
		$V_{CE} = 5$ v, $I_C = 10$ ma (See Note 7)	50	150	50	200	
V_{BE}	Base-Emitter Voltage	$I_B = 5$ ma, $I_C = 50$ ma		0.9		0.9	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 5$ ma, $I_C = 50$ ma		1.2		1.2	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	20	30	20	30	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc				3.0×10^{-4}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_C = 1$ ma, $f = 1$ kc				0.5	μmho
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	1000	4000			ohm
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	50	150	40	200	
h_{oe}	Small-Signal Common-Emitter Output Admittance	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	4	16			μmho
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 50$ ma, $f = 20$ mc	3.0		2.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ mc		15		15	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, $f = 1$ mc		85		85	pf

* triode matching characteristics

PARAMETER		TEST CONDITIONS	2N2060 MIN	2N2060 MAX	2N2223 MIN	2N2223 MAX	2N2223A MIN	2N2223A MAX	UNIT
$\frac{h_{FE1}}{h_{FE2}}$	Static Forward Current Gain Balance Ratio	$V_{CE} = 5$ v, $I_C = 100\ \mu a$, (See Note 8)	0.9	1.0	0.8	1.0	0.9	1.0	
		$V_{CE} = 5$ v, $I_C = 1$ ma, (See Note 8)	0.9	1.0					
$\|V_{BE1}-V_{BE2}\|$	Base-Emitter-Voltage Differential	$V_{CE} = 5$ v, $I_C = 100\ \mu a$		5		15		5	mv
		$V_{CE} = 5$ v, $I_C = 1$ ma		5					mv
$\left\|\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}\right\|$	Base-Emitter-Voltage - Differential Temperature Gradient	$V_{CE} = 5$ v, $I_C = 100\ \mu a$, From $T_A = -55°C$ to $T_A = 125°C$		10		25		25	μv/C°

operating characteristics at 25°C free-air temperature

*individual triode characteristics (see note 6)

PARAMETER		TEST CONDITIONS	2N2060 MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CE} = 10$ v, $I_C = 300\ \mu a$, $R_G = 510\ \Omega$ Noise Bandwidth = 900 cps to 1100 cps	8	db
		$V_{CE} = 10$ v, $I_C = 300\ \mu a$, $R_G = 1.0\ k\Omega$ Noise Bandwidth = 15.7 kc (See Note 9)	8	db

*Indicates JEDEC registered data.

TYPES 2N2639, 2N2640, 2N2641, 2N2642, 2N2643 AND 2N2644
DUAL N-P-N PLANAR SILICON TRANSISTORS

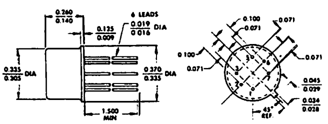
TYPES 2N2639, 2N2640, 2N2641, 2N2642, 2N2643 AND 2N2644
BULLETIN NO. DL-S 683321, JANUARY 1963
REVISED MAY 1968

TWO TRANSISTORS IN ONE PACKAGE
RECOMMENDED FOR

- **Differential Amplifiers**
- **High-Gain, Low-Noise Audio Amplifiers**
- **Transducer Signal-Conditioner Amplifiers**
- **Low-Level Flip-Flops**

*mechanical data

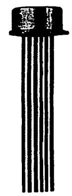
ALL LEADS INSULATED FROM CASE



1. COLLECTOR 1
2. BASE 1
3. EMITTER 1
5. EMITTER 2
6. BASE 2
7. COLLECTOR 2

JEDEC TO-5 NOTES 2, 3 AND 4 ARE APPLICABLE.

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	Each Triode	Total Device
Collector-Base Voltage	45 v	
Collector-Emitter Voltage (See Note 1)	45 v	
Emitter-Base Voltage	5 v	
Collector Current	30 ma	
Total Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.3 w	0.6 w
Total Dissipation at (or below) 25°C Case Temperature (See Note 3)	0.6 w	1.2 w
Storage Temperature Range	—65°C to 200°C	

NOTES: 1. This value applies when the emitter-base diode is open-circuited.
2. For each triode derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.
3. For each triode derate linearly to 175°C case temperature at the rate of 4 mw/C°.

*Indicates JEDEC registered data

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TYPES 2N2639, 2N2640, 2N2641, 2N2642, 2N2643 AND 2N2644
DUAL N-P-N PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

* individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	2N2639 2N2640 2N2641			2N2642 2N2643 2N2644			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 5	45			45			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 45$ v, $I_E = 0$ $V_{CB} = 45$ v, $I_E = 0$, $T_A = 150°C$			10 10			10 10	na μa
I_{CEO}	Collector Cutoff Current	$V_{CE} = 5$ v, $I_B = 0$			10			10	na
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$			10			10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu$a $V_{CE} = 5$ v, $I_C = 10\ \mu$a, $T_A = -55°C$ $V_{CE} = 5$ v, $I_C = 100\ \mu$a $V_{CE} = 5$ v, $I_C = 1$ ma	50 10 55 65		300	100 20 110 130	150 40 170 200	300	
V_{BE}	Base-Emitter Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma	0.6	0.76	1	0.6	0.76	1	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma			1		0.35	1	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc	25	26.5	32	25	26.5	32	ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc		120×10^{-6}	600×10^{-6}		120×10^{-6}	600×10^{-6}	
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc		0.1	1		0.1	1	μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, f = 1 kc	65		600	130	250	600	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, f = 20 mc	4	11		4	11		db
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 1 mc		5	8		5	8	pf

*triode matching characteristics

PARAMETER		TEST CONDITIONS	2N2639 2N2642		2N2640 2N2643		UNIT
			MIN	MAX	MIN	MAX	
$\frac{h_{FE1}}{h_{FE2}}$	Static Forward-Current-Gain Balance Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu$a, See Note 6	0.9	1	0.8	1	
$\|V_{BE1}-V_{BE2}\|$	Base-Emitter-Voltage Differential	$V_{CE} = 5$ v, $I_C = 10\ \mu$a		5		10	mv
$\left\|\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}\right\|$	Base-Emitter-Voltage-Differential Temperature Gradient	$V_{CE} = 5$ v, $I_C = 10\ \mu$a $\Delta T_A = [25°C - (-55°C)]$ and $[125°C - 25°C]$		10		20	μv/C°

operating characteristics at 25°C free-air temperature

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	ALL TYPES		UNIT
			TYP	MAX	
NF	Average Noise Figure	$V_{CB} = 5$ v, $I_E = -10\ \mu$a, $R_G = 10$ kΩ Noise Bandwidth 10 cps to 15.7 kc	1.8	4	db

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq 2\%$.

6. The lower of the two h_{FE} readings is taken as h_{FE1}.

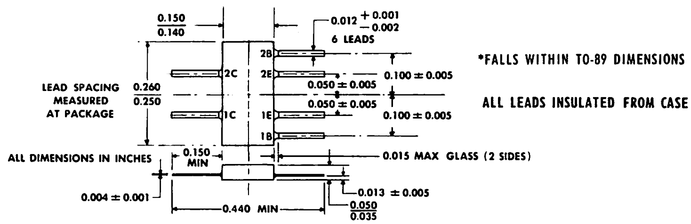
*Indicates JEDEC registered data (Typical data excluded.)

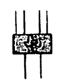
TYPES 2N3043 THRU 2N3048
BULLETIN NO. DL-S 634208, AUGUST 1963
REVISED APRIL 1967

DESIGNED FOR DIFFERENTIAL AMPLIFIERS AND HIGH-GAIN LOW-NOISE AUDIO AMPLIFIERS

- Electrically Similar to 2N2639-2N2644 Series
- Individual Triodes are Electrically Similar to 2N929, 2N930
- Popular TO-89 Flatpack Facilitates High-Density Packaging
- Welded Metal Construction

mechanical data





*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH TRIODE	TOTAL DEVICE
Collector-Base Voltage	45 v	
Collector-Emitter Voltage (See Note 1)	45 v	
Emitter-Base Voltage	5 v	
Continuous Collector Current	30 ma	
Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mw	350 mw
Continuous Dissipation at (or below) 25°C Case Temperature (See Note 3)	0.7 w	1.4 w
Storage Temperature Range	−65°C to +200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds		230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. Derate linearly to 175°C free-air temperature at the rate of 1.67 mw/C° for each triode and 2.33 mw/C° for total device.

3. Derate linearly to 175°C case temperature at the rate of 4.67 mw/C° for each triode and 9.33 mw/C° for total device.

*Indicates JEDEC registered data

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	2N3043 2N3044 2N3045		2N3046 2N3047 2N3048		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CBO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 5	45		45		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	5		5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 45$ v, $I_E = 0$		10		10	na
		$V_{CB} = 45$ v, $I_E = 0$, $T_A = 150°C$		10		10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 4$ v, $I_C = 0$		10		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu a$	100	300	50	200	
		$V_{CE} = 5$ v, $I_C = 1$ ma	130		65		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ v, $I_C = 10$ ma	0.6	0.8	0.6	0.8	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma		1		1	v
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	3.2	19	1.6	13	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	130	600	65	400	
h_{oe}	Small-Signal Common-Emitter Output Admittance	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc		100		70	μmho
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 20$ Mc	1.5		1.5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, $f = 1$ Mc		8		8	pf

*triode matching characteristics

PARAMETER		TEST CONDITIONS	2N3043 2N3046		2N3044 2N3047		UNIT
			MIN	MAX	MIN	MAX	
$\frac{h_{FE1}}{h_{FE2}}$	Static Forward-Current-Gain Balance Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, See Note 6	0.9	1	0.8	1	
$\lvert V_{BE1} - V_{BE2}\rvert$	Base-Emitter-Voltage-Differential	$V_{CE} = 5$ v, $I_C = 10\ \mu a$		5		10	mv
$\lvert \Delta(V_{BE1} - V_{BE2})_{\Delta T_A}\rvert$	Base-Emitter-Voltage-Differential Change With Temperature	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = -55°C$		0.8		1.6	mv
		$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = 125°C$		1		2	mv

operating characteristics at 25°C free-air temperature

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	ALL TYPES		UNIT
			TYP	MAX	
$\overline{NF}$	Average Noise Figure	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $R_G = 10$ kΩ, Noise Bandwidth = 15.7 kc, See Note 7	2	5	db

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

6. The lower of the two h_{FE} readings is taken as h_{FE1}.

7. Average Noise Figure is measured in an amplifier with low-frequency-response down 3 db at 10 cps.

*Indicates JEDEC registered data

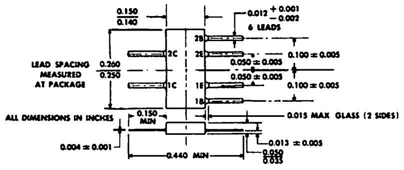
DUAL P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TYPES 2N3049, 2N3050, 2N3051
BULLETIN NO. DL-S 634230, AUGUST 1963
REVISED APRIL 1967

DESIGNED FOR DIFFERENTIAL AMPLIFIERS, LOW-NOISE AMPLIFIERS, AND LOW-LEVEL SWITCHING

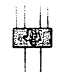
- Each Triode Electrically Similar to 2N2411 and 2N2412 Transistors
- Popular TO-89 Flatpack Facilitates High-Density Packaging
- Welded Metal Construction

mechanical data



*FALLS WITHIN TO-89 DIMENSIONS

ALL LEADS INSULATED FROM CASE



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH TRIODE	TOTAL DEVICE
Collector-Base Voltage	−25 v	
Collector-Emitter Voltage (See Note 1)	−20 v	
Emitter-Base Voltage	−5 v	
Continuous Collector Current	−100 ma	
Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mw	350 mw
Continuous Dissipation at (or below) 25°C Case Temperature (See Note 3)	0.7 w	1.4 w
Storage Temperature Range	−65°C to + 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds		230°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 5	−20		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -25$ v, $I_E = 0$		−10	na
		$V_{CB} = -25$ v, $I_E = 0$, $T_A = 150°C$		−10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ v, $I_C = 0$		−10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -10$ μa	20	120	
		$V_{CE} = -5$ v, $I_C = -100$ μa	30	120	
		$V_{CE} = -5$ v, $I_C = -1$ ma	30	120	
		$V_{CE} = -5$ v, $I_C = -10$ ma, See Note 5	30	120	
		$V_{CE} = -1$ v, $I_C = -10$ ma	20		
V_{BE}	Base-Emitter Voltage	$I_B = -1$ ma, $I_C = -10$ ma	−0.7	−0.9	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ ma, $I_C = -10$ ma		−0.2	v
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc	0.75	4.5	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc	30	130	
h_{oe}	Small-Signal Common-Emitter Output Admittance	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc		50	μmho
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 20 Mc	3		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 Mc		8	pf

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 1.67 mw/C° for each triode and 2.33 mw/C° for total device.
3. Derate linearly to 175°C case temperature at the rate of 4.67 mw/C° for each triode and 9.33 mw/C° for total device.
4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.
5. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N3049, 2N3050, 2N3051
DUAL P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

*triode matching characteristics

PARAMETER		TEST CONDITIONS	2N3049		2N3050		UNIT
			MIN	MAX	MIN	MAX	
$\frac{h_{FE1}}{h_{FE2}}$	Static-Forward-Current-Gain Balance Ratio	$V_{CE} = -5$ v, $I_C = -100\ \mu a$, See Note 6	0.9	1	0.8	1	
$\lvert V_{BE1} - V_{BE2} \rvert$	Base-Emitter-Voltage-Differential	$V_{CE} = -5$ v, $I_C = -100\ \mu a$		5		10	mv
$\lvert \Delta (V_{BE1} - V_{BE2})_{\Delta T_A} \rvert$	Base-Emitter-Voltage-Differential Change With Temperature	$V_{CE} = -5$ v, $I_C = -100\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = -55°C$		0.8		1.6	mv
		$V_{CE} = -5$ v, $I_C = -100\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = 125°C$		1		2	mv

NOTE 6: The lower of the two h_{FE} readings is taken as h_{FE1}.

operating characteristics at 25°C free-air temperature

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	ALL TYPES		UNIT
			TYP	MAX	
$\overline{NF}$	Average Noise Figure	$V_{CE} = -5$ v, $I_C = -100\ \mu a$, $R_G = 1\ k\Omega$, Noise Bandwidth = 15.7 kc, See Note 7	2	6	db

NOTE 7: Average Noise Figure is measured in an amplifier with low-frequency-response down 3 db at 10 cps.

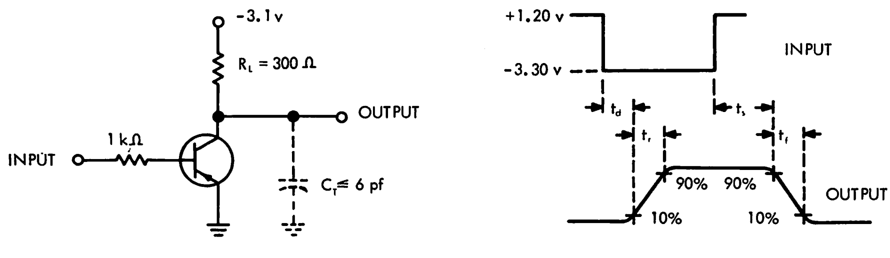
switching characteristics at 25°C free-air temperature

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS†	2N3051		UNIT
			TYP	MAX	
t_d	Delay Time	$I_C = -10$ ma, $I_{B(1)} = -2.5$ ma, $I_{B(2)} = 2$ ma, $V_{BE(off)} = +1.2$ v, $R_L = 300\ \Omega$, See Figure 1	10	15	nsec
t_r	Rise Time		15	20	nsec
t_s	Storage Time		60	120	nsec
t_f	Fall Time		18	30	nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 1 — SWITCHING TIMES

NOTES: a. The input waveform has the following characteristics: $t_r \leq 1$ nsec, $t_f \leq 1$ nsec, PW ≥ 200 nsec, Duty Cycle ≤ 2%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100\ k\Omega$, $C_{in} \leq 3$ pf. The input impedance of the oscilloscope is included in the values shown for R_L, Total Collector Load Resistance, and C_T, Total Collector Shunt Capacitance.

*Indicates JEDEC registered data (typical data excluded).

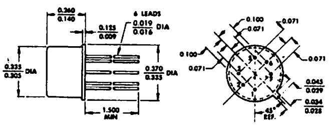
TYPES 2N3347, 2N3348, 2N3349, 2N3350, 2N3351, 2N3352
DUAL P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

TWO P-N-P TRANSISTORS IN ONE PACKAGE

- **Each triode electrically similar to 2N2604 and 2N2605 transistors**
- **Recommended for low-noise, high-gain differential amplifiers**
- **Designed for complementary use with TI 2N2639 through 2N2644 dual N-P-N transistors**

*mechanical data

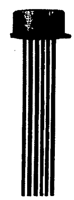
ALL LEADS INSULATED FROM CASE



1. COLLECTOR 1
2. BASE 1
3. EMITTER 1
5. EMITTER 2
6. BASE 2
7. COLLECTOR 2

JEDEC TO-5 NOTES 2, 3 AND 4 ARE APPLICABLE.

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH TRIODE	TOTAL DEVICE
Collector-Base Voltage	−60 v	
Collector-Emitter Voltage (See Note 1)	−45 v	
Emitter-Base Voltage	−6 v	
Collector Current	−30 ma	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.3 w	0.6 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	0.6 w	1.2 w
Storage Temperature Range	−65°C to	+200°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. Derate linearly to 175°C free-air temperature at the rate of 2.0 mw/C° for each triode and 4.0 mw/C° for total device.

3. Derate linearly to 175°C case temperature at the rate of 4.0 mw/C° for each triode and 8.0 mw/C° for total device.

*Indicates JEDEC registered data.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N3347, 2N3348, 2N3349, 2N3350, 2N3351, 2N3352
DUAL P-N-P EPITAXIAL PLANAR SILICON TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)
*individual triode characteristics (see note 4)

	PARAMETER	TEST CONDITIONS	2N3347 2N3348 2N3349 MIN	MAX	2N3350 2N3351 2N3352 MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -10\ \mu a$, $I_E = 0$	−60		−60		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -10$ ma, $I_B = 0$, See Note 5	−45		−45		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu a$, $I_C = 0$	−6		−6		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -45$ v, $I_E = 0$		−10		−10	na
		$V_{CB} = -45$ v, $I_E = 0$, $T_A = 150°C$		−10		−10	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -6$ v, $I_C = 0$		−2		−2	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -10\ \mu a$	40	300	100	300	
		$V_{CE} = -5$ v, $I_C = -1$ ma	60		150		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -5$ v, $I_C = -10$ ma		−0.9		−0.9	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma		−0.5		−0.5	v
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc	1.5	20	3.7	20	kohm
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc	60	600	150	600	
h_{oe}	Small-Signal Common-Emitter Output Admittance	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc		100		100	μmho
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 30 Mc	2.0	8.0	2.0	8.0	
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 Mc		6		6	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -0.5$ v, $I_C = 0$, f = 1 Mc		8		8	pf

*triode matching characteristics

	PARAMETER	TEST CONDITIONS	2N3347 2N3350 MIN	MAX	2N3348 2N3351 MIN	MAX	2N3349 2N3352 MIN	MAX	UNIT
$\frac{h_{FE1}}{h_{FE2}}$	Static Forward-Current-Gain Balance Ratio	$V_{CE} = -5$ v, $I_C = -10\ \mu a$, See Note 6	0.9	1.0	0.8	1.0	0.6	1.0	
$\|V_{BE1} - V_{BE2}\|$	Base-Emitter-Voltage Differential	$V_{CE} = -5$ v, $I_C = -10\ \mu a$		5		10		20	mv
$\|\Delta(V_{BE1} - V_{BE2})_{T_A}\|$	Base-Emitter-Voltage-Differential Change With Temperature	$V_{CE} = -5$ v, $I_C = -10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = -55°C$		0.8		1.6		3.2	mv
		$V_{CE} = -5$ v, $I_C = -10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = 125°C$		1.0		2.0		4.0	mv

operating characteristics at 25°C free-air temperature
*individual triode characteristics (see note 4)

	PARAMETER	TEST CONDITIONS	ALL TYPES TYP	MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CE} = -5$ v, $I_C = -10\ \mu a$, $R_G = 10\ k\Omega$, Noise Bandwidth = 15.7 kc, See Note 7	2	4	db

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

6. The lower of the two h_{FE} readings is taken as h_{FE1}.

7. Average Noise Figure is measured in an amplifier with low-frequency response down 3 db at 10 cps.

*Indicates JEDEC registered data (typical data excluded).

TYPE 2N3680
DUAL N-P-N PLANAR SILICON TRANSISTOR

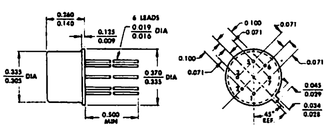
TYPE 2N3680
BULLETIN NO. DL-S 686439, FEBRUARY 1965
REVISED MAY 1968

RECOMMENDED FOR DIFFERENTIAL AMPLIFIERS

- **Featuring Matching and Tracking Improvements over 2N2453, 2N2642, and 2N2920**
- **Each Triode Electrically Similar to 2N2484 and 2N930**
- **h_{FE} at 1 μa: 80 Min**
- **Matched from −55°C to 125°C**
- $\dfrac{\Delta (V_{BE1} - V_{BE2})}{\Delta T_A}$**: 5 μv/C° Max, Averaged over Temperature Range**
- **Also Recommended for Low-Level Flip-Flops; High-Gain, Low-Noise Audio Amplifiers; and Transducer Signal-Conditioner Amplifiers**

***mechanical data**

ALL LEADS INSULATED FROM CASE



1. COLLECTOR 1
2. BASE 1
3. EMITTER 1
5. EMITTER 2
6. BASE 2
7. COLLECTOR 2

JEDEC TO-5 NOTES 2, 3 AND 4 ARE APPLICABLE.

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

***absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)**

	Each Triode	Total Device
Collector-Base Voltage	60 v	
Collector-Emitter Voltage (See Note 1)	50 v	
Emitter-Base Voltage	6 v	
Collector-1—Collector-2 Voltage		± 120 v
Lead-to-Case Voltage		± 120 v
Collector Current	30 ma	
Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	0.3 w	0.6 w
Continuous Dissipation at (or below) 25°C Case Temperature (See Note 3)	0.6 w	1.2 w
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch From Case For 10 Seconds		300°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. Derate linearly to 175°C free-air temperature at the rate of 2 mw/C° for each triode and 4 mw/C° for total device.

3. Derate linearly to 175°C case temperature at the rate of 4 mw/C° for each triode and 8 mw/C° for total device.

*Indicates JEDEC registered data

TYPE 2N3680
DUAL N-P-N PLANAR SILICON TRANSISTOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu a$, $I_E = 0$	60		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 5	50		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	6		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = 45$ v, $I_E = 0$		10	na
		$V_{CB} = 45$ v, $I_E = 0$, $T_A = 150°C$		10	μa
I_{CEO}	Collector Cutoff Current	$V_{CE} = 5$ v, $I_B = 0$		10	na
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1\ \mu a$	80		
		$V_{CE} = 5$ v, $I_C = 10\ \mu a$	150	600	
		$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_A = -55°C$	45		
		$V_{CE} = 5$ v, $I_C = 100\ \mu a$	225		
		$V_{CE} = 5$ v, $I_C = 1$ ma	300		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ v, $I_C = 10$ ma	0.6	0.8	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma		0.7	v
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 5$ v, $I_C = 1$ ma, $f = 1$ kc	7.5	24	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio		300	900	
h_{re}	Small-Signal Common-Emitter Reverse Voltage Transfer Ratio			10×10^{-4}	
h_{oe}	Small-Signal Common-Emitter Output Admittance			45	μmho
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 500\ \mu a$, $f = 30$ Mc	2	6	
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, $f = 1$ Mc		6	pf
C_{ibo}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5$ v, $I_C = 0$, $f = 1$ Mc		6	pf

*triode matching characteristics

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$\frac{h_{FE1}}{h_{FE2}}$	Static Forward-Current-Gain Balance Ratio	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, See Note 6	0.9	1	
		$V_{CE} = 5$ v, $I_C = 100\ \mu a$, See Note 6, $T_A = -55°C$ to $125°C$	0.85	1	
$\|V_{BE1}-V_{BE2}\|$	Base-Emitter-Voltage Differential	$V_{CE} = 5$ v, $I_C = 10\ \mu a$		3	mv
$\|\Delta (V_{BE1} - V_{BE2})_{\Delta T_A}\|$	Base-Emitter-Voltage-Differential Change With Temperature	$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = -55°C$		400	μv
		$V_{CE} = 5$ v, $I_C = 10\ \mu a$, $T_{A(1)} = 25°C$, $T_{A(2)} = 125°C$		500	μv

operating characteristics at 25°C free-air temperature

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$\overline{NF}$	Average Noise Figure	$V_{CB} = 5$ v, $I_E = -10\ \mu a$, $R_G = 10$ kΩ, Noise Bandwidth = 15.7 kc, See Note 7		3	db

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq 2\%$.

6. The lower of the two h_{FE} readings is taken as h_{FE1}.

7. Average Noise Figure is measured in an amplifier with low-frequency response down 3 db at 10 cps.

*Indicates JEDEC registered data.

TYPICAL MATCHING CHARACTERISTICS

BASE-EMITTER-VOLTAGE DIFFERENTIAL
vs
COLLECTOR CURRENT

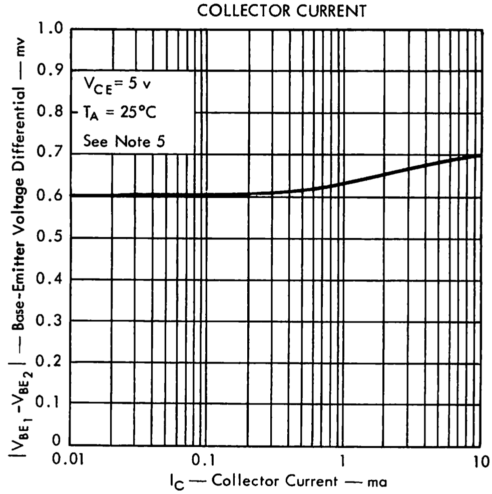


FIGURE 1

BASE-EMITTER-VOLTAGE DIFFERENTIAL
vs
FREE-AIR TEMPERATURE

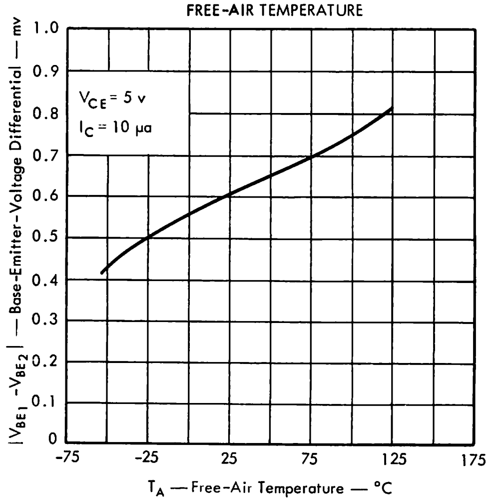


FIGURE 2

NOTE 5: This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

TYPICAL MATCHING CHARACTERISTICS

STATIC FORWARD-CURRENT-GAIN BALANCE RATIO
vs
COLLECTOR CURRENT

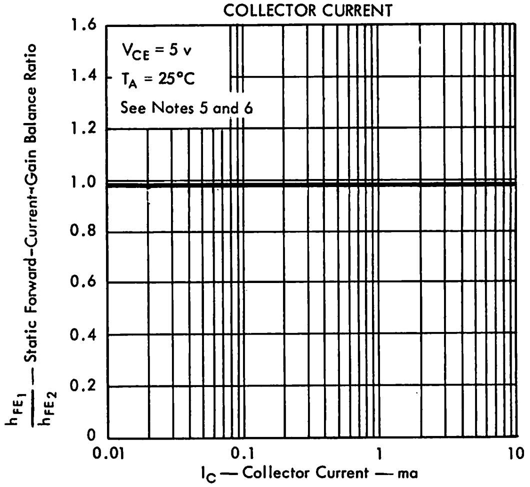


FIGURE 3

THERMAL INFORMATION

CONTINUOUS DISSIPATION
vs
FREE-AIR TEMPERATURE

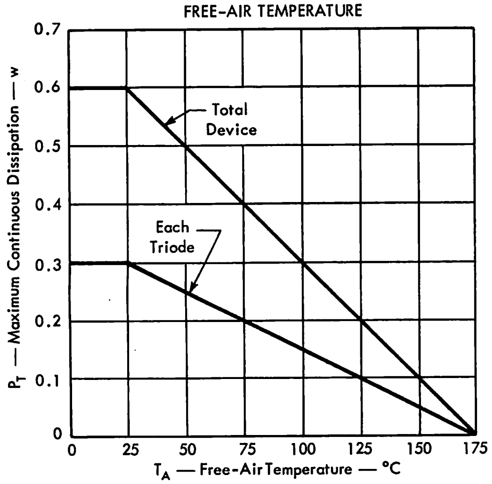


FIGURE 4

CONTINUOUS DISSIPATION
vs
CASE TEMPERATURE

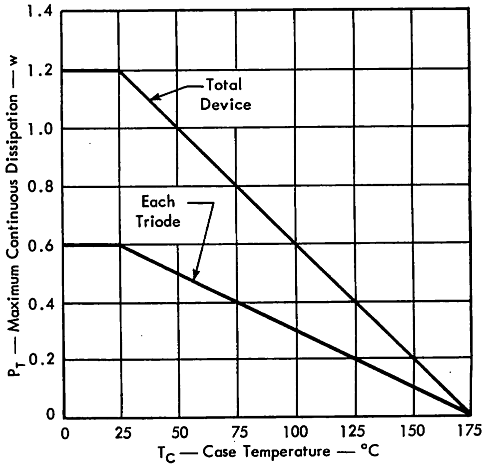


FIGURE 5

NOTES: 5. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.
6. The lower of the two h_{FE} readings is taken as h_{FE1}.

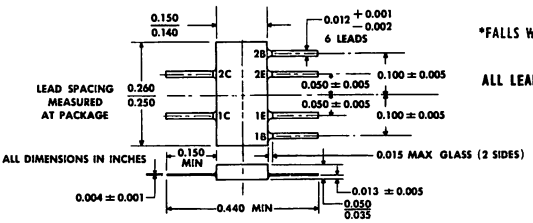
TYPE 2N3838
N-P-N P-N-P DUAL EPITAXIAL PLANAR SILICON TRANSISTOR

TYPE 2N3838
BULLETIN NO. DL-S 657501, MARCH 1965
REVISED APRIL 1967

DESIGNED FOR COMPLEMENTARY MEDIUM-POWER, HIGH-SPEED SWITCHING AND GENERAL PURPOSE AMPLIFIER APPLICATIONS

- **Electrically Similar to 2N2222/2N2907**
- **D-C Beta — Guaranteed from 100 μa to 150 ma**
- **Miniature Flatpack Facilitates High-Density Packaging**

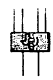
mechanical data



*FALLS WITHIN TO-89 DIMENSIONS

ALL LEADS ARE INSULATED FROM CASE

TERMINAL DESIGNATIONS
1B N-P-N BASE
1E N-P-N EMITTER
2E P-N-P EMITTER
2B P-N-P BASE
2C P-N-P COLLECTOR
1C N-P-N COLLECTOR



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)†

	EACH TRIODE	TOTAL DEVICE
Collector-Base Voltage	60 v	
Collector-Emitter Voltage (See Note 1)	40 v	
Emitter-Base Voltage	5 v	
Collector-1 — Collector-2 Voltage		±120 v
Lead-to-Case Voltage		±120 v
Continuous Collector Current	600 ma	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	250 mw	350 mw
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	700 mw	1400 mw
Storage Temperature Range	−65°C to +200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds		300°C

NOTES: 1. This value applies between 0 and 10 ma when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 1.67 mw/C° for each triode and 2.34 mw/C° for total device.
3. Derate linearly to 175°C case temperature at the rate of 4.67 mw/C° for each triode and 9.34 mw/C° for total device.

*Indicates JEDEC registered data

†Voltages and currents apply to the N-P-N triode. For the P-N-P triode, the values are the same, but the signs are reversed.

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INCORPORATED
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TYPE 2N3838
N-P-N P-N-P DUAL EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)†

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu a$, $I_E = 0$	60		v
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ ma, $I_B = 0$, See Note 5	40		v
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu a$, $I_C = 0$	5		v
I_{CEV}	Collector Cutoff Current	$V_{CE} = 50$ v, $V_{BE} = -0.5$ v		10	na
		$V_{CE} = 50$ v, $V_{BE} = -0.5$ v, $T_A = 150°C$		10	μa
I_{BEV}	Base Cutoff Current	$V_{CE} = 50$ v, $V_{BE} = -0.5$ v		−10	na
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ v, $I_C = 0$		10	na
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 1$ v, $I_C = 150$ ma, See Note 5	50		
		$V_{CE} = 10$ v, $I_C = 100\ \mu a$	35		
		$V_{CE} = 10$ v, $I_C = 1$ ma	50		
		$V_{CE} = 10$ v, $I_C = 10$ ma, See Note 5	75		
		$V_{CE} = 10$ v, $I_C = 150$ ma, See Note 5	100	300	
V_{BE}	Base-Emitter Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 5	0.85	1.3	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ ma, $I_C = 150$ ma, See Note 5		0.4	v
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 10$ v, $I_C = 1$ ma, $f = 1$ kc	1.5	9	kΩ
h_{fe}	Small-Signal Forward Current Transfer Ratio		60	300	
h_{oe}	Small-Signal Common-Emitter Output Admittance			50	μmho
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 20$ ma, $f = 100$ Mc	2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 140$ kc		8	pf

operating characteristics at 25°C free-air temperature†

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS‡	MIN	MAX	UNIT
t_d	Delay Time	$I_C = 150$ ma, $I_{B(1)} = 15$ ma, $V_{BE(off)} = 0$,		10	nsec
t_r	Rise Time	$R_L = 64\ \Omega$, See Figure 1		40	nsec
t_s	Storage Time	$I_C = 150$ ma, $I_{B(1)} = -I_{B(2)} = 15$ ma,		250	nsec
t_f	Fall Time	$R_L = 64\ \Omega$, See Figure 2		90	nsec
$V_{CEO(NL)}$	Collector-Emitter Nonlatching Voltage§	$I_{C(on)} = 600$ ma, $I_{B(on)} = 120$ ma, $I_{B(off)} = 0$, See Figure 3	40		v
NF	Spot Noise Figure	$V_{CE} = 10$ v, $I_C = 100\ \mu a$, $R_G = 1$ kΩ, $f = 1$ kc		8	db

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

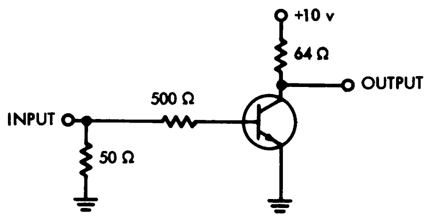
*Indicates JEDEC registered data

†Voltages and currents apply to the N-P-N triode. For the P-N-P triode, the values are the same, but the signs are reversed.

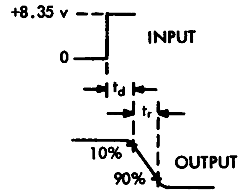
‡Voltages and current values shown are nominal; exact values vary with device parameters.

§This characteristic is the highest value of collector supply voltage which may be safely used with a resistive-load switching circuit in which the collector current approaches 600 ma.

*PARAMETER MEASUREMENT INFORMATION



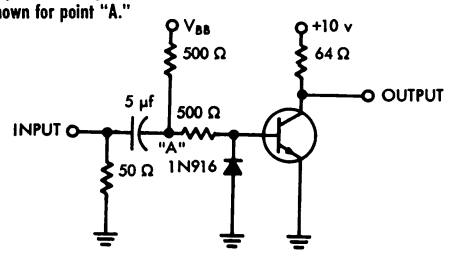
TEST CIRCUIT



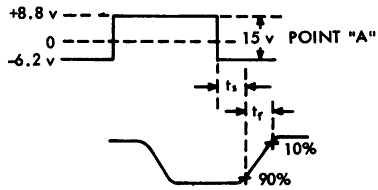
VOLTAGE WAVEFORMS
(See Notes a, b and d)

FIGURE 1

$V_{BB} \approx -11.4$ v
Adjust for voltages
shown for point "A."

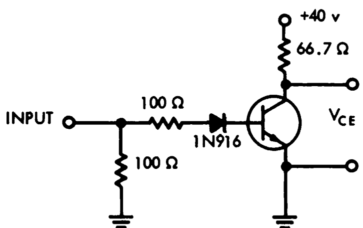


TEST CIRCUIT



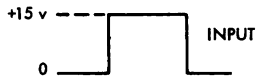
VOLTAGE WAVEFORMS
(See Notes a, b and d)

FIGURE 2



TEST CIRCUIT

Monitor to ensure that $V_{CE} \approx V_{CC}$ after pulse is completed



VOLTAGE WAVEFORM
(See Notes c and d)

FIGURE 3 — COLLECTOR-EMITTER NONLATCHING VOLTAGE TEST CIRCUIT

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: for Figure 1, $Z_{out} = 50\ \Omega$, $t_r \leq 1$ nsec, PW ≥ 400 nsec, Duty Cycle $\leq 2\%$; for Figure 2, $Z_{out} = 50\ \Omega$, $t_r \leq 10$ nsec, PW $= 10\ \mu$sec, Duty Cycle $\leq 2\%$.

b. The waveforms are monitored on an oscilloscope with the following characteristics: for Figure 1, $t_r \leq 1$ nsec, $R_{in} \geq 100$ kΩ, $C_{in} \leq 5$ pf; for Figure 2, $t_r \leq 5$ nsec, $R_{in} \geq 100$ kΩ, $C_{in} \leq 12$ pf.

c. The input waveform in Figure 3 has the following characteristics: PW $\leq 10\ \mu$sec, Duty Cycle $\leq 2\%$.

d. The signs and polarity symbols shown are for the N-P-N triode; the signs and polarity symbols are reversed for the P-N-P triode.

*Indicates JEDEC registered data.

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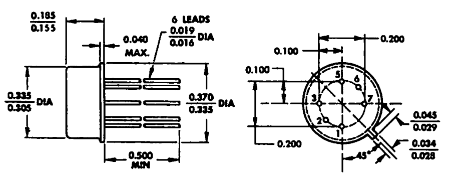
TYPES 2N4854, 2N4855
N-P-N, P-N-P, DUAL EPITAXIAL PLANAR SILICON TRANSISTORS

DESIGNED FOR COMPLEMENTARY MEDIUM-POWER, HIGH-SPEED SWITCHING AND GENERAL PURPOSE AMPLIFIER APPLICATIONS

- **2N4854 Electrically Similar to 2N2222/2N2907**
- **2N4855 Electrically Similar to 2N2221/2N2906**
- **h_{FE} — Guaranteed from 100 μA to 300 mA**
- **Low-Profile Case**

*mechanical data

ALL LEADS INSULATED FROM CASE



Dimensions without tolerance designate true position. Leads having maximum diameter (0.019″) measured in gaging plane 0.054″ +0.001″ −0.000″ below the seating plane of the device shall be within 0.007″ of their true positions relative to a maximum-width tab.

1. N-P-N COLLECTOR
2. N-P-N BASE
3. N-P-N EMITTER
5. P-N-P EMITTER
6. P-N-P BASE
7. P-N-P COLLECTOR

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)†

	EACH TRIODE	TOTAL DEVICE
Collector-Base Voltage	60 V	
Collector-Emitter Voltage (See Note 1)	40 V	
Emitter-Base Voltage	5 V	
Collector-1 — Collector-2 Voltage		±120 V
Lead-to-Case Voltage		±120 V
Continuous Collector Current	600 mA	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	300 mW	600 mW
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	1 W	2 W
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds		300°C

NOTES: 1. This value applies between 0 and 600 mA collector current when the base-emitter diode is open-circuited. 40 V and 600 mA collector current may be simultaneously applied provided the time of application is 10 μs or less and the duty cycle is 2% or less.

2. Derate linearly to 175°C free-air temperature at the rate of 2 mW/deg for each triode and 4 mW/deg for total device.

3. Derate linearly to 175°C case temperature at the rate of 6.67 mW/deg for each triode and 13.33 mW/deg for total device.

*Indicates JEDEC registered data

†Voltages and currents apply to the N-P-N triode. For the P-N-P triode the values are the same, but the signs are reversed.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)†

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	2N4854 MIN	2N4854 MAX	2N4855 MIN	2N4855 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$	60		60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$, See Note 5	40		40		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$	5		5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 50$ V, $I_E = 0$		10		10	nA
		$V_{CB} = 50$ V, $I_E = 0$, $T_A = 150°C$		10		10	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$		10		10	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 1$ V, $I_C = 150$ mA, See Note 5	50		20		
		$V_{CE} = 10$ V, $I_C = 100\ \mu A$	35		20		
		$V_{CE} = 10$ V, $I_C = 1$ mA	50		25		
		$V_{CE} = 10$ V, $I_C = 10$ mA, See Note 5	75		35		
		$V_{CE} = 10$ V, $I_C = 150$ mA, See Note 5	100	300	40	120	
		$V_{CE} = 10$ V, $I_C = 300$ mA, See Note 5	35		20		
V_{BE}	Base-Emitter Voltage	$I_B = 15$ mA, $I_C = 150$ mA, See Note 5	0.75	1.2	0.75	1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 15$ mA, $I_C = 150$ mA, See Note 5		0.4		0.4	V
h_{ie}	Small-Signal Common-Emitter Input Impedance	$V_{CE} = 10$ V, $I_C = 1$ mA, f = 1 kHz	1.5	9	0.75	4.5	kΩ
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio		60	300	30	150	
h_{oe}	Small-Signal Common-Emitter Output Admittance			50		25	μmho
$\lvert h_{fe}\rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 20$ mA, f = 100 MHz	2		2		
C_{cb}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz, See Note 6		8		8	pF

operating characteristics at 25°C free-air temperature†

*individual triode characteristics (see note 4)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
t_d	Delay Time	$I_C = 150$ mA, $I_{B(1)} = 15$ mA, $V_{BE(off)} = -0.5$ V,		20	ns
t_r	Rise Time	$R_L = 200\ \Omega$, See Note 7 and Figure 1		40	ns
t_s	Storage Time	$I_C = 150$ mA, $I_{B(1)} = 15$ mA, $I_{B(2)} = -15$ mA,		280	ns
t_f	Fall Time	$R_L = 200\ \Omega$, See Note 7 and Figure 2		70	ns
NF	Spot Noise Figure	$V_{CE} = 10$ V, $I_C = 100\ \mu A$, $R_G = 1$ kΩ, f = 1 kHz		8	dB

NOTES: 4. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.

5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

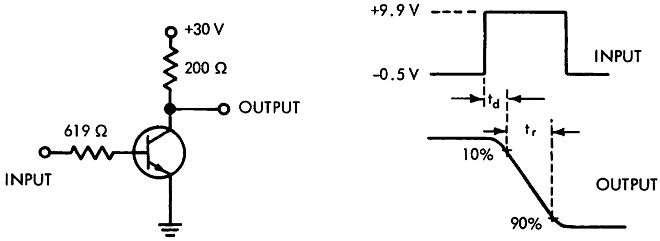
6. Collector-Base Capacitance is measured using three-terminal measurement techniques with the emitter and case guarded.

7. Voltages and current values shown are nominal; exact values vary with device parameters.

*Indicates JEDEC registered data

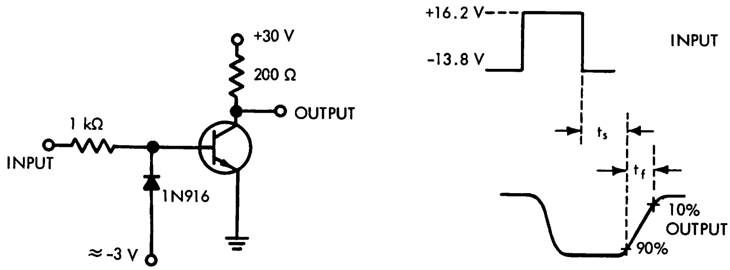
†Voltages and currents apply to the N-P-N triode. For the P-N-P triode the values are the same, but the signs are reversed.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT — VOLTAGE WAVEFORMS

FIGURE 1 – DELAY AND RISE TIMES



TEST CIRCUIT — VOLTAGE WAVEFORMS

FIGURE 2 – STORAGE AND FALL TIMES

NOTES: a. The input waveforms have the following characteristics: For figure 1, $t_r \leq 2$ ns, $t_p = 200$ ns, duty cycle $\leq 2\%$; for figure 2, $t_f \leq 5$ ns, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. All waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ ns, $R_{in} \geq 100\ k\Omega$, $C_{in} \leq 12$ pF.

c. The signs and polarity symbols shown are for the N-P-N triode; for the P-N-P triode the signs and polarity symbols are reversed.

*Indicates JEDEC registered data

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TYPES TIS68, TIS69, TIS70
BULLETIN NO. DL-S 679669, MARCH 1967

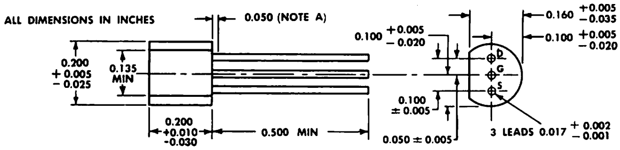
SILECT† FIELD-EFFECT TRANSISTORS SUPPLIED AS MATCHED PAIRS

- **High $|y_{fs}|/C_{iss}$ Ratio (High-Frequency Figure-of-Merit)**
- **Low Input Capacitance, C_{iss} . . . 8 pF Max**
- **Low Gate Reverse Current Differential . . . 10 nA Max at $T_A = 100°C$**
- **Recommended for Low-Cost, Low-Level D-C Amplifiers, Sample-Hold Circuits, and Series-Shunt Choppers**

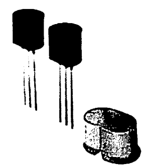
mechanical data

Each TIS68, TIS69, or TIS70 comprises a matched pair of transistors. A clip is supplied with each transistor pair. These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

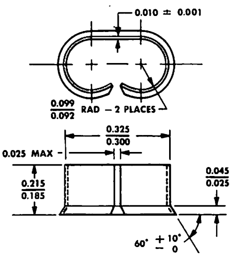
ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTE A: Lead diameter is not controlled in this area.



ALL DIMENSIONS ARE IN INCHES AND APPLY TO THE CLIP WHEN EMPTY



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	25 V
Reverse Gate-Source Voltage	–25 V
Continuous Forward Gate Current	30 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	360 mW
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTE 1: Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

†Trademark of Texas Instruments

‡Patent Pending

TYPES TIS68, TIS69, TIS70
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

individual triode characteristics

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
I_{GSS}	Gate Reverse Current	$V_{GS} = -25$ V, $V_{DS} = 0$		−1	μA
		$V_{GS} = -15$ V, $V_{DS} = 0$		−2	nA
		$V_{GS} = -15$ V, $V_{DS} = 0$, $T_A = 100°C$		−2	μA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ V, $I_D = 2$ nA	−0.5	−5	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 2	0.5	8	mA
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 kHz	1	6	mmho
$\|y_{os}\|$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 kHz		35	μmho
C_{iss}	Small-Signal Common-Source Input Capacitance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 MHz		8	pF
C_{rss}	Small-Signal Common-Source Reverse Transfer Capacitance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 MHz		4	pF
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 100 MHz	0.8		mmho

triode matching characteristics

PARAMETER		TEST CONDITIONS	TIS68		TIS69		TIS70		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$\|I_{GSS1} - I_{GSS2}\|$	Gate-Reverse-Current Differential	$V_{GS} = -15$ V, $V_{DS} = 0$, $T_A = 100°C$		10		10		10	nA
$\|V_{GS1} - V_{GS2}\|$	Gate-Source-Voltage Differential	$V_{DS} = 15$ V, $I_D = 50$ μA		8		16		32	mV
		$V_{DS} = 15$ V, $I_D = 500$ μA		5		10		15	mV
$\|\Delta(V_{GS1} - V_{GS2})_{\Delta T_A}\|$	Gate-Source-Voltage Differential Change with Temperature	$V_{DS} = 15$ V, $I_D = 500$ μA, $T_{A(1)} = 25°C$, $T_{A(2)} = -40°C$		5		10		15	mV
		$V_{DS} = 15$ V, $I_D = 500$ μA, $T_{A(1)} = 25°C$, $T_{A(2)} = 100°C$		5		10		15	mV
$\frac{I_{DSS1}}{I_{DSS2}}$	Zero-Gate-Voltage Drain Current Ratio	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 3	0.95	1	0.9	1	0.8	1	
$\frac{\|y_{fs}\|_1}{\|y_{fs}\|_2}$	Small-Signal Common-Source Forward Transfer Admittance Ratio	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 kHz, See Note 3	0.95	1	0.9	1	0.8	1	

NOTES: 2. This parameter must be measured using pulse techniques. $t_p \approx 100$ ms, duty cycle $\leq 10\%$.

3. The lower of the two characteristic readings is taken as the numerator.

N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

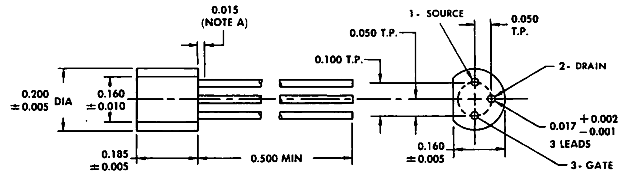
TYPES TIS73, TIS74, TIS75
BULLETIN NO. DL-S 679709, MARCH 1967

SYMMETRICAL N-CHANNEL SILECT† FIELD-EFFECT TRANSISTORS FOR HIGH-SPEED COMMUTATOR AND CHOPPER APPLICATIONS

- **Low $r_{ds(on)}$: 25 Ω Max (TIS73)**
- **Low $I_{D(off)}$: 2 nA Max**
- **Low Drain-Gate Capacitance (C_{rss}): 8 pF Max**
- **Rugged, One-Piece Construction with Standard TO-18 100-mil Pin-Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	30 V
Drain-Source Voltage	30 V
Reverse Gate-Source Voltage	−30 V
Continuous Forward Gate Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	360 mW
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 2)	500 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

2. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the gate lead 1/16 inch from the case.

†Trademark of Texas Instruments
‡Patent Pending

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIS73 MIN	TIS73 MAX	TIS74 MIN	TIS74 MAX	TIS75 MIN	TIS75 MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu A$, $V_{DS} = 0$	−30		−30		−30		V
I_{GSS}	Gate Reverse Current	$V_{GS} = -15$ V, $V_{DS} = 0$		−2		−2		−2	nA
		$V_{GS} = -15$ V, $V_{DS} = 0$, $T_A = 100°C$		−5		−5		−5	μA
$I_{D(off)}$	Drain Cutoff Current	$V_{DS} = 15$ V, $V_{GS} = -10$ V		−2		−2		−2	nA
		$V_{DS} = 15$ V, $V_{GS} = -10$ V, $T_A = 100°C$		−5		−5		−5	μA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ V, $I_D = 4$ nA	−4	−10	−2	−6	−0.8	−4	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 3	50		20	100	8	80	mA
$V_{DS(on)}$	Drain-Source On-State Voltage	$I_D = 20$ mA, $V_{GS} = 0$		0.75					V
		$I_D = 10$ mA, $V_{GS} = 0$				0.5			V
		$I_D = 5$ mA, $V_{GS} = 0$						0.5	V
$r_{ds(on)}$	Small-Signal Drain-Source On-State Resistance	$V_{GS} = 0$, $I_D = 0$, $f = 1$ kHz		25		40		60	Ω
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 0$, $V_{GS} = -10$ V, $f = 1$ MHz		18		18		18	pF
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance	$V_{DS} = 0$, $V_{GS} = -10$ V, $f = 1$ MHz		8		8		8	pF

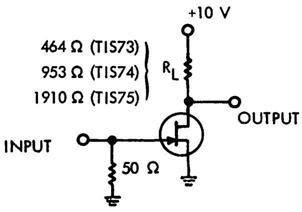
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIS73 MIN	TIS73 MAX	TIS74 MIN	TIS74 MAX	TIS75 MIN	TIS75 MAX	UNIT
$t_{d(on)}$	Turn-On Delay Time	$V_{DS} = 10$ V, $I_{D(on)}$† = 20 mA (TIS73), 10 mA (TIS74), 5 mA (TIS75); $V_{GS(on)} = 0$, $V_{GS(off)}$ = −10 V (TIS73), −6 V (TIS74), −4 V (TIS75); See Figure 1		6		6		10	ns
t_r	Rise Time			3		4		10	ns
t_{off}	Turn-Off Time			25		50		100	ns

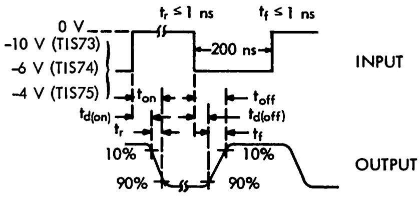
NOTE 3: These parameters must be measured using pulse techniques. $t_p \approx 100$ ms, duty cycle $\leq 10\%$.

†These are nominal values, exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, duty cycle $\approx$ 2%.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 0.75$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 2.5$ pF.

TYPICAL CHARACTERISTICS

COMMON-SOURCE SHORT-CIRCUIT
INPUT CAPACITANCE
vs
GATE-SOURCE VOLTAGE

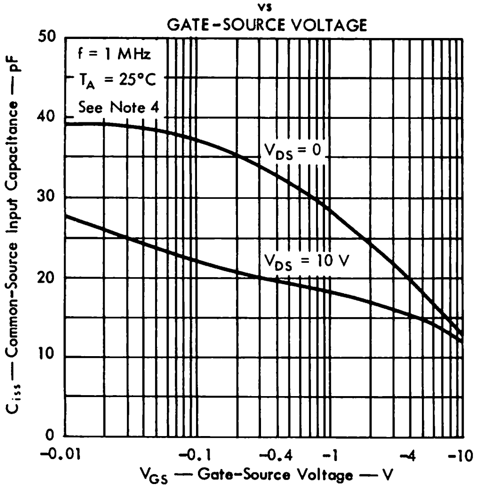


FIGURE 2

COMMON-SOURCE SHORT-CIRCUIT
REVERSE TRANSFER CAPACITANCE
vs
GATE-SOURCE VOLTAGE

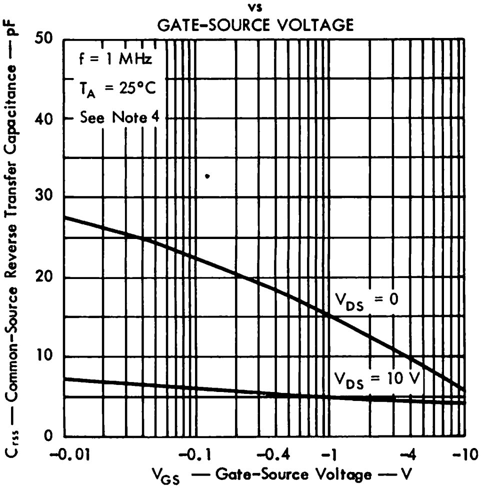


FIGURE 3

NOTE 4: These parameters were measured with bias voltages applied for less than five seconds to avoid overheating the devices.

TYPICAL CHARACTERISTICS

TIS73
SMALL-SIGNAL DRAIN-SOURCE ON-STATE RESISTANCE vs FREE-AIR TEMPERATURE

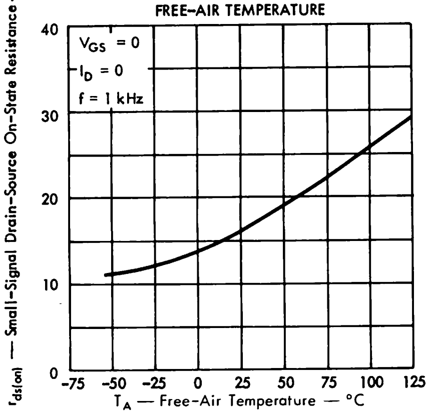


FIGURE 4

TIS73
SWITCHING TIMES vs LOAD RESISTANCE

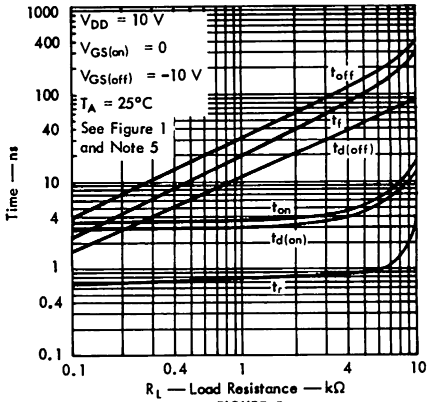


FIGURE 5

AVERAGE OUTPUT VOLTAGE ‡ vs RISE AND FALL TIMES

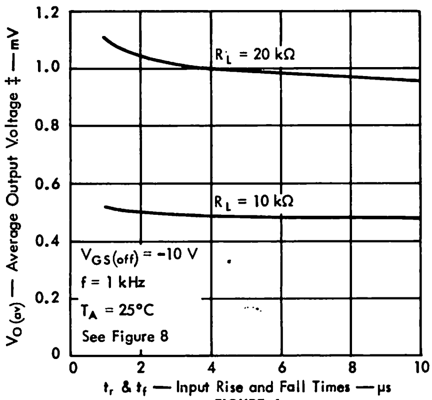


FIGURE 6

AVERAGE OUTPUT VOLTAGE ‡ vs FREQUENCY

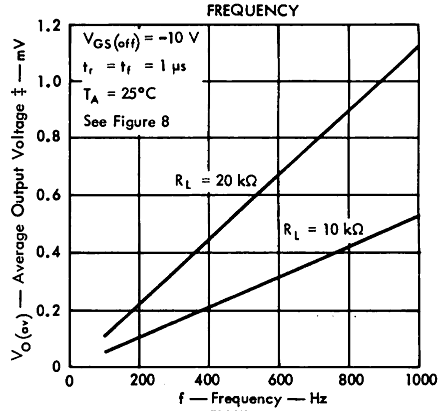
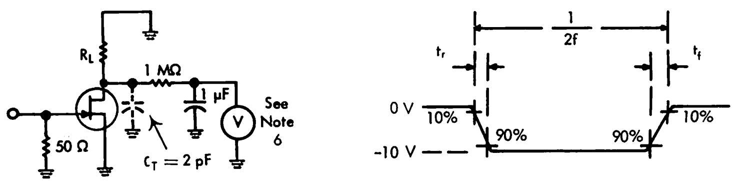


FIGURE 7



TEST CIRCUIT INPUT VOLTAGE WAVEFORM

FIGURE 8-MEASUREMENT INFORMATION FOR FIGURES 6 & 7

NOTES: 5. The circuit of figure 1 is used, varying R_L from 100 Ω to 10 kΩ. t_p = 1 µs, duty cycle ≤ 2%.
6. Voltmeter input resistance R_{in} ≥ 10 MΩ.

‡In the circuit of figure 8, Average Output Voltage results from capacitive feed-through of the gate-drive signal.

N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTOR

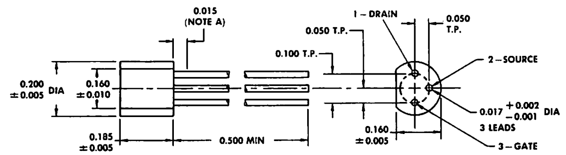
TYPE TIS88
BULLETIN NO. DL-S 6710200, JUNE 1967

N-CHANNEL SILECT† FIELD-EFFECT TRANSISTOR FOR VHF AMPLIFIER AND MIXER APPLICATIONS

- **High Power Gain . . . 10 dB Min at 400 MHz**
- **High Transconductance . . . 4000 μmho Min at 400 MHz**
- **Low C_{rss} . . . 1 pF Max**
- **High $|y_{fs}|/C_{iss}$ Ratio (High-Frequency Figure-of-Merit)**
- **Drain and Gate Leads Separated for High Maximum Stable Gain**
- **Cross-Modulation Minimized by Square-Law Transfer Characteristic**
- **For Use in VHF Amplifiers in FM, TV, and Mobile Communications Equipment**

mechanical data

This transistor is encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. This device exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C method 106B. The transistor is insensitive to light.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	30 V
Drain-Source Voltage	30 V
Reverse Gate-Source Voltage	–30 V
Continuous Forward Gate Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	360 mW
Continuous Device Dissipation at (or below) 25°C Lead Temperature (See Note 2)	500 mW
Storage Temperature Range	–65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

2. Derate linearly to 150°C lead temperature at the rate of 4 mW/deg. Lead temperature is measured on the gate lead 1/16 inch from the case.

†Trademark of Texas Instruments
‡Patent pending

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TYPE TIS88
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

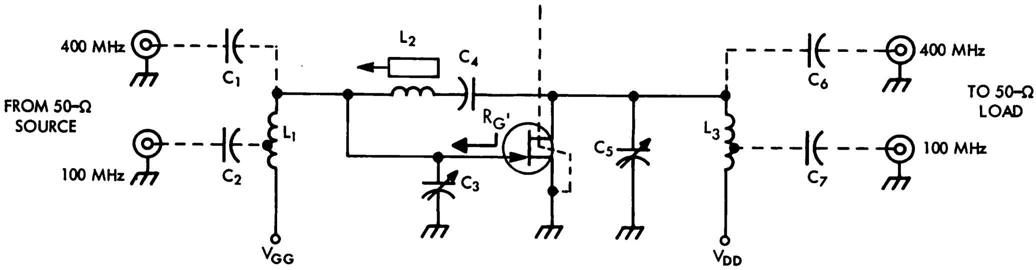
PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu A$, $V_{DS} = 0$	−30		V
I_{GSS}	Gate Reverse Current	$V_{GS} = -20\ V$, $V_{DS} = 0$		−1	nA
		$V_{GS} = -20\ V$, $V_{DS} = 0$, $T_A = 100°C$		−0.5	μA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15\ V$, $I_D = 10\ nA$	−1	−6	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15\ V$, $V_{GS} = 0$, See Note 3	5	15	mA
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15\ V$, $V_{GS} = 0$, $f = 1\ kHz$	4.5	7.5	mmho
$\|y_{os}\|$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15\ V$, $V_{GS} = 0$, $f = 1\ kHz$		0.05	mmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 15\ V$, $V_{GS} = 0$, $f = 1\ MHz$		4.5	pF
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			1	pF
$Re(y_{is})$	Small-Signal Common-Source Input Conductance	$V_{DS} = 15\ V$, $V_{GS} = 0$, $f = 100\ MHz$		0.1	mmho
$Im(y_{is})$	Small-Signal Common-Source Input Susceptance			3	mmho
$Re(y_{os})$	Small-Signal Common-Source Output Conductance			0.075	mmho
$Im(y_{os})$	Small-Signal Common-Source Output Susceptance			0.9	mmho
$Re(y_{is})$	Small-Signal Common-Source Input Conductance	$V_{DS} = 15\ V$, $V_{GS} = 0$, $f = 400\ MHz$		1	mmho
$Im(y_{is})$	Small-Signal Common-Source Input Susceptance			12	mmho
$Re(y_{fs})$	Small-Signal Common-Source Forward Transfer Conductance		4		mmho
$Re(y_{os})$	Small-Signal Common-Source Output Conductance			0.1	mmho
$Im(y_{os})$	Small-Signal Common-Source Output Susceptance			4	mmho

NOTE 3: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
G_{ps}	Small-Signal Common-Source Neutralized Insertion Power Gain	$V_{DS} = 15\ V$, $I_D = 5\ mA$, $f = 100\ MHz$, $R_{G'} = 1\ k\Omega$, See Figure 1	18		dB
		$V_{DS} = 15\ V$, $I_D = 5\ mA$, $f = 400\ MHz$, $R_{G'} = 1\ k\Omega$, See Figure 1	10		
NF	Spot Noise Figure	$V_{DS} = 15\ V$, $I_D = 5\ mA$, $f = 100\ MHz$, $R_{G'} = 1\ k\Omega$, See Figure 1		2	dB
		$V_{DS} = 15\ V$, $I_D = 5\ mA$, $f = 400\ MHz$, $R_{G'} = 1\ k\Omega$, See Figure 1		4	

PARAMETER MEASUREMENT INFORMATION



CIRCUIT COMPONENT INFORMATION					
CAPACITORS			COILS		
	100 MHz	400 MHz		100 MHz	400 MHz
C_1	not used	1.8 pF	L_1	8.5 T, #16 copper, tapped 2.5 T from bottom, 3/8" ID, 1 1/4" long	1.25 T, #20 copper, 3/16" ID, 3/8" long
C_2	7 pF	not used			
C_3	1–12 pF	0.8–8 pF	L_2	15 T, #20 enameled copper, close-wound, 1/4" ID	4 T, #20 enameled copper, close-wound, 3/16" ID
C_4	1000 pF	27 pF			
C_5	1–12 pF	0.8–8 pF			
C_6	not used	1 pF	L_3	13.5 T, #16 copper, tapped 5 T from bottom, 3/8" ID, 1 1/4" long	0.5 T, #20 copper, 1/2" ID, no length
C_7	3 pF	not used			

FIGURE 1 — SCHEMATIC AND COMPONENT INFORMATION FOR 100-MHz AND 400-MHz NEUTRALIZED INSERTION POWER GAIN AND SPOT NOISE FIGURE TEST CIRCUITS

TYPICAL CHARACTERISTICS

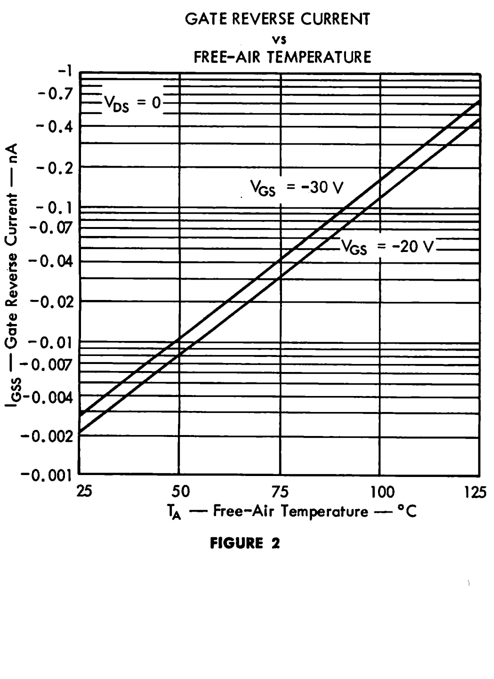


FIGURE 2

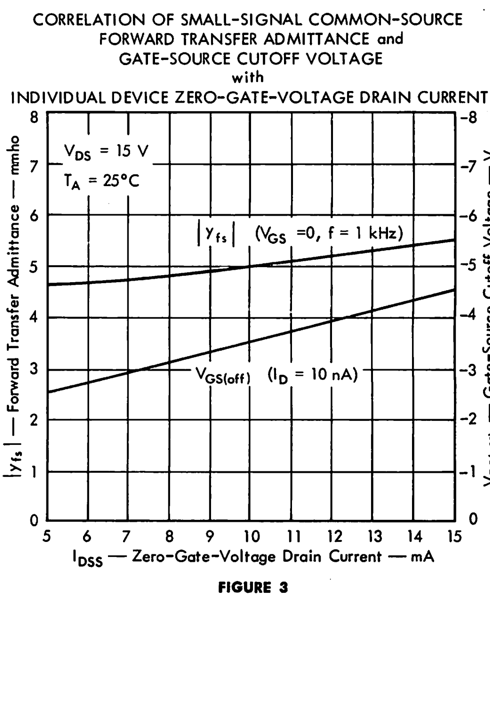


FIGURE 3

TYPICAL CHARACTERISTICS

DRAIN CURRENT
vs
GATE-SOURCE VOLTAGE

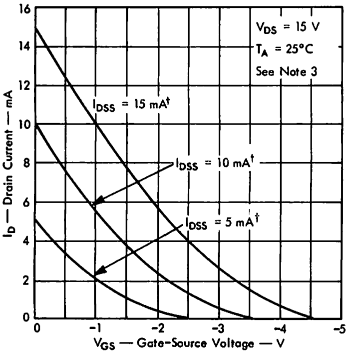


FIGURE 4

ZERO-GATE-VOLTAGE-DRAIN CURRENT
vs
FREE-AIR TEMPERATURE

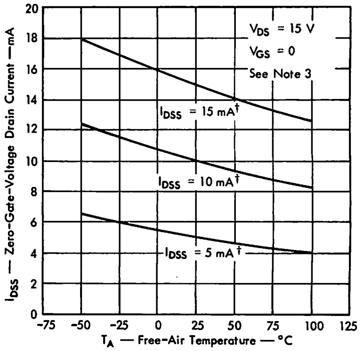


FIGURE 5

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
FREE-AIR TEMPERATURE

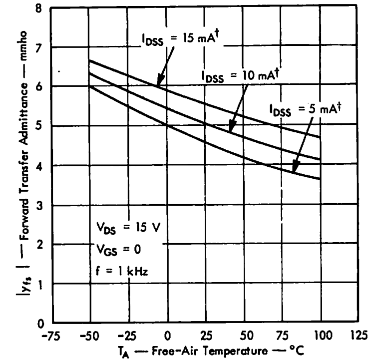


FIGURE 6

COMMON-SOURCE SHORT-CIRCUIT INPUT CAPACITANCE
vs
GATE-SOURCE VOLTAGE

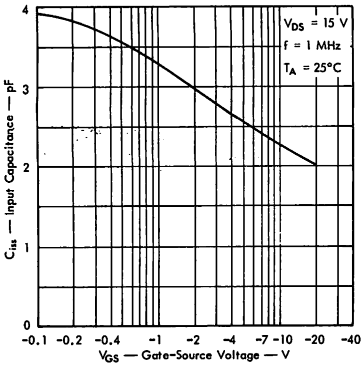


FIGURE 7

COMMON-SOURCE SHORT-CIRCUIT
REVERSE TRANSFER CAPACITANCE
vs
GATE-SOURCE VOLTAGE

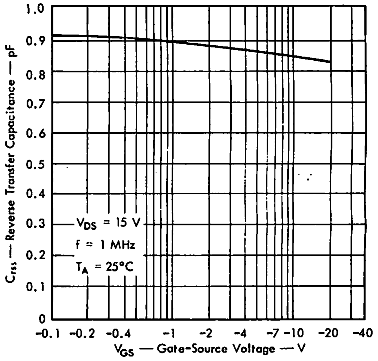


FIGURE 8

NOTE 3: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

†Data is for devices having the indicated values of I_{DSS} at V_{DS} = 15 V, V_{GS} = 0, and T_A = 25°C.

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-SOURCE INPUT ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

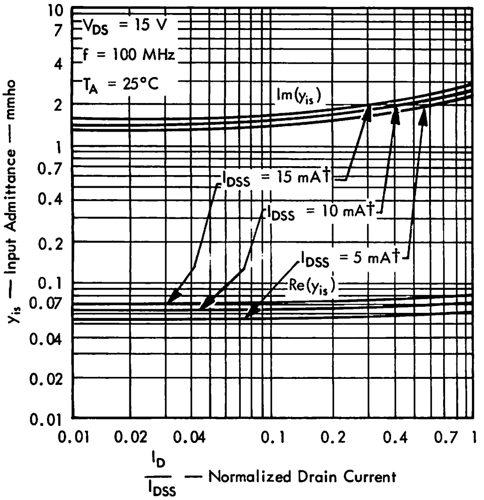


FIGURE 9

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

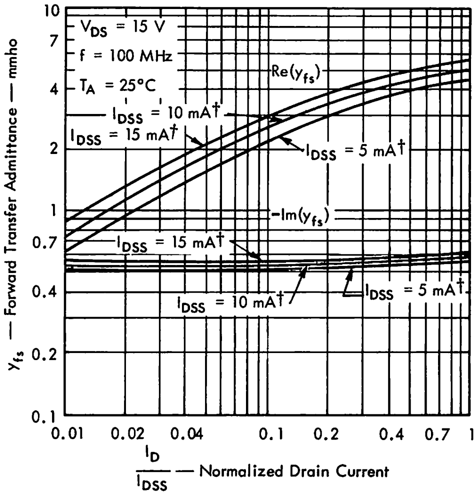


FIGURE 10

SMALL-SIGNAL COMMON-SOURCE
REVERSE TRANSFER ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

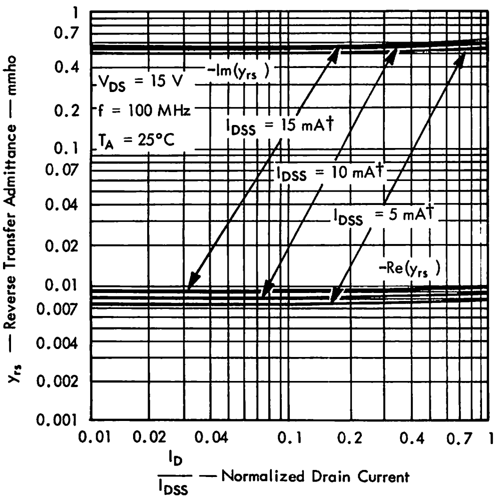


FIGURE 11

SMALL-SIGNAL COMMON-SOURCE OUTPUT ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

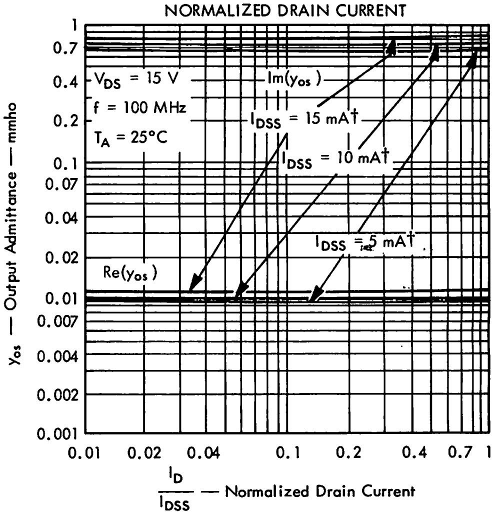


FIGURE 12

†Data is for devices having the indicated values of I_{DSS} at $V_{DS} = 15$ V, $V_{GS} = 0$, and $T_A = 25°C$.

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-SOURCE INPUT ADMITTANCE
vs
FREQUENCY

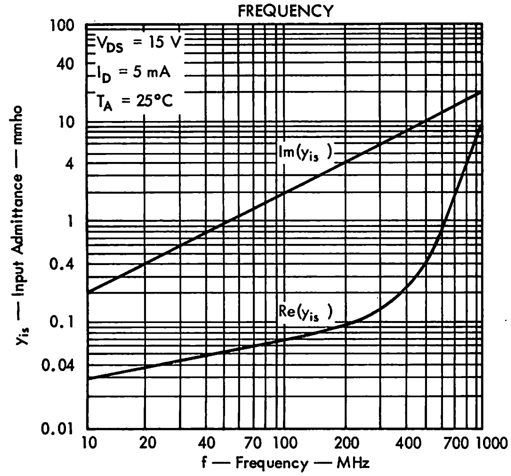


FIGURE 13

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
FREQUENCY

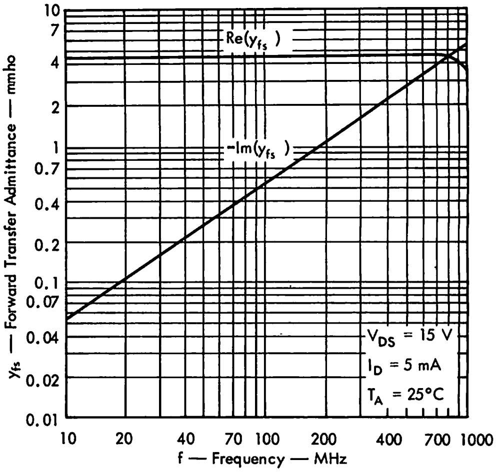


FIGURE 14

SMALL-SIGNAL COMMON-SOURCE
REVERSE TRANSFER ADMITTANCE
vs
FREQUENCY

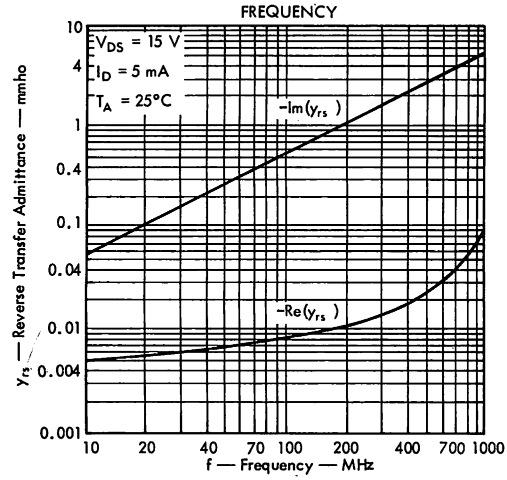


FIGURE 15

SMALL-SIGNAL COMMON-SOURCE OUTPUT ADMITTANCE
vs
FREQUENCY

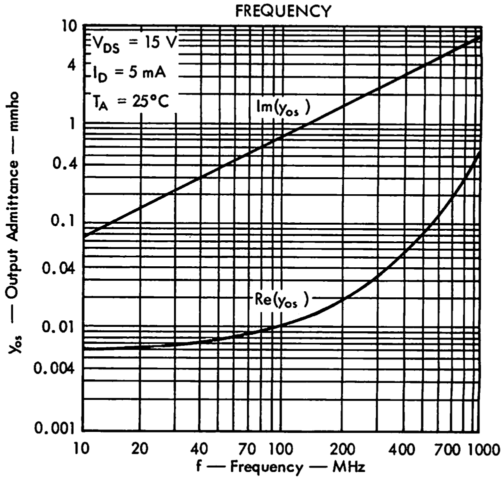


FIGURE 16

TYPICAL CHARACTERISTICS

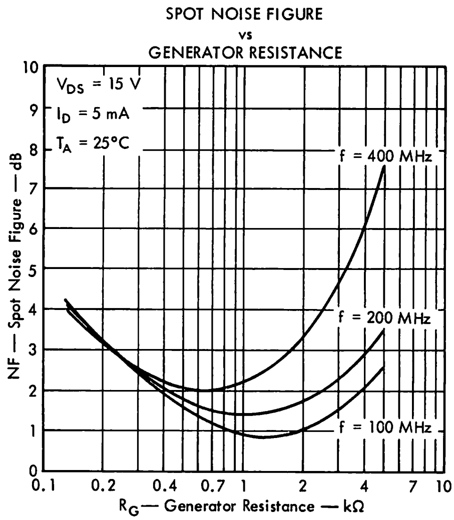


FIGURE 17

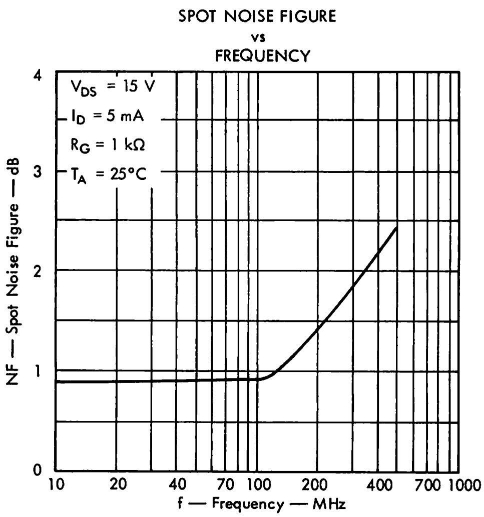
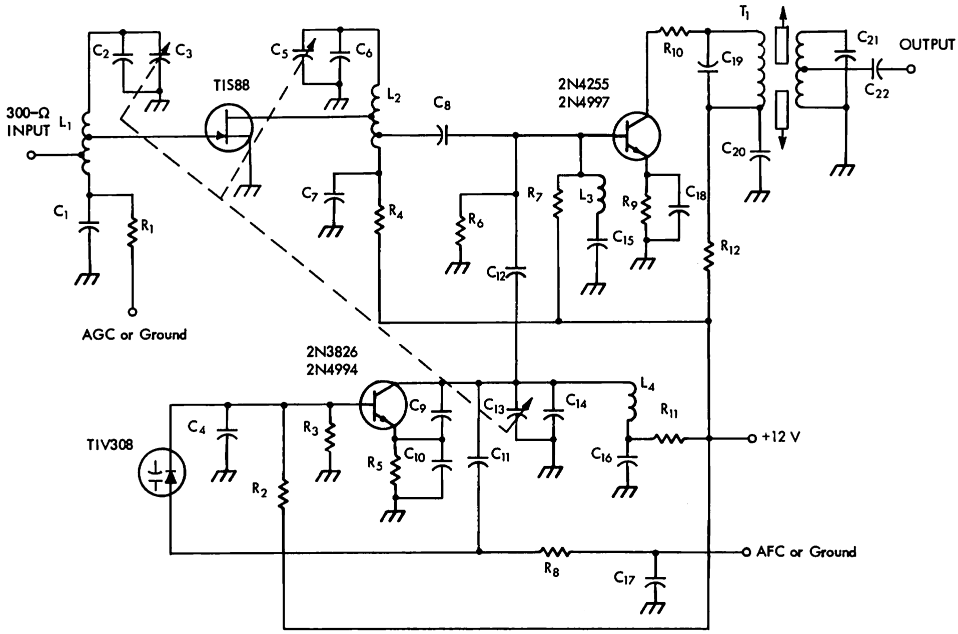


FIGURE 18

TYPICAL APPLICATION DATA



TYPICAL TUNER PERFORMANCE AT $f_0 = 98$ MHz	
Image Rejection (119.4 MHz)	47 dB
$f_0 + \frac{1}{2}$ IF Rejection (103.35 MHz)	73 dB
Sensitivity for 30-dB $\frac{S+N}{N}$ (±75-kHz deviation)	2.3 μV
Sensitivity for 30-dB $\frac{S+N}{N}$ (±22.5-kHz deviation)	3.4 μV
Voltage Gain from Input to Primary of IF Transformer	37 dB

CIRCUIT COMPONENT INFORMATION

CAPACITORS

C_1: 0.001 μF	C_{12}: 1.2 pF
C_2: 10 pF	C_{13}: †
C_3: †	C_{14}: 10 pF
C_4: 0.001 μF	C_{15}: 240 pF
C_5: †	C_{16}: 0.001 μF
C_6: 10 pF	C_{17}: 0.1 μF
C_7: 0.001 μF	C_{18}: 0.01 μF
C_8: 12 pF	C_{19}: 47 pF
C_9: 4.7 pF	C_{20}: 0.01 μF
C_{10}: 6.8 pF	C_{21}: 100 pF
C_{11}: 4.7 pF	C_{22}: 0.01 μF

†Three-gang, 6–21 pF each, with trimmers.

RESISTORS

R_1: 27 kΩ	R_7: 10 kΩ
R_2: 10 kΩ	R_8: 330 kΩ
R_3: 2.7 kΩ	R_9: 820 Ω
R_4: 330 Ω	R_{10}: 120 Ω
R_5: 1 kΩ	R_{11}: 330 Ω
R_6: 2.7 kΩ	R_{12}: 330 Ω

All resistors ½ W, ten percent tolerance

TRANSFORMER

T_1: 10.7 MHz IF transformer

COILS

L_1: 2.5 T, #16 bus, ¼" ID, carbonyl "E" core, tapped at 1 T and 2 T from bottom

L_2: 4 T, #16 bus, ¼" ID, air core, tapped at 1.3 T and 1 T from bottom

L_3: 1 μH

L_4: 3 T, #16 bus, ¼" ID, carbonyl "E" core

FIGURE 19 — TYPICAL FM TUNER

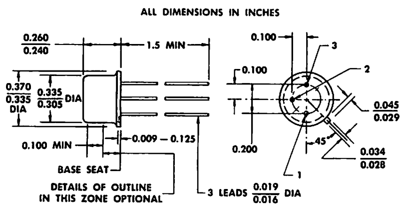
P-CHANNEL DIFFUSED PLANAR SILICON FIELD-EFFECT TRANSISTOR

TYPE 2N2386
BULLETIN NO. DL-S 683860, JULY 1963
REVISED MAY 1968

FOR INDUSTRIAL SMALL-SIGNAL APPLICATIONS

- High Input Impedance (>3 megohms at 1 kc)

*mechanical data



THE GATE IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

1 — SOURCE 2 — GATE 3 — DRAIN

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Continuous Forward Gate Current	–10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	0.5 w
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	1.5 w
Storage Temperature Range	–65°C to 200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
BV_{DGO}	Drain-Gate Breakdown Voltage (See Note 3)	$I_D = -10\ \mu a$, $I_S = 0$	–20		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$		0.01	μa
		$V_{GS} = 10$ v, $V_{DS} = 0$, $T_A = 100°C$		1.0	μa
$I_{D(off)}$	Pinch-Off Drain Current	$V_{DS} = -12$ v, $V_{GS} = 8$ v		–10	μa
$\lvert y_{is} \rvert$	Small-Signal Common-Source Input Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc		0.3	μmho
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc	1000		μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 140 kc		50	pf

NOTES: 1. Derate linearly to 175°C free-air temperature at the rate of 3.3 mw/C°.

2. Derate linearly to 175°C case temperature at the rate of 10 mw/C°.

3. This parameter corresponds closely to BV_{DSS} (the Drain-Source Breakdown Voltage for $V_{GS} = 0$). BV_{DSX} (the Drain-Source Breakdown Voltage for other values of V_{GS}) may be calculated from: $|BV_{DSX}| \cong |BV_{DGO}| - |V_{GS}|$.

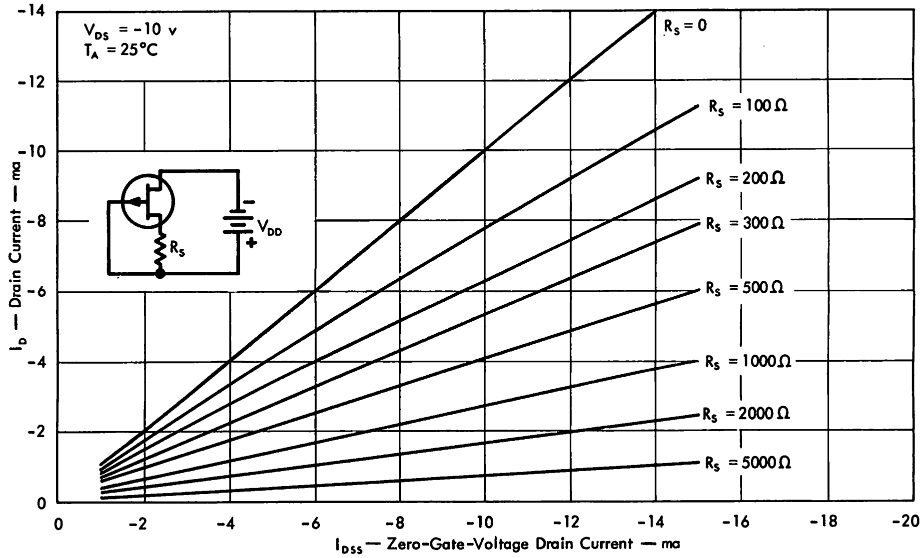
*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPE 2N2386
P-CHANNEL DIFFUSED PLANAR SILICON FIELD-EFFECT TRANSISTOR

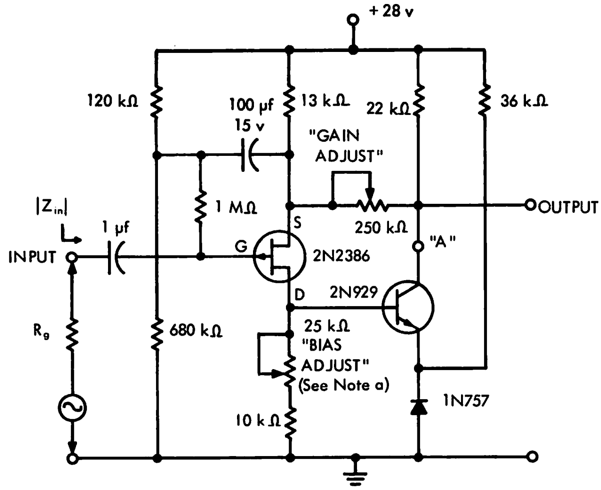
BIAS DESIGN CURVE FOR TYPICAL UNITS

DRAIN CURRENT
vs
ZERO-GATE-VOLTAGE DRAIN CURRENT



TYPICAL APPLICATION DATA

HIGH-INPUT-IMPEDANCE AMPLIFIER



NOTES: a. Adjust for + 18 v at Point "A".
b. All resistors ± 5% tolerance, 1/2 watt.

TYPICAL SMALL-SIGNAL CIRCUIT PERFORMANCE CHARACTERISTICS

FREQUENCY	$\lvert Z_{in} \rvert$ †
10 cps	70 MΩ
100 cps	70 MΩ
1 kc	50 MΩ
10 kc	10 MΩ

R_g	3-db BANDWIDTH †
100 kΩ	1 cps to 200 kc
1 MΩ	1 cps to 50 kc
10 MΩ	1 cps to 8 kc

VOLTAGE GAIN
Adjustable from 1 to 20

† T_A = 25°C, "Gain Adjust" set for Gain of 10

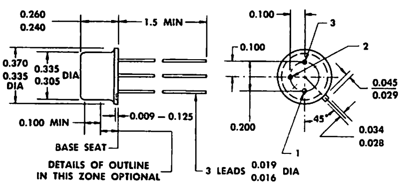
TYPES 2N2497, 2N2498, 2N2499, 2N2500
P-CHANNEL DIFFUSED PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N2497, 2N2498, 2N2499, 2N2500
BULLETIN NO. DL-S 683519, MAY 1963
REVISED MAY 1968

FOR SMALL-SIGNAL, LOW-NOISE APPLICATIONS

- Guaranteed 10 cps Noise Figure (2N2500)
- High Input Impedance (>5 megohms at 1 kc)
- High Nuclear Radiation-Damage Resistance

*mechanical data

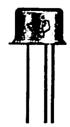


THE GATE IS IN ELECTRICAL CONTACT WITH THE CASE

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

1 — SOURCE 2 — GATE
3 — DRAIN

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Continuous Forward Gate Current	−10 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	0.5 w
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	1.5 w
Storage Temperature Range	−195°C to +200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2497 MIN	2N2497 MAX	2N2498 MIN	2N2498 MAX	2N2499 MIN	2N2499 MAX	2N2500 MIN	2N2500 MAX	UNIT
BV_{DGO}	Drain-Gate Breakdown Voltage (See Note 3)	$I_D = -10\ \mu a$, $I_S = 0$	−20		−20		−20		−20		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$		0.01		0.01		0.01		0.01	μa
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$, $T_A = 150°C$		10		10		10		10	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = -10$ v, $V_{GS} = 0$	−1	−3	−2	−6	−5	−15	−1	−6	ma
$I_{D(off)}$	Pinch-Off Drain Current	$V_{DS} = -15$ v, V_{GS}: See Note 4		−10		−10		−10		−10	μa
r_{DS}	Static Drain-Source Resistance	$I_D = -100\ \mu a$, $V_{GS} = 0$		1000		800		600			ohm
$\lvert y_{is}\rvert$	Small-Signal Common-Source Input Admittance	$V_{DS} = -10$ v, I_D: See Note 5, f = 1 kc		0.2		0.2		0.2		0.2	μmho
$\lvert y_{fs}\rvert$	Small-Signal Common-Source Forward Transfer Admittance		1000	2000	1500	3000	2000	4000	1000	2200	μmho
$\lvert y_{rs}\rvert$	Small-Signal Common-Source Reverse Transfer Admittance			0.1		0.1		0.1		0.1	μmho
$\lvert y_{os}\rvert$	Small-Signal Common-Source Output Admittance			20		40		100		20	μmho
$\lvert y_{fs}\rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, I_D: See Note 5, f = 10 mc	900		1350		1800		900		μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{GS} = 0$, $V_{DS} = -10$ v, f = 140 kc		32		32		32		32	pf

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N2497 MIN	2N2497 MAX	2N2498 MIN	2N2498 MAX	2N2499 MIN	2N2499 MAX	2N2500 MIN	2N2500 MAX	UNIT
NF	Spot Noise Figure	$V_{DS} = -5$ v, $I_D = -1$ ma, f = 1 kc, $R_G = 1\ M\Omega$		3		3		4		1	db
		$V_{DS} = -5$ v, $I_D = -1$ ma, f = 10 cps, $R_G = 10\ M\Omega$								5	db

NOTES: 1. Derate linearly to 175°C free-air temperature at the rate of 3.3 mw/C°.
2. Derate linearly to 175°C case temperature at the rate of 10 mw/C°.
3. This parameter corresponds closely to BV_{DSS} (the Drain-Source Breakdown Voltage for $V_{GS} = 0$). BV_{DSX} (the Drain-Source Breakdown Voltage for other values of V_{GS}) may be calculated from: $|BV_{DSX}| \cong |BV_{DGO}| - |V_{GS}|$.

	2N2497	2N2498	2N2499	2N2500
NOTE 4: V_{GS} =	5 v	6 v	8 v	6 v
NOTE 5: I_D =	−1 ma	−2 ma	−5 ma	−1 ma

*Indicates JEDEC registered data.

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PARAMETER MEASUREMENT INFORMATION

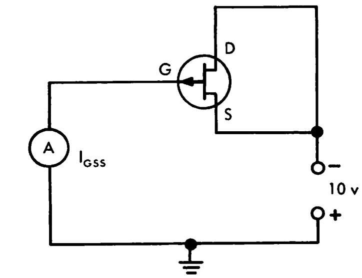
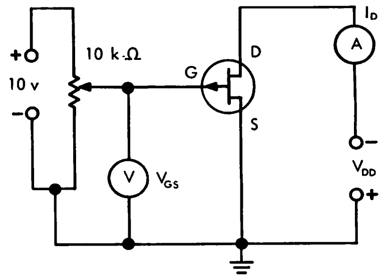


FIGURE 1 — GATE CUTOFF CURRENT TEST CIRCUIT



* FIGURE 2 — PINCH-OFF DRAIN CURRENT TEST CIRCUIT

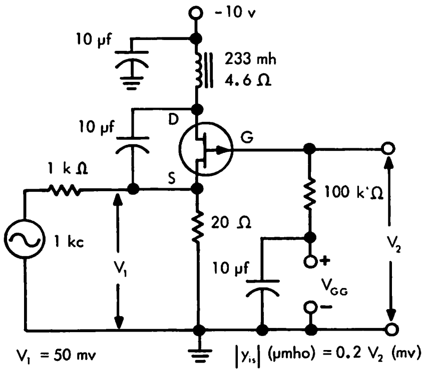


FIGURE 3 — INPUT ADMITTANCE TEST CIRCUIT

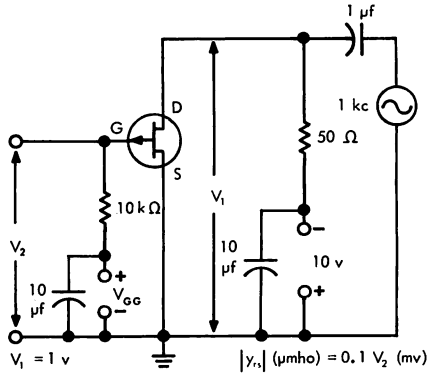
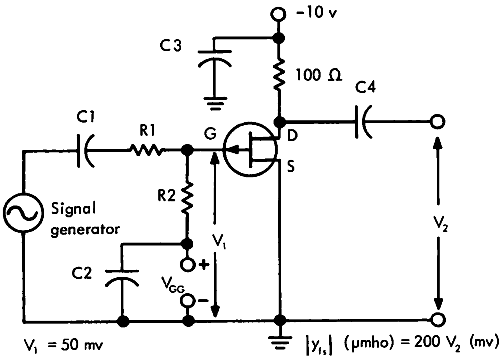


FIGURE 4 — REVERSE TRANSFER ADMITTANCE TEST CIRCUIT



f	R1	R2	C1	C2	C3	C4
1 kc	1 k Ω	10 Ω	10 μf	10 μf	10 μf	10 μf
10 mc	30 Ω	20 Ω	39pf	0.02μf	0.02 μf	0.02μf

FIGURE 5 — FORWARD TRANSFER ADMITTANCE TEST CIRCUIT

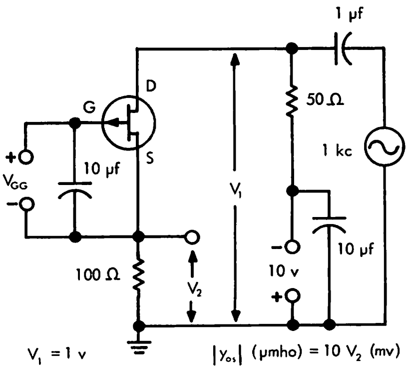


FIGURE 6 — OUTPUT ADMITTANCE TEST CIRCUIT

* Indicates JEDEC registered data.

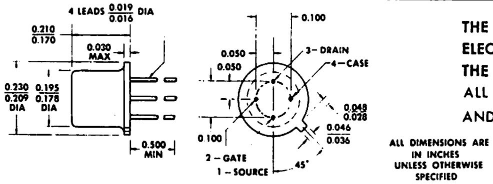
TYPES 2N3329, 2N3330, 2N3331, 2N3332
P-CHANNEL DIFFUSED PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N3329, 2N3330, 2N3331, 2N3332
BULLETIN NO. DL-S 644905, MARCH 1964

FOR SMALL-SIGNAL, LOW-NOISE APPLICATIONS

- **Active Elements Insulated from Case**
- **High Input Impedance (> 5 megohms at 1 kc)**
- **High Nuclear Radiation-Damage Resistance**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72 DIMENSIONS AND NOTES ARE APPLICABLE

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Gate Current . . . . −10 ma
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1) . . . . 0.3 w
Storage Temperature Range . . . . −65°C to +200°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	2N3329 MIN	2N3329 MAX	2N3330 MIN	2N3330 MAX	2N3331 MIN	2N3331 MAX	2N3332 MIN	2N3332 MAX	UNIT
BV_{GSS}	Gate-Source Breakdown Voltage	$I_G = 10\ \mu a$, $V_{DS} = 0$	20		20		20		20		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$		0.01		0.01		0.01		0.01	μa
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$, $T_A = 150°C$		10		10		10		10	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = -10$ v, $V_{GS} = 0$	−1	−3	−2	−6	−5	−15	−1	−6	ma
V_{GS}	Gate-Source Cutoff Voltage	$V_{DS} = -15$ v, $I_D = -10\ \mu a$		5		6		8		6	v
r_{DS}	Static Drain-Source Resistance	$I_D = -100\ \mu a$, $V_{GS} = 0$		1000		800		600			ohm
$\lvert y_{is} \rvert$	Small-Signal Common-Source Input Admittance	$V_{DS} = -10$ v, I_D — See Note 2, f = 1 kc		0.2		0.2		0.2		0.2	μmho
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, I_D — See Note 2, f = 1 kc	1000	2000	1500	3000	2000	4000	1000	2200	μmho
$\lvert y_{rs} \rvert$	Small-Signal Common-Source Reverse Transfer Admittance	$V_{DS} = -10$ v, I_D — See Note 2, f = 1 kc		0.1		0.1		0.1		0.1	μmho
$\lvert y_{os} \rvert$	Small-Signal Common-Source Output Admittance	$V_{DS} = -10$ v, I_D — See Note 2, f = 1 kc		20		40		100		20	μmho
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, I_D — See Note 2, f = 10 Mc	900		1350		1800		900		μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = -10$ v, $V_{GS} = 1$ v, f = 1 Mc		20		20		20		20	pf

*operating characteristics at 25°C free-air temperature

			2N3329	2N3330	2N3331	2N3332	
NF	Spot Noise Figure	$V_{DS} = -5$ v, $I_D = -1$ ma, f = 1 kc, $R_G = 1\ M\Omega$	3	3	4	1	db
		$V_{DS} = -5$ v, $I_D = -1$ ma, f = 10 cps, $R_G = 10\ M\Omega$				5	db

NOTE 1: Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.

	2N3329	2N3330	2N3331	2N3332
NOTE 2: $I_D =$	−1 ma	−2 ma	−5 ma	−1 ma

†The fourth lead (case) is connected to the source for all measurements.

*Indicates JEDEC registered data.

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N-CHANNEL PLANAR SILICON FIELD-EFFECT TRANSISTOR

TYPE 2N3819
BULLETIN NO. DL-S 688047, AUGUST 1965
REVISED MAY 1968

SILECT† FIELD-EFFECT TRANSISTOR

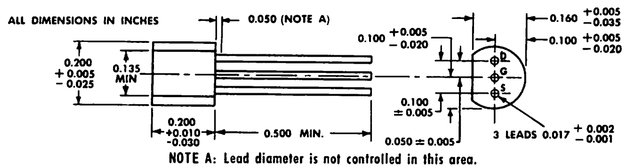
For Industrial and Consumer Small-Signal Applications

- Low C_{rss}: $\leq$ 4 pf
- High y_{fs}/C_{iss} Ratio (High-Frequency Figure of Merit)
- Cross Modulation Minimized by Square-Law Transfer Characteristics

mechanical data

This transistor is encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. This device exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C method 106B. The transistor is insensitive to light.

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTE A: Lead diameter is not controlled in this area.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	25 v
Drain-Source Voltage	25 v
Reverse Gate-Source Voltage	−25 v
Gate Current	10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	360 mw
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu a$, $V_{DS} = 0$	−25		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = -15$ v, $V_{DS} = 0$		−2	na
		$V_{GS} = -15$ v, $V_{DS} = 0$, $T_A = 100°C$		−2	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ v, $V_{GS} = 0$, See Note 2	2	20	ma
V_{GS}	Gate-Source Voltage	$V_{DS} = 15$ v, $I_D = 200\ \mu a$	−0.5	−7.5	v
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ v, $I_D = 2$ na		−8	v
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2	2000	6500	μmho
$\lvert y_{os} \rvert$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2		50	μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 Mc		8	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			4	pf
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 100 Mc	1600		μmho

NOTES: 1. Derate linearly to 150°C free-air temperature at the rate of 2.88 mw/C°.
2. These parameters must be measured using pulse techniques. PW $\approx$ 100 msec, Duty Cycle $\leq$ 10%.

*Indicates JEDEC registered data.
†Trademark of Texas Instruments
‡Patent Pending

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TYPE 2N3820
P-CHANNEL PLANAR SILICON FIELD-EFFECT TRANSISTOR

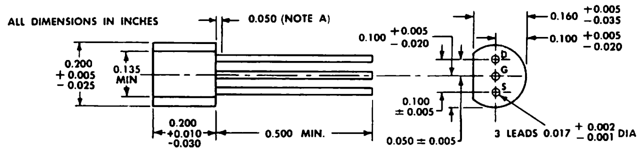
TYPE 2N3820
BULLETIN NO. DL-S 687947, AUGUST 1965
REVISED JULY 1968

SILECT† FIELD-EFFECT TRANSISTOR
For Industrial and Consumer Small-Signal Applications

mechanical data

This transistor is encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. This device exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C method 106B. The transistor is insensitive to light.

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTE A: Lead diameter is not controlled in this area.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	−20 v
Drain-Source Voltage	−20 v
Reverse Gate-Source Voltage	20 v
Gate Current	−10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	360 mw
Storage Temperature Range	−65°C to +150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = 10\ \mu a$, $V_{DS} = 0$	20		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$		20	na
		$V_{GS} = 10$ v, $V_{DS} = 0$, $T_A = 100°C$		2	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = -10$ v, $V_{GS} = 0$, See Note 2	−0.3	−15	ma
V_{GS}	Gate-Source Voltage	$V_{DS} = -10$ v, $I_D = -30\ \mu a$	0.3	7.9	v
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = -10$ v, $I_D = -10\ \mu a$		8	v
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc, See Note 2	800	5000	μmho
$\lvert y_{os} \rvert$	Small-Signal Common-Source Output Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc, See Note 2		200	μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 Mc		32	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			16	pf
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 10 Mc	700		μmho

NOTES: 1. Derate linearly to 150°C free-air temperature at the rate of 2.88 mw/C°.
2. These parameters must be measured using pulse techniques. PW ≈ 100 msec, Duty Cycle ≤ 10%.

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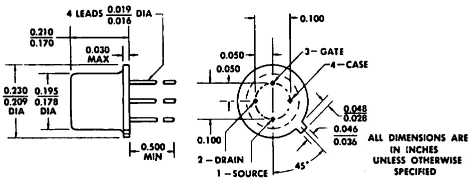
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N3821, 2N3822
BULLETIN NO. DL-S 657246, MARCH 1965

SYMMETRICAL N-CHANNEL FIELD-EFFECT TRANSISTORS FOR SMALL-SIGNAL APPLICATIONS

- **Low Leakage: ≤ 100 pa**
- **Low Input Capacitance: ≤ 6 pf**
- **High y_{fs}/C_{iss} Ratio (High-Frequency Figure-of-Merit)**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72 DIMENSIONS AND NOTES ARE APPLICABLE

TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	50 v
Drain-Source Voltage	50 v
Reverse Gate-Source Voltage	−50 v
Gate Current	10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	300 mw
Storage Temperature Range	−65°C to +200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	2N3821 MIN	2N3821 MAX	2N3822 MIN	2N3822 MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu a$, $V_{DS} = 0$	−50		−50		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = -30$ v, $V_{DS} = 0$		−0.1		−0.1	na
		$V_{GS} = -30$ v, $V_{DS} = 0$, $T_A = 150°C$		−0.1		−0.1	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ v, $V_{GS} = 0$, See Note 2	0.5	2.5	2	10	ma
V_{GS}	Gate-Source Voltage	$V_{DS} = 15$ v, $I_D = 50\ \mu a$	−0.5	−2			v
		$V_{DS} = 15$ v, $I_D = 200\ \mu a$			−1	−4	v
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ v, $I_D = 0.5$ na		−4		−6	v
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2	1500	4500	3000	6500	μmho
$\lvert y_{os} \rvert$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2		10		20	μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 Mc		6		6	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			3		3	pf
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 100 Mc	1500		3000		μmho

NOTES: 1. Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.
2. These parameters must be measured using pulse techniques. PW = 100 msec, Duty Cycle ≤ 10%.

†The fourth lead (case) is connected to the source for all measurements.

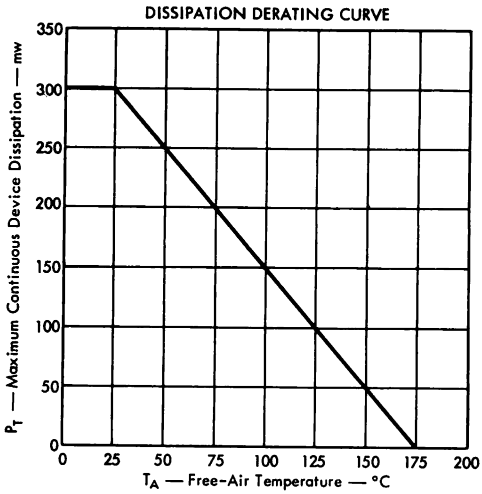
*Indicates JEDEC registered data

***operating characteristics at 25°C free-air temperature**

PARAMETER	TEST CONDITIONS†	MAX	UNIT
$\overline{NF}$ Average Noise Figure	$V_{DS}=15$ v, $V_{GS}=0$, f=10 cps, $R_G=1\ M\Omega$, Noise Bandwidth=5 cps	5	db
e_n Equivalent Input Noise Voltage	$V_{DS}=15$ v, $V_{GS}=0$, f=10 cps, Noise Bandwidth=5 cps	200	nv/ cps$^{1/2}$

†The fourth lead (case) is connected to the source for all measurements.

THERMAL INFORMATION



•Indicates JEDEC registered data.

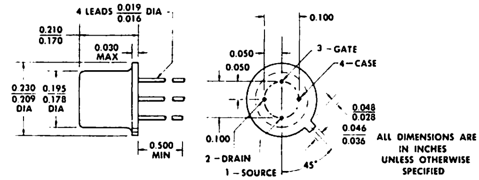
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTOR

TYPE 2N3823
BULLETIN NO. DL-S 657816, JULY 1965

SYMMETRICAL N-CHANNEL FIELD-EFFECT TRANSISTOR FOR VHF AMPLIFIER AND MIXER APPLICATIONS

- **Low Noise Figure: ≤ 2.5 db at 100 Mc**
- **Low C_{rss}: ≤ 2 pf**
- **High y_{fs}/C_{iss} Ratio (High-Frequency Figure-of-Merit)**
- **Cross Modulation Minimized by Square-Law Transfer Characteristic**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 except for addition of a fourth lead.

* absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	30 v
Drain-Source Voltage	30 v
Reverse Gate-Source Voltage	−30 v
Gate Current	10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	300 mw
Storage Temperature Range	−65°C to + 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS‡	MIN	MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu a$, $V_{DS} = 0$	−30		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = -20$ v, $V_{DS} = 0$		−0.5	na
		$V_{GS} = -20$ v, $V_{DS} = 0$, $T_A = 150°C$		−0.5	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ v, $V_{GS} = 0$, See Note 2	4	20	ma
V_{GS}	Gate-Source Voltage	$V_{DS} = 15$ v, $I_D = 400\ \mu a$	−1	−7.5	v
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ v, $I_D = 0.5$ na		−8	v
$\lvert y_{fs}\rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2	3500	6500	μmho
$\lvert y_{os}\rvert$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 kc, See Note 2		35	μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 1 Mc		6	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			2	pf
$\lvert y_{fs}\rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 200 Mc	3200		μmho
$Re(y_{is})$	Small-Signal Common-Source Input Conductance			800	μmho
$Re(y_{os})$	Small-Signal Common-Source Output Conductance			200	μmho

NOTES: 1. Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.
2. These parameters must be measured using pulse techniques. PW = 100 msec, Duty Cycle ≤ 10%.

*Indicates JEDEC registered data.
‡The fourth lead (case) is connected to the source for all measurements.

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TYPE 2N3823
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTOR

*** operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS‡	MAX	UNIT
NF	Common-Source Spot Noise Figure	$V_{DS} = 15$ v, $V_{GS} = 0$, f = 100 Mc, $R_G = 1$ kΩ	2.5	db

TYPICAL CHARACTERISTICS‡

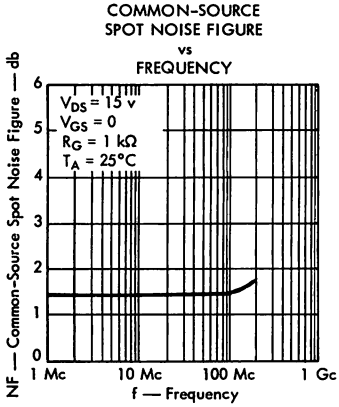


FIGURE 1

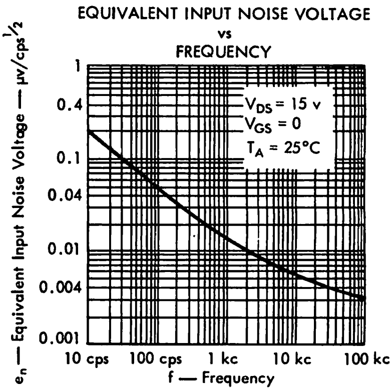


FIGURE 2

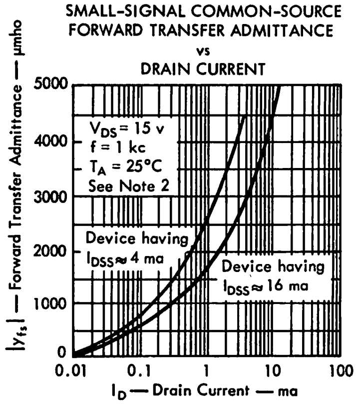


FIGURE 3

NOTE 2: These parameters must be measured using pulse techniques. PW = 100 msec, Duty Cycle ≤ 10%.

*Indicates JEDEC registered data.
‡The fourth lead (case) is connected to the source for all measurements.

TYPICAL CHARACTERISTICS‡

SMALL-SIGNAL COMMON-SOURCE FORWARD TRANSFER ADMITTANCE vs GATE-SOURCE VOLTAGE

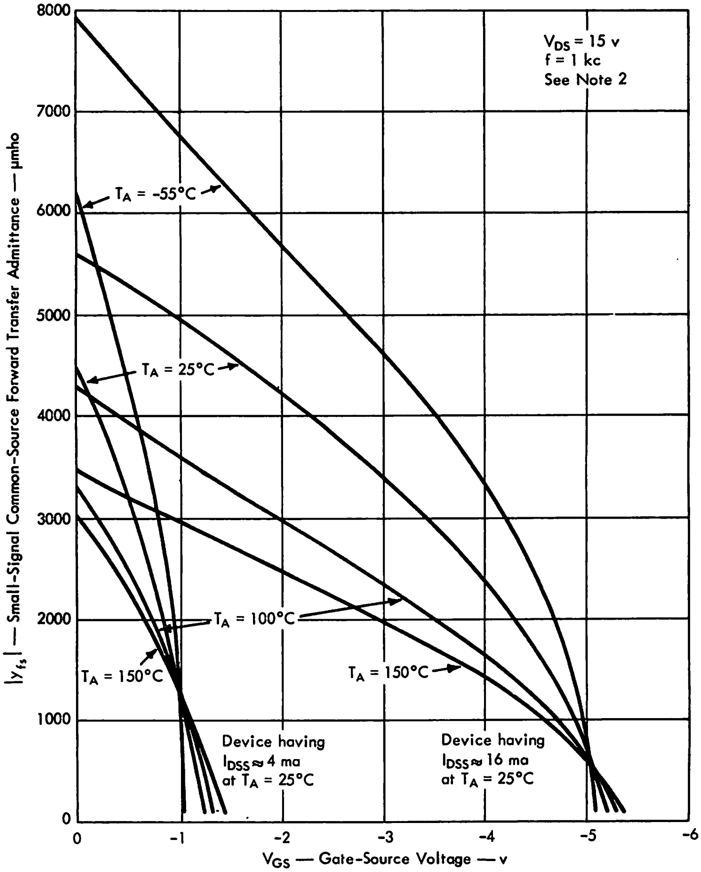


FIGURE 4

NOTE 2: These parameters must be measured using pulse techniques. PW = 100 msec, Duty Cycle ≤ 10%.

‡The fourth lead (case) is connected to the source for all measurements.

TYPICAL CHARACTERISTICS‡

GATE CUTOFF CURRENT vs FREE-AIR TEMPERATURE

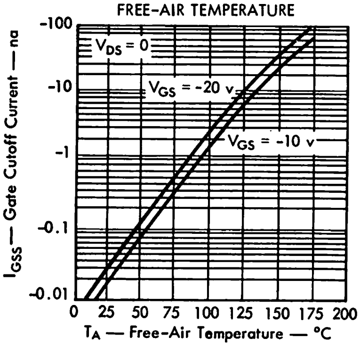


FIGURE 5

SMALL-SIGNAL COMMON-SOURCE INPUT ADMITTANCE vs FREQUENCY

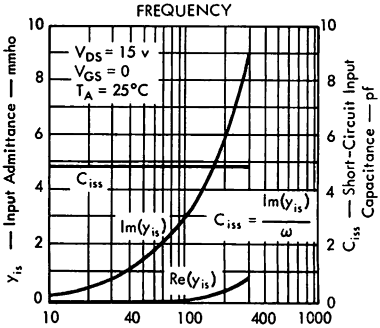


FIGURE 6

SMALL-SIGNAL COMMON SOURCE FORWARD TRANSFER ADMITTANCE vs FREQUENCY

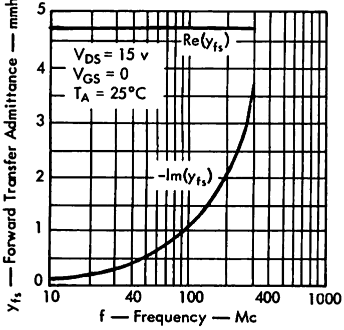


FIGURE 7

SMALL-SIGNAL COMMON-SOURCE REVERSE TRANSFER ADMITTANCE vs FREQUENCY

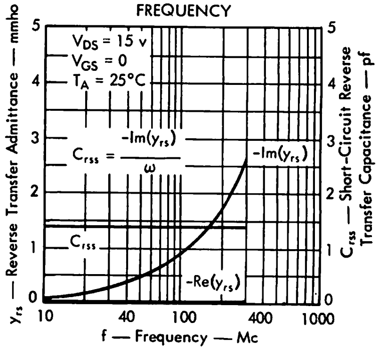


FIGURE 8

SMALL-SIGNAL COMMON-SOURCE OUTPUT ADMITTANCE vs FREQUENCY

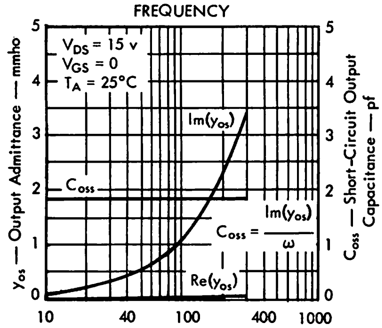


FIGURE 9

COMMON-SOURCE SHORT-CIRCUIT INPUT AND REVERSE-TRANSFER CAPACITANCES vs GATE-SOURCE VOLTAGE

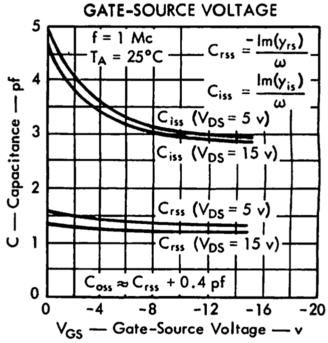


FIGURE 10

‡The fourth lead (case) is connected to the source for all measurements.

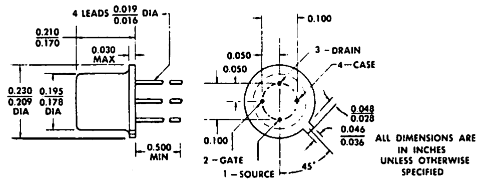
TYPE 2N3909
P-CHANNEL PLANAR SILICON FIELD-EFFECT TRANSISTOR

TYPE 2N3909
BULLETIN NO. DL-S 657690, JUNE 1965

FOR INDUSTRIAL SMALL-SIGNAL APPLICATIONS

- **Electrically Similar to 2N2386**
- **TO-72 Case Outline**
- **Active Elements Insulated From Case**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72 † DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline, except for fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	−20 v
Drain-Source Voltage	−20 v
Reverse Gate-Source Voltage	20 v
Gate Current	−10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	300 mw
Storage Temperature Range	−65°C to +200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS‡	MIN	MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = 10\ \mu a$, $V_{DS} = 0$	20		v
I_{GSS}	Gate Cutoff Current	$V_{GS} = 10$ v, $V_{DS} = 0$		10	na
		$V_{GS} = 10$ v, $V_{DS} = 0$, $T_A = 100°C$		1	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = -10$ v, $V_{GS} = 0$	−0.3	−15	ma
V_{GS}	Gate-Source Voltage	$V_{DS} = -10$ v, $I_D = -30\ \mu a$	0.3	7.9	v
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = -10$ v, $I_D = -10\ \mu a$		8	v
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc	1000	5000	μmho
$\lvert y_{os} \rvert$	Small-Signal Common-Source Output Admittance			100	μmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 Mc		32	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			16	pf
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 10 Mc	900		μmho

NOTE 1: Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.
‡The fourth lead (case) is connected to the source for all measurements.
*Indicates JEDEC registered data.

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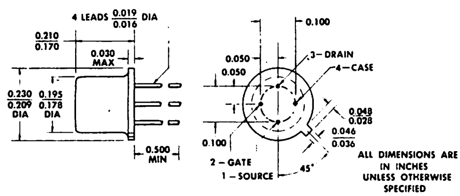
TYPES 2N3993, 2N3994
P-CHANNEL DIFFUSED PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N3993, 2N3994
BULLETIN NO. DL-S 658051, AUGUST 1965

FOR HIGH-SPEED COMMUTATOR AND CHOPPER APPLICATIONS

- Low $r_{ds(on)}$: — 150 ohms max (2N3993)
- High y_{fs} / C_{iss} Ratio (High-Frequency Figure-of-Merit)
- Low Leakage
- Low Capacitance

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Drain-Gate Voltage	−25 v
Drain-Source Voltage	−25 v
Reverse Gate-Source Voltage	25 v
Gate Current	−10 ma
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	300 mw
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS‡	2N3993 MIN	2N3993 MAX	2N3994 MIN	2N3994 MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = 1\ \mu a$, $V_{DS} = 0$	25		25		v
I_{DGO}	Drain Reverse Current	$V_{DG} = -15$ v, $I_S = 0$		−1.2		−1.2	na
		$V_{DG} = -15$ v, $I_S = 0$, $T_A = 150°C$		−1.2		−1.2	μa
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = -10$ v, $V_{GS} = 0$, See Note 2	−10		−2		ma
$I_{D(off)}$	Drain Cutoff Current	$V_{DS} = -10$ v, $V_{GS} = 6$ v				−1.2	na
		$V_{DS} = -10$ v, $V_{GS} = 6$ v, $T_A = 150°C$				−1	μa
		$V_{DS} = -10$ v, $V_{GS} = 10$ v		−1.2			na
		$V_{DS} = -10$ v, $V_{GS} = 10$ v, $T_A = 150°C$		−1			μa
V_{GS}	Gate-Source Voltage	$V_{DS} = -10$ v, $I_D = -1\ \mu a$	4	9.5	1	5.5	v
$r_{ds(on)}$	Small-Signal Drain-Source "On" Resistance	$V_{GS} = 0$, $I_D = 0$, f = 1 kc		150		300	Ω
$\lvert y_{fs} \rvert$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 kc, See Note 2	6	12	4	10	mmho
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = -10$ v, $V_{GS} = 0$, f = 1 Mc		16		16	pf
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance	$V_{GS} = 6$ v, $V_{DS} = 0$, f = 1 Mc				5	pf
		$V_{GS} = 10$ v, $V_{DS} = 0$, f = 1 Mc		4.5			pf

NOTES: 1. Derate linearly to 175°C free-air temperature at the rate of 2 mw/C°.

2. These parameters must be measured using pulse techniques. PW ≈ 100 msec, Duty Cycle ≤ 10%.

*Indicates JEDEC registered data.

‡The fourth lead (case) is connected to the source for all measurements.

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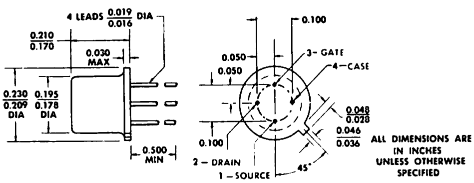
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N4416, 2N4416A
BULLETIN NO. DL-S 6810649, JANUARY 1968
REPLACES BULLETIN NO. DL-S 6710392, NOVEMBER, 1967

FOR VHF AMPLIFIER AND MIXER APPLICATIONS

- **High Power Gain... 10 dB Min at 400 MHz**
- **Low Noise Figure... 4 dB Max at 400 MHz**
- **High Transconductance... 4000 μmho Min at 400 MHz**
- **Low C_{rss} ... 0.8 pF Max**
- **High $|y_{fs}|/C_{iss}$ Ratio (High-Frequency Figure-of-Merit)**
- **Cross-Modulation Minimized by Square-Law Transfer Characteristic**
- **Recommended for Use in VHF-UHF Bandpass Amplifiers**
- **Excellent for General-Purpose Amplifier and Chopper Applications**

*mechanical data



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-72† DIMENSIONS AND NOTES ARE APPLICABLE

†TO-72 outline is same as TO-18 outline with the addition of a fourth lead.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N4416	2N4416A
*Drain-Gate Voltage	30 V	35 V
*Drain-Source Voltage	30 V	35 V
*Reverse Gate-Source Voltage	−30 V	−35 V
*Continuous Forward Gate Current	← 10 mA →	
*Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	← 300 mW →	
Continuous Device Dissipation at (or below) 125°C Case Temperature (See Note 2)	← 450 mW →	
*Storage Temperature Range	−65°C to 200°C	
*Lead Temperature 1/16 Inch from Case for 60 Seconds	← 300°C →	

NOTES: 1. Derate linearly to 200°C free-air temperature at the rate of 1.7 mW/deg.
2. Derate linearly to 200°C case temperature at the rate of 6 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N4416, 2N4416A
N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4416 MIN	2N4416 MAX	2N4416A MIN	2N4416A MAX	UNIT
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu A$, $V_{DS} = 0$	−30*		−35*		V
$V_{GS(f)}$	Gate-Source Forward Voltage	$I_G = 1$ mA, $V_{DS} = 0$		1*		1*	V
I_{GSS}	Gate Reverse Current	$V_{GS} = -20$ V, $V_{DS} = 0$		−0.1*		−0.1*	nA
		$V_{GS} = -20$ V, $V_{DS} = 0$, $T_A = 150°C$		−0.2* −0.1†		−0.2* −0.1†	μA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ V, $I_D = 1$ nA		−6*	−2.5*	−6*	V
V_{GS}	Gate-Source Voltage	$V_{DS} = 15$ V, $I_D = 0.5$ mA	−1*	−5.5*	−1*	−5.5*	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 3	5*	15*	5*	15*	mA
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, $f = 1$ kHz	4.5*	7.5*	4.5*	7.5*	mmho
$\|y_{os}\|$	Small-Signal Common-Source Output Admittance			0.05*		0.05*	
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{DS} = 15$ V, $V_{GS} = 0$, $f = 1$ MHz		4*		4*	pF
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance			0.8*		0.8*	
C_{oss}	Common-Source Short-Circuit Output Capacitance			2*		2*	
$Re(y_{is})$	Small-Signal Common-Source Input Conductance	$V_{DS} = 15$ V, $V_{GS} = 0$, $f = 100$ MHz		0.1*		0.1*	mmho
$Im(y_{is})$	Small-Signal Common-Source Input Susceptance			2.5*		2.5*	
$Re(y_{os})$	Small-Signal Common-Source Output Conductance			0.075*		0.075*	
$Im(y_{os})$	Small-Signal Common-Source Output Susceptance			1*		1*	
$Re(y_{is})$	Small-Signal Common-Source Input Conductance	$V_{DS} = 15$ V, $V_{GS} = 0$, $f = 400$ MHz		1*		1*	mmho
$Im(y_{is})$	Small-Signal Common-Source Input Susceptance			10*		10*	
$Re(y_{fs})$	Small-Signal Common-Source Forward Transfer Conductance		4*		4*		
$Re(y_{os})$	Small-Signal Common-Source Output Conductance			0.1*		0.1*	
$Im(y_{os})$	Small-Signal Common-Source Output Susceptance			4*		4*	

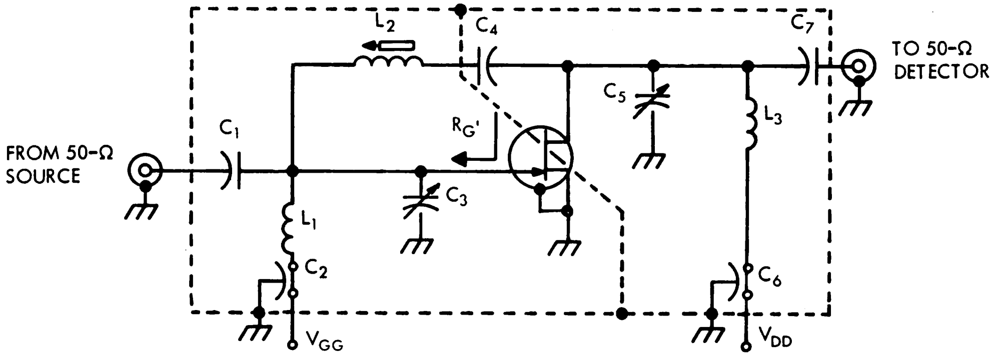
NOTE 3: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 1\%$.
†Texas Instruments guarantees this value in addition to the JEDEC registered value, which is also shown.

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
G_{ps}	Small-Signal Common-Source Neutralized Insertion Power Gain	$V_{DS} = 15$ V, $I_D = 5$ mA, $f = 100$ MHz, $R_G' = 1\ k\Omega$, See Figure 1	18		dB
		$V_{DS} = 15$ V, $I_D = 5$ mA, $f = 400$ MHz, $R_G' = 1\ k\Omega$, See Figure 1	10		
NF	Spot Noise Figure	$V_{DS} = 15$ V, $I_D = 5$ mA, $f = 100$ MHz, $R_G' = 1\ k\Omega$, See Figure 1		2	dB
		$V_{DS} = 15$ V, $I_D = 5$ mA, $f = 400$ MHz, $R_G' = 1\ k\Omega$, See Figure 1		4	

*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



CIRCUIT COMPONENT INFORMATION (See Note 4)					
CAPACITORS			COILS		
	100 MHz	400 MHz		100 MHz	400 MHz
C_1	7 pF	1.8 pF	L_1	0.14 μH, 3.5 T, #18 enameled copper wire, ⅜" I.D., ¼" long	0.022 μH, ⅝" of #16 copper wire formed to 0.5 T, ¼" I.D.
C_2	0.0015 μF	0.001 μF			
C_3	1–12 pF	0.8–8 pF	L_2	3 μH, 17 T, #28 enameled copper wire, close wound, 9/32" I.D., powdered iron slug	0.2 μH, 6 T, #24 enameled copper wire, close wound, 7/32" I.D., aluminum slug
C_4	1000 pF	27 pF			
C_5	1–12 pF	0.8–8 pF			
C_6	0.0015 μF	0.001 μF	L_3	0.25 μH, 4.5 T, #18 enameled copper wire, ⅜" I.D., 5/16" long	0.03 μH, 1½" of #16 enameled copper wire formed to 1 T, ⅜" I.D.
C_7	3 pF	1 pF			

FIGURE 1 — NEUTRALIZED POWER GAIN AND SPOT NOISE FIGURE TEST CIRCUIT

NOTE 4: Transformed equivalent source resistance (R'g) is 1000 Ω at 100 MHz for 100-MHz amplifier, and 1000 Ω at 400 MHz for 400-MHz amplifier.

TYPICAL CHARACTERISTICS

GATE REVERSE CURRENT
vs
FREE-AIR TEMPERATURE

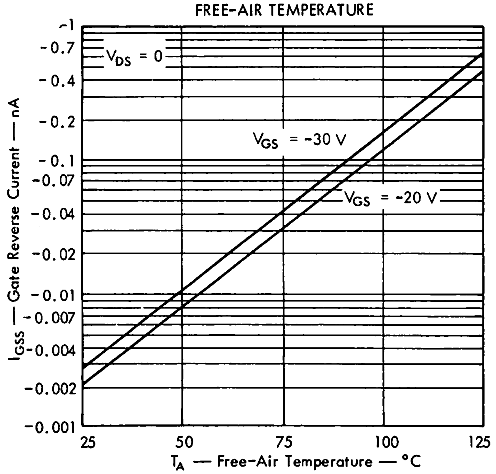


FIGURE 2

CORRELATION OF SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE and
GATE-SOURCE CUTOFF VOLTAGE
with
INDIVIDUAL DEVICE ZERO-GATE-VOLTAGE DRAIN CURRENT

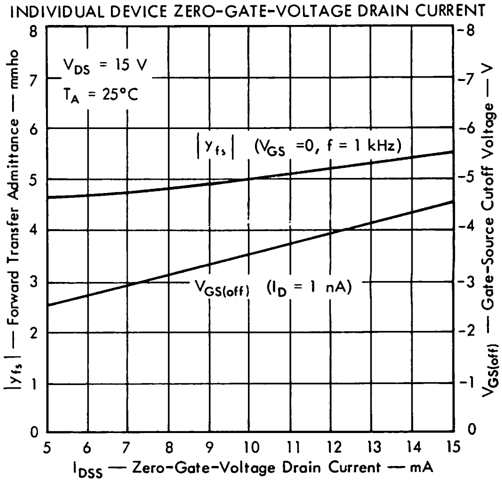


FIGURE 3

TYPICAL CHARACTERISTICS

DRAIN CURRENT
vs
GATE-SOURCE VOLTAGE

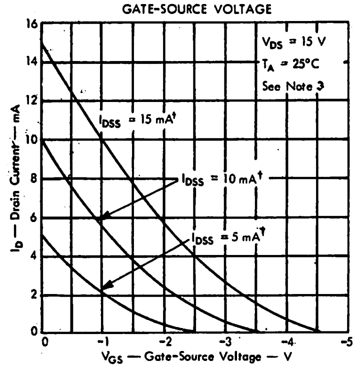


FIGURE 4

ZERO-GATE-VOLTAGE-DRAIN CURRENT
vs
FREE-AIR TEMPERATURE

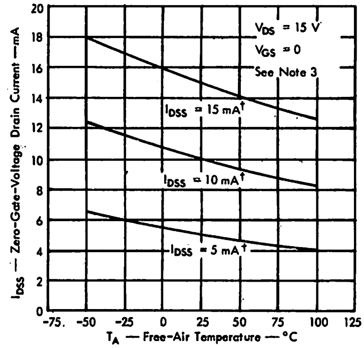


FIGURE 5

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
FREE-AIR TEMPERATURE

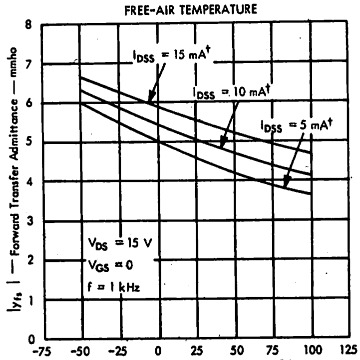


FIGURE 6

COMMON-SOURCE SHORT-CIRCUIT INPUT CAPACITANCE
vs
GATE-SOURCE VOLTAGE

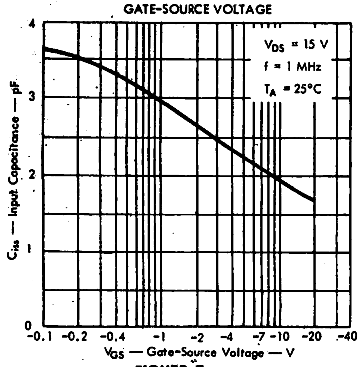


FIGURE 7

COMMON-SOURCE SHORT-CIRCUIT
REVERSE TRANSFER CAPACITANCE
vs
GATE-SOURCE VOLTAGE

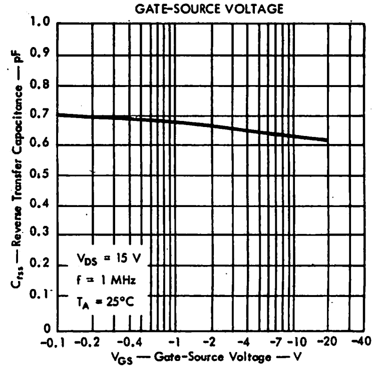


FIGURE 8

NOTE 3: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

†Data is for devices having the indicated values of I_{DSS} at V_{DS} = 15 V, V_{GS} = 0, and T_A = 25°C.

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-SOURCE INPUT ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

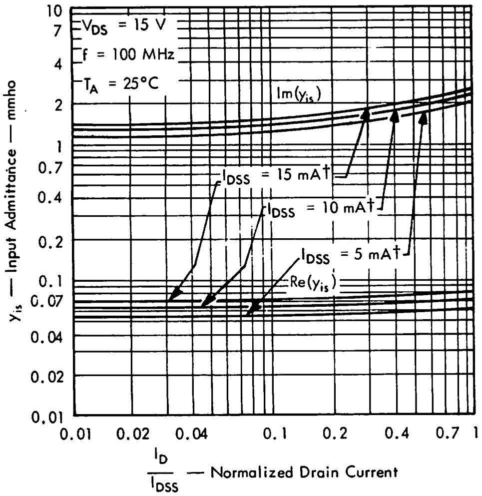


FIGURE 9

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

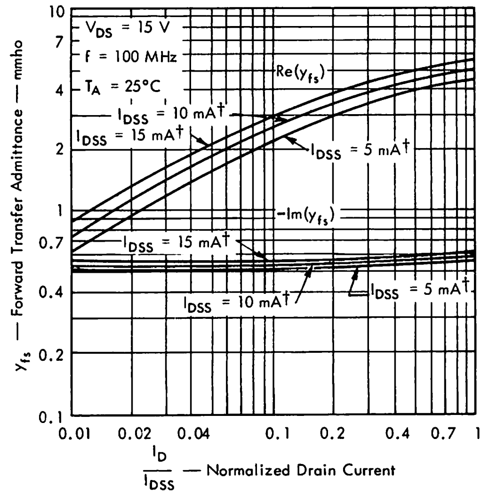


FIGURE 10

SMALL-SIGNAL COMMON-SOURCE
REVERSE TRANSFER ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

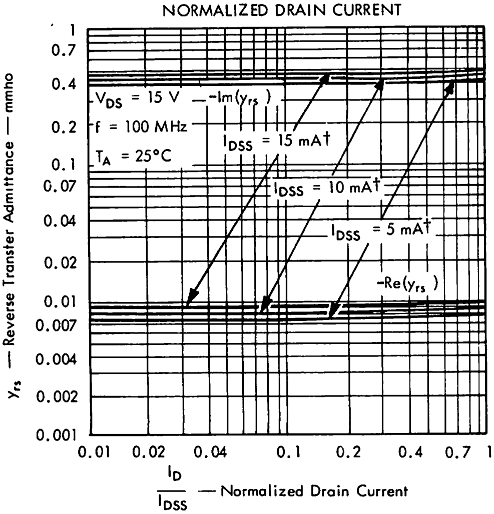


FIGURE 11

SMALL-SIGNAL COMMON-SOURCE OUTPUT ADMITTANCE
vs
NORMALIZED DRAIN CURRENT

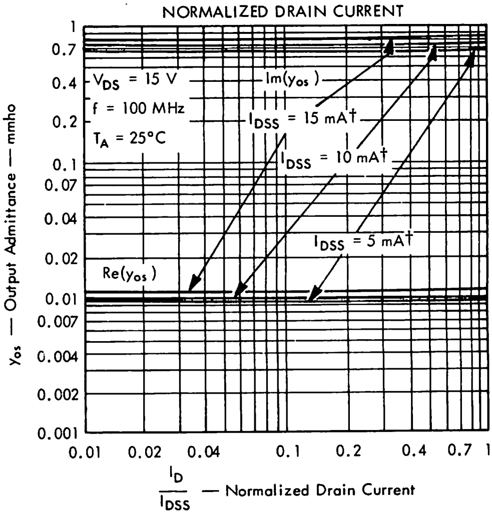


FIGURE 12

†Data is for devices having the indicated values of I_{DSS} at V_{DS} = 15 V, V_{GS} = 0, and T_A = 25°C.

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-SOURCE INPUT ADMITTANCE
vs
FREQUENCY

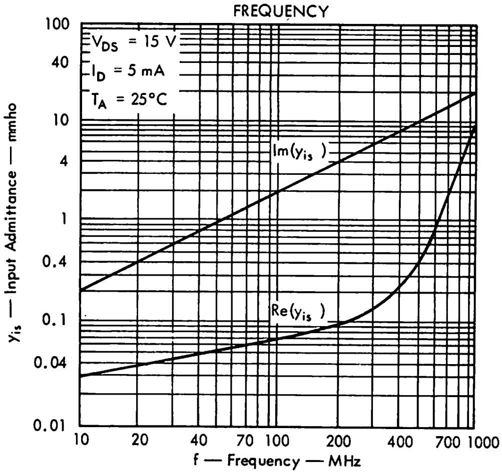


FIGURE 13

SMALL-SIGNAL COMMON-SOURCE
FORWARD TRANSFER ADMITTANCE
vs
FREQUENCY

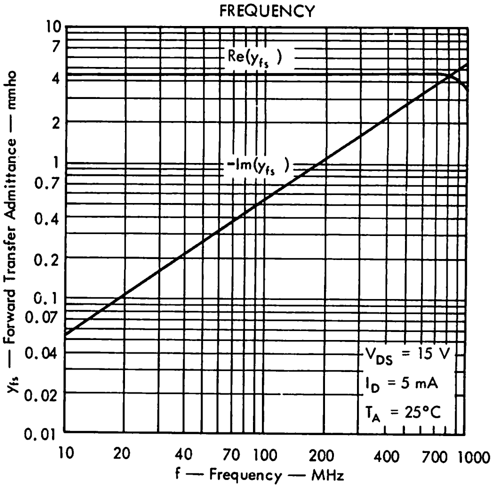


FIGURE 14

SMALL-SIGNAL COMMON-SOURCE
REVERSE TRANSFER ADMITTANCE
vs
FREQUENCY

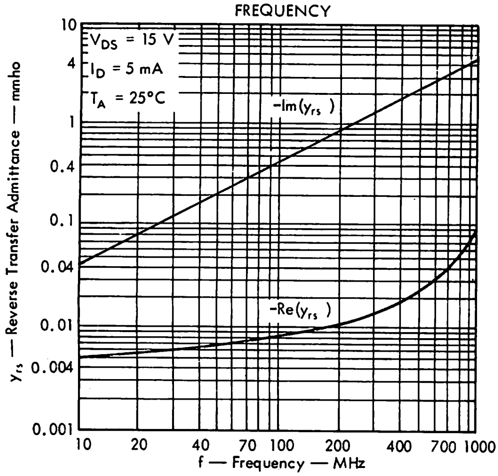


FIGURE 15

SMALL-SIGNAL COMMON-SOURCE OUTPUT ADMITTANCE
vs
FREQUENCY

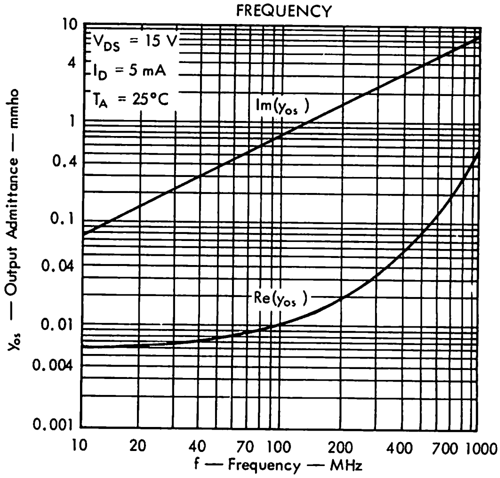


FIGURE 16

TYPICAL CHARACTERISTICS

SPOT NOISE FIGURE
vs
GENERATOR RESISTANCE

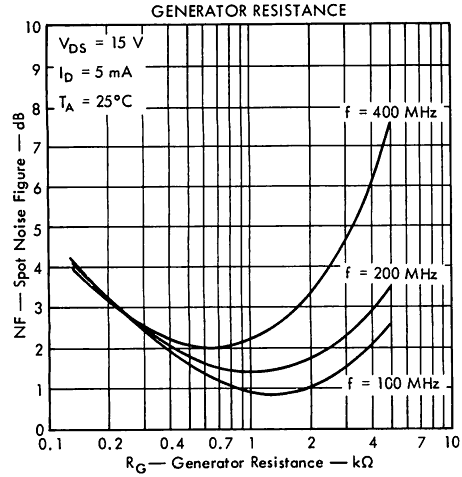


FIGURE 17

SPOT NOISE FIGURE
vs
FREQUENCY

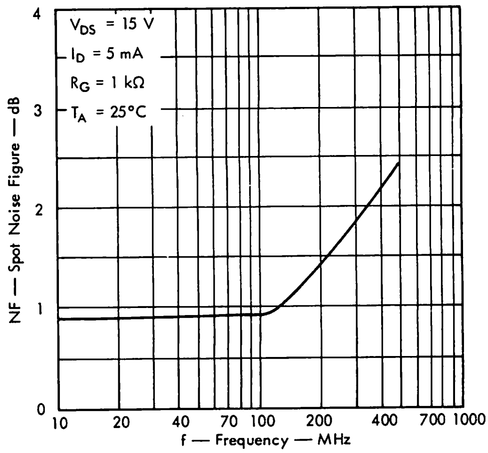


FIGURE 18

THERMAL INFORMATION

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

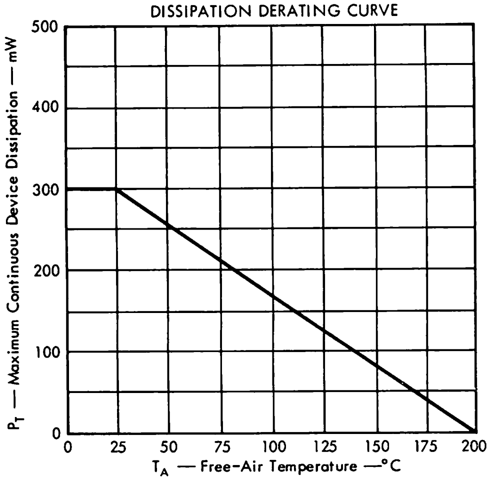


FIGURE 19

CASE TEMPERATURE
DISSIPATION DERATING CURVE

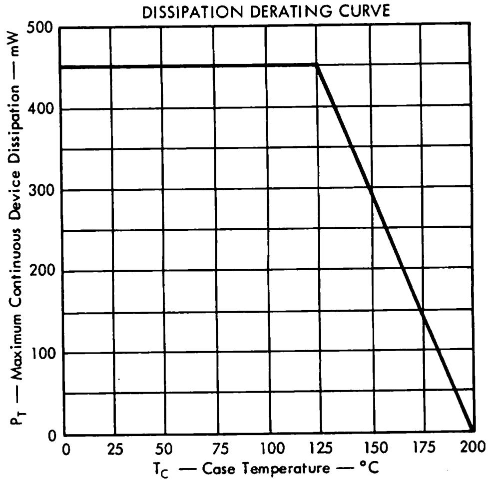


FIGURE 20

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N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N4856 THRU 2N4861
BULLETIN NO. DL-S 669371, NOVEMBER 1966

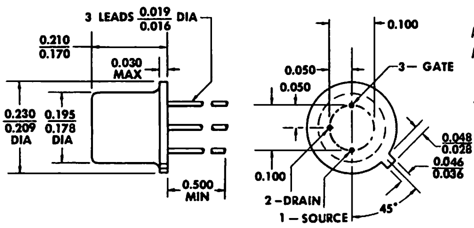
SYMMETRICAL N-CHANNEL FIELD-EFFECT TRANSISTORS FOR HIGH-SPEED COMMUTATOR AND CHOPPER APPLICATIONS

2N4859 Formerly TIXS41

- **Low $r_{ds(on)}$: 25 Ω Max (2N4856, 2N4859)**
- **Low $I_{D(off)}$: 0.25 nA Max**

*mechanical data

THE GATE IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N4856 2N4857 2N4858	2N4859 2N4860 2N4861
Drain-Gate Voltage	40 V	30 V
Drain-Source Voltage	40 V	30 V
Reverse Gate-Source Voltage	−40 V	−30 V
Forward Gate Current	←50 mA→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	←360 mW→	
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	←300°C→	

NOTE 1: Derate linearly to 175°C free-air temperature at the rate of 2.4 mW/deg.
*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4856		2N4857		2N4858		2N4859		2N4860		2N4861		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)GSS}$	Gate-Source Breakdown Voltage	$I_G = -1\ \mu A$, $V_{DS} = 0$	−40		−40		−40		−30		−30		−30		V
I_{GSS}	Gate Reverse Current	$V_{GS} = -20$ V, $V_{DS} = 0$		−0.25		−0.25		−0.25							nA
		$V_{GS} = -20$ V, $V_{DS} = 0$, $T_A = 150°C$		−0.5		−0.5		−0.5							μA
		$V_{GS} = -15$ V, $V_{DS} = 0$								−0.25		−0.25		−0.25	nA
		$V_{GS} = -15$ V, $V_{DS} = 0$, $T_A = 150°C$								−0.5		−0.5		−0.5	μA
$I_{D(off)}$	Drain Cutoff Current	$V_{DS} = 15$ V, $V_{GS} = -10$ V		0.25		0.25		0.25		0.25		0.25		0.25	nA
		$V_{DS} = 15$ V, $V_{GS} = -10$ V, $T_A = 150°C$		0.5		0.5		0.5		0.5		0.5		0.5	μA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ V, $I_D = 0.5$ nA	−4	−10	−2	−6	−0.8	−4	−4	−10	−2	−6	−0.8	−4	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 2	50		20	100	8	80	50		20	100	8	80	mA
$V_{DS(on)}$	Drain-Source On-State Voltage	$I_D = 20$ mA, $V_{GS} = 0$		0.75						0.75					V
		$I_D = 10$ mA, $V_{GS} = 0$				0.50						0.50			V
		$I_D = 5$ mA, $V_{GS} = 0$						0.50						0.50	V
$r_{ds(on)}$	Small-Signal Drain-Source On-State Resistance	$V_{GS} = 0$, $I_D = 0$, $f = 1$ kHz		25		40		60		25		40		60	Ω
C_{iss}	Common-Source Short-Circuit Input Capacitance	$V_{GS} = -10$ V, $V_{DS} = 0$, $f = 1$ MHz		18		18		18		18		18		18	pF
C_{rss}	Common-Source Short-Circuit Reverse Transfer Capacitance	$V_{GS} = -10$ V, $V_{DS} = 0$, $f = 1$ MHz		8		8		8		8		8		8	pF

*switching characteristics at 25°C free-air temperature

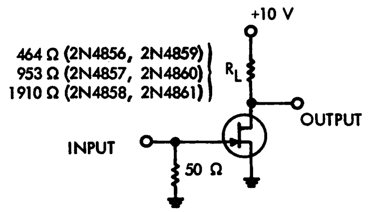
PARAMETER		TEST CONDITIONS	2N4856 2N4859	2N4857 2N4860	2N4858 2N4861	UNIT
			MAX	MAX	MAX	
$t_{d(on)}$	Turn-On Delay Time	$V_{DD} = 10$ V, $I_{D(on)}† = \begin{cases} 20\text{ mA (2N4856, 2N4859)} \\ 10\text{ mA (2N4857, 2N4860)} \\ 5\text{ mA (2N4858, 2N4861)} \end{cases}$	6	6	10	ns
t_r	Rise Time	$V_{GS(on)} = 0$,	3	4	10	ns
t_{off}	Turn-Off Time	See Figure 1 $V_{GS(off)} = \begin{cases} -10\text{ V (2N4856, 2N4859)} \\ -6\text{ V (2N4857, 2N4860)} \\ -4\text{ V (2N4858, 2N4861)} \end{cases}$	25	50	100	ns

NOTE 2: This parameter must be measured using pulse techniques. $t_p \approx 100$ ms, duty cycle $\leq 10\%$.

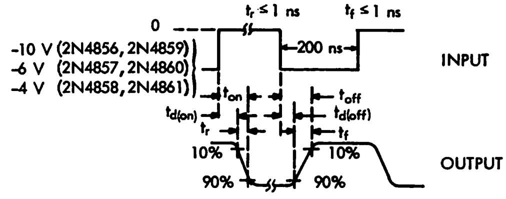
*Indicates JEDEC registered data

†These are nominal values; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, duty cycle $\approx$ 2%.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 0.75$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 2.5$ pF.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

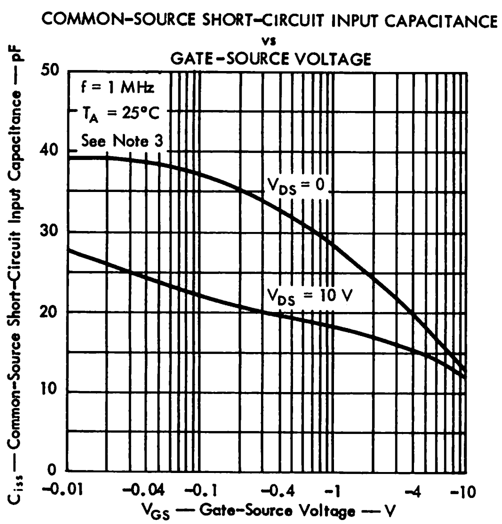


FIGURE 2

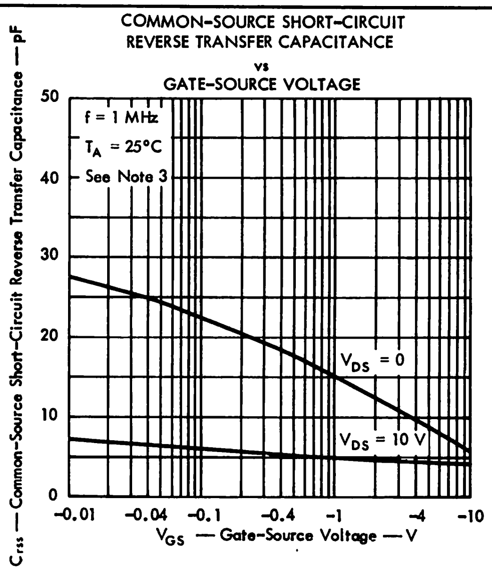


FIGURE 3

NOTE 3: These parameters were measured with bias voltages applied for less than five seconds to avoid overheating the devices.

TYPICAL CHARACTERISTICS

2N4856, 2N4859
SMALL-SIGNAL DRAIN-SOURCE ON-STATE RESISTANCE vs FREE-AIR TEMPERATURE

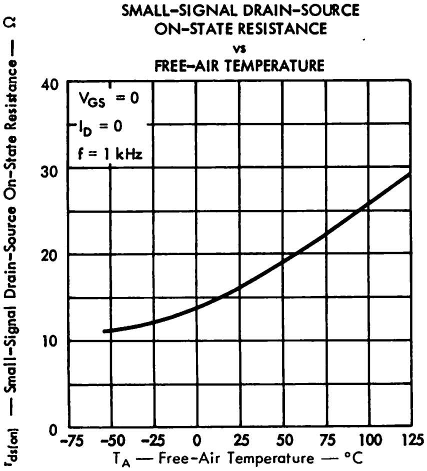


FIGURE 4

2N4856, 2N4859
SWITCHING TIMES vs LOAD RESISTANCE

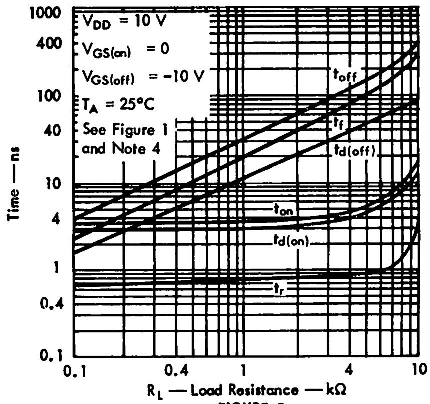


FIGURE 5

AVERAGE OUTPUT VOLTAGE ‡ vs RISE AND FALL TIMES

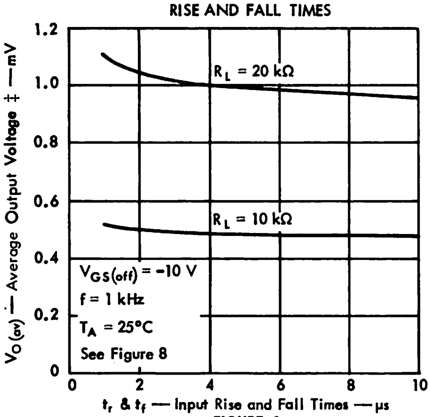


FIGURE 6

AVERAGE OUTPUT VOLTAGE ‡ vs FREQUENCY

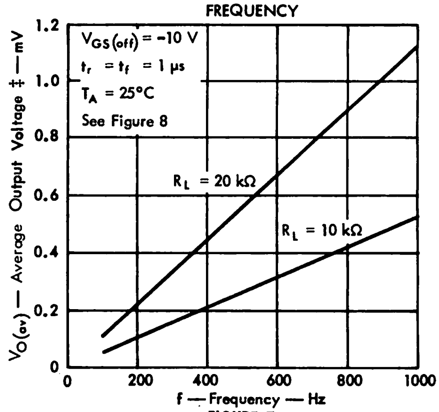
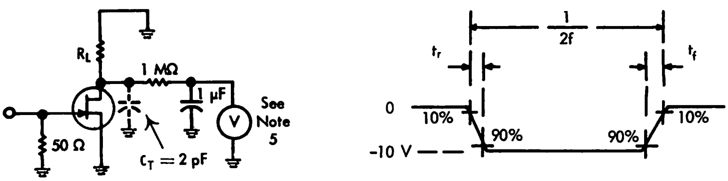


FIGURE 7



TEST CIRCUIT INPUT VOLTAGE WAVEFORM

FIGURE 8. MEASUREMENT INFORMATION FOR FIGURES 6 & 7

NOTES: 4. The circuit of figure 1 is used, varying R_L from 100 Ω to 10 kΩ. t_p = 1 µs, duty cycle ≤ 2%.
5. Voltmeter input resistance $R_{in} \geq$ 10 MΩ.

‡In the circuit of figure 8, Average Output Voltage results from capacitive feed-through of the gate-drive signal.

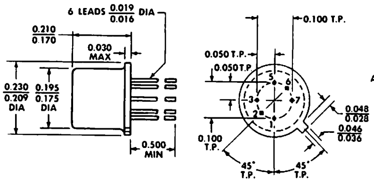
DUAL N-CHANNEL EPITAXIAL PLANAR SILICON FIELD-EFFECT TRANSISTORS

TYPES 2N5045, 2N5046, 2N5047
BULLETIN NO. DL-S 679714, MARCH 1967

MATCHED, SYMMETRICAL, FIELD-EFFECT TRANSISTORS

- High $|y_{fs}|/C_{iss}$ Ratio (High-Frequency Figure-of-Merit)
- Low Input Capacitance C_{iss} . . . 8 pF Max
- Low Gate Reverse Current Differential . . . 10 nA Max at $T_A = 100°C$
- Recommended for Low-Level D-C Amplifiers, Sample-Hold Circuits, and Series-Shunt Choppers

*mechanical data



1. SOURCE 1
2. DRAIN 1
3. GATE 1
5. SOURCE 2
6. DRAIN 2
7. GATE 2

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL JEDEC TO-71 DIMENSIONS AND NOTES ARE APPLICABLE

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH TRIODE	TOTAL DEVICE
Drain-Gate Voltage	50 V	
Reverse Gate-Source Voltage	−50 V	
Gate-1 — Gate-2 Voltage		±100 V
Lead-to-Case Voltage		±100 V
Continuous Forward Gate Current	30 mA	
Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	250 mW	400 mW
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds		300°C

NOTE 1: Derate linearly to 175°C free-air temperature at the rate of 1.67 mW/deg for each triode and 2.67 mW/deg for the total device.
*Indicates JEDEC registered data

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

individual triode characteristics (see note 2)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
I_{GSS}	Gate Reverse Current	$V_{GS} = -50$ V, $V_{DS} = 0$		−1	μA
		$V_{GS} = -30$ V, $V_{DS} = 0$		−0.25	nA
		$V_{GS} = -30$ V, $V_{DS} = 0$, $T_A = 150°C$		−250	nA
$V_{GS(off)}$	Gate-Source Cutoff Voltage	$V_{DS} = 15$ V, $I_D = 0.5$ nA	−0.5	−4.5	V
I_{DSS}	Zero-Gate-Voltage Drain Current	$V_{DS} = 15$ V, $V_{GS} = 0$	0.5	8	mA
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 kHz	1.5	6	mmho
$\|y_{os}\|$	Small-Signal Common-Source Output Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 kHz		25	μmho
C_{iss}	Small-Signal Common-Source Input Capacitance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 MHz		8	pF
C_{rss}	Small-Signal Common-Source Reverse Transfer Capacitance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 1 MHz		4	pF
$\|y_{fs}\|$	Small-Signal Common-Source Forward Transfer Admittance	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 100 MHz	1.5		mmho

triode matching characteristics

PARAMETER		TEST CONDITIONS	2N5045		2N5046		2N5047		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$\|I_{GSS1} - I_{GSS2}\|$	Gate-Reverse-Current Differential	$V_{GS} = -15$ V, $V_{DS} = 0$, $T_A = 100°C$		10		10		10	nA
$\|V_{GS1} - V_{GS2}\|$	Gate-Source-Voltage Differential	$V_{DS} = 15$ V, $I_D = 50$ μA		5		10		15	mV
		$V_{DS} = 15$ V, $I_D = 200$ μA		5		10		15	mV
$\|\Delta(V_{GS1}-V_{GS2})_{\Delta T_A}\|$	Gate-Source-Voltage-Differential Change with Temperature	$V_{DS} = 15$ V, $I_D = 200$ μA, $T_{A(1)} = 25°C$, $T_{A(2)} = -25°C$		5		10		15	mV
		$V_{DS} = 15$ V, $I_D = 200$ μA, $T_{A(1)} = 25°C$, $T_{A(2)} = 100°C$		5		10		15	mV
$\frac{I_{DSS1}}{I_{DSS2}}$	Zero-Gate-Voltage Drain Current Ratio	$V_{DS} = 15$ V, $V_{GS} = 0$, See Note 3	0.95	1	0.9	1	0.8	1	
$\frac{\|y_{fs}\|_1}{\|y_{fs}\|_2}$	Small-Signal Common-Source Forward Transfer Admittance Ratio	$V_{DS} = 15$ V, $I_D = 200$ μA, f = 1 kHz, See Note 3	0.95	1	0.9	1	0.8	1	
$\|y_{os}\|_1 - \|y_{os}\|_2$	Small-Signal Common-Source Output Admittance Differential	$V_{DS} = 15$ V, $I_D = 200$ μA, f = 1 kHz		1		2		3	μmho

*operating characteristics at 25°C free-air temperature

individual triode characteristics (see note 2)

PARAMETER		TEST CONDITIONS	2N5045 MAX	2N5046 MAX	UNIT
NF	Spot Noise Figure	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 10 Hz, $R_G = 1$ MΩ, Noise Bandwidth = 5 Hz	5	5	dB
V_n	Equivalent Input Noise Voltage	$V_{DS} = 15$ V, $V_{GS} = 0$, f = 10 Hz, Noise Bandwidth = 5 Hz	200	200	nV/Hz$^{1/2}$

NOTES: 2. The terminals of the triode not under test are open-circuited for the measurement of these characteristics.
3. The lower of the two characteristic readings is taken as the numerator.

*Indicates JEDEC registered data

TYPES 2N489 THRU 2N494, 2N489A THRU 2N494A, 2N489B THRU 2N494B
BULLETIN NO. DL-S 683190, OCTOBER 1962
REVISED MAY 1968

P-N GROWN SILICON UNIJUNCTION TRANSISTORS

Designed for Medium-Power Switching, Oscillator and Pulse Timing Circuits

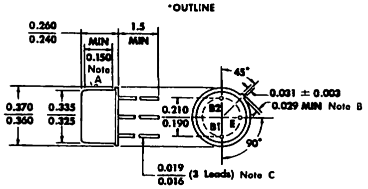
- **Highly Stable Negative Resistance and Firing Voltage**
- **Low Firing Current**
- **High Pulse Current Capabilities**
- **Simplified Circuit Design**

mechanical data

The transistors are hermetically sealed in a welded package with glass-to-metal seal between case and leads. Approximate weight is one gram.

*ALL LEADS INSULATED FROM CASE.

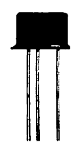
*OUTLINE



NOTES A. This zone is controlled for automatic handling. The variation in actual diameter within this zone shall not exceed 0.010.

B. Measured from max. diameter of the actual device.

C. The specified lead diameter applies in the zone between 0.050 and 0.250 from the base seat. Between 0.250 and 1.5 maximum of 0.021 diameter is held. Outside of these zones the lead diameter is not controlled.



DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Emitter-Base Reverse Voltage below 150°C Junction Temperature	−60 v
Interbase Voltage	See Note 1
RMS Emitter Current	70 ma
Peak Emitter Current below 150°C Junction Temperature	2 a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	450 mw
Total Device Dissipation at (or below) 25°C Free-Air Temperature, Stabilized (See Notes 3, 4)	600 mw
Operating Temperature Range	−65°C to 140°C
Operating Temperature Range, Stabilized (See Note 4)	−65°C to 175°C
Storage Temperature Range	−65°C to 175°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES 1. For maximum interbase voltage see Figure 1
2. Derate linearly to 140°C free-air temperature at the rate of 3.9 mw/°C.
3. Derate linearly to 175°C free-air temperature at the rate of 4.0 mw/°C.
4. Total interbase power dissipation must be limited by external circuit.

* Indicates JEDEC registered data.

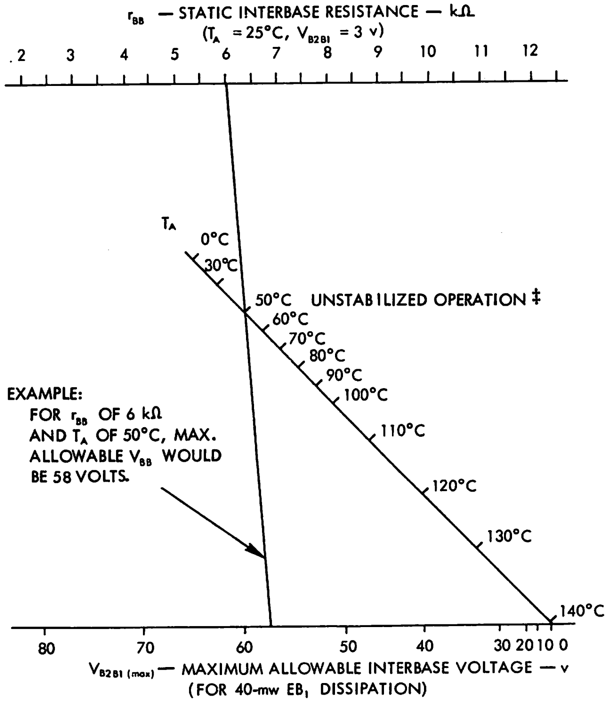
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N489 THRU 2N494, 2N489A THRU 2N494A, 2N489B THRU 2N494B
P-N GROWN SILICON UNIJUNCTION TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	PARENT SERIES MIN	PARENT SERIES MAX	A SERIES MIN	A SERIES MAX	B SERIES MIN	B SERIES MAX	UNIT
r_{BB}	Static Interbase Resistance	$V_{B2B1} = 3$ v, $I_E = 0$	2N489, 2N491, 2N493	4.7	6.8	4.7	6.8	4.7	6.8	kΩ
			2N490, 2N492, 2N494	6.2	9.1	6.2	9.1	6.2	9.1	kΩ
η	Intrinsic Standoff Ratio	$V_{B2B1} = 10$ v See Figure 5	2N489, 2N490	0.51	0.62	0.51	0.62	0.51	0.62	
			2N491, 2N492	0.56	0.68	0.56	0.68	0.56	0.68	
			2N493, 2N494	0.62	0.75	0.62	0.75	0.62	0.75	
$I_{B2(mod)}$	Modulated Interbase Current	$V_{B2B1} = 10$ v, $I_E = 50$ ma	All Types	6.8	22	6.8	22	6.8	22	ma
I_{EB2O}	Emitter Reverse Current	$V_{B2E} = 60$ v, $I_{B1} = 0$	All Types		−2		−2		−2	μa
		$V_{B2E} = 30$ v, $I_{B1} = 0$	All Types						− 0.2	μa
		$V_{B2E} = 10$ v, $I_{B1} = 0$ $T_J = 150°C$	All Types		− 20		− 20		− 20	μa
I_P	Peak-Point Emitter Current	$V_{B2B1} = 25$ v	All Types		12		12		6	μa
$V_{EB1(sat)}$	Emitter Base-One Saturation Voltage	$V_{B2B1} = 10$ v, $I_E = 50$ ma	2N489, 2N490		5.0		4.0		4.0	v
			2N491, 2N492		5.0		4.3		4.3	v
			2N493, 2N494		5.0		4.6		4.6	v
I_V	Valley-Point Emitter Current	$V_{B2B1} = 20$ v, $R_{B2} = 100\ \Omega$	All Types	8		8		8		ma
V_{OB1}	Base-One Peak Pulse Voltage	$V_1 = 20$ v $R_{B1} = 20\ \Omega$ See Figure 4	All Types			3.0		3.0		v

FIGURE 1—INTERBASE VOLTAGE RATING CURVE



‡For stabilized operation multiply temperature shown by 1.25 (i.e., 175/140)

*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION

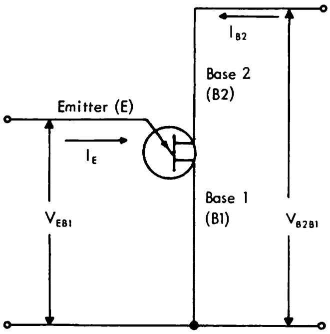


FIGURE 2 — UNIJUNCTION TRANSISTOR NOMENCLATURE

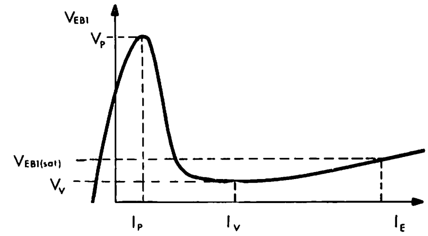


FIGURE 3 — GENERAL STATIC EMITTER CHARACTERISTIC CURVE

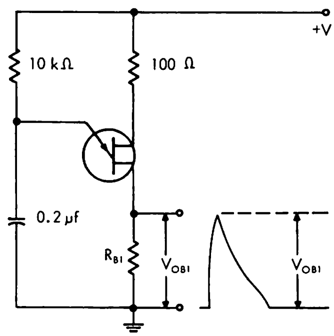


FIGURE 4 — V_{OB1} TEST CIRCUIT

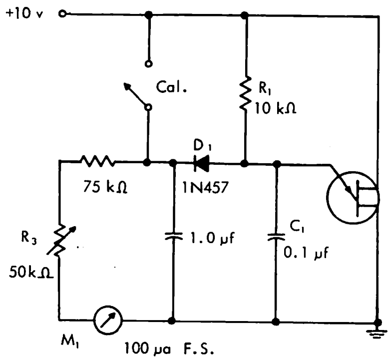


FIGURE 5 — TEST CIRCUIT FOR INTRINSIC STANDOFF RATIO (η)

TEST CIRCUIT FOR INTRINSIC STANDOFF RATIO

η — Intrinsic Standoff Ratio — This parameter is defined in terms of the peak-point voltage, V_P, by means of the equation: $V_P = \eta\, V_{B2\text{-}B1} + V_F$, where V_F is about 0.56 v at 25°C and decreases with temperature at about 3 mv/deg.

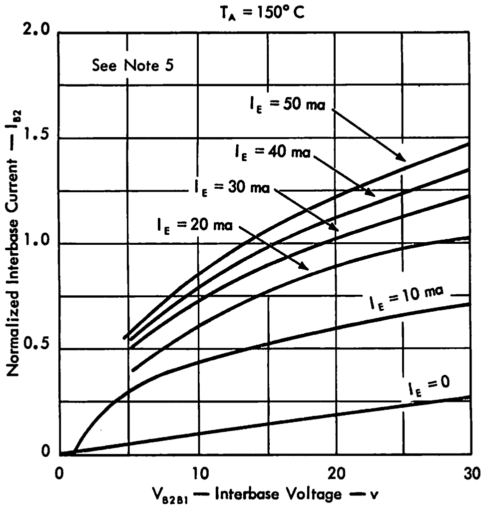
The circuit used to measure η is shown in the figure. In this circuit, R_1, C_1, and the unijunction transistor form a relaxation oscillator, and the remainder of the circuit serves as a peak-voltage detector with the diode D_1 automatically subtracting the voltage V_F. To use the circuit, the "cal" button is pushed, and R_3 is adjusted to make the current meter M_1 read full scale. The "cal" button then is released and the value of η is read directly from the meter, with $\eta = 1$ corresponding to full-scale deflection of 100 μa.

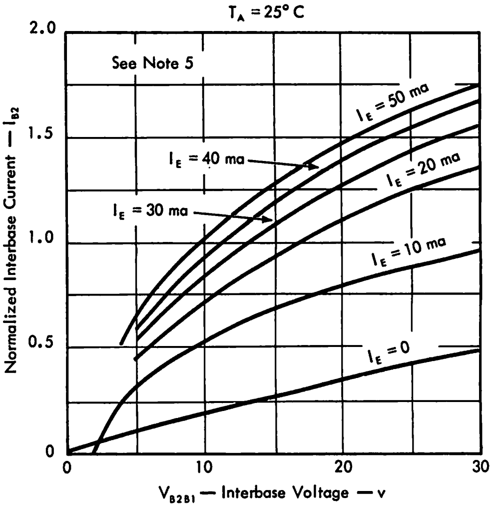
TYPES 2N489 THRU 2N494, 2N489A THRU 2N494A, 2N489B THRU 2N494B
P-N GROWN SILICON UNIJUNCTION TRANSISTORS

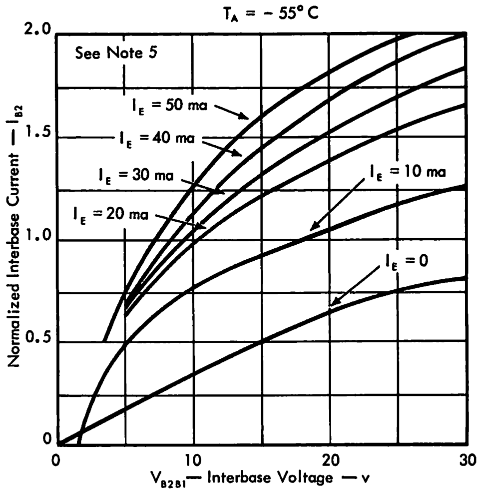
TYPICAL CHARACTERISTICS

NORMALIZED INTERBASE CHARACTERISTICS

Normalized to Value at $V_{B2B1} = 10$ v, $I_E = 50$ ma, $T_A = 25°C$.



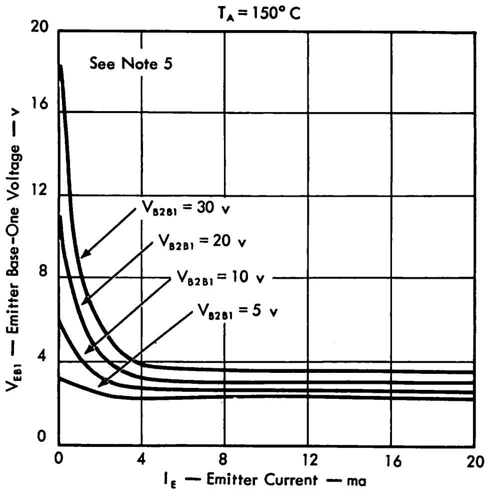


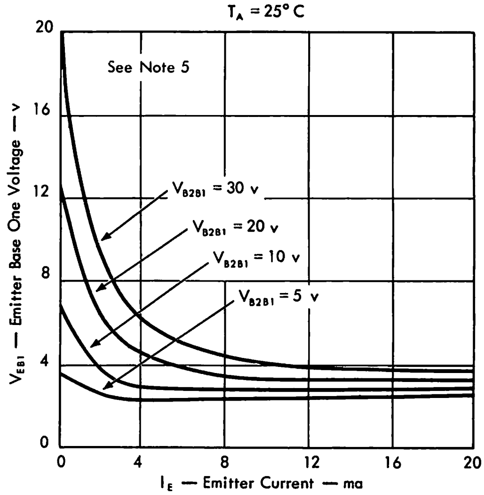


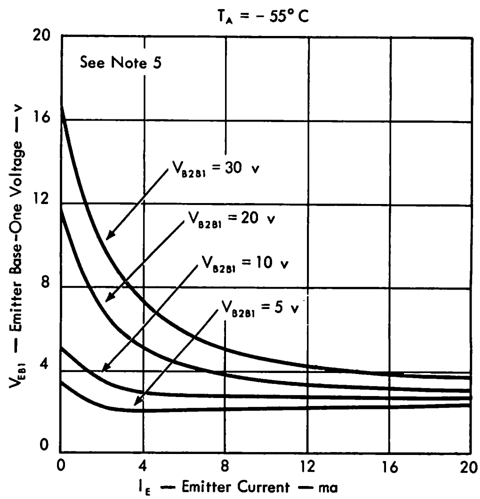
NOTE 5: This parameter is measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

STATIC EMITTER CHARACTERISTICS

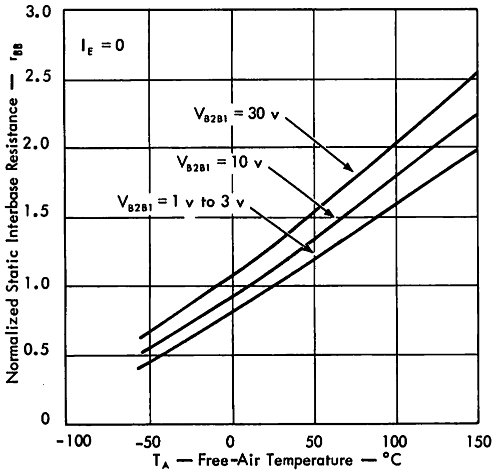


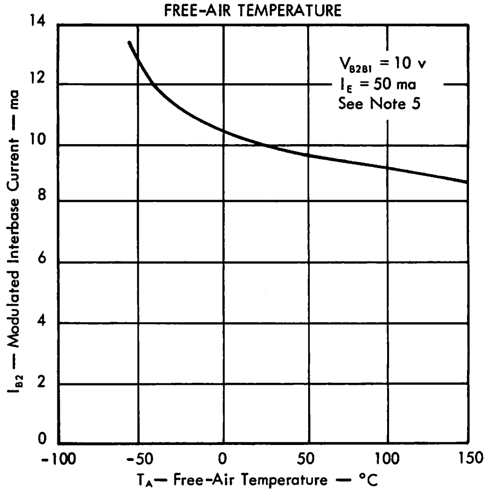


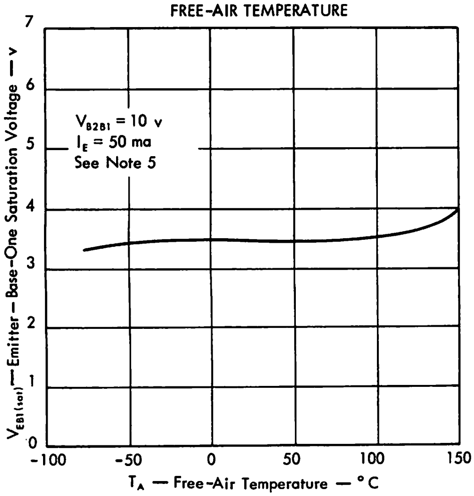


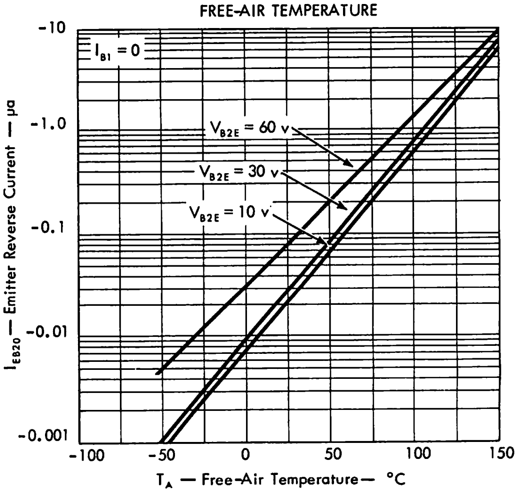
NOTE 5: This parameter is measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS





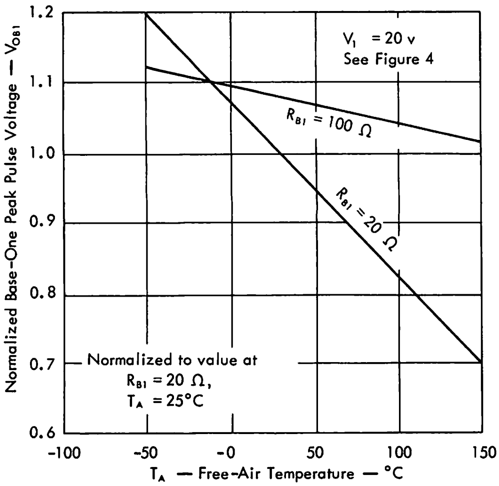




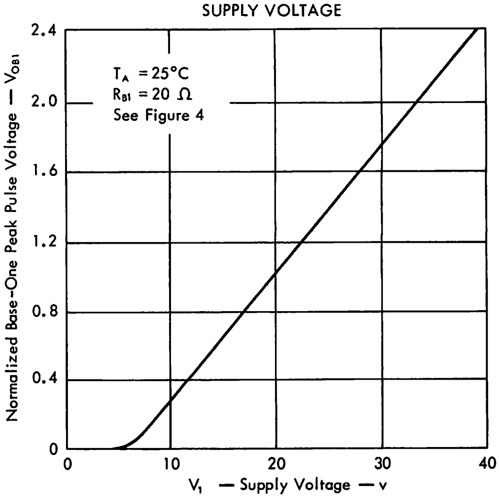
NOTE 5: This parameter is measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

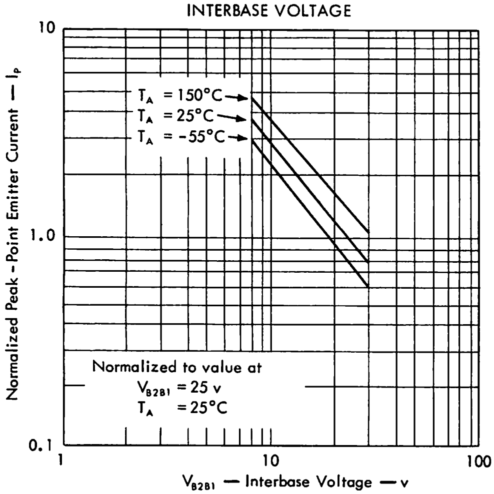
NORMALIZED BASE-ONE PEAK PULSE VOLTAGE
vs
FREE-AIR TEMPERATURE



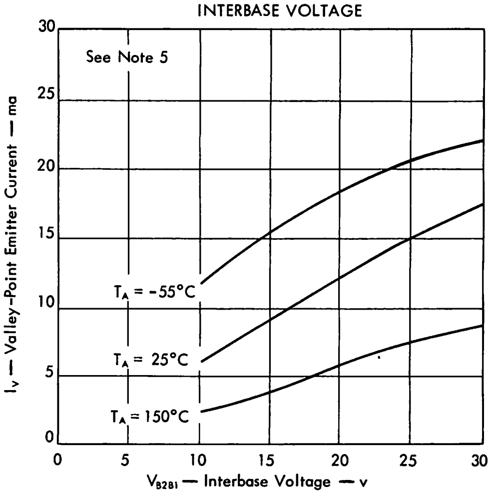
NORMALIZED BASE-ONE PEAK PULSE VOLTAGE
vs
SUPPLY VOLTAGE



NORMALIZED PEAK-POINT EMITTER CURRENT,
vs
INTERBASE VOLTAGE



VALLEY-POINT EMITTER CURRENT
vs
INTERBASE VOLTAGE

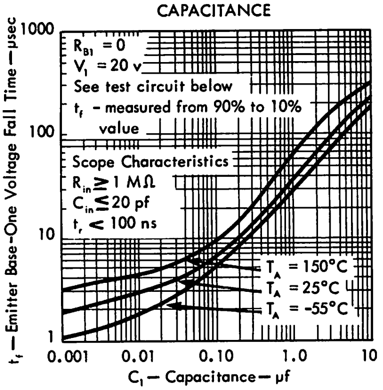


NOTE 5: This parameter is measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

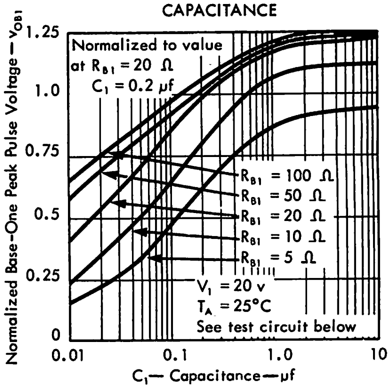
TYPES 2N489 THRU 2N494, 2N489A THRU 2N494A, 2N489B THRU 2N494B
P-N GROWN SILICON UNIJUNCTION TRANSISTORS

TYPICAL CHARACTERISTICS

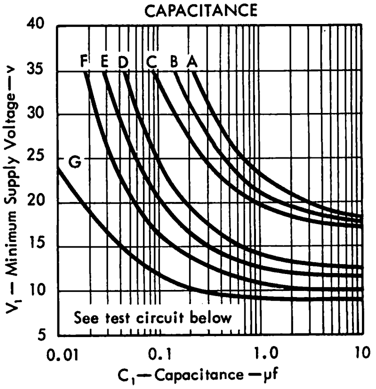
EMITTER BASE-ONE VOLTAGE FALL TIME
vs
CAPACITANCE



NORMALIZED BASE-ONE PEAK PULSE VOLTAGE
vs
CAPACITANCE

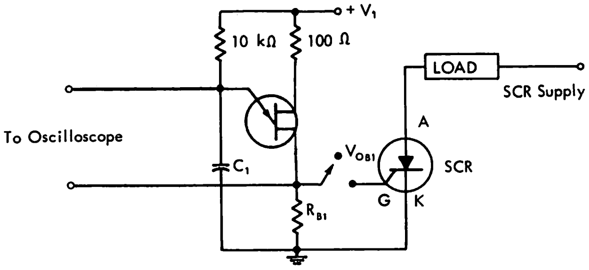


MINIMUM SUPPLY VOLTAGE TO TRIGGER SCR
vs
CAPACITANCE



CURVE	SCR TYPE	R_{B1}
A	High-Current SCR's	27 Ω
B	[I_{GT} up to 200 ma]	47 Ω
C	[V_{GT} up to 3.5 v]	Pulse Eng PE 2231 †
D	2N681, A, 2N1842,	27 Ω
E	A, B, TI145A0	47 Ω
F	[I_{GT} up to 150 ma; V_{GT} up to 3 v]	Sprague 31Z204 †
E	2N1595, 2N1600	27 Ω
	2N1770, 2N1929	
F	[I_{GT} up to 50 ma]	47 Ω
G	[V_{GT} up to 3 v]	Sprague 31Z204 †

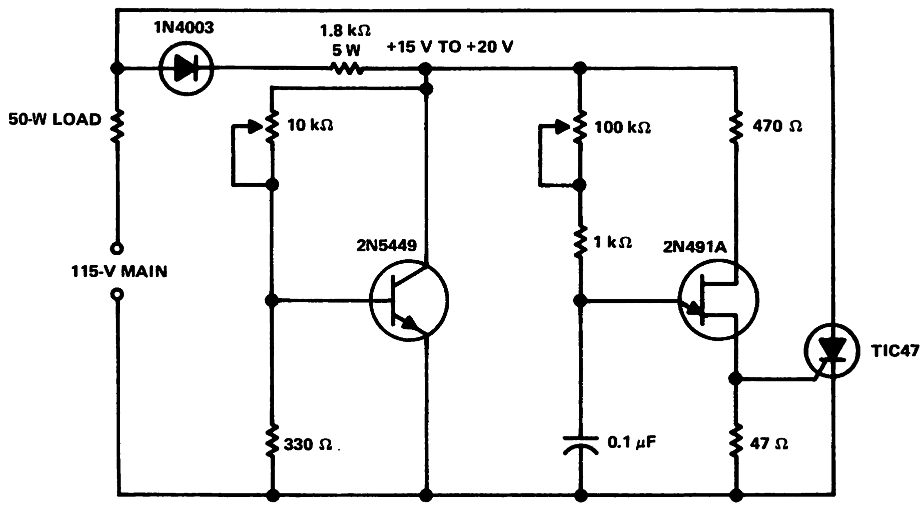
† or equivalent



TEST CIRCUIT

TYPICAL CHARACTERISTICS

A-C PHASE CONTROL SYSTEM USING 2N491A UNIJUNCTION

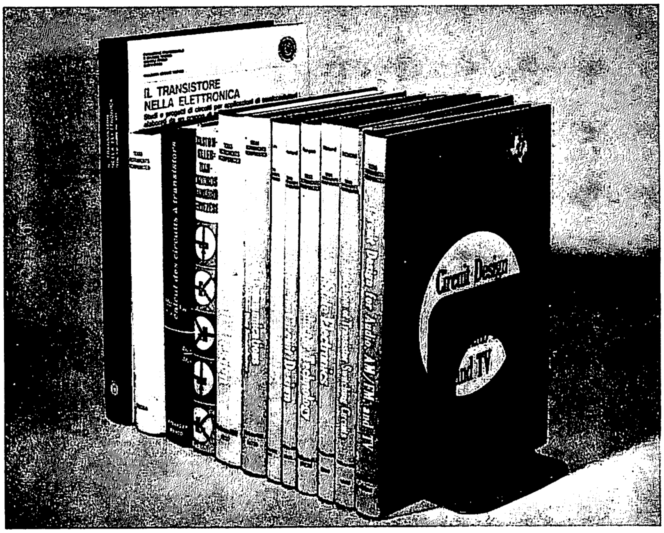


CAI7111

CIRCUIT FEATURES

- Unijunction provides accurate and smooth control.
- Half-wave operation conducts from 10° to 170° of waveform.
- 2N5449 acts as zener and synchronizes the 2N491A to line frequency.
- Circuit used as lamp dimmer, relay driver, motor control, or small heater control.

TI Microlibrary Books for Creative Circuit Designers



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P-N GROWN SILICON UNIJUNCTION TRANSISTORS

TYPES 2N1671, 2N1671A, 2N1671B, 2N2160
BULLETIN NO. DL-S 683189, OCTOBER 1962
REVISED MAY 1968

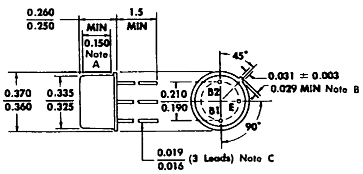
Designed for Medium-Power Switching, Oscillator and Pulse Timing Circuits

- **Highly Stable Negative Resistance and Firing Voltage**
- **Low Firing Current**
- **High Pulse Current Capabilities**
- **Simplified Circuit Design**

mechanical data

The transistors are hermetically sealed in a welded package with glass-to-metal seal between case and leads. Approximate weight is one gram.

*ALL LEADS INSULATED FROM CASE.



NOTES A. This zone is controlled for automatic handling. The variation in actual diameter within this zone shall not exceed 0.010.

B. Measured from max. diameter of the actual device.

C. The specified lead diameter applies in the zone between 0.050 and 0.250 from the base seat. Between 0.250 and 1.5 maximum of 0.021 diameter is held. Outside of these zones the lead diameter is not controlled.

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N1671 2N1671A 2N1671B	2N2160
Emitter-Base Reverse Voltage	−30 v	
Emitter-Base Reverse Voltage below 140°C Junction Temperature		−30 v
Interbase Voltage	35 v	35 v
RMS Emitter Current	50 ma	
DC Emitter Current		70 ma
Peak Emitter Current (See Note 1)	2 a	
Peak Emitter Current below 140°C Junction Temperature		2 a
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Notes 2 & 3)	450 mw	450 mw
Operating Temperature Range (See Note 3)	−65°C to 140°C	
Storage Temperature Range (See Note 4)	−65°C to 150°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C	260°C

NOTES: 1. Capacitor discharge — 10 μf or less, 30 volts or less — total interbase power dissipation must be limited by external circuitry.
2. Derate linearly to 140°C free-air temperature at the rate of 3.9 mw/°C. (2N1671 series only, thermal resistance to case = 0.16°C/mw.)
3. Texas Instruments guarantees a maximum operating temperature of 175°C free-air. Derate linearly at the rate of 3 mw/°C.
4. Texas Instruments guarantees a maximum storage temperature of 175°C.

*Indicates JEDEC registered data

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TYPES 2N1671, 2N1671A, 2N1671B, 2N2160 P-N GROWN SILICON UNIJUNCTION TRANSISTORS

*electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N1671 MIN	2N1671 MAX	2N1671A MIN	2N1671A MAX	2N1671B MIN	2N1671B MAX	2N2160 MIN	2N2160 MAX	UNIT
r_{BB}	Static Interbase Resistance	$V_{B2B1} = 3$ v, $I_E = 0$	4.7	9.1	4.7	9.1	4.7	9.1	4.0	12	kΩ
η	Intrinsic Standoff Ratio	$V_{B2B1} = 10$ v, See Figure 4	0.47	0.62	0.47	0.62	0.47	0.62	0.47	0.80	
$I_{B2(mod)}$	Modulated Interbase Current	$V_{B2B1} = 10$ v, $I_E = 50$ ma	6.8	22	6.8	22	6.8	22	6.8	30	ma
I_{EB2O}	Emitter Reverse Current	$V_{B2E} = 30$ v, $I_{B1} = 0$		−12		−12		−0.2		−12	μa
I_P	Peak-Point Emitter Current	$V_{B2B1} = 25$ v		25		25		6		25	μa
$V_{EB1(sat)}$	Emitter Saturation Voltage	$V_{B2B1} = 10$ v, $I_E = 50$ ma		5		5		5			v
I_V	Valley-Point Emitter Current	$V_{B2B1} = 20$ v, $R_{B2} = 100\ \Omega$	8		8		8		8		ma
V_{OB1}	Base-One Peak Pulse Voltage	$V_1 = 20$ v, $R_{B1} = 20\ \Omega$, See Figure 3			3		3		3		v

*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION

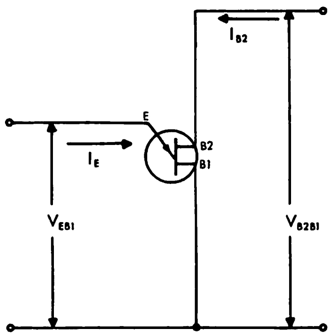


FIGURE 1—UNIJUNCTION TRANSISTOR NOMENCLATURE

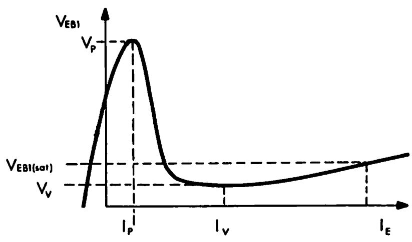


FIGURE 2—GENERAL STATIC EMITTER CHARACTERISTIC CURVE

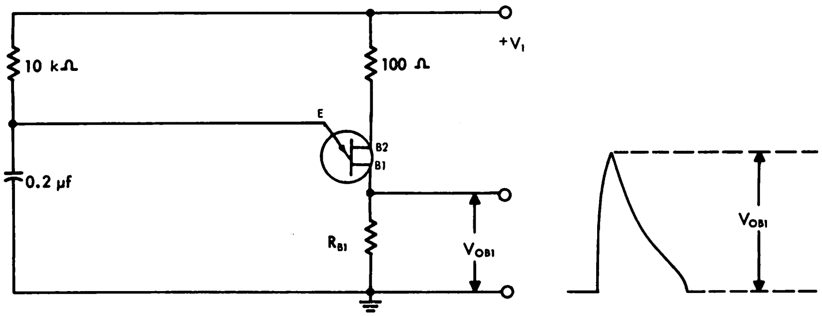
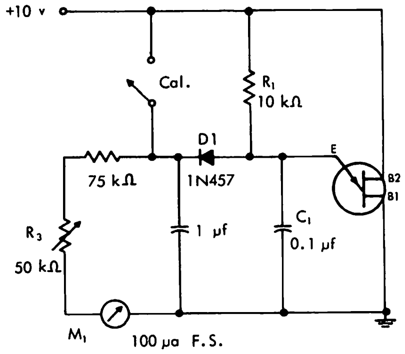


FIGURE 3 — V_{OB1} TEST CIRCUIT

PARAMETER MEASUREMENT INFORMATION

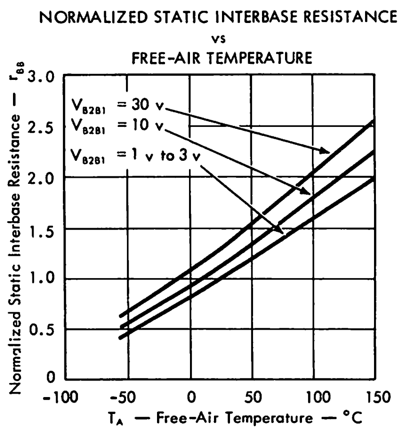


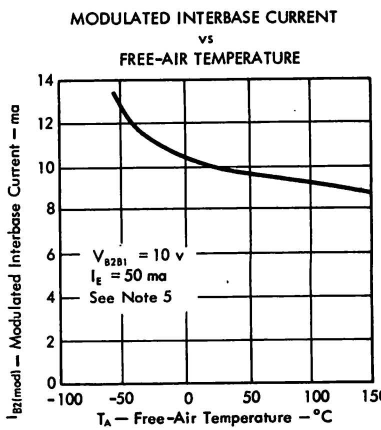
η — Intrinsic Standoff Ratio — This parameter is defined in terms of the peak-point voltage, V_P, by means of the equation: $V_P = \eta V_{B2\text{-}B1} + V_F$, where V_F is about 0.56 v at 25°C and decreases with temperature at about 3 mv/deg.

The circuit used to measure η is shown in the figure. In this circuit, R_1, C_1, and the unijunction transistor form a relaxation oscillator, and the remainder of the circuit serves as a peak-voltage detector with the diode D_1 automatically subtracting the voltage V_F. To use the circuit, the "cal" button is pushed, and R_3 is adjusted to make the current meter M_1 read full scale. The "cal" button then is released and the value of η is read directly from the meter, with $\eta = 1$ corresponding to full-scale deflection of 100 μa.

FIGURE 4—TEST CIRCUIT FOR INTRINSIC STANDOFF RATIO (η)

TYPICAL CHARACTERISTICS

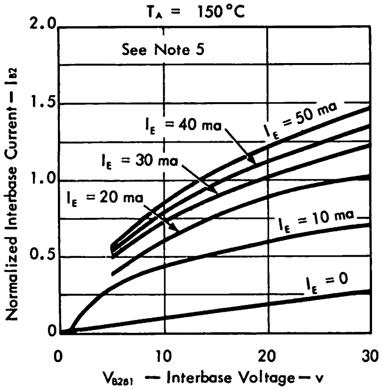


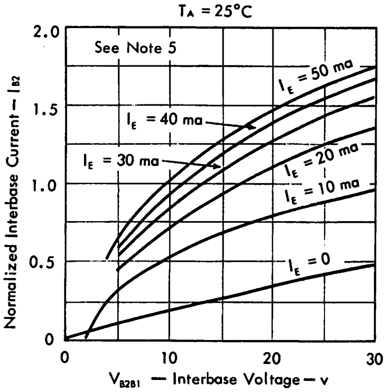


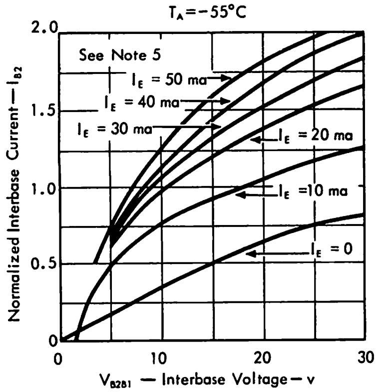
NOTE 5: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS

NORMALIZED INTERBASE CHARACTERISTICS†

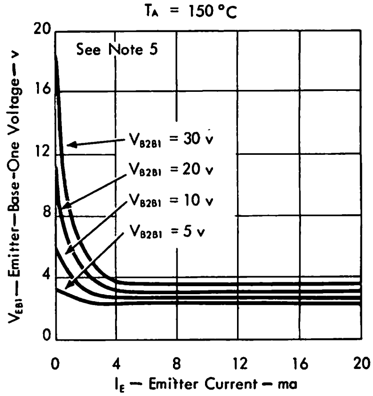


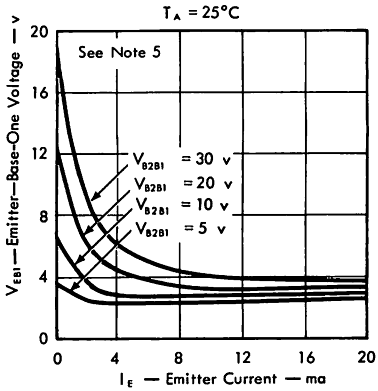


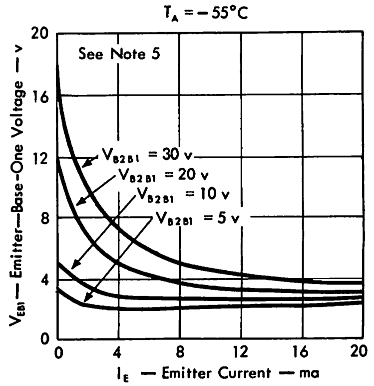


† Normalized to value at $V_{B2B1} = 10$ v, $I_E = 50$ ma, $T_A = 25°C$.

STATIC EMITTER CHARACTERISTICS



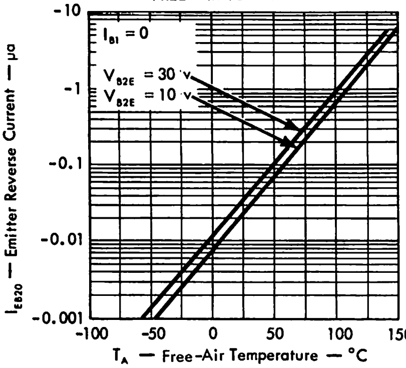




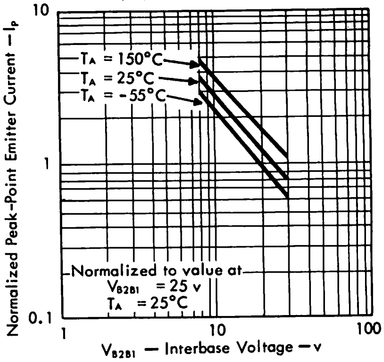
NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

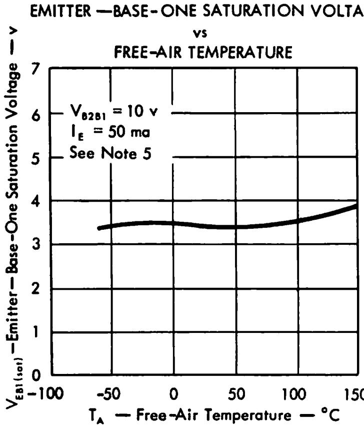
EMITTER REVERSE CURRENT vs FREE-AIR TEMPERATURE



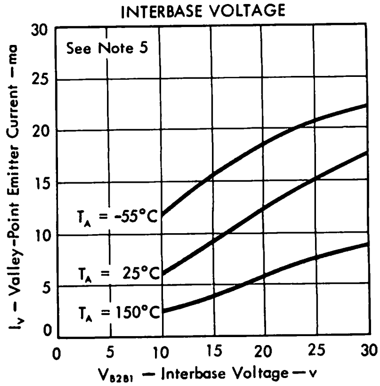
NORMALIZED PEAK-POINT EMITTER CURRENT vs INTERBASE VOLTAGE



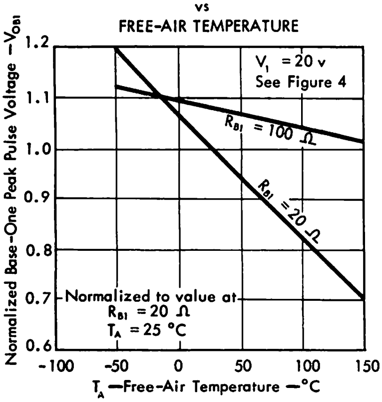
EMITTER—BASE-ONE SATURATION VOLTAGE vs FREE-AIR TEMPERATURE



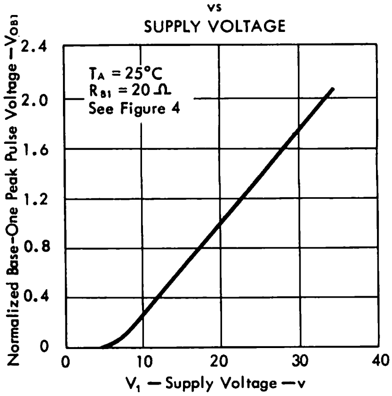
VALLEY-POINT EMITTER CURRENT vs INTERBASE VOLTAGE



NORMALIZED BASE-ONE PEAK PULSE VOLTAGE vs FREE-AIR TEMPERATURE

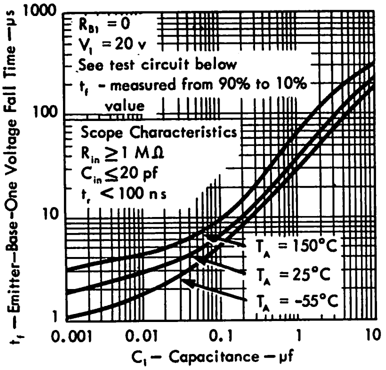


NORMALIZED BASE-ONE PEAK PULSE VOLTAGE vs SUPPLY VOLTAGE

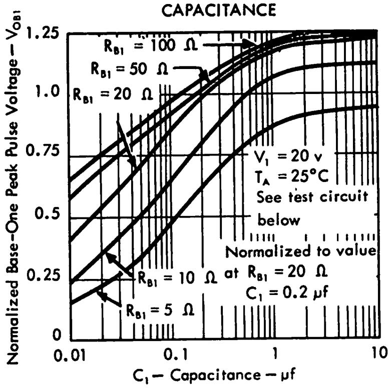


TYPICAL APPLICATION DATA

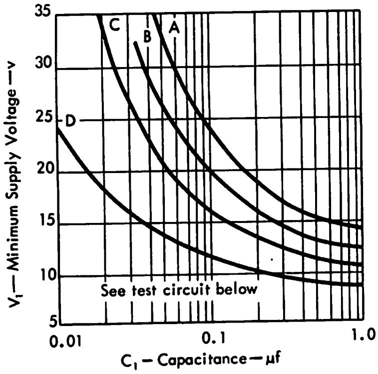
EMITTER — BASE-ONE VOLTAGE FALL TIME
vs
CAPACITANCE



NORMALIZED BASE-ONE PEAK PULSE VOLTAGE
vs
CAPACITANCE

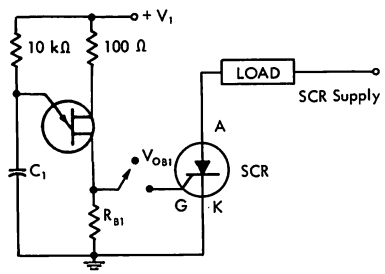


MINIMUM SUPPLY VOLTAGE TO TRIGGER SCR
vs
CAPACITANCE



CURVE	SCR TYPE	R_{B1}
A	2N681, A, 2N1842, TI145A0 [I_{GT} up to 150 ma, V_{GT} up to 3 v]	27 Ω
B		47 Ω
C		Sprague 31Z204†
B	2N1595, 2N1600 [I_{GT} up to 50 ma, V_{GT} up to 3 v]	27 Ω
C		47 Ω
D		Sprague 31Z204†

† or equivalent



TEST CIRCUIT

TYPES 2N3980, 2N4947 THRU 2N4949
BULLETIN NO. DL-S 679565, MARCH 1967
REPLACES BULLETIN NO. DL-S 658008, REVISED OCTOBER 1966

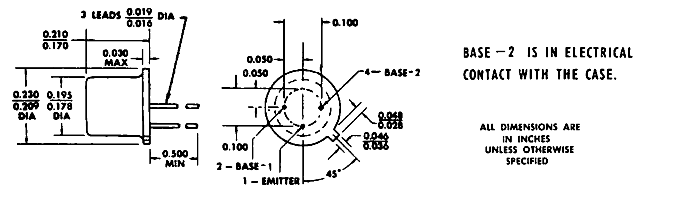
PLANAR UNIJUNCTION TRANSISTORS SPECIFICALLY CHARACTERIZED FOR A WIDE RANGE OF MILITARY, SPACE, AND INDUSTRIAL APPLICATIONS:

2N3980 for General-Purpose UJT Applications
2N4947 for High-Frequency Relaxation-Oscillator Circuits
2N4948 for Thyristor (SCR) Trigger Circuits
2N4949 for Long-Time-Delay Circuits

- **Planar Process Ensures Extremely Low Leakage, High Performance for Low Driving Currents, and Greatly Improved Reliability**

*mechanical data

Package outline is same as JEDEC TO-18 except for lead position. All TO-18 registration notes also apply to this outline.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Emitter—Base-Two Reverse Voltage	–30 V
Interbase Voltage	See Note 1
Continuous Emitter Current	50 mA
Peak Emitter Current (See Note 2)	1 A
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	360 mW
Storage Temperature Range	–65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. Interbase voltage is limited solely by power dissipation, $V_{B2\text{-}B1} = \sqrt{r_{BB} \cdot P_T}$

2. This value applies for a capacitor discharge through the emitter—base-one diode. Current must fall to 0.37 A within 3 ms and pulse-repetition rate must not exceed 10 pps.

3. Derate linearly to 175°C free-air temperature at the rate of 2.4 mW/deg.

*Indicates JEDEC registered data

TYPES 2N3980, 2N4947 THRU 2N4949
P-N PLANAR UNIJUNCTION SILICON TRANSISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3980 MIN	2N3980 MAX	2N4947 MIN	2N4947 MAX	2N4948 MIN	2N4948 MAX	2N4949 MIN	2N4949 MAX	UNIT
r_{BB}	Static Interbase Resistance	$V_{B2\text{-}B1} = 3$ V, $I_E = 0$	4	8	4	9.1	4	12	4	12	kΩ
α_{rBB}	Interbase Resistance Temperature Coefficient	$V_{B2\text{-}B1} = 3$ V, $I_E = 0$, $T_A = -65°C$ to 100°C, See Note 4	0.4	0.9	0.1	0.9	0.1	0.9	0.1	0.9	%/deg
η	Intrinsic Standoff Ratio	$V_{B2\text{-}B1} = 10$ V, See Figure 1	0.68	0.82	0.51	0.69	0.55	0.82	0.74	0.86	
$I_{B2(mod)}$	Modulated Interbase Current	$V_{B2\text{-}B1} = 10$ V, $I_E = 50$ mA, See Note 5	12		12		12		12		mA
I_{EB2O}	Emitter Reverse Current	$V_{EB2} = -30$ V, $I_{B1} = 0$		−10		−10		−10		−10	nA
		$V_{EB2} = -30$ V, $I_{B1} = 0$, $T_A = 125°C$		−1		−1		−1		−1	μA
I_P	Peak-Point Emitter Current	$V_{B2\text{-}B1} = 25$ V		2		2		2		1	μA
$V_{EB1(sat)}$	Emitter — Base-One Saturation Voltage	$V_{B2\text{-}B1} = 10$ V, $I_E = 50$ mA, See Note 5		3		3		3		3	V
I_V	Valley-Point Emitter Current	$V_{B2\text{-}B1} = 20$ V	1	10	4		2		2		mA
V_{OB1}	Base-One Peak Pulse Voltage	See Figure 2	6		3		6		3		V

NOTES: 4. Temperature coefficient α_{rBB} is determined by the following formula:

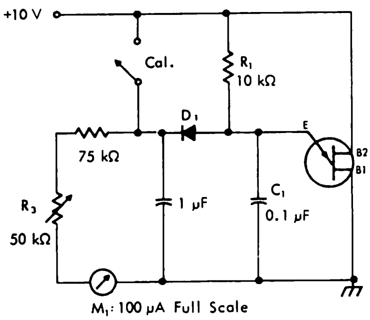
$$\alpha_{rBB} = \left[\frac{(r_{BB} @ 100°C) - (r_{BB} @ -65°C)}{(r_{BB} @ 25°C)}\right] \frac{100\%}{165 \text{ deg}}$$

To obtain r_{BB} for a given temperature $T_{A(2)}$, use the following formula:

$$r_{BB(2)} = [r_{BB} @ 25°C]\,[1 + (\alpha_{rBB}/100\%)(T_{A(2)} - 25°C)]$$

5. These parameters are measured using pulse techniques. $t_p = 300$ μs, duty cycle ≤ 2%.

*PARAMETER MEASUREMENT INFORMATION



η — Intrinsic Standoff Ratio — This parameter is defined in terms of the peak-point voltage, V_p, by means of the equation: $V_p = \eta V_{B2B1} + V_F$, where V_F is about 0.56 volt at 25°C and decreases with temperature at about 3 millivolts/deg.

The circuit used to measure η is shown in the figure. In this circuit, R_1, C_1 and the unijunction transistor form a relaxation oscillator, and the remainder of the circuit serves as a peak-voltage detector with the diode D_1 automatically subtracting the voltage V_F. To use the circuit, the "cal" button is pushed, and R_3 is adjusted to make the current meter M_1 read full scale. The "cal" button then is released and the value of η is read directly from the meter, with $\eta = 1$ corresponding to full-scale deflection of 100 μA.

D_1: 1N457, or equivalent, with the following characteristics:
$V_F = 0.565$ V at $I_F = 50$ μA,
$I_R \leq 2$ μA at $V_R = 20$ V

FIGURE 1 — TEST CIRCUIT FOR INTRINSIC STANDOFF RATIO (η)

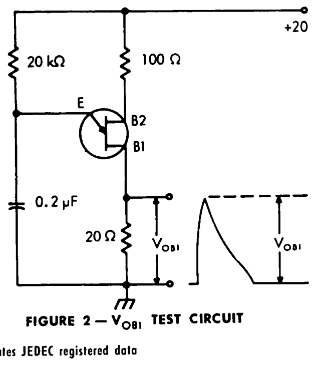


FIGURE 2 — V_{OB1} TEST CIRCUIT

EMITTER—BASE-ONE VOLTAGE
vs
EMITTER CURRENT

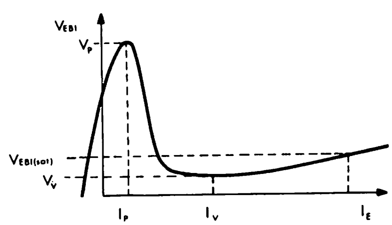


FIGURE 3 — GENERAL STATIC EMITTER CHARACTERISTIC CURVE

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

2N4947, 2N4948, 2N4949

STATIC INTERBASE RESISTANCE
vs
FREE-AIR TEMPERATURE

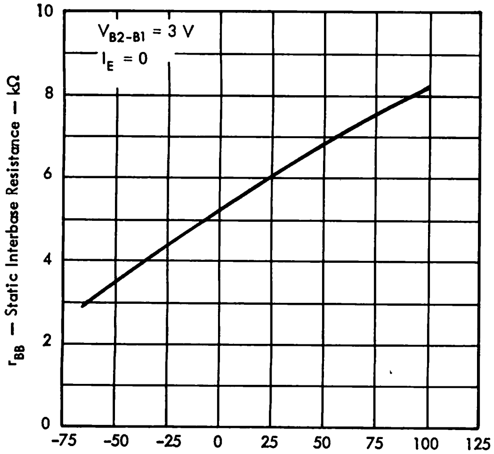


FIGURE 4

EMITTER REVERSE CURRENT
vs
FREE-AIR TEMPERATURE

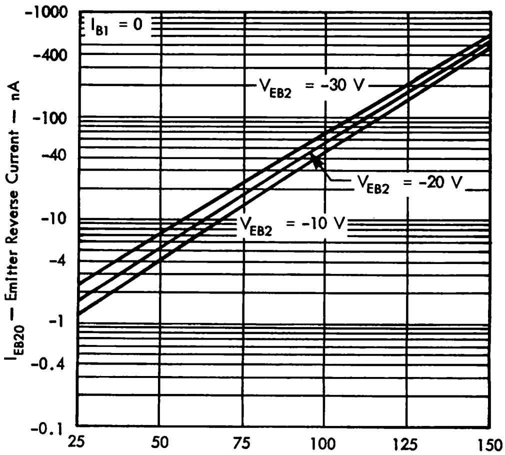


FIGURE 5

2N3980, 2N4948

BASE-ONE PEAK PULSE VOLTAGE
vs
FREE-AIR TEMPERATURE

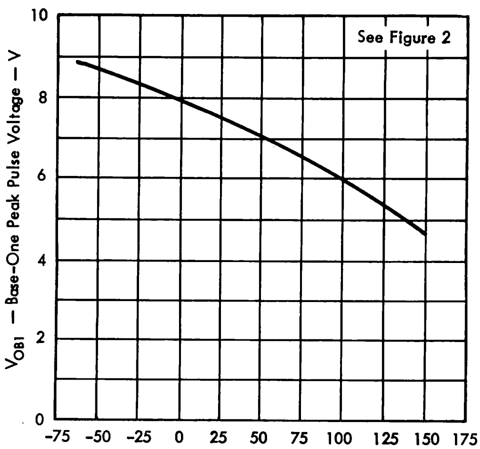


FIGURE 6

TYPICAL CHARACTERISTICS

MODULATED INTERBASE CURRENT
vs
INTERBASE VOLTAGE

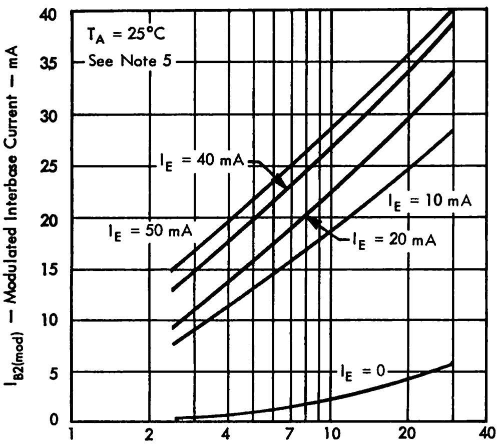


FIGURE 7

MODULATED INTERBASE CURRENT
vs
FREE-AIR TEMPERATURE

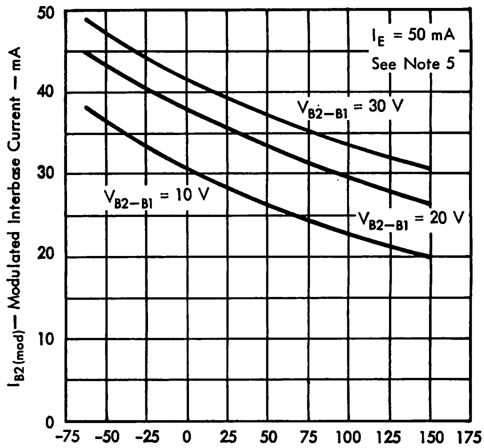


FIGURE 8

2N4949
PEAK-POINT EMITTER CURRENT
vs
FREE-AIR TEMPERATURE

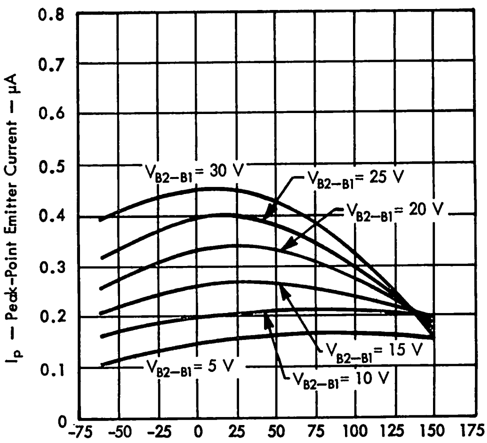


FIGURE 9

NOTE 5: These parameters are measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS

EMITTER—BASE-ONE VOLTAGE
vs
EMITTER CURRENT

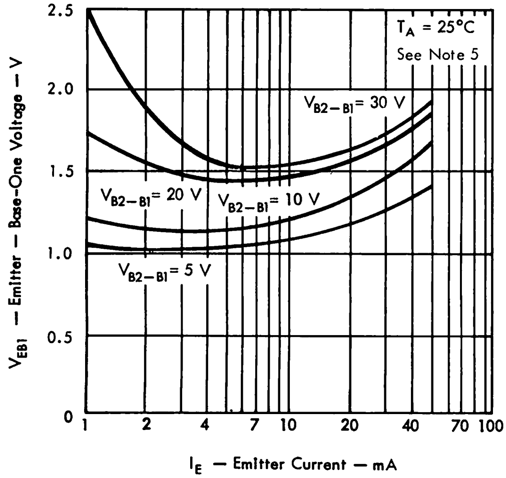


FIGURE 10

EMITTER — BASE-ONE SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE

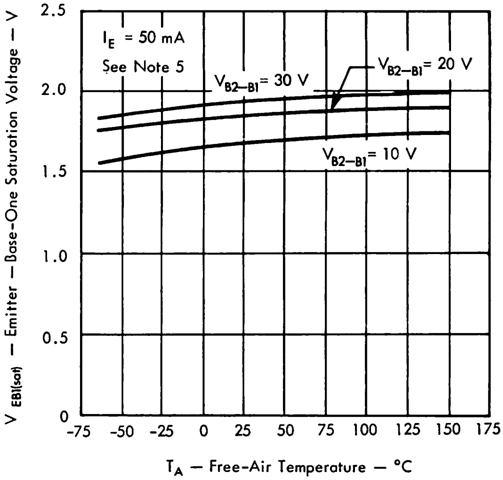


FIGURE 11

2N4947
VALLEY-POINT EMITTER CURRENT
vs
FREE-AIR TEMPERATURE

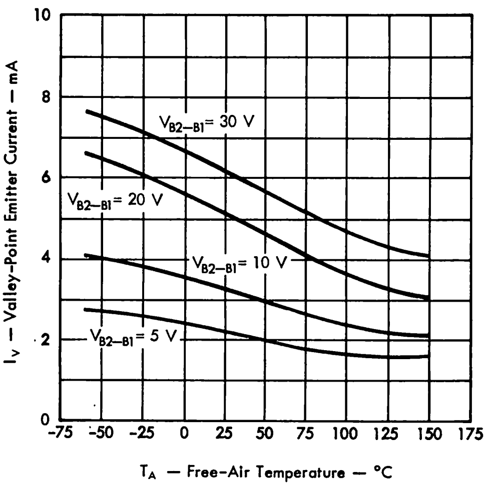
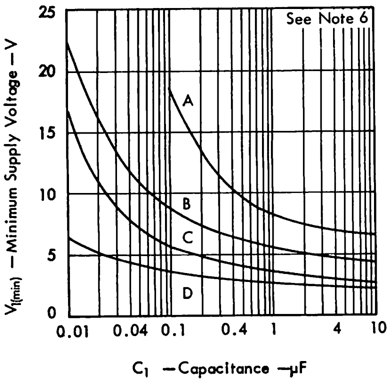


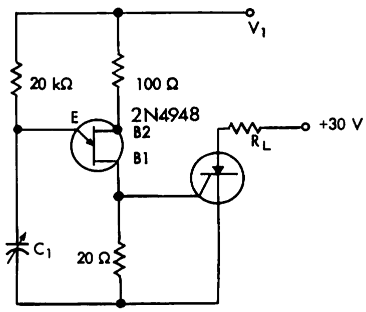
FIGURE 12

NOTE 5: These parameters are measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

TYPICAL CHARACTERISTICS

TYPICAL MINIMUM SUPPLY VOLTAGE TO TRIGGER THYRISTOR
vs
CAPACITANCE





INDEX OF THYRISTOR TYPES

CURVE	THYRISTOR TYPES	R_L
A	TI3037-42, 2N3936-40	35 Ω
B	2N681-88, 2N681A-89A, 2N1842B-50B	70 Ω
C	TI145A0-A4, 2N1595-99, TI40A0-A5, 2N1600-04, 2N1770-77, 2N2653, TI3010, TIC28-31	70 Ω
D	2N3001-08, 2N877-81, 2N885-88, 2N2687-90, 2N3555-62, TIC44-47	70 Ω

FIGURE 13 — OPERATING INFORMATION (2N4948)

NOTE 6: This chart shows typical observed values of minimum base-two supply voltage required to trigger individual thyristors of the types indicated.

TYPES 2N4891 THRU 2N4894
BULLETIN NO. DL-S 689776, JANUARY 1967
REVISED MAY 1968

PLANAR UNIJUNCTION SILECT† TRANSISTORS SPECIFICALLY CHARACTERIZED FOR A WIDE RANGE OF MILITARY, SPACE AND INDUSTRIAL APPLICATIONS:

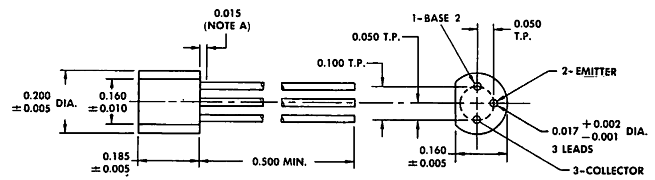
2N4891 for General Purpose UJT Applications (Replaces TIS43)
2N4892 for High-Frequency Relaxation-Oscillator Circuits
2N4893 for Thyristor (SCR) Trigger Circuits
2N4894 for Long-Time-Delay Circuits

- **Planar Process Provides Extremely Low Leakage, High Performance at Low Driving Currents, and Greatly Improved Reliability**
- **Rugged, One-Piece Construction Features Standard 100-mil TO-18 Pin-Circle**

mechanical data

These transistors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process‡ developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The transistors are insensitive to light.

*CASE OUTLINE



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Emitter—Base-Two Reverse Voltage	−30 V
Interbase Voltage	See Note 1
Continuous Emitter Current	50 mA
Peak Emitter Current (See Note 2)	1 A
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	360 mW
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. Interbase voltage is limited solely by power dissipation, $V_{B2-B1} = \sqrt{r_{BB} \cdot P_T}$.
2. This values applies for a capacitor discharge through the emitter—base-one diode. Current must fall to 0.37 A within 3 ms and pulse-repetition rate must not exceed 10 pps.
3. Derate linearly to 150°C free-air temperature at the rate of 2.88 mW/deg.

*Indicates JEDEC registered data
†Trademark of Texas Instruments
‡Patent Pending

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N4891 THRU 2N4894
P-N PLANAR UNIJUNCTION SILICON TRANSISTORS

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

	PARAMETER	TEST CONDITIONS	2N4891 MIN	2N4891 MAX	2N4892 MIN	2N4892 MAX	2N4893 MIN	2N4893 MAX	2N4894 MIN	2N4894 MAX	UNIT
r_{BB}	Static Interbase Resistance	$V_{B2\text{-}B1} = 3$ V, $I_E = 0$	4	9.1	4	9.1	4	12	4	12	kΩ
α_{rBB}	Interbase Resistance Temperature Coefficient	$V_{B2\text{-}B1} = 3$ V, $I_E = 0$, $T_A = -55°C$ to $100°C$, See Note 4	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	%/deg
η	Intrinsic Standoff Ratio	$V_{B2\text{-}B1} = 10$ V, See Figure 1	0.55	0.82	0.51	0.69	0.55	0.82	0.74	0.86	
$I_{B2(mod)}$	Modulated Interbase Current	$V_{B2\text{-}B1} = 10$ V, $I_E = 50$ mA, See Note 5	10		10		10		10		mA
I_{EB2O}	Emitter Reverse Current	$V_{EB2} = -30$ V, $I_{B1} = 0$		−10		−10		−10		−10	nA
I_P	Peak-Point Emitter Current	$V_{B2\text{-}B1} = 25$ V		5		2		2		1	μA
$V_{EB1(sat)}$	Emitter – Base-One Saturation Voltage	$V_{B2\text{-}B1} = 10$ V, $I_E = 50$ mA, See Note 5		4		4		4		4	V
I_V	Valley-Point Emitter Current	$V_{B2\text{-}B1} = 20$ V	2		4		2		2		mA
V_{OB1}	Base-One Peak Pulse Voltage	See Figure 2	3		3		6		3		V

NOTES: 4. Temperature coefficient, α_{rBB}, is determined by the following formula:

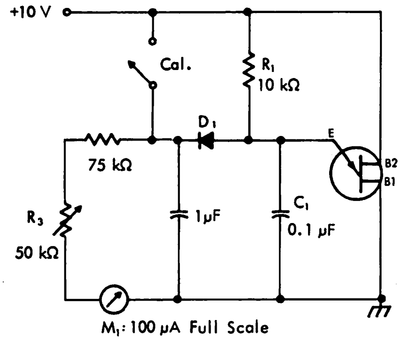
$$\alpha_{rBB} = \left[\frac{(r_{BB} @ 100°C) - (r_{BB} @ -55°C)}{(r_{BB} @ 25°C)}\right]\frac{100\%}{155 \text{ deg}}$$

To obtain r_{BB} for a given temperature $T_{A(2)}$, use the following formula: $r_{BB(2)} = [r_{BB} @ 25°C]\,[1 + (\alpha_{rBB}/100)\,(T_{A(2)} - 25°C)]$

5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*Indicates JEDEC registered data.

PARAMETER MEASUREMENT INFORMATION



η — Intrinsic Standoff Ratio — This parameter is defined in terms of the peak-point voltage, V_p, by means of the equation: $V_p = \eta V_{B2B1} + V_F$, where V_F is about 0.56 volt at 25°C and decreases with temperature at about 3 millivolts/deg.

The circuit used to measure η is shown in the figure. In this circuit, R_1, C_1 and the unijunction transistor form a relaxation oscillator, and the remainder of the circuit serves as a peak-voltage detector with the diode D_1 automatically subtracting the voltage V_F. To use the circuit, the "cal" button is pushed, and R_3 is adjusted to make the current meter M_1 read full scale. The "cal" button then is released and the value of η is read directly from the meter, with $\eta = 1$ corresponding to full-scale deflection of 100 μA.

D_1: 1N457, or equivalent, with the following characteristics:
$V_F = 0.565$ V at $I_F = 50\ \mu A$,
$I_R \leq 2\ \mu A$ at $V_R = 20$ V

FIGURE 1 — TEST CIRCUIT FOR INTRINSIC STANDOFF RATIO (η)

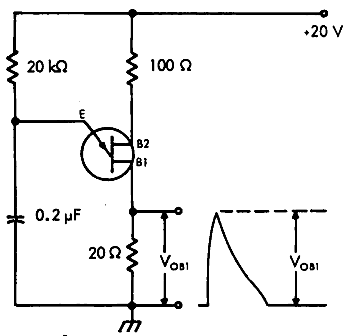


FIGURE 2 — V_{OB1} TEST CIRCUIT

EMITTER—BASE-ONE VOLTAGE
vs
EMITTER CURRENT

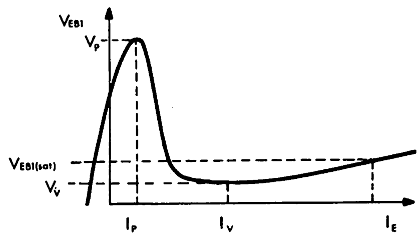


FIGURE 3 — GENERAL STATIC EMITTER CHARACTERISTIC CURVE

TYPICAL CHARACTERISTICS

STATIC INTERBASE RESISTANCE
vs
FREE-AIR TEMPERATURE

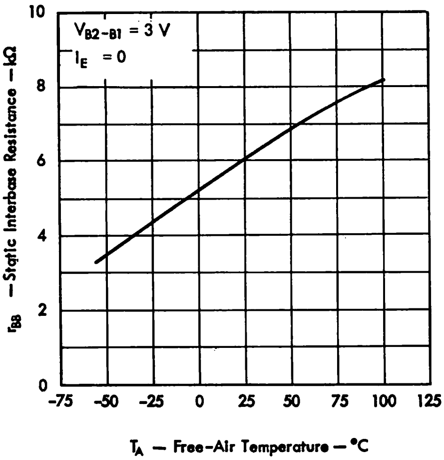


FIGURE 4

EMITTER REVERSE CURRENT
vs
FREE-AIR TEMPERATURE

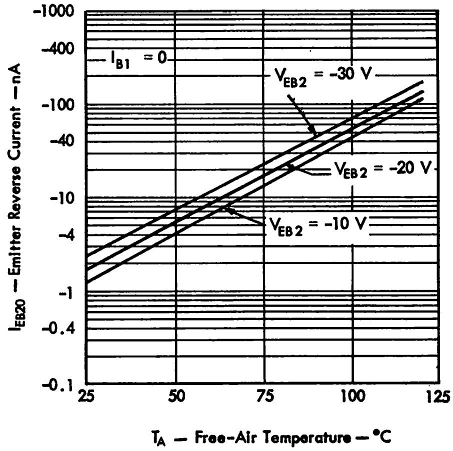


FIGURE 5

2N4893
BASE-ONE PEAK PULSE VOLTAGE
vs
FREE-AIR TEMPERATURE

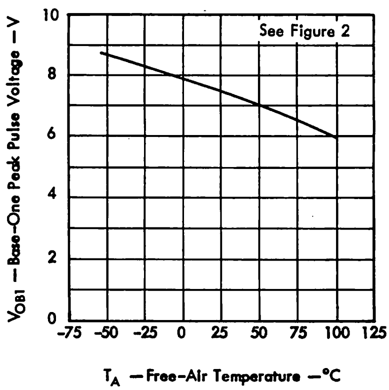


FIGURE 6

TYPICAL CHARACTERISTICS

MODULATED INTERBASE CURRENT
vs
INTERBASE VOLTAGE

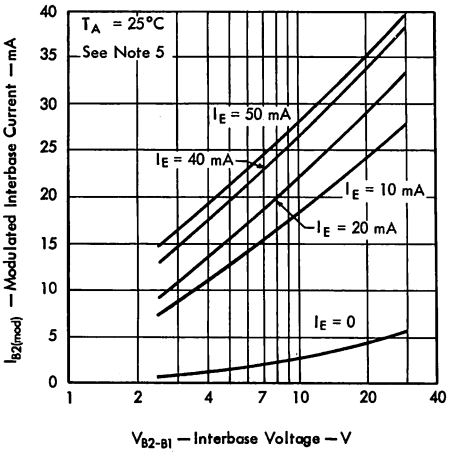


FIGURE 7

MODULATED INTERBASE CURRENT
vs
FREE-AIR TEMPERATURE

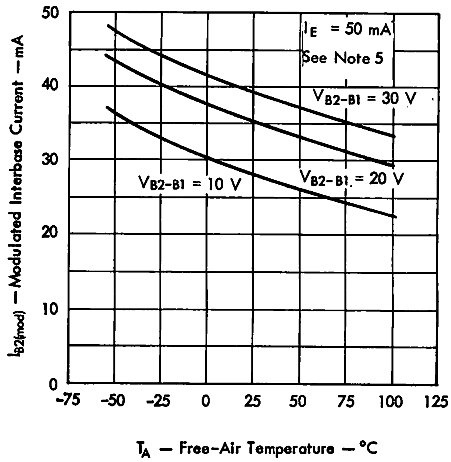


FIGURE 8

2N4894
PEAK-POINT EMITTER CURRENT
vs
FREE-AIR TEMPERATURE

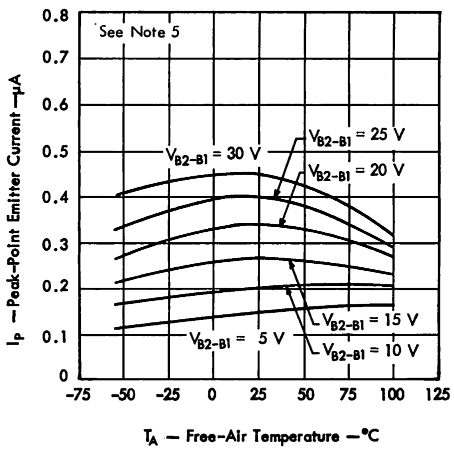


FIGURE 9

NOTE 5: This parameter is measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

EMITTER—BASE-ONE VOLTAGE
vs
EMITTER CURRENT

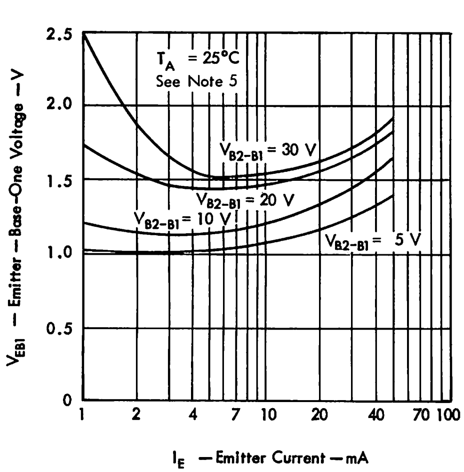


FIGURE 10

EMITTER— BASE-ONE SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE

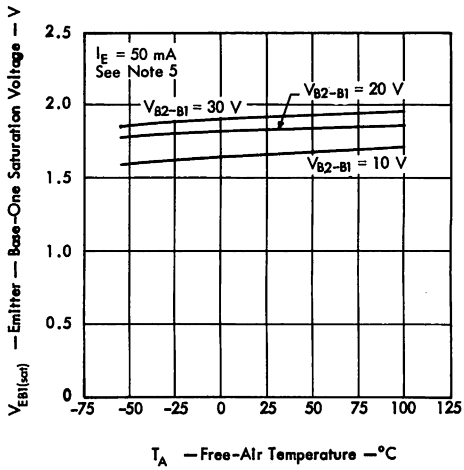


FIGURE 11

2N4892
VALLEY-POINT EMITTER CURRENT
vs
FREE-AIR TEMPERATURE

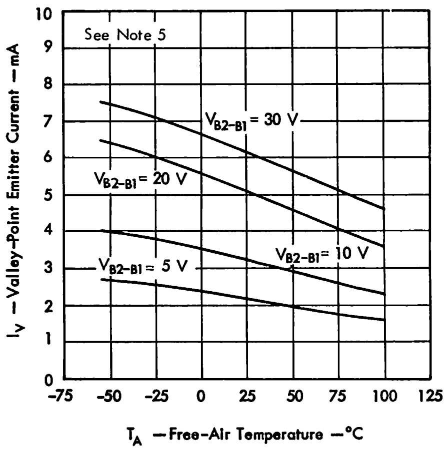
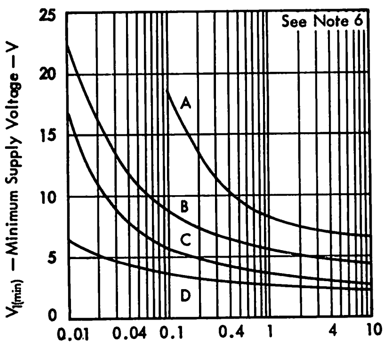


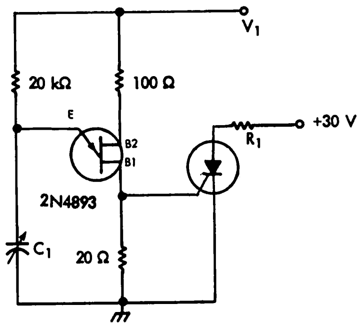
FIGURE 12

NOTE 5: This parameter is measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

TYPICAL CHARACTERISTICS

TYPICAL MINIMUM SUPPLY VOLTAGE TO TRIGGER THYRISTOR
vs
CAPACITANCE





TEST CIRCUIT

INDEX OF THYRISTOR TYPES

CURVE	THYRISTOR TYPES	R_1
A	TI3037-42, 2N3936-40	35 Ω
B	2N681-88, 2N681A-89A, 2N1842B-50B	70 Ω
C	TI145A0-A4, 2N1595-99, TI40A0-A5, 2N1600-04, 2N1770-77, 2N2653, TI3010, TIC28-31	70 Ω
D	2N3001-08, 2N876-81, 2N884-88, 2N2687-90, 2N3555-62, TIC44-47	70 Ω

FIGURE 13 — OPERATING INFORMATION (2N4893)

NOTE 6: This chart shows typical observed values of minimum base-two supply voltage required to trigger individual thyristors of the types indicated.

TYPES 2N398, 2N398A AND 2N398B
BULLETIN NO. DL-S 622993, AUGUST 1962

High-Voltage Transistors
For Direct Control of
Neon Indicators

environmental tests

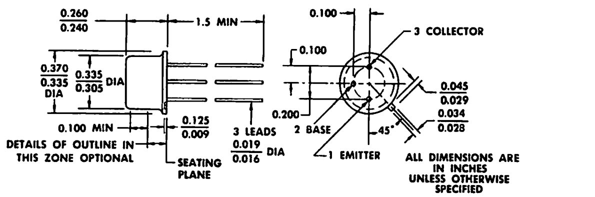
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to specified characteristics.

- All devices receive a 100°C stabilization bake for 100 hours minimum.
- The hermetic seal is verified by submerging all devices in a 2% detergent solution at 100 psi for 24 hours.
- Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.
- Continuous Quality Control checks on in-process assembly are maintained.

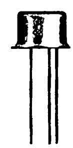
*mechanical data

The transistors are in a JEDEC TO-5 hermetically sealed welded package with glass-to-metal seal between case and leads. Approximate weight is one gram.

ALL LEADS INSULATED FROM CASE



DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N398	2N398A	2N398B
Collector-Base Voltage	105 v	105 v	105 v
Collector-Emitter Voltage (See Note 1)	105 v	105 v	105 v
Emitter-Base Voltage	50 v	50 v	75 v
Collector Current	100 ma	200 ma	200 ma
Emitter Current	100 ma	200 ma	200 ma
Total Device Dissipation (See Note 2)	50 mw	150 mw	250 mw
Operating Temperature	55°C	100°C	100°C
Storage Temperature Range	− 65°C to + 85°C	− 65°C to + 100°C	− 65°C to + 100°C

NOTES: 1. This value applies when the base-emitter diode is short-circuited.

2. For 2N398 derate linearly to 55°C maximum free-air temperature at the rate of 0.75 mw/C°; this corresponds to 10 mw maximum dissipation at 55°C.
For 2N398A derate linearly to 100°C free-air temperature at the rate of 2.0 mw/C°.
For 2N398B derate linearly to 100°C free-air temperature at the rate of 3.33 mw/C°.

*Indicates JEDEC registered data.

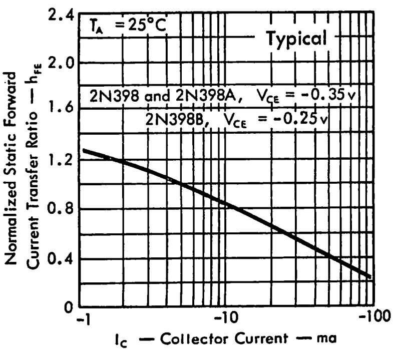
TYPES 2N398, 2N398A, AND 2N398B
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

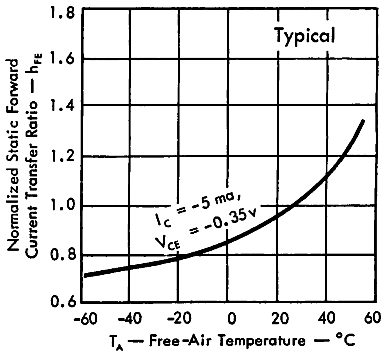
PARAMETER		TEST CONDITIONS	2N398			2N398A			2N398B			UNIT
			MIN*	TYP	MAX*	MIN*	TYP	MAX*	MIN*	TYP	MAX*	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -50\mu a$, $I_E = 0$	−105									v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -50\mu a$, $I_C = 0$	−50									v
V_{PT}	Punch-Through Voltage (See Note 3)	$V_{EBfl} = -1$ v, $R_{BE} = 11$ MΩ	−105			−105			−105			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -2.5$ v, $I_E = 0$		−6	−14		−6	−14		−4	−6	μa
I_{CBO}	Collector Cutoff Current	$V_{CB} = -105$ v, $I_E = 0$					−10	−50		−8	−25	μa
I_{CBO}	Collector Cutoff Current	$V_{CB} = -105$ v, $I_E = 0$, $T_A = 71°C$								−180	−300	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ v, $I_C = 0$		−5			−5			−3	−6	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -50$ v, $I_C = 0$		−6			−6	−50				μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -75$ v, $I_C = 0$								−8	−50	μa
I_{CES}	Collector Cutoff Current	$V_{CE} = -105$ v, $V_{BE} = 0$		−60	−600		−60	−600		−40	−300	μa
I_{CER}	Collector Cutoff Current	$V_{CE} = -55$ v, $R_{BE} = 10$ KΩ								−140	−300	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.35$ v, $I_C = -5$ ma	20	35		20	35					
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.25$ v, $I_C = -5$ ma							20	45		
V_{BE}	Base-Emitter Voltage	$I_B = -0.25$ ma, $I_C = -5$ ma		−0.23	−0.40		−0.23	−0.40		−0.20	−0.30	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.25$ ma, $I_C = -5$ ma		−0.14	−0.35		−0.14	−0.35		−0.12	−0.25	v
h'_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -6$ v, $I_C = -1$ ma, f = 1 kc		45		20	45		40	65		
f_{hfb}	Common-Base Alpha-Cutoff Frequency	$V_{CB} = -6$ v, $I_E = 1$ ma		0.8			0.8		1	1.4		mc

3. V_{PT} is determined by measuring the emitter-base floating potential, V_{BEfl}. Collector-base voltage, V_{CB}, is increased until $V_{BEfl} = -1$ v; this value of $V_{CB} = (V_{PT} - 1$ v).

NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
FREE-AIR TEMPERATURE

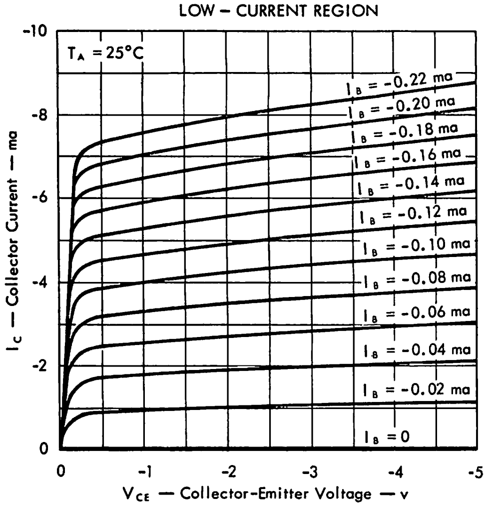


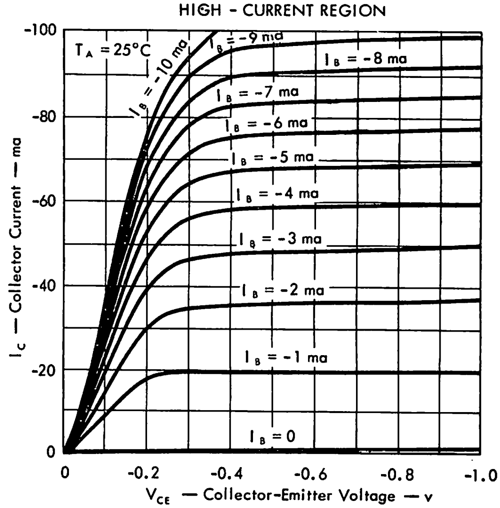
TYPES 2N398, 2N398A, AND 2N398B
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPICAL CHARACTERISTICS

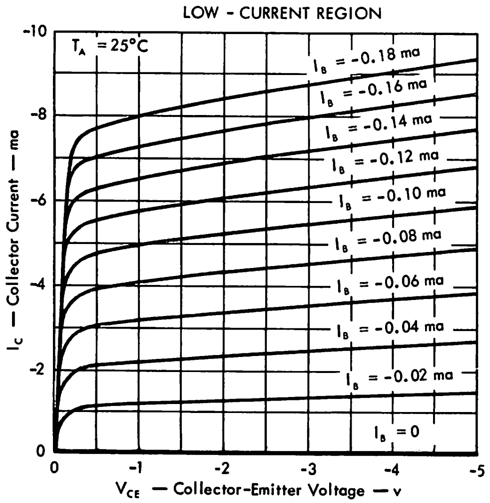
COMMON-EMITTER COLLECTOR CHARACTERISTICS

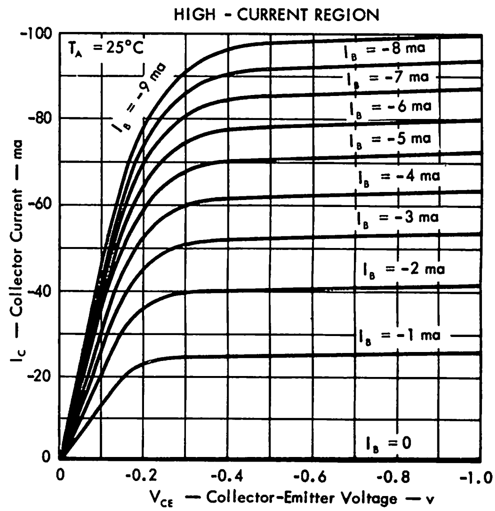
2N398 and 2N398A





2N398B

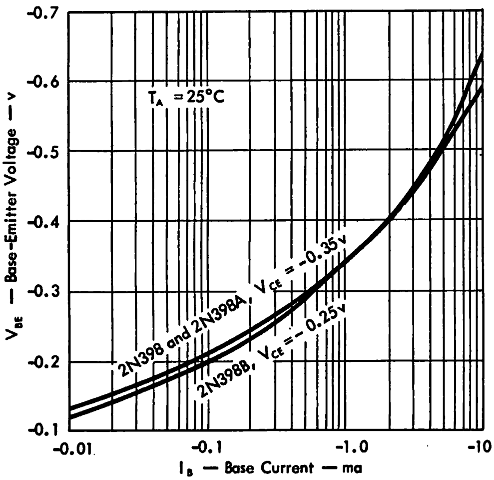




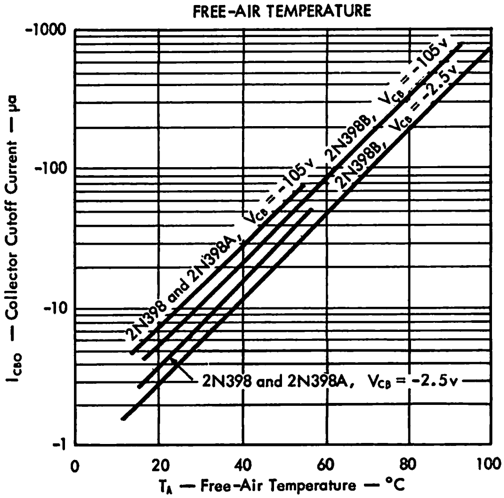
NOTE: These characteristics are measured by the sweep method using Tektronix 575 curve tracer or equivalent.

TYPICAL CHARACTERISTICS

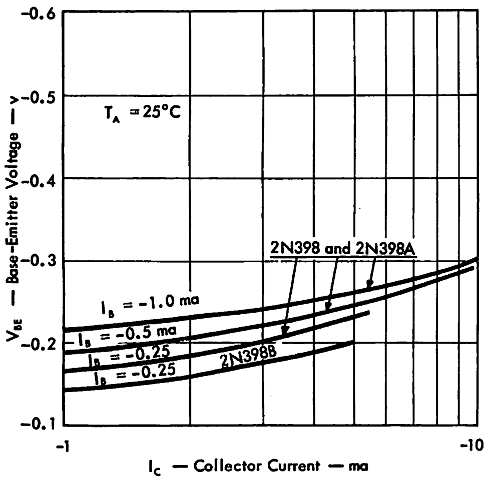
COMMON-EMITTER INPUT CHARACTERISTICS



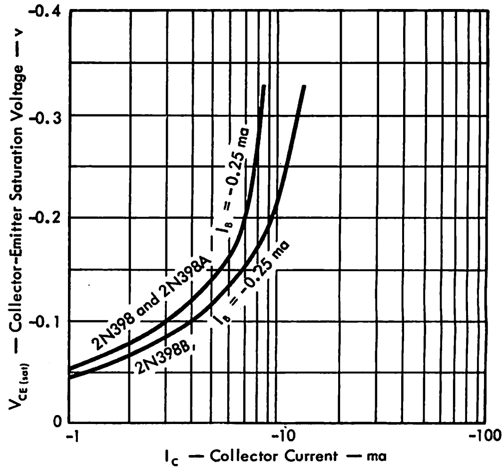
COLLECTOR CUTOFF CURRENT vs FREE-AIR TEMPERATURE



BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT



COLLECTOR-EMITTER SATURATION VOLTAGE vs COLLECTOR CURRENT



TYPES 2N404, 2N404A
BULLETIN NO. DL-S 612176, DECEMBER 1961

High-Frequency Transistors for Computer and Switching Applications

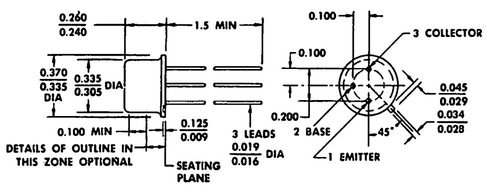
Close parameter control and the JEDEC TO-5 welded package ensure device reliability and stable characteristics

environmental tests

To ensure maximum reliability, stability, and long life, all units are aged at 100°C for 100 hours minimum prior to electrical characterization. All transistors are thoroughly tested for complete adherence to specified design characteristics. In addition, continuous qualification tests are made comprising temperature-humidity cycling, shock, and vacuum leak testing under rigid in-process control procedures.

mechanical data

Metal case with glass-to-metal hermetic seal between case and leads. Unit weight is approximately 1 gram. These units meet JEDEC TO-5 registration.



All leads insulated from the case.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N404	2N404A
Collector-Base Voltage	25 v	40 v
Collector-Emitter Voltage (see note 1)	24 v	35 v
Emitter-Base Voltage	12 v	25 v
Collector Current	100 ma	150 ma
Emitter Current	100 ma	150 ma
Total Device Dissipation (see note 2)	150 mw	150 mw
Operating Collector Junction Temperature	85°C	100°C
Storage Temperature Range	–65°C to +100°C	–65°C to +100°C

NOTES: 1. Punch-through voltage.
2. For 2N404 derate linearly to 85°C free-air temperature at the rate of 2.5 mw/°C;
For 2N404A derate linearly to 100°C free-air temperature at the rate of 2.0 mw/°C.

*Indicates JEDEC registered data.

The maximum power dissipation at 25°C case temperature is 300 mw.

TYPES 2N404, 2N404A
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

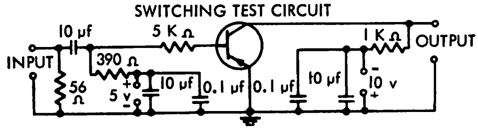
parameter		test conditions	2N404 min	2N404 typ	2N404 max	2N404A min	2N404A typ	2N404A max	unit
I_{CBO}	Collector cutoff current	$V_{CB} = -12$ v, $I_E = 0$		−1	−5*		−1	−5*	μa
		$V_{CB} = -12$ v, $I_E = 0$, $T_A = 80°C$		−40	−90*		−40	−90*	μa
I_{EBO}	Emitter cutoff current	$V_{EB} = -2.5$ v, $I_C = 0$		−1	−2.5*		−1	−2.5*	μa
BV_{CBO}	Collector-base breakdown voltage	$I_C = -20 \mu a$, $I_E = 0$	−25*			−40*			v
BV_{EBO}	Emitter-base breakdown voltage	$I_E = -20 \mu a$, $I_C = 0$	−12*			−25*			v
h_{FE}	DC forward current transfer ratio	$V_{CE} = -0.15$ v, $I_C = -12$ ma	30	100		30	100		
		$V_{CE} = -0.20$ v, $I_C = -24$ ma	24	110		24	110		
V_{BE}	Base-emitter voltage	$I_B = -0.4$ ma, $I_C = -12$ ma		−0.26	−0.35*		−0.26	−0.35*	v
		$I_B = -1$ ma, $I_C = -24$ ma		−0.30	−0.40*		−0.30	−0.40*	v
$V_{CE(sat)}$	Collector-emitter saturation voltage	$I_B = -0.4$ ma, $I_C = -12$ ma		−0.08	−0.15*		−0.08	−0.15*	v
		$I_B = -1$ ma, $I_C = -24$ ma		−0.08	−0.20*		−0.08	−0.20*	v
V_{pt}	Punch-through voltage†	$V_{EBfl} = -1$ v	−24*						v
V_{EBfl}	Emitter-base floating potential	$V_{CB} = -35$ v					−0.2	−1*	v
h_{fe}	AC common-emitter forward current transfer ratio	$V_{CE} = -6$ v, $I_C = -1$ ma, f = 1 kc		135			135		
h_{ie}	AC common-emitter input impedance	$V_{CE} = -6$ v, $I_C = -1$ ma, f = 1 kc		4			4		Kohm
h_{oe}	AC common-emitter output admittance	$V_{CE} = -6$ v, $I_C = -1$ ma, f = 1 kc		50			50		μmho
h_{re}	AC common-emitter reverse voltage transfer ratio	$V_{CE} = -6$ v, $I_C = -1$ ma, f = 1 kc		7×10^{-4}			7×10^{-4}		
C_{ob}	Common-base output capacitance	$V_{CB} = -6$ v, $I_E = 0$, f = 1 mc		9	20*				pf
		$V_{CB} = -6$ v, $I_E = 1$ ma, f = 2 mc					9	20*	pf
f_{hfb}	Common-base alpha cutoff frequency	$V_{CB} = -6$ v, $I_E = 1$ ma	4*	12		4*	12		mc

†V_{pt} is determined by measuring the emitter-base floating potential V_{EBfl}, using a voltmeter with 11 megohms minimum input impedance. The collector-base voltage, V_{CB}, is increased until $V_{EBfl} = -1$ v; this value of $V_{CB} = (V_{pt} + 1)$. Care must be taken not to exceed maximum collector-base voltage specified under maximum ratings.

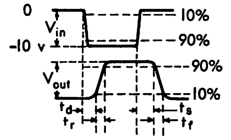
switching characteristics at 25°C free-air temperature

parameter		test conditions	2N404 min	2N404 typ	2N404 max	2N404A min	2N404A typ	2N404A max	unit
t_d	Delay time	See Circuit 1		0.14			0.15		μsec
t_r	Rise time	See Circuit 1		0.20			0.27		μsec
t_s	Storage time	See Circuit 1		0.38			0.38		μsec
t_f	Fall time	See Circuit 1		0.19			0.24		μsec
Q_{sb}	Stored base charge	See Circuit 2		800	1400*		800	1400*	pcb

CIRCUIT I
SWITCHING TEST CIRCUIT



VOLTAGE WAVEFORMS



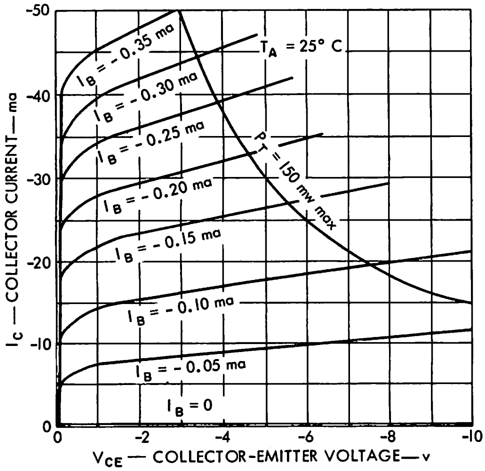
NOTES: 1. Input pulse supplied by generator with following characteristics:
a. Output impedance: 50 ohms
b. Repetition rate: 1 kc
c. Rise and fall time: 20 nanoseconds maximum
2. Waveforms monitored on scope with following characteristics:
a. Input resistance — 10 megohms minimum
b. Input capacitance — 15 pf maximum
c. Risetime — 15 nanoseconds maximum
3. All resistors ±1% tolerance.

TYPES 2N404, 2N404A
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

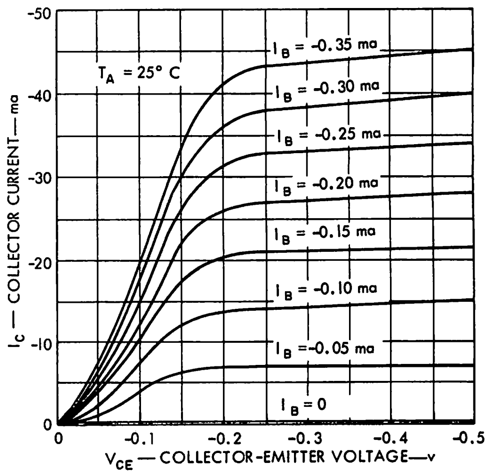
TYPICAL CHARACTERISTICS

COMMON-EMITTER COLLECTOR CHARACTERISTICS . . . AS MEASURED ON TEKTRONIX 575 CURVE TRACER

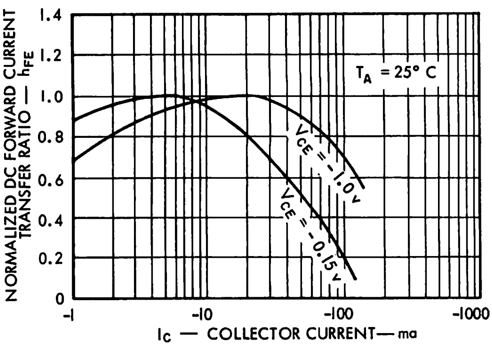
ACTIVE REGION



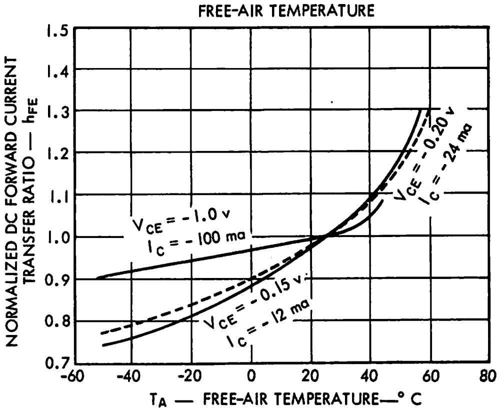
SATURATION REGION



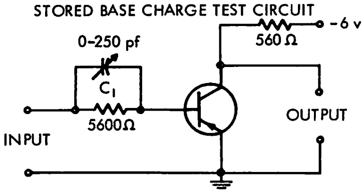
NORMALIZED DC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT



NORMALIZED DC FORWARD CURRENT TRANSFER RATIO vs FREE-AIR TEMPERATURE

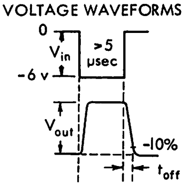


CIRCUIT 2
STORED BASE CHARGE TEST CIRCUIT



SAME NOTES AS CIRCUIT I

VOLTAGE WAVEFORMS

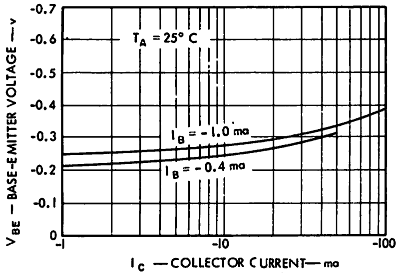


MEASUREMENT PROCEDURE

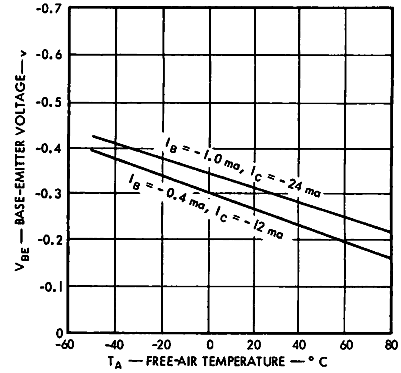
C_1 is increased until the t_{off} time of the output waveform is decreased to 0.2 μsec. Q_{sb} is then calculated by $Q_{sb} = C_1\ V_{in}$.

TYPICAL CHARACTERISTICS

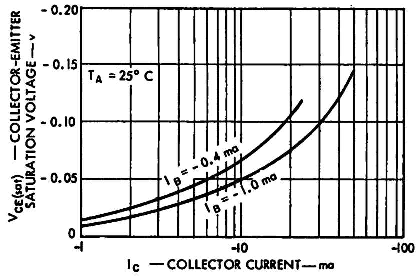
BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT



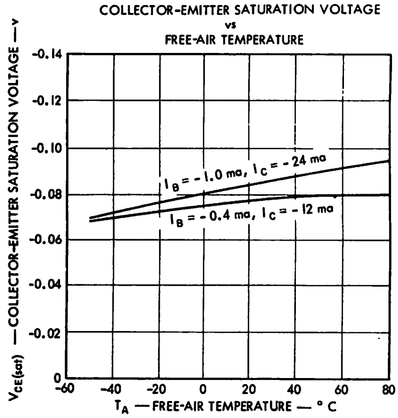
BASE-EMITTER VOLTAGE vs FREE-AIR TEMPERATURE



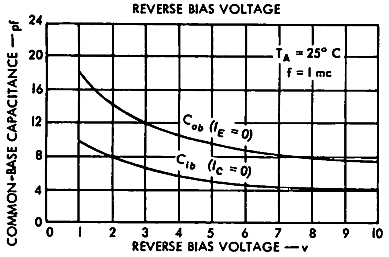
COLLECTOR-EMITTER SATURATION VOLTAGE vs COLLECTOR CURRENT



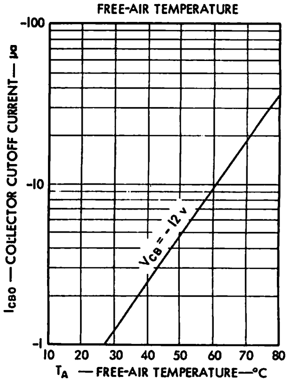
COLLECTOR-EMITTER SATURATION VOLTAGE vs FREE-AIR TEMPERATURE



COMMON-BASE CAPACITANCE vs REVERSE BIAS VOLTAGE



COLLECTOR CUTOFF CURRENT vs FREE-AIR TEMPERATURE



N-P-N TYPES 2N1302, 2N1304, 2N1306, AND 2N1308
P-N-P TYPES 2N1303, 2N1305, 2N1307, AND 2N1309
COMPLEMENTARY ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPES 2N1302, 2N1304, 2N1306, 2N1308
TYPES 2N1303, 2N1305, 2N1307, 2N1309
BULLETIN NO. DL-S 633149, MARCH 1963
REPLACES BULLETIN NO. DL-S 60349, MAY 1960

High-Frequency Transistors for Computer and Switching Applications

- Complementary Families
- Proven Reliability and Stability

environmental tests

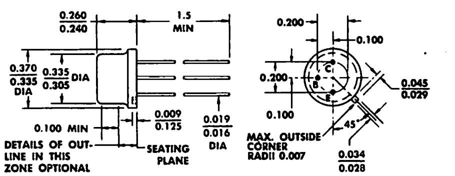
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to specified characteristics.

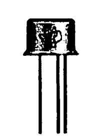
- All devices receive a 100°C stabilization bake for 100 hours.
- The hermetic seal for all devices is verified by helium leak testing.
- Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.
- Continuous Quality Control checks on in-process assembly are maintained.

*mechanical data

The transistors are in a JEDEC TO-5 hermetically sealed welded package with glass to metal seal between case and leads. Approximate weight is one gram.

THE BASE IS IN ELECTRICAL CONTACT WITH CASE





DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N1302, 2N1304, 2N1306, 2N1308	2N1303, 2N1305, 2N1307, 2N1309
Collector-Base Voltage	25 v	30 v
Emitter-Base Voltage	25 v	
Collector Current	300 ma	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	150 mw	
Operating Collector Junction Temperature	85°C	
Storage Temperature Range	−65°C to 100°C	

NOTE: 1. Derate linearly to 85°C free-air temperature at the rate of 2.5 mw/C°.
*Indicates JEDEC registered data.

TYPES 2N1302, 2N1304, 2N1306, AND 2N1308
N-P-N ALLOY-JUNCTION GERMANIUM TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	2N1302			2N1304			2N1306			2N1308			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CBO} Collector-Base Breakdown Voltage	$I_C = 100\ \mu a$, $I_E = 0$	25			25			25			25			v
BV_{EBO} Emitter-Base Breakdown Voltage	$I_E = 100\ \mu a$, $I_C = 0$	25			25			25			25			v
*V_{PT} Punch Through Voltage†	$V_{EBfl} = 1$ v	25			20			15			15			v
*I_{CBO} Collector Cutoff Current	$V_{CB} = 25$ v, $I_E = 0$		3	6		3	6		3	6		3	6	μa
*I_{EBO} Emitter Cutoff Current	$V_{EB} = 25$ v, $I_C = 0$		2	6		2	6		2	6		2	6	μa
*h_{FE} Static Forward Current Transfer Ratio	$V_{CE} = 1$ v, $I_C = 10$ ma	20	100		40	115	200	60	130	300	80	160		
	$V_{CE} = 0.35$ v, $I_C = 200$ ma	10	100		15	110		20	125		20	140		
*V_{BE} Base-Emitter Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma	0.15	0.22	0.40	0.15	0.22	0.35	0.15	0.22	0.35	0.15	0.22	0.35	v
*$V_{CE(sat)}$ Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma, $I_C = 10$ ma		0.07	0.20										v
	$I_B = 0.25$ ma, $I_C = 10$ ma					0.07	0.20							v
	$I_B = 0.17$ ma, $I_C = 10$ ma								0.07	0.20				v
	$I_B = 0.13$ ma, $I_C = 10$ ma											0.07	0.20	v
h_{ib} Small-Signal Common-Base Input Impedance	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc		28			28			28			28		ohm
h_{rb} Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc		5×10^{-4}			5×10^{-4}			5×10^{-4}			5×10^{-4}		
h_{ob} Small-Signal Common-Base Output Admittance	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc		0.34			0.34			0.34			0.34		μmho
h_{fe} Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, f = 1 kc		105			120			135			170		
*f_{hfb} Common-Base Alpha-Cutoff Frequency	$V_{CB} = 5$ v, $I_E = -1$ ma	3	12		5	14		10	16		15	20		mc
*C_{ob} Common-Base Open Circuit Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 1 mc		14	20		14	20		14	20		14	20	pf
C_{ib} Common-Base Open-Circuit Input Capacitance	$V_{EB} = 5$ v, $I_C = 0$, f = 1 mc		13			13			13			13		pf

†V_{PT} is determined by measuring the emitter-base floating potential V_{EBfl}. The collector-base voltage, V_{CB}, is increased until $V_{EBfl} = 1$ volt; this value of $V_{CB} = (V_{PT} + 1\ v)$.

switching characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS††	2N1302			2N1304			2N1306			2N1308			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_d Delay Time	$I_C = 10$ ma, $I_{B(1)} = 1.3$ ma, $I_{B(2)} = -0.7$ ma, $V_{BE(off)} = -0.8$ v, $R_L = 1\ k\Omega$ (See Fig. 1)		0.07			0.07			0.06			0.06		μsec
t_r Rise Time			0.20			0.20			0.18			0.15		μsec
t_s Storage Time			0.70			0.70			0.64			0.64		μsec
t_f Fall Time			0.40			0.40			0.36			0.34		μsec
Q_{sb} Stored Base Charge	$I_{B(1)} = 1$ ma, $I_C = 10$ ma (See Fig. 2)		800			760			720			680		pcb

††Voltage and current values shown are nominal; exact values vary slightly with device parameters.

operating characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	2N1302			2N1304			2N1306			2N1308			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
NF Spot Noise Figure	$V_{CB} = 5$ v, $I_E = -1$ ma, f = 1 kc, $R_G = 1\ k\Omega$		4			4			3			3		db

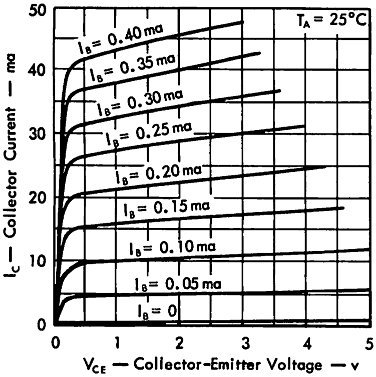
*Indicates JEDEC registered data (typical values excluded).

TYPES 2N1302, 2N1304, 2N1306, AND 2N1308
N-P-N ALLOY-JUNCTION GERMANIUM TRANSISTORS

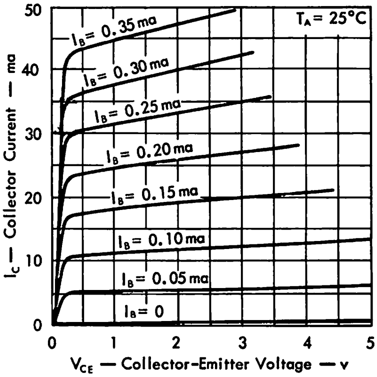
TYPICAL CHARACTERISTICS

COMMON-EMITTER COLLECTOR CHARACTERISTICS

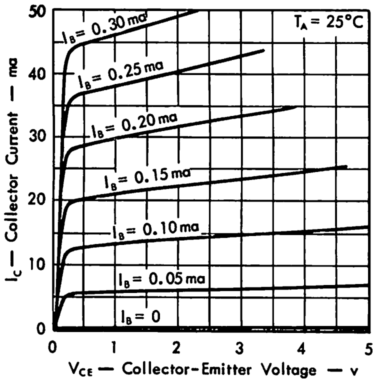
2N1302



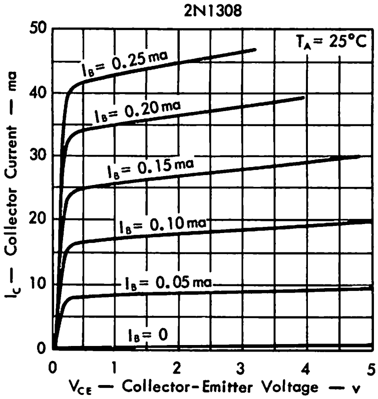
2N1304



2N1306



2N1308



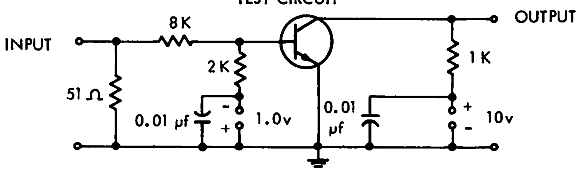
NOTE: These Characteristics are measured by the sweep method using a 575 Tektronix Curve Tracer (or equivalent).

PARAMETER MEASUREMENT INFORMATION

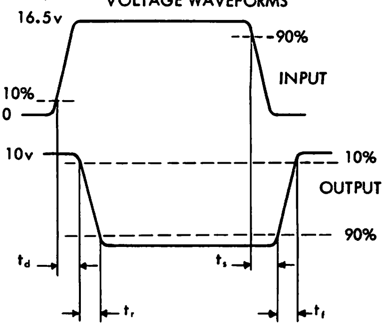
FIGURE 1 SWITCHING TIMES

(POLARITIES SHOWN APPLY TO N-P-N)

TEST CIRCUIT



VOLTAGE WAVEFORMS



NOTES: 1. Input pulse supplied by generator with following characteristics:
- a. Output impedance: 50 ohms
- b. Repetition rate: 1 kc
- c. Rise and fall time: 20 nanoseconds maximum
- d. Pulse width: 10 microseconds

2. Waveforms monitored on scope with following characteristics:
- a. Input resistance: 10 megohms minimum
- b. Input capacitance: 15 pf maximum
- c. Risetime: 15 nanoseconds maximum

3. All resistors ±1% tolerance

TYPES 2N1303, 2N1305, 2N1307, AND 2N1309
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N1303			2N1305			2N1307			2N1309			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$	−30			−30			−30			−30			v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−25			−25			−25			−25			v
$^*V_{pt}$	Punch Through Voltage†	$V_{EBfl} = -1$ v	−25			−20			−15			−15			v
$^*I_{CBO}$	Collector Cutoff Current	$V_{CB} = -25$ v, $I_E = 0$		−2	−6		−2	−6		−2	−6		−2	−6	μa
$^*I_{EBO}$	Emitter Cutoff Current	$V_{EB} = -25$ v, $I_C = 0$		−1.5	−6		−1.5	−6		−1.5	−6		−1.5	−6	μa
$^*h_{FE}$	Static Forward Current Transfer Ratio	$V_{CE} = -1$ v, $I_C = -10$ ma	20	100		40	115	200	60	130	300	80	160		
		$V_{CE} = -0.35$ v, $I_C = -200$ ma	10	45		15	55		20	65		20	75		
$^*V_{BE}$	Base-Emitter Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma	−0.15	−0.25	−0.40	−0.15	−0.25	−0.35	−0.15	−0.25	−0.35	−0.15	−0.25	−0.35	v
$^*V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma		−0.08	−0.20										v
		$I_B = -0.25$ ma, $I_C = -10$ ma					−0.08	−0.20							v
		$I_B = -0.17$ ma, $I_C = -10$ ma								−0.08	−0.20				v
		$I_B = -0.13$ ma, $I_C = -10$ ma											−0.08	−0.20	v
h_{ib}	Small-Signal Common-Base Input Impedance	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc		29			29			29			29		ohm
h_{rb}	Small-Signal Common-Base Reverse Voltage Transfer Ratio	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc		7×10^{-4}			7×10^{-4}			7×10^{-4}			7×10^{-4}		
h_{ob}	Small-Signal Common-Base Output Admittance	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc		0.40			0.40			0.40			0.40		μmho
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ v, $I_C = -1$ ma, f = 1 kc		115			130			150			190		
$^*f_{hfb}$	Common-Base Alpha-Cutoff Frequency	$V_{CB} = -5$ v, $I_E = 1$ ma	3	12		5	14		10	16		15	20		mc
$^*C_{ob}$	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 mc		10	20		10	20		10	20		10	20	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -5$ v, $I_C = 0$, f = 1 mc		9			9			9			9		pf

†V_{PT} is determined by measuring the emitter-base floating potential V_{EBfl}. The collector-base voltage, V_{CB}, is increased until $V_{EBfl} = -1$ volt; this value of $V_{CB} = (V_{PT} - 1\ v)$.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS††	2N1303			2N1305			2N1307			2N1309			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_d	Delay Time	$I_C = -10$ ma, $I_{B(1)} = -1.3$ ma, $I_{B(2)} = 0.7$ ma, $V_{BE(off)} = 0.8$ v, $R_L = 1\ k\Omega$ (See Fig. 1)		0.06			0.06			0.06			0.05		μsec
t_r	Rise Time			0.18			0.18			0.14			0.14		μsec
t_s	Storage Time			0.80			0.80			0.78			0.76		μsec
t_f	Fall Time			0.38			0.38			0.36			0.30		μsec
Q_{sb}	Stored Base Charge	$I_{B(1)} = -1$ ma, $I_C = -10$ ma (See Fig. 2)		960			920			880			800		pcb

††Voltage and current values shown are nominal, exact values vary slightly with device parameters.

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N1303			2N1305			2N1307			2N1309			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
NF	Spot Noise Figure	$V_{CB} = -5$ v, $I_E = 1$ ma, f = 1 kc, $R_G = 1\ k\Omega$		4			4			3			3		db

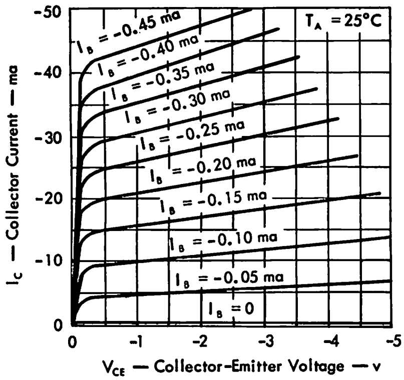
*Indicates JEDEC registered data (typical values excluded).

TYPES 2N1303, 2N1305, 2N1307, AND 2N1309
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

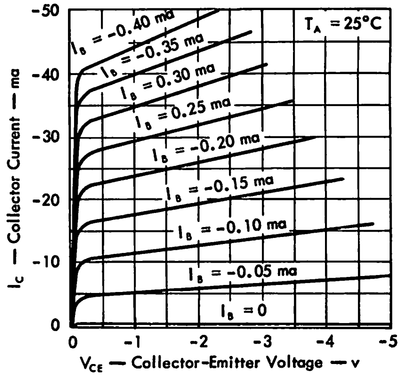
TYPICAL CHARACTERISTICS

COMMON-EMITTER COLLECTOR CHARACTERISTICS

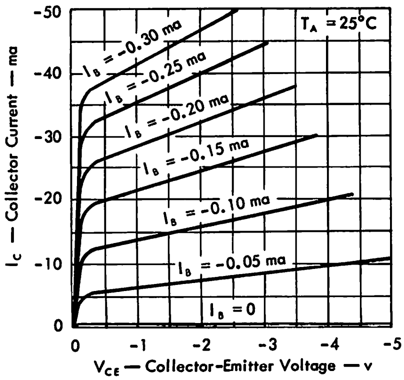
2N1303



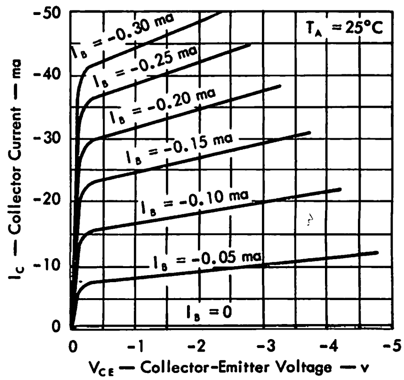
2N1305



2N1307



2N1309



NOTE: These Characteristics are measured by the sweep method using a 575 Tektronix Curve Tracer (or equivalent).

PARAMETER MEASUREMENT INFORMATION

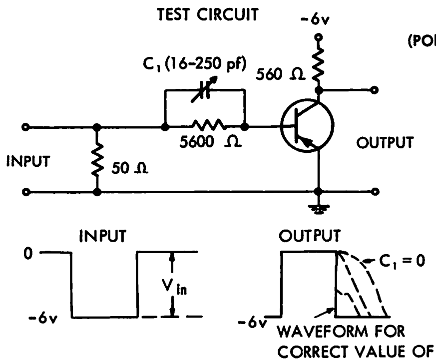


FIGURE 2
STORED BASE CHARGE
(POLARITIES SHOWN APPLY TO P-N-P)

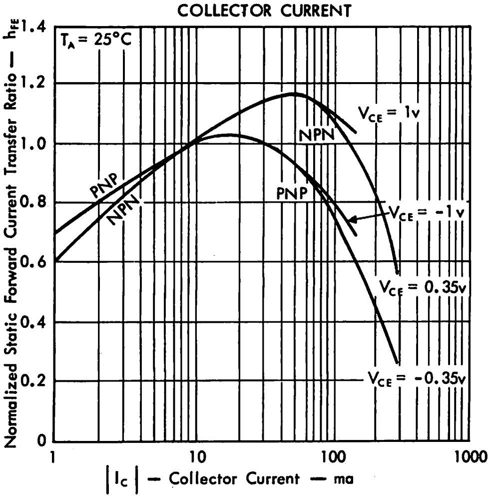
TEST PROCEDURE

The value of capacitor C_1 is increased until the transistor turns off monotonically, as shown. The stored base charge is then calculated from $Q_{sb} = V_{in} C_1$.

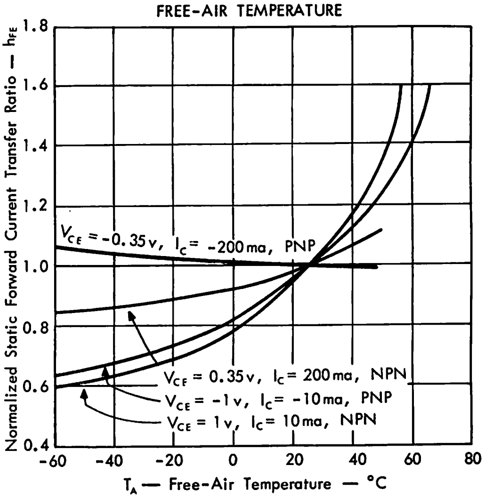
NOTES:
1. Input pulse supplied by generator with following characteristics:
   a. Output impedance: 50 ohms
   b. Repetition rate: 1 kc
   c. Rise and fall time: 20 nanoseconds maximum
   d. Pulse width: 10 microseconds
2. Waveforms monitored on scope with following characteristics:
   a. Input resistance: 10 megohms minimum
   b. Input capacitance: 15 pf maximum
   c. Risetime: 15 nanoseconds maximum
3. All resistors ±1% tolerance

TYPICAL CHARACTERISTICS

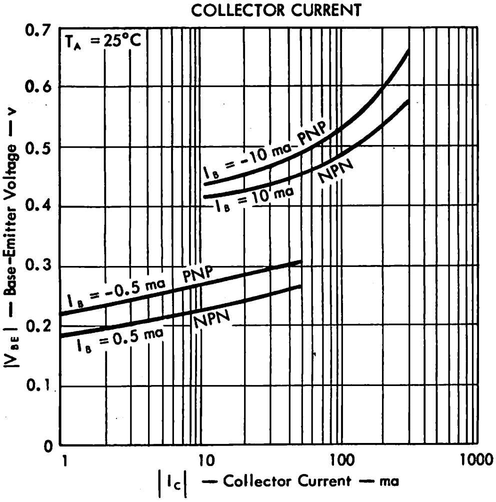
NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT



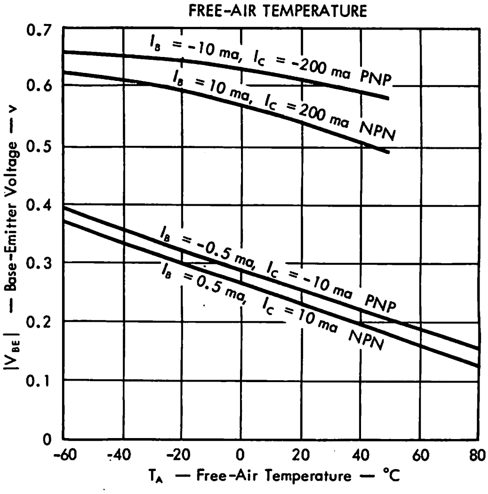
NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO vs FREE-AIR TEMPERATURE



BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT



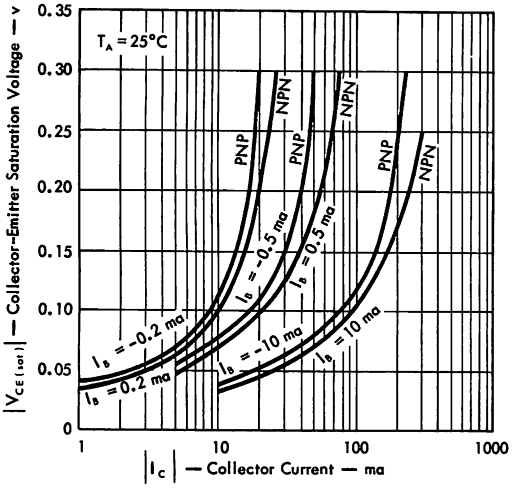
BASE-EMITTER VOLTAGE vs FREE-AIR TEMPERATURE



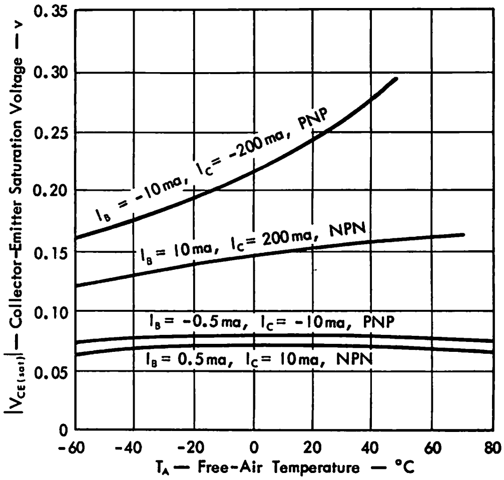
N-P-N TYPES 2N1302, 2N1304, 2N1306, AND 2N1308
P-N-P TYPES 2N1303, 2N1305, 2N1307, AND 2N1309
COMPLEMENTARY ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPICAL CHARACTERISTICS

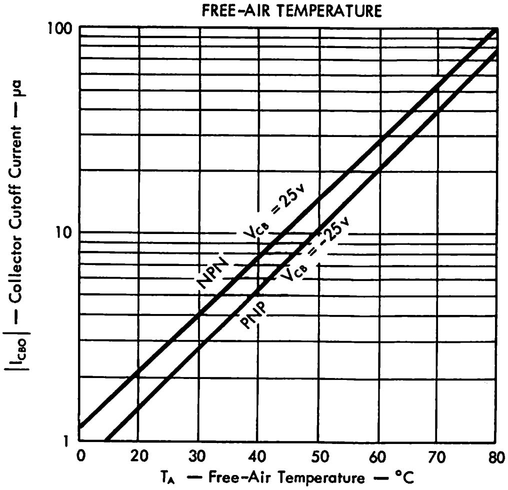
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT



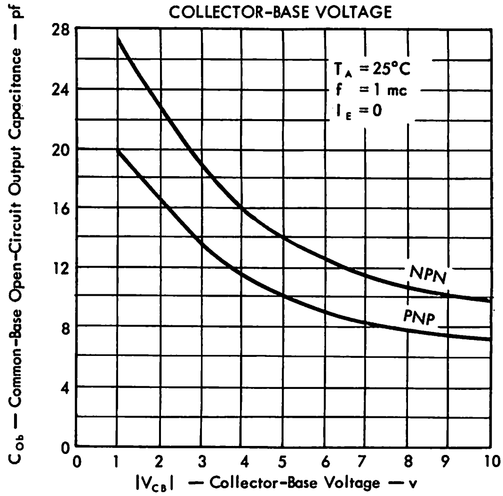
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



COLLECTOR CUTOFF CURRENT
vs
FREE-AIR TEMPERATURE

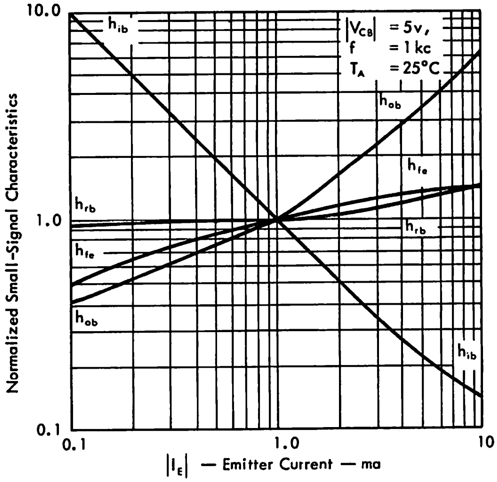


COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

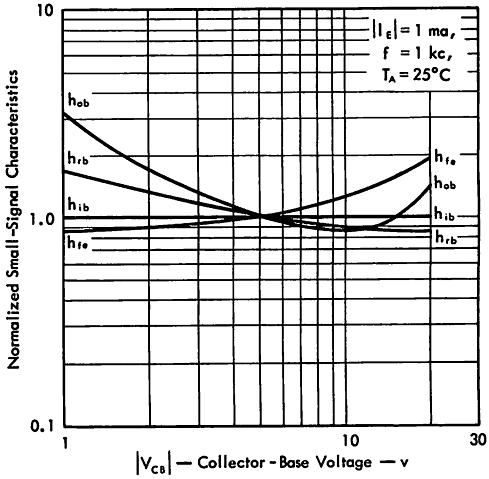


TYPICAL CHARACTERISTICS

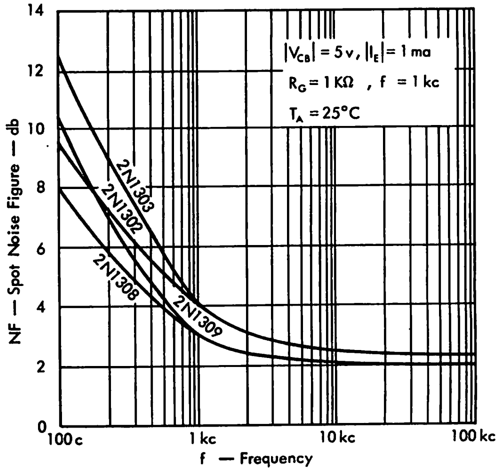
NORMALIZED SMALL-SIGNAL CHARACTERISTICS vs EMITTER CURRENT



NORMALIZED SMALL-SIGNAL CHARACTERISTICS vs COLLECTOR-BASE VOLTAGE



SPOT NOISE FIGURE vs FREQUENCY



TYPES 2N1372 THRU 2N1381
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPES 2N1372 THRU 2N1381
BULLETIN NO. DL-S 668313, JUNE 1966
REPLACES BULLETIN NO. DL-S 60424, DECEMBER 1960

LINEAR BETA, LOW DISTORTION, HIGH POWER GAIN

Specifically designed for low-frequency general-purpose industrial applications

- switching
- servo amplifiers
- audio amplifiers
- pagers
- intercoms
- motor controls

environmental tests

To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to specified characteristics.

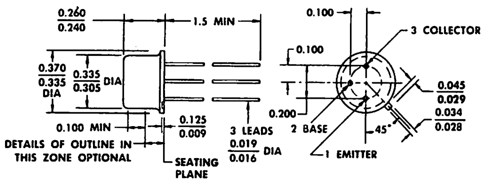
- Continuous Quality Control checks on in-process assembly are maintained.
- All devices are heat aged at 100°C for 100 hours minimum.
- The hermetic seal is verified for all devices by gross-leak tests.

Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.

mechanical data

The transistors are in a JEDEC TO-5* hermetically sealed welded package with glass-to-metal seal between case and leads. Approximate weight is one gram.

*ALL LEADS INSULATED FROM CASE



DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N1372 2N1374 2N1376	2N1373 2N1375 2N1377	2N1378 2N1380	2N1379 2N1381
Collector-Base Voltage	−25 V	−45 V	−12 V	−25 V
Collector-Emitter Voltage (See Note 1)	−25 V	−45 V	−12 V	−25 V
Emitter-Base Voltage	−15 V	−25 V	− 7 V	−15 V
Continuous Collector Current	←——— −200 mA ———→			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←——— 250 mW ———→			
Storage Temperature Range	←——— −55°C to 100°C ———→			
Lead Temperature 1/16 Inch from Case for 12 Seconds	←——— 235°C ———→			

NOTES: 1. This value applies when base-emitter resistance $R_{BE} \leq 2.2\ k\Omega$.
2. Derate linearly to 100°C free-air temperature at the rate of 3.33 mW/deg.
*Indicates JEDEC registered data.

***electrical characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	2N1372		2N1373		2N1374		2N1375		2N1376		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$, $I_E = 0$	−25		−45		−25		−45		−25		V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	$I_C = -100\ \mu A$, $R_{BE} = 2.2\ k\Omega$	−25		−45		−25		−45		−25		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$, $I_C = 0$	−15		−25		−15		−25		−15		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -20\ V$, $I_E = 0$		−7		−7		−7		−7		−7	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4.5\ V$, $I_C = 0$		−15		−15		−15		−15		−15	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -1\ V$, $I_C = -50\ mA$	27	105	27	105	45	165	45	165	67	165	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -1\ V$, $I_C = -100\ mA$	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -5\ mA$, $I_C = -100\ mA$		−1		−1							V
		$I_B = -3\ mA$, $I_C = -100\ mA$						−1		−1			
		$I_B = -2.5\ mA$, $I_C = -100\ mA$										−1	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5\ V$, $I_E = 1\ mA$, $f = 1\ kHz$	18	127	18	127	36	187	36	187	54	187	

PARAMETER		TEST CONDITIONS	2N1377		2N1378		2N1379		2N1380		2N1381		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$, $I_E = 0$	−45		−12		−25		−12		−25		V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	$I_C = -100\ \mu A$, $R_{BE} = 2.2\ k\Omega$	−45		−12		−25		−12		−25		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$, $I_C = 0$	−25		−7		−15		−7		−15		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -12\ V$, $I_E = 0$				−7				−14			μA
		$V_{CB} = -20\ V$, $I_E = 0$		−7				−7				−14	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4.5\ V$, $I_C = 0$		−15		−15		−15		−15		−15	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -1\ V$, $I_C = -50\ mA$	67	165	85	330	85	330	27	330	27	330	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -1\ V$, $I_C = -100\ mA$	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	−0.2	−0.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -5\ mA$, $I_C = -100\ mA$								−1		−1	V
		$I_B = -2.5\ mA$, $I_C = -100\ mA$		−1									
		$I_B = -1.5\ mA$, $I_C = -100\ mA$				−1		−1					
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5\ V$, $I_E = 1\ mA$, $f = 1\ kHz$	54	187	67	385	67	385	18	385	18	385	

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

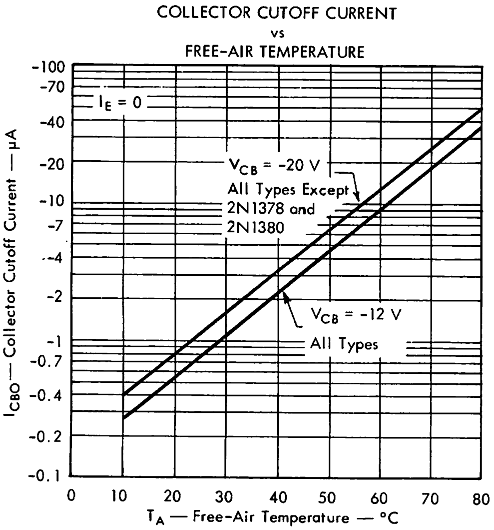


FIGURE 1

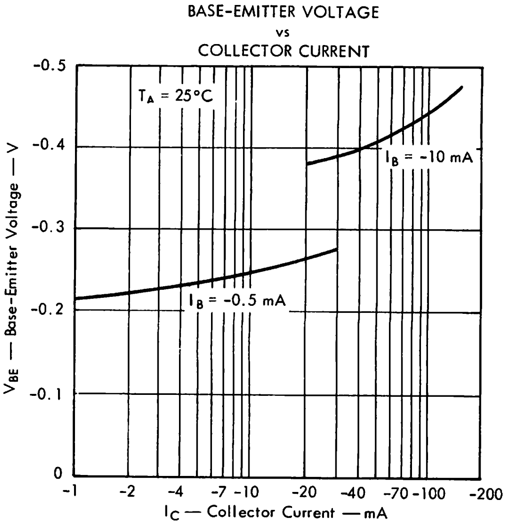


FIGURE 2

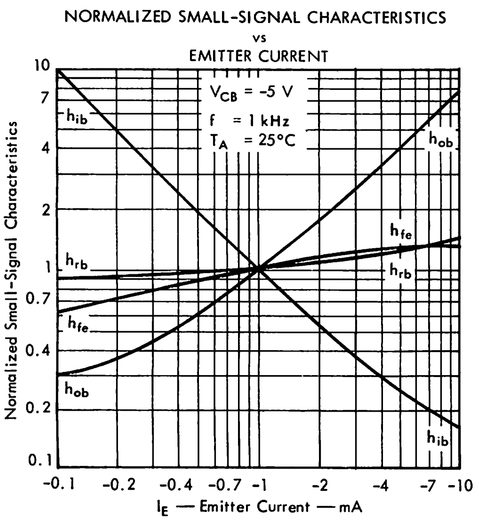


FIGURE 3

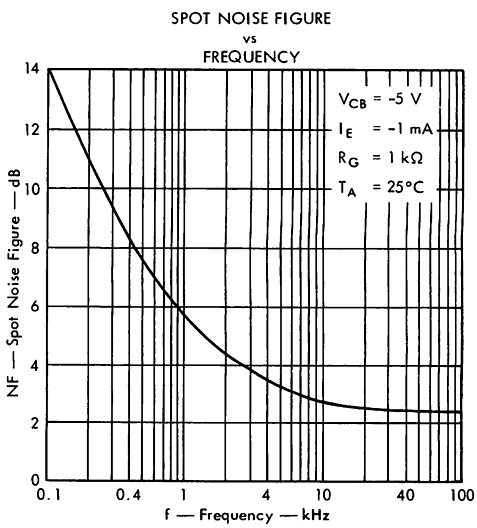


FIGURE 4

TYPICAL CHARACTERISTICS

NORMALIZED STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

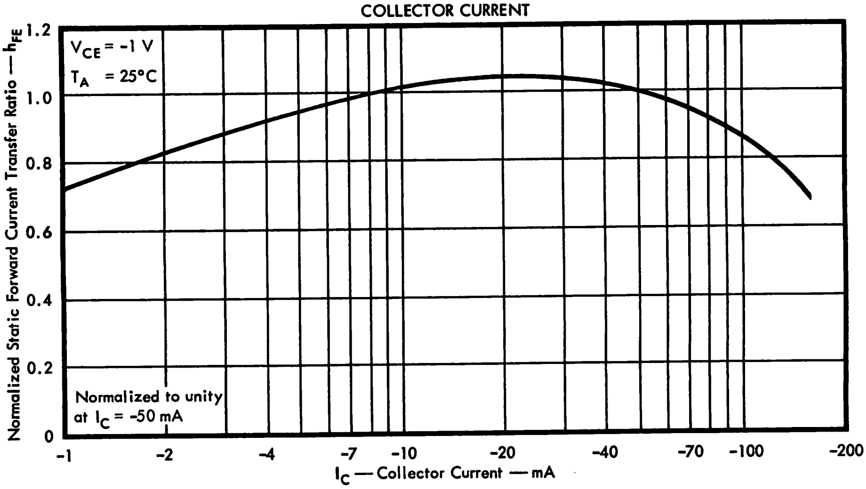


FIGURE 5

NORMALIZED STATIC FORWARD
CURRENT TRANSFER RATIO
vs
FREE-AIR TEMPERATURE

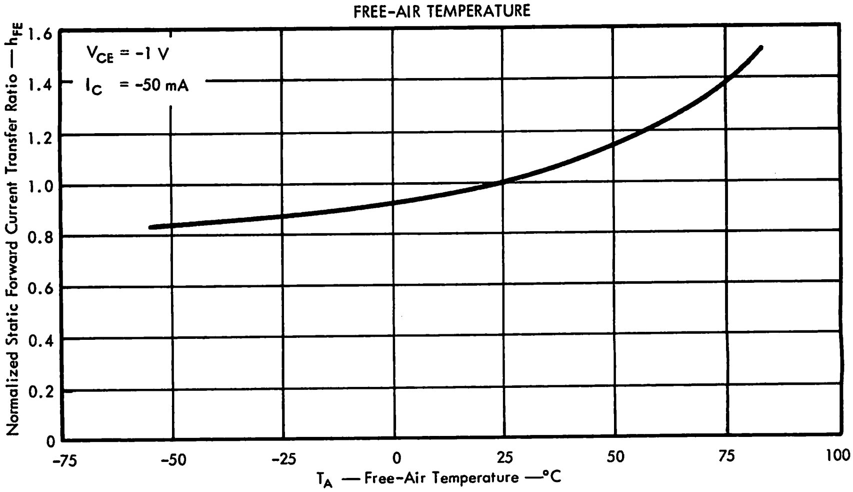


FIGURE 6

TYPES 2N1997, 2N1998, and 2N1999
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPES 2N1997, 2N1998, AND 2N1999
BULLETIN NO. DL-S 611879, AUGUST 1961

For Medium-Power Switching and General Purpose Applications

- **High Current Gain**
- **High Cutoff Frequency**
- **Guaranteed Switching Times**
- **Leads Isolated From Case**

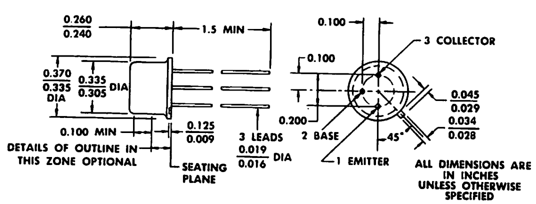
environmental tests

To ensure maximum reliability, stability, and long life, all units are aged at 100°C for 100 hours minimum prior to electrical characterization. All transistors are thoroughly tested for complete adherence to specified design characteristics. In addition, continuous qualification tests are made comprising temperature-humidity cycling, shock, and vacuum leak testing under rigid in-process control procedures.

mechanical data

Metal case with glass-to-metal hermetic seal between case and leads. Unit weight is approximately one gram. These units meet JEDEC outline TO-5.

ALL LEADS INSULATED FROM CASE



absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

	2N1997	2N1998	2N1999
Collector-Base Voltage	45 v	35 v	30 v
Collector-Emitter Voltage (see note 1)	40 v	35 v	20 v
Emitter-Base Voltage	45 v	30 v	20 v
Collector Current	500 ma	500 ma	500 ma
Base Current	50 ma	50 ma	50 ma
Total Device Dissipation (see note 2)	250 mw	250 mw	250 mw
Total Device Dissipation at 25°C Case (see note 3)	500 mw	500 mw	500 mw
Collector Junction Temperature	100°C	100°C	100°C
Storage Temperature Range	–65°C to +100°C	–65°C to +100°C	–65°C to +100°C

NOTES: 1. $V_{BE} = 0.3$ v
2. Derate 3.3 mw/°C above ambient temperature of 25°C.
3. Derate 6.6 mw/°C above case temperature of 25°C.

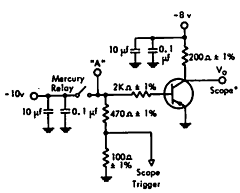
TYPES 2N1997, 2N1998, and 2N1999
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

electrical characteristics at 25°C ambient temperature

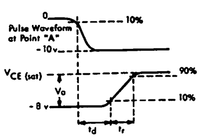
parameter		test conditions	2N1997 min	2N1997 typ	2N1997 max	2N1998 min	2N1998 typ	2N1998 max	2N1999 min	2N1999 typ	2N1999 max	unit
I_{CBO}	Collector reverse current	$V_{CB} = -1.5$ v, $I_E = 0$		−1.5	−5		−1.5	−5		−1.5	−5	μa
I_{CBO}	Collector reverse current	$V_{CB} = -15$ v, $I_E = 0$		−2.5	−6		−2.5	−6		−2.5	−6	μa
BV_{CBO}	Collector-base breakdown voltage	$I_C = -25\ \mu a$, $I_E = 0$	−45			−35			−30			v
BV_{CEX}	Collector-emitter breakdown voltage	$I_C = -100\ \mu a$, $V_{BE} = 0.3$ v	−40			−35			−20			v
BV_{EBO}	Emitter-base breakdown voltage	$I_E = -50\ \mu a$, $I_C = 0$	−45			−30			−20			v
h_{FE}	DC forward current transfer ratio	$V_{CE} = -1$ v, $I_C = -100$ ma	40	70	200	70	95	225	100	150	350	
h_{FE}	DC forward current transfer ratio	$V_{CE} = -1$ v, $I_C = -200$ ma				50	70	160	75	120	250	
V_{BE}	Base-emitter voltage	$I_B = -0.33$ ma, $I_C = -10$ ma		−0.26	−0.34	−0.15	−0.25	−0.34	−0.15	−0.24	−0.34	v
V_{BE}	Base-emitter voltage	$I_B = -6.6$ ma, $I_C = -200$ ma				−0.30	−0.56	−0.65	−0.30	−0.52	−0.65	v
$V_{CE(sat)}$	Collector-emitter saturation voltage	$I_B = -0.33$ ma, $I_C = -10$ ma		−0.10	−0.20		−0.07	−0.20		−0.06	−0.20	v
$V_{CE(sat)}$	Collector-emitter saturation voltage	$I_B = -6.6$ ma, $I_C = -200$ ma					−0.23	−0.35		−0.20	−0.35	v
$\|h_{fe}\|$	AC common-emitter forward current transfer ratio	$V_{CE} = -5$ v, $I_E = 3$ ma, f = 4 mc				1.4	2.0		2.5	4.0		
C_{ob}	Common-base output capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 mc		10	20		10	20		10	20	pf
f_{hfb}	Common-base alpha cutoff frequency	$V_{CB} = -5$ v, $I_E = 3$ ma	3	6			10			17		mc

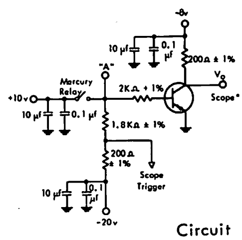
switching characteristics at 25°C ambient temperature

parameter		test conditions	2N1997 min	2N1997 typ	2N1997 max	2N1998 min	2N1998 typ	2N1998 max	2N1999 min	2N1999 type	2N1999 max	unit
t_d	Delay time	See Circuit A		0.040	0.060		0.040	0.060		0.030	0.060	μsec
t_r	Rise time	See Circuit A		0.250	0.300		0.180	0.240		0.110	0.175	μsec
t_s	Storage time	See Circuit B		0.440	0.750		0.430	0.750		0.390	0.750	μsec
t_f	Fall time	See Circuit B		0.200	0.400		0.150	0.330		0.090	0.185	μsec
t_T	Total switching time			0.930			0.800			0.620		μsec

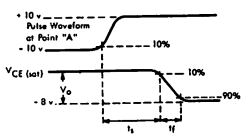


Circuit A





Circuit B



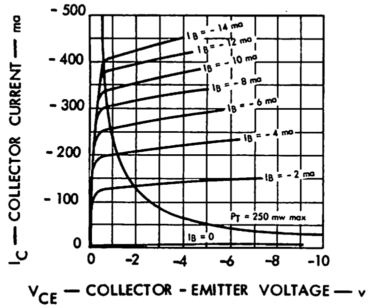
*Tektronix 541 scope with type CA plug-in, or equivalent. Maximum probe capacitance 15 pf.

TYPICAL COMMON-EMITTER COLLECTOR CHARACTERISTICS

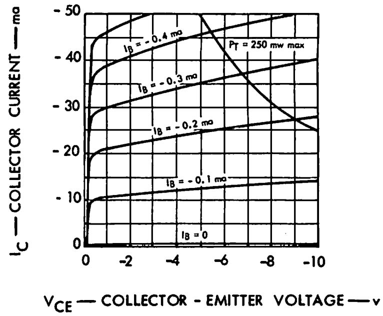
MEASURED ON TEKTRONIX 575 CURVE TRACER, $T_A = 25°C$

2N1997

HIGH - CURRENT REGION

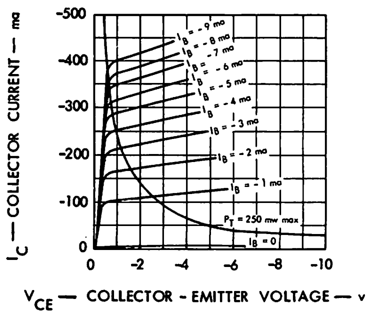


LOW - CURRENT REGION

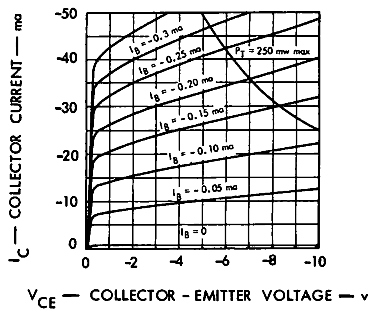


2N1998

HIGH - CURRENT REGION

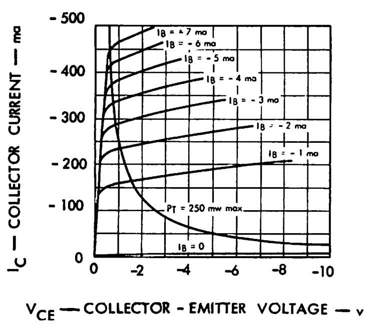


LOW - CURRENT REGION

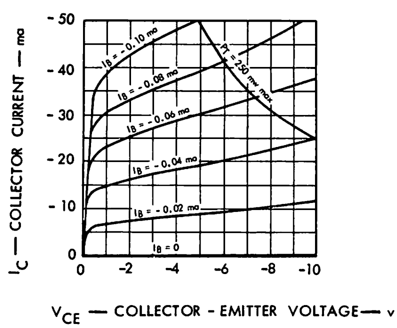


2N1999

HIGH - CURRENT REGION



LOW - CURRENT REGION



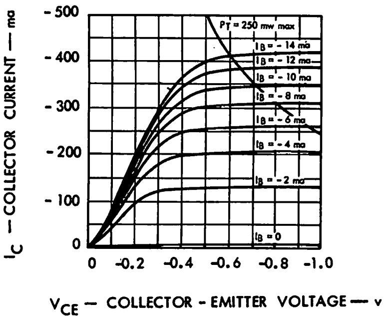
TYPES 2N1997, 2N1998, and 2N1999
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPICAL COMMON-EMITTER COLLECTOR CHARACTERISTICS

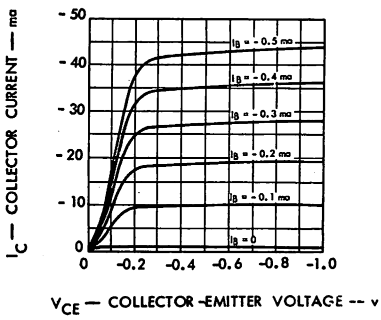
MEASURED ON TEKTRONIX 575 CURVE TRACER, $T_A = 25°C$

2N1997

HIGH - CURRENT SATURATION REGION

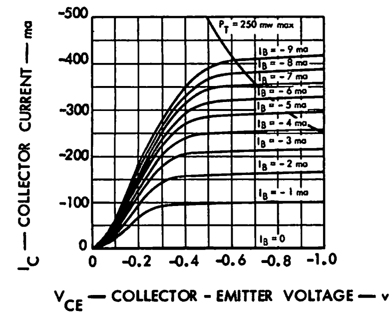


LOW - CURRENT SATURATION REGION

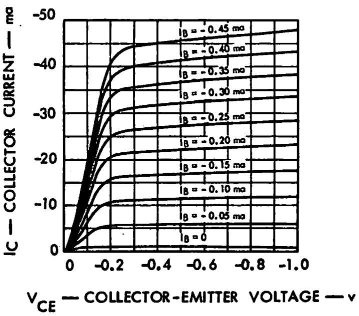


2N1998

HIGH - CURRENT SATURATION REGION

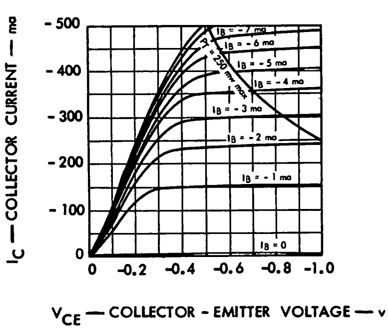


LOW - CURRENT SATURATION REGION

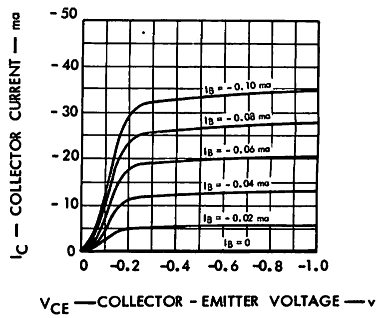


2N1999

HIGH - CURRENT SATURATION REGION

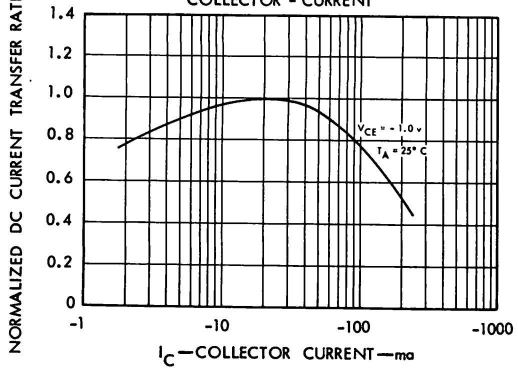


LOW - CURRENT SATURATION REGION

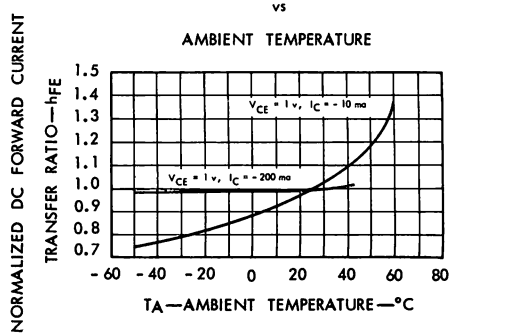


TYPICAL CHARACTERISTICS

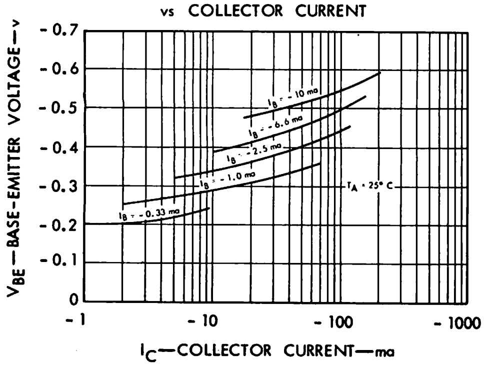
NORMALIZED DC FORWARD CURRENT
TRANSFER RATIO
vs
COLLECTOR - CURRENT



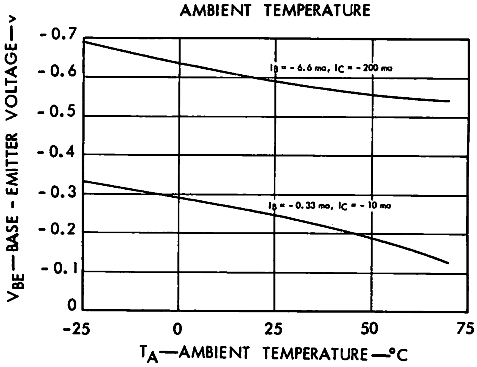
NORMALIZED DC FORWARD CURRENT TRANSFER RATIO
vs
AMBIENT TEMPERATURE



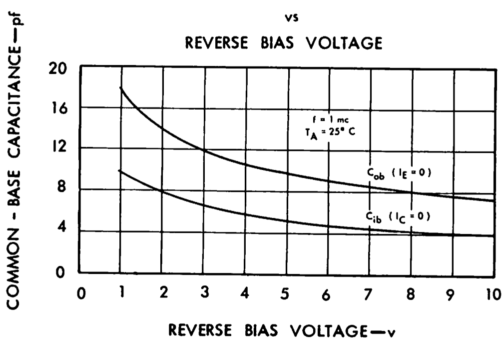
BASE - EMITTER VOLTAGE
vs COLLECTOR CURRENT



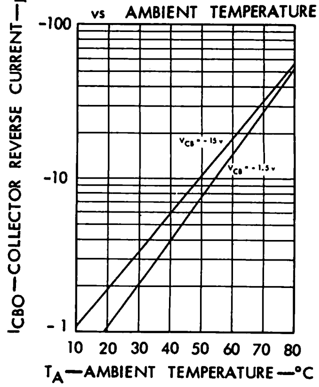
BASE - EMITTER VOLTAGE
vs
AMBIENT TEMPERATURE



COMMON - BASE INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE



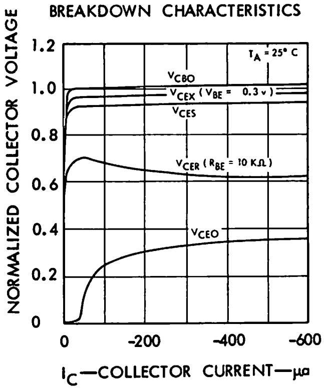
COLLECTOR REVERSE CURRENT
vs AMBIENT TEMPERATURE



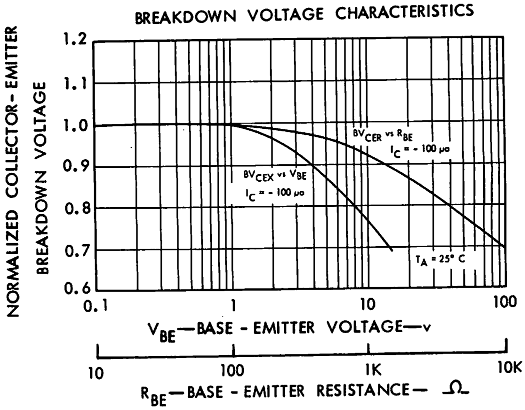
TYPES 2N1997, 2N1998, and 2N1999
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPICAL CHARACTERISTICS

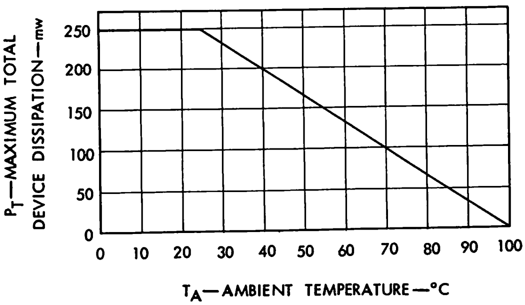
NORMALIZED COLLECTOR VOLTAGE
BREAKDOWN CHARACTERISTICS



NORMALIZED COLLECTOR - EMITTER
BREAKDOWN VOLTAGE CHARACTERISTICS



DISSIPATION DERATING CURVE



P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

TYPES 2N2000 AND 2N2001
BULLETIN NO. DL-S 651872, AUGUST 1961
REVISED OCTOBER 1965

High-Frequency Transistors for Computer and Switching Applications

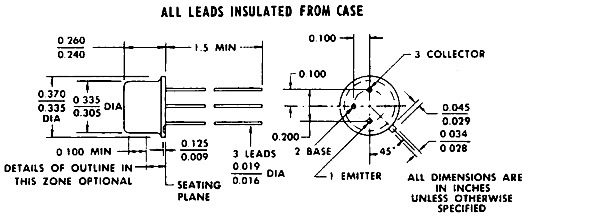
- **High Beta**
- **1 Amp Collector Current**
- **Guaranteed Switching Times**

environmental tests

To ensure maximum reliability, stability, and long life, all units are aged at 100°C for 100 hours minimum prior to electrical characterization. In addition, the hermetic seal is checked by a helium leak test to detect 50 x 10^{-8} standard cubic centimeters/second of helium. All transistors are thoroughly tested for complete adherence to specified electrical characteristics.

mechanical data

Metal case with glass-to-metal hermetic seal between case and leads. Unit weight is approximately 1 gram. These units meet JEDEC outline TO-5.



absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

	2N2000	2N2001	unit
Collector-Base Voltage	50	30	v
Emitter-Base Voltage	20	20	v
Collector Current	1	1	amp
Total Device Dissipation (see note)	300	300	mw
Collector Junction Temperature	100°C		
Storage Temperature Range	−65°C to 100°C		

NOTE: Derate 4.0 mw/°C above ambient temperature of 25°C. This is equivalent to a maximum power rating of 600 mw at a case temperature of 25°C.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N2000 and 2N2001
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS

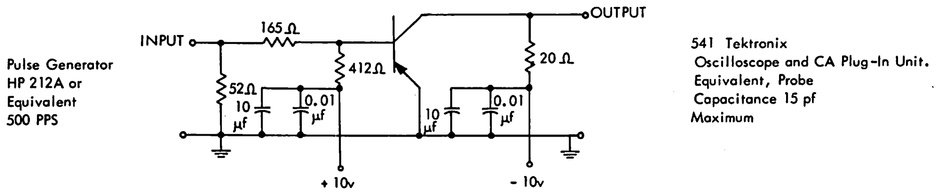
electrical characteristics at 25°C ambient temperature (unless otherwise noted)

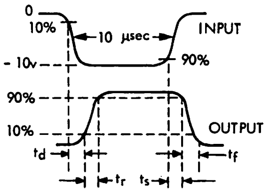
	parameter	test conditions	2N2000 min	2N2000 max	2N2001 min	2N2001 max	unit
I_{CBO}	Collector reverse current	$V_{CB} = -30$ v, $I_E = 0$ $V_{CB} = -15$ v, $I_E = 0$		−10		 −6	μa μa
BV_{CBO}	Collector-base breakdown voltage	$I_C = -100$ μa, $I_E = 0$	−50		−30		v
BV_{CEX}	Collector-emitter breakdown voltage	$I_C = -100$ μa, $V_{BE} = 0.5$ v	−50		−30		v
BV_{EBO}	Emitter-base breakdown voltage	$I_E = -100$ μa, $I_C = 0$	−20		−20		v
h_{FE}	DC forward current transfer ratio	$V_{CE} = -0.3$ v, $I_C = -100$ ma	50	300	100		
h_{FE}	DC forward current transfer ratio	$V_{CE} = -0.5$ v, $I_C = -500$ ma	50	300	60		
V_{BE}	Base-emitter voltage	$I_B = -2$ ma, $I_C = -100$ ma $I_B = -20$ ma, $I_C = -500$ ma	−0.2 −0.4	−0.4 −0.7	−0.2 −0.4	−0.4 −0.7	v v
$V_{CE(sat)}$	Collector-emitter saturation voltage	$I_B = -2$ ma, $I_C = -100$ ma $I_B = -20$ ma, $I_C = -500$ ma		−0.25 −0.35		−0.20 −0.35	v v
C_{ob}	Common-base output capacitance	$V_{CB} = -10$ v, $I_E = 0$, f = 1 mc		35		35	pf
f_{hfb}	Common-base alpha cutoff frequency	$V_{CB} = -5$ v, $I_E = 3$ ma	2		6		mc

switching characteristics (measured in switching test circuit shown below at 25°C ambient temp.)

	parameter	2N2000 min	2N2000 max	2N2001 min	2N2001 max	unit
t_d	Delay time		0.12		0.10	μsec
t_r	Rise time		0.70		0.60	μsec
t_s	Storage time		0.65		0.65	μsec
t_f	Fall time		0.75		0.65	μsec

SWITCHING CIRCUIT

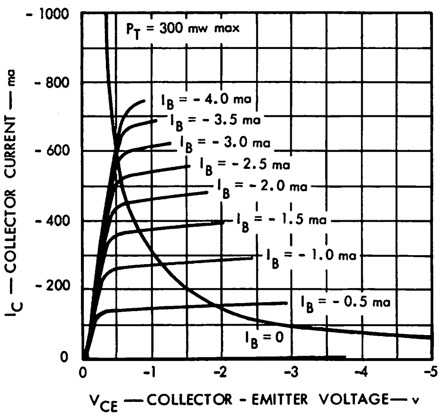




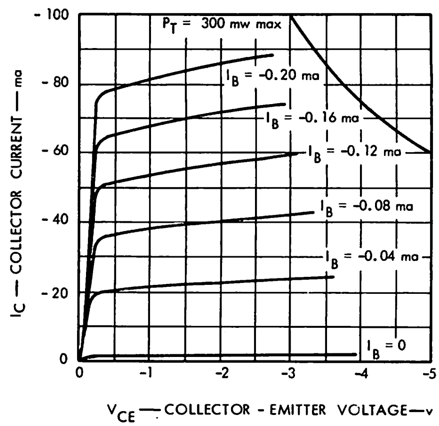
TYPICAL COMMON-EMITTER COLLECTOR CHARACTERISTICS AT 25°C AMBIENT TEMPERATURE AS MEASURED ON TEKTRONIX 575 CURVE TRACER

2N2000

HIGH - CURRENT REGION

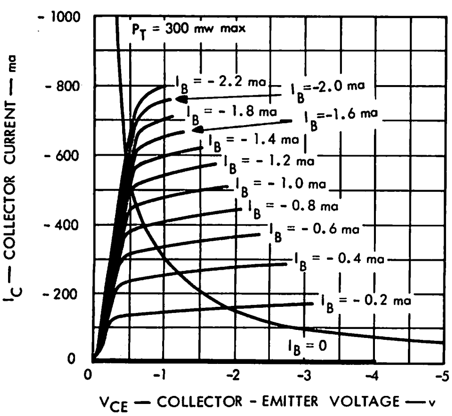


LOW - CURRENT REGION

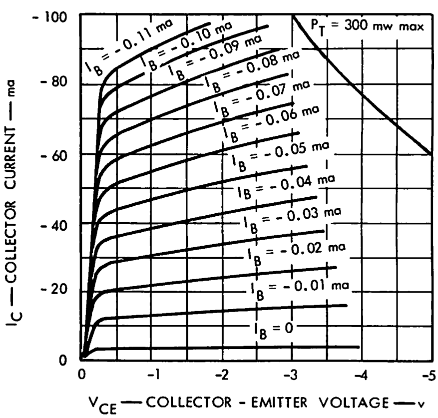


2N2001

HIGH - CURRENT REGION



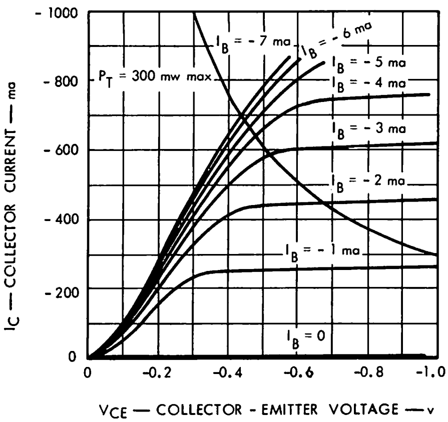
LOW - CURRENT REGION



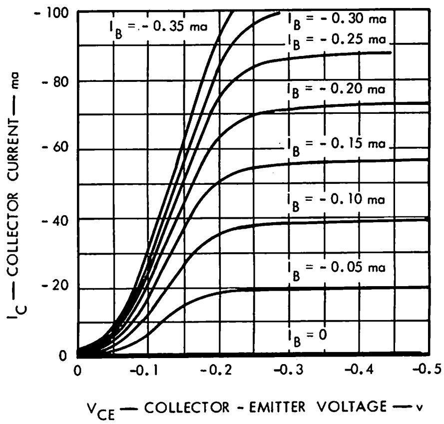
TYPICAL COMMON-EMITTER COLLECTOR CHARACTERISTICS AT 25°C AMBIENT TEMPERATURE AS MEASURED ON TEKTRONIX 575 CURVE TRACER

2N2000

HIGH - CURRENT SATURATION REGION

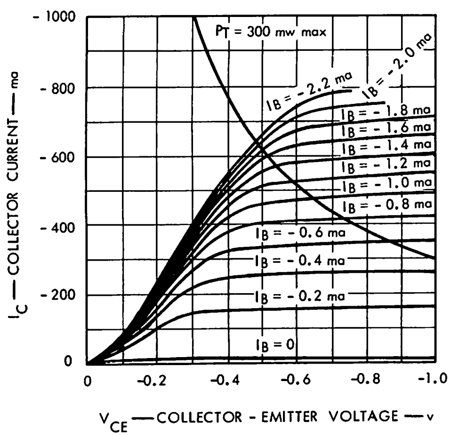


LOW - CURRENT SATURATION REGION

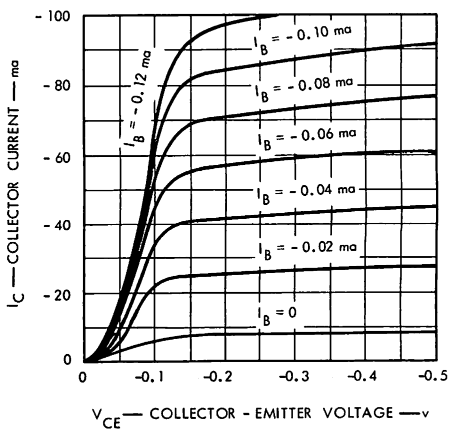


2N2001

HIGH - CURRENT SATURATION REGION

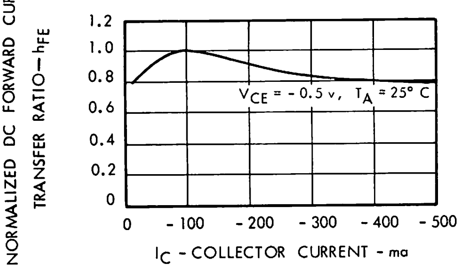


LOW - CURRENT SATURATION REGION

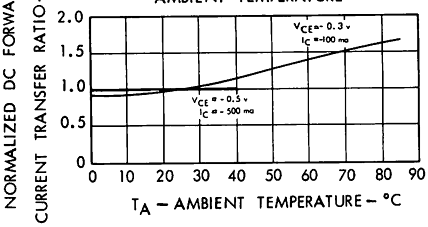


TYPICAL CHARACTERISTICS

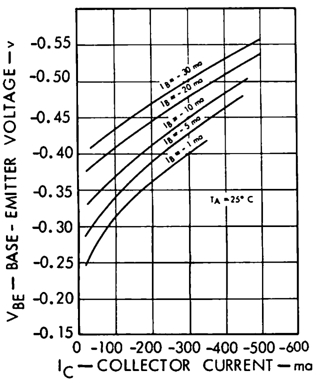
NORMALIZED DC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



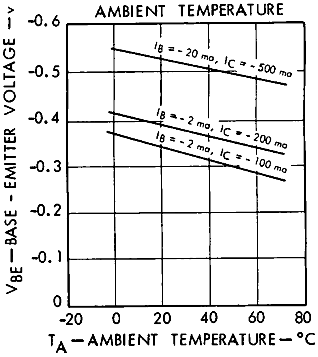
NORMALIZED DC FORWARD CURRENT TRANSFER RATIO
vs
AMBIENT TEMPERATURE



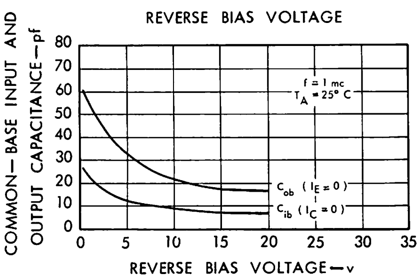
BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT



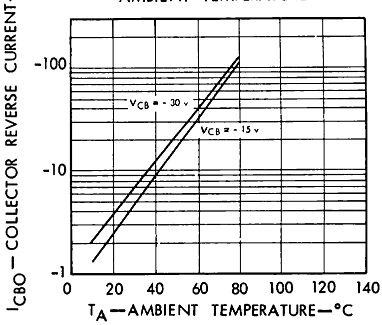
BASE-EMITTER VOLTAGE
vs
AMBIENT TEMPERATURE



COMMON-BASE INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

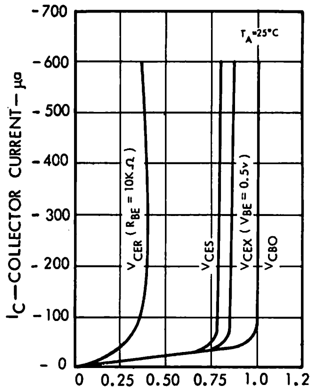


COLLECTOR REVERSE CURRENT
vs
AMBIENT TEMPERATURE

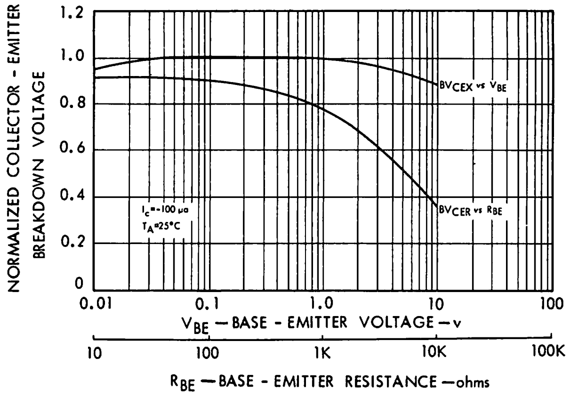


TYPES 2N2000 and 2N2001
P-N-P ALLOY-JUNCTION GERMANIUM TRANSISTORS
TYPICAL CHARACTERISTICS

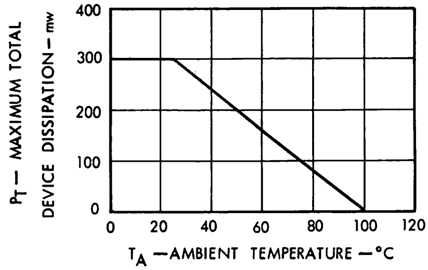
NORMALIZED COLLECTOR VOLTAGE CHARACTERISTICS



NORMALIZED COLLECTOR - EMITTER BREAKDOWN VOLTAGE CHARACTERISITCS



DISSIPATION DERATING CURVE



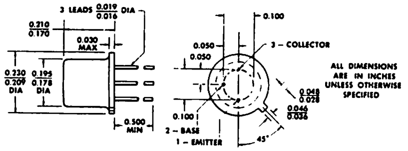
TYPE 2N797
N-P-N DIFFUSED-BASE MESA GERMANIUM TRANSISTOR

TYPE 2N797
BULLETIN NO. DL-S 612267, FEBRUARY 1962
REVISED OCTOBER 1966

VERY-HIGH-SPEED SWITCHING TRANSISTOR

Guaranteed Total Switching Time —120 nsec Maximum at 10 ma
Guaranteed $V_{CE(sat)}$ — 0.14 v Maximum at 10 ma
Guaranteed $V_{CE(sat)}$ — 0.35 v Maximum at 50 ma
Guaranteed f_T — 600 mc Minimum
Complementary to Ultra-High-Speed P-N-P Germanium Switching Transistors

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	20 v
Collector-Emitter Voltage (See note 1)	7 v
Emitter-Base Voltage	4 v
Collector Current	150 ma
Total Device Dissipation at 25°C Free-Air Temperature (See note 2)	150 mw
Collector Junction Operating Temperature	100°C
Storage Temperature Range	−65°C to +100°C

electrical characteristics at 25°C free-air temperature

parameter		test conditions		*min	typ	*max	unit
I_{CBO}	Collector Cutoff Current	$V_{CB} = 10$ v,	$I_E = 0$		0.1	1.0	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 1$ v,	$I_C = 0$		0.1	1.0	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 4$ v,	$I_C = 0$			100	μa
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 100$ μa,	$I_E = 0$	20			v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 5$ ma,	$I_B = 0$	7.0			v
h_{FE}	DC Forward Current Transfer Ratio	$V_{CE} = 0.25$ v,	$I_C = 10$ ma	40	75		
h_{FE}	DC Forward Current Transfer Ratio	$V_{CE} = 0.5$ v,	$I_C = 50$ ma	40	85		
V_{BE}	Base-Emitter Voltage	$I_B = 0.5$ ma,	$I_C = 10$ ma	0.30	0.38	0.44	v
V_{BE}	Base-Emitter Voltage	$I_B = 2.5$ ma,	$I_C = 50$ ma	0.40	0.58	0.72	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ ma,	$I_C = 10$ ma		0.10	0.14	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 2.5$ ma,	$I_C = 50$ ma		0.26	0.35	v
$\|h_{fe}\|$	AC Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ v, $f = 100$ mc	$I_C = 30$ ma	6.0	10		
C_{cb}	Collector-Base Capacitance †	$V_{CB} = 5$ v, $f = 1$ mc	$I_E = 0$		3.0	4.0	pf

NOTES: 1. This value applies when the emitter-base diode is open-circuited. This value can be exceeded in applications where the dc circuit resistance (R_{BE}) between base and emitter is a finite value.

2. Derate linearly to 100°C free-air temperature at the rate of 2 mw/°C.

† Collector-Base Capacitance is measured using three-terminal measurement techniques with the emitter guarded.

The device is capable of 300mw dissipation at 25°C case temperature. Derate linearly to 100°C case temperature at the rate of 4 mw/°C.

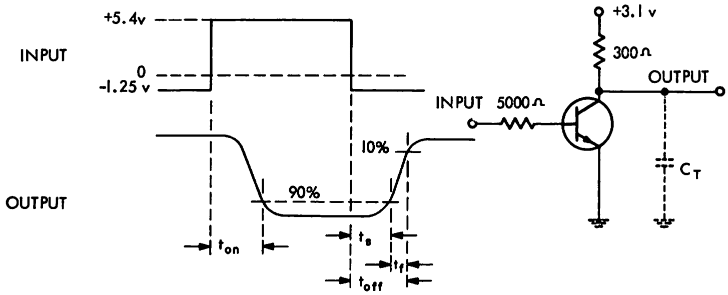
* Indicates JEDEC registered data.

TYPE 2N797
N-P-N DIFFUSED-BASE MESA GERMANIUM TRANSISTOR

switching characteristics at 25°C free-air temperature

parameter	*test conditions	approximate circuit conditions	typ	*max	unit
t_{on} Turn-on Time	See Figure 1	$V_{BE(0)} = -1.25$ v, $I_{B(1)} = 1$ ma, $I_C = 10$ ma (See note 3)	27	40	nsec
t_{off} Turn-off Time		$I_{B(1)} = 1$ ma, $I_{B(2)} = -0.33$ ma, $I_C = 10$ ma (See note 3)	60	80	nsec

SWITCHING CIRCUIT



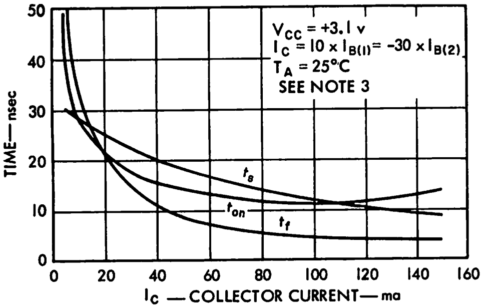
Input pulse rise time ≤ 1 nsec
Input pulse fall time ≤ 1 nsec
Input pulse width ≥ 200 nsec
Oscilloscope rise time ≤ 1 nsec
Total collector shunt capacitance (C_T) ≤ 6 pf

FIGURE I

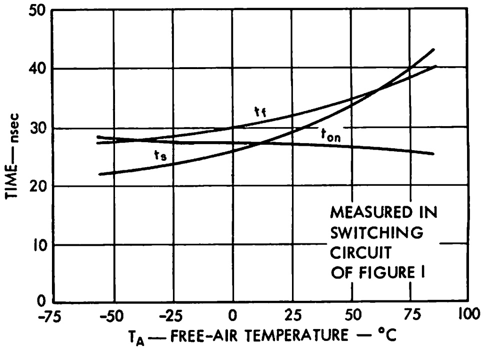
For accurate measurement of switching speed of this transistor, a mercury relay input pulse and sampling scope are required. Oscilloscope input resistance is approximately 100K; the input capacitance is approximately 3 pf.

TYPICAL CHARACTERISTICS

SWITCHING CHARACTERISTICS vs COLLECTOR CURRENT



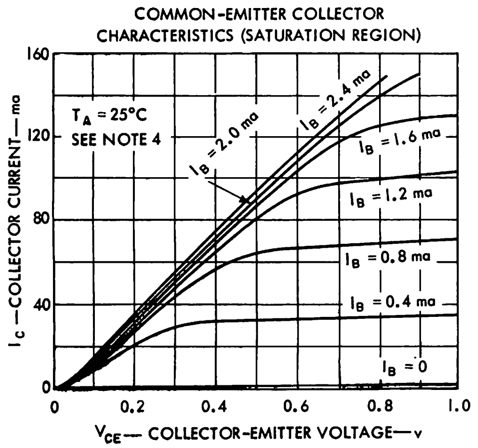
SWITCHING CHARACTERISTICS vs FREE-AIR TEMPERATURE

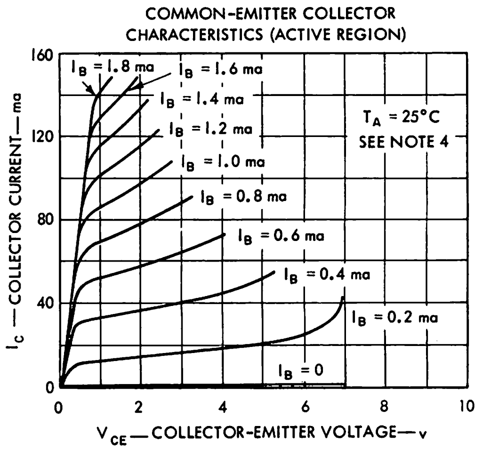


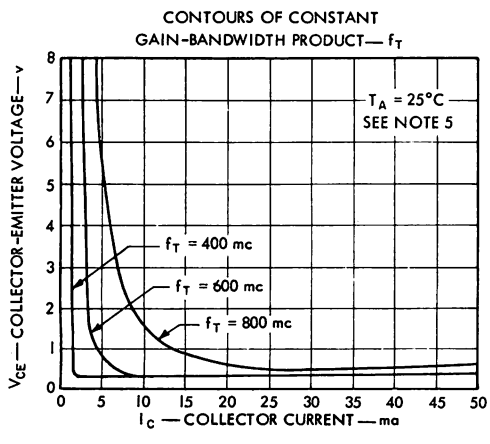
NOTE 3: Current calculations ($I_{B(1)}$, $I_{B(2)}$, and I_C) include the typical values of V_{BE} or $V_{CE(sat)}$ for appropriate values of collector current.
*Indicates JEDEC registered data.

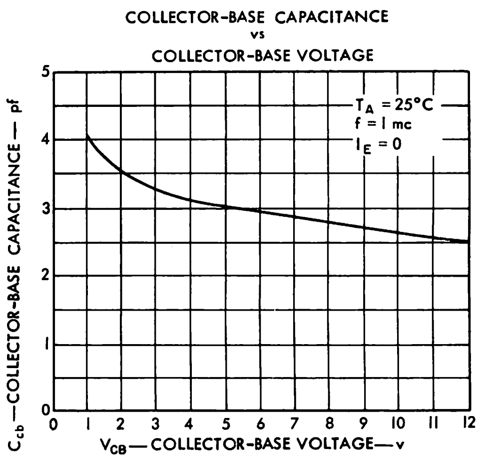
TYPE 2N797
N-P-N DIFFUSED-BASE MESA GERMANIUM TRANSISTOR

TYPICAL CHARACTERISTICS







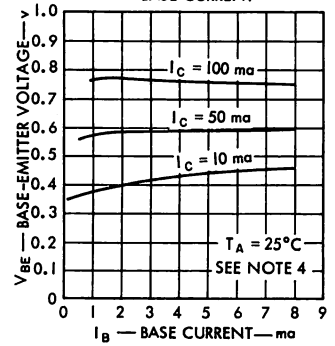


NOTES: 4. These parameters were measured using pulse techniques. PW = 300 μsec, duty cycle $\leq$ 2%.

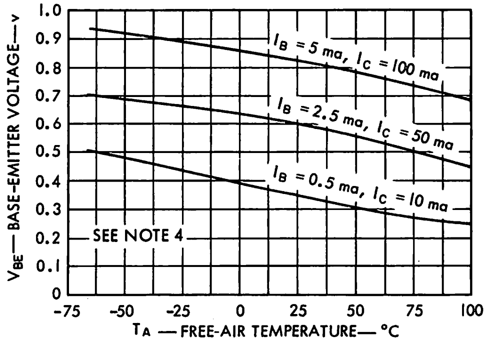
5. To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at −6 db/octave from f = 100 mc to the frequency at which $|h_{fe}|$ = 1.

TYPICAL CHARACTERISTICS

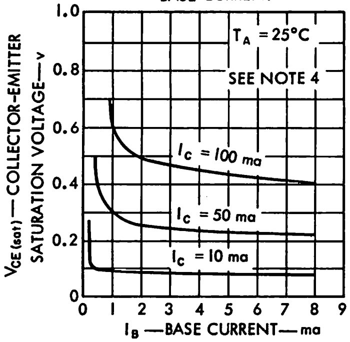
BASE-EMITTER VOLTAGE
vs
BASE CURRENT



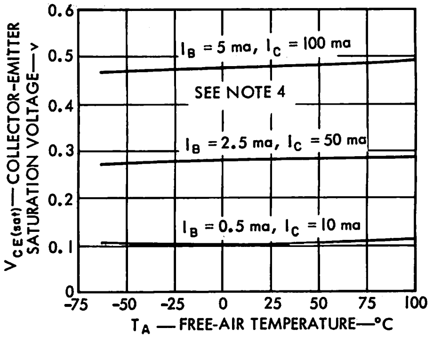
BASE-EMITTER VOLTAGE
vs
FREE-AIR TEMPERATURE



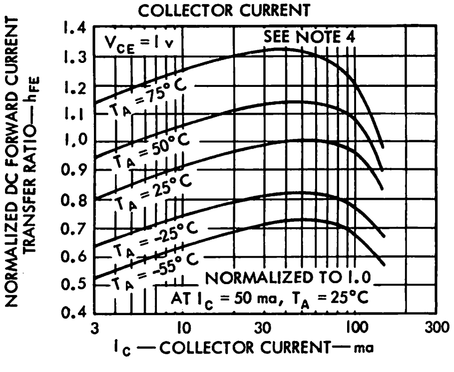
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
BASE CURRENT



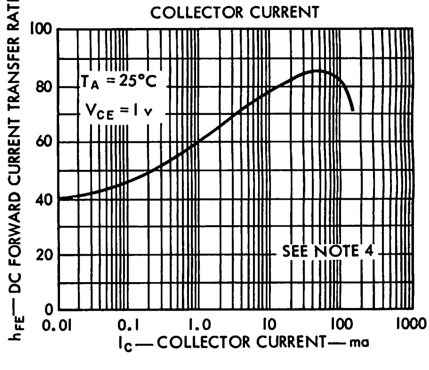
COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE



NORMALIZED DC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



DC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT



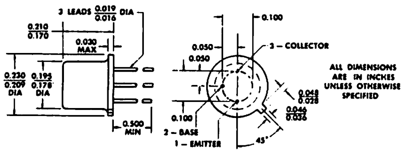
TYPES 2N960, 2N961, 2N962, 2N964, 2N965, 2N966
P-N-P EPITAXIAL DIFFUSED-BASE MESA GERMANIUM TRANSISTORS

TYPES 2N960, 2N961, 2N962, 2N964, 2N965, 2N966
BULLETIN NO. DL-S 622628, MAY 1962

FOR ULTRA-HIGH-SPEED SWITCHING APPLICATIONS

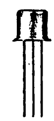
- **Epitaxial Process**
- **Rugged Mesa Construction**
- **Low $V_{CE(sat)}$ — Guaranteed at 10 ma, 50 ma, and 100 ma**
  Typically 0.11 v at 10 ma
- **Ultra-Fast-Switching Time — Guaranteed at 10 ma and 100 ma**
- **High f_T — Guaranteed Minimum of 300 mc, Typically 500 mc**

*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	2N960 2N964	2N961 2N965	2N962 2N966
Collector-Base Voltage	15 v	12 v	12 v
Collector-Emitter Voltage (See Note 1)	15 v	12 v	12 v
Collector-Emitter Voltage (See Note 2)	7 v	7 v	7 v
Emitter-Base Voltage	2.5 v	2.0 v	1.25 v
Collector Current	← 100 ma →		
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 150 mw →		
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 4)	← 300 mw →		
Operating Collector Junction Temperature	← 100°C →		
Storage Temperature Range	−65°C to +100°C		

quick-selection guide (for details see characteristics on pages 2 and 3)

TYPE	MINIMUM BV_{CBO}		MINIMUM h_{FE}		MAXIMUM t_{off}	
	15 v	12 v	40	20	60 nsec	75 nsec
2N960	•			•	•	
2N961		•		•	•	
2N962		•		•		•
2N964	•		•		•	
2N965		•	•		•	
2N966		•	•			•

NOTES: 1. This value applies when the emitter-base diode is short-circuited.
2. This value applies when the emitter-base diode is open-circuited.
3. Derate linearly to 100°C free-air temperature at the rate of 2 mw/C°.
4. Derate linearly to 100°C case temperature at the rate of 4 mw/C°.

*Indicates JEDEC registered data.

TYPES 2N960, 2N961, 2N962, 2N964, 2N965, 2N966
P-N-P EPITAXIAL DIFFUSED-BASE MESA GERMANIUM TRANSISTORS

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N960			2N961			2N962			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$	−15*			−12*			−12*			v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−2.5*			−2.0*			−1.25*			v
$V_{CEX(L)}$	Collector-Emitter Latching Voltage	$V_{CC} = -11.5$ v, $R_L = 220\ \Omega$ (See Figure 1, Page 3)	−11.5			−11.5			−11.5			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -6$ v, $I_E = 0$			−3.0*			−3.0*			−3.0*	μa
I_{CES}	Collector Cutoff Current	$V_{CE} = -15$ v, $V_{BE} = 0$			−100*							μa
		$V_{CE} = -12$ v, $V_{BE} = 0$						−100*			−100*	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ v, $I_C = 0$			−100*							μa
		$V_{EB} = -2.0$ v, $I_C = 0$						−100*				μa
		$V_{EB} = -1.25$ v, $I_C = 0$									−100*	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.3$ v, $I_C = -10$ ma	20*			20*			20*			
		$V_{CE} = -1$ v, $I_C = -50$ ma	20*			20*			20*			
		$V_{CE} = -1$ v, $I_C = -100$ ma	20*			20*			20*			
V_{BE}	Base-Emitter Voltage	$I_B = -1$ ma, $I_C = -10$ ma	−0.30*	−0.40	−0.50*	−0.30*	−0.40	−0.50*	−0.30*	−0.40	−0.50*	v
		$I_B = -5$ ma, $I_C = -50$ ma	−0.40*	−0.51	−0.75*	−0.40*	−0.51	−0.75*	−0.40*	−0.51	−0.75*	v
		$I_B = -10$ ma, $I_C = -100$ ma	−0.40*	−0.60	−1.00*	−0.40*	−0.60	−1.00*	−0.40*	−0.60	−1.25*	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ ma, $I_C = -10$ ma		−0.12	−0.20*		−0.12	−0.20*		−0.12	−0.20*	v
		$I_B = -5$ ma, $I_C = -50$ ma		−0.17	−0.40*		−0.17	−0.40*		−0.17	−0.40*	v
		$I_B = -10$ ma, $I_C = -100$ ma		−0.27	−0.70*		−0.27	−0.70*		−0.27	−0.70*	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CB} = -1$ v, $I_E = 20$ ma, f = 100 mc (See Note 5)	3.0*	5.0		3.0*	5.0		3.0*	5.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ v, $I_E = 0$, f = 1 mc		3.0	4.0*		3.0	4.0*		3.0	4.0*	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -1$ v, $I_C = 0$, f = 100 kc		2.0	3.5*		2.0	3.5*		2.0	3.5*	pf

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N964			2N965			2N966			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$	−15*			−12*			−12*			v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−2.5*			−2.0*			−1.25*			v
$V_{CEX(L)}$	Collector-Emitter Latching Voltage	$V_{CC} = -11.5$ v, $R_L = 220\ \Omega$ (See Figure 1, Page 3)	−11.5			−11.5			−11.5			v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -6$ v, $I_E = 0$			−3.0*			−3.0*			−3.0*	μa
I_{CES}	Collector Cutoff Current	$V_{CE} = -15$ v, $V_{BE} = 0$			−100*							μa
		$V_{CE} = -12$ v, $V_{BE} = 0$						−100*			−100*	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ v, $I_C = 0$			−100*							μa
		$V_{EB} = -2.0$ v, $I_C = 0$						−100*				μa
		$V_{EB} = -1.25$ v, $I_C = 0$									−100*	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.3$ v, $I_C = -10$ ma	40*			40*			40*			
		$V_{CE} = -1$ v, $I_C = -50$ ma	40*			40*			40*			
		$V_{CE} = -1$ v, $I_C = -100$ ma	40*			40*			40*			
V_{BE}	Base-Emitter Voltage	$I_B = -1$ ma, $I_C = -10$ ma	−0.30*	−0.40	−0.50*	−0.30*	−0.40	−0.50*	−0.30*	−0.40	−0.50*	v
		$I_B = -5$ ma, $I_C = -50$ ma	−0.40*	−0.51	−0.75*	−0.40*	−0.51	−0.75*	−0.40*	−0.51	−0.75*	v
		$I_B = -10$ ma, $I_C = -100$ ma	−0.40*	−0.60	−1.00*	−0.40*	−0.60	−1.00*	−0.40*	−0.60	−1.25*	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1$ ma, $I_C = -10$ ma		−0.11	−0.18*		−0.11	−0.18*		−0.11	−0.18*	v
		$I_B = -5$ ma, $I_C = -50$ ma		−0.16	−0.35*		−0.16	−0.35*		−0.16	−0.35*	v
		$I_B = -10$ ma, $I_C = -100$ ma		−0.26	−0.60*		−0.26	−0.60*		−0.26	−0.60*	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CB} = -1$ v, $I_E = 20$ ma, f = 100 mc (See Note 5)	3.0*	5.0		3.0*	5.0		3.0*	5.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ v, $I_E = 0$, f = 1 mc		3.0	4.0*		3.0	4.0*		3.0	4.0*	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -1$ v, $I_C = 0$, f = 100 kc		2.0	3.5*		2.0	3.5*		2.0	3.5*	pf

NOTE 5: This is equivalent to $f_T = 300$ mc minimum. To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at the rate of −6 db/octave from f = 100 mc to the frequency at which $|h_{fe}| = 1$.

* Indicates JEDEC registered data.

TYPES 2N960, 2N961, 2N962, 2N964, 2N965, 2N966
P-N-P EPITAXIAL DIFFUSED-BASE MESA GERMANIUM TRANSISTORS

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†			2N960 2N961 2N964 2N965		2N962 2N966		UNIT
					TYP	MAX	TYP	MAX	
t_{on}	Turn-On Time	$I_C = -10$ ma,	$I_{B(1)} = -1$ ma	See Figure 3	22	30	22	30	nsec
		$V_{BE(off)} = +1.25$ v,	$R_L = 300\ \Omega$	See Figure 4		50*		50*	nsec
		$I_C = -100$ ma,	$I_{B(1)} = -5$ ma	See Figure 5	15	30	15	30	nsec
		$V_{BE(off)} = +1.25$ v,	$R_L = 50\ \Omega$	See Figure 6		50*		50*	nsec
t_{off}	Turn-Off Time	$I_C = -10$ ma,	$I_{B(1)} = -1$ ma	See Figure 3	48	60	55	75	nsec
		$I_{B(2)} = +0.25$ ma,	$R_L = 300\ \Omega$	See Figure 4		85*		100*	nsec
		$I_C = -100$ ma,	$I_{B(1)} = -5$ ma	See Figure 5	40	60	42	75	nsec
		$I_{B(2)} = +1.25$ ma,	$R_L = 50\ \Omega$	See Figure 6		85*		100*	nsec
Q_T	Total Control Charge	$I_C = -10$ ma,	$I_{B(1)} = -1$ ma	See Figure 7		80*		90*	pcb
		$I_C = -100$ ma,	$I_{B(1)} = -5$ ma	See Figure 8		125*		150*	pcb

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

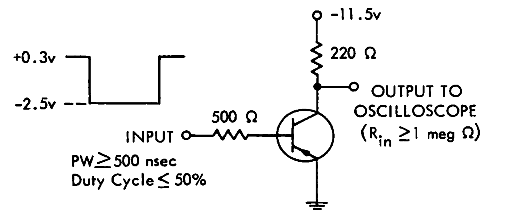


FIGURE 1 — COLLECTOR-EMITTER LATCHING VOLTAGE TEST CIRCUIT

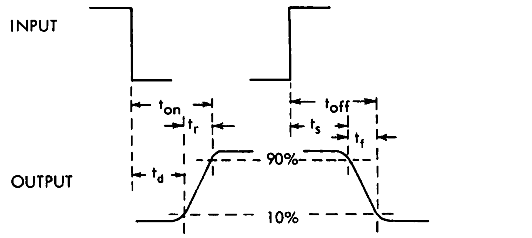


FIGURE 2 — VOLTAGE WAVEFORM DETAILS FOR 10 ma AND 100 ma (I_C) SWITCHING CIRCUITS

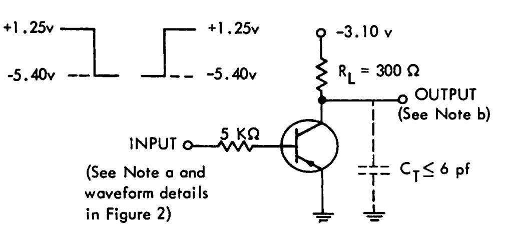


FIGURE 3 — 10 ma (I_C) SWITCHING CIRCUIT

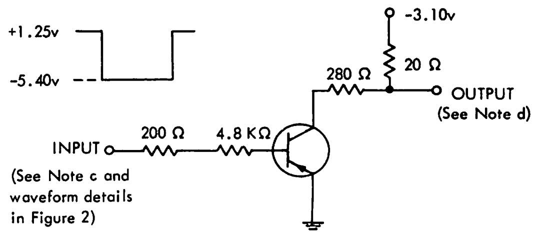


*FIGURE 4 — 10 ma (I_C) SWITCHING CIRCUIT

NOTES: a. The input waveforms in Figures 3 and 5 have the following characteristics: $t_r \leq 1$ nsec, $t_f \leq 1$ nsec, PW ≥ 200 nsec.

b. Waveforms in Figures 3 and 5 are monitored on an oscilloscope with the following characteristics: $t_r \leq 1$ nsec, $R_{in} \geq 100$ K Ω, $C_{in} \leq 3$ pf. The input impedance of the oscilloscope is included in the values shown for R_L, Total Collector Load Resistance, and C_T, Total Collector Shunt Capacitance.

c. The input waveforms in Figures 4 and 6 are supplied by a generator with the following characteristics: $t_r \leq 2$ nsec, $t_f \leq 2$ nsec, $Z_{out} = 50\ \Omega$

d. Waveforms in Figures 4 and 6 are monitored on an oscilloscope with the following characteristics: $t_r \leq 10$ nsec, $R_{in} \geq 1$ meg Ω, $C_{in} \leq 20$ pf.

e. All resistors ± 1% tolerance.

*Indicates JEDEC registered data.

PARAMETER MEASUREMENT INFORMATION

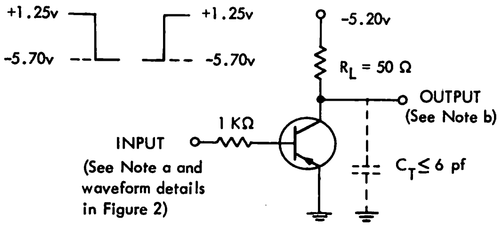
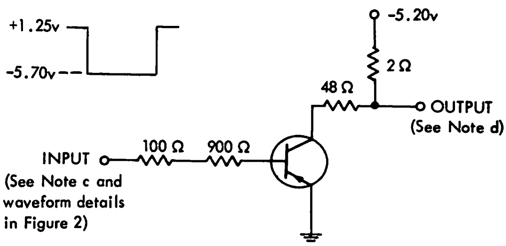
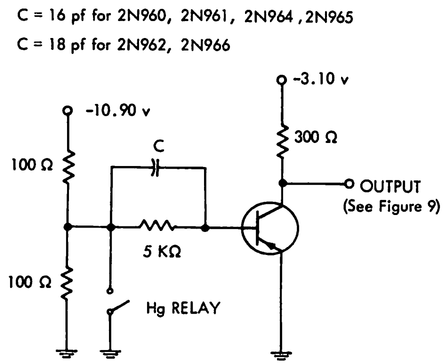


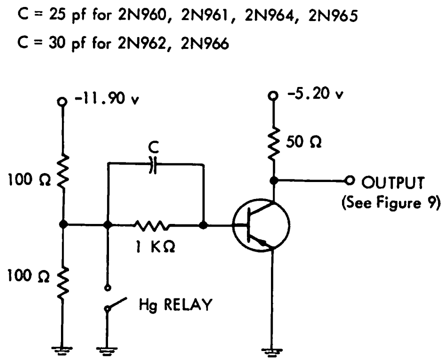
FIGURE 5 — 100 ma (I_C) SWITCHING CIRCUIT



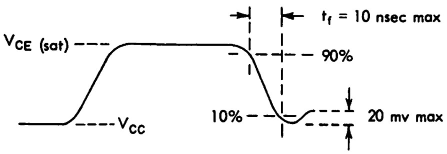
•FIGURE 6 — 100 ma (I_C) SWITCHING CIRCUIT



•FIGURE 7 — 10 ma (I_C) TOTAL CONTROL CHARGE TEST CIRCUIT



•FIGURE 8 — 100 ma (I_C) TOTAL CONTROL CHARGE TEST CIRCUIT



The output waveform is viewed on an oscilloscope with the following characteristics: $t_r \leq 3.5$ nsec, $R_{in} \geq 100K\Omega$, $C_{in} \leq 10$ pf

FIGURE 9 — OUTPUT VOLTAGE WAVEFORM DETAILS FOR TOTAL CONTROL CHARGE CIRCUITS

•Indicates JEDEC registered data.

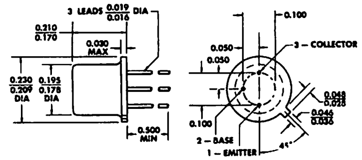
TYPE 2N2635
P-N-P EPITAXIAL DIFFUSED-BASE MESA GERMANIUM TRANSISTOR

TYPE 2N2635
BULLETIN NO. DL-S 633341, JANUARY 1963

FOR HIGH-VOLTAGE, HIGH-SPEED SWITCHING APPLICATIONS

- **EPITAXIAL PROCESS**
- **RUGGED MESA CONSTRUCTION**
- **BV_{CBO} — GUARANTEED 30 v**
- **HIGH SPEED — GUARANTEED t_T OF 300 nsec**

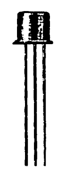
*mechanical data



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

All JEDEC TO-18 dimensions and notes are applicable.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

* Collector-Base Voltage	30 v
* Collector-Emitter Voltage (See Note 1)	15 v
* Emitter-Base Voltage	2.5 v
* Collector Current	100 ma
* Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	150 mw
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	300 mw
* Storage Temperature Range	−65°C to +100°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	*MIN	*MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -100\ \mu a$, $I_E = 0$	−30		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -2$ ma, $I_B = 0$	−15		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu a$, $I_C = 0$	−2.5		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -25$ v, $I_E = 0$		−5	μa
		$V_{CB} = -25$ v, $I_E = 0$, $T_A = +55°C$		−20	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -1$ v, $I_C = 0$		−20	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ v, $I_C = -10$ ma	30		
		$V_{CE} = -1$ v, $I_C = -50$ ma	45	300	
		$V_{CE} = -1$ v, $I_C = -50$ ma, $T_A = -55°C$	25		
		$V_{CE} = -1$ v, $I_C = -100$ ma	30		
V_{BE}	Base-Emitter Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma		−0.45	v
		$I_B = -2.5$ ma, $I_C = -50$ ma		−0.70	v
		$I_B = -2.5$ ma, $I_C = -50$ ma, $T_A = -55°C$		−0.85	v
		$I_B = -10$ ma, $I_C = -100$ ma		−0.90	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ ma, $I_C = -10$ ma		−0.20	v
		$I_B = -2.5$ ma, $I_C = -50$ ma		−0.40	v
		$I_B = -2.5$ ma, $I_C = -50$ ma, $T_A = +55°C$		−0.45	v
		$I_B = -10$ ma, $I_C = -100$ ma		−0.75	v
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -2$ v, $I_C = -30$ ma, f = 100 mc	1.5		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -5$ v, $I_E = 0$, f = 1 mc		5.0	pf
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = -1$ v, $I_C = 0$, f = 1 mc		4.0	pf

*Indicates JEDEC registered data.

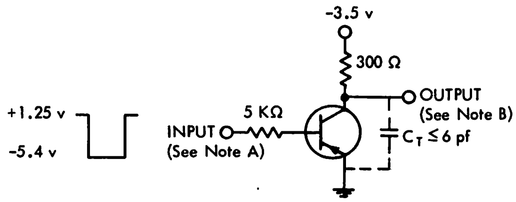
NOTES: 1. This value applies when the emitter-base diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 2 mw/C°.
3. Derate linearly to 100°C case temperature at the rate of 4 mw/C°.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS †	MIN	TYP	*MAX	UNIT
t_d	Delay Time	$I_C = -11$ ma, $I_{B(1)} = -1$ ma, $I_{B(2)} = +0.25$ ma, $V_{BE(off)} = 1.25$ v, $R_L = 300\ \Omega$ (See Figure 1)			20	nsec
t_r	Rise Time				30	nsec
t_s	Storage Time				185	nsec
t_f	Fall Time				65	nsec
t_{on}	Turn-on Time	$I_C = -40$ ma, $I_{B(1)} = -2.5$ ma, $V_{BE(off)} = 1.8$v (See Figure 2)		25		nsec
t_{off}	Turn-off Time	$I_C = -14$ ma, $I_{B(1)} = -2.5$ ma, $I_{B(2)} = 1.5$ ma (See Figure 3)		80		nsec

†Voltage and current values shown are nominal; exact values vary slightly with device parameters.

PARAMETER MEASUREMENT INFORMATION



* FIGURE 1 SWITCHING CIRCUIT

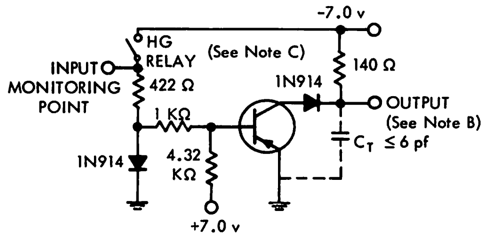


FIGURE 2 TDL NAND TURN-ON SWITCHING CIRCUIT SIMULATED FOR M = N = 3

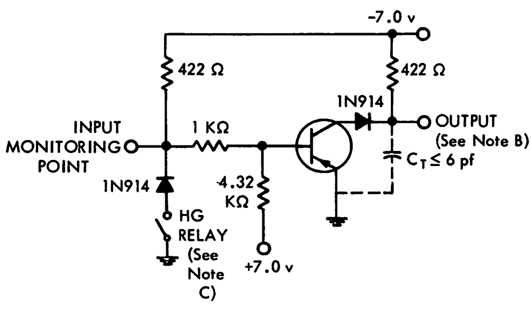


FIGURE 3 TDL NAND TURN-OFF SWITCHING CIRCUIT SIMULATED FOR M = N = 3

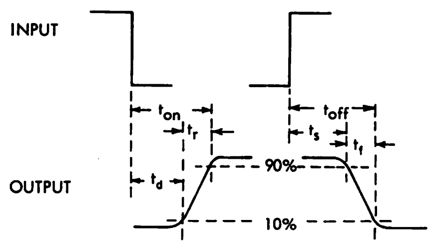


FIGURE 4 VOLTAGE WAVEFORM DETAILS FOR SWITCHING MEASUREMENTS

NOTES: A. The input waveform of Figure 1 has following characteristics: t_r and $t_f \leq 1$ nsec; PW $\geq 0.5\ \mu$sec; Duty cycle $\leq 50\%$.

B. Waveforms are monitored on equipment with following characteristics: $t_r \leq 3.5$ nsec; $R_{in} \geq 100$k Ω; $C_{in} \leq 3$pf; C_T, total output shunt capacitance, includes C_{in}.

C. Operating frequency is 60 cps.

*Indicates JEDEC registered data.

TYPES 2N5043, 2N5044
P-N-P EPITAXIAL PLANAR GERMANIUM TRANSISTORS

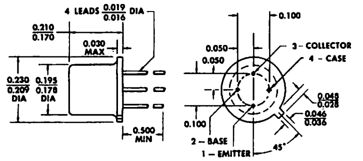
TYPES 2N5043, 2N5044
BULLETIN NO. DL-S 679705, MARCH 1967

FOR APPLICATIONS REQUIRING LOW NOISE FIGURE AND SUPERIOR SMALL-SIGNAL PERFORMANCE FROM VHF TO 1 GIGAHERTZ
(Improved Versions of TIXM101)
2N5043 Features

- **Guaranteed Noise Figure . . . 2.5 dB Max at 400 MHz**
- **Guaranteed f_T . . . 1.5 GHz Min**
- **Guaranteed 50-Ohm Insertion Power Gain $|S_{21e}|^2$ . . . 8.5 dB Min at 400 MHz**
- **Operation over the Entire Military Temperature Range . . . —65°C to 125°C**

***mechanical data**

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE



DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED

ALL JEDEC TO-72 DIMENSIONS
AND NOTES ARE APPLICABLE

***absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)**

Collector-Base Voltage	–15 V
Collector-Emitter Voltage (See Note 1)	–7 V
Emitter-Base Voltage	–0.3 V
Continuous Collector Current	–30 mA
Continuous Device Dissipation at (or below) 100°C Free-Air Temperature (See Note 2)	30 mW
Storage Temperature Range	–65°C to 125°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTES: 1. This value applies between 0 and 3 mA collector current when the emitter-base diode is open-circuited.
2. Derate linearly to 125°C free-air temperature at the rate of 1.2 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5043 MIN	2N5043 MAX	2N5044 MIN	2N5044 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$, $I_E = 0$	−15		−15		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -3$ mA, $I_B = 0$	−7		−7		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -100\ \mu A$, $I_C = 0$	−0.3		−0.3		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -10$ V, $I_E = 0$		−6		−6	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -3$ mA	15	150	15	150	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -3$ mA, f = 400 MHz	3.75	7.5	2.5	6.25	
$\|S_{21e}\|^2$	Unneutralized Small-Signal Common-Emitter Insertion Power Gain	$V_{CE} = -5$ V, $I_C = -3$ mA, $Z_G = Z_L = 50\ \Omega + j0$, f = 400 MHz	8.5	12.5	6.5	10.5	dB
C_{cb}	Collector-Base Capacitance	$V_{CB} = -5$ V, $I_E = 0$, f = 1 MHz, See Note 3	0.2	1	0.2	1	pF

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N5043 MIN	2N5043 MAX	2N5044 MIN	2N5044 MAX	UNIT
NF	Common-Emitter Spot Noise Figure	$V_{CB} = -5$ V, $I_E = 3$ mA, $R_G = 50\ \Omega$, f = 400 MHz, See Note 4	1	2.5	1	3.5	dB

NOTES: 3. C_{cb} is measured using three-terminal measurement techniques with the case and emitter guarded.

4. This noise figure measurement is made using a temperature-limited noise diode (Hewlett-Packard VHF Noise Source, Type 343A, or equivalent) operated according to the manufacturer's specification.

*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION

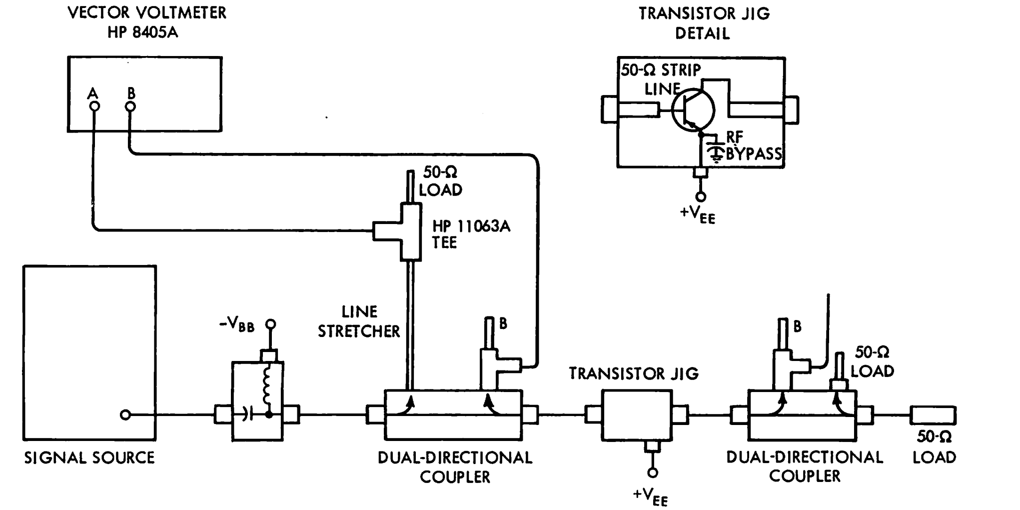


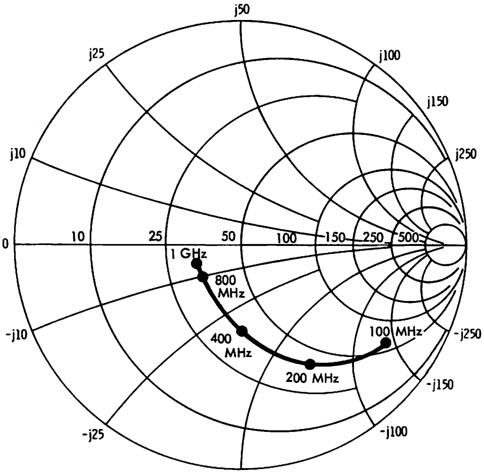
FIGURE 1–BLOCK DIAGRAM OF A TYPICAL S-PARAMETER MEASUREMENT SYSTEM

TYPICAL CHARACTERISTICS

SMALL-SIGNAL COMMON-EMITTER S PARAMETERS

$V_{CE} = -5$ V, $I_C = -3$ mA, $Z_G = Z_L = 50$ ohms $+ j0$, $T_A = 25°C$

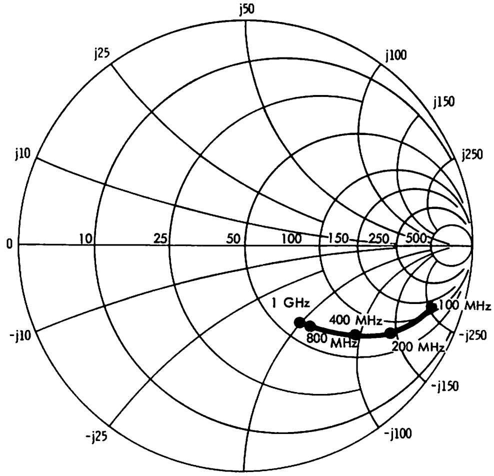
INPUT IMPEDANCE and
INPUT REFLECTION COEFFICIENT, S_{11e}



Coordinates in ohms

FIGURE 2

OUTPUT IMPEDANCE and
OUTPUT REFLECTION COEFFICIENT, S_{22e}



Coordinates in ohms

FIGURE 3

FORWARD TRANSFER COEFFICIENT, S_{21e}

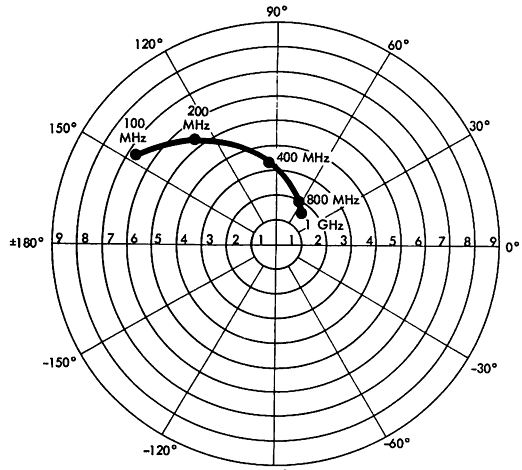


FIGURE 4

REVERSE TRANSFER COEFFICIENT, S_{12e}

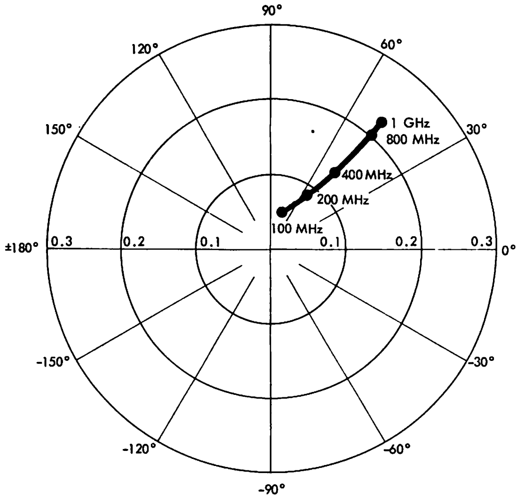


FIGURE 5

TYPICAL CHARACTERISTICS

GAIN
vs
FREQUENCY

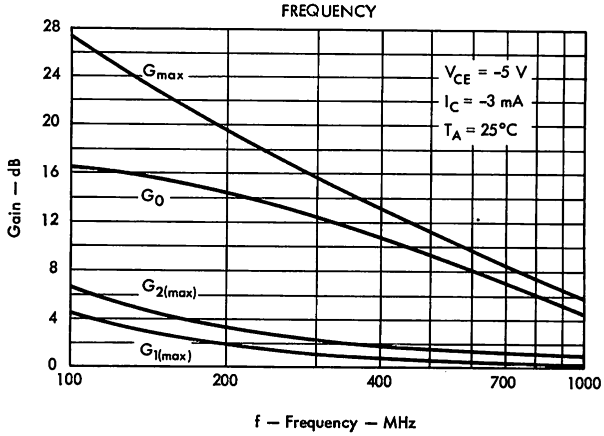


FIGURE 6

G_{max} is the gain equal to the sum of G_0, $G_{1(max)}$, and $G_{2(max)}$. G_{max} is achieved when the input and output of the transistor are terminated in the complex conjugates of S_{11e} and S_{22e} respectively. G_{max} is calculated using the expression:

$$G_{max} = 10 \log \frac{|S_{21e}|^2}{(1 - |S_{11e}|^2)(1 - |S_{22e}|^2)}$$

G_0 is the forward power gain with the input and output terminated in 50 ohms. G_0 is calculated using the expression:

$$G_0 = 10 \log |S_{21e}|^2$$

$G_{1(max)}$ is the additional power gain resulting from conjugately matching the generator to S_{11e}. $G_{1(max)}$ is calculated using the expression:

$$G_{1(max)} = 10 \log \frac{1}{1 - |S_{11e}|^2}$$

$G_{2(max)}$ is the additional power gain resulting from conjugately matching the load to S_{22e}. $G_{2(max)}$ is calculated using the expression:

$$G_{2(max)} = 10 \log \frac{1}{1 - |S_{22e}|^2}$$

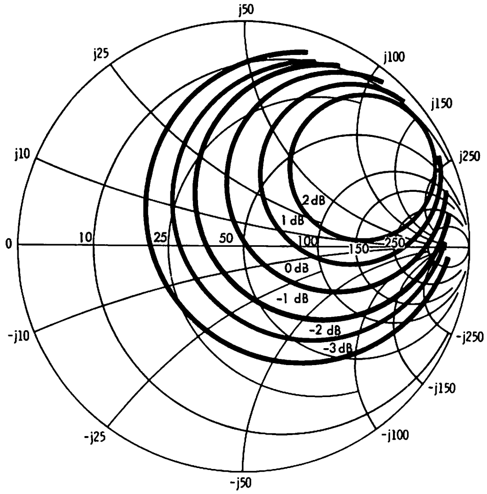
These expressions assume that the value of $|S_{12e}|$ is so small that its effect is negligible.
In general, gain is the sum of G_0, G_1, and G_2 and can be calculated from the data given in figures 6 through 14 when generator and load impedances are known.

TYPICAL CHARACTERISTICS

CIRCLES OF CONSTANT G_1

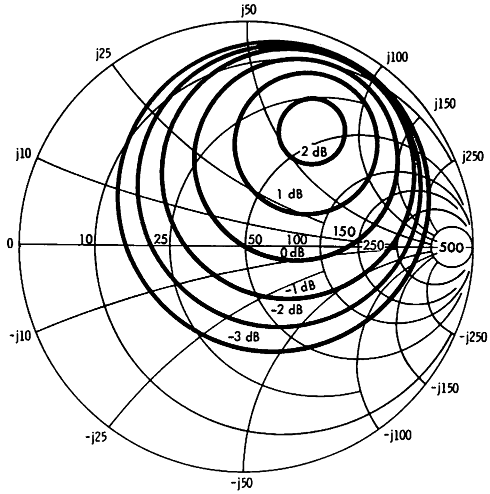
$V_{CE} = -5$ V, $I_C = -3$ mA, $T_A = 25°C$

Generator Impedances in Ohms



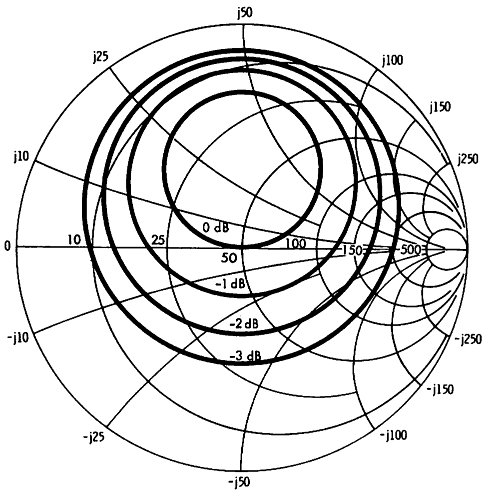
100 MHz

FIGURE 7



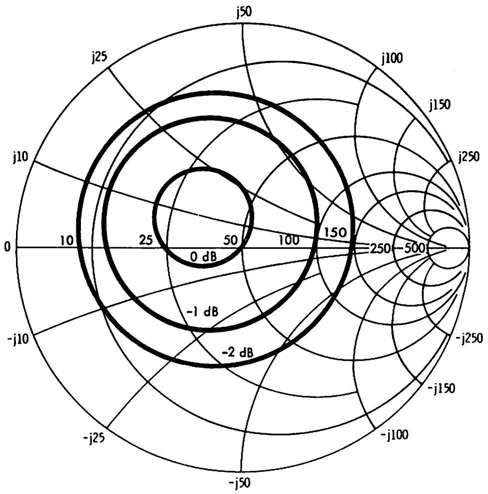
200 MHz

FIGURE 8



400 MHz

FIGURE 9

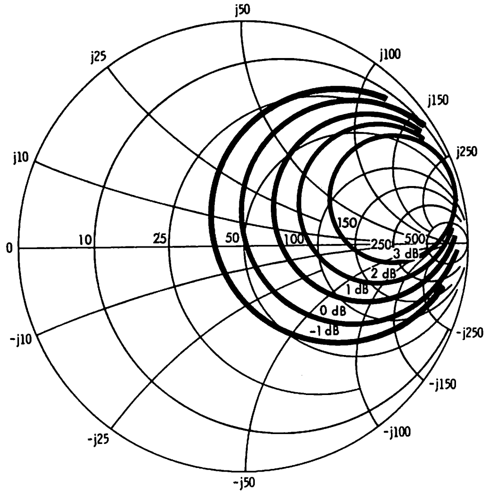


800 MHz

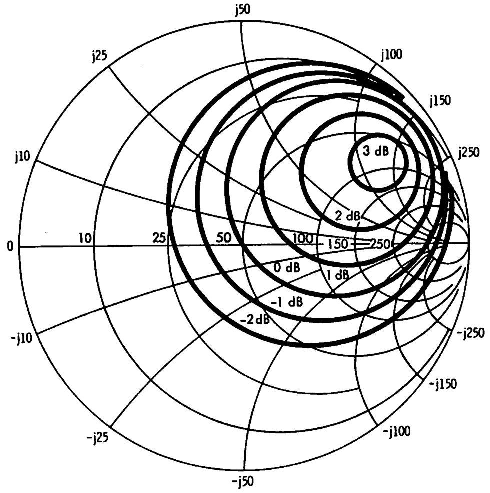
FIGURE 10

TYPICAL CHARACTERISTICS

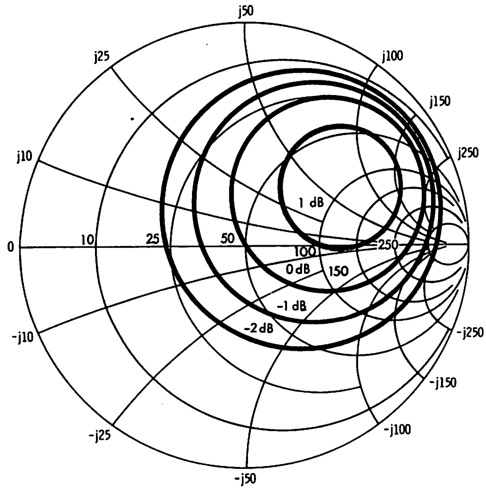
CIRCLES OF CONSTANT G_2
$V_{CE} = -5$ V, $I_C = -3$ mA, $T_A = 25°C$
Load Impedances in Ohms



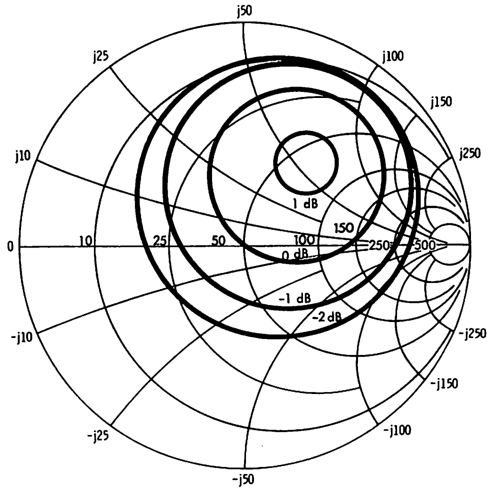
100 MHz
FIGURE 11



200 MHz
FIGURE 12



400 MHz
FIGURE 13



800 MHz
FIGURE 14

TYPICAL CHARACTERISTICS

CONTOURS OF CONSTANT SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO, $|h_{fe}|$

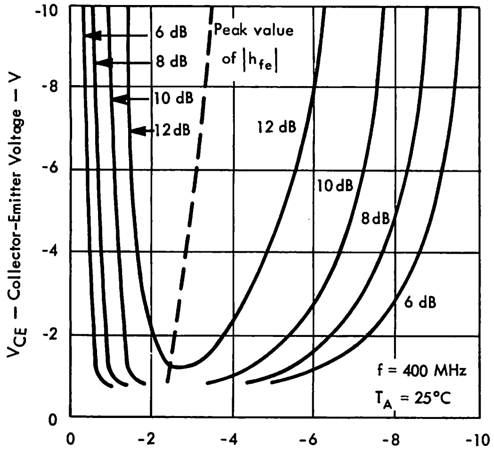


FIGURE 15

COMMON-EMITTER SPOT NOISE FIGURE
vs
FREQUENCY

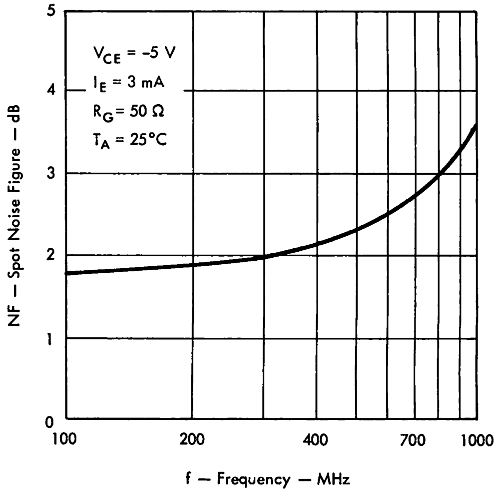


FIGURE 16

COMMON-EMITTER SPOT NOISE FIGURE DEVIATION
vs
FREE-AIR TEMPERATURE

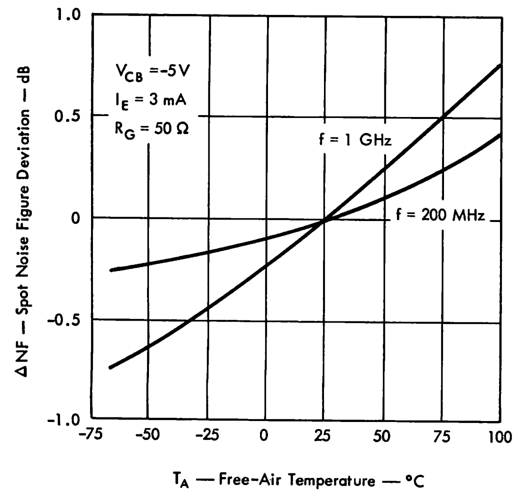


FIGURE 17

COMMON-EMITTER SPOT NOISE FIGURE
vs
EMITTER CURRENT

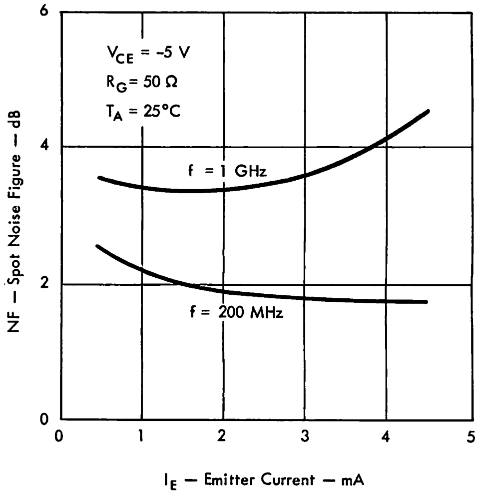


FIGURE 18

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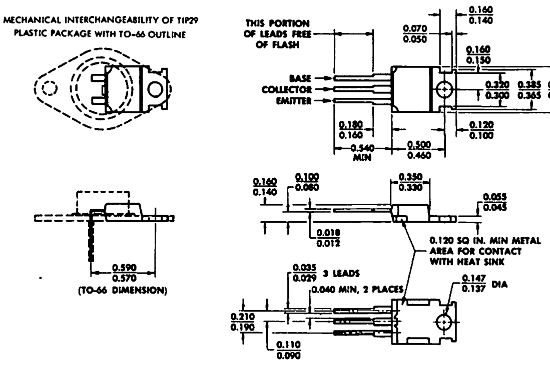
TYPES TIP29, TIP29A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP30, TIP30A

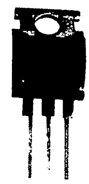
- **30 Watts at 25°C Case Temperature**
- **1 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 200 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP29	TIP29A
Collector-Base Voltage	40 V	60 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V
Emitter-Base Voltage	← 5 V →	
Continuous Collector Current	← 1 A →	
Continuous Base Current	← 0.4 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 30 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 2 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.24 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 16 mW/deg.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIP29, TIP29A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP29 MIN	TIP29 MAX	TIP29A MIN	TIP29A MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 4	40		60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.3		0.3	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = 40$ V, $V_{BE} = 0$		0.2			mA
		$V_{CE} = 60$ V, $V_{BE} = 0$				0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 0.2$ A, See Notes 4 and 5	40	200	40	200	
		$V_{CE} = 4$ V, $I_C = 1$ A, See Notes 4 and 5	10		10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 1$ A, See Notes 4 and 5		1.3		1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 125$ mA, $I_C = 1$ A, See Notes 4 and 5		0.7		0.7	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.2$ A, $f = 1$ kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.2$ A, $f = 1$ MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ μs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

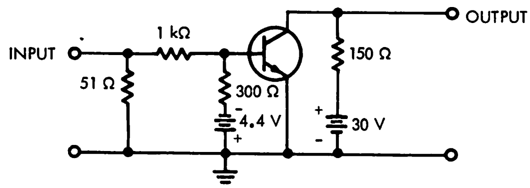
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	4.17	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

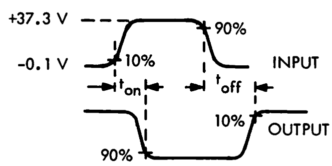
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 200$ mA, $I_{B(1)} = 20$ mA, $I_{B(2)} = -20$ mA,	0.35	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.4$ V, $R_L = 150\ \Omega$, See Figure 1	1.10	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

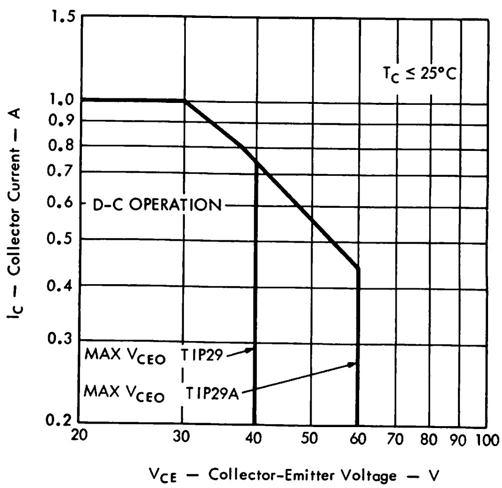


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

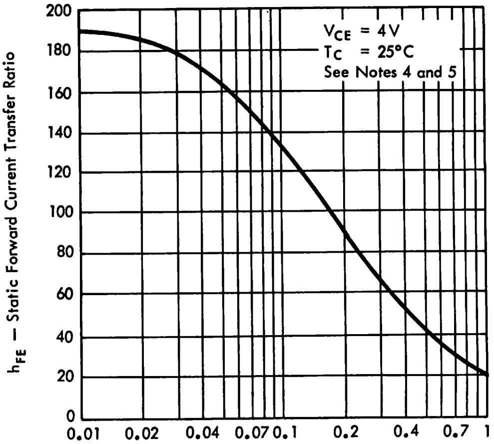


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

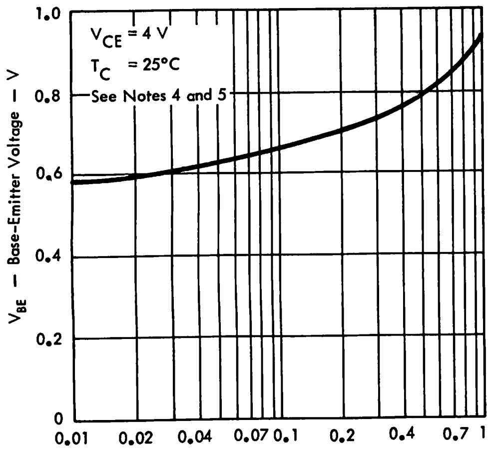


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

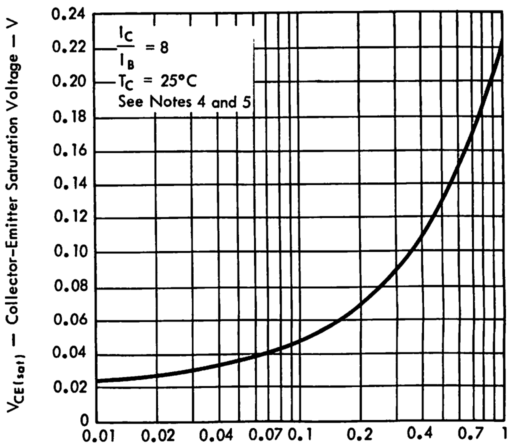


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES TIP30, TIP30A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

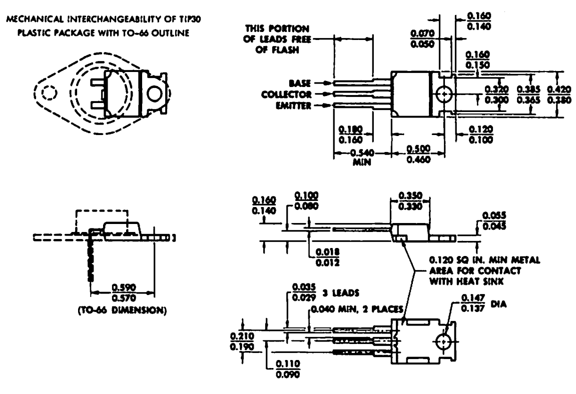
TYPES TIP30, TIP30A
BULLETIN NO. DL-S 6810956, JULY 1968

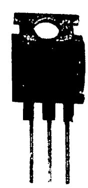
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP29, TIP29A

- **30 Watts at 25°C Case Temperature**
- **1 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 200 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP30	TIP30A
Collector-Base Voltage	−40 V	−60 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V
Emitter-Base Voltage	←— −5 V —→	
Continuous Collector Current	←— −1 A —→	
Continuous Base Current	←— −0.4 A —→	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	←— 30 W —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	←— 2 W —→	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	←— 260°C —→	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.24 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 16 mW/deg.

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TYPES TIP30, TIP30A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP30 MIN	TIP30 MAX	TIP30A MIN	TIP30A MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 4	−40		−60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.3		−0.3	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.2			mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -0.2$ A, See Notes 4 and 5	40	200	40	200	
		$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 4 and 5	10		10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 4 and 5		−1.3		−1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -125$ mA, $I_C = -1$ A, See Notes 4 and 5		−0.7		−0.7	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.2$ A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.2$ A, f = 1 MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

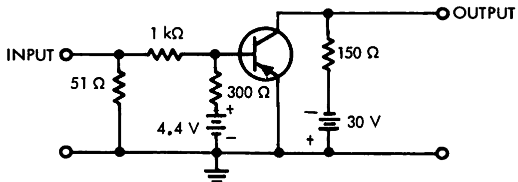
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	4.17	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	62.5	deg/W

switching characteristics at 25°C case temperature

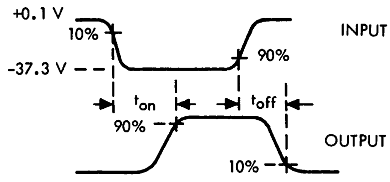
PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = -200$ mA,	$I_{B(1)} = -20$ mA,	$I_{B(2)} = 20$ mA,	0.25	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.4$ V,	$R_L = 150\ \Omega$,	See Figure 1	0.90	μs

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

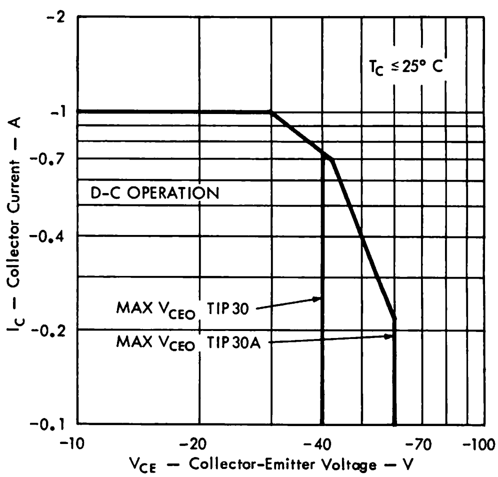


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

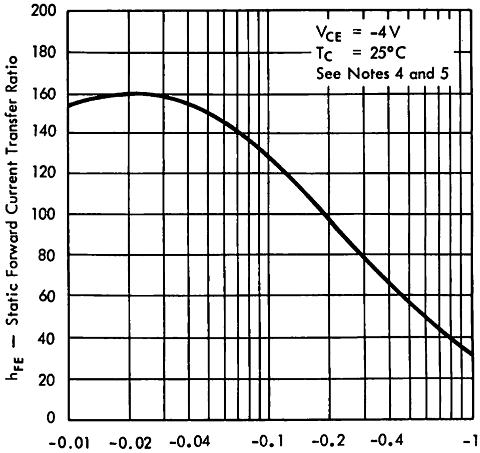


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

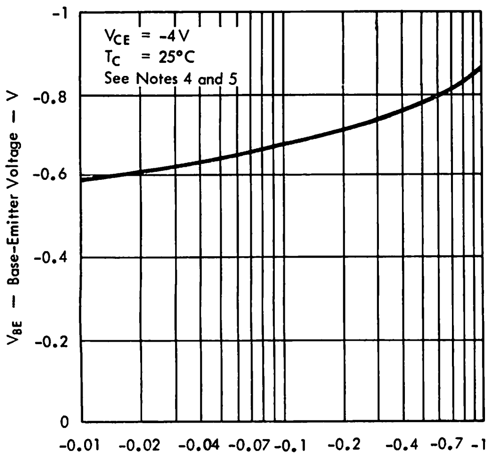


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

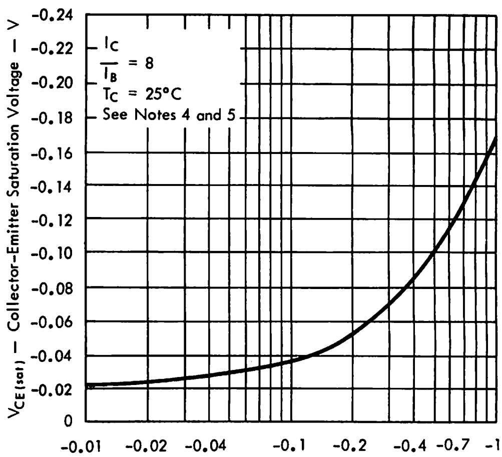


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES TIP31, TIP31A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

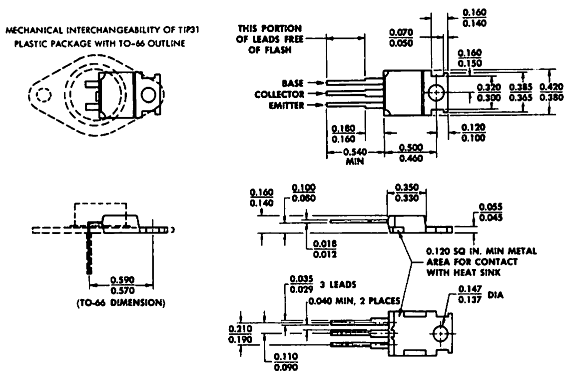
TYPES TIP31, TIP31A
BULLETIN NO. DL-S 6810953, JULY 1968

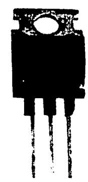
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP32, TIP32A

- **40 Watts at 25°C Case Temperature**
- **3 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP31	TIP31A
Collector-Base Voltage	40 V	60 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V
Emitter-Base Voltage	← 5 V →	
Continuous Collector Current	← 3 A →	
Continuous Base Current	← 1 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 40 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 2 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.32 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 16 mW/deg.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS			TIP31		TIP31A		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 50$ mA,	$I_B = 0$,	See Note 4	40		60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V,	$I_B = 0$			0.5		0.5	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = 40$ V,	$V_{BE} = 0$			0.3			mA
		$V_{CE} = 60$ V,	$V_{BE} = 0$					0.3	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 1$ A,	See Notes 4 and 5	20	100	20	100	
		$V_{CE} = 4$ V,	$I_C = 3$ A,	See Notes 4 and 5	8		8		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V,	$I_C = 1$ A,	See Notes 4 and 5		1.3		1.3	V
		$V_{CE} = 4$ V,	$I_C = 3$ A,	See Notes 4 and 5		1.8		1.8	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ mA,	$I_C = 1$ A,	See Notes 4 and 5		0.6		0.6	V
		$I_B = 375$ mA,	$I_C = 3$ A,	See Notes 4 and 5		1.2		1.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 0.5$ A,	$f = 1$ kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 0.5$ A,	$f = 1$ MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ μs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	3.125	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	62.5	deg/W

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 1$ A, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA,	0.45	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.65	μs

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

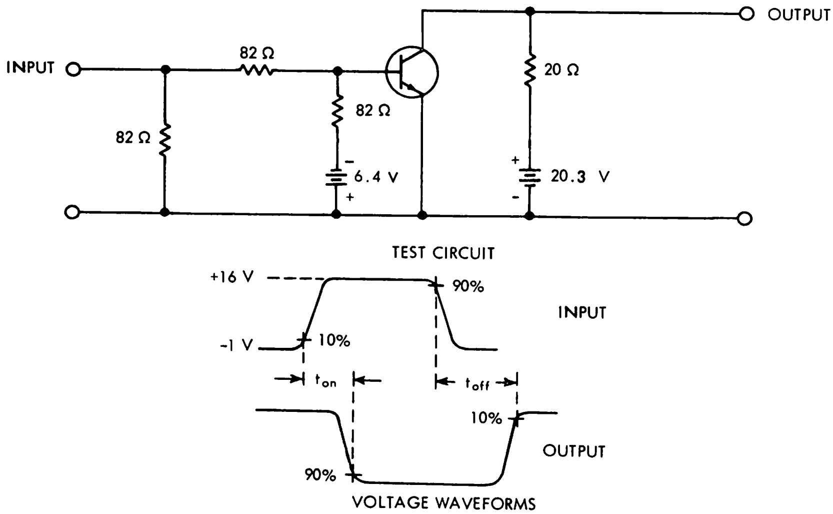


FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

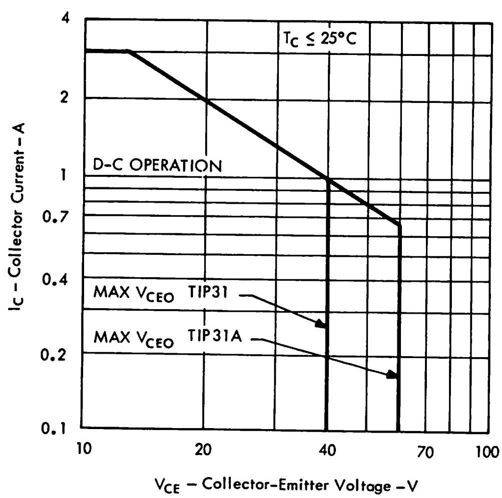


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

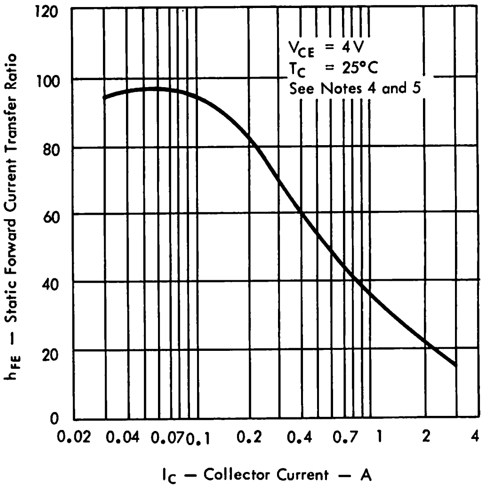


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

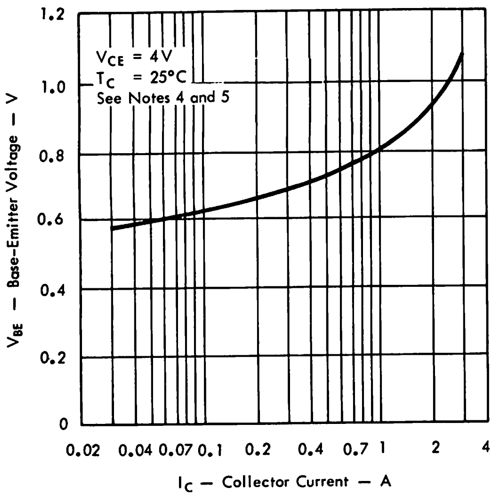


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

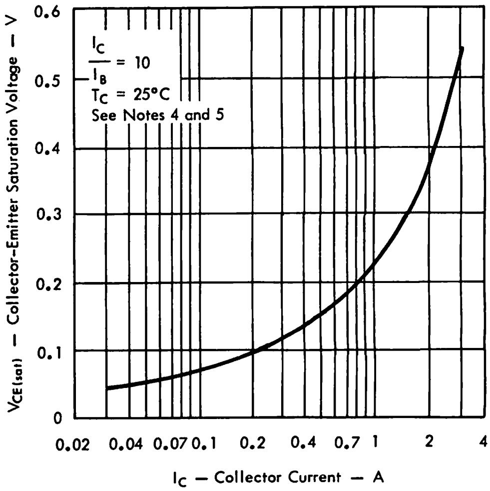


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ μs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES TIP32, TIP32A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

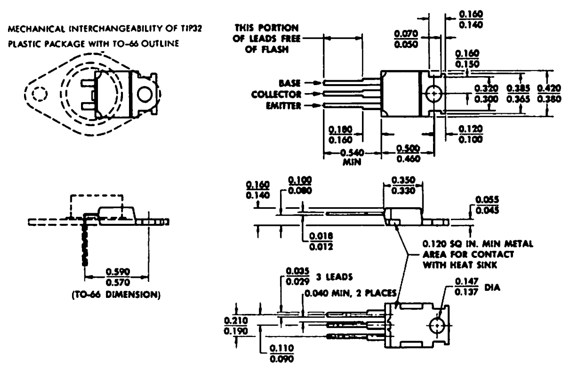
TYPES TIP32, TIP32A
BULLETIN NO. DL-S 6810952, JULY 1968

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP31, TIP31A

- **40 Watts at 25°C Case Temperature**
- **3 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP32	TIP32A
Collector-Base Voltage	−40 V	−60 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V
Emitter-Base Voltage	←— −5 V —→	
Continuous Collector Current	←— −3 A —→	
Continuous Base Current	←— −1 A —→	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	←— 40 W —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	←— 2 W —→	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	←—260°C—→	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.32 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 16 mW/deg.

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TYPES TIP32, TIP32A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP32		TIP32A		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -50$ mA, $I_B = 0$, See Note 4	−40		−60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.5		−0.5	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.3			mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.3	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 4 and 5	20	100	20	100	
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 4 and 5	8		8		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 4 and 5		−1.3		−1.3	V
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 4 and 5		−1.8		−1.8	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100$ mA, $I_C = -1$ A, See Notes 4 and 5		−0.6		−0.6	V
		$I_B = -375$ mA, $I_C = -3$ A, See Notes 4 and 5		−1.2		−1.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ μs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

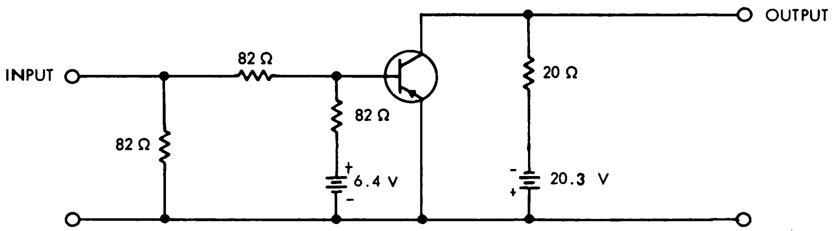
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	3.125	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

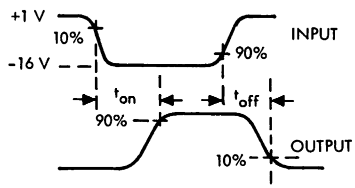
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -100$ mA, $I_{B(2)} = 100$ mA,	0.17	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

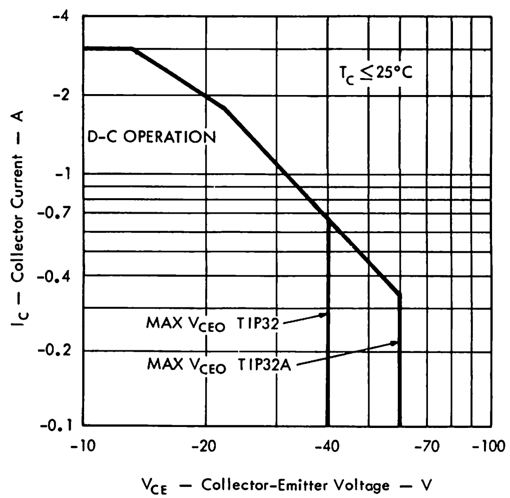


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

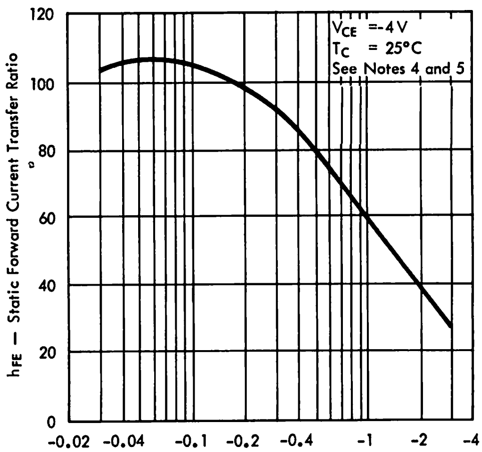


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

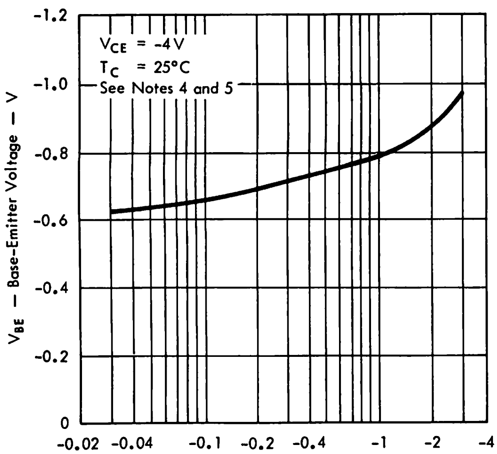


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

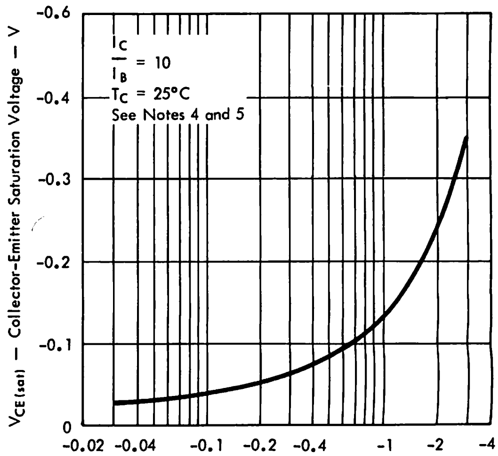


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES TIP33, TIP33A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

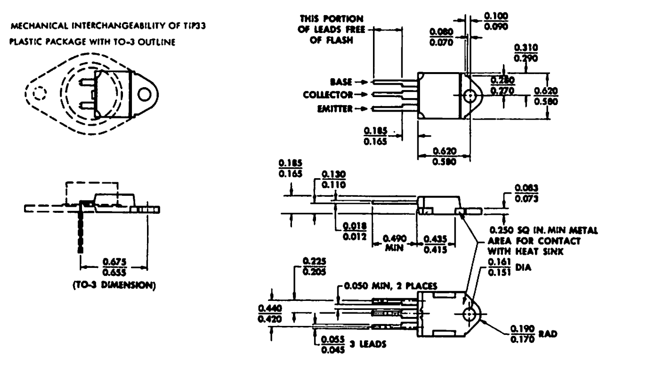
TYPES TIP33, TIP33A
BULLETIN NO. DL-S 6810957, JULY 1968

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP34, TIP34A

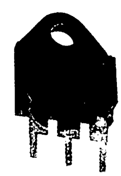
- **80 Watts at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP33	TIP33A
Collector-Base Voltage	40 V	60 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V
Emitter-Base Voltage	← 5 V →	
Continuous Collector Current	← 10 A →	
Continuous Base Current	← 3 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 80 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 3.5 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.64 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 28 mW/deg.

TYPES TIP33, TIP33A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP33 MIN	TIP33 MAX	TIP33A MIN	TIP33A MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 4	40		60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7		0.7	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = 40$ V, $V_{BE} = 0$		0.4			mA
		$V_{CE} = 60$ V, $V_{BE} = 0$				0.4	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, See Notes 4 and 5	25	125	25	125	
		$V_{CE} = 4$ V, $I_C = 3$ A, See Notes 4 and 5	12		12		
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 4 and 5	4		4		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 3$ A, See Notes 4 and 5		1.6		1.6	V
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 4 and 5		3		3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 300$ mA, $I_C = 3$ A, See Notes 4 and 5		1		1	V
		$I_B = 2.5$ A, $I_C = 10$ A, See Notes 4 and 5		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, f = 1 MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.56	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 1$ A, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA,	0.45	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.35	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

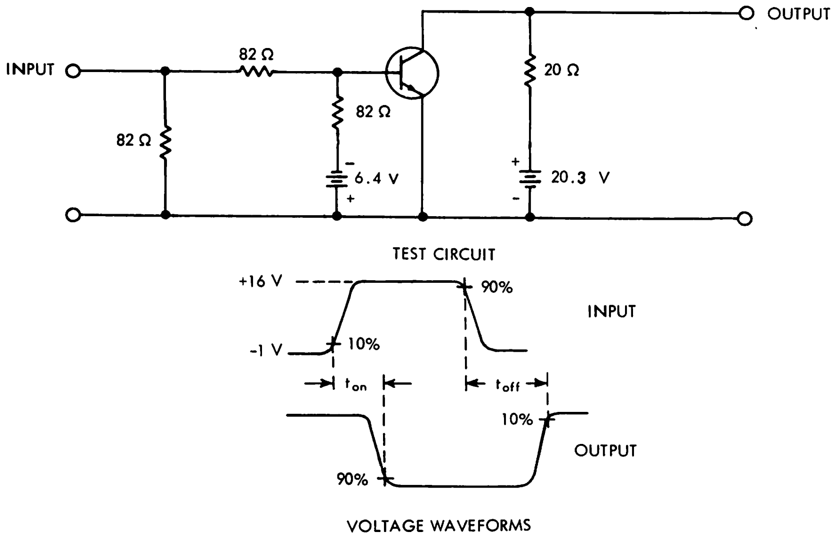


FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

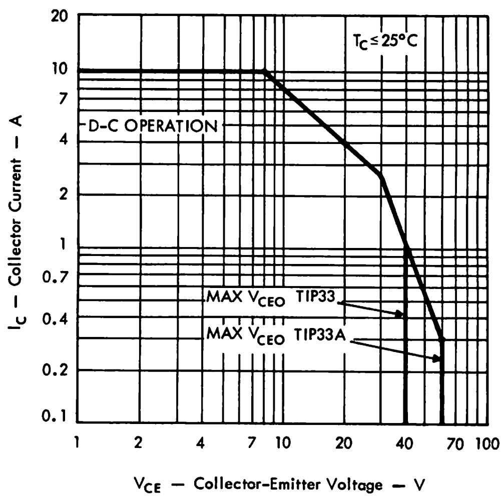


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

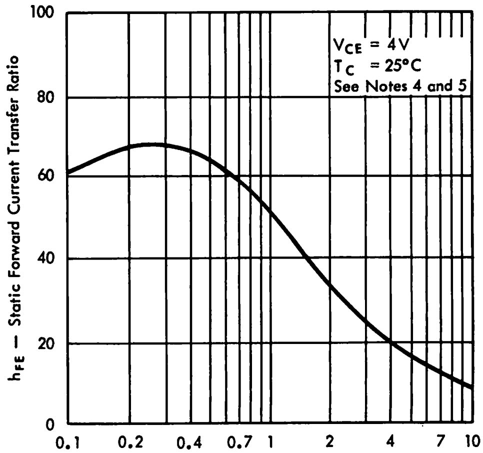


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

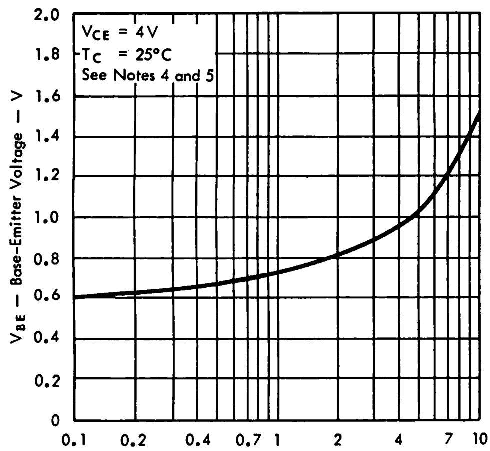


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

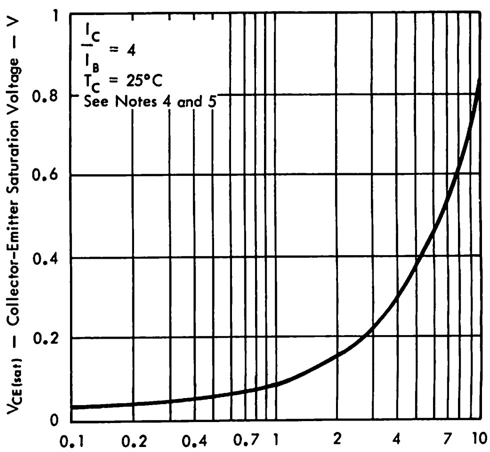


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

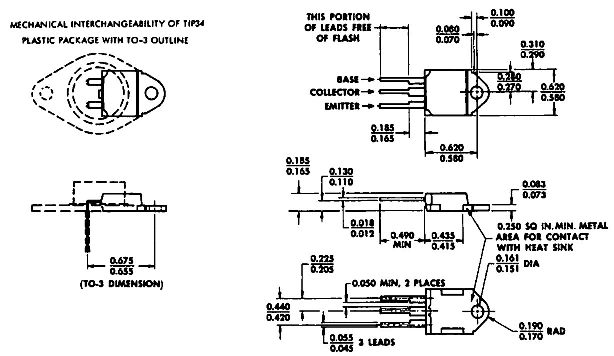
TYPES TIP34, TIP34A
BULLETIN NO. DL-S 6810958, JULY 1968

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH TIP33, TIP33A

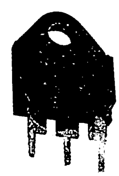
- **80 Watts at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP34	TIP34A
Collector-Base Voltage	−40 V	−60 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V
Emitter-Base Voltage	← −5 V →	
Continuous Collector Current	← −10 A →	
Continuous Base Current	← −3 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 80 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 3.5 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.64 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 28 mW/deg.

TEXAS INSTRUMENTS
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TYPES TIP34, TIP34A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP34 MIN	TIP34 MAX	TIP34A MIN	TIP34A MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 4	−40		−60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.7		−0.7	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.4			mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.4	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 4 and 5	25	125	25	125	
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 4 and 5	12		12		
		$V_{CE} = -4$ V, $I_C = -10$ A, See Notes 4 and 5	4		4		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 4 and 5		−1.6		−1.6	V
		$V_{CE} = -4$ V, $I_C = -10$ A, See Notes 4 and 5		−3		−3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -300$ mA, $I_C = -3$ A, See Notes 4 and 5		−1		−1	V
		$I_B = -2.5$ A, $I_C = -10$ A, See Notes 4 and 5		−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ µs, duty cycle $\leq 2\%$. Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.

5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts

thermal characteristics

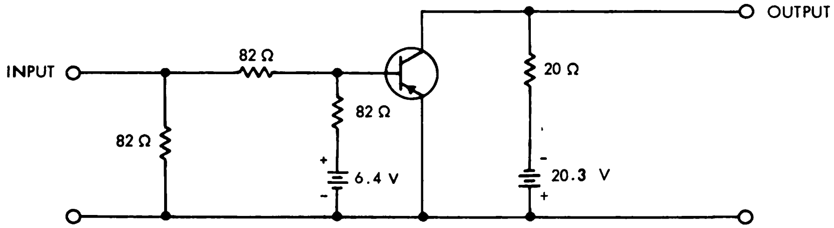
PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1.56	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

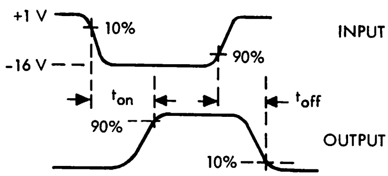
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -100$ mA, $I_{B(2)} = 100$ mA,	0.35	µs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.80	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

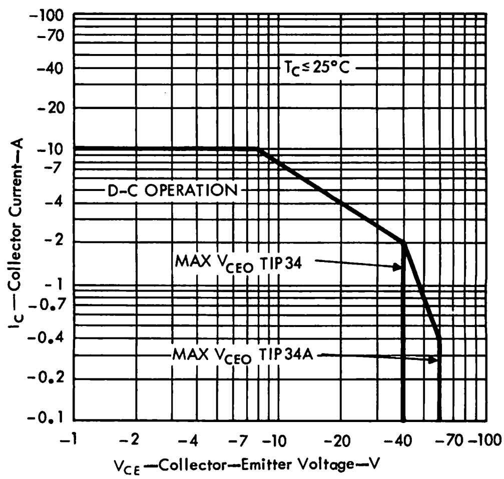


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

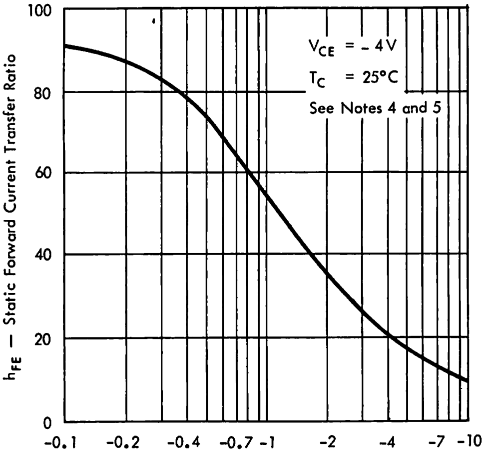


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

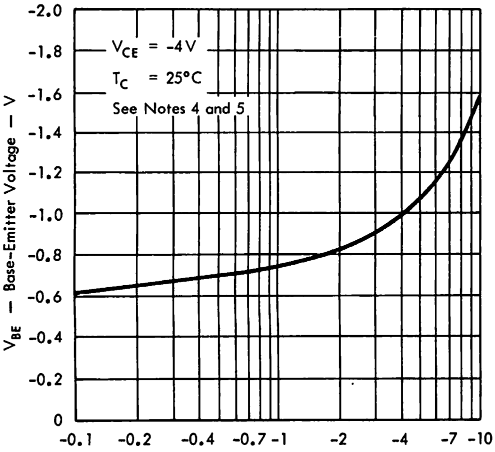


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

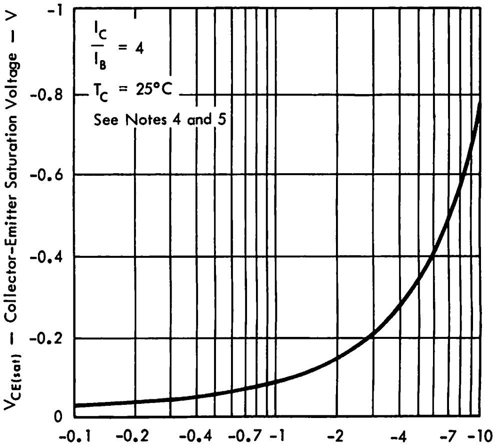


FIGURE 5

NOTES:
4. These parameters must be measured using pulse techniques. $t_p \leq 300$ µs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

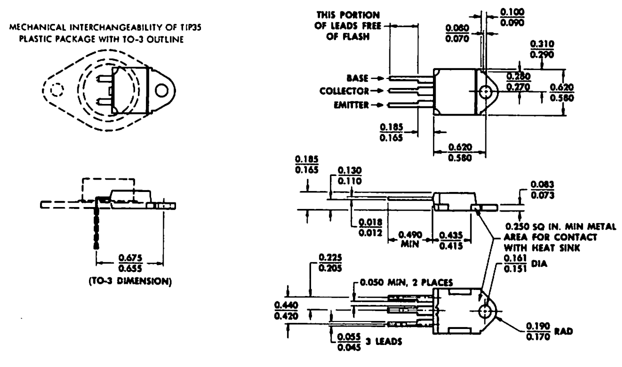
TYPES TIP35, TIP35A
BULLETIN NO. DL-S 6810959, JULY 1968

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP36, TIP36A

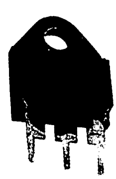
- **90 Watts at 25°C Case Temperature**
- **25 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP35	TIP35A
Collector-Base Voltage	40 V	60 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V
Emitter-Base Voltage	← 5 V →	
Continuous Collector Current	← 25 A →	
Continuous Base Current	← 5 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 90 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 3.5 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.72 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 28 mW/deg.

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TYPES TIP35, TIP35A
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP35		TIP35A		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 4	40		60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		1		1	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = 40$ V, $V_{BE} = 0$		0.7			mA
		$V_{CE} = 60$ V, $V_{BE} = 0$				0.7	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 5$ A, See Notes 4 and 5	20	100	20	100	
		$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 4 and 5	10		10		
		$V_{CE} = 4$ V, $I_C = 25$ A, See Notes 4 and 5	5		5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 4 and 5		2		2	V
		$V_{CE} = 4$ V, $I_C = 25$ A, See Notes 4 and 5		4		4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1.5$ A, $I_C = 15$ A, See Notes 4 and 5		1.8		1.8	V
		$I_B = 5$ A, $I_C = 25$ A, See Notes 4 and 5		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 1$ kHz	25		25		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 1$ MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

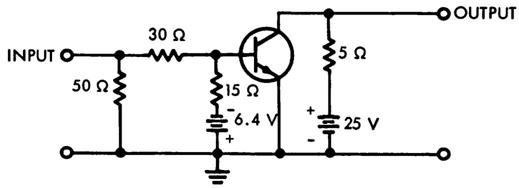
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.39	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

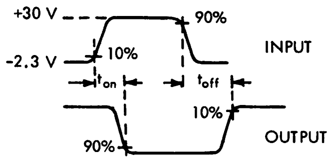
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 5$ A, $I_{B(1)} = 500$ mA, $I_{B(2)} = -500$ mA,	0.6	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -5$ V, $R_L = 5\ \Omega$, See Figure 1	0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 5\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

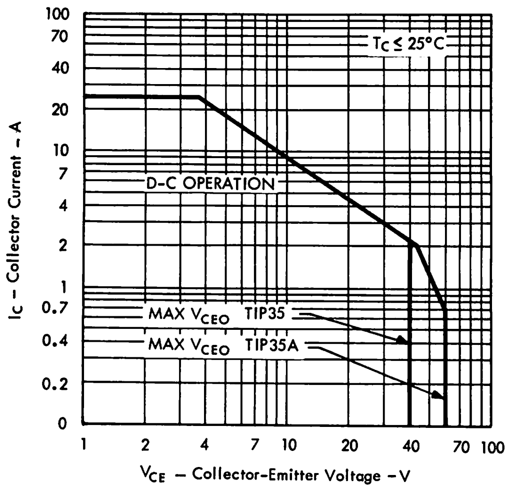


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

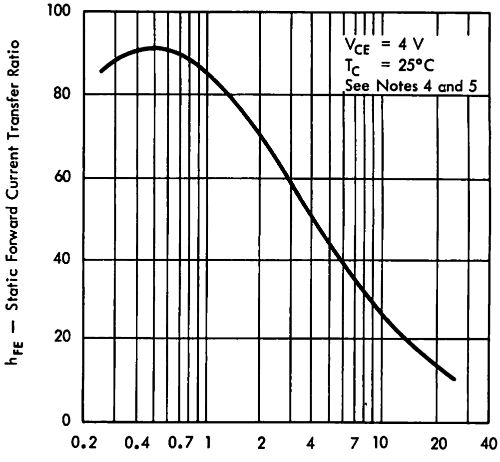


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

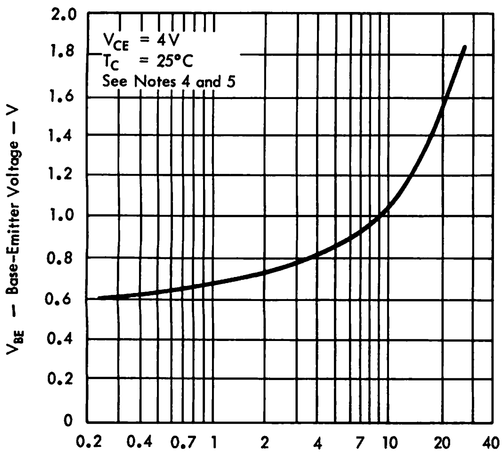


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

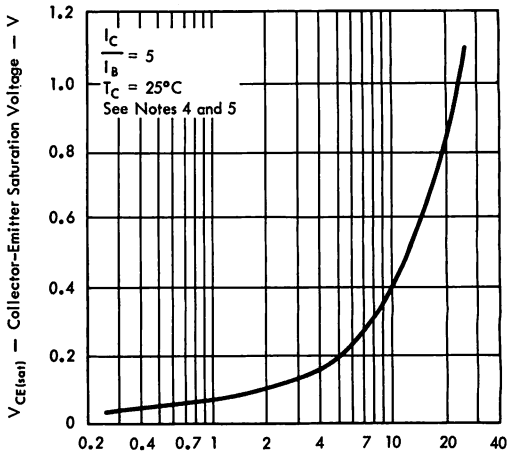


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES TIP36, TIP36A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

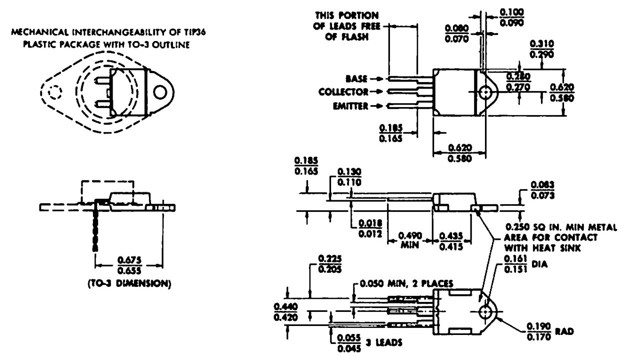
TYPES TIP36, TIP36A
BULLETIN NO. DL-S 6810955, JULY 1968

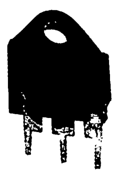
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP35, TIP35A

- **90 Watts at 25°C Case Temperature**
- **25 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP36	TIP36A
Collector-Base Voltage	−40 V	−60 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V
Emitter-Base Voltage	← −5 V →	
Continuous Collector Current	← −25 A →	
Continuous Base Current	← −5 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 90 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 3.5 W →	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature ⅛ Inch from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 150°C case temperature at the rate of 0.72 W/deg.
3. Derate linearly to 150°C free-air temperature at the rate of 28 mW/deg.

TEXAS INSTRUMENTS
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TYPES TIP36, TIP36A
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP36 MIN	TIP36 MAX	TIP36A MIN	TIP36A MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 4	−40		−60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−1		−1	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.7			mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.7	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 4 and 5	20	100	20	100	
		$V_{CE} = -4$ V, $I_C = -15$ A, See Notes 4 and 5	10		10		
		$V_{CE} = -4$ V, $I_C = -25$ A, See Notes 4 and 5	5		5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -15$ A, See Notes 4 and 5		−2		−2	V
		$V_{CE} = -4$ V, $I_C = -25$ A, See Notes 4 and 5		−4		−4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1.5$ A, $I_C = -15$ A, See Notes 4 and 5		−1.8		−1.8	V
		$I_B = -5$ A, $I_C = -25$ A, See Notes 4 and 5		−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 kHz	25		25		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 MHz	3		3		

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300$ μs, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

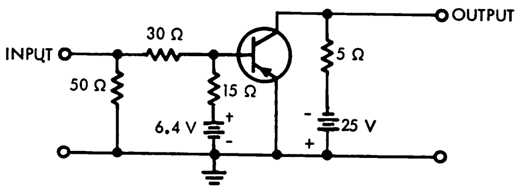
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.39	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

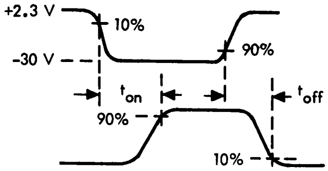
PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = -5$ A,	$I_{B(1)} = -500$ mA,	$I_{B(2)} = 500$ mA,	0.45	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 5$ V,	$R_L = 5\ \Omega$,	See Figure 1	0.55	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

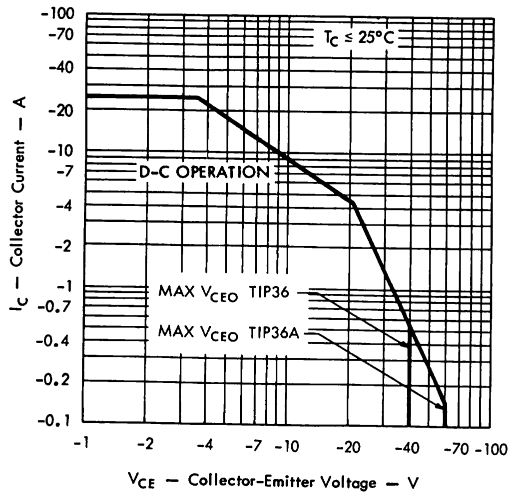


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

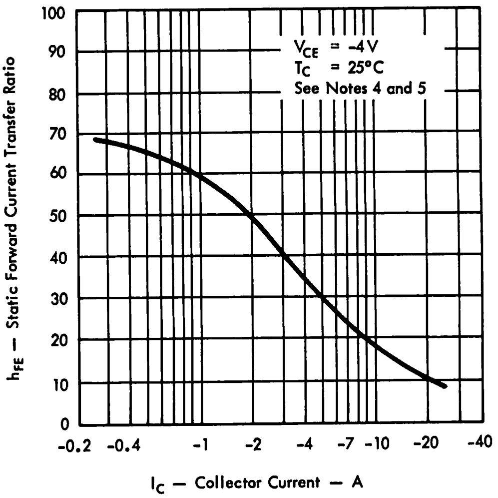


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

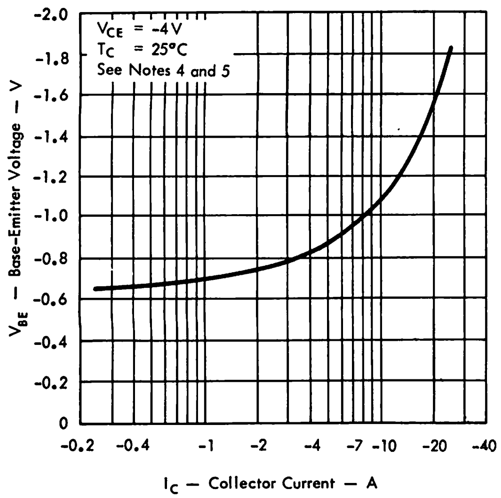


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

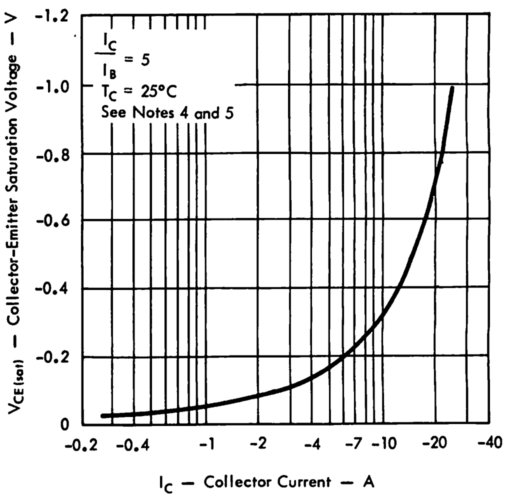


FIGURE 5

NOTES: 4. These parameters must be measured using pulse techniques. $t_p \leq 300\ \mu s$, duty cycle $\leq 2\%$.
Pulse width must be such that halving or doubling does not cause a change greater than the required accuracy of the measurement.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPES 2N1722, 2N1724
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

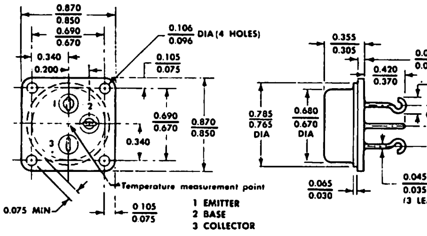
TYPES 2N1722, 2N1724
BULLETIN NO. DL-S 61315, APRIL 1961
REPLACES BULLETIN NO. DL-S 6143I, MARCH 1961

HIGH-FREQUENCY POWER TRANSISTORS

- **50 Watts at 100°C Case Temperature**
- **Minimum f_T of 10 Megacyles**
- **Maximum R_{CS} of 0.5 Ohm at 2 Amperes I_C**
- **Maximum V_{BE} of 2 Volts at 2 Amperes I_C**

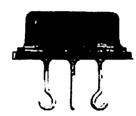
mechanical data

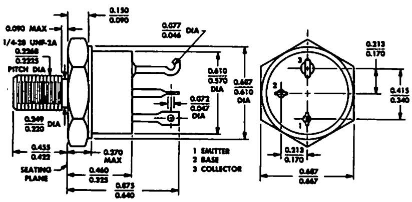
*THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



2N1722

*ALL JEDEC TO-53 DIMENSIONS AND NOTES ARE APPLICABLE

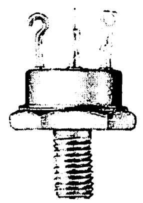




2N1724

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 0.125" FROM STUD

*ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

Collector-Emitter Voltage (See Note 1)	80 v
Emitter-Base Voltage	10 v
Collector Current, Continuous	5 a
Collector Current, Peak (See Note 2)	7.5 a
Total Device Dissipation at 100°C Case Temperature (See Note 3)	50 w
Total Device Dissipation at 25°C Ambient Temperature (See Note 4)	3 w
Collector Junction Operating Temperature	+ 175°C
Storage Temperature Range	− 65°C to + 200°C

Note 1 This is the voltage at which $|h_{FB}|$ approaches one when the emitter-base diode is open-circuited. Maximum allowable collector-emitter voltage shall be derated with increasing collector current as shown in the maximum V_{CE} curve which appears with the collector characteristics. Average power dissipation shall not exceed the maximum ratings for this device.

Note 2 Maximum peak collector current may be allowed if maximum junction temperature is not exceeded. See Figure 2, "Junction Temperature Response vs Pulse Width and Duty Cycle."

Note 3 Derate linearly to 175°C case temperature at the rate of 0.67 w/C°.

Note 4 Derate linearly to 175°C ambient temperature at the rate of 20 mw/C°.

Note 5 For correct measurement of I_{CES}, the base must be shorted to the emitter. The current meter must not be placed in the base-emitter short-circuit loop. I_{CES} may be used in place of I_{CBO} for circuit-stability calculations.

Note 6 For typical BV_{CER} at finite values of R_{BE}, refer to BV_{CER} vs R_{BE} curve. Peak collector-emitter voltage of 120 v may be allowed in the cutoff-current region if the emitter-base diode is short-circuited.

Note 7 Heat-sinking sufficient to limit case temperature to 40°C or less over a 10-second measurement period must be used for this test.

Note 8 DC collector current should not be applied longer than 5 seconds to maintain case temperature less than 40°C without a heat sink.

Note 9 To obtain f_T, the $|h_{fe}|$ response with frequency is extrapolated at 6 db/octave to $|h_{fe}| = 1$ from f = 10 mc. The product of f_T x 1 has been referred to as the gain-bandwidth product.

TYPES 2N1722, 2N1724
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

electrical characteristics at 25°C ambient temperature (unless otherwise noted)

	Parameter	Test Conditions	Min.	Max.	Unit
I_{CES}	Collector Reverse Current	V_{CE} = 60 v, V_{BE} = 0 (See note 5)		1	ma
I_{CES}	Collector Reverse Current	V_{CE} = 60 v, V_{BE} = 0, T_C = + 150°C (See note 5)		2	ma
I_{CES}	Collector Reverse Current	V_{CE} = 120 v, V_{BE} = 0, T_C = + 150°C (See note 5)		10	ma
I_{EBO}	Emitter Reverse Current	V_{EB} = 10 v, I_C = 0		10	ma
*BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 200 ma, I_B = 0 (See notes 6 & 7)	80		v
*h_{FE}	DC Forward Current Transfer Ratio	V_{CE} = 15 v, I_C = 2 a	20	90	
*h_{FE}	DC Forward Current Transfer Ratio	V_{CE} = 15 v, I_C = 2 a, T_A = −55°C	12		
*h_{FE}	DC Forward Current Transfer Ratio	V_{CE} = 15 v, I_C = 100 ma	20		
*V_{BE}	Base-Emitter Voltage	I_B = 200 ma, I_C = 2 a		2.0	v
*$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 200 ma, I_C = 2 a		1.0	v
$\|h_{fe}\|$	AC Common-Emitter Forward Current Transfer Ratio	V_{CE} = 15 v, I_C = 500 ma, f = 10 mc (See note 8)	1.0		
C_{ob}	Common-Base Output Capacitance	V_{CB} = 15 v, I_E = 0, f = 1 mc		550	pf

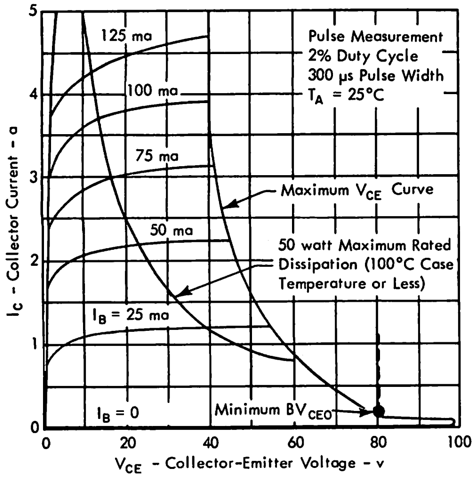
Thermal Characteristics

θ_{J-C}	Thermal Resistance, Junction to Case (Bottom, Center of Case)		1.5	C°/w

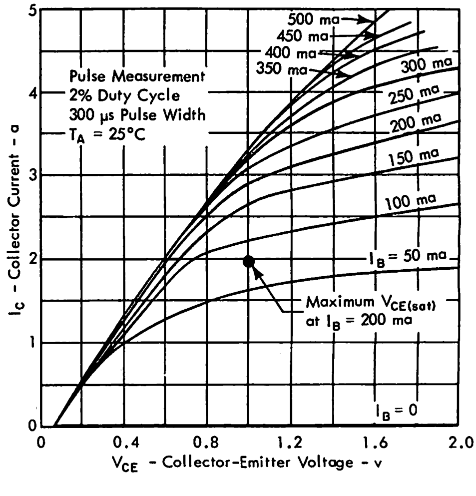
*Semi-automatic testing is facilitated by using pulse techniques to measure these parameters. A 300 μsec pulse (approximately 2% duty cycle) is utilized.

TYPICAL CHARACTERISTICS

COMMON-EMITTER COLLECTOR CHARACTERISTICS

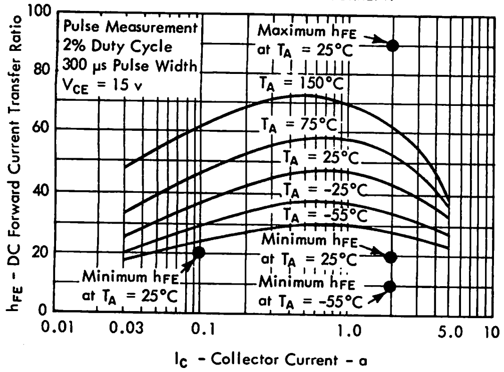


COMMON-EMITTER COLLECTOR CHARACTERISTICS
(Low - Voltage)

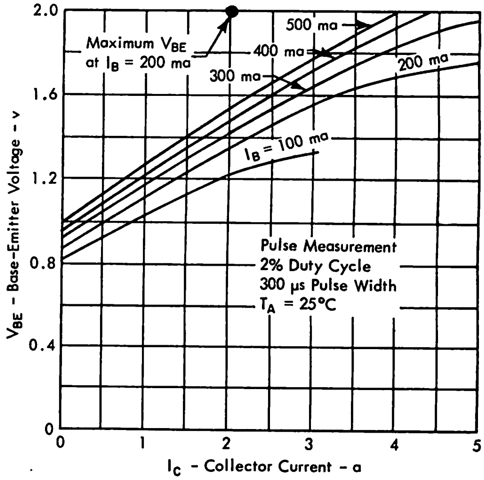


TYPICAL CHARACTERISTICS

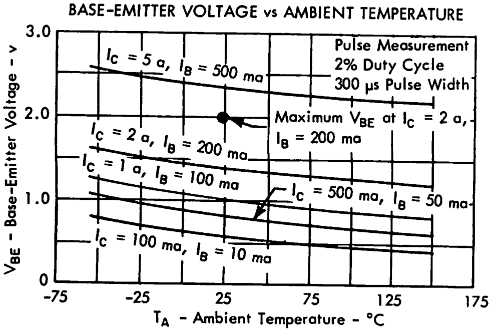
DC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT



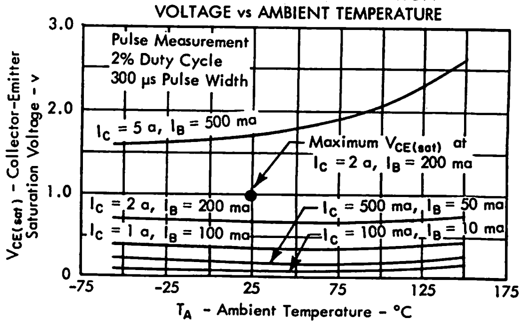
BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT



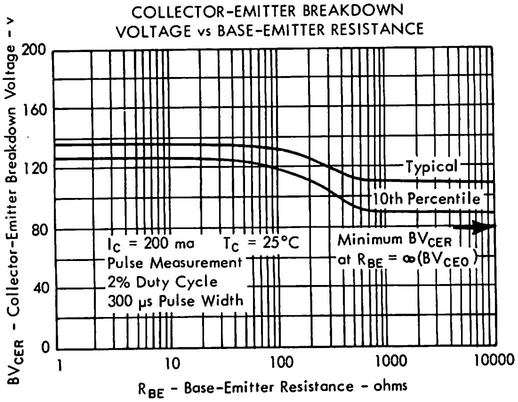
BASE-EMITTER VOLTAGE vs AMBIENT TEMPERATURE

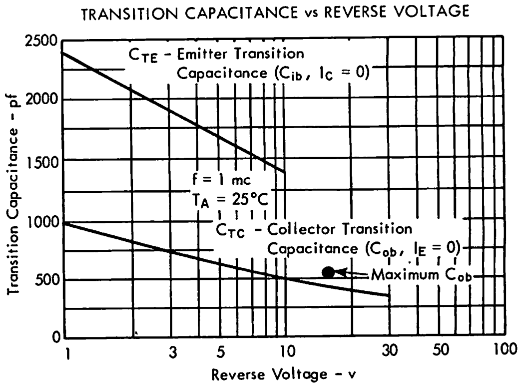


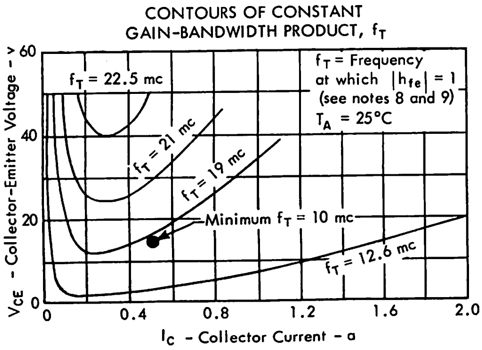
COLLECTOR-EMITTER SATURATION VOLTAGE vs AMBIENT TEMPERATURE

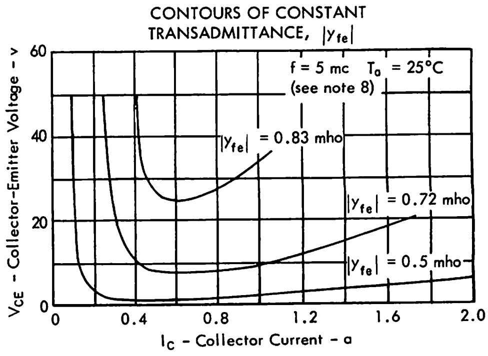


TYPICAL CHARACTERISTICS









TYPICAL CHARACTERISTICS

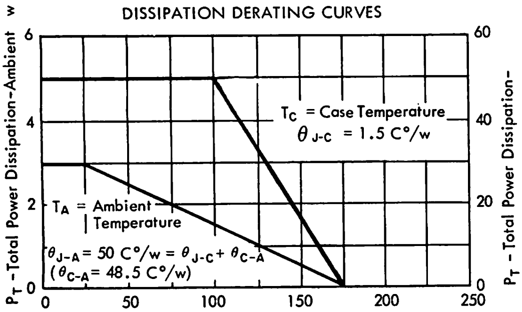


FIGURE 1

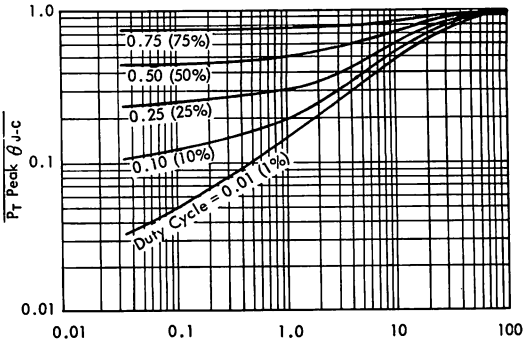


FIGURE 2

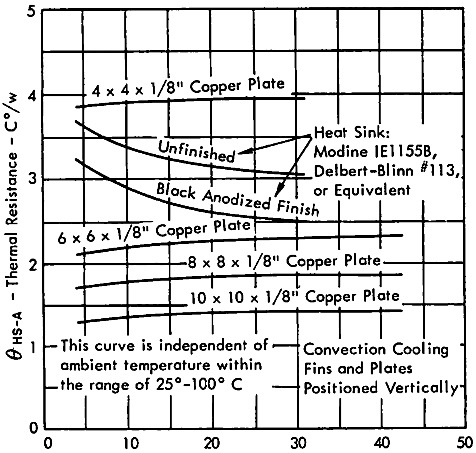


FIGURE 3

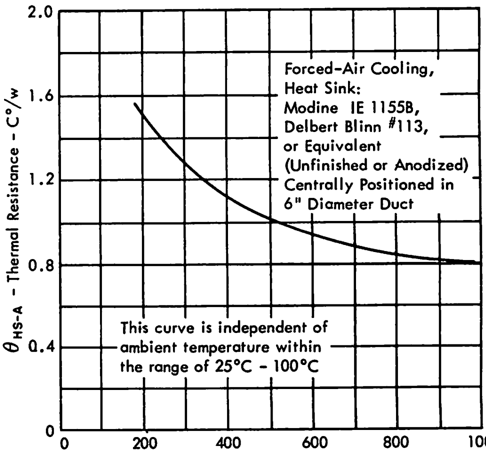


FIGURE 4

TYPES 2N1722, 2N1724
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

THERMAL INFORMATION

TABLE I

Mounting Conditions	2N1722 mounted with four 2-56 screws at 4 in-lb torque 2N1724 mounted at 30 in.-lb. torque			
	Unfinished Alum. or Copper	Alum. or Copper with .0025" mica ins.	Anodized Aluminum	Anodized Alum. with DC-200 Oil
$\theta_{C\text{-}HS}$ — contact thermal resistance C°/w	0.15	0.45	0.40	0.28

Symbol	Definition	Unit
P_T	DC or average total power dissipation	w
P_{Tpeak}	Peak total power dissipation (pulsed operation)	w
$\theta_{HS\text{-}A}$	Heat-sink-to-ambient thermal resistance	C°/w
$\theta_{C\text{-}HS}$	Case-to-heat-sink (contact) thermal resistance	C°/w
$\theta_{J\text{-}C}$	Junction-to-case thermal resistance	C°/w
$\theta_{J\text{-}A}$	Junction-to-ambient thermal resistance (no heat sink)	C°/w
$\theta_{C\text{-}A}$	Case-to-ambient thermal resistance (no heat sink)	C°/w
T_A	Ambient temperature	°C
T_{HS}	Heat-sink mounting surface temperature	°C
T_C	Case temperature (transistor mounting surface)	°C
T_{Jmax}	Maximum junction temperature	°C
t_o	Pulse width	msec

For steady-state power dissipation or pulsed dissipation with $t_o < 100$ µsec, maximum junction temperature may be considered equal to the ambient temperature plus the product of average power dissipation and total junction-to-ambient thermal resistance. Under these pulse conditions, the junction-to-case temperature gradient varies so slightly with instantaneous power dissipation that average dissipation may be used in thermal calculations. When a heat sink is used, junction-to-ambient thermal resistance may be broken down into three quantities: $\theta_{J\text{-}C}$, $\theta_{C\text{-}HS}$, and $\theta_{HS\text{-}A}$. Thermal performance can then be calculated using the following equation:

$$T_{Jmax} = T_A + P_T(\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A})$$

Or, if no heat sink is used,

$$T_{Jmax} = T_A + P_T\theta_{J\text{-}A}$$

$\theta_{J\text{-}C}$, $\theta_{J\text{-}A}$, and $\theta_{C\text{-}A}$ are shown in Figure 1. To minimize contact thermal resistance, $\theta_{C\text{-}HS}$, the heat sink mounting surface should be as smooth as possible. $\theta_{C\text{-}HS}$ for several surface and mounting conditions is given in Table 1. These figures represent maximum values encountered on surfaces equivalent to those of most commercially available heat sinks. Note that in some cases, as with the anodized aluminum finish, $\theta_{C\text{-}HS}$ can be reduced substantially by the application of a film of silicone grease between transistor and heat sink.

As t_o exceeds 100 µsec during pulsed operation, the instantaneous variation of the junction-to-case temperature gradient increases sharply. Therefore, maximum rather than average junction temperature must be considered. Figure 2 shows the ratio of maximum instantaneous case-to-junction temperature rise at any pulse width and duty cycle to the rise which would occur at 100% duty cycle. Use of this curve is best explained by the equations below and by the example problems. Provided the other operating conditions are known, T_{Jmax} or P_{Tpeak} may be found using the relation

$$T_{Jmax} = T_A + P_{Tpeak} \times \text{duty cycle} \times (\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + \left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] P_{Tpeak}\,\theta_{J\text{-}C}$$

Or, if no heat sink is used,

$$T_{Jmax} = T_A + P_{Tpeak} \times \text{duty cycle} \times \theta_{C\text{-}A} + \left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] P_{Tpeak}\,\theta_{J\text{-}C}$$

Note that the ambient-to-transistor case temperature rise remains constant at a value proportional to average power dissipation throughout the pulse width and duty cycle range shown in Figure 2. Values for $\theta_{HS\text{-}A}$ taken from Figures 3 and 4 are used in the example problems. However, the curves in Figures 1 and 2 may be used for any heat sink provided its thermal resistance is known. Under no circumstances should peak power dissipation exceed the value indicated by the maximum V_{CE} curve on the collector characteristics.

Example 1, Find T_{Jmax}

Operating Conditions

Heat sink = Modine 1E1155B, Delbert Blinn 113, or equivalent, anodized finish, convection cooling

t_o = 1 msec

duty cycle = 0.10 (10%)

P_{Tpeak} = 50 w

T_A = 50°C

$$T_{Jmax} = T_A + P_{Tpeak} \times \text{duty cycle} \times (\theta_{CH\text{-}S} + \theta_{HS\text{-}A}) + \left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] P_{Tpeak}\,\theta_{J\text{-}C}$$

From Figure 1, $\theta_{J\text{-}C} = 1.5$ C°/w

From Figure 3, $\theta_{HS\text{-}A} = 3.15$ C°/w ($P_T = P_{Tpeak} \times$ duty cycle)

From Table 1, $\theta_{C\text{-}HS} = 0.40$ C°/w

From Figure 2, $\left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] = 0.20$

then

$$T_{Jmax} = 50°C + 50w \times 0.10 \times (3.15 + 0.40)C°/w + 0.20 \times 50w \times 1.5C°/w$$
$$= 50 + 17.7 + 15$$
$$= \underline{82.7°C}$$

Example 2; Find P_{Tpeak}

Operating Conditions

heat sink = none

t_o = 10 msec

duty cycle = 0.01 (1%)

T_{Jmax} (design limit) = 175°C

T_A = 25°C

$$T_{Jmax} = T_A + P_{Tpeak} \times \text{duty cycle} \times \theta_{C\text{-}A} + \left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] P_{Tpeak}\,\theta_{J\text{-}C}$$

From Figure 1, $\theta_{C\text{-}A} = 48.5$ C°/w

From Figure 1, $\theta_{J\text{-}C} = 1.5$ C°/w

From Figure 2, $\left[\frac{T_{Jmax} - T_C}{P_{Tpeak}\,\theta_{J\text{-}C}}\right] = 0.50$

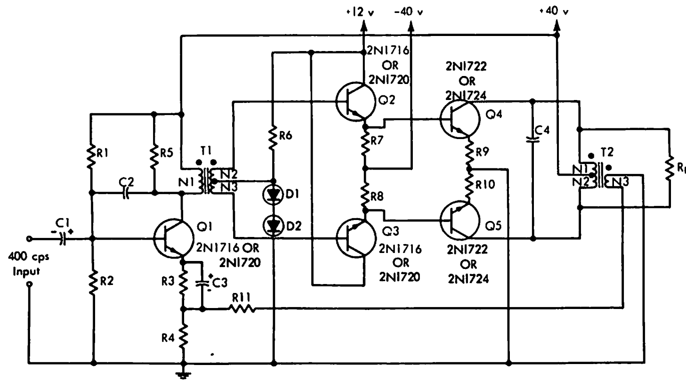
then

$$175°C = 25°C + P_{Tpeak} \times 0.01 \times 48.5C°/w + 0.50 \times P_{Tpeak} \times 1.5C°/w$$

$$P_{Tpeak} = \frac{150}{0.485 + 0.75} = \underline{121\ \text{watts}}$$

TYPICAL APPLICATION DATA, $T_A = -55°C$ TO 125°C.

35 watt, 400 cps SERVO AMPLIFIER



Circuit Characteristics at 35 w Power Output:

Power Gain - 45 db min.
Voltage Amplification - 36.5 ± 1.5 db
Circuit Input Resistance - 700 Ω min.
Total Harmonic Distortion - 5%

R_L - 68, 35 w
R1 - 4.32 K, 1/2 w
R2 - 3.32 K, 1/2 w
R3 - 1.00 K, 1 w
R4 - 33.2, 1/2 w

R5 - 2.21 K, 1/2 w
R6 - 390, 1/2 w
R7 & R8 - 2.00 K, 1 w
R9 & R10 - 1.00, 2 w
R11 - 1.00 K, 1/2 w

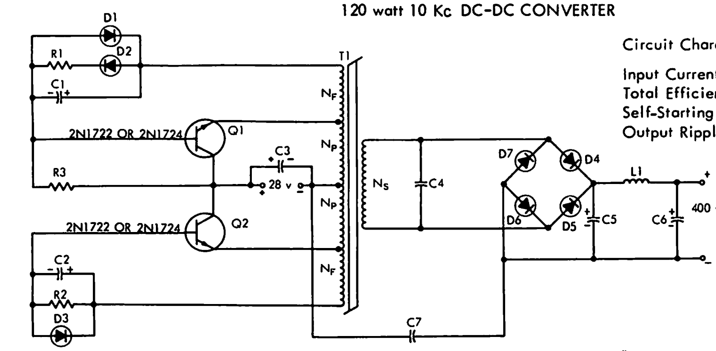
C1 - 40 μf, 25 v
C2 - 500 pf, 100 v
C3 - 1000 μf, 25 v
C4 - 2.0 μf, 100 v
D1 & D2 - TI 1N538
Q1, Q2, & Q3 - TI 2N1716 OR TI 2N1720
Q4 & Q5 - TI 2N1722 OR TI 2N1724

T1: N1 = 755 T, #30 AWG; N2 = N3 = 330 T, #28 AWG Bifilar Wound.
Core - Magnetic Metals 75EI SL14 or equivalent - 1 x 1 interleaved.

T2: N1 = N2 = 100 T, #20 AWG Bifilar Wound; N3 = 67 T, #28 AWG.
Core - Magnetic Metals 100 EI SL14 or equivalent - Butt Joint.

NOTES:
1. All Resistance Values in ohms - 5% Tolerance
2. Resistor Wattage Ratings at 125°C Ambient
3. Capacitor Voltage Ratings at 125°C Ambient
4. Q1 on Heat Sink with $\theta_{C-HS} + \theta_{HS-A} \leq 40$ C°/w
5. Q2 and Q3 on same Heat Sink. $\theta_{C-HS} + \theta_{HS-A} \leq 40$C°/w each. h_{FE}'s matched within 10%.
6. Q4 and Q5 on Heat Sinks with $\theta_{C-HS} + \theta_{HS-A} \leq 1.5$C°/w. h_{FE}'s matched within 10%.

120 watt 10 Kc DC-DC CONVERTER



Circuit Characteristics at 120 w Power Output:

Input Current - 5a
Total Efficiency - 85%
Self-Starting and Short-Circuit Protected
Output Ripple - 0.6 v max.

Q1 & Q2 - TI 2N1722 OR TI 2N1724
D1 - D3 - TI 1N645
D4 - D7 - TI 1N1096
C1 & C2 - 22 μf, 15 v
C3 - 100 μf, 35 v
C4 - 510 pf, 500 v

C5 - 0.1 μf, 500 v
C6 - 3 μf, 500 v
C7 - 0.01 μf, 500 v
L1 - 15 μh
R1 - 2.74, 2 w
R2 - 3.32, 2 w
R3 - 511, 2 w

T1: N_P = 18 T #16 AWG
N_S = 290 T #25 AWG
N_F = 3 T #22 AWG
Core: Toroid, Magnetic Metals Inc. 51026-ID or equivalent.

NOTES:
1. All Resistance Values in ohms, 5% Tolerance.
2. All Resistor Wattage Ratings at 125°C Ambient.
3. Capacitor Voltage Ratings at 125°C Ambient.
4. Q1 and Q2 on Same Heat Sink, $\theta_{C-HS} + \theta_{HS-A} \leq 4$ C°/w each.

TYPES 2N1722, 2N1724
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

TYPICAL APPLICATION DATA, $T_A = -55°C$ TO 125°C.

30 volt, 0 - 2.5 a VOLTAGE REGULATOR

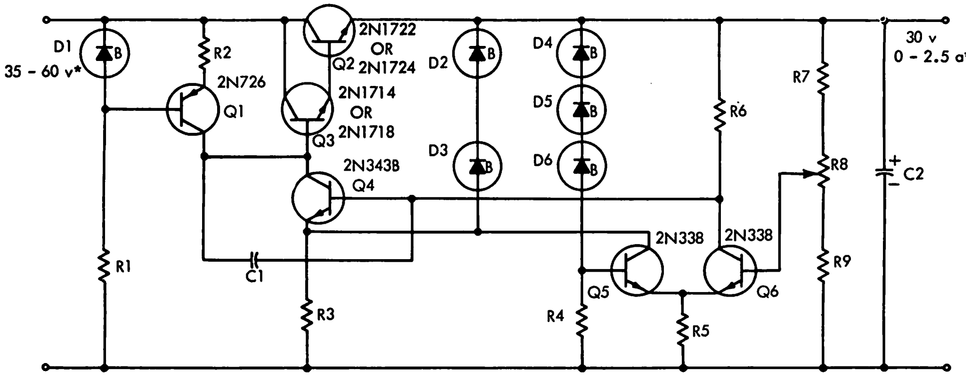
Circuit Characteristics:

$$\left.\frac{\Delta V_{OUT}}{\Delta I_{OUT}}\right|_{\Delta V_{IN}=0} = \text{Output Resistance} \leq 0.007 \text{ ohm}$$

$$100X \left.\frac{\Delta V_{OUT}}{\Delta V_{IN}}\right|_{\Delta I_{OUT}=0} = \text{Input Regulation} \leq 0.05\% \text{ at } I_{OUT} = 2.0 \text{ a}$$

$$100X \left.\frac{\Delta V_{OUT}/V_{OUT}}{\Delta T_A}\right|_{\substack{\Delta I_{OUT}=0 \\ \Delta V_{IN}=0}} = \text{Output Voltage Temperature Coefficient} \leq 0.007\%/°C \text{ at } I_{OUT} = 2.0 \text{ a}, V_{IN} = 45 \text{ v}$$

$$\frac{\text{Input Ripple}}{\text{Output Ripple}} = \text{Ripple Reduction} \geq 10{,}000$$

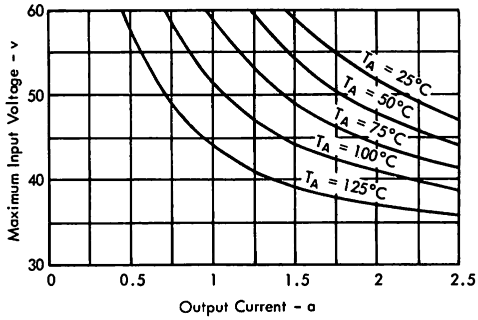


Q1 - TI 2N726	Q4 - TI 2N343B	C1 - 0.01 μf, 50 v	R4 - 2.43 K, 1/4w (Wirewound)
Q2 - TI 2N1722 OR TI 2N1724	Q5 & Q6 - TI 2N338	C2 - 100 μf, 50 v	R5 - 35.7 K, 1/4 w
	D1 - TI 1N746	R1 - 5.11 K, 1/2 w	R6 - 35.7 K, 1/4 w
Q3 - TI 2N1714 OR TI 2N1718	D2 & D3 - TI 1N751	R2 - 681, 1/4 w	R7 & R9 - 3.57 K, 1/4 w (Wirewound)
	D4 - D6 - TI 1N752A	R3 - 2.00 K, 1/4 w	R8 - 200, 1/4 w (Wirewound)

NOTES:
1. All Resistor Values in ohms, 5% Tolerance.
2. Resistor Wattage Ratings at 125°C Ambient.
3. Capacitor Voltage Ratings at 125°C Ambient.
4. Q2 and Q3 on Same Heat Sink: Q2: $\theta_{C-HS} + \theta_{HS-A} \leq 2$ C°/w
   Q3: $\theta_{C-HS} + \theta_{HS-A} \leq 22$ C°/w
5. Q5 and Q6 on Same Heat Sink: Each, $\theta_{C-HS} + \theta_{HS-A} \leq 80$ C°/w

*See Voltage - Current Derating Curves Below

MAXIMUM ALLOWABLE INPUT VOLTAGE vs OUTPUT CURRENT - 0-2.5 a VOLTAGE REGULATOR



TYPES 2N2987, 2N2988, 2N2989, 2N2990, 2N2991, 2N2992, 2N2993, 2N2994
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

TYPES 2N2987, 2N2988, 2N2989, 2N2990
2N2991, 2N2992, 2N2993, 2N2994
BULLETIN NO. DL-S 634284, AUGUST 1963

PLANAR
INTERMEDIATE-POWER TRANSISTORS

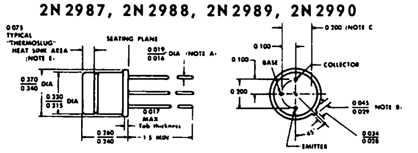
- **15 Watts at 100°C Case Temperature**
- **Nanoampere Leakages**
- **Beta Guaranteed at Seven Levels**
- **Guaranteed Parameters from −55°C to +175°C**
- **Minimum f_T of 30 mc**

*mechanical data

The transistors are in a hermetically-sealed welded package with glass-to-metal seal between case and leads.

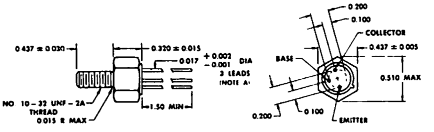
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

2N2987, 2N2988, 2N2989, 2N2990



FALLS WITHIN TO-5 DIMENSIONS

2N2991, 2N2992, 2N2993, 2N2994



DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

A. The specified lead diameter applies in the zone between .050" and .250" from the seating plane. Between .250" and 1.5" a maximum of .021" diameter is held. Outside of these zones the lead diameter is not controlled.

B. Measured from max. diameter of the actual device.

C. Leads having maximum diameter (0.019") measured in gaging plane 0.054" +0.001" −0.000" below the seating plane of the device shall be within 0.007" of their true locations relative to a maximum-width tab.

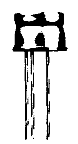
D. The device may be measured by direct methods or by the gage and gaging procedure described on the JEDEC TO-5 base gage drawing.

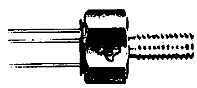
E. Crimping is used to secure the "thermo-slug" heat sink in place.

F. The can diameter referenced is exclusive of crimping.

G. The orientation of the leads in relation to the hex flats is not controlled.

H. Temperature measurement point 0.060 nominal from seat of heat sink.





*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N2987 2N2989	2N2991 2N2993	2N2988 2N2990	2N2992 2N2994
Collector-Base Voltage	95 v		155 v	
Collector-Emitter Voltage (See Note 1)	80 v		100 v	
Emitter-Base Voltage	7 v		7 v	
Collector Current, Continuous	← 1.0 a →			
Base Current, Continuous	← 0.2 a →			
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	1 w	2 w	1 w	2 w
Total Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 15 w →			
Operating Case Temperature Range	−65°C to +200°C			
Storage Temperature Range	−65°C to +200°C			
Lead Temperature 1/16" from Case for 10 Seconds	← 230°C →			

NOTES: 1. This value applies when base-emitter diode is open-circuited.
2. Derate linearly to 200°C free-air temperature at the rate of 5.7 mw/C° for the TO-5 series and 11.4 mw/C° for the studded series.
3. Derate linearly to 200°C case temperature at the rate of 150 mw/C°.
*Indicates JEDEC registered data.

TYPES 2N2987, 2N2988, 2N2989, 2N2990, 2N2991, 2N2992, 2N2993, 2N2994
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

***electrical characteristics at 25°C case temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	2N2987 2N2991 MIN	2N2987 2N2991 MAX	2N2988 2N2992 MIN	2N2988 2N2992 MAX	2N2989 2N2993 MIN	2N2989 2N2993 MAX	2N2990← 2N2994← MIN	2N2990← 2N2994← MAX	TO-5 STUD UNIT
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 30$ ma, $I_B = 0$, (See Note 4)	80		100		80		100		v
I_{CEO}	Collector Cutoff Current	$V_{CE} = 50$ v, $I_B = 0$		0.1				0.1			μa
		$V_{CE} = 90$ v, $I_B = 0$				0.1				0.1	
I_{CEX}	Collector Cutoff Current	$V_{CE} = 90$ v, $V_{BE} = -1.5$ v		0.025				0.025			μa
		$V_{CE} = 150$ v, $V_{BE} = -1.5$ v				0.025				0.025	
		$V_{CE} = 90$ v, $V_{BE} = -1.5$ v, $T_C = 175°C$		15				15			
		$V_{CE} = 150$ v, $V_{BE} = -1.5$ v, $T_C = 175°C$				15				15	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ v, $I_C = 0$		0.025		0.025		0.025		0.025	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ v, $I_C = 1$ ma, (See Note 4)	20		20		40		40		
		$V_{CE} = 5$ v, $I_C = 200$ ma, (See Note 4)	25	75	25	75	60	120	60	120	
		$V_{CE} = 5$ v, $I_C = 500$ ma, (See Note 4)	20		20		40		40		
		$V_{CE} = 10$ v, $I_C = 100$ ma, (See Note 4)	25		25		50		50		
		$V_{CE} = 5$ v, $I_C = 200$ ma, $T_A = -55°C$, (See Note 4)	10		10		20		20		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ v, $I_C = 200$ ma, (See Note 4)		0.9		0.9		0.9		0.9	v
		$I_B = 20$ ma, $I_C = 200$ ma, (See Note 4)		1.0		1.0		1.0		1.0	
		$I_B = 50$ ma, $I_C = 500$ ma, (See Note 4)		1.4		1.4		1.4		1.4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 20$ ma, $I_C = 200$ ma, (See Note 4)		0.8		0.8		0.8		0.8	v
		$I_B = 50$ ma, $I_C = 500$ ma, (See Note 4)		3.0		3.0		3.0		3.0	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100$ ma, f = 1 kc	25	85	25	85	50	170	50	170	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100$ ma, f = 30 mc	1		1		1		1		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 mc		50		50		50		50	pf

NOTE: 4. This parameter must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

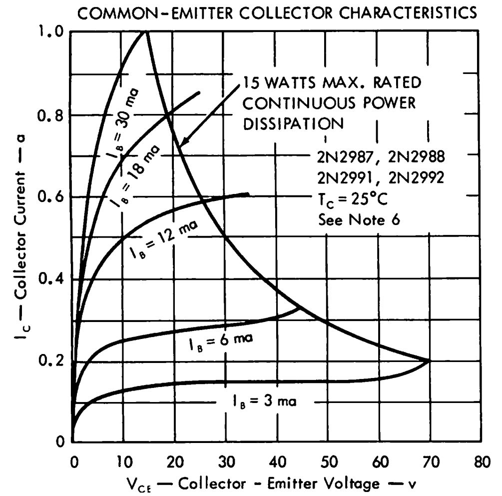


FIGURE 1

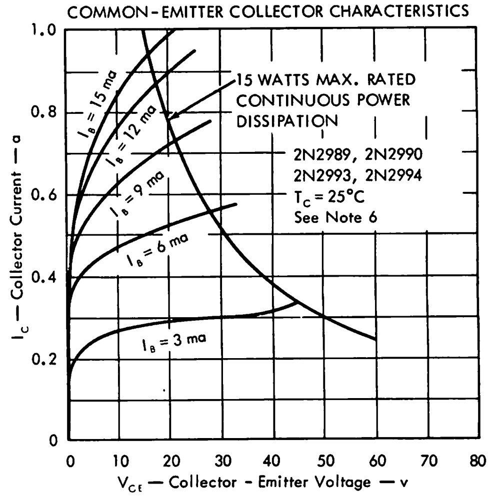


FIGURE 2

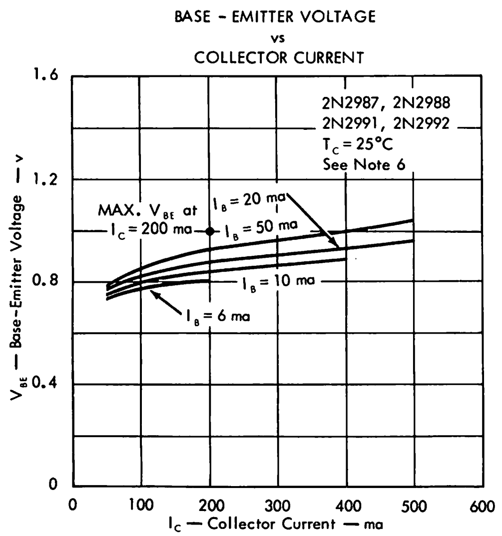


FIGURE 3

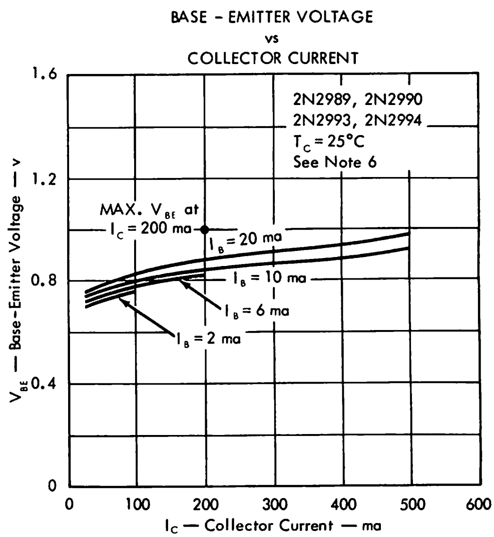


FIGURE 4

NOTE: 6. These characteristics were measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

TYPES 2N2987, 2N2988, 2N2989, 2N2990, 2N2991, 2N2992, 2N2993, 2N2994
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

TYPICAL CHARACTERISTICS

BASE - EMITTER VOLTAGE vs FREE - AIR TEMPERATURE

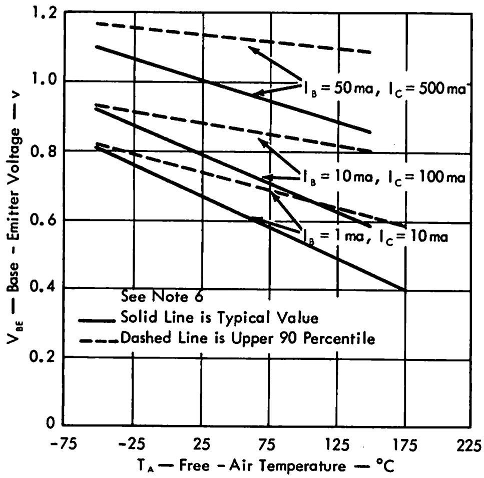


FIGURE 5

COLLECTOR - EMITTER SATURATION VOLTAGE vs FREE - AIR TEMPERATURE

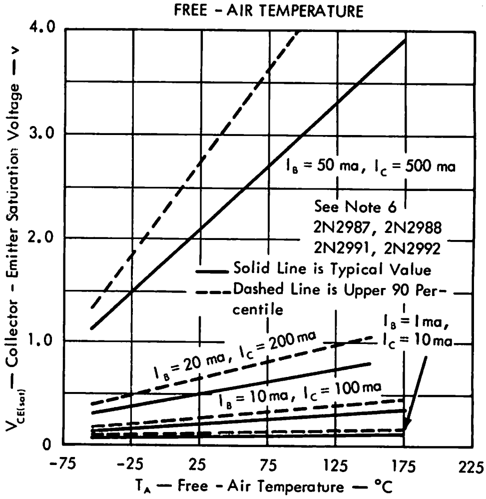


FIGURE 6

COLLECTOR - EMITTER SATURATION VOLTAGE vs FREE - AIR TEMPERATURE

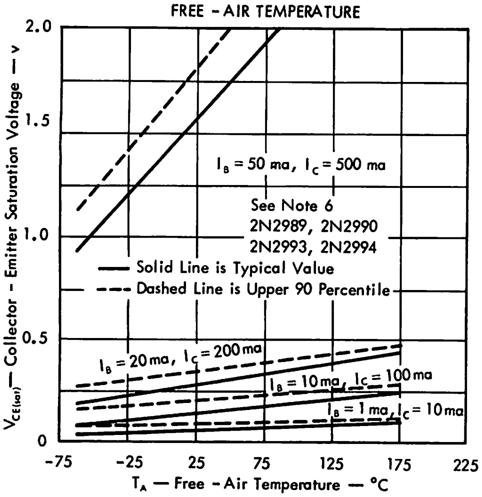


FIGURE 7

NORMALIZED COLLECTOR - EMITTER BREAKDOWN VOLTAGE vs BASE - EMITTER RESISTANCE

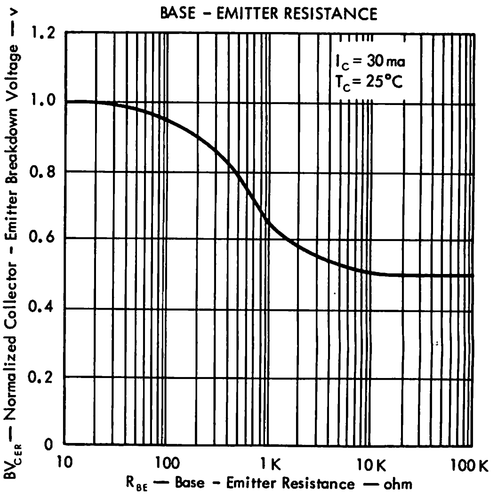


FIGURE 8

NOTE: 6. These characteristics were measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

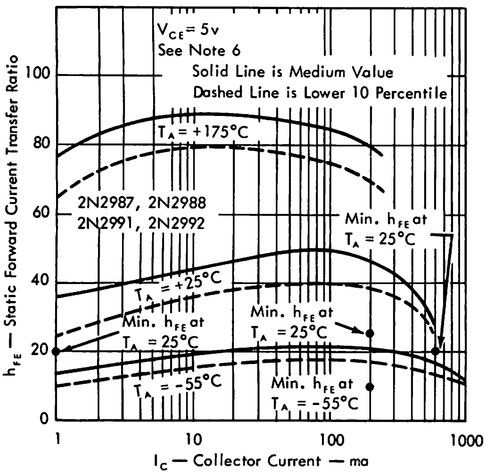


FIGURE 9

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

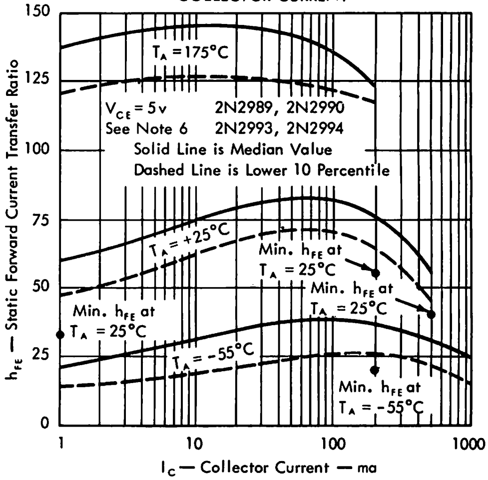


FIGURE 10

COMMON-BASE OPEN-CIRCUIT INPUT
AND OUTPUT CAPACITANCE CHARACTERISTICS

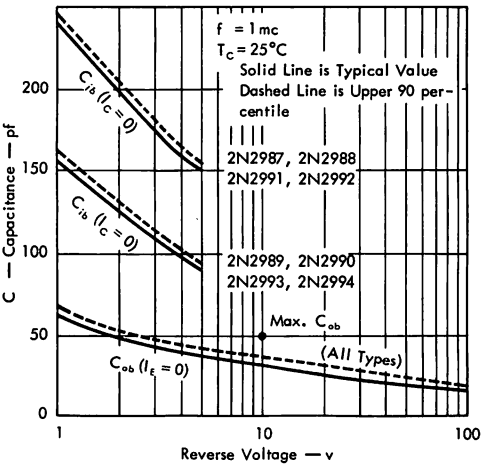


FIGURE 11

NOTE: 6. These characteristics were measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

THERMAL INFORMATION

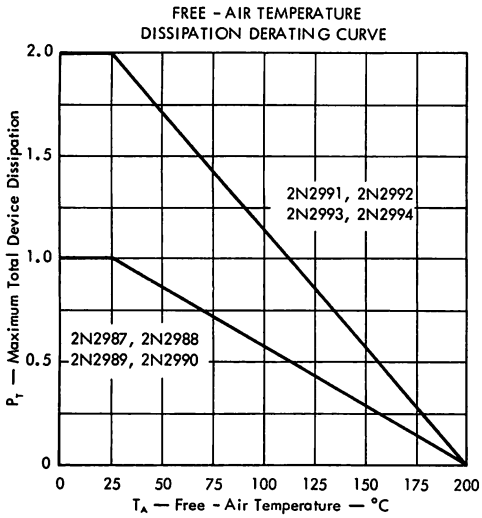


FIGURE 12

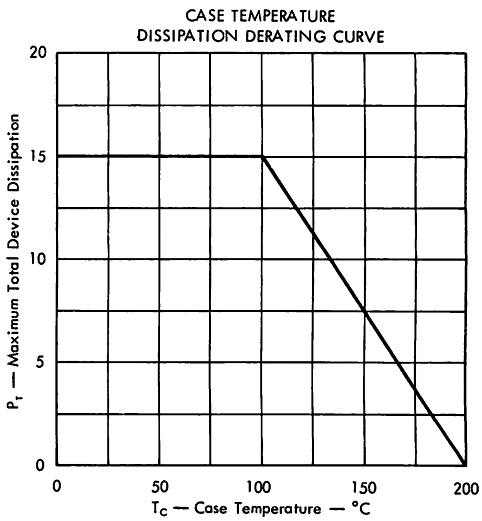


FIGURE 13

MAXIMUM SAFE CONTINUOUS OPERATING REGIONS

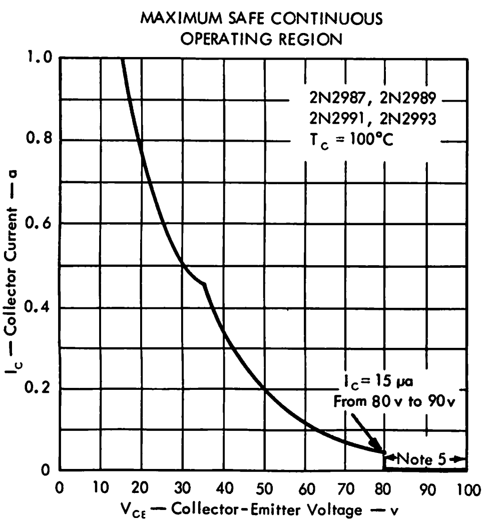


FIGURE 14

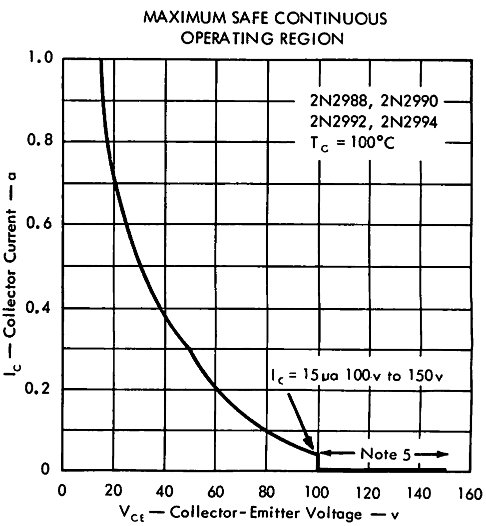


FIGURE 15

NOTE: 5. Operation in this region is permissible only when the base is reverse-voltage-biased with respect to the emitter.

TYPE 2N3055
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

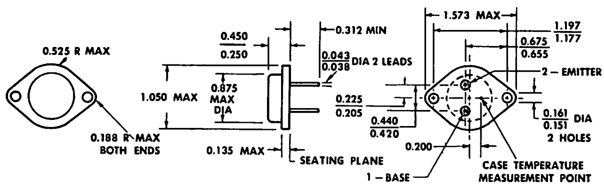
TYPE 2N3055
BULLETIN NO. DL-S 689659, AUGUST 1967
REVISED JULY 1968

FOR POWER-AMPLIFIER APPLICATIONS

- **115 W at 25°C Case Temperature**
- **Max I_C of 15 A**
- **Min f_{hfe} of 20 kHz**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN INCHES

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	70 V
Emitter-Base Voltage	7 V
Continuous Collector Current	15 A
Continuous Base Current	7 A
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	115 W
Operating Case Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Lead Temperature 1/32 Inch from Case for 10 Seconds	235°C

NOTES: 1. This value applies when the base-emitter resistance $R_{BE} = 100\ \Omega$.

2. Derate linearly to 200°C case temperature at the rate of 0.66 W/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
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TYPE 2N3055
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

***electrical characteristics at 25°C case temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 4	60		V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $R_{BE} = 100\ \Omega$	70		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 100$ V, $V_{BE} = -1.5$ V		5	mA
		$V_{CE} = 100$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$		30	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ V, $I_C = 0$		5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 3 and 4	20	70	
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 3 and 4	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 3 and 4		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 400$ mA, $I_C = 4$ A, See Notes 3 and 4		1.1	V
		$I_B = 3.3$ A, $I_C = 10$ A, See Notes 3 and 4		8	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, f = 1 kHz	15	120	
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	$V_{CE} = 4$ V, $I_C = 1$ A, See Note 5	20		kHz

NOTES: 3. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.
5. f_{hfe} is the frequency at which the magnitude of the small-signal forward current transfer ratio is 0.707 of its low-frequency value. For this device, the reference measurement is made at 1 kHz.

*Indicates JEDEC registered data

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.52	deg/W

TYPES 2N3418, 2N3419, 2N3420, 2N3421
N-P-N EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

TYPES 2N3418, 2N3419, 2N3420, 2N3421
BULLETIN NO. DL-S 685521, JUNE 1964
REPLACES BULLETIN NO. DL-S 645114, MARCH 1964
REVISED MAY 1968

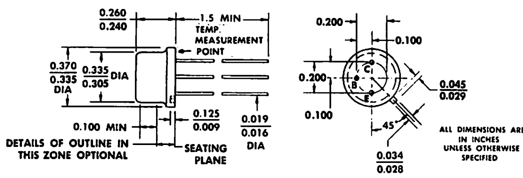
HIGH-FREQUENCY MEDIUM-POWER TRANSISTORS

Formerly TIX3033, TIX3034, TIX3035, TIX3036

- **High-Power Dissipation in TO-5 Package:** 15 watts at $T_C = 100°C$
- **Low-Leakage Current:** 0.5 μa at max voltage
- **Low-Saturation Voltage:** $V_{CE(sat)} = 0.25$ v max at $I_C = 1$ a
- **High f_T:** 40 Mc min at 10 v, 100 ma

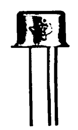
mechanical data

These transistors are in precision welded, hermetically sealed enclosures. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate unit weight is 1.8 grams.



*THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

*ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3418 2N3420	2N3419 2N3421
Collector-Base Voltage	85 v	125 v
Collector-Emitter Voltage (See Note 1)	60 v	80 v
Emitter-Base Voltage	← 8 v →	
Collector Current, Continuous	← 3 a →	
Collector Current, Peak (See Note 2)	← 5 a →	
Base Current	← 1 a →	
Safe Operating Region	See Figures 8 and 9	
Total Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 15 w →	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 1 w →	
Operating Case Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 230°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for PW $\leq$ 1 msec, Duty Cycle $\leq$ 50%.
3. Derate linearly to 200°C case temperature at the rate of 0.15 w/C°.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mw/C°.

*Indicates JEDEC registered data.

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TYPES 2N3418, 2N3419, 2N3420, 2N3421
N-P-N EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3418 MIN	2N3418 MAX	2N3419 MIN	2N3419 MAX	2N3420 MIN	2N3420 MAX	2N3421 MIN	2N3421 MAX	UNIT
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 50$ ma, $I_B = 0$, See Note 5	60		80		60		80		v
I_{CEX}	Collector Cutoff Current	$V_{CE} = 80$ v, $V_{BE} = -0.5$ v		0.5				0.5			μa
		$V_{CE} = 120$ v, $V_{BE} = -0.5$ v				0.5				0.5	μa
		$V_{CE} = 80$ v, $V_{BE} = -0.5$ v, $T_C = 150°C$		50				50			μa
		$V_{CE} = 120$ v, $V_{BE} = -0.5$ v, $T_C = 150°C$				50				50	μa
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 6$ v, $I_C = 0$		500		500		500		500	na
		$V_{EB} = 8$ v, $I_C = 0$		10		10		10		10	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ v, $I_C = 100$ ma, See Notes 5 and 6	20		20		40		40		
		$V_{CE} = 2$ v, $I_C = 1$ a, See Notes 5 and 6	20	60	20	60	40	120	40	120	
		$V_{CE} = 2$ v, $I_C = 2$ a, See Notes 5 and 6	15		15		30		30		
		$V_{CE} = 5$ v, $I_C = 5$ a, See Notes 5 and 6	10		10		15		15		
		$V_{CE} = 2$ v, $I_C = 1$ a, $T_C = -55°C$ See Notes 5 and 6	10		10		10		10		
V_{BE}	Base-Emitter Voltage	$I_B = 100$ ma, $I_C = 1$ a, See Notes 5 and 6	0.6	1.2	0.6	1.2	0.6	1.2	0.6	1.2	v
		$I_B = 200$ ma, $I_C = 2$ a, See Notes 5 and 6	0.7	1.4	0.7	1.4	0.7	1.4	0.7	1.4	v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ ma, $I_C = 1$ a, See Notes 5 and 6		0.25		0.25		0.25		0.25	v
		$I_B = 200$ ma, $I_C = 2$ a, See Notes 5 and 6		0.5		0.5		0.5		0.5	v
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100$ ma, $f = 20$ Mc	2		2		2		2		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ Mc		150		150		150		150	pf

NOTES: 5. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts located 0.25 in. from the header of the transistor. Voltage-sensing contacts are separate from current-carrying contacts.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TYP	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 1$ a, $I_{B(1)} = 100$ ma, $I_{B(2)} = -100$ ma,	165	300	nsec
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ v, $R_L = 20\ \Omega$, See Figure 10	540	1200	nsec
t_{on}	Turn-On Time	$I_C = 2$ a, $I_{B(1)} = 200$ ma, $I_{B(2)} = -200$ ma,	200		nsec
t_{off}	Turn-Off Time	$V_{BE(off)} = -4.7$ v, $R_L = 20\ \Omega$, See Figure 10	350		nsec

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data (typical values excluded).

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

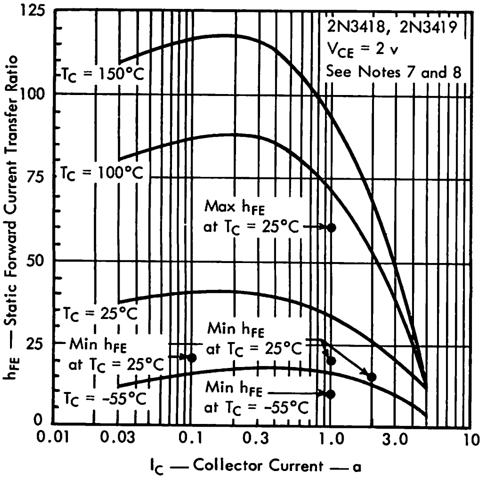


FIGURE 1

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

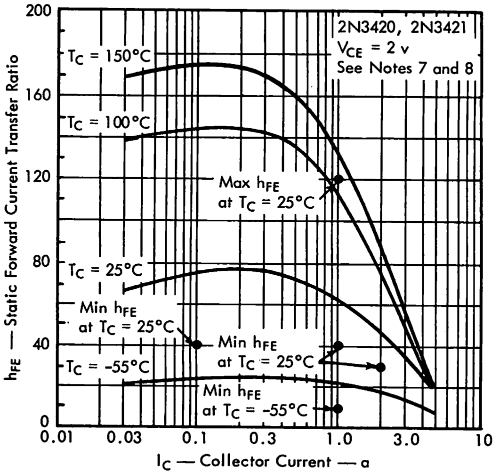


FIGURE 2

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

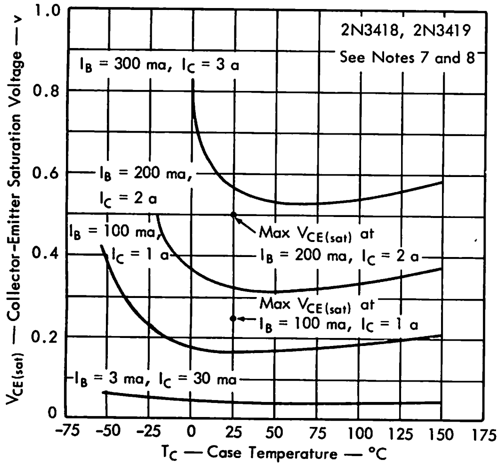


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

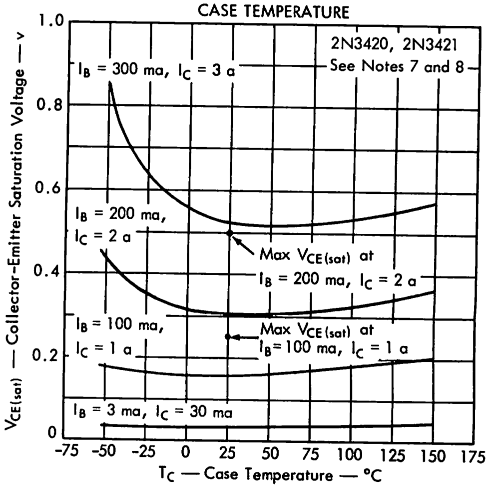


FIGURE 4

NOTES: 7. These parameters were measured using pulse techniques. PW = 300 μsec. Duty Cycle $\leq$ 2%.

8. Separate voltage-sensing and current-carrying contacts were used.

TYPICAL CHARACTERISTICS

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

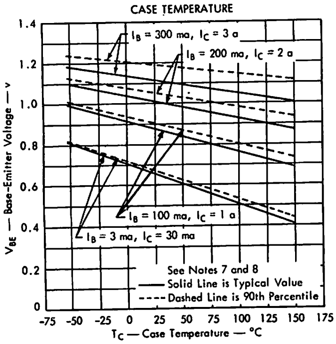


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

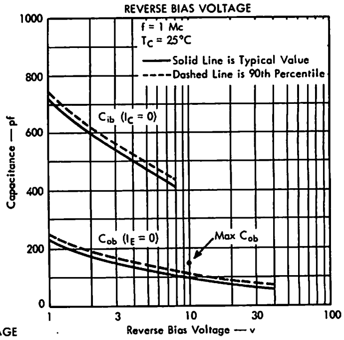


FIGURE 6

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

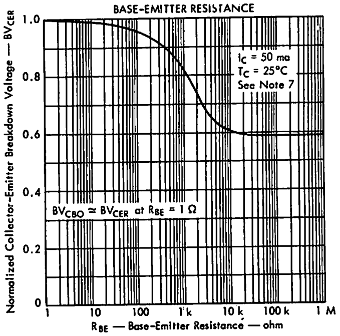


FIGURE 7

MAXIMUM SAFE OPERATING REGION

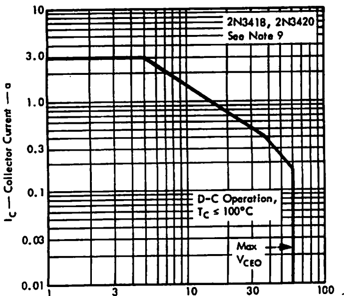


FIGURE 8

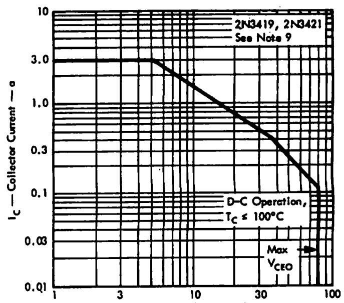
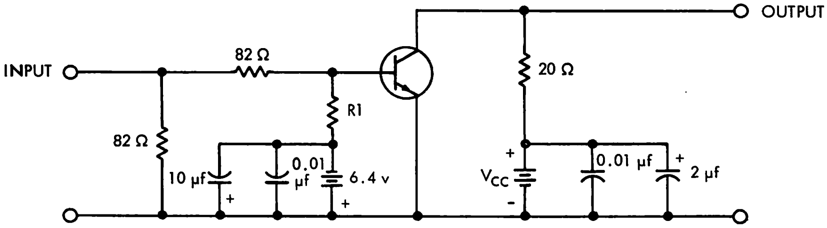


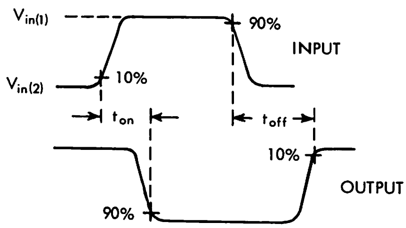
FIGURE 9

NOTE 9: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base voltage rating is not exceeded.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

Nominal I_C	R1	V_{CC}	$V_{in(1)}$	$V_{in(2)}$
1 a	82 Ω	20.3 v	+16.0 v	-1.0 v
2 a	41 Ω	40.5 v	+32.0 v	-1.3 v

CIRCUIT CONDITIONS

FIGURE 10

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ nsec, $t_f \leq 15$ nsec, $Z_{out} = 50\ \Omega$, PW = 2 µsec, Duty Cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ nsec, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pf.

c. Resistors must be non-inductive types.

THERMAL INFORMATION

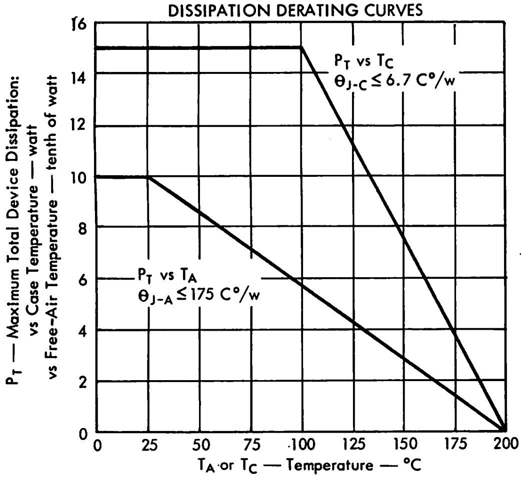


FIGURE 11

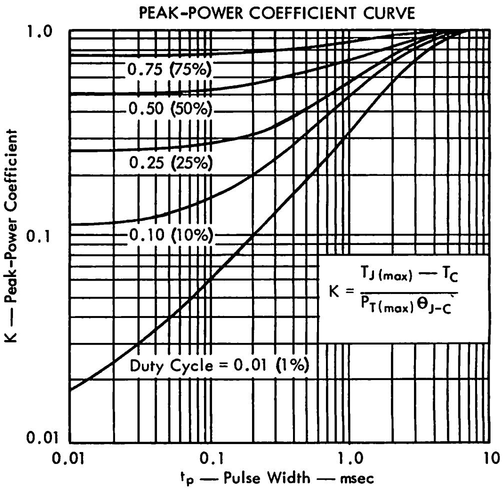


FIGURE 12

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		w
$P_{T(max)}$	Peak Power Dissipation		w
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	C°/w
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.67	C°/w
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168.33	C°/w
$\theta_{C\text{-}HS}$	Case-to-Heat Sink Thermal Resistance		C°/w
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		C°/w
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 12	
t_p	Pulse Width		msec
t_x	Pulse Period		msec
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}}$$ for 100°C $\leq T_C \leq$ 200°C, as in Figure 11

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}}$$ for 25°C $\leq T_A \leq$ 200°C, as in Figure 11

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$ for 100°C $\leq T_C \leq$ 200°C

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}}$$ for 25°C $\leq T_A \leq$ 200°C

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ C°/w (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) = 200°C

$T_A = 50$°C

d = 10% (0.1)

$t_p = 0.1$ msec

Solution:

From Figure 12, Peak-Power Coefficient

K = 0.155 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.155\,(6.67)} = 86 \text{ w}$$

TYPES 2N3551, 2N3552
BULLETIN NO. DL-S 645883, AUGUST 1964
REPLACES BULLETIN NO. DL-S 634276, AUGUST 1963

THIN-PAC†

HIGH-SPEED POWER SWITCH, ISOLATED COLLECTOR

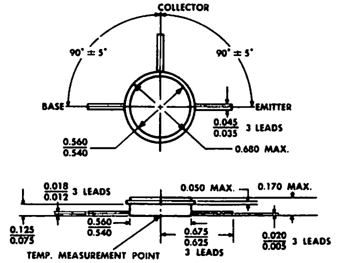
FORMERLY TIX210, TIX211

- **40 Watts at 100°C Case Temperature**
- **Maximum r_{CS} of 0.1 Ohm at 10 Amperes I_C**
- **Maximum V_{BE} of 1.4 Volts at 10 Amperes I_C**
- **Maximum t_{on} of 300 nsec**

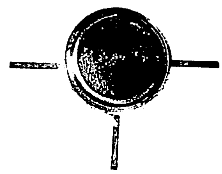
mechanical data

These transistors are in precision welded, hermetically sealed enclosures. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate unit weight is 3.8 grams.

*OUTLINE DRAWING
*ALL LEADS INSULATED FROM CASE



DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3551	2N3552
Collector-Base Voltage	115 v	140 v
Collector-Emitter Voltage (See Note 1)	60 v	80 v
Emitter-Base Voltage	← 7 v →	
Continuous Collector Current	← 12 a →	
Continuous Base Current	← 5 a →	
Continuous Emitter Current	← 12 a →	
Safe Operating Region at 100°C Case Temperature	See Figures 3 and 4	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	← 1.2 w →	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 40 w →	
Operating Collector Junction Temperature	← 175°C →	
Operating Case Temperature Range	← −65°C to + 175°C →	
Storage Temperature Range	← −65°C to + 200°C →	
Lead Temperature 1/16 Inch from Case for 12 Seconds	← 235°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 8 mw/C°.
3. Derate linearly to 175°C case temperature at the rate of 0.53 w/C°.

†Trademark of Texas Instruments.
*Indicates JEDEC registered data.

TYPES 2N3551, 2N3552
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

***electrical characteristics at 25°C case temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	2N3551 MIN	2N3551 MAX	2N3552 MIN	2N3552 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10$ ma, $I_E = 0$, See Note 4	115		140		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 200$ ma, $I_B = 0$, See Note 4	60		80		v
I_{CEV}	Collector Cutoff Current	$V_{CE} = 110$ v, $V_{BE} = -1.5$ v		10			ma
		$V_{CE} = 135$ v, $V_{BE} = -1.5$ v				10	
		$V_{CE} = 60$ v, $V_{BE} = -1.5$ v, $T_C = 150°C$		10			
		$V_{CE} = 80$ v, $V_{BE} = -1.5$ v, $T_C = 150°C$				10	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ v, $I_C = 0$		0.1		0.1	ma
		$V_{EB} = 7$ v, $I_C = 0$		1		1	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ v, $I_C = 5$ a, See Note 4	25		25		
		$V_{CE} = 2$ v, $I_C = 10$ a, See Note 4	20	90	20	90	
		$V_{CE} = 2$ v, $I_C = 10$ a, $T_C = -55°C$, See Note 4	10		10		
V_{BE}	Base-Emitter Voltage	$I_B = 0.5$ a, $I_C = 5$ a, See Note 4		1.2		1.2	v
		$I_B = 1$ a, $I_C = 10$ a, See Note 4		1.4		1.4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ a, $I_C = 5$ a, See Note 4		0.5		0.5	v
		$I_B = 1$ a, $I_C = 10$ a, See Note 4		1.0		1.0	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 3$ a, $f = 10$ Mc	4		4		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, $f = 1$ Mc		850		850	pf

NOTE 4: These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq$ 2%.

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.875	C°/w
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	125	C°/w

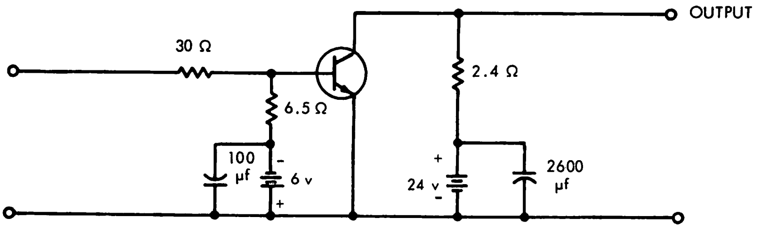
***switching characteristics at 25°C case temperature**

PARAMETER		TEST CONDITIONS‡	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 10$ a, $I_{B(1)} = 1$ a, $I_{B(2)} = -1$ a	0.3	μsec
t_{off}	Turn-Off Time	$V_{BE(off)} = -6$ v, $R_L = 2.4\Omega$, See Figure 1	2.5	μsec

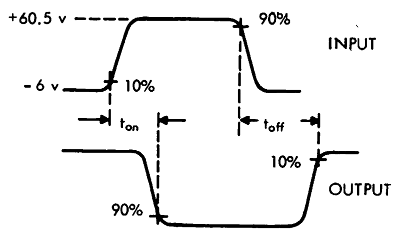
‡Voltage and current values shown are nominal; exact values vary slightly with device parameters.

*Indicates JEDEC Registered Data.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 20$ nsec, $t_f \leq 20$ nsec, $Z_{out} = 1500\ \Omega$, PW = 5 µsec, Duty Cycle $\leq 0.5\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ nsec, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pf.

c. Resistors must be noninductive types.

THERMAL INFORMATION

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

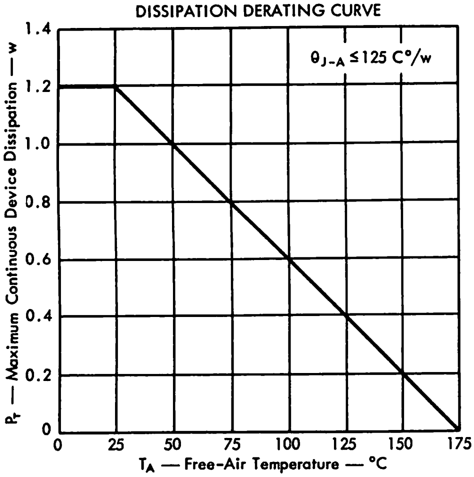


FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVE

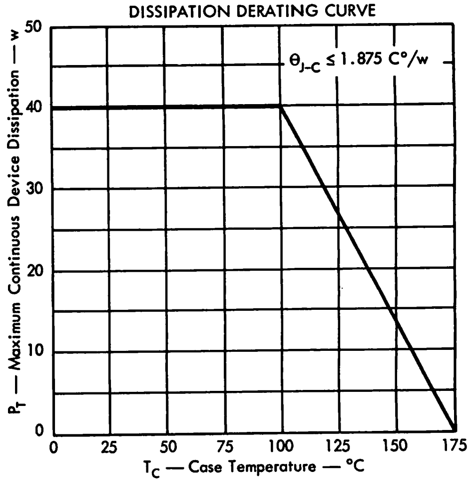


FIGURE 2

MAXIMUM SAFE OPERATING REGIONS

2N3551

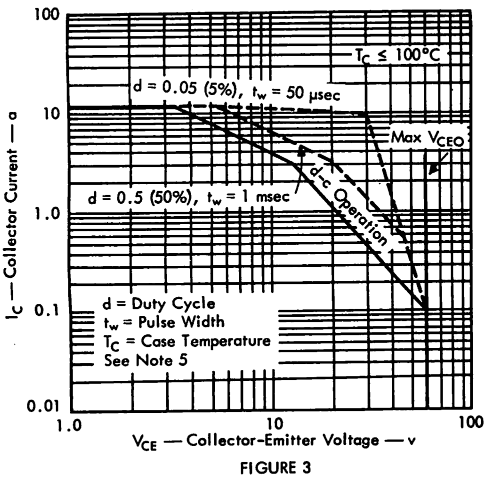


FIGURE 3

2N3552

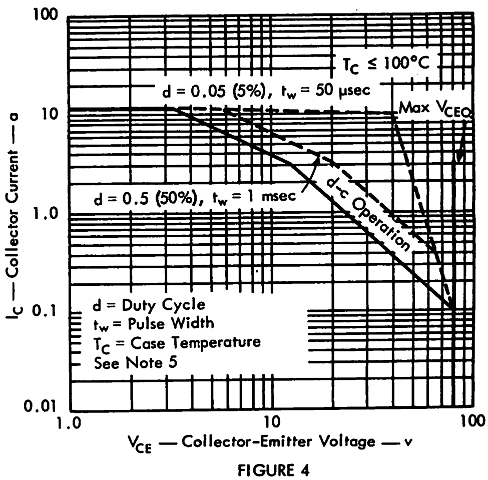


FIGURE 4

NOTE 5: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

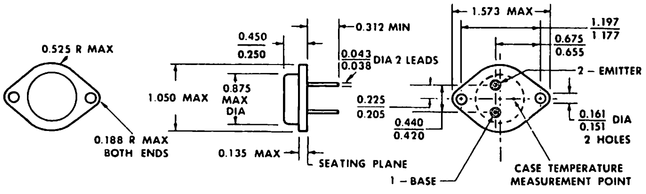
TYPES 2N3713, 2N3714, 2N3715, 2N3716
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

FOR POWER-AMPLIFIER AND SWITCHING APPLICATIONS

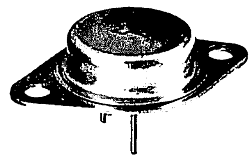
- **150 W at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_{hfe} of 30 kHz**
- **Min f_T of 4 MHz**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3713	2N3714	2N3715	2N3716
*Collector-Base Voltage	80 V	100 V	80 V	100 V
*Collector-Emitter Voltage (See Note 1)	60 V	80 V	60 V	80 V
*Emitter-Base Voltage	← 7 V →			
*Continuous Collector Current	← 10 A →			
Peak Collector Current (See Note 2)	← 15 A →			
*Continuous Base Current	← 4 A →			
*Safe Operating Region at (or below) 25°C Case Temperature	See Figures 8 and 9			
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 150 W →			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →			
*Operating Collector Junction Temperature Range	← −65°C to 200°C →			
*Storage Temperature Range	← −65°C to 200°C →			
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 235°C →			

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for t_p = 0.3 ms, duty cycle ≤ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.855 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3713 MIN	2N3713 MAX	2N3714 MIN	2N3714 MAX	2N3715 MIN	2N3715 MAX	2N3716 MIN	2N3716 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 5	60		80		60		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7				0.7			mA
		$V_{CE} = 40$ V, $I_B = 0$				0.7				0.7	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 80$ V, $V_{BE} = -1.5$ V		1				1			mA
		$V_{CE} = 100$ V, $V_{BE} = -1.5$ V				1				1	
		$V_{CE} = 60$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$		10				10			mA
		$V_{CE} = 80$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$				10				10	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ V, $I_C = 0$		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 1$ A, See Notes 5 and 6	25	75	25	75	50	150	50	150	
		$V_{CE} = 2$ V, $I_C = 3$ A, See Notes 5 and 6	15		15		30		30		
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6	5		5		5		5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V, $I_C = 5$ A, See Notes 5 and 6		2		2		1.8		1.8	V
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6		4		4		4		4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A, $I_C = 5$ A, See Notes 5 and 6		1		1		0.8		0.8	V
		$I_B = 2$ A, $I_C = 10$ A, See Notes 5 and 6		4		4		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, $f = 1$ kHz	25	250	25	250	25	250	25	250	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, $f = 1$ MHz	4		4		4		4		
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	$V_{CE} = 10$ V, $I_C = 0.5$ A	30		30		30		30		kHz
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 100$ kHz		250		250		250		250	pF

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

	PARAMETER	MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1.17	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	

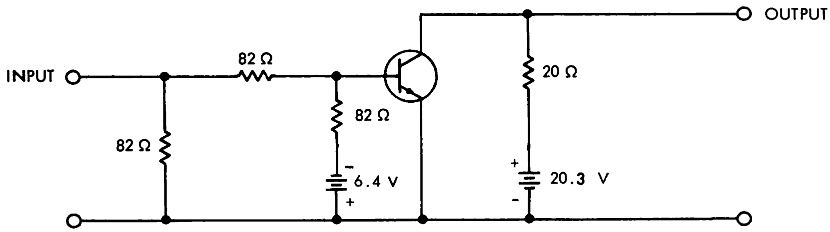
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

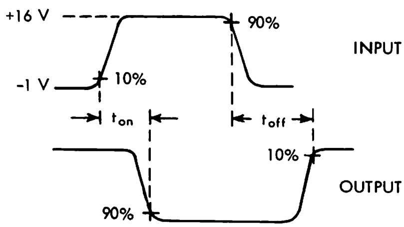
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 1$ A, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA,	450	ns
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	350	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

2N3713, 2N3714
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

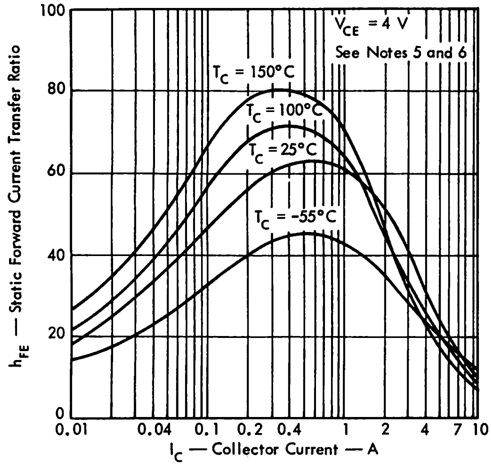


FIGURE 2

2N3715, 2N3716
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

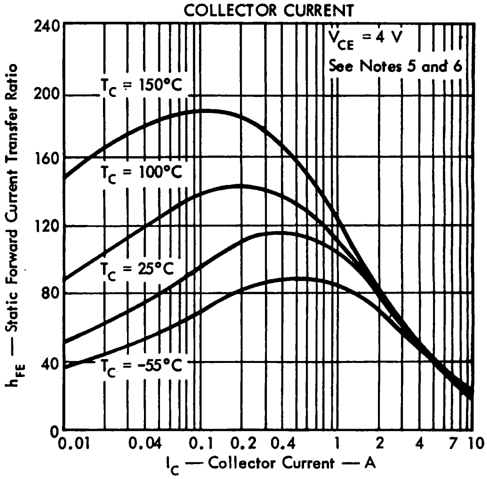


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

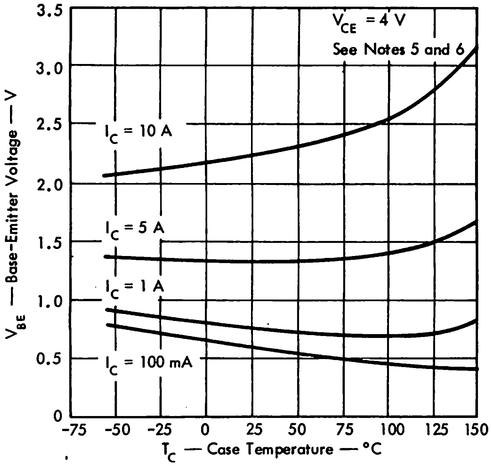


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

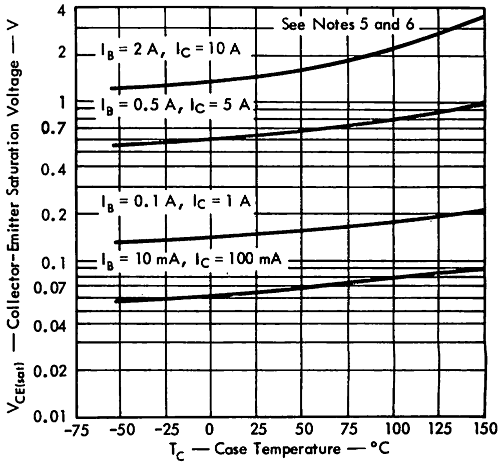


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

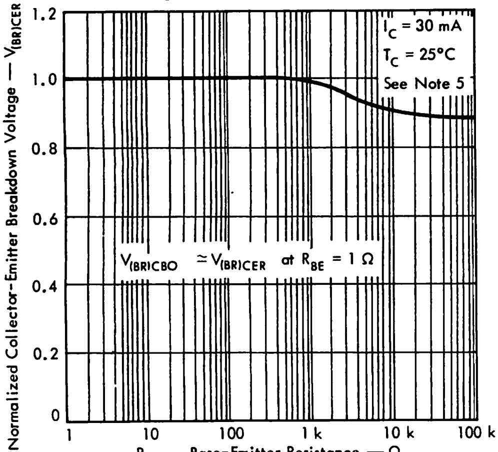


FIGURE 6

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE vs COLLECTOR-BASE VOLTAGE

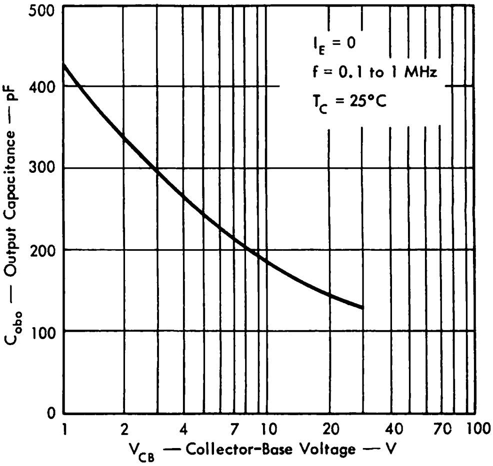


FIGURE 7

MAXIMUM SAFE OPERATING REGIONS

2N3713, 2N3715

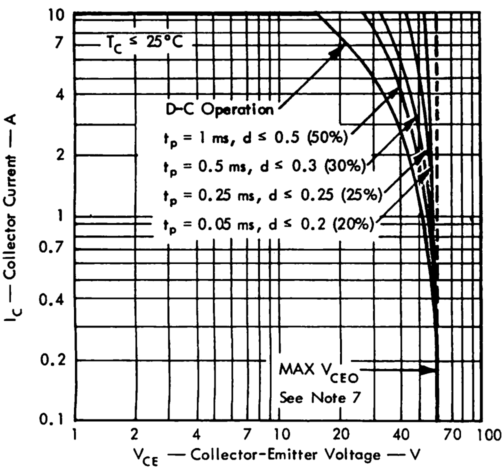


FIGURE 8

2N3714, 2N3716

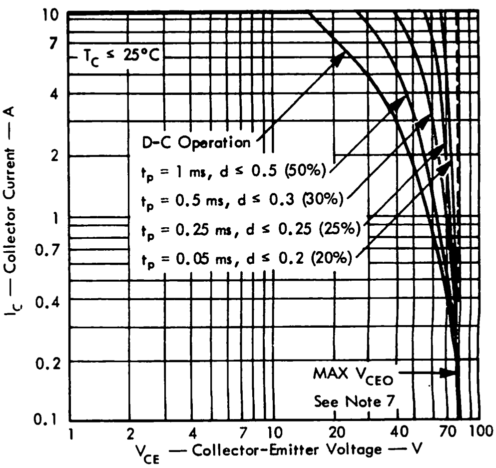


FIGURE 9

NOTES: 5. This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

7. Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL INFORMATION

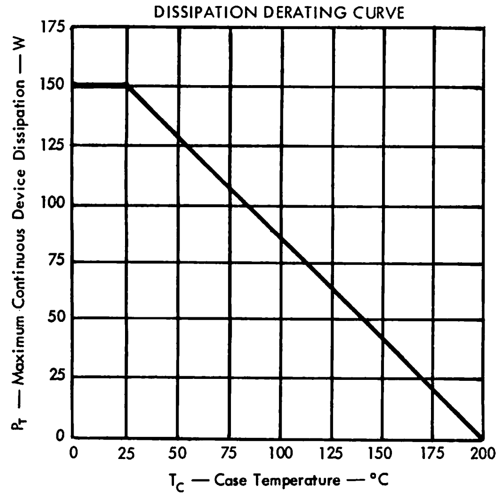


FIGURE 10

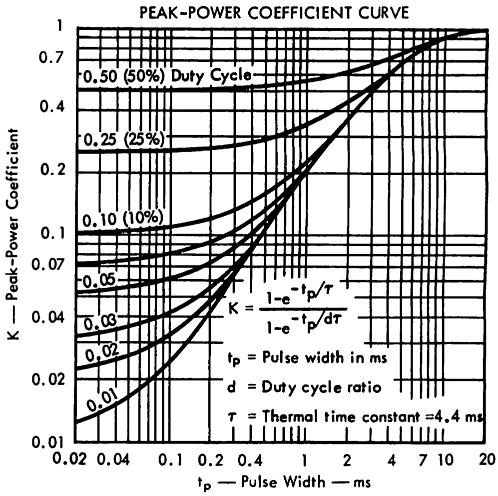


FIGURE 11

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.17	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	42.5	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 11	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 25\,°C \leq T_C \leq 200°C, \text{ as in figure 10.}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 25\,°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.25$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From figure 11, Peak-Power Coefficient $K = 0.11$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.25) + 0.11(1.17)} = 424\text{ W}$$

TYPES 2N3996, 2N3997, 2N3998, 2N3999
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

TYPES 2N3996, 2N3997, 2N3998, 2N3999
BULLETIN NO. DL-S 668257, MARCH 1966

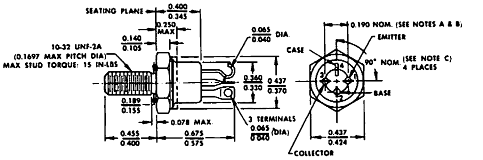
FOR HIGH-SPEED POWER SWITCHING APPLICATIONS

- **30 W at 100°C Case Temperature**
- **Isolated-Stud Package (2N3996, 2N3997)**
- **Max $V_{CE(sat)}$ of 0.25 V at 1 A I_C**
- **Max t_{on} of 300 ns at 1 A I_C**
- **Min f_T of 40 MHz**

*mechanical data

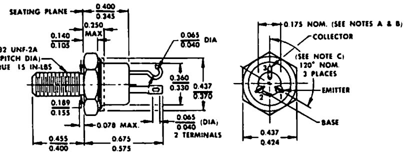
2N3996, 2N3997

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE



2N3998, 2N3999

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



NOTES: A. Position of terminals with respect to hexagon is not controlled.
B. Terminals located on true position within 0.030 inch relative to diameter of can.
C. This dimension applies to the location of the center line of the terminals.
D. The case temperature may be measured anywhere on the seating plane within 0.125 inch of the stud.
E. All dimensions are in inches unless otherwise specified.

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	8 V
Continuous Collector Current	5 A
Peak Collector Current (See Note 2)	10 A
Continuous Base Current	1 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 8
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Operating Collector Junction Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 1$ ms, duty cycle $\leq 50\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/deg.

*Indicates JEDEC registered data.

TYPES 2N3996, 2N3997, 2N3998, 2N3999
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3996 2N3998 MIN	2N3996 2N3998 MAX	2N3997 2N3999 MIN	2N3997 2N3999 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 50$ mA, $I_B = 0$, See Note 5	80		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 60$ V, $I_B = 0$		10		10	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		5		5	μA
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		50		50	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		0.5		0.5	μA
		$V_{EB} = 8$ V, $I_C = 0$		10		10	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA	30		60		
		$V_{CE} = 2$ V, $I_C = 1$ A, See Note 5	40	120	80	240	
		$V_{CE} = 5$ V, $I_C = 5$ A, See Note 5	15		20		
		$V_{CE} = 2$ V, $I_C = 1$ A, $T_C = -55°C$, See Note 5	10		20		
V_{BE}	Base-Emitter Voltage	$I_B = 100$ mA, $I_C = 1$ A, See Note 5	0.6	1.2	0.6	1.2	V
		$I_B = 500$ mA, $I_C = 5$ A, See Note 5		1.6		1.6	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ mA, $I_C = 1$ A, See Note 5		0.25		0.25	V
		$I_B = 500$ mA, $I_C = 5$ A See Note 5		2		2	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 10$ MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz		150		150	pF

NOTE 5: This parameter must be measured using pulse techniques: $t_p = 300$ μs, duty cycle $\leq 2\%$.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	3.33	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	87.5	deg/W

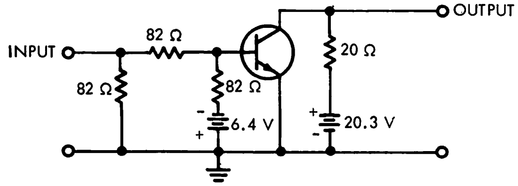
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	2N3996 2N3998 MAX	2N3997 2N3999 MAX	UNIT
t_{on}	Turn-On Time	$I_C = 1$ A, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA,	0.3	0.3	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	1.5	2	

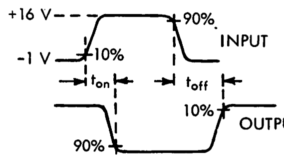
†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 2\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

2N3996, 2N3998
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

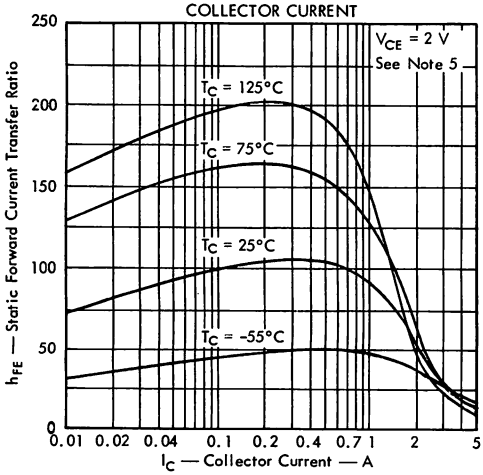


FIGURE 2

2N3997, 2N3999
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

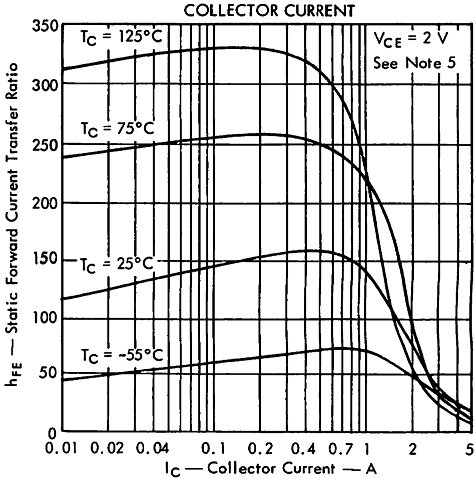


FIGURE 3

NOTE 5: This parameter must be measured using pulse techniques: $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

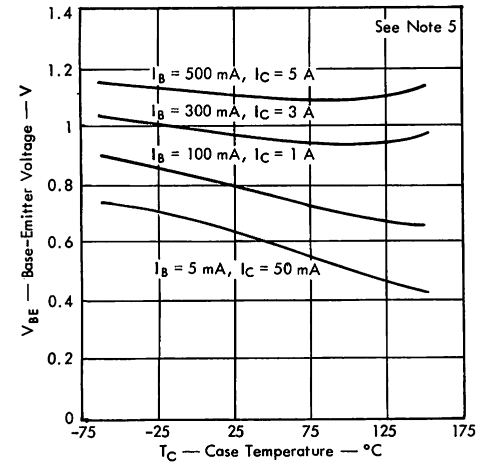


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

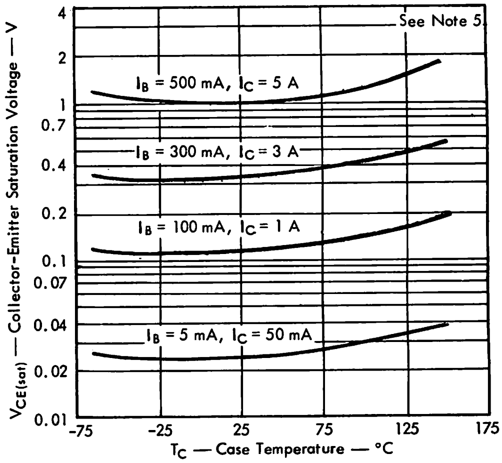


FIGURE 5

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

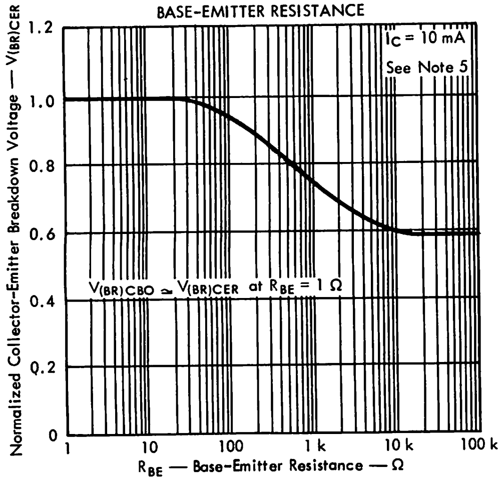


FIGURE 6

COMMON-BASE OPEN-CIRCUIT
INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

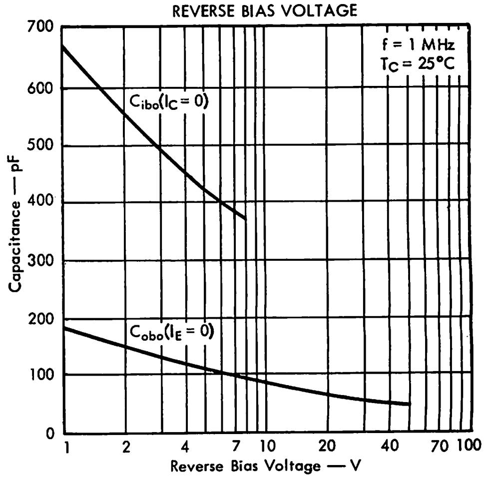


FIGURE 7

NOTE 5: This parameter must be measured using pulse techniques: $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

MAXIMUM SAFE OPERATING REGION

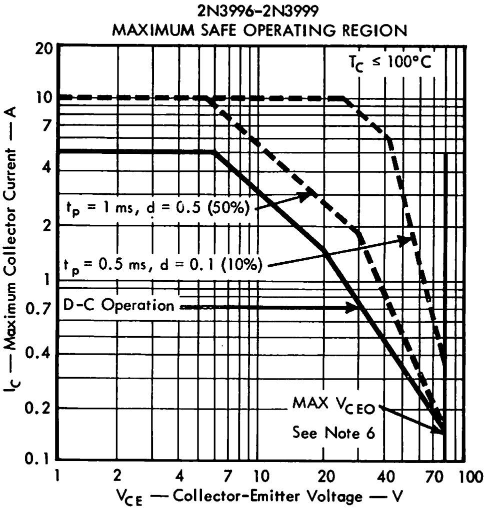


FIGURE 8

NOTE 6: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base voltage rating is not exceeded.

THERMAL INFORMATION

CASE TEMPERATURE DISSIPATION DERATING CURVE

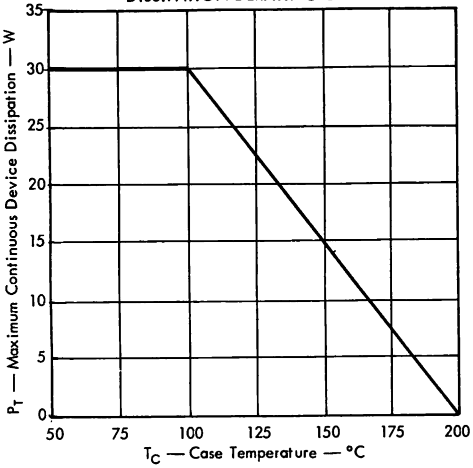


FIGURE 9

PEAK-POWER COEFFICIENT CURVE

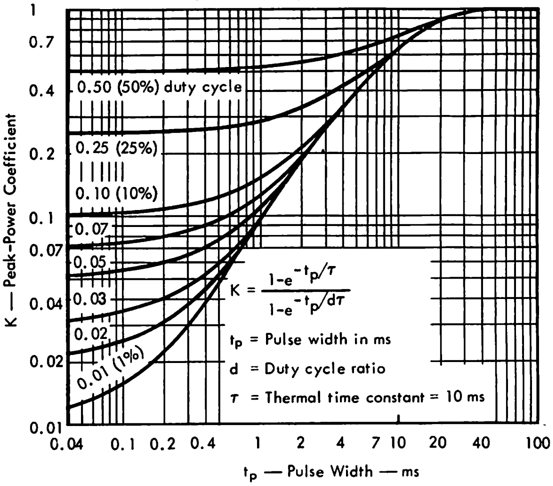


FIGURE 10

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	87.5	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	3.33	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	84.17	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	$\leq$ 200	°C
$T_{J(max)}$	Peak Junction Temperature	$\leq$ 200	°C
K	Peak-Power Coefficient	See Figure 10	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 9}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C.$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 10, Peak-Power Coefficient

K = 0.103 and by use of equation No. 3

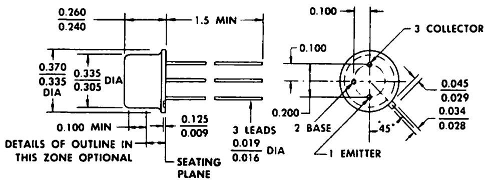
$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + (0.103)\,3.33} = 143\text{ W}$$

FOR HIGH-SPEED POWER SWITCHING APPLICATIONS

- 15 W at 100°C Case Temperature
- Max $V_{CE(sat)}$ of 0.3 V at 0.5 A I_C
- Max t_{on} of 300 ns at 0.5 A I_C
- Min f_T of 40 MHz

*mechanical data

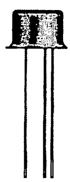


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

CASE TEMPERATURE IS MEASURED 0.144 INCH ±0.010 INCH DOWN FROM TOP OF CAN.



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4000	2N4001
Collector-Base Voltage	100 V	120 V
Collector-Emitter Voltage (See Note 1)	80 V	100 V
Emitter-Base Voltage	← 8 V →	
Continuous Collector Current	← 1 A →	
Peak Collector Current (See Note 2)	← 3 A →	
Continuous Base Current	← 0.5 A →	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 8	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 15 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 1 W →	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 230°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 1$ ms, duty cycle $\leq 50\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.15 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mW/deg.

*Indicates JEDEC registered data.

TYPES 2N4000, 2N4001
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4000 MIN	2N4000 MAX	2N4001 MIN	2N4001 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 60$ V, $I_B = 0$		10			μA
		$V_{CE} = 80$ V, $I_B = 0$				10	
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		2			μA
		$V_{CE} = 110$ V, $V_{BE} = 0$				2	
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		50			
		$V_{CE} = 110$ V, $V_{BE} = 0$, $T_C = 150°C$				50	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		500		500	nA
		$V_{EB} = 8$ V, $I_C = 0$		10		10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA	10		20		
		$V_{CE} = 2$ V, $I_C = 0.5$ A, See Note 5	30	120	40	120	
		$V_{CE} = 5$ V, $I_C = 1$ A, See Note 5	10		20		
		$V_{CE} = 2$ V, $I_C = 0.5$ A, $T_C = -55°C$, See Note 5	10		15		
V_{BE}	Base-Emitter Voltage	$I_B = 50$ mA, $I_C = 0.5$ A, See Note 5		1		1	V
		$I_B = 100$ mA, $I_C = 1$ A, See Note 5		1.2		1.2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 50$ mA, $I_C = 0.5$ A, See Note 5		0.3		0.3	V
		$I_B = 100$ mA, $I_C = 1$ A, See Note 5		0.5		0.5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ A, $f = 20$ MHz	2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz		60		60	pF

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	6.67	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	

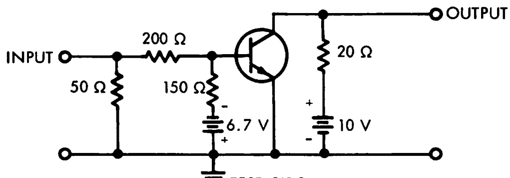
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 0.5$ A, $I_{B(1)} = 50$ mA, $I_{B(2)} = -50$ mA,	0.3	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4$ V, $R_L = 20\ \Omega$, See Figure 1	2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data.

PARAMETER MEASUREMENT INFORMATION



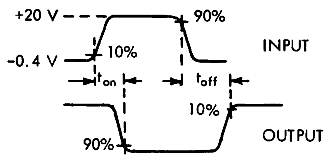


FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 10$ ns, $t_f \leq 10$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPES 2N4000, 2N4001
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

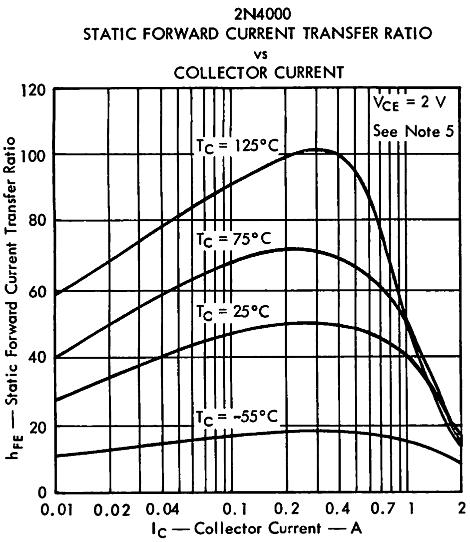


FIGURE 2

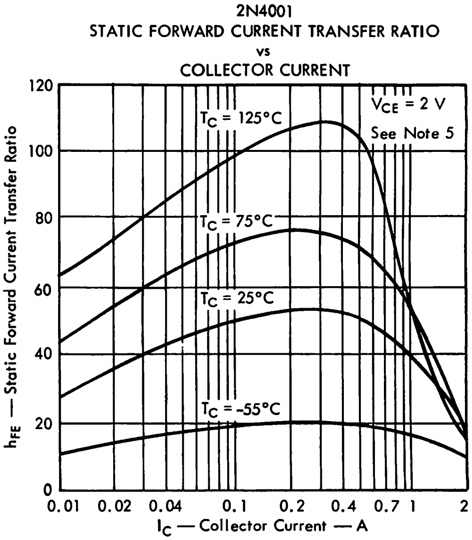


FIGURE 3

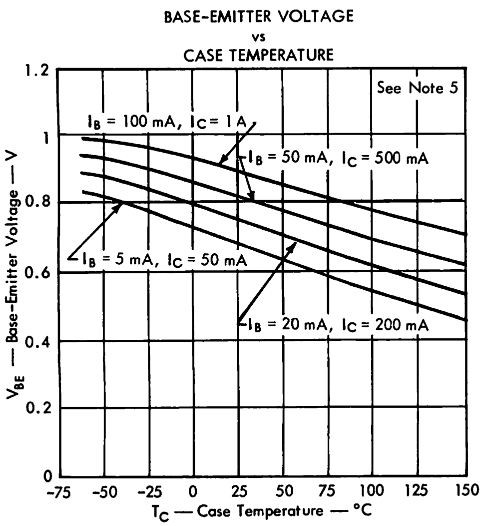


FIGURE 4

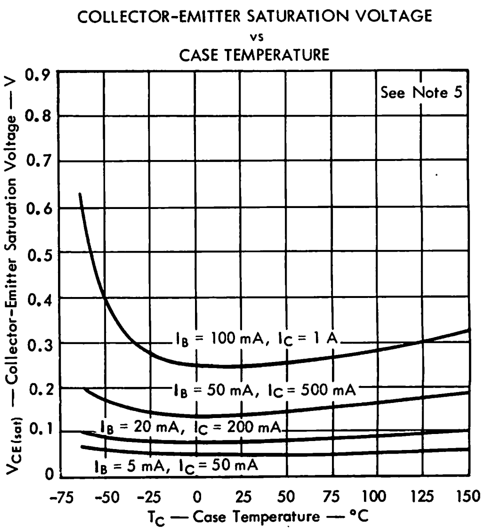


FIGURE 5

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

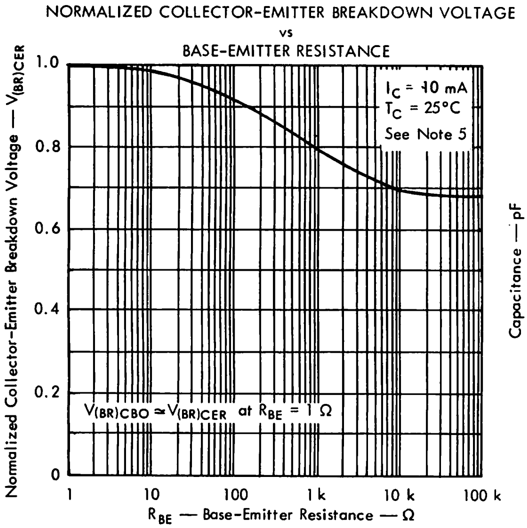


FIGURE 6

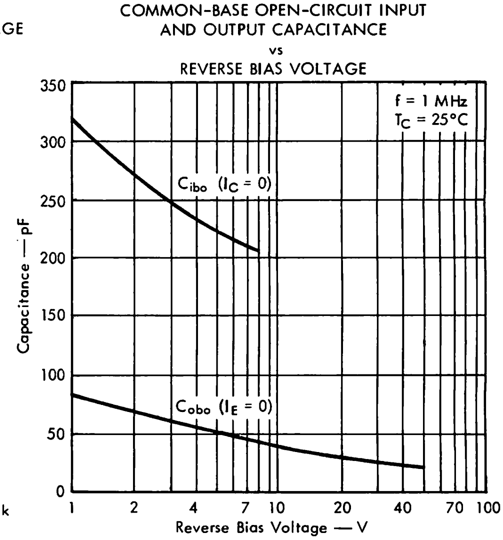


FIGURE 7

NOTE 5: These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

MAXIMUM SAFE OPERATING REGION

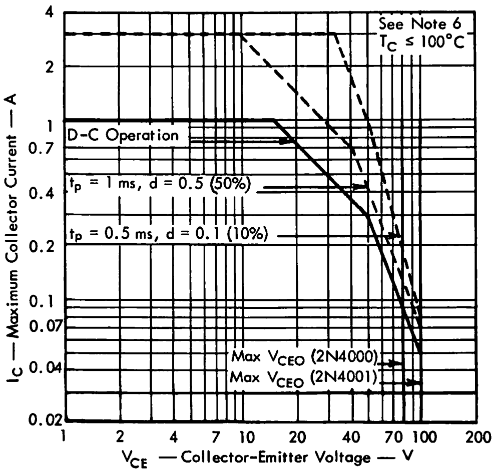


FIGURE 8

NOTE 6: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base voltage rating is not exceeded.

THERMAL INFORMATION

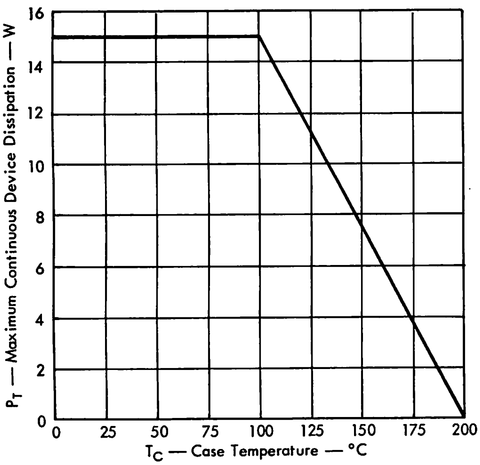


FIGURE 9

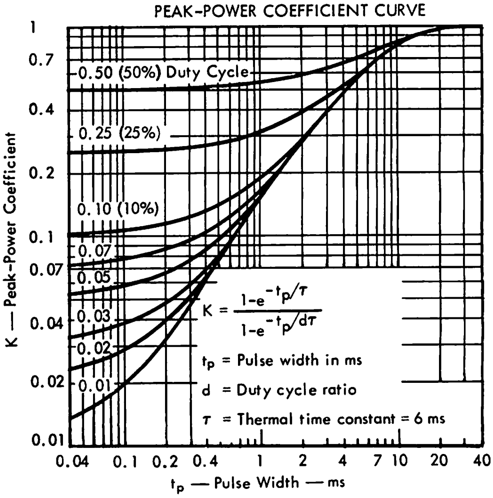


FIGURE 10

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.67	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168.33	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 10	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 9}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\ \theta_{C\text{-}A} + K\ \theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C.$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%\ (0.1)$

$t_p = 1$ ms

Solution:

From Figure 10, Peak-Power Coefficient $K = 0.19$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + (0.19)\,(6.67)} = 76\text{ W}$$

N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

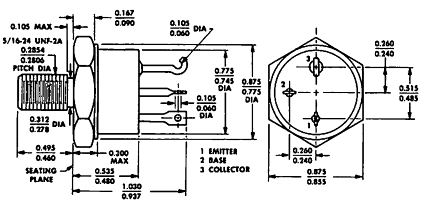
TYPES 2N4002, 2N4003
BULLETIN NO. DL-S 668606, MAY 1966

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **30-A Rated Continuous Collector Current**
- **100 Watts at 100°C Case Temperature**
- **Maximum $V_{CE(sat)}$ of 1.2 V at 30 A**
- **Maximum V_{BE} of 1.8 V at 30 A**
- **Maximum t_{on} of 1 μs at 15 A**

*mechanical data

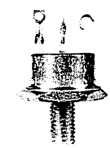
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 0.125" FROM STUD

ALL DIMENSIONS ARE IN INCHES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4002	2N4003
Collector-Base Voltage	100 V	120 V
Collector-Emitter Voltage (See Note 1)	80 V	100 V
Emitter-Base Voltage	←8 V→	
Continuous Collector Current	←30 A→	
Peak Collector Current (See Note 2)	←40 A→	
Continuous Base Current	←10 A→	
Continuous Emitter Current	←30 A→	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	←100 W→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←4 W→	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1/16 Inch from Case for 10 Seconds	←230°C→	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_p \le 0.3$ ms, duty cycle $\le 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N4002, 2N4003
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4002		2N4003		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		2			mA
		$V_{CE} = 50$ V, $I_B = 0$				2	
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		1			mA
		$V_{CE} = 110$ V, $V_{BE} = 0$				1	
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		2			
		$V_{CE} = 110$ V, $V_{BE} = 0$, $T_C = 150°C$				2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		100		100	μA
		$V_{EB} = 8$ V, $I_C = 0$		50		50	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 30$ A, See Notes 5 and 6	10		10		
		$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 5 and 6	20	80	20	80	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 30$ A, See Notes 5 and 6		1.8		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 4$ A, $I_C = 30$ A, See Notes 5 and 6		1.2		1.2	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	30		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 10$ MHz	3		3		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	deg/W

*Indicates JEDEC registered data.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 15$ A, $I_{B(1)} = 1.5$ A, $I_{B(2)} = -1.5$ A,	1	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -2$ V, $R_L = 3\ \Omega$, See Figure 1	3	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION

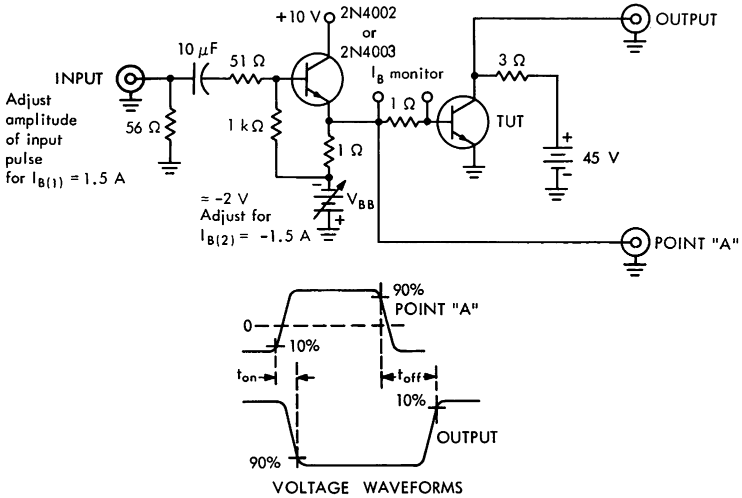


FIGURE 1

NOTES: a. The input waveform at point "A" has the following characteristics: $t_r \leq 100$ ns, $t_f \leq 100$ ns, $t_p = 20$ μs, duty cycle $\leq 0.2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data.

16615

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

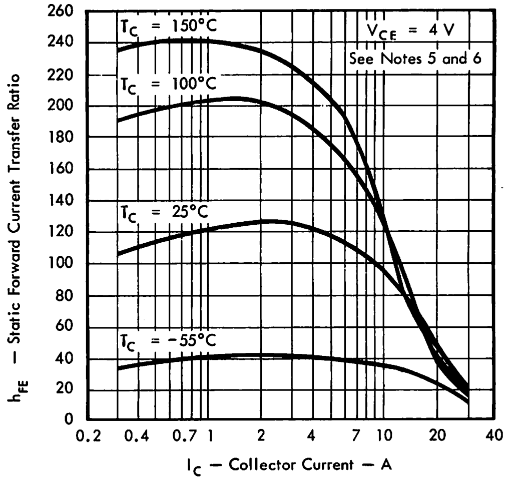


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

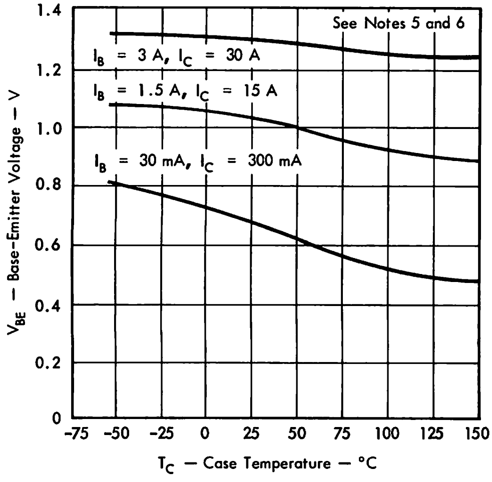


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

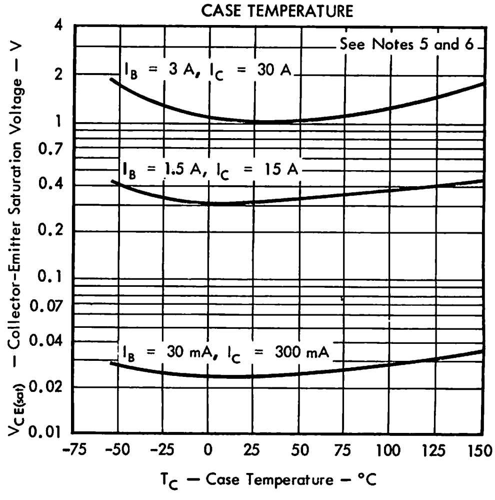


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

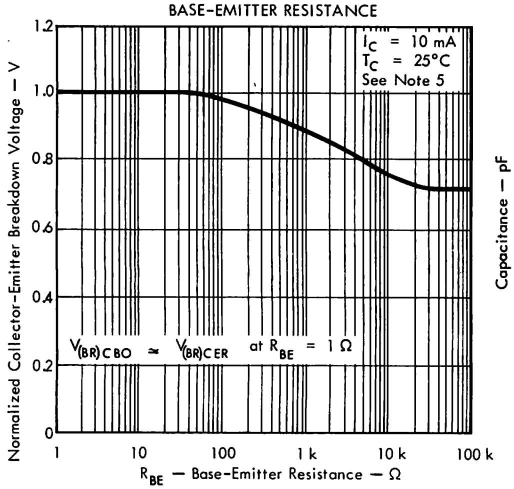


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

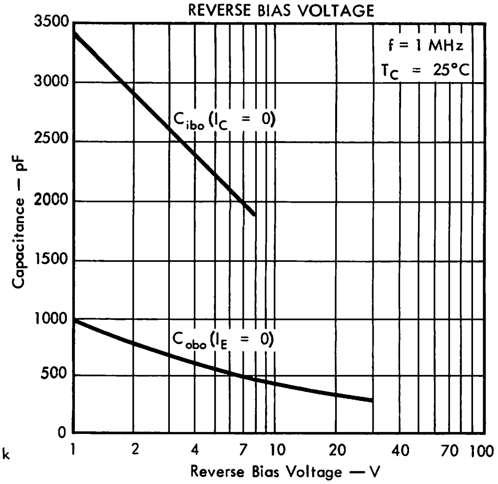


FIGURE 6

NOTE 5: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

MAXIMUM SAFE OPERATING REGION

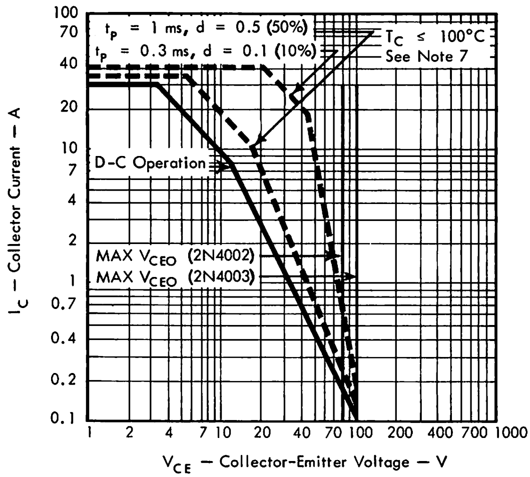


FIGURE 7

Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base voltage rating is not exceeded.

THERMAL INFORMATION

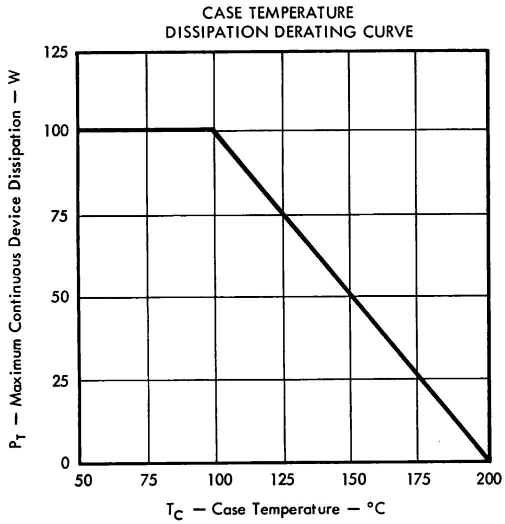


FIGURE 8

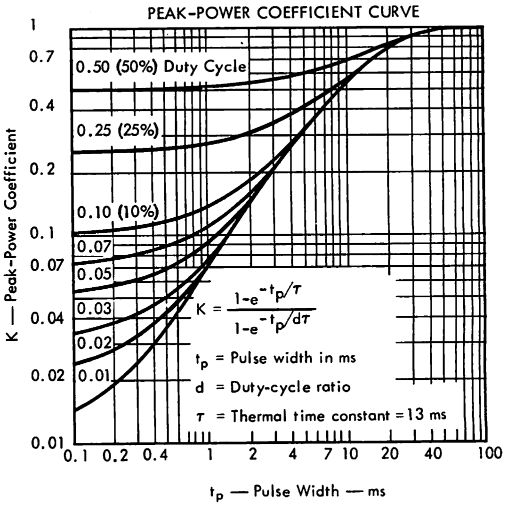


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	42.7	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C, \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.5$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%\ (0.1)$

$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient $K = 0.1$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.5) + 0.1(1)} = 428\ \text{W}$$

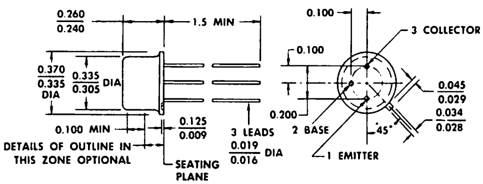
TYPE 2N4300
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

TYPE 2N4300
BULLETIN NO. DL-S 668562, MAY 1966

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **15 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.3 V at 1 A I_C**
- **Typ t_{on} of 130 ns at 1 A I_C**
- **Min f_T of 30 MHz**

*mechanical data

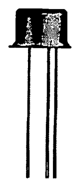


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE.

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

CASE TEMPERATURE IS MEASURED 0.144 INCH ± 0.010 INCH DOWN FROM TOP OF CAN.



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	8 V
Continuous Collector Current	2 A
Peak Collector Current (See Note 2)	4 A
Continuous Base Current	1 A
Continuous Emitter Current	3 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	15 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	1 W
Operating Collector Junction Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.

3. Derate linearly to 200°C case temperature at the rate of 0.15 W/deg.

4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mW/deg.

*Indicates JEDEC registered data.

TYPE 2N4300
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		1	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		10	μA
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		75	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		0.5	μA
		$V_{EB} = 8$ V, $I_C = 0$		10	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 1$ A, See Notes 5 and 6	30	120	
		$V_{CE} = 2$ V, $I_C = 2$ A, See Notes 5 and 6	15		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V, $I_C = 2$ A, See Notes 5 and 6		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ mA, $I_C = 1$ A, See Notes 5 and 6		0.3	V
		$I_B = 200$ mA, $I_C = 2$ A, See Notes 5 and 6		0.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 1$ kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 15$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.66	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	

*Indicates JEDEC registered data.

switching characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS†			TYP	UNIT
t_{on} Turn-On Time	$I_C = 1$ A,	$I_{B(1)} = 100$ mA,	$I_{B(2)} = -100$ mA,	0.13	μs
t_{off} Turn-Off Time	$V_{BE(off)} = -3.7$ V,	$R_L = 20\ \Omega$,	See Figure 1	1.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

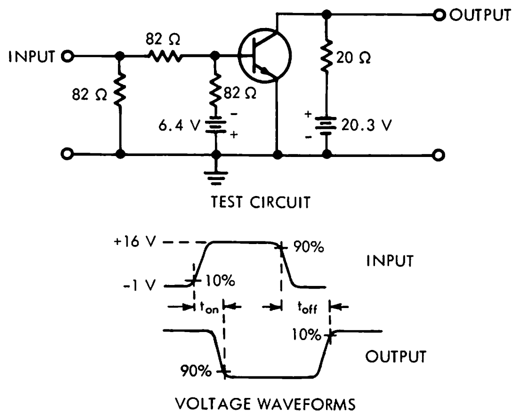


FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 2\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPE 2N4300
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

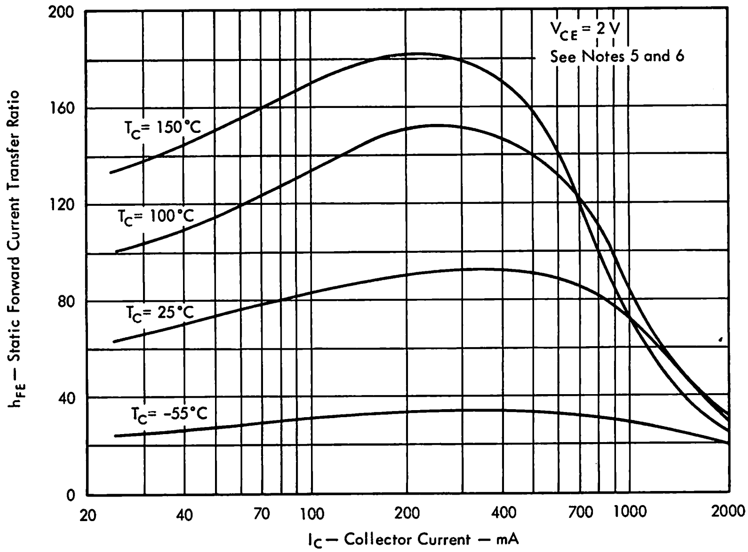


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

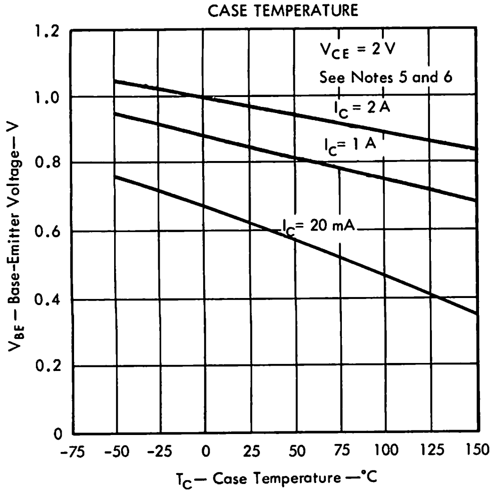


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

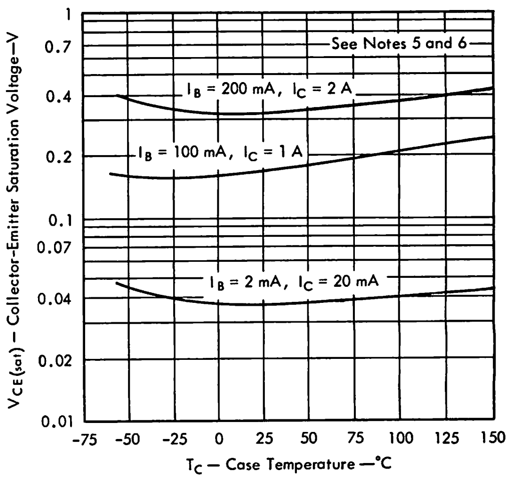


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR - EMITTER BREAKDOWN VOLTAGE vs BASE - EMITTER RESISTANCE

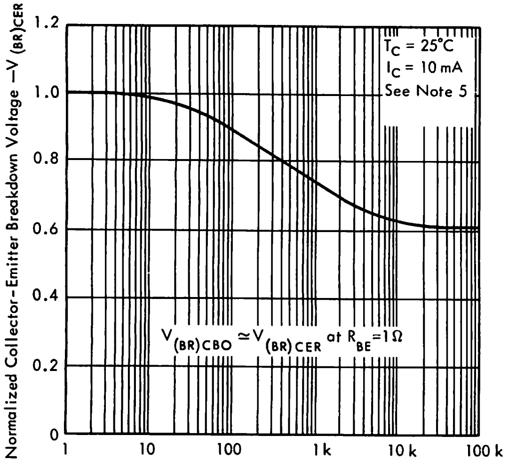


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

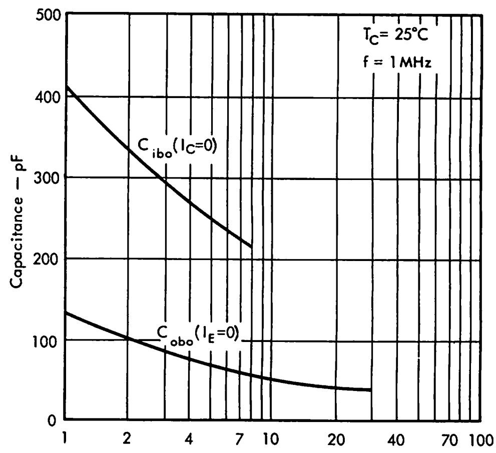


FIGURE 6

NOTE 5: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

MAXIMUM SAFE OPERATING REGION

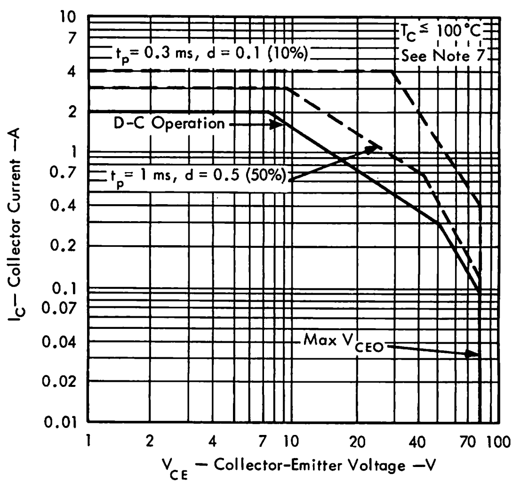


FIGURE 7

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

TYPE 2N4300
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

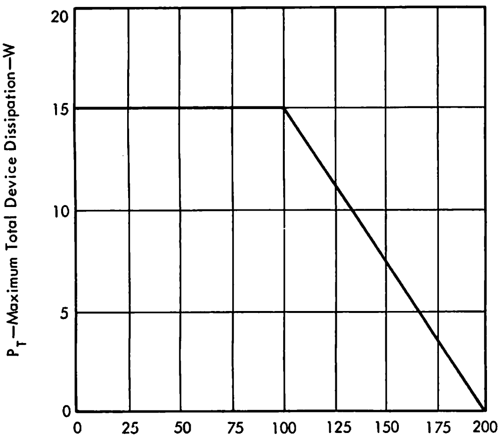


FIGURE 8

PEAK-POWER COEFFICIENT CURVE

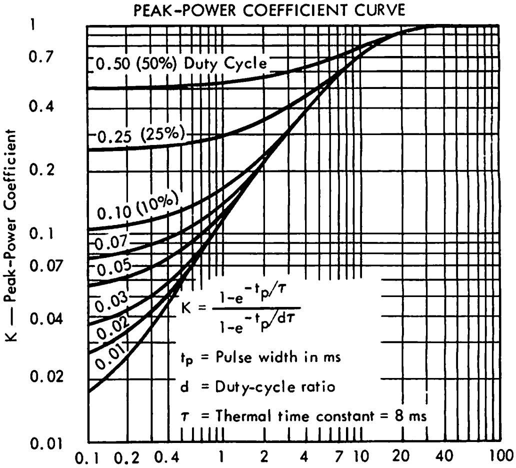


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	deg/W
θ_{J-C}	Junction-to-Case Thermal Resistance	6.66	deg/W
θ_{C-A}	Case-to-Free-Air Thermal Resistance	168	deg/W
θ_{C-HS}	Case-to-Heat-Sink Thermal Resistance		deg/W
θ_{HS-A}	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J-A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C-A} + K\,\theta_{J-C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)
OPERATING CONDITIONS:

$\theta_{C-HS} + \theta_{HS-A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$
$T_A = 50°C$
$d = 10\%$ (0.1)
$t_p = 0.1$ ms

Solution:
From Figure 9, Peak-Power Coefficient
K = 0.105 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.105\,(6.66)} = 107\text{ W}$$

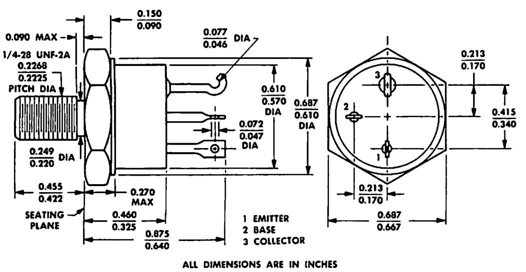
TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 50 W at 100°C Case Temperature
- Max $V_{CE(sat)}$ of 0.4 V at 5 A I_C
- Typ t_{on} of 150 ns at 5 A I_C
- Min f_T of 40 MHz

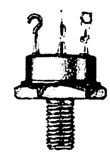
*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 0.125" FROM STUD



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	8 V
Continuous Collector Current	10 A
Peak Collector Current (See Note 2)	20 A
Continuous Base Current	4 A
Continuous Emitter Current	10 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	50 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W
Operating Collector Junction Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Terminal Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data.

TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

***electrical characteristics at 25°C case temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		10	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		10	μA
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		5	μA
		$V_{EB} = 8$ V, $I_C = 0$		50	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 5$ A, See Notes 5 and 6	30	120	
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6	15		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A, $I_C = 5$ A, See Notes 5 and 6		0.4	V
		$I_B = 1.3$ A, $I_C = 10$ A, See Notes 5 and 6		1	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 1$ kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 20$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

***thermal characteristics**

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

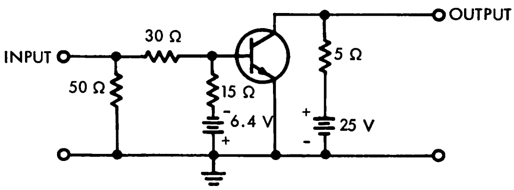
*Indicates JEDEC registered data.

switching characteristics at 25°C case temperature

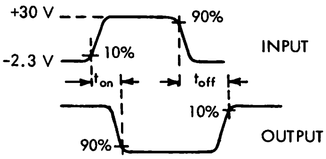
PARAMETER	TEST CONDITIONS†	TYP	UNIT
t_{on} Turn-On Time	$I_C = 5$ A, $I_{B(1)} = 500$ mA, $I_{B(2)} = -500$ mA,	0.15	μs
t_{off} Turn-Off Time	$V_{BE(off)} = -5$ V, $R_L = 5\ \Omega$, See Figure 1	1.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

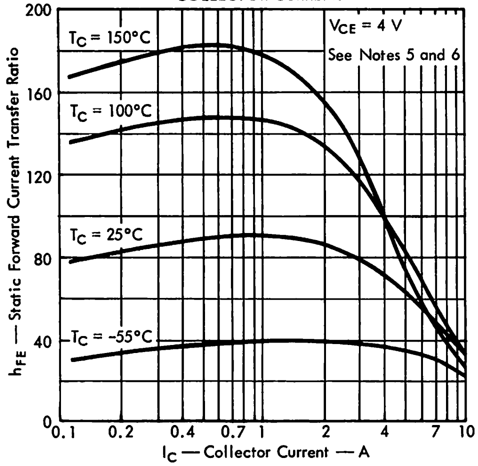


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

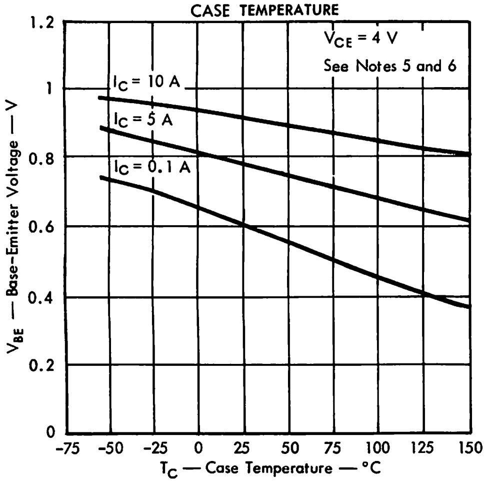


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

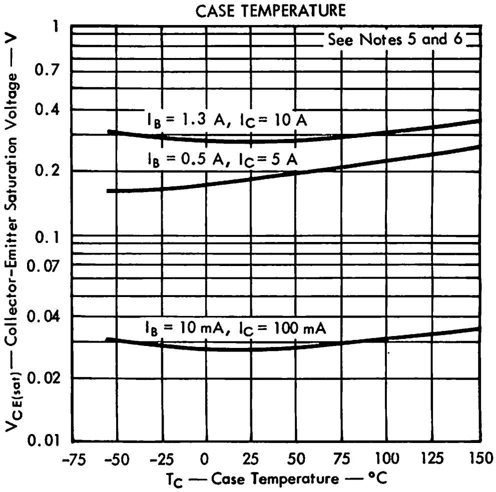


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

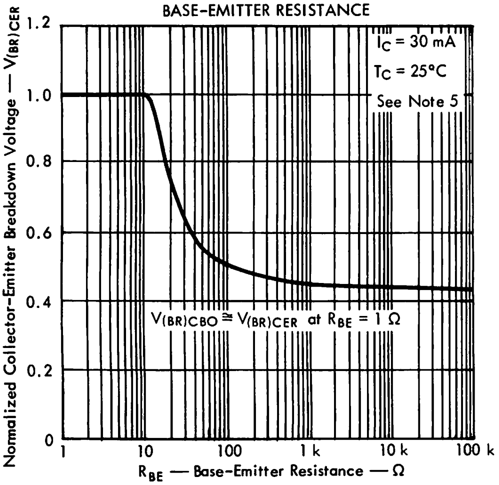


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

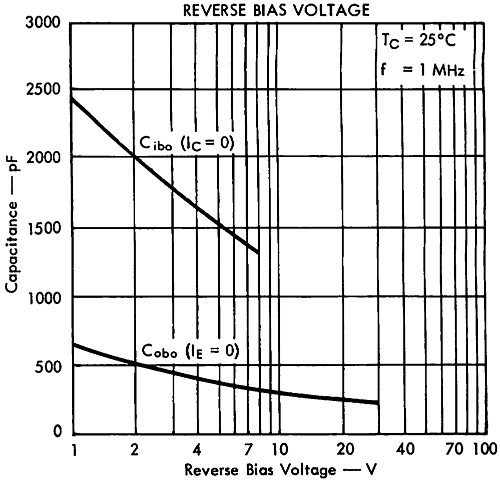


FIGURE 6

MAXIMUM SAFE OPERATING REGION

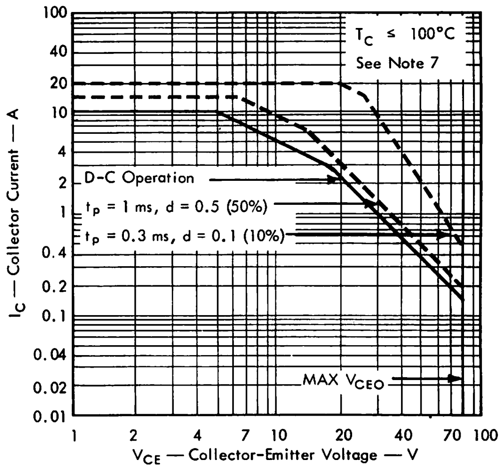


FIGURE 7

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

THERMAL INFORMATION

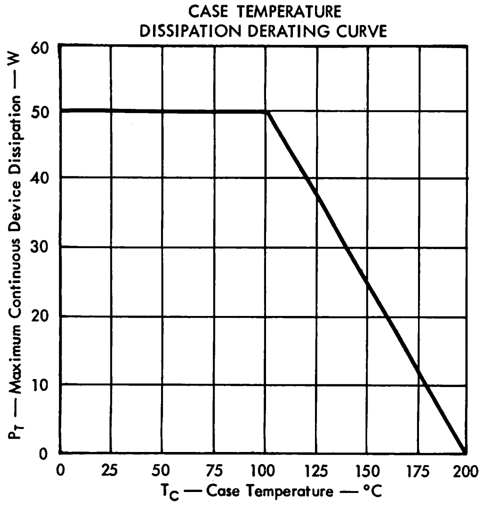


FIGURE 8

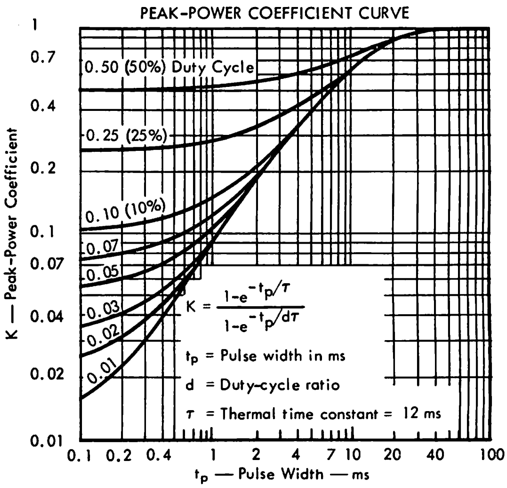


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	48	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)
OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 1.3$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$
$T_A = 50°C$
$d = 10\%\ (0.1)$
$t_p = 0.1$ ms

Solution:
From Figure 9, Peak-Power Coefficient

K = 0.101 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(1.3) + 0.101\,(2)} = 450 \text{ W}$$

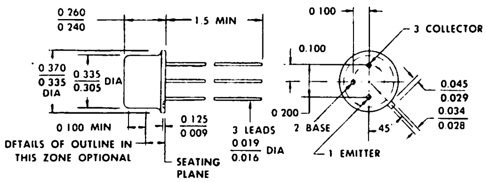
TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

TYPE 2N5333
BULLETIN NO. DL-S 689281, MARCH 1968

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4300

- **15 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.45 V at 1 A I_C**
- **Typ t_{on} of 150 ns at 1 A I_C**
- **Min f_T of 30 MHz**

*mechanical data

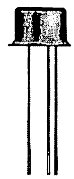


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

CASE TEMPERATURE IS MEASURED 0.144 INCH ±0.010 INCH DOWN FROM TOP OF CAN.



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−2 A
Peak Collector Current (See Note 2)	−5 A
Continuous Base Current	−1 A
Continuous Emitter Current	−3 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	15 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	1 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.15 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	μA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−1	μA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 5 and 6	30	120	
		$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.1$ A, $I_C = -1$ A, See Notes 5 and 6		−0.45	V
		$I_B = -0.4$ A, $I_C = -2$ A, See Notes 5 and 6		−1	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 1$ kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 15$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	6.66	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	

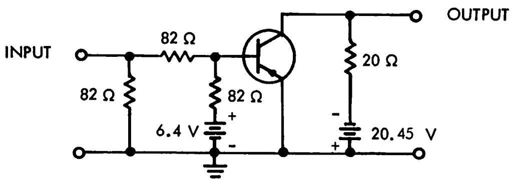
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

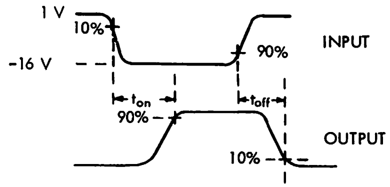
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -0.1$ A, $I_{B(2)} = 0.1$ A,	150	ns
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, See Figure 1	450	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 2\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

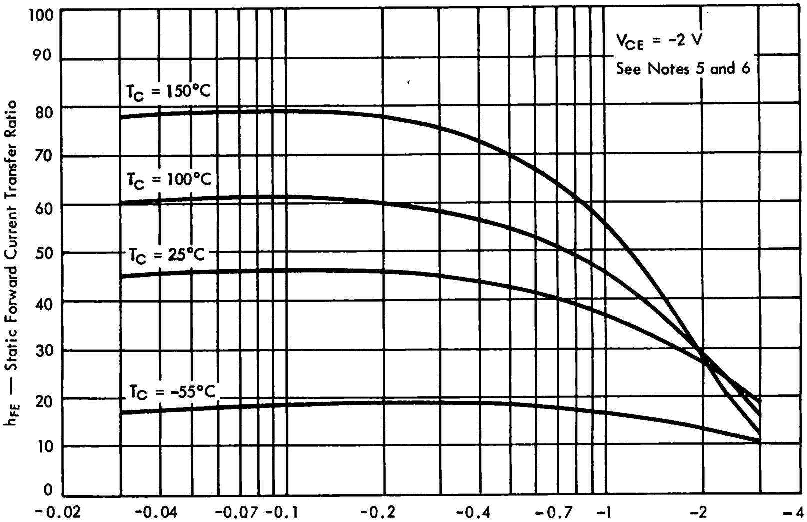


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

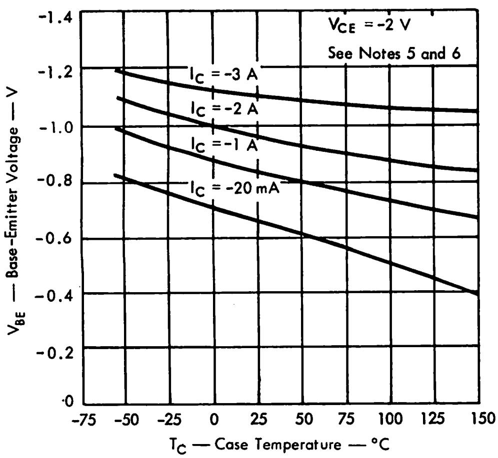


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

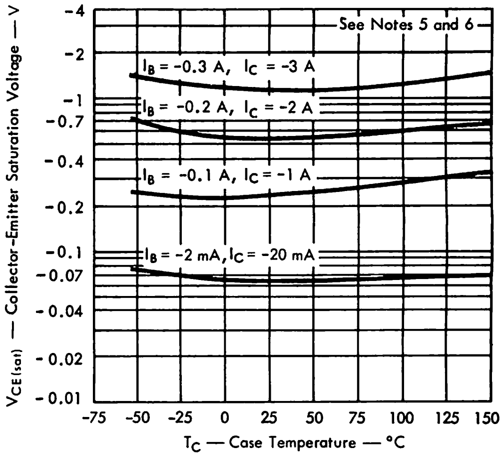


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

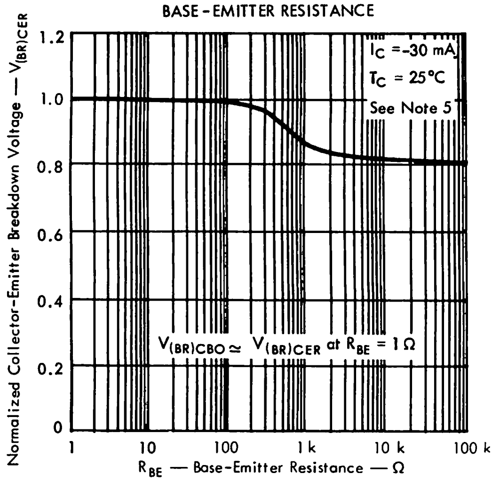


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

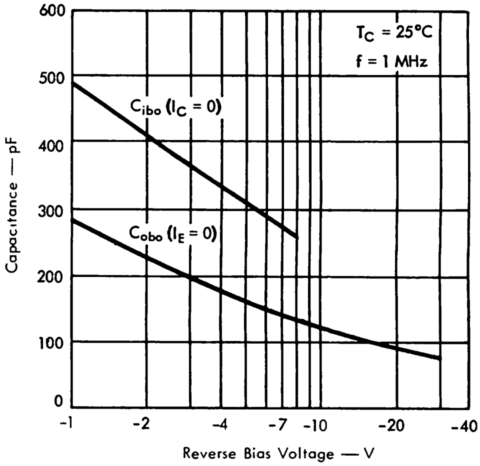


FIGURE 6

NOTE 5: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

MAXIMUM SAFE OPERATING REGION

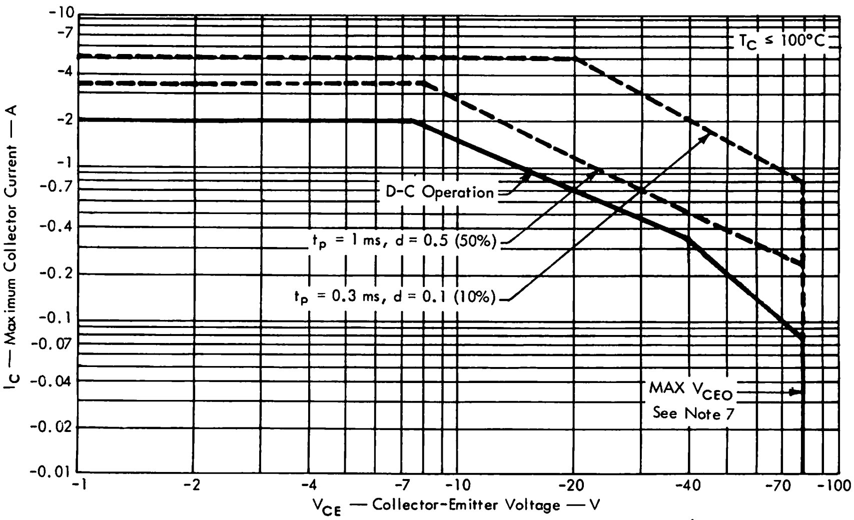


FIGURE 7

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

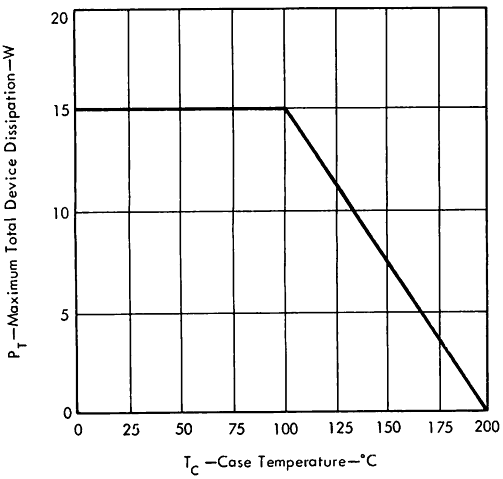


FIGURE 8

PEAK-POWER COEFFICIENT CURVE

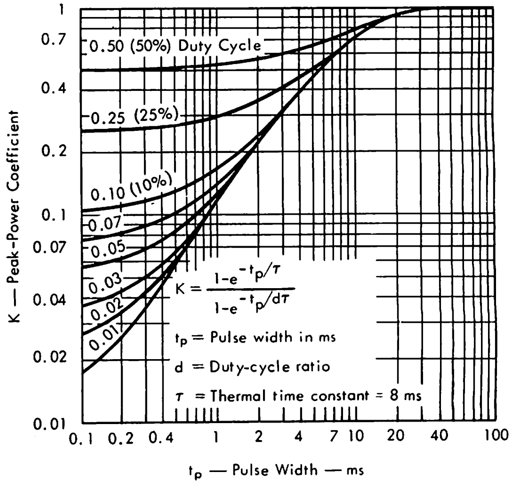


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.66	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)
OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$
$T_A = 50°C$
$d = 10\%\ (0.1)$
$t_p = 0.1$ ms

Solution:
From Figure 9, Peak-Power Coefficient
K = 0.105 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.105\,(6.66)} = 107 \text{ W}$$

TYPES 2N5384, 2N5385
BULLETIN NO. DL-S 689279, MARCH 1968

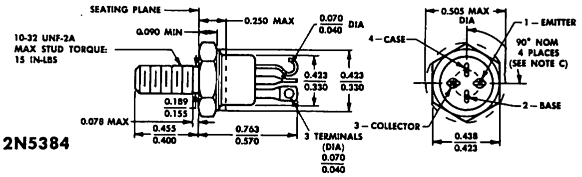
TYPES 2N5384, 2N5385
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTORS

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N3996 AND 2N3998

- 30 W at 100°C Case Temperature
- Typ t_{on} of 160 ns at 2 A I_C
- Max $V_{CE(sat)}$ of 0.6 V at 2 A I_C
- Min f_T of 30 MHz

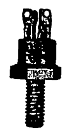
*mechanical data

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

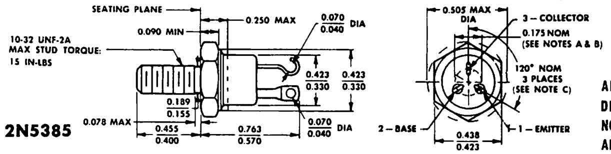


2N5384

ALL JEDEC TO-111 DIMENSIONS AND NOTES ARE APPLICABLE

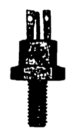


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



2N5385

ALL JEDEC TO-111 DIMENSIONS AND NOTES ARE APPLICABLE



NOTES: A. Position of terminals with respect to hexagon is not controlled.
B. Terminals located on true position within 0.030 inch relative to diameter of can.
C. This dimension applies to the location of the center line of the terminals.
D. The case temperature may be measured anywhere on the seating plane within 0.125 inch of the stud.
E. All dimensions are in inches unless otherwise specified.

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−5 A
Peak Collector Current (See Note 2)	−12 A
Continuous Base Current	−1 A
Continuous Emitter Current	−6 A
Safe Operating Region at (or below) 100° C Case Temperature	See Figure 2
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
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*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	μA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−1	μA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	20	80	
		$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.2$ A, $I_C = -2$ A, See Notes 5 and 6		−0.6	V
		$I_B = -1$ A, $I_C = -5$ A, See Notes 5 and 6		−1.4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 1$ kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 15$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	3.33	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	87.5	

*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -2$ A, $I_{B(1)} = -150$ mA, $I_{B(2)} = 150$ mA,	160	ns
t_{off}	Turn-Off Time	$V_{BE(off)} = 2.8$ V, $R_L = 15\ \Omega$, See Figure 1	550	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

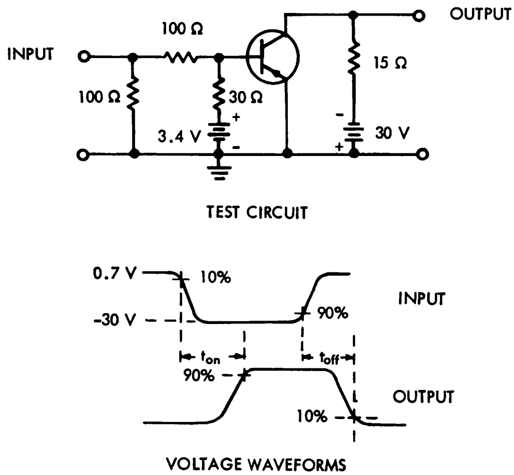


FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 5\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

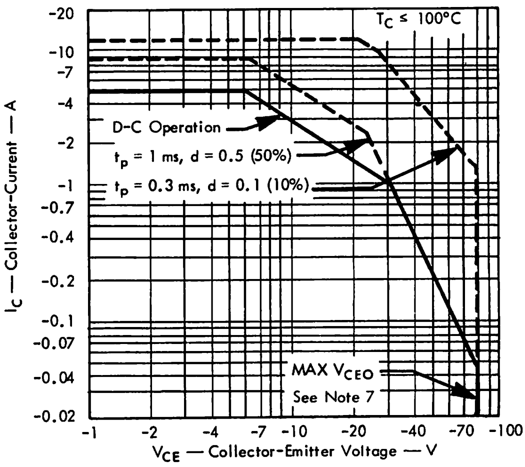


FIGURE 2

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL CHARACTERISTICS

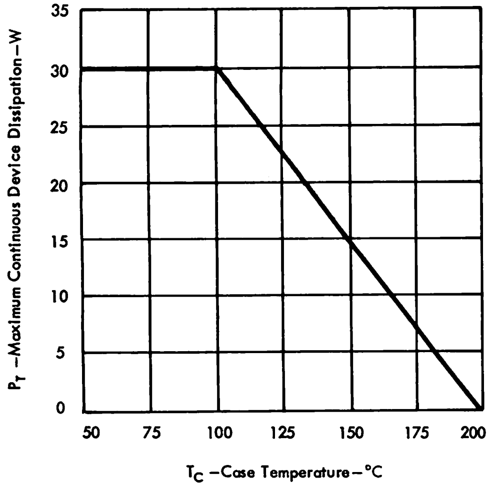


FIGURE 3

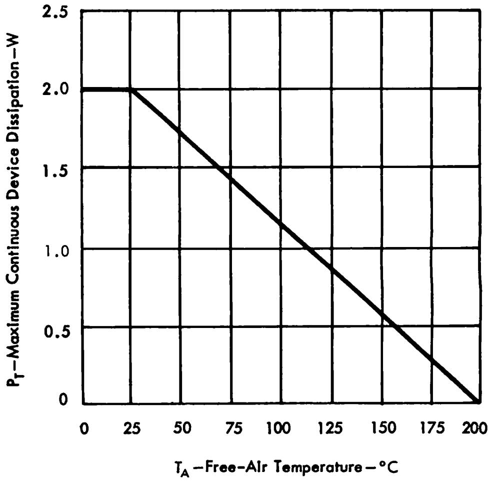


FIGURE 4

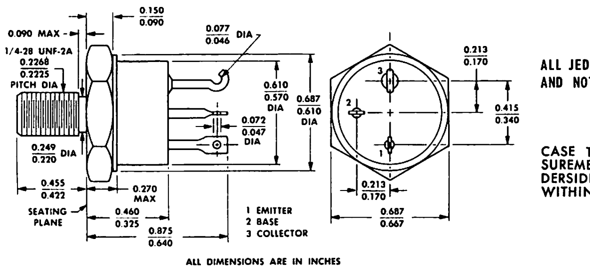
TYPE 2N5386
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4301

- **50 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.6 V at 6 A I_C**
- **Typ t_{on} of 230 ns at 6 A I_C**
- **Min f_T of 30 MHz at 10 V, 1 A**

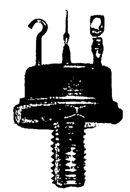
*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 0.125" FROM STUD



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−12 A
Peak Collector Current (See Note 2)	−25 A
Continuous Base Current	−4 A
Continuous Emitter Current	−13 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 2
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	50 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data

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TYPE 2N5386
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	μA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−5	μA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -6$ A, See Notes 5 and 6	20	80	
		$V_{CE} = -4$ V, $I_C = -12$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -12$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.6$ A, $I_C = -6$ A, See Notes 5 and 6		−0.6	V
		$I_B = -2.4$ A, $I_C = -12$ A, See Notes 5 and 6		−1.4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 kHz	20		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 15 MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg /W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

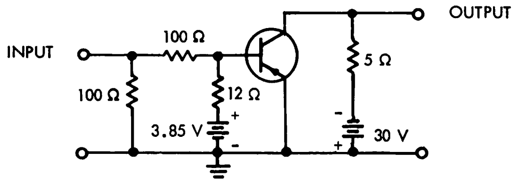
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

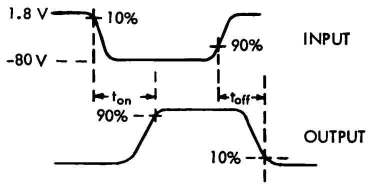
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -6$ A, $I_{B(1)} = -400$ mA, $I_{B(2)} = 400$ mA, $V_{BE(off)} = 3.6$ V, $R_L = 5\ \Omega$, See Figure 1	230	ns
t_{off}	Turn-Off Time		750	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 1.5$ kΩ, $t_p = 5$ µs, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

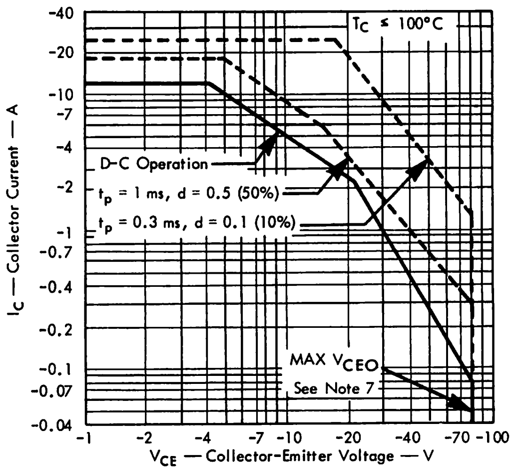


FIGURE 2

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL CHARACTERISTICS

CASE TEMPERATURE
DISSIPATION DERATING CURVE

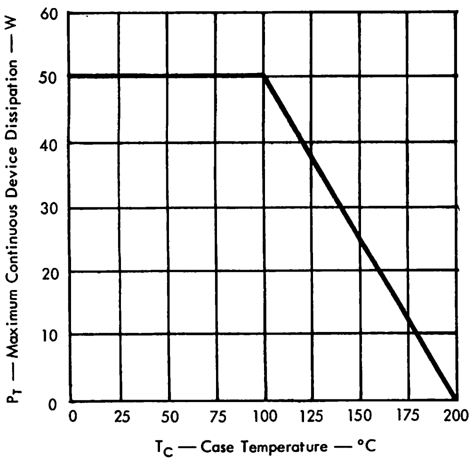


FIGURE 3

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

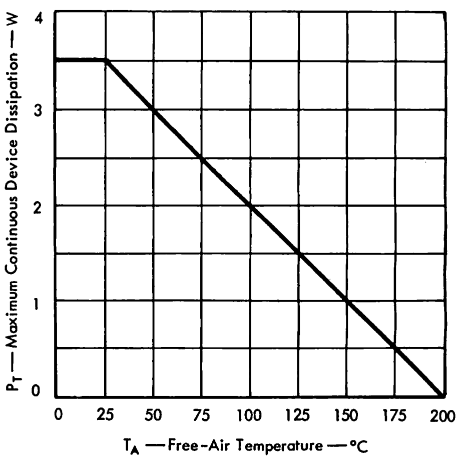


FIGURE 4

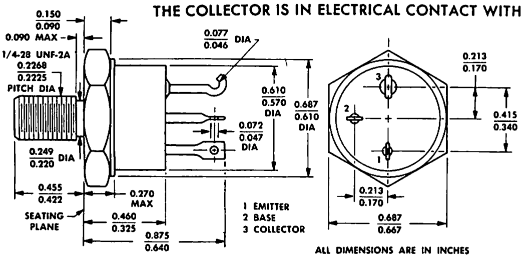
TYPES 2N5387, 2N5388, 2N5389
BULLETIN NO. DL-S 6810682 MARCH 1968

FOR POWER-AMPLIFIER APPLICATIONS

- **200 V, 250 V, 300 V Rated Collector-Emitter Voltages**
- **100 Watts at 100°C Case Temperature**
- **Typ t_{on} of 300 ns at 2 A I_C**
- **Min f_T of 15 MHz at 10 V, 1 A**

*mechanical data

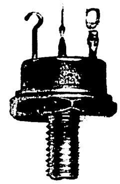
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES

ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 0.125" FROM STUD



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5387	2N5388	2N5389
Collector-Base Voltage	200 V	250 V	300 V
Collector-Emitter Voltage (See Note 1)	200 V	250 V	300 V
Emitter-Base Voltage	←	10 V	→
Continuous Collector Current	←	7.5 A	→
Peak Collector Current (See Note 2)	←	10 A	→
Continuous Base Current	←	3 A	→
Continuous Emitter Current	←	8 A	→
Safe Operating Region at (or below) 100°C Case Temperature	←	See Figure 6	→
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	←	100 W	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←	3.5 W	→
Operating Collector Junction Temperature Range	←	−65°C to 200°C	→
Storage Temperature Range	←	−65°C to 200°C	→
Terminal Temperature 1/16 Inch from Case for 10 Seconds	←	260°C	→

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5387		2N5388		2N5389		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	200		250		300		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 180$ V, $I_B = 0$		30					mA
		$V_{CE} = 225$ V, $I_B = 0$				30			
		$V_{CE} = 270$ V, $I_B = 0$						30	
I_{CES}	Collector Cutoff Current	$V_{CE} = 180$ V, $V_{BE} = 0$		1					mA
		$V_{CE} = 225$ V, $V_{BE} = 0$				1			
		$V_{CE} = 270$ V, $V_{BE} = 0$						1	
		$V_{CE} = 100$ V, $V_{BE} = 0$, $T_C = 150°C$		10					
		$V_{CE} = 125$ V, $V_{BE} = 0$, $T_C = 150°C$				10			
		$V_{CE} = 150$ V, $V_{BE} = 0$, $T_C = 150°C$						10	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 8$ V, $I_C = 0$		0.1		0.1		0.1	mA
		$V_{EB} = 10$ V, $I_C = 0$		1		1		1	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 2$ A, See Notes 5 and 6	25	100	25	100	25	100	
		$V_{CE} = 5$ V, $I_C = 5$ A, See Notes 5 and 6	15		15		15		
		$V_{CE} = 5$ V, $I_C = 7$ A, See Notes 5 and 6	5		5		5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ V, $I_C = 7$ A, See Notes 5 and 6		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ A, $I_C = 5$ A, See Notes 5 and 6		2		2		2	V
		$I_B = 1.4$ A, $I_C = 7$ A, See Notes 5 and 6		2.2		2.2		2.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 1$ kHz	20		20		20		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 10$ MHz	1.5		1.5		1.5		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	50	

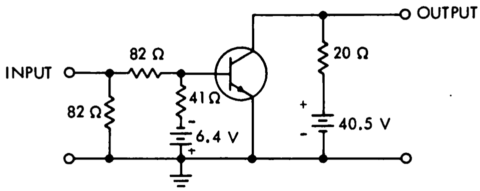
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

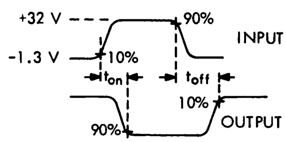
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 2$ A, $I_{B(1)} = 200$ mA, $I_{B(2)} = -200$ mA,	0.3	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4.7$ V, $R_L = 20\ \Omega$, See Figure 1	1	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPES 2N5387, 2N5388, 2N5389
N-P-N TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

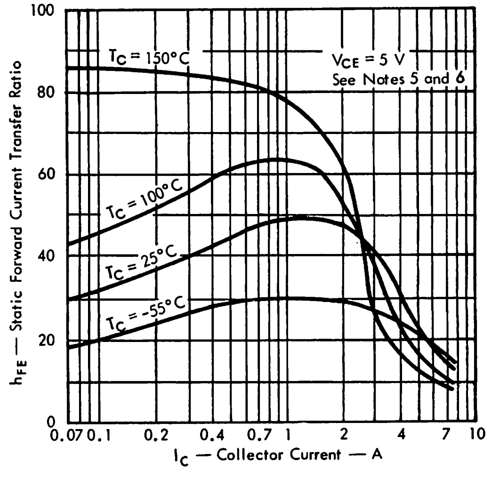


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

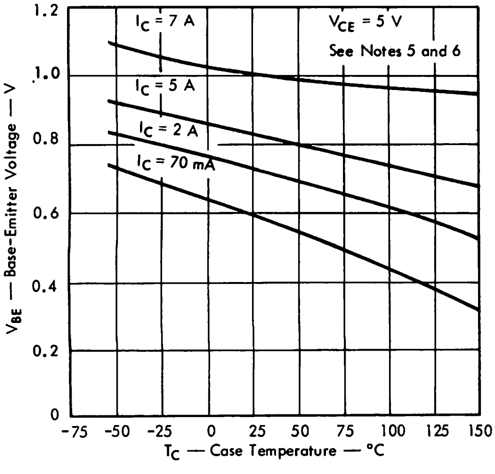


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

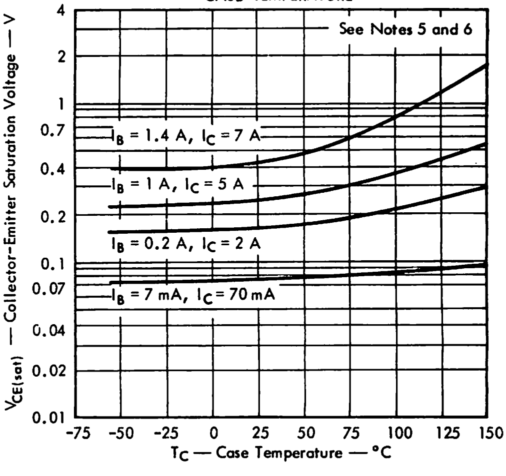


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

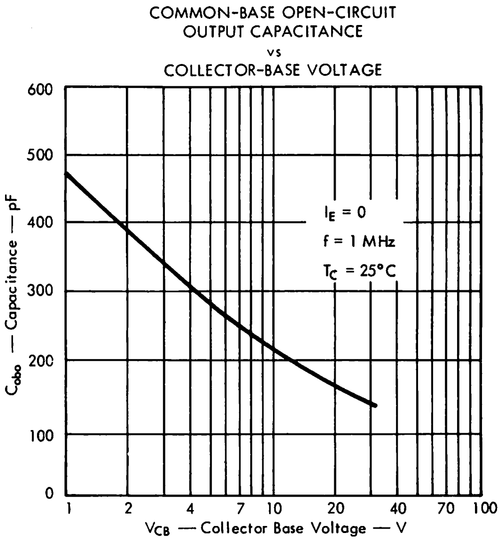


FIGURE 5

MAXIMUM SAFE OPERATING REGION

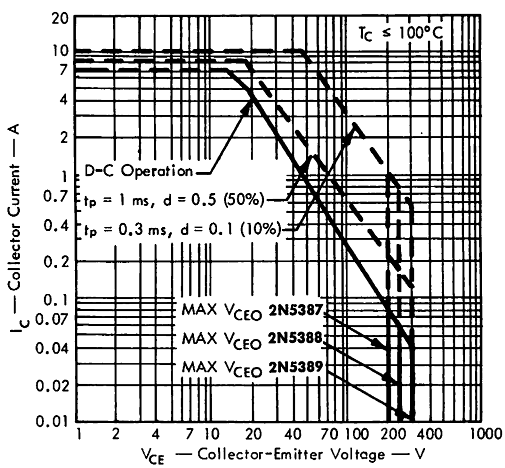


FIGURE 6

NOTE 5: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

TYPES 2N5387, 2N5388, 2N5389
N-P-N TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

THERMAL INFORMATION

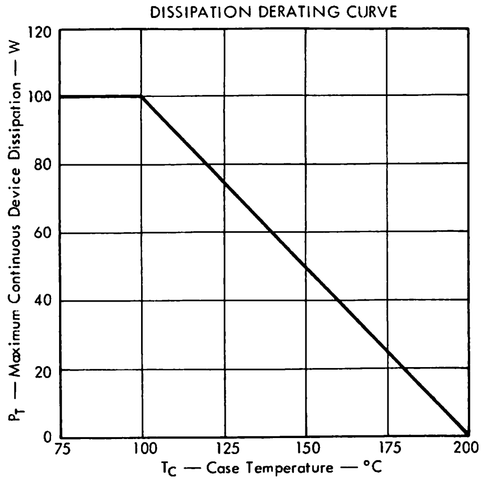


FIGURE 7

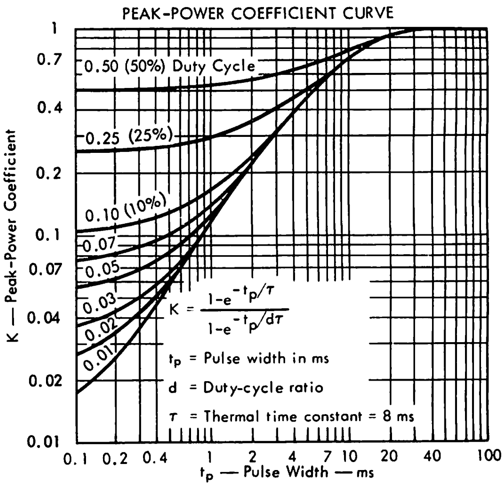


FIGURE 8

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	49	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 8	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 7}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 4$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 8, Peak-Power Coefficient

K = 0.105 and by use of equation No. 3 ,

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(4) + 0.106\,(1)} = 296 \text{ W}$$

TYPES 2N456A, 2N457A, 2N458A, 2N1021 AND 2N1022
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

TYPES 2N456A, 2N457A, 2N458A, 2N1021, and 2N1022
BULLETIN NO. DL-S 611419, MARCH 1961
REPLACES BULLETIN NO. DL-S 60341, MAY 1960

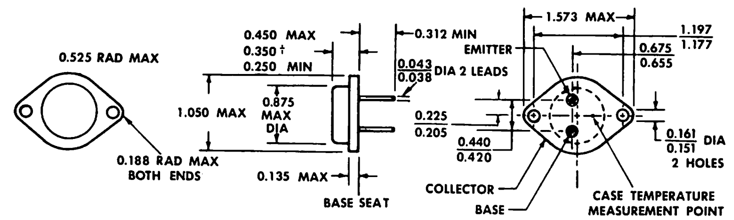
CHOICE OF 40v, 60v, 80v, 100v, or 120v DEVICES
LOW I_{CO} HIGH BETA LOW R_{CS}
LOW THERMAL RESISTANCE
150 WATTS DISSIPATION

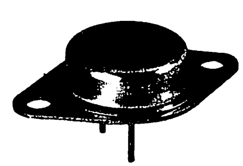
Designed specifically for High-Voltage Power Converters, High-Voltage Amplifiers and Switching Circuits. Featuring Low Distortion, Low Saturation Resistance and Fast Switching Times.

mechanical data

The use of silver alloy to assemble the mounting base and the use of resistance welding to seal the can, provide a hermetically sealed enclosure. During the assembly process the absence of flux, combined with extreme cleanliness, prevents sealed-in contamination.
The mounting base provides an excellent heat path from the collector junction to a heat sink which must be in intimate contact to permit operation at maximum rated dissipation.

The transistors are in a JEDEC TO-3 case.





THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
†The TI guaranteed maximum value.
DIMENSIONS ARE IN INCHES

absolute maximum ratings for all devices at 25°C mounting-base temperature (unless otherwise noted)*

Collector Current	7a
Base Current	3a
Total Device Dissipation**	150w
Collector Junction Temperature	100° C
Storage Temperature Range	−55 to +100° C
Thermal Resistance	0.5°C/W

*Maximum voltage ratings not specified because exceeding breakdown voltages will not permanently damage transistor characteristics so long as other maximum ratings are not exceeded.
**Derate at 2 w/°C.

TYPES 2N456A, 2N457A, 2N458A, 2N1021 AND 2N1022
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

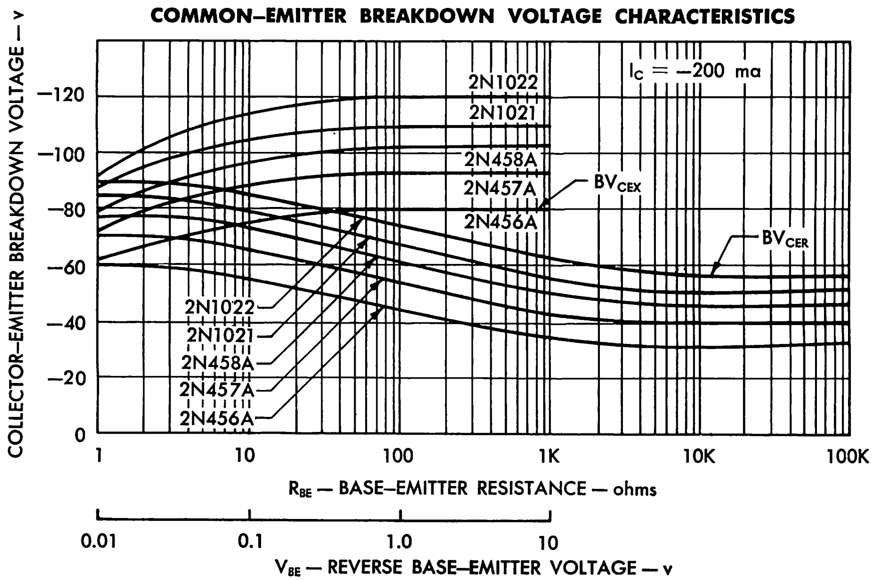
electrical characteristics at 25°C mounting-base temperature

PARAMETER	TYPE	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CBO} Collector Reverse Current	2N456A	V_{CB} = —40 v I_E = 0, 25°C		—1.0	—2.0	ma
		V_{CB} = —20 v I_E = 0, 25°C		—0.2	—0.5	ma
		V_{CB} = —40 v I_E = 0, 71°C		—6.0	—10.0	ma
	2N457A	V_{CB} = —60 v I_E = 0, 25°C		—1.0	—2.0	ma
		V_{CB} = —30 v I_E = 0, 25°C		—0.2	—0.5	ma
		V_{CB} = —60 v I_E = 0, 71°C		—6.0	—10.0	ma
	2N458A	V_{CB} = —80 v I_E = 0, 25°C		—1.0	—2.0	ma
		V_{CB} = —40 v I_E = 0, 25°C		—0.2	—0.5	ma
		V_{CB} = —80 v I_E = 0, 71°C		—6.0	—10.0	ma
	2N1021	V_{CB} = —100 v I_E = 0, 25°C		—1.0	—2.0	ma
		V_{CB} = —50 v I_E = 0, 25°C		—0.2	—0.5	ma
		V_{CB} = —100 v I_E = 0, 71°C		—6.0	—10.0	ma
	2N1022	V_{CB} = —120 v I_E = 0, 25°C		—1.0	—2.0	ma
		V_{CB} = —60 v I_E = 0, 25°C		—0.2	—0.5	ma
		V_{CB} = —120 v I_E = 0, 71°C		—6.0	—10.0	ma
I_{EBO} Emitter Reverse Current	All	V_{EB} = — 10 v I_C = 0		—0.2		ma
BV_{CBO} Collector-Base Breakdown Voltage	2N456A	I_C = —2 ma I_E = 0	—40			v
	2N457A	I_C = —2 ma I_E = 0	—60			v
	2N458A	I_C = —2 ma I_E = 0	—80			v
	2N1021	I_C = —2 ma I_E = 0	—100			v
	2N1022	I_C = —2 ma I_E = 0	—120			v
BV_{CEO} Collector-Emitter Breakdown Voltage	2N456A	I_C = —500 ma I_B = 0	— 30	— 40		v
	2N457A	I_C = —500 ma I_B = 0	— 40	— 50		v
	2N458A	I_C = —500 ma I_B = 0	— 45	— 55		v
	2N1021	I_C = —500 ma I_B = 0	— 50	— 60		v
	2N1022	I_C = —500 ma I_B = 0	— 55	— 60		v
BV_{CER} Collector-Emitter Breakdown Voltage	2N456A	I_C = —200 ma R_{BE} = 33 Ω		—50		v
	2N457A	I_C = —200 ma R_{BE} = 33 Ω		—60		v
	2N458A	I_C = —200 ma R_{BE} = 33 Ω		—67		v
	2N1021	I_C = —200 ma R_{BE} = 33 Ω		—73		v
	2N1022	I_C = —200 ma R_{BE} = 33 Ω		—78		v
BV_{CES} Collector-Emitter Breakdown Voltage	2N456A	I_C = —200 ma V_{BE} = 0	—50	—60		v
	2N457A	I_C = —200 ma V_{BE} = 0	—60	—70		v
	2N458A	I_C = —200 ma V_{BE} = 0	—65	—78		v
	2N1021	I_C = —200 ma V_{BE} = 0	—70	—85		v
	2N1022	I_C = —200 ma V_{BE} = 0	—75	—90		v
BV_{EBO} Emitter-Base Breakdown Voltage	All	I_E = —2 ma I_C = 0	—20			v
h_{FE} DC Forward Current Transfer Ratio	All	V_{CE} = —1.5 v I_C = —7 a	22	47		
		V_{CE} = —1.5 v I_C = —5 a	30	60	90	
		V_{CE} = —1.5 v I_C = —3 a	35	82		
		V_{CE} = —1.5 v I_C = —1 a	40	120		

TYPES 2N456A, 2N457A, 2N458A, 2N1021 AND 2N1022
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

electrical characteristics at 25°C mounting-base temperature

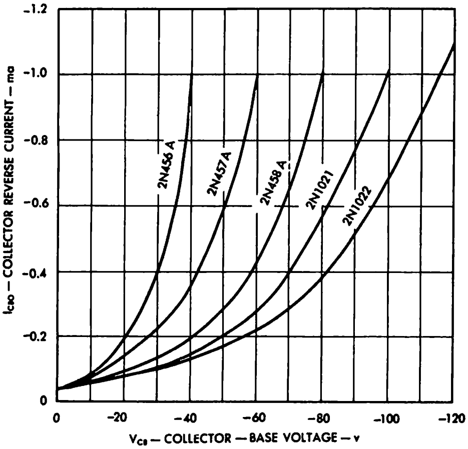
	PARAMETER	TYPE	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{BE}	Base-Emitter Voltage	All	$V_{CE} = -1.5$ v $I_C = -7$ a		−1.2		v
			$V_{CE} = -1.5$ v $I_C = -5$ a		−0.9	−1.5	v
			$V_{CE} = -1.5$ v $I_C = -3$ a		−0.6		v
			$V_{CE} = -1.5$ v $I_C = -1$ a		−0.35		v
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	All	$I_B = -700$ ma $I_C = -7$ a		−0.3		v
			$I_B = -500$ ma $I_C = -5$ a		−0.2	−0.5	v
			$I_B = -300$ ma $I_C = -3$ a		−0.1		v
			$I_B = -100$ ma $I_C = -1$ a		−.05		v
y_{FE}	DC Common-Emitter Forward Transfer Admittance	All	$V_{CE} = -1.5$ v $I_C = -7$ a		5.7		mhos
			$V_{CE} = -1.5$ v $I_C = -5$ a	3.3	5.5		mhos
			$V_{CE} = -1.5$ v $I_C = -3$ a		4.8		mhos
			$V_{CE} = -1.5$ v $I_C = -1$ a		3.0		mhos
h_{IE}	DC Common-Emitter Input Impedance	All	$V_{CE} = -1.5$ v $I_C = -7$ a		8		ohms
			$V_{CE} = -1.5$ v $I_C = -5$ a		11	28	ohms
			$V_{CE} = -1.5$ v $I_C = -3$ a		16		ohms
			$V_{CE} = -1.5$ v $I_C = -1$ a		42		ohms
f_T	Internal Cutoff Frequency (where $\lvert h_{fe} \rvert = 1$)	All	$V_{CE} = -2$ v $I_C = -1$ a		430		kc



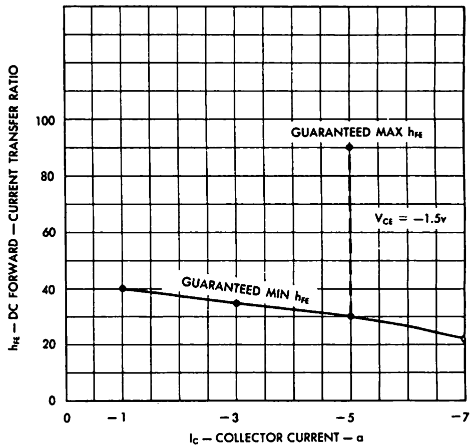
TYPES 2N456A, 2N457A, 2N458A, 2N1021 AND 2N1022
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

TYPICAL CHARACTERISTICS

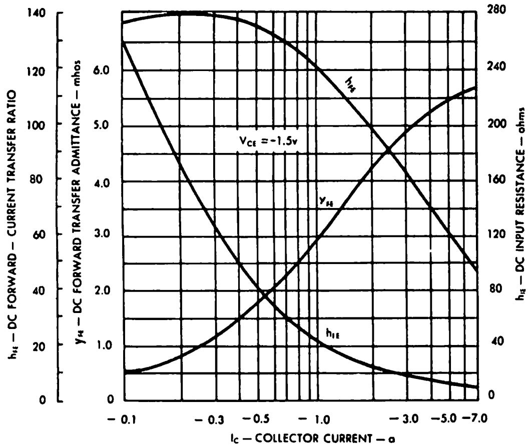
COLLECTOR REVERSE-CURRENT CHARACTERISTICS



GUARANTEED COMMON-EMITTER DC FORWARD-CURRENT TRANSFER RATIO VS COLLECTOR CURRENT

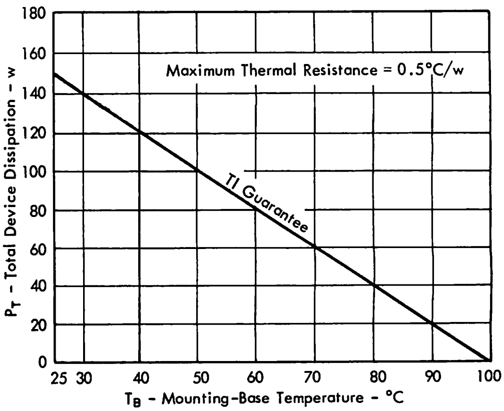


COMMON-EMITTER DC FORWARD CURRENT TRANSFER RATIO, DC INPUT RESISTANCE, AND DC FORWARD TRANSFER ADMITTANCE VS COLLECTOR CURRENT



DISSIPATION DERATING

POWER DISSIPATION DERATING CURVE



P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS

TYPES 2N1038 THRU 2N1041, 2N2552 THRU 2N2559
BULLETIN NO. 683397, JULY 1963
REPLACES BULLETIN NO. DL-S 60332, MAY 1960
REVISED FEBRUARY 1968

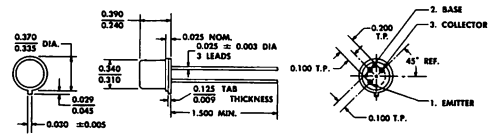
40-, 60-, 80-, or 100-VOLT UNITS
20 WATTS AT 25°C CASE TEMPERATURE
Choice of TO-5, Stud, or Hex Package
Guaranteed Beta at 1 amp and 50 ma I_C

Guaranteed I_{CEX} at 85°C
LOW r_{CS} • LOW I_{CBO} • LOW V_{BE}
for
RELAY DRIVERS • PULSE AMPLIFIERS
SERVO AMPLIFIERS • AUDIO AMPLIFIERS

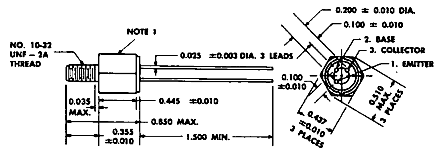
mechanical data

The transistors are in hermetically sealed, resistance-welded cases with glass-to-metal seals between case and leads. These devices are available in (1) a round TO-5 package weighing approximately 2.4 grams (2N1038 series), (2) a stud heat-sink package which weighs approximately 5.4 grams (2N2552 series) and (3) a hexagonal flanged-nut heat-sink package which weighs approximately 8.6 grams (2N2556 series). Mounting hardware available is shown on page 8.

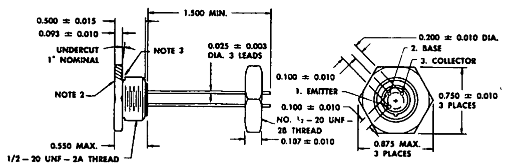
*THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



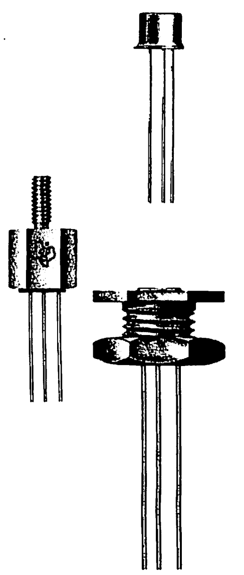
* OUTLINE — 2N1038 SERIES



* OUTLINE — 2N2552 SERIES



* OUTLINE — 2N2556 SERIES



NOTES:

1. TEMPERATURE MEASUREMENT POINT 0.060 NOMINAL FROM SEAT OF HEAT SINK.
2. TEMPERATURE MEASUREMENT POINT 0.160 NOMINAL FROM CENTER OF HEAT SINK.
3. THREAD RELIEF IS 0.090 MAX. BY 0.430 DIA. NOMINAL.
4. THE ORIENTATION OF THE LEADS IN RELATION TO THE HEX FLATS IS NOT CONTROLLED.
5. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

*Indicates JEDEC Registered Data.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES 2N1038, 2N1039, 2N1040, 2N1041 • 2N2552, 2N2553, 2N2554, 2N2555 • 2N2556, 2N2557, 2N2558, 2N2559
P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N1038 2N2552 2N2556	2N1039 2N2553 2N2557	2N1040 2N2554 2N2558	2N1041 2N2555 2N2559
Collector-Base Voltage	40 v	60 v	80 v	100 v
Collector-Emitter Voltage (see Note 1)	40 v	60 v	80 v	100 v
Emitter-Base Voltage	←	20 v		→
Collector Current	←	3 a		→
Base Current	←	1 a		→
Total Device Dissipation at (or below) 25°C Case Temperature (see Note 2)	←	20 w		→
Operating Case Temperature Range	←	−55°C to +100°C		→
Storage Temperature Range	←	−55°C to +100°C		→

NOTES: 1. This value applies when base-emitter voltage $V_{BE} = +0.2$ v.
2. Derate linearly to +100°C case temperature at the rate of 267 mw/C°.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -650\mu a,\ I_E = 0$	2N1038 2N2552 2N2556	−40			v
			2N1039 2N2553 2N2557	−60			
			2N1040 2N2554 2N2558	−80			
			2N1041 2N2555 2N2559	−100			
*BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -100$ ma, $I_B = 0$	2N1038 2N2552 2N2556	−30			v
			2N1039 2N2553 2N2557	−40			
			2N1040 2N2554 2N2558	−50			
			2N1041 2N2555 2N2559	−60			

*Indicates JEDEC Registered Data.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
*I_{CBO}	Collector Cutoff Current	$V_{CB} = -20$ v, $I_E = 0$	2N1038 2N2552 2N2556			−125	μa
		$V_{CB} = -30$ v, $I_E = 0$	2N1039 2N2553 2N2557				
		$V_{CB} = -40$ v, $I_E = 0$	2N1040 2N2554 2N2558				
		$V_{CB} = -50$ v, $I_E = 0$	2N1041 2N2555 2N2559				
*I_{CEO}	Collector Cutoff Current	$V_{CE} = -15$ v, $I_B = 0$	2N1038 2N2552 2N2556			−25	ma
		$V_{CE} = -20$ v, $I_B = 0$	2N1039 2N2553 2N2557			−20	
		$V_{CE} = -25$ v, $I_B = 0$	2N1040 2N2554 2N2558			−20	
		$V_{CE} = -30$ v, $I_B = 0$	2N1041 2N2555 2N2559			−20	
*I_{CEX}	Collector Cutoff Current	$V_{CE} = -40$ v, $V_{BE} = +0.2$ v	2N1038 2N2552 2N2556			−650	μa
		$V_{CE} = -60$ v, $V_{BE} = +0.2$ v	2N1039 2N2553 2N2557				
		$V_{CE} = -80$ v, $V_{BE} = +0.2$ v	2N1040 2N2554 2N2558				
		$V_{CE} = -100$ v, $V_{BE} = +0.2$ v	2N1041 2N2555 2N2559				
*I_{CEX}	Collector Cutoff Current	$V_{CE} = -20$ v, $V_{BE} = +0.2$ v, $T_C = +85°C$	2N1038 2N2552 2N2556			−5	ma
		$V_{CE} = -30$ v, $V_{BE} = +0.2$ v, $T_C = +85°C$	2N1039 2N2553 2N2557				
		$V_{CE} = -40$ v, $V_{BE} = +0.2$ v, $T_C = +85°C$	2N1040 2N2554 2N2558				
		$V_{CE} = -50$ v, $V_{BE} = +0.2$ v, $T_C = +85°C$	2N1041 2N2555 2N2559				
*I_{EBO}	Emitter Cutoff Current	$V_{EB} = -20$ v, $I_C = 0$	All			−650	μa

*Indicates JEDEC Registerea Data.

TYPES 2N1038, 2N1039, 2N1040, 2N1041 • 2N2552, 2N2553, 2N2554, 2N2555 • 2N2556, 2N2557, 2N2558, 2N2559
P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
h_{IE}	Static Common Emitter Input Impedance	$V_{CE} = -0.5$ v, $I_C = -1$ a (see Note 3)	All			60	ohm
$*h_{FE}$	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ v, $I_C = -1$ a (see Note 3)	All	20		60	
		$V_{CE} = -0.5$ v, $I_C = -50$ ma	All	33		200	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -0.5$ v, $I_C = -1$ a, $T_C = -55°C$ (See Note 3)	All	15		60	
		$V_{CE} = -0.5$ v, $I_C = -1$ a, $T_C = +85°C$	All	20		75	
y_{FE}	Static Common-Emitter Forward Transfer Admittance	$V_{CE} = -0.5$ v, $I_C = -1$ a (see Note 3)	All	1.0			mho
$*V_{BE}$	Base-Emitter Voltage	$V_{CE} = -0.5$ v, $I_C = -1$ a (see Note 3)	All			-1.0	v
V_{BE}	Base-Emitter Voltage	$V_{CE} = -0.5$ v, $I_C = -50$ ma	All			-0.35	v
$*V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100$ ma, $I_C = -1$ a (see Note 3)	All			-0.25	v
$*h_{fe}$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -1.5$ v, $I_C = -0.5$ a, $f = 1$ kc	All	18		72	
$*\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -1.5$ v, $I_C = -0.5$ a, $f = 112.5$ kc	All	2.0			
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -6$ v, $I_E = 0$, $f = 135$ kc	All		100		pf

NOTES: 3. Measurements are made with voltage sensing contacts located 0.25 inches from header of transistor. Voltage sensing contacts are separate from current carrying contacts.

*Indicates JEDEC Registered Data.

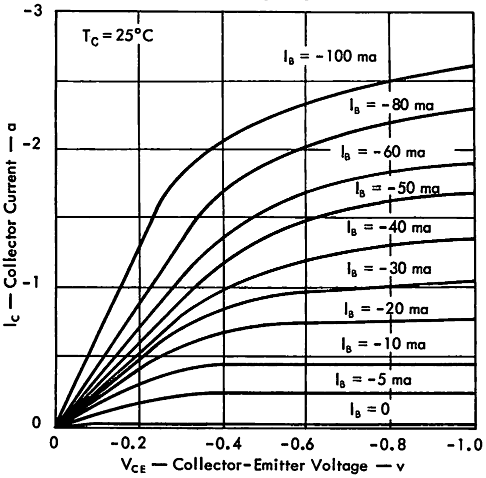
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYPICAL	UNIT
t_d	Delay Time	$I_C = -1$a	0.18	μsec
t_r	Rise Time	$V_{BE(off)} = 7.4$v	0.47	μsec
t_s	Storage Time	$R_L = 29\ \Omega$	0.59	μsec
t_f	Fall Time	(See circuit on Page 8)	1.21	μsec
t_T	Total Switching Time		2.45	μsec

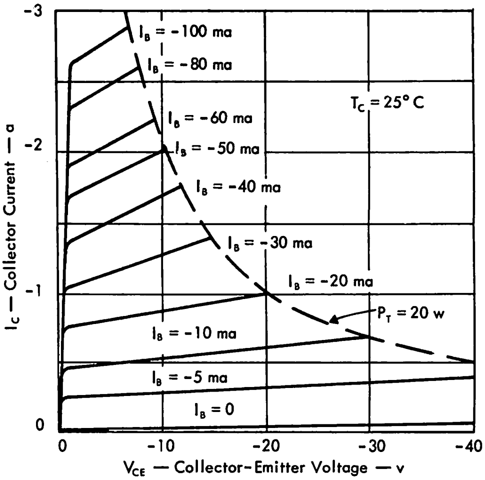
†Voltage and current values are nominal; exact values vary slightly with device parameters.

TYPICAL CHARACTERISTICS

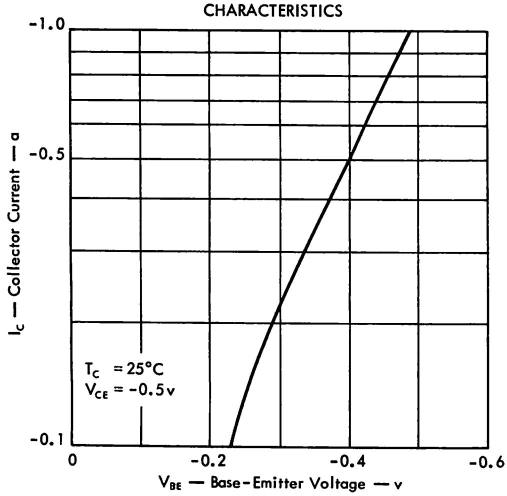
COMMON-EMITTER COLLECTOR CHARACTERISTICS (Low-Voltage Region)



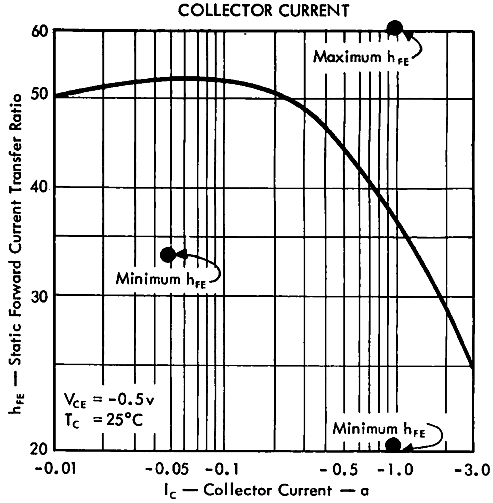
COMMON-EMITTER COLLECTOR CHARACTERISTICS (High-Voltage Region)



COMMON-EMITTER TRANSFER CHARACTERISTICS



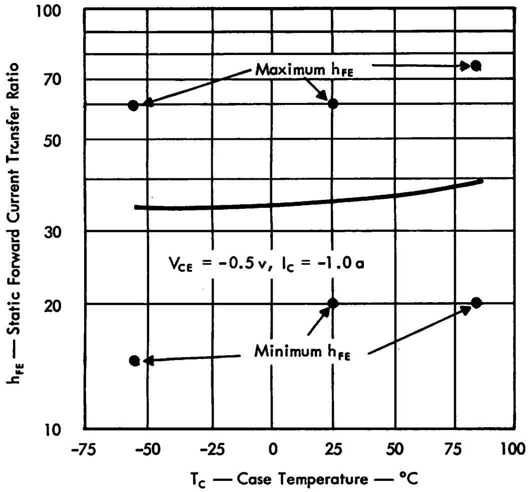
STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT



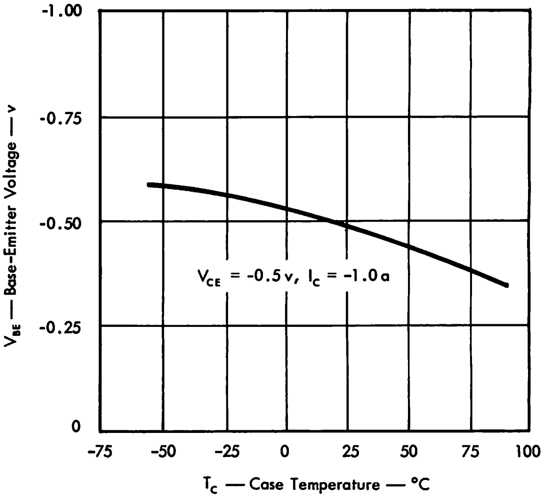
17205

TYPES 2N1038, 2N1039, 2N1040, 2N1041 • 2N2552, 2N2553, 2N2554, 2N2555 • 2N2556, 2N2557, 2N2558, 2N2559
P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS
TYPICAL CHARACTERISTICS

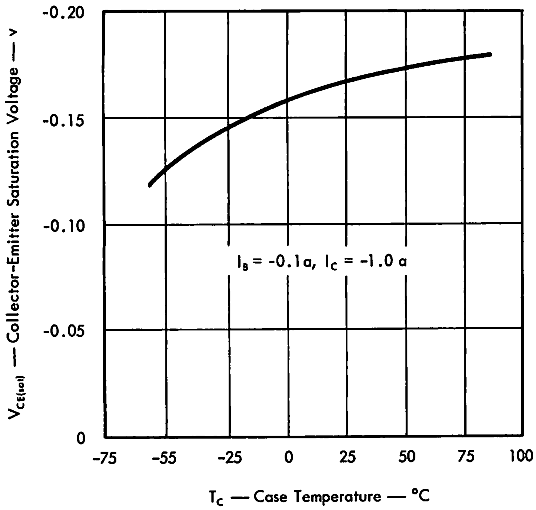
STATIC FORWARD CURRENT TRANSFER RATIO
vs
CASE TEMPERATURE



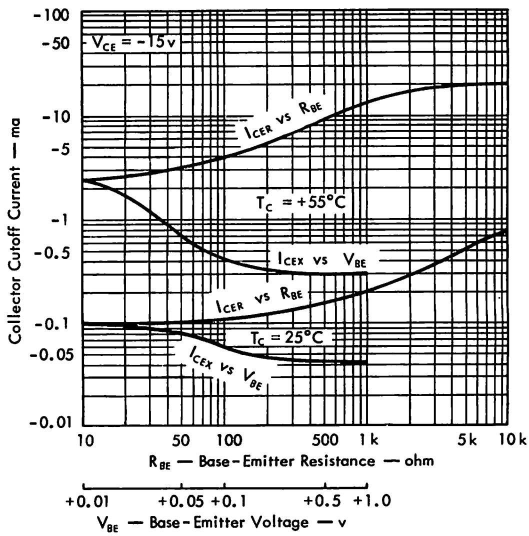
BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE



COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE



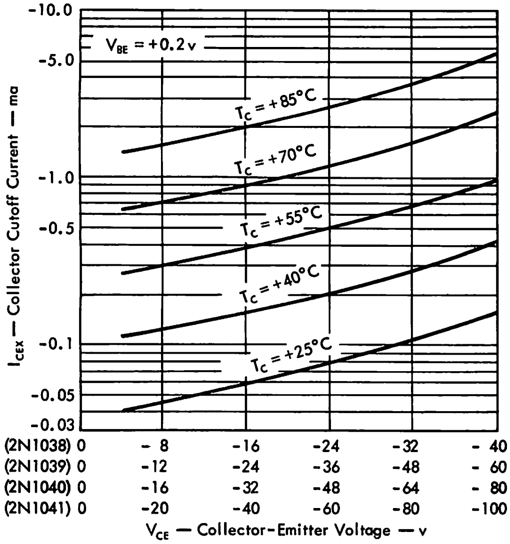
COLLECTOR CUTOFF CURRENT
vs
BASE-EMITTER RESISTANCE
and
BASE-EMITTER VOLTAGE



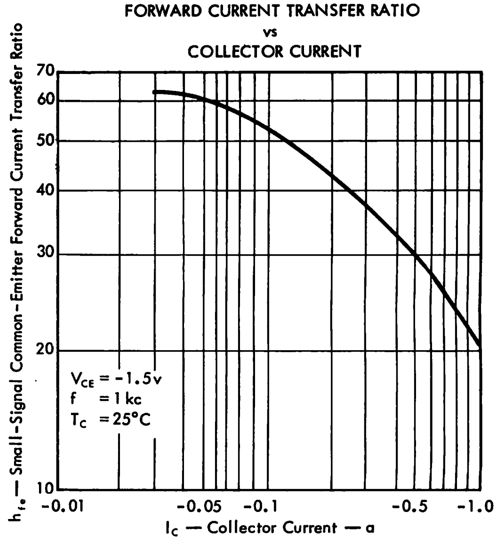
TYPES 2N1038, 2N1039, 2N1040, 2N1041 • 2N2552, 2N2553, 2N2554, 2N2555 • 2N2556, 2N2557, 2N2558, 2N2559
P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS

TYPICAL CHARACTERISTICS

COLLECTOR CUTOFF CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

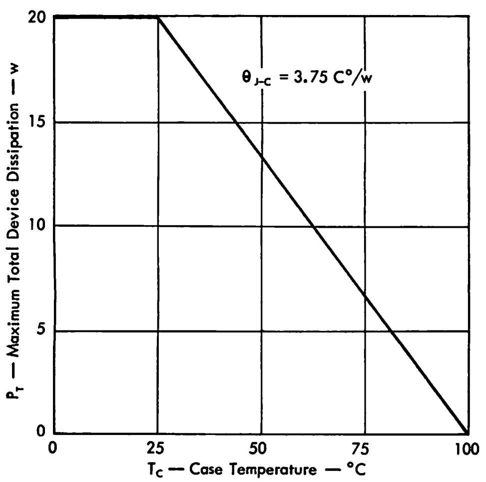


SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

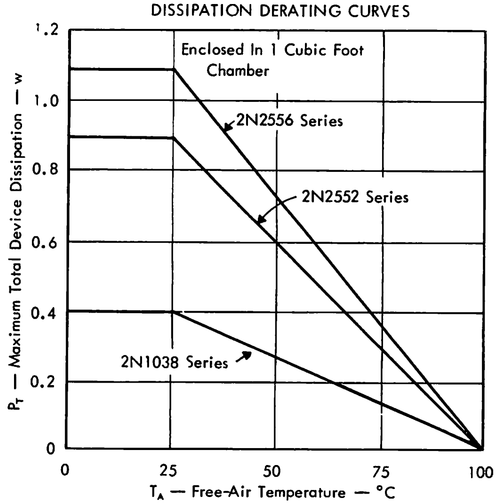


THERMAL CHARACTERISTICS

CASE TEMPERATURE
DISSIPATION DERATING CURVE

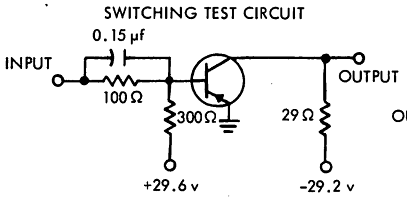


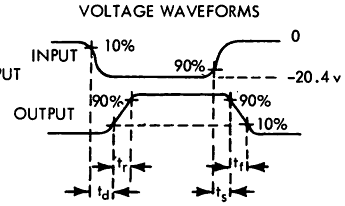
FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVES



TYPES 2N1038, 2N1039, 2N1040, 2N1041 • 2N2552, 2N2553, 2N2554, 2N2555 • 2N2556, 2N2557, 2N2558, 2N2559
P-N-P ALLOY-JUNCTION GERMANIUM MEDIUM-POWER TRANSISTORS

PARAMETER MEASUREMENT INFORMATION



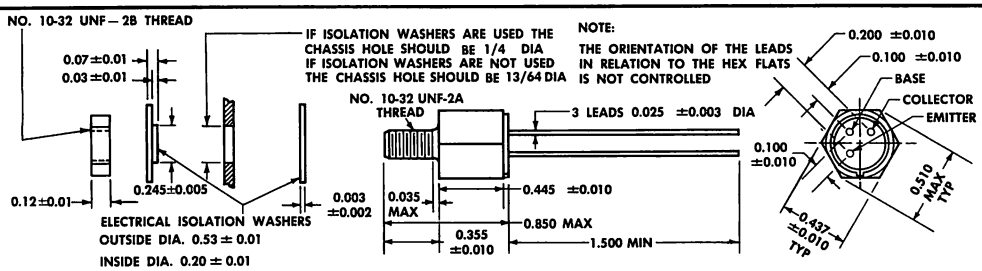


NOTES: a. The input waveform has the following characteristics: $t_r \leq 10$ nsec, $t_f \leq 10$ nsec, PW = 1.6 msec, Duty Cycle = 10%.

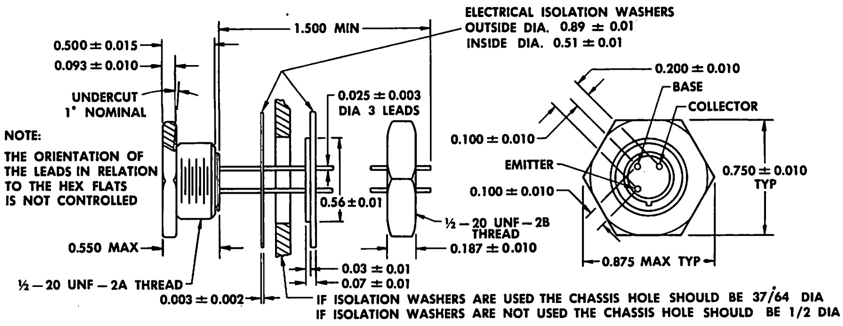
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 14$ nsec, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pf.

c. Resistors must be non-inductive types.

MOUNTING HARDWARE INFORMATION



2N2552 SERIES



2N2556 SERIES

TYPES 2N1539, 2N1540, 2N1541, 2N1542, 2N1543
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

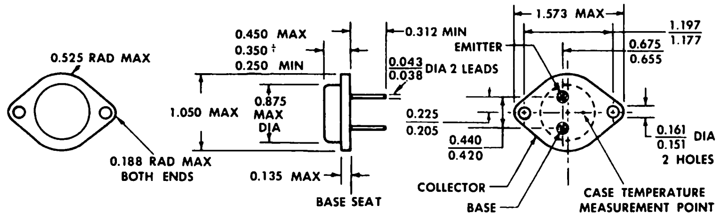
TYPES 2N1539, 2N1540, 2N1541, 2N1542, 2N1543
BULLETIN NO. DL-S 633560, FEBRUARY 1963

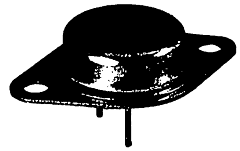
FOR HIGH-POWER SWITCHING AND AMPLIFIER APPLICATIONS

mechanical data

The use of silver alloy to assemble the mounting base and the use of resistance welding to seal the can, provides a hermetically sealed enclosure. During the assembly process the absence of flux, combined with extreme cleanliness, prevents sealed-in contamination.
The mounting base provides an excellent heat path from the collector junction to a heat sink which must be in intimate contact to permit operation at maximum rated dissipation.

*The transistors are in a JEDEC TO-3 case.





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N1539	2N1540	2N1541	2N1542	2N1543
*Collector-Base Voltage	40v	60v	80v	100v	120v
*Collector-Emitter Voltage (See Note 1)	30v	45v	60v	75v	90v
*Emitter-Base Voltage	20v	30v	40v	50v	60v
*Collector Current	←		5a		→
*Emitter Current	←		5a		→
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	←		150w		→
*Operating Collector Junction Temperature	←		100°C		→
*Storage Temperature Range	←		−65°C to +100°C		→

NOTES: 1. This value applies when base-emitter diode is short-circuited.
2. Derate linearly to + 100°C case temperature at the rate of 2 w/C°.

*Indicates JEDEC registered data.

TYPES 2N1539, 2N1540, 2N1541, 2N1542, 2N1543
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -20$ ma, $I_E = 0$	2N1539 2N1540 2N1541 2N1542 2N1543	−40 −60 −80 −100 −120		v
*BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -500$ ma, $I_B = 0$	2N1539 2N1540 2N1541 2N1542 2N1543	−20 −30 −40 −50 −60		v
*BV_{CES}	Collector-Emitter Breakdown Voltage	$I_C = -500$ ma, $V_{BE} = 0$	2N1539 2N1540 2N1541 2N1542 2N1543	−30 −45 −60 −75 −90		v
*I_{CBO}	Collector Cutoff Current	$V_{CB} = -2.0$ v, $I_E = 0$	All		−200	μa
*I_{CBO}	Collector Cutoff Current	$V_{CB} = -25$ v, $I_E = 0$ $V_{CB} = -40$ v, $I_E = 0$ $V_{CB} = -55$ v, $I_E = 0$ $V_{CB} = -65$ v, $I_E = 0$ $V_{CB} = -80$ v, $I_E = 0$	2N1539 2N1540 2N1541 2N1542 2N1543		−2.0	ma
*I_{CBO}	Collector Cutoff Current	$V_{CB} = -40$ v, $I_E = 0$ $V_{CB} = -60$ v, $I_E = 0$ $V_{CB} = -80$ v, $I_E = 0$ $V_{CB} = -100$ v, $I_E = 0$ $V_{CB} = -120$ v, $I_E = 0$	2N1539 2N1540 2N1541 2N1542 2N1543		−20	ma
*I_{CBO}	Collector Cutoff Current	$V_{CB} = -15$ v, $I_E = 0$, $T_C = 90°C$ $V_{CB} = -22.5$ v, $I_E = 0$, $T_C = 90°C$ $V_{CB} = -30$ v, $I_E = 0$, $T_C = 90°C$ $V_{CB} = -37.5$ v, $I_E = 0$, $T_C = 90°C$ $V_{CB} = -45$ v, $I_E = 0$, $T_C = 90°C$	2N1539 2N1540 2N1541 2N1542 2N1543		−20	ma
*I_{CEX}	Collector Cutoff Current	$V_{CE} = -40$ v, $V_{BE} = +1.0$ v $V_{CE} = -60$ v, $V_{BE} = +1.0$ v $V_{CE} = -80$ v, $V_{BE} = +1.0$ v $V_{CE} = -100$ v, $V_{BE} = +1.0$ v $V_{CE} = -120$ v, $V_{BE} = +1.0$ v	2N1539 2N1540 2N1541 2N1542 2N1543		−20	ma
*I_{EBO}	Emitter Cutoff Current	$V_{EB} = -12$ v, $I_C = 0$	All		−0.5	ma
*I_{EBO}	Emitter Cutoff Current	$V_{EB} = -20$ v, $I_C = 0$	All		−25	ma
*h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ v, $I_C = -3.0$ a	All	50	100	
*g_{FE}	Static Common-Emitter Forward Transfer Conductance	$V_{CE} = -2$ v, $I_C = -3.0$ a	All	3.0		mho
*V_{BE}	Base-Emitter Voltage	$I_B = -300$ ma, $I_C = -3.0$ a	All		−0.7	v
*$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -300$ ma, $I_C = -3.0$ a	All		−0.3	v
*f_{hfe}	Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	$V_{CE} = -2$ v, $I_C = -5$ a	All	1		kc
f_T	Transition Frequency (See Note 3)	$V_{CE} = -2$ v, $I_C = -1$ a $f = 100$ kc	All	200		kc

thermal characteristics

PARAMETER		TEST CONDITIONS	TYPE	MIN	MAX	UNIT
* $\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance		All		0.8	C°/w

NOTE 3: To obtain f_T, the $|h_{fe}|$ response is extrapolated at the rate of −6 db per octave from $f = 100$ kc to the frequency at which $|h_{fe}| = 1$.

*Indicates JEDEC registered data

TYPES 2N1907, 2N1908
BULLETIN NO. DL-S 64426, FEBRUARY 1964
REPLACES BULLETIN NO. DL-S 61450, FEBRUARY 1961

HIGH-FREQUENCY POWER TRANSISTORS for MILITARY AND INDUSTRIAL APPLICATIONS

environmental tests

To ensure maximum integrity, stability, and long life, finished transistors are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

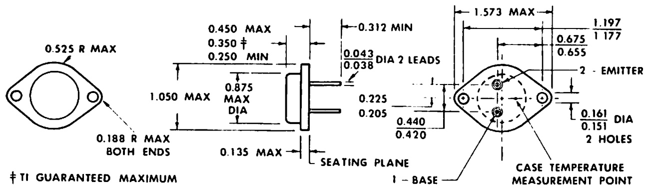
- All transistors are temperature cycled from − 55°C to + 110°C for four complete cycles.
- All transistors are heat aged at 110°C for 100 hours minimum.
- The hermetic seal is verified for all devices by the use of both helium and gross leak tests.

Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.

mechanical data

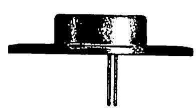
These transistors are in precision welded, hermetically sealed enclosures. The mounting base provides an excellent heat path from the collector junction to a heat sink. The mounting base and heat sink must be in intimate contact for maximum heat transfer. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate weight of the unit is 18 grams.

*ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE.
*THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



† TI GUARANTEED MAXIMUM

DIMENSIONS ARE IN INCHES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N1907	2N1908
Collector-Base Voltage	100 v*	130 v*
Collector-Emitter Voltage (See Note 1)	40 v	50 v
Emitter-Base Voltage	←{1.5 v* / 2.0 v†}→	
Collector Current	← 20 a* →	
Base Current	← 3 a* →	
Safe Continuous Operating Region	See Figures 15 and 16	
Total Device Dissipation at (or below) 70°C Case Temperature (See Note 2)	← 60 w →	
Peak Collector Power Dissipation at (or below) 25°C Case Temperature (See Note 3)	800 w	1000 w
Operating Collector Junction Temperature	← 100°C* →	
Storage Temperature Range	{− 55°C to + 100°C* / − 55°C to + 110°C†}	

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. Derate linearly to 100°C case temperature at the rate of 2 w/C°. This corresponds to the JEDEC registered maximum value of thermal resistance, $\theta_{J\text{-}C}$, 0.5 C°/w.

3. These values apply for rectangular waveshape. See Figure 14 for allowable pulse width and duty cycle combinations. Derate linearly to 100°C case temperature.

*Indicates JEDEC registered data.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

TYPES 2N1907, 2N1908
P-N-P ALLOY-DIFFUSED GERMANIUM POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N1907 MIN	2N1907 MAX	2N1908 MIN	2N1908 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -10$ ma, $I_E = 0$	−100		−130		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = -200$ ma, $I_B = 0$, See Note 4	−40*		−50*		v
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = -2$ ma, $I_C = 0$	−1.5		−1.5		v
		$I_E = -10$ ma, $I_C = 0$	−2.0		−2.0		
I_{CBO}	Collector Cutoff Current	$V_{CB} = -3$ v, $I_E = 0$		−0.5* −0.3†			ma
		$V_{CB} = -75$ v, $I_E = 0$		−2.0			
		$V_{CB} = -100$ v, $I_E = 0$		−10*			
		$V_{CB} = -75$ v, $I_E = 0$, $T_C = +70°C$		−12			
		$V_{CB} = -3$ v, $I_E = 0$				−0.5* −0.3†	
		$V_{CB} = -100$ v, $I_E = 0$				−2.0	
		$V_{CB} = -130$ v, $I_E = 0$				−10*	
		$V_{CB} = -100$ v, $I_E = 0$, $T_C = +70°C$				−12	
I_{CEX}	Collector Cutoff Current	$V_{CE} = -75$v, $V_{BE} = +0.2$ v		−2.0			ma
		$V_{CE} = -100$ v, $V_{BE} = +0.2$ v				−2.0	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -0.5$ v, $I_C = 0$		−0.2* −0.1†		−0.2* −0.1†	ma
		$V_{EB} = -1.5$ v, $I_C = 0$		−2.0*		−2.0*	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -1.5$ v, $I_C = -1$ a, See Note 4	80		80		
		$V_{CE} = -1.5$ v, $I_C = -5$ a, See Note 4	90		90		
		$V_{CE} = -1.5$ v, $I_C = -10$ a, See Note 4	30	170	30	170	
		$V_{CE} = -1.5$ v, $I_C = -15$ a, See Note 4	20		20		
		$V_{CE} = -1.5$ v, $I_C = -10$ a, $T_C = -55°C$, See Note 4	30 (See Fig. 4)		30 (See Fig. 4)		
		$V_{CE} = -1.5$ v, $I_C = -10$ a, $T_C = +70°C$, See Note 4	15 (See Fig. 4)	100	15 (See Fig. 4)	100	
V_{BE}	Base-Emitter Voltage	$I_B = -100$ ma, $I_C = -1$ a, See Note 4		−0.4		−0.4	v
		$I_B = -500$ ma, $I_C = -5$ a, See Note 4		−0.7		−0.7	
		$I_B = -1$ a, $I_C = -10$ a, See Note 4		−1.0		−1.0	
		$I_B = -1.5$ a, $I_C = -15$ a, See Note 4		−1.5		−1.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100$ ma, $I_C = -1$ a, See Note 4		−0.2		−0.2	v
		$I_B = -500$ ma, $I_C = -5$ a, See Note 4		−0.4		−0.4	
		$I_B = -1$ a, $I_C = -10$ a, See Note 4		−0.7		−0.7	
		$I_B = -1.5$ a, $I_C = -15$ a, See Note 4		−1.0*		−1.0*	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -15$ v, $I_C = -0.5$ a, f = 10 mc	1.0* 2.0†		1.0* 2.0†		

NOTE 4: If these parameters are measured without a heat sink, d-c collector current must not be applied longer than 250 msec.

*Indicates JEDEC registered data.

†Texas Instruments guarantees these values in addition to the JEDEC registered values which are also shown.

switching characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS †	TYPICAL	UNIT
t_d Delay Time	$I_C = -10a$, $I_{B(1)} = -1.33a$, $I_{B(2)} = 1.33a$, $V_{BE(off)} = 2$ v, $R_L = 2\,\Omega$, See Figure 1	0.1	μsec
t_r Rise Time		0.8	μsec
t_s Storage Time		2.5	μsec
t_f Fall Time		1.0	μsec
t_T Total Switching Time		4.4	μsec

† Voltage and current values are nominal; exact values vary slightly with device parameters.

PARAMETER MEASUREMENT INFORMATION

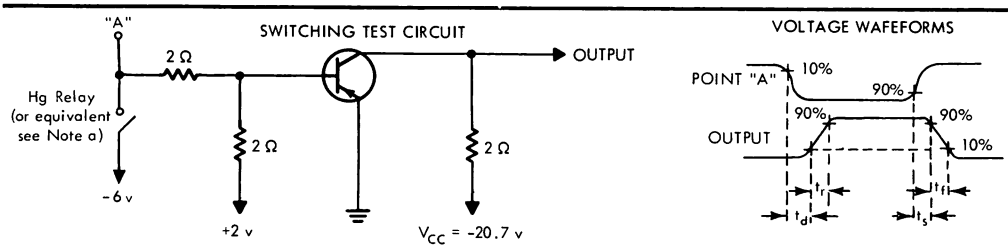


FIGURE 1

NOTES: a. The pulse at point "A" has the following characteristics: $t_r \leq 20$ nsec, $t_f \leq 20$ nsec, PW ≥ 50 μsec, duty cycle $\leq 5\%$.
b. The waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ nsec, $R_{in} \geq 1$ MΩ, $C_{in} \leq 20$ pf.

TYPICAL CHARACTERISTICS

COMMON-EMITTER COLLECTOR CHARACTERISTICS
(Low-Voltage Region)

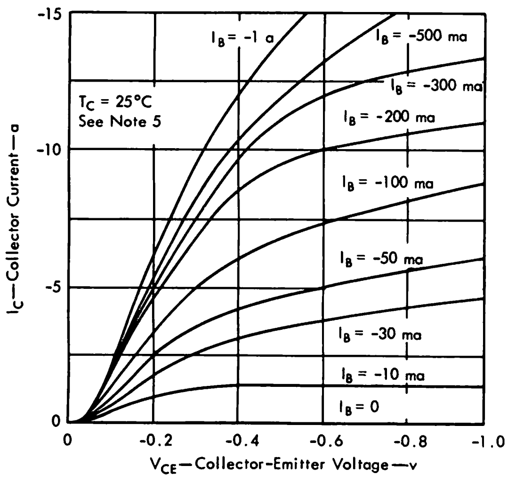


FIGURE 2

COMMON-EMITTER COLLECTOR CHARACTERISTICS
(High-Voltage Region)

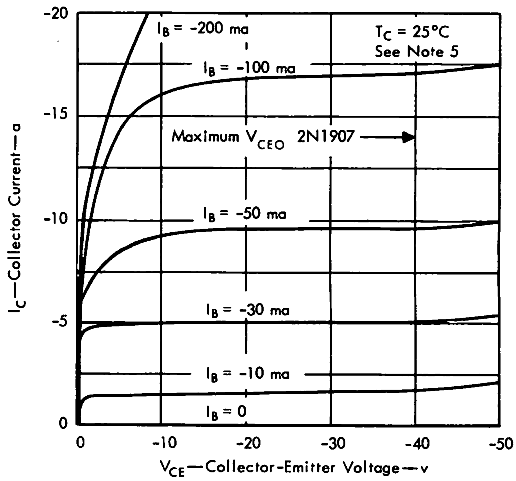


FIGURE 3

NOTE 5: These characteristics were measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq 2\%$.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

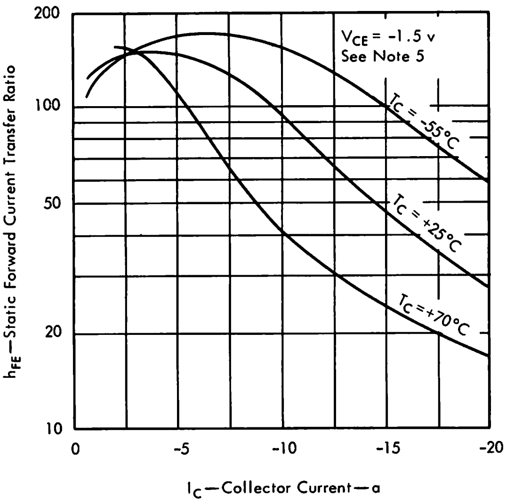


FIGURE 4

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

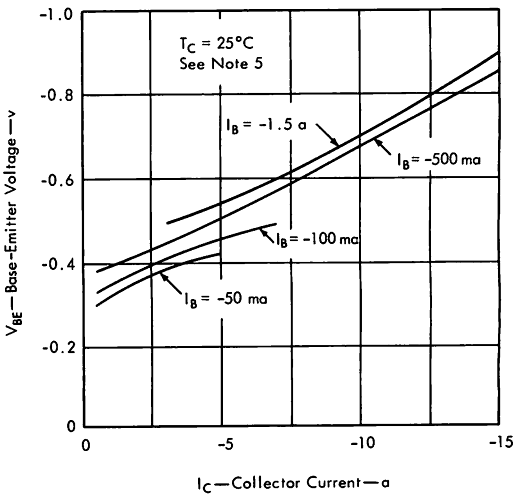


FIGURE 5

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

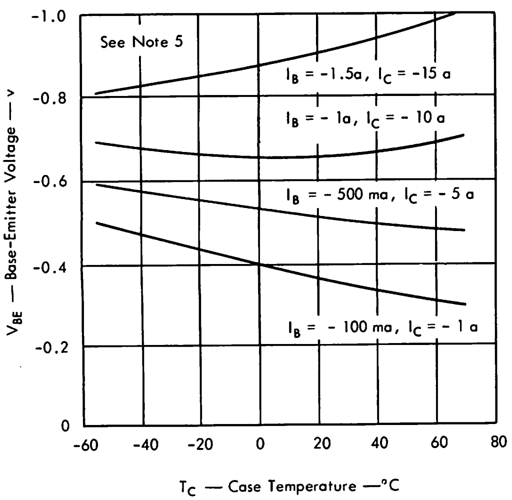


FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

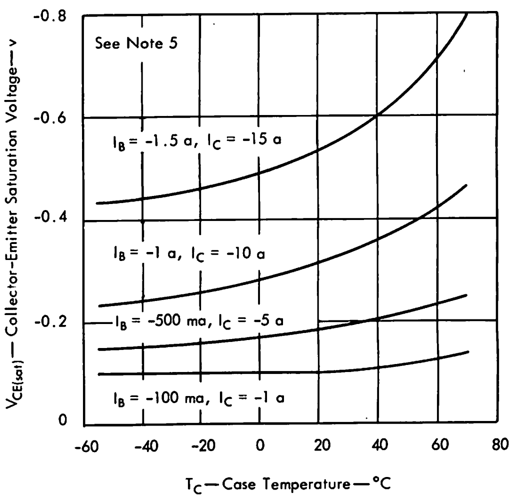


FIGURE 7

NOTE 5: These characteristics were measured using pulse techniques. PW = 300 μsec., Duty Cycle ≤ 2%.

TYPICAL CHARACTERISTICS

2N1907
NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

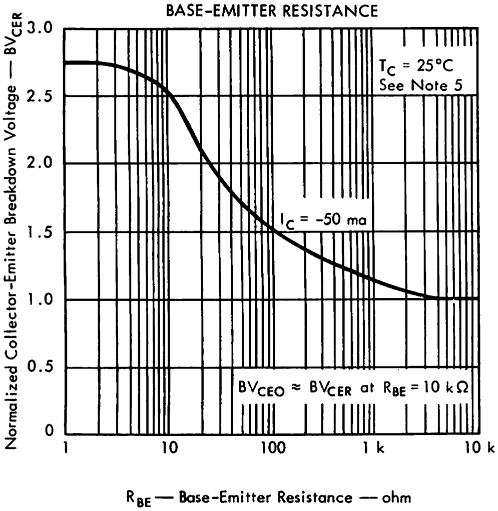


FIGURE 8

2N1908
NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

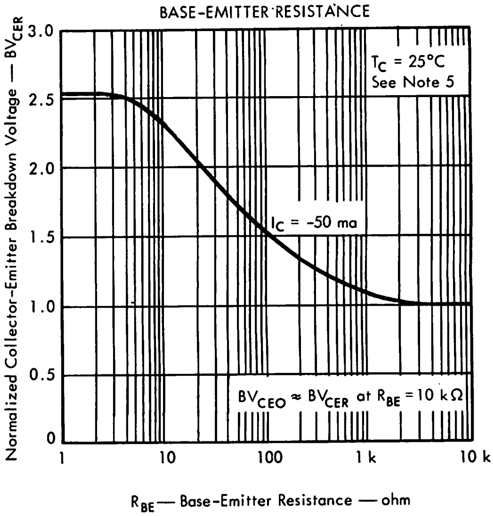


FIGURE 9

2N1907
COLLECTOR CUTOFF CURRENT
vs
COLLECTOR-BASE VOLTAGE

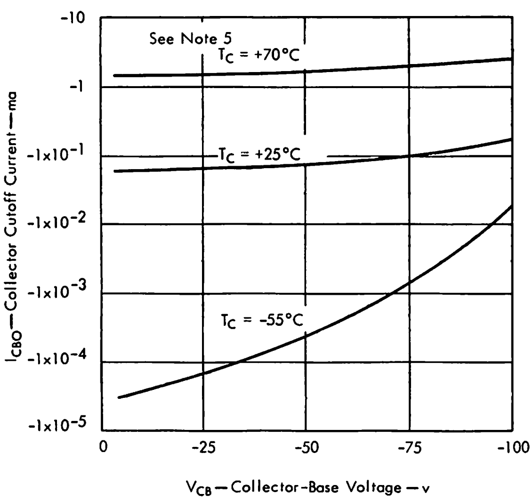


FIGURE 10

2N1908
COLLECTOR CUTOFF CURRENT
vs
COLLECTOR-BASE VOLTAGE

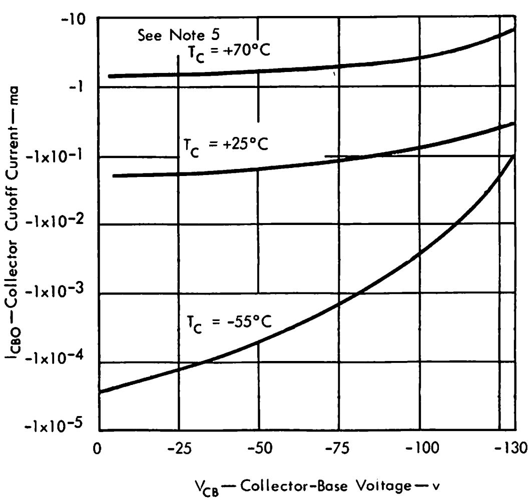


FIGURE 11

NOTE 5: These characteristics were measured using pulse techniques. PW = 300 μsec., Duty Cycle ≤ 2%.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

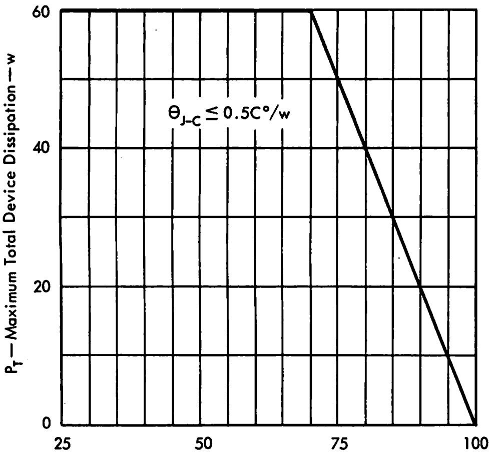


FIGURE 12

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

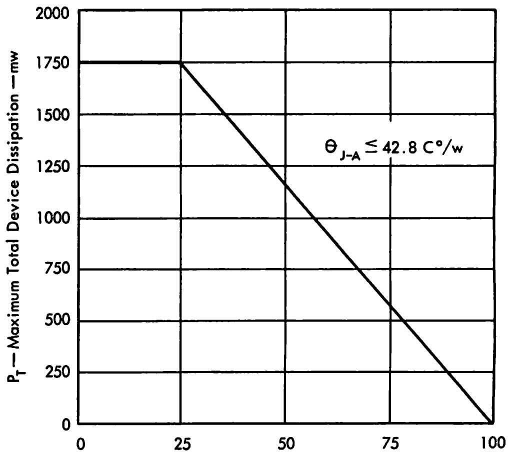


FIGURE 13

PEAK-POWER- COEFFICIENT CURVE

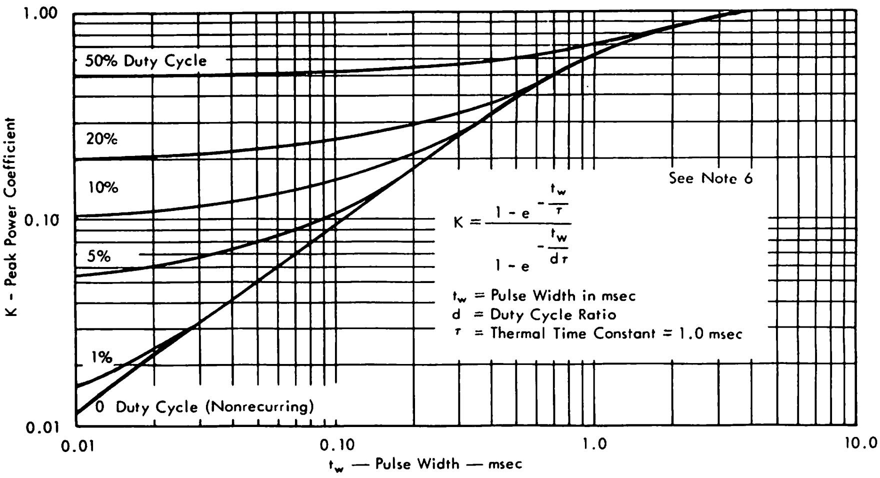


FIGURE 14

NOTE 6: When $t_w > 3.0$ msec or $d > 0.5$ (50%), operation must be confined to the continuous operating regions of Figure 15 or 16.

MAXIMUM SAFE OPERATING REGIONS

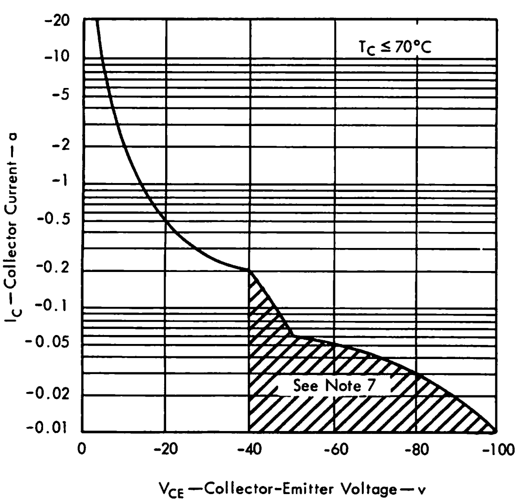


FIGURE 15

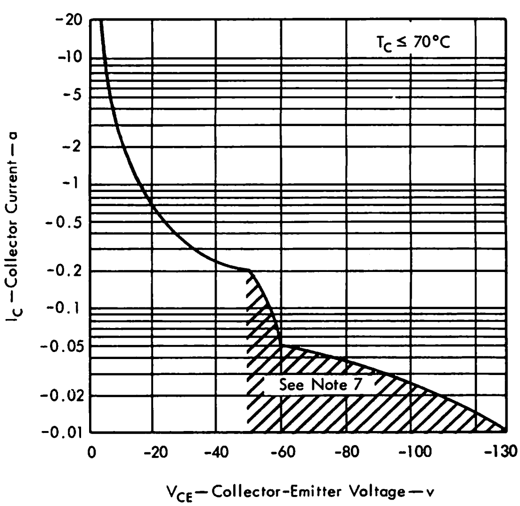


FIGURE 16

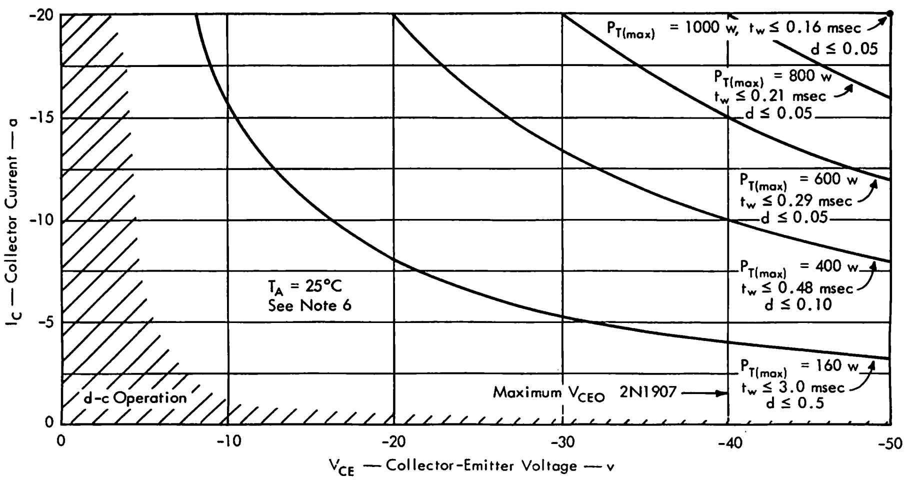


FIGURE 17

NOTES: 6. When $t_w > 3.0$ msec or $d > 0.5$ (50%), operation must be confined to the continuous operating regions of Figure 15 or 16.

7. Operation in this region is permissible when base-emitter resistance $R_{BE} \leq 5\ \Omega$.

THERMAL INFORMATION

TABLE I

HEAT SINK Type	HEAT SINK Dimensions	†θ_{HS-A}
Bright Copper	4" x 4" x 1/8"	3.8 C°/w
	6" x 6" x 1/8"	2.2 C°/w
	8" x 8" x 1/8"	1.8 C°/w
	10" x 10" x 1/8"	1.4 C°/w
Bright Aluminum	4" x 4" x 1/8"	6.5 C°/w
	6" x 6" x 1/8"	4.5 C°/w
	8" x 8" x 1/8"	3.5 C°/w
	10" x 10" x 1/8"	2.8 C°/w
Delbert Blinn #113 or Modine 1E1155B, Unfinished (or Equivalents)		3.7 C°/w
Delbert Blinn #113 or Modine 1E1155B, Black Anodized (or Equivalents)		3.2 C°/w

†θ_{HS-A} are typical values based on convection cooling; plates and fins mounted in vertical position.

‡All transistors mounted in the center of the heat sink with two 6-32 screws at 6 inch - pounds of torque.

TABLE II

SYMBOL	DEFINITION	UNIT	VALUE
$P_{T\,(avg)}$	Average Power Dissipation	w	
$P_{T\,(max)}$	Peak Power Dissipation	w	
θ_{J-C}	Junction-to-Case Thermal Resistance	C°/w	0.5
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	C°/w	42.8
θ_{C-A}	Case-to-Free-Air Thermal Resistance	C°/w	42.3
‡θ_{C-HS}	Case-to-Heat-Sink Thermal Resistance Typical With Dry Mounting Base	C°/w	0.65
	Typical with DC-11 Silicone Grease		0.45
θ_{HS-A}	Heat-Sink-to-Free-Air Thermal Resistance	C°/w	see Table 1
T_A	Free-Air Temperature	C°	
$T_{J\,(avg)}$	Average Junction Temperature	C°	≤ 100
$T_{J\,(max)}$	Peak Junction Temperature	C°	≤ 100
T_C	Case Temperature	C°	
K	Peak-Power Coefficient		see Fig. 14
t_w	Pulse Width	msec	
t_p	Pulse Period	msec	
d	Duty Cycle Ratio (t_w/t_p)		

For d-c operation, these transistors are voltage limited as well as thermally limited. Figure 12 and Figure 15 or 16 are recommended as a guide for selecting safe voltage and current combinations.

These transistors have a very low thermal resistance that may be fully utilized in a pulse-power application provided the pulse width is equal to (or less than) 3 milliseconds. If the power pulse is longer than 3 milliseconds, then the operating path is limited to the safe operating region described by Figure 12 and Figure 15 or 16.

The PEAK-POWER-COEFFICIENT CURVE shows the ratio of maximum instantaneous junction-to-case temperature rise for any pulse width and duty cycle to the rise which occurs at 100% duty cycle. Use of this curve is best explained by the equations and example below. See Table II for a definition of terms.

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T\,(avg)} = \frac{T_{J\,(avg)} - T_A}{\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T\,(avg)} = \frac{T_{J\,(avg)} - T_A}{\theta_{J-A}}$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T\,(max)} = \frac{T_{J\,(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}}$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T\,(max)} = \frac{T_{J\,(max)} - T_A}{d\,\theta_{C-A} + K\,\theta_{J-C}}$$

Example — Find $P_{T\,(max)}$ (design limit)

OPERATING CONDITIONS:

Heat Sink = 8" x 8" x 1/8" copper,
$\theta_{HS-A} = 1.8$ C°/w
with DC-11 grease, $\theta_{C-HS} = 0.45$ C°/w
$T_{J\,(max)}$ (design limit) = 100°C
$T_A = 35°C$
d = 20% (0.2)
$t_w = 0.1$ msec

SOLUTION:

From Figure 14 Peak-Power Coefficient,
K = 0.24, and by use of equation No. 3

$$P_{T\,(max)} = \frac{T_{J\,(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}}$$

$$P_{T\,(max)} = \frac{100 - 35}{0.2\,(0.45 + 1.8) + 0.24\,(0.5)} = 114 \text{ w}$$

TYPES TI3027, TI3028
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

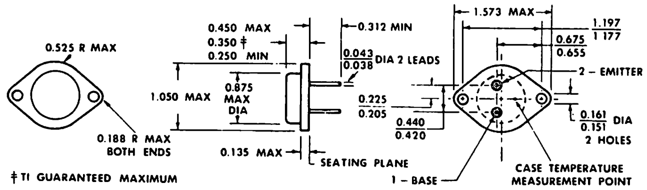
TYPES TI3027, TI3028
BULLETIN NO. DL-S 645053, APRIL 1964

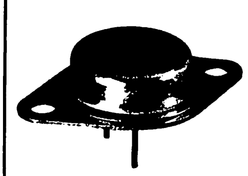
HIGH-POWER TRANSISTORS
for
CONSUMER APPLICATIONS

mechanical data

These transistors are in a resistance-welded, hermetically sealed enclosure. The mounting base provides an excellent heat path from the collector junction to a heat sink. The entire mounting base must be in intimate contact with the heat sink for maximum heat transfer. A minimum torque of 10 inch-pounds applied to each of the mounting screws is recommended for mounting the device to the heat sink. Extreme cleanliness and the absence of flux during the assembly process prevents sealed-in contamination.

*ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE.
*THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ǂ TI GUARANTEED MAXIMUM

DIMENSIONS ARE IN INCHES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TI3027	TI3028
Collector-Base Voltage	−45 v	−60 v
Collector-Emitter Voltage (See Note 1)	−40 v	−50 v
Emitter-Base Voltage	← −20 v →	
Collector Current	← −7 a →	
Base Current	← −3 a →	
Total Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 150 w →	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 2.0 w →	
Operating Case Temperature Range	−65°C to +100°C	
Storage Temperature Range	−65°C to +100°C	
Lead Temperature, ⅛ Inch from Case for 10 Seconds	← 230°C →	

NOTES: 1. These values apply when the base-emitter resistance $R_{BE} \leq 68\ \Omega$.
2. Derate linearly to 100°C case temperature at the rate of 2 w/C°.
3. Derate linearly to 100°C free-air temperature at the rate of 26.7 mw/C°.

TYPES TI3027, TI3028
P-N-P ALLOY-JUNCTION GERMANIUM POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TI3027 MIN	TI3027 MAX	TI3028 MIN	TI3028 MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = -5$ ma, $I_E = 0$	−45		−60		v
BV_{CER}	Collector-Emitter Breakdown Voltage	$I_C = -600$ ma, $R_{BE} = 68\,\Omega$, See Note 4	−40		−50		v
I_{CBO}	Collector Cutoff Current	$V_{CB} = -2$ v, $I_E = 0$		−0.15		−0.15	ma
		$V_{CB} = -30$ v, $I_E = 0$		−1			
		$V_{CB} = -40$ v, $I_E = 0$				−1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -20$ v, $I_C = 0$		−1		−1	ma
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ v, $I_C = -1$ a, See Note 4	70		70		
		$V_{CE} = -2$ v, $I_C = -3$ a, See Note 4	40	250	40	250	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ v, $I_C = -1$ a, See Note 4		−0.5		−0.5	v
		$V_{CE} = -2$ v, $I_C = -3$ a, See Note 4		−1.0		−1.0	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100$ ma, $I_C = -1$ a, See Note 4		−0.4		−0.4	v
		$I_B = -300$ ma, $I_C = -3$ a, See Note 4		−0.5		−0.5	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -2$ v, $I_C = -1$ a, f = 100 kc	2		2		

NOTE 4: These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.

thermal characteristics

PARAMETER		TEST CONDITIONS	MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	See notes in Thermal Characteristics section	0.5	C°/w
$\theta_{J\text{-}HS}$	Junction-to-Heat-Sink Thermal Resistance		1.1	C°/w
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance		37.5	C°/w

NUMERICAL SYSTEM FOR h_{FE} CODING

Upon request the transistors will be numerically coded to identify matched pairs. The transistors are in-house classified into 2-db (ratio 1.26 to 1) h_{FE} brackets and any two units within a bracket constitute a matched pair. A 10% tolerance is included in the bracket limits shown below to allow for test-set correlation.

No h_{FE}-bracket distribution is implied by this classification system.

BRACKET NUMBER	h_{FE} RANGE at $V_{CE} = -2$ v, $I_C = -3$ a
1	40 — 60
2	50 — 80
3	65 — 100
4	80 — 125
5	100 — 150
6	125 — 200
7	160 — 250

THERMAL INFORMATION

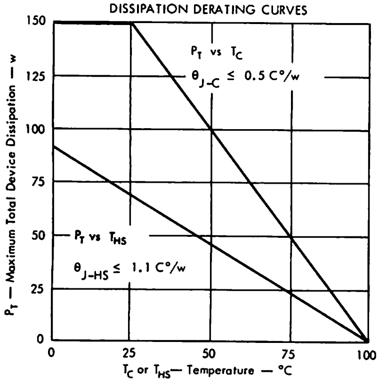


FIGURE 1

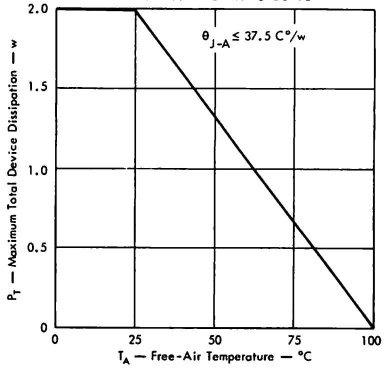


FIGURE 2

θ_{J-A} is the thermal resistance from the junction of the transistor to free-air. The curve shown above was determined by positioning the transistor in the center of a box 12 inches by 12 inches by 12 inches with the temperature measured two inches below the transistor.

θ_{J-C} is the thermal resistance from the junction of the transistor to the point on the mounting base of the transistor case specified on the outline drawing.

θ_{C-HS} is the thermal resistance from the mounting base of the transistor case to the mounting surface of the heat sink. The heat sink used to determine this value was a smooth, flat, copper plate, with the thermocouple mounted 0.05 inches below the mounting surface in an area beneath the center of the transistor. The transistor was mounted directly to a clean, dry, heat-sink surface, without the use of silicone grease, and a torque of ten inch-pounds was applied to each of the mounting screws.

θ_{J-HS} is the thermal resistance from the junction of the transistor to the mounting surface of the heat sink.
$\theta_{J-HS} = \theta_{J-C} + \theta_{C-HS}$

The dissipation levels shown above are verified statistically by operating-life tests.

TYPICAL CHARACTERISTICS

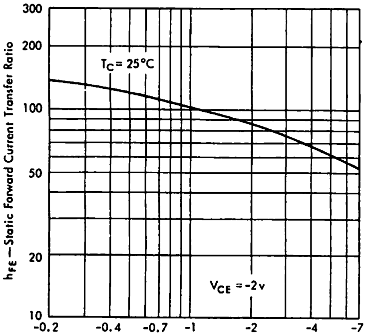


FIGURE 3

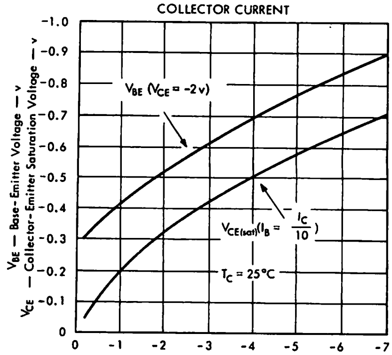
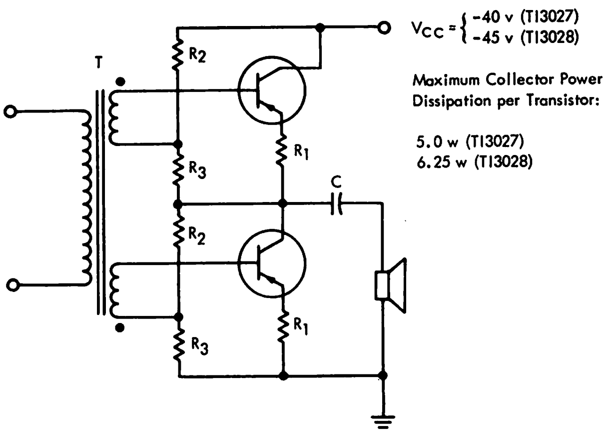


FIGURE 4

TYPICAL APPLICATION DATA

CLASS B AUDIO AMPLIFIER



TYPICAL CIRCUIT PERFORMANCE CHARACTERISTICS

$T_A = 25°C$, f = 1000 cps (except where noted)

	TI3027	TI3028
Minimum RMS Power Output at 5% Total Harmonic Distortion	20 w	25 w
Minimum Power Gain	18 db	20 db
Frequency Response	20 to 20,000 cps	
D-C Collector Current with Zero Signal	–0.05 a	–0.05 a
D-C Collector Current with Maximum Signal	–1.25 a	–1.10 a
Peak Collector Current with Maximum Signal	–3.9 a	–3.5 a
Input Impedance, Base-to-Base	73 Ω	68 Ω

CIRCUIT COMPONENT INFORMATION

	TI3027	TI3028
R_1:	0.56 Ω, 1 w	0.56 Ω, 1 w
R_2:	125 Ω, 5 w	150 Ω, 5 w
R_3:	1.1 Ω, ½ w	1.2 Ω, ½ w
Speaker Impedance:	8 Ω	8 Ω

All resistors ±10% tolerance

C: Selected to meet desired low-frequency response. Working voltage equals 40 v.

T: Driver transformer primary-winding impedance, current-carrying capacity, and d-c resistance are determined by large-signal characteristics of driver stage. Secondary windings are bifilar wound. The a-c impedance of each secondary winding equals 18 ohms for TI3027 and 17 ohms for TI3028.

UNI/G†

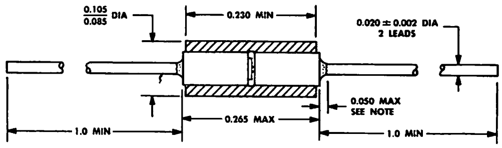
TYPES 1N456, 1N457, 1N458, 1N459
SILICON GENERAL PURPOSE DIODES

TYPES 1N456, 1N457, 1N458, 1N459
BULLETIN NO. DL-S 688612, MARCH 1966
REVISED MAY 1968

$V_{RM(wkg)}$ . . . 25 to 175 Volts

- **Rugged Whiskerless Construction**
- **Small Size**
- **Low Reverse Current**

mechanical data



DIMENSIONS ARE IN INCHES

NOTE: WITHIN THESE ZONES DIAMETER OF EACH LEAD IS UNCONTROLLED

REGISTERED BODY DIMENSIONS*
LENGTH ....0.265 MAX.
DIAMETER ....0.105 MAX.

CATHODE END IS DENOTED BY COLOR BANDS

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

		1N456	1N457	1N458	1N459	UNIT
V_{RM}	Peak Reverse Voltage	30	70	150	200	V
$V_{RM(wkg)}$	Working Peak Reverse Voltage	25	60	125	175	V
I_O	Average Rectified Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2)	90	75	55	40	mA
I_F	Steady State Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	135	110	80	60	mA
$I_{FM(surge)}$	Peak Surge Current, One Second (See Note 3)	0.7	0.6	0.5	0.4	A
$I_{FM(surge)}$	Peak Surge Current, Two Microseconds (See Note 4)	1.2	1	0.8	0.7	A
P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 5)	200				mW
T_{stg}	Storage Temperature Range	–80 to 200				°C
	Altitude	Any				

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	1N456		1N457		1N458		1N459		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 100\ \mu A$	30		70		150		200		V
I_R	Static Reverse Current	V_R = Rated $V_{RM(wkg)}$		25		25		25		25	nA
		V_R = Rated $V_{RM(wkg)}$, $T_A = 150°C$		5		5		5		5	µA
V_F	Static Forward Voltage	$I_F = 40$ mA		1							V
		$I_F = 20$ mA				1					V
		$I_F = 7$ mA						1			V
		$I_F = 3$ mA								1	V

NOTES: 1. These values may be applied continuously under single-phase 60-c/s half-sine-wave operation with resistive load.
2. Derate linearly to 0 at 200°C free-air temperature.
3. These values apply for a one-second square-wave pulse with the device at nonoperating thermal equilibrium immediately prior to the surge.
4. These values apply for 2-µs pulses, duty cycle ≤ 1%, with the device at nonoperating thermal equilibrium immediately prior to the surge.
5. Derate linearly to 200°C free-air temperature at the rate of 1.14 mW/deg.

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*Indicates JEDEC registered data

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UNI/G†

TYPES 1N482, 1N483, 1N484, 1N485
DIFFUSED SILICON GENERAL PURPOSE DIODES

$V_{RM(wkg)}$ . . . 36 to 180 Volts

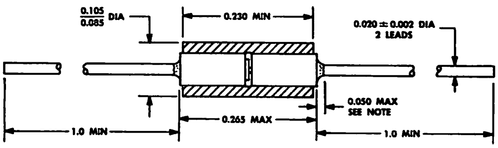
Rugged Whiskerless Construction • Small Size

Designed for

Magnetic Amplifiers • Modulators • Demodulators

Networks • Power Supplies

mechanical data



REGISTERED BODY DIMENSIONS*
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DIAMETER 0.105 MAX.

DIMENSIONS ARE IN INCHES
NOTE: WITHIN THESE ZONES DIAMETER OF EACH LEAD IS UNCONTROLLED

CATHODE END IS DENOTED BY COLOR BANDS

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

		1N482	1N483	1N484	1N485	UNIT
$V_{RM(wkg)}$	Working Peak Reverse Voltage	36	70	130	180	V
I_O	Average Rectified Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2)	100				mA
I_O	Average Rectified Forward Current at 150°C Free-Air Temperature (See Notes 1 and 3)	25				mA
$I_{FM(rep)}$	Repetitive Peak Forward Current at (or below) 25°C Free-Air Temperature (See Note 4)	400				mA
$I_{FM(surge)}$	Peak Surge Current, 100 Milliseconds (See Note 5)	1				A
P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 6)	250				mW
$T_{A(opr)}$	Operating Free-Air Temperature Range	–65 to 200				°C
T_{stg}	Storage Temperature Range	–65 to 200				°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		1N482		1N483		1N484		1N485		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 100\ \mu A$		40		80		150		200		V
I_R	Static Reverse Current	1N482: $V_R = 30$ V 1N483: $V_R = 60$ V 1N484: $V_R = 125$ V 1N485: $V_R = 175$ V	$T_A = 25°C$		0.25		0.25		0.25		0.25	μA
			$T_A = 150°C$		30		30		30		30	μA
V_F	Static Forward Voltage	$I_F = 100$ mA			1.1		1.1		1.1		1.1	V

NOTES: 1. These values may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load.
2. Derate linearly to 25 mA at 150°C free-air temperature.
3. Derate linearly to 0 at 200°C free-air temperature.
4. These values apply for a 4-ms square-wave pulse, duty cycle ≤ 25%.
5. These values apply for a 1/10-second square-wave pulse with the device at nonoperating thermal equilibrium immediately prior to the surge.
6. Derate linearly to 200°C free-air temperature at the rate of 1.43 mW/deg.

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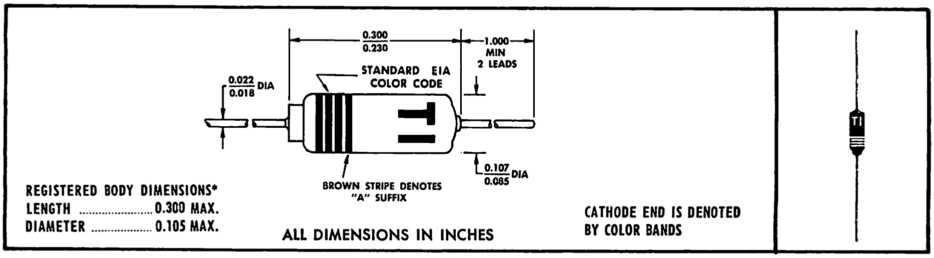
TYPES 1N645 THRU 1N649, 1N645A DIFFUSED SILICON GENERAL-PURPOSE DIODES

TYPES 1N645 THRU 1N649, 1N645A
BULLETIN NO. DL-S 669125, OCTOBER 1966
REPLACES BULLETIN NO. DL-S 1011, NOVEMBER 1958
AND BULLETIN NO. DL-S 1171, OCTOBER 1959

400 mA • 225 V to 600 V
Ruggedized to meet stringent military requirements

mechanical data

The diode is encased in a hermetically sealed hard-glass package. The outline drawing meets the JEDEC DO-7 outline.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

		1N645	1N645A	1N646	1N647	1N648	1N649	UNIT
$V_{RM(wkg)}$	Working Peak Reverse Voltage over Operating Free-Air Temperature Range	225	225	300	400	500	600	V
I_O	Average Rectified Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	400						mA
I_O	Average Rectified Forward Current at 150°C Free-Air Temperature (See Note 1)	150						mA
$I_{FM(surge)}$	Peak Surge Current, One Second, at 25°C to 150°C Free-Air Temperature (See Note 2)	3						A
P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	600						mW
$T_{A(opr)}$	Operating Free-Air Temperature Range	−65 to 150						°C
	Altitude at Rated Working Peak Reverse Voltage	100 000						ft

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	1N645 MIN	1N645 MAX	1N645A MIN	1N645A MAX	1N646 MIN	1N646 MAX	1N647 MIN	1N647 MAX	1N648 MIN	1N648 MAX	1N649 MIN	1N649 MAX	UNIT
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 100\ \mu A$, $T_A = 100°C$	275		275		360		480		600		720		V
I_R	Static Reverse Current	V_R = Rated $V_{RM(wkg)}$		0.2		0.2		0.2		0.2		0.2		0.2	μA
		V_R = Rated $V_{RM(wkg)}$, $T_A = 100°C$		15		15		15		20		20		25	μA
		$V_R = 60$ V				0.05									μA
		$V_R = 60$ V, $T_A = 125°C$				10									μA
V_F	Static Forward Voltage	$I_F = 400$ mA		1		1		1		1		1		1	V
C_T	Total Capacitance	$V_R = 12$ V, f = 1 MHz	6 typ		6 typ		6 typ		6 typ		6 typ		6 typ		pF

NOTES: 1. These values may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load. Above 25°C derate according to figure 3.
2. These values apply for a one-second square-wave pulse with the device at nonoperating thermal equilibrium immediately prior to the surge.
3. Derate linearly to 200 mW at 150°C free-air temperature at the rate of 3.2 mW/deg.

*Indicates JEDEC registered data.

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TYPICAL CHARACTERISTICS

STATIC REVERSE CURRENT
vs
REVERSE VOLTAGE

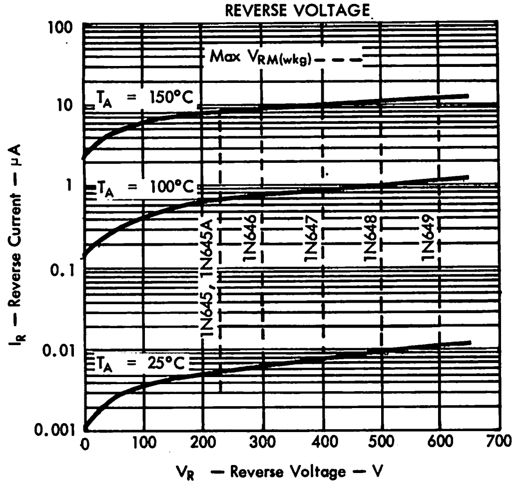


FIGURE 1

STATIC FORWARD CONDUCTION CHARACTERISTICS

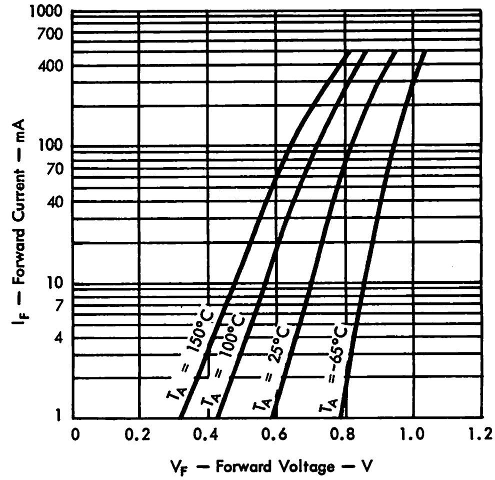


FIGURE 2

THERMAL CHARACTERISTICS

AVERAGE RECTIFIED FORWARD CURRENT DERATING CURVE

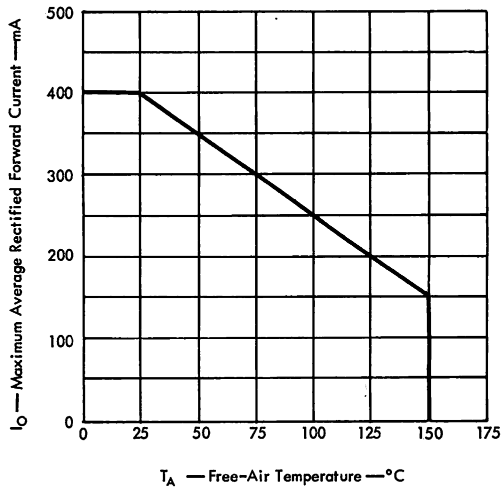


FIGURE 3

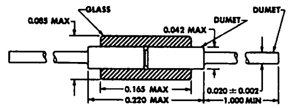
UNI/G*

TYPES 1N914, 1N914A, 1N914B, 1N915, 1N916, 1N916A, 1N916B and 1N917
DIFFUSED SILICON SWITCHING DIODES

TYPES 1N914, 1N914A, 1N914B,
1N915, 1N916, 1N916A, 1N916B, 1N917
BULLETIN NO. DL-S 683424, JANUARY 1963
REVISED MAY 1968

- **Extremely Stable and Reliable High-Speed Diodes**

mechanical data



ALL DIMENSIONS IN INCHES

absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

		1N914	1N914A	1N914B	1N915	1N916	1N916A	1N916B	1N917	Unit
V_R	Reverse Voltage at — 65 to + 150°C	75	75	75	50	75	75	75	30	v
I_o	Average Rectified Fwd. Current	75	75	75	75	75	75	75	50	ma
I_o	Average Rectified Fwd. Current at + 150°C	10	10	10	10	10	10	10	10	ma
i_f	Recurrent Peak Fwd. Current	225	225	225	225	225	225	225	150	ma
$i_{f(surge)}$,	Surge Current, 1 sec	500	500	500	500	500	500	500	300	ma
P	Power Dissipation	250	250	250	250	250	250	250	250	mw
T_A	Operating Temperature Range	— 65 to + 175								°C
T_{stg}	Storage Temperature Range	200								°C

maximum electrical characteristics at 25°C ambient temperature (unless otherwise noted)

		1N914	1N914A	1N914B	1N915	1N916	1N916A	1N916B	1N917	Unit
BV_R	Min Breakdown Voltage at 100 μa	100	100	100	65	100	100	100	40	v
I_R	Reverse Current at V_R	5	5	5	5	5	5	5		μa
I_R	Reverse Current at — 20 v	0.025	0.025	0.025		0.025	0.025	0.025		μa
I_R	Reverse Current at — 20 v at 100°C	3	3	3	5	3	3	3	25	μa
I_R	Reverse Current at — 20 v at + 150°C	50	50	50		50	50	50		μa
I_R	Reverse Current at — 10 v				0.025				0.05	μa
I_R	Reverse Current at — 10 v at 125°C									μa
I_F	Min Fwd Current at V_F = 1 v	10	20	100	50	10	20	30	10	ma
V_F	at 250 μa								0.64	v
V_F	at 1.5 ma								0.74	v
V_F	at 3.5 ma								0.83	v
V_F	at 5 ma			0.72	0.73			0.73		v
V_F	Min at 5 ma				0.60					v
C	Capacitance at V_R = 0	4	4	4	4	2	2	2	2.5	pf

operating characteristics at 25°C ambient temperature (unless otherwise noted)

		1N914	1N914A	1N914B	1N915	1N916	1N916A	1N916B	1N917	Unit
t_{rr}	Max Reverse Recovery Time	**4 °8	**4 °8	**4 °8	°10	**4 °8	**4 °8	**4 °8	°3	nsec nsec
V_f	Fwd Recovery Voltage (50 ma Peak Sq. wave, 0.1 μsec pulse width, 10 nsec rise time, 5 kc to 100 kc rep. rate)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	v

* Trademark of Texas Instruments
° Lumatron (10 ma I_F 10 ma I_R, recover to 1 ma)
** EG&G (10 ma I_F, 6v V_R, recover to 1 ma)

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UNI/G†

TYPE 1N3064
DIFFUSED SILICON SWITCHING DIODE

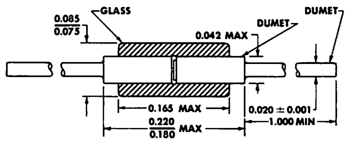
TYPE 1N3064
BULLETIN NO. DL-S 669114, SEPTEMBER 1966
REPLACES BULLETIN NO. DL-S 622683, MAY 1962

WHISKERLESS, DOUBLE-PLUG CONSTRUCTION

mechanical data

The glass-passivated silicon wafer is encased in a hermetically sealed glass package. The high-temperature bond between wafer and leads ensures integral positive contact under extreme environmental conditions.

ALL DIMENSIONS IN INCHES



CATHODE END IS DENOTED BY COLOR BANDS

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

*V_{RM}	Peak Reverse Voltage	75 V
I_F	Steady-State Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	115 mA
$I_{FM(surge)}$	Peak Surge Current, One Second (See Note 2)	500 mA
$I_{FM(surge)}$	Peak Surge Current, One Microsecond (See Note 2)	2 A
*P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	250 mW
*T_{stg}	Storage Temperature Range	–65°C to 200°C
*T_L	Lead Temperature 1/16 Inch from Case for 2 Seconds	250°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 5\ \mu A$	75		V
I_R	Static Reverse Current	$V_R = 50$ V		0.1	μA
		$V_R = 50$ V, $T_A = 150°C$		100	μA
V_F	Static Forward Voltage	$I_F = 10$ mA		1	V
α_{VF}	Temperature Coefficient of Static Forward Voltage	$I_F = 10$ mA, See Note 4		3	mV/deg
C_T	Total Capacitance	$V_R = 0$, $f = 1$ MHz		2	pF

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
t_{rr}	Reverse Recovery Time	$I_F = 10$ mA, $I_{RM} = 10$ mA, $R_L = 100\ \Omega$, $C_L = 10$ pF, $i_{rr} = 1$ mA, See Figure 1		4	ns
$V_{FM(rec)}$	Forward Recovery Voltage	$I_F = 100$ mA, $R_L = 50\ \Omega$, See Figure 2		3	V
η_r	Rectification Efficiency	$V_r = 2$ V, $R_L = 5$ kΩ, $C_L = 20$ pF, $Z_{source} = 50\ \Omega$, $f = 100$ MHz	45 %		

NOTES: 1. These values may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load. Derate linearly to 0 at 150°C free-air temperature.
2. These values apply for the specified square-wave pulse with the device at nonoperating thermal equilibrium immediately prior to the surge.
3. Derate linearly at the rate of 1.5 mW/deg.
4. Temperature coefficient, α_{VF}, is determined by the following formula:

$$\alpha_{VF} = \frac{V_F @ 150°C - V_F @ -55°C}{150°C - (-55°C)}$$

†Trademark of Texas Instruments
*Indicates JEDEC registered data

PARAMETER MEASUREMENT INFORMATION

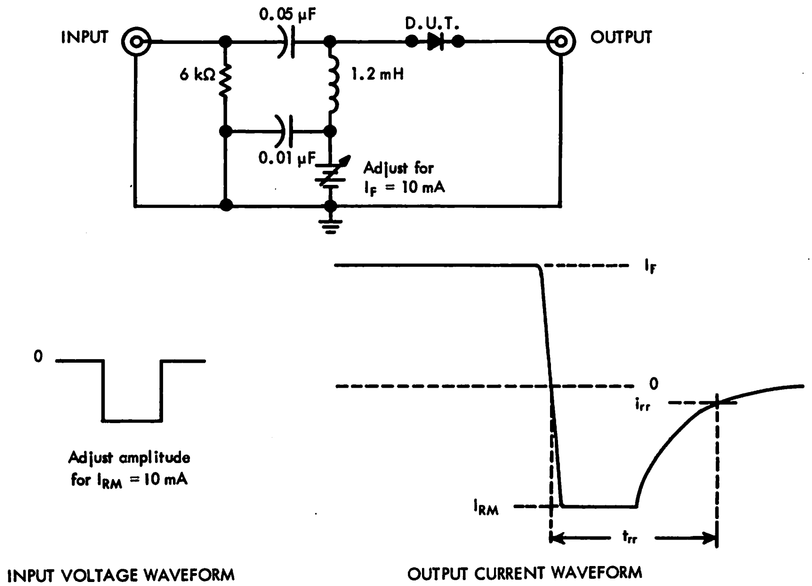


FIGURE 1 — REVERSE RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 0.25$ ns, $t_p = 100$ ns.
b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.35$ ns, $Z_{in} = 50\ \Omega$.

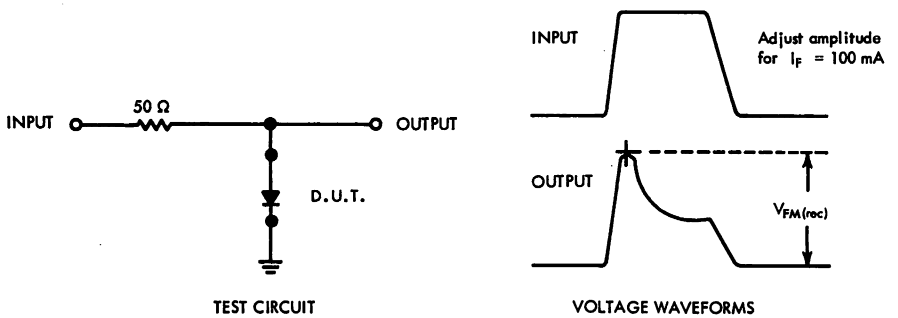


FIGURE 2 — FORWARD RECOVERY VOLTAGE

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 20$ ns, $t_p = 100$ ns, PRR ≤ 100 kHz.
d. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.4$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.

UNI / G†

TYPE 1N3070
DIFFUSED SILICON SWITCHING DIODE

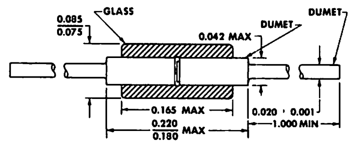
TYPE 1N3070
BULLETIN NO. DL-S 669370, NOVEMBER 1966

WHISKERLESS, DOUBLE-PLUG CONSTRUCTION

mechanical data

The glass-passivated silicon wafer is encased in a hermetically sealed glass package. The high-temperature bond between wafer and leads ensures integral positive contact under extreme environmental conditions.

ALL DIMENSIONS IN INCHES



CATHODE END IS DENOTED BY COLOR BANDS

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

*V_{RM}	Peak Reverse Voltage	200 V
I_F	Steady-State Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	150 mA
$I_{FM(surge)}$	Peak Surge Current, One Second (See Note 2)	500 mA
$I_{FM(surge)}$	Peak Surge Current, One Microsecond (See Note 2)	2 A
*P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	250 mW
*T_{stg}	Storage Temperature Range	−65°C to 200°C
*T_L	Lead Temperature 1/16 Inch from Case for 2 Seconds	250°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 0.1$ mA	200		V
I_R	Static Reverse Current	$V_R = 175$ V		0.1	μA
		$V_R = 175$ V, $T_A = 150°C$		100	μA
V_F	Static Forward Voltage	$I_F = 100$ mA		1	V
α_{VF}	Temperature Coefficient of Static Forward Voltage	$I_F = 100$ mA, See Note 4		3	mV/deg
C_T	Total Capacitance	$V_R = 0$, $f = 1$ MHz		5	pF

*operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
t_{rr}	Reverse Recovery Time	$I_F = 30$ mA, $I_{RM} = 30$ mA, $R_L = 150\ \Omega$, $C_L = 10$ pF, $i_{rr} = 1$ mA, See Figure 2		50	ns
η_r	Rectification Efficiency	$V_r = 2$ V, $R_L = 5\ k\Omega$, $C_L = 20$ pF, $Z_{source} = 50\ \Omega$, $f = 100$ MHz	35 %		

NOTES: 1. These values may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load. Derate linearly to 0 at 200°C free-air temperature.
2. These values apply for the specified square-wave pulse with the device at nonoperating thermal equilibrium immediately prior to the surge.
3. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve, figure 1.
4. Temperature coefficient, α_{VF}, is determined by the following formula:

$$\alpha_{VF} = \frac{V_F\ @\ 150°C - V_F\ @\ -55°C}{150°C - (-55°C)}$$

†Trademark of Texas Instruments
*Indicates JEDEC registered data

TYPE 1N3070
DIFFUSED SILICON SWITCHING DIODE

THERMAL INFORMATION

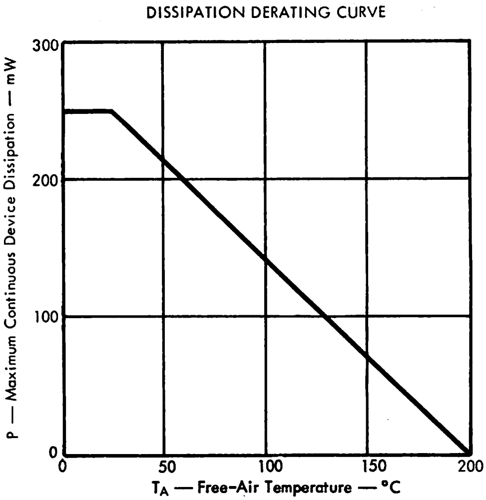


FIGURE 1

PARAMETER MEASUREMENT INFORMATION

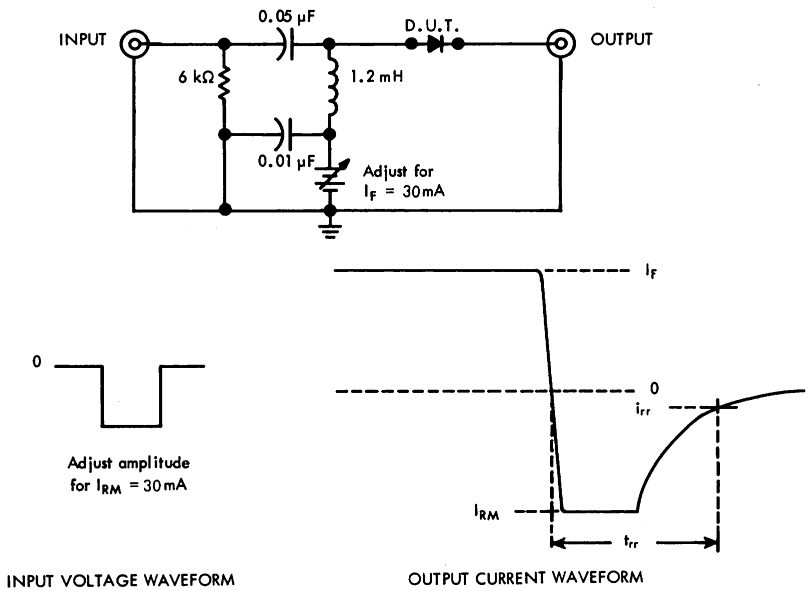


FIGURE 2 — REVERSE RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 0.25$ ns, $t_p = 100$ ns.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.35$ ns, $Z_{in} = 50\ \Omega$.

TYPES 1N4148, 1N4149, 1N4446, 1N4447, 1N4448, 1N4449
PLANAR SILICON SWITCHING DIODES

- **Small-Size, Whiskerless, Double-Plug Construction**
- **Extremely Stable and Reliable High-Speed Diodes**

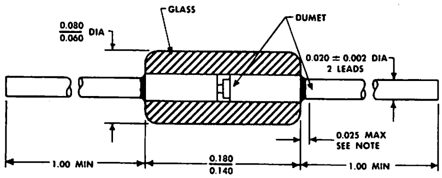
Electrical Equivalents

1N4148 • 1N914
1N4149 • 1N916
1N4446 • 1N914A
1N4447 • 1N916A
1N4448 • 1N914B
1N4449 • 1N916B

mechanical data

The glass-passivated silicon wafer is encased in a hermetically sealed glass package. High-temperature bond between wafer and leads insures integral positive contact under extreme environmental conditions.

*CASE OUTLINE



DIMENSIONS ARE IN INCHES
NOTE: WITHIN THIS ZONE DIAMETER OF EACH LEAD IS UNCONTROLLED

CATHODE END IS DENOTED BY COLOR BAND

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

$V_{RM(wkg)}$	Working Peak Reverse Voltage	75 V
P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	500 mW
T_{stg}	Storage Temperature Range	−65°C to 200°C
T_L	Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS	1N4148		1N4149		1N4446		1N4447		1N4448		1N4449		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)}$ Reverse Breakdown Voltage	$I_R = 5\ \mu A$	75		75		75		75		75		75		V
	$I_R = 100\ \mu A$	100		100		100		100		100		100		V
I_R Static Reverse Current	$V_R = 20$ V		25		25		25		25		25		25	nA
	$V_R = 20$ V, $T_A = 100°C$										3		3	μA
	$V_R = 20$ V, $T_A = 150°C$		50		50		50		50		50		50	μA
V_F Static Forward Voltage	$I_F = 5$ mA									0.62	0.72	0.63	0.73	V
	$I_F = 10$ mA		1		1									V
	$I_F = 20$ mA						1		1					V
	$I_F = 30$ mA												1	V
	$I_F = 100$ mA										1			V
C_T Total Capacitance	$V_R = 0$, $f = 1$ MHz		4		2		4		2		4		2	pF

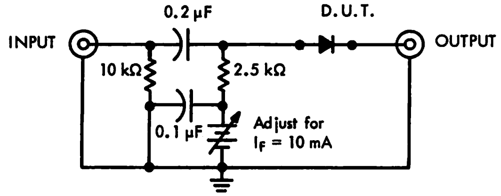
NOTE 1: Derate linearly to 200°C at the rate of 2.85 mW/deg.
†Trademark of Texas Instruments
*Indicates JEDEC registered data

TYPES 1N4148, 1N4149, 1N4446, 1N4447, 1N4448, 1N4449
PLANAR SILICON SWITCHING DIODES

***switching characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	1N4148		1N4149		1N4446		1N4447		1N4448		1N4449		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
t_{rr}	Reverse Recovery Time	$I_F = 10$ mA, $V_R = 6$ V, $i_{rr} = 1$ mA, $R_L = 100\ \Omega$, See Figure 1		4		4		4		4		4		4	ns
$V_{FM(rec)}$	Forward Recovery Voltage	$I_F = 50$ mA, $R_L = 50\ \Omega$, See Figure 2										2.5		2.5	V

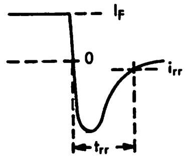
*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

Adjust amplitude
for V_R = 6 V

INPUT VOLTAGE WAVEFORM

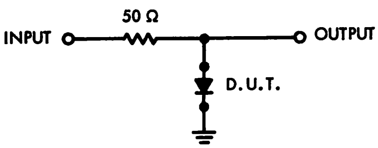


OUTPUT CURRENT WAVEFORM

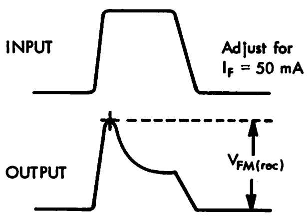
FIGURE 1 — REVERSE RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 0.5$ ns, $t_p = 100$ ns.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.6$ ns, $Z_{in} = 50\ \Omega$.



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 2 — FORWARD RECOVERY VOLTAGE

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 30$ ns, $t_p = 100$ ns, PRR = 5 to 100 kHz.

d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 5$ pF.

*Indicates JEDEC registered data

UNI/G†

TYPES 1N4305, 1N4444, 1N4454
PLANAR SILICON SWITCHING DIODES

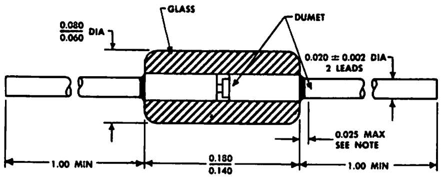
TYPES 1N4305, 1N4444, 1N4454
BULLETIN NO. DL-S 669266, OCTOBER 1966

- **Small-Size, Whiskerless, Double-Plug Construction**
- **Extremely Stable and Reliable High-Speed Diodes**
- **1N4305 Electrically Equivalent to 1N3063**
- **1N4454 Electrically Equivalent to 1N3064**

mechanical data

The glass-passivated silicon wafer is encased in a hermetically sealed glass package. High-temperature bond between wafer and leads insures integral positive contact under extreme environmental conditions.

*CASE OUTLINE



DIMENSIONS ARE IN INCHES
NOTE: WITHIN THIS ZONE DIAMETER OF EACH LEAD IS UNCONTROLLED

CATHODE END IS DENOTED BY COLOR BAND

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

		1N4305	1N4444	1N4454	UNIT
V_{RM}	Peak Reverse Voltage	75		75	V
$V_{RM(wkg)}$	Working Peak Reverse Voltage		50		V
P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	500			mW
T_{stg}	Storage Temperature Range	–65 to 200			°C
T_L	Lead Temperature 1/16 Inch from Case for 10 Seconds	300			°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	1N4305		1N4444		1N4454		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 5\ \mu A$	75		70		75		V
I_R	Static Reverse Current	$V_R = 50$ V		0.1		0.05		0.1	μA
		$V_R = 50$ V, $T_A = 150°C$		100		50		100	μA
V_F	Static Forward Voltage	$I_F = 0.1$ mA			0.44	0.55			V
		$I_F = 0.25$ mA	0.505	0.575					V
		$I_F = 1$ mA	0.55	0.65	0.56	0.68			V
		$I_F = 2$ mA	0.61	0.71					V
		$I_F = 10$ mA	0.70	0.85	0.69	0.82		1	V
		$I_F = 100$ mA			0.85	1			V
α_{VF}	Forward Voltage Temperature Coefficient	$I_F = 10\ \mu A$ to 10 mA, See Note 2		3					mV/deg
C_T	Total Capacitance	$V_R = 0$, f = 1 MHz		2		2		2	pF

NOTES: 1. Derate linearly to 200°C at the rate of 2.85 mW/deg.
2. Temperature coefficient, α_{VF}, is determined by the following formula:

$$\alpha_{VF} = \frac{V_F\ @\ 150°C - V_F\ @\ -55°C}{150°C - (-55°C)}$$

†Trademark of Texas Instruments
*Indicates JEDEC registered data

*operating characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	1N4305 MIN	1N4305 MAX	1N4444 MIN	1N4444 MAX	1N4454 MIN	1N4454 MAX	UNIT
t_{rr} Reverse Recovery Time	I_F = 10 mA, I_{RM} = 10 mA, i_{rr} = 1 mA, R_L = 100 Ω, See Figure 1, Condition 1		4		7		4	ns
	I_F = 10 mA, V_R = 6 V, i_{rr} = 1 mA, R_L = 100 Ω, See Figure 1, Condition 2		2				2	ns
$V_{FM(rec)}$ Forward Recovery Voltage	I_F = 100 mA, R_L = 50 Ω, See Figure 2						3	V
η_r Rectification Efficiency	V_r = 2 V, R_L = 5 kΩ, C_L = 20 pF, Z_{source} = 50 Ω, f = 100 MHz	45						%

*PARAMETER MEASUREMENT INFORMATION

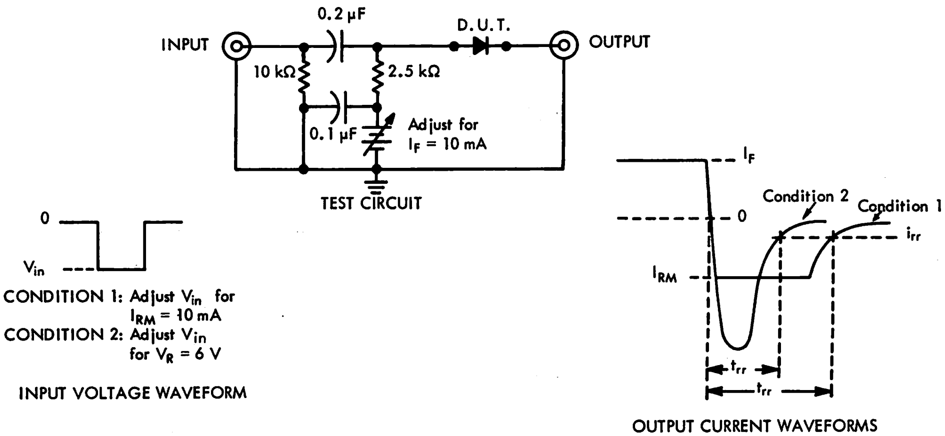


FIGURE 1 — REVERSE RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq$ 0.5 ns, t_p = 100 ns.
b. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq$ 0.6 ns, Z_{in} = 50 Ω.

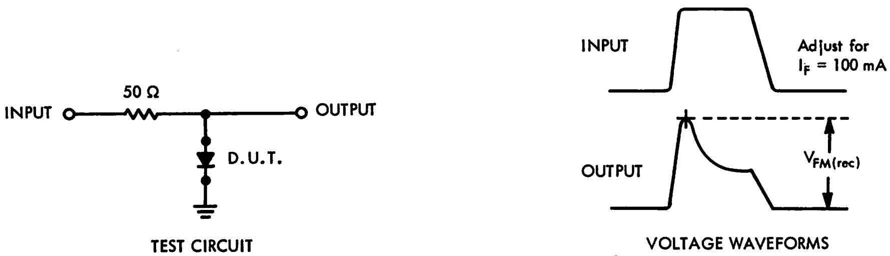


FIGURE 2 — FORWARD RECOVERY VOLTAGE

NOTES: c. The input pulse is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq$ 30 ns, t_p = 100 ns, PRR = 5 to 100 kHz.
d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq$ 15 ns, $R_{in} \geq$ 1 MΩ, $C_{in} \leq$ 5 pF.

*Indicates JEDEC registered data.

UNI/G†

TYPES 1N4531 THRU 1N4534, 1N4536
PLANAR SILICON SWITCHING DIODES

TYPES 1N4531 THRU 1N4534, 1N4536
BULLETIN NO. DL-S 679774, MARCH 1967

- **Microminiature, Whiskerless, Double-Plug Construction**
- **Extremely Stable and Reliable High-Speed Diodes**

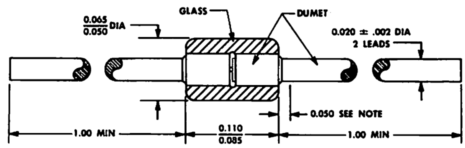
Electrical Equivalents

1N4531 • 1N914　　1N4532 • 1N3064
1N4533 • 1N3605　　1N4534 • 1N3606
1N4536 • 1N4009

mechanical data

The glass-passivated planar silicon wafer is encased in a hermetically sealed glass package. High-temperature bond between wafer and leads insures integral positive contact under extreme environmental conditions.

CASE OUTLINE FALLS WITHIN JEDEC DO-34



DIMENSIONS ARE IN INCHES
NOTE: WITHIN THIS ZONE DIAMETER OF EACH LEAD IS UNCONTROLLED

REGISTERED BODY DIMENSIONS*

	MIN	MAX
LENGTH	0.080	0.110
DIAMETER	0.045	0.065

CATHODE END IS DENOTED BY COLOR BAND

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

		1N4531	1N4532	1N4533	1N4534	1N4536	UNIT
V_{RM}	Peak Reverse Voltage	75	75	40	75	35	V
*$V_{RM(wkg)}$	Working Peak Reverse Voltage	75	75	40	50	25	V
*P	Continuous Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	500					mW
*T_{stg}	Storage Temperature Range	−65 to 200					°C
*T_L	Lead Temperature 1/16 Inch from Case for 10 Seconds	300					°C

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS	1N4531 MIN	1N4531 MAX	1N4532 MIN	1N4532 MAX	1N4533 MIN	1N4533 MAX	1N4534 MIN	1N4534 MAX	1N4536 MIN	1N4536 MAX	UNIT
$V_{(BR)}$ Reverse Breakdown Voltage	$I_R = 5\ \mu A$	75		75		40		75		35		V
	$I_R = 100\ \mu A$	100										V
I_R Static Reverse Current	$V_R = 20$ V		0.025									μA
	$V_R = 20$ V, $T_A = 150°C$		50									μA
	$V_R = 25$ V										0.1	μA
	$V_R = 25$ V, $T_A = 150°C$										100	μA
	$V_R = 30$ V						0.05					μA
	$V_R = 30$ V, $T_A = 150°C$						50					μA
	$V_R = 50$ V				0.1				0.05			μA
	$V_R = 50$ V, $T_A = 150°C$				100				50			μA
V_F Static Forward Voltage	$I_F = 0.1$ mA					0.49	0.55	0.49	0.55			V
	$I_F = 0.25$ mA					0.53	0.59	0.53	0.59			V
	$I_F = 1$ mA					0.59	0.67	0.59	0.67			V
	$I_F = 2$ mA					0.62	0.70	0.62	0.70			V
	$I_F = 10$ mA		1		1	0.70	0.81	0.70	0.81			V
	$I_F = 20$ mA					0.74	0.88	0.74	0.88			V
	$I_F = 30$ mA										1	V
C_T Total Capacitance	$V_R = 0$, f = 1 MHz		4		2		2		2		4	pF

NOTE 1: Derate linearly to 200°C free-air temperature at the rate of 2.85 mW/deg.

†Trademark of Texas Instruments
*Indicates JEDEC registered data

***operating characteristics at 25°C free-air temperature**

PARAMETER		TEST CONDITIONS	1N4531		1N4532		1N4533		1N4534		1N4536		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
t_{rr}	Reverse Recovery Time	$I_F = 10$ mA, $I_{RM} = 10$ mA, $i_{rr} = 1$ mA, $R_L = 100\ \Omega$, See Figure 1, Condition 1				4		4		4		4	ns
		$I_F = 10$ mA, $V_R = 6$ V, $i_{rr} = 1$ mA, $R_L = 100\ \Omega$, See Figure 1, Condition 2		4		2		2		2		2	ns
$V_{FM(rec)}$	Forward Recovery Voltage	$I_F = 100$ mA, $R_L = 50\ \Omega$, See Figure 2				3							V

*PARAMETER MEASUREMENT INFORMATION

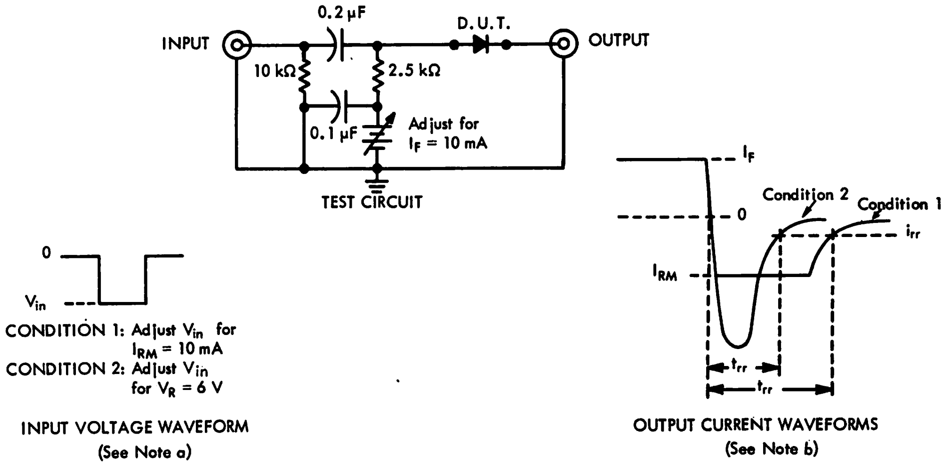


FIGURE 1 — REVERSE RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 0.5$ ns, $t_p = 100$ ns.
b. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 0.6$ ns, $Z_{in} = 50\ \Omega$.

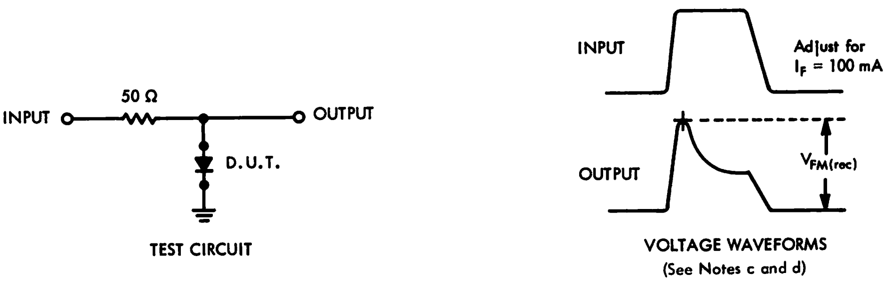


FIGURE 2 — FORWARD RECOVERY VOLTAGE

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 30$ ns, $t_p = 100$ ns, PRR = 5 to 100 kHz.
d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.

*Indicates JEDEC registered data

TYPES TID21, TID22, TID23, TID24
EPITAXIAL PLANAR SILICON 8-DIODE ARRAYS

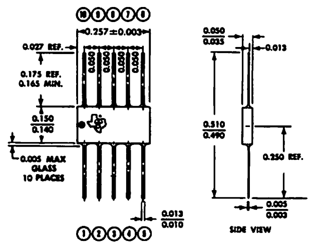
TYPES TID21, TID22, TID23, TID24
BULLETIN NO. DL-S 669405, OCTOBER 1966
REPLACES BULLETIN NO. DL-S 657541, MAY 1965

8-DIODE CORE DRIVERS
For Application With
Magnetic Cores • Memory Drums • Memory Tapes
Magnetic Discs • Diode-Capacitor Storage

mechanical data

The diode arrays are mounted in a glass-to-metal hermetically sealed, welded package which falls within the JEDEC TO-89 outline. Leads are goldplated F-15† glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic.

ALL LEADS INSULATED FROM CASE



NOTES: a. All dimensions in inches.

b. All decimals ±0.005 except as noted.

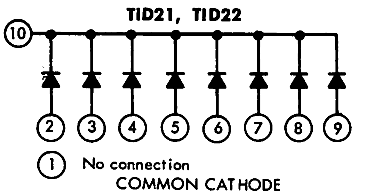
c. Lead-spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.

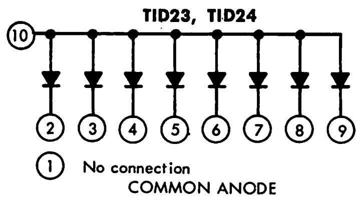
d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.

e. Symbolization denotes orientation of package.

†F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 29% nickel, 17% cobalt, and 53% iron.

schematic diagrams





absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH DIODE		TOTAL DEVICE	UNIT
	TID21 TID23	TID22 TID24	ALL TYPES	
Peak Reverse Voltage (See Note 1)	60	40		V
Steady State Reverse Voltage, V_R	30	15		V
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1, 2, and 3)	500		500	mA
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Notes 2 and 4)	100		200	mA
Storage Temperature Range	–65 to 200			°C
Lead Temperature 1/16 Inch From Case for 10 Seconds	300			°C

NOTES: 1. These values apply for 100-μs pulses, duty cycle $\leq$ 20%.

2. The values shown for total device apply for any combination provided the ratings of individual diodes are not exceeded.

3. Derate linearly to 150°C free-air temperature at the rate of 4 mA/deg.

4. Derate linearly to 150°C free-air temperature at the rate of 0.8 mA/deg for each diode and 1.6 mA/deg for the total device.

TYPES TID21, TID22, TID23, TID24
EPITAXIAL PLANAR SILICON 8-DIODE ARRAYS

electrical characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS		TID21		TID22		TID23		TID24		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 10\ \mu A$		60		40		60		40		V
I_R	Static Reverse Current	$V_R = 30$ V			0.1				0.1			μA
		$V_R = 15$ V					0.1				0.1	μA
V_F	Static Forward Voltage	$I_F = 100$ mA			1		1.1		1		1.1	V
v_F	Instantaneous Forward Voltage	$I_F = 500$ mA,	See Note 6		1.3		1.5		1.3		1.5	V
V_{FM}	Peak Forward Voltage	$I_F = 500$ mA,	See Note 7		5		5		5		5	V
C_T	Total Capacitance	$V_R = 0$,	$f = 1$ MHz		4		4		7		7	pF

multiple-diode operation (see note 8)

PARAMETER		TEST CONDITIONS	TID21		TID22		TID23		TID24		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
I_{R1}	Static Reverse Current	V_{R1} = rated V_R, $I_{FN} = 25$ mA		10		10		10		10	μA
V_{F1}	Static Forward Voltage	$I_{F1} = I_{FN} = 25$ mA		1		1		1		1	V

switching characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS	ALL TYPES MAX	UNIT
t_{fr}	Forward Recovery Time	$I_F = 500$ mA, See Figure 2	40	ns
t_{rr}	Reverse Recovery Time	$I_F = 200$ mA, $I_{RM} = 200$ mA, $R_L = 100\ \Omega$, $i_{rr} = 20$ mA, See Figure 3	20	ns

NOTES: 5. Test conditions and limits apply separately to each of the diodes. The diodes not under test are open-circuited during the measurement of these characteristics.

6. This parameter is measured using pulse techniques. $t_p = 100\ \mu s$, duty cycle $\leq 2\%$. Read time is 90 μs from leading edge of the pulse.

7. The initial instantaneous value is measured using pulse techniques. $t_p = 150\ \mu s$, duty cycle $\leq 2\%$ pulse rise time ≤ 10 ns. The total diode shunt capacitance is 19 pF max and the equipment bandwidth is 80 MHz.

8. Subscript numeral 1 refers to the diode under test; subscript N refers simultaneously to each of the other diodes. Each diode is individually tested after the device reaches operating thermal equilibrium.

TYPICAL CHARACTERISTICS

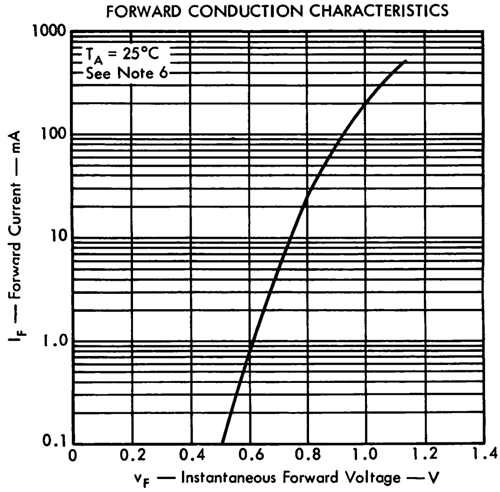
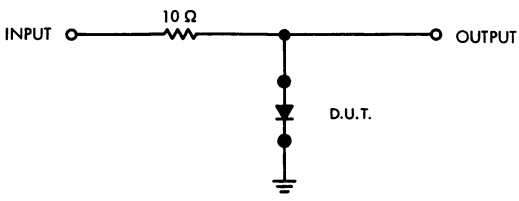


FIGURE 1

PARAMETER MEASUREMENT INFORMATION



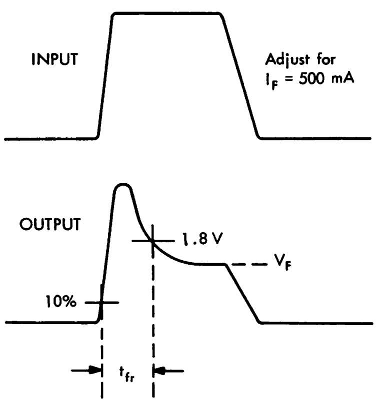
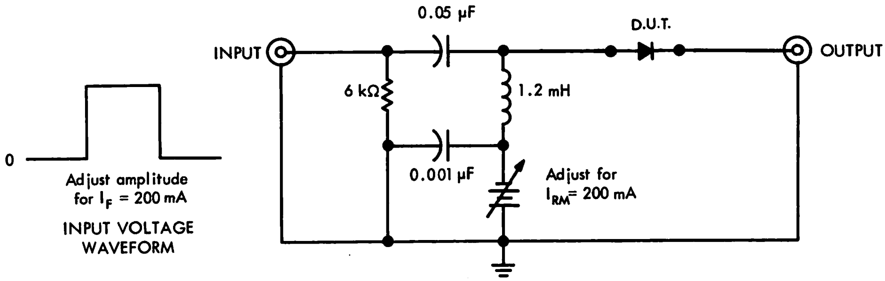


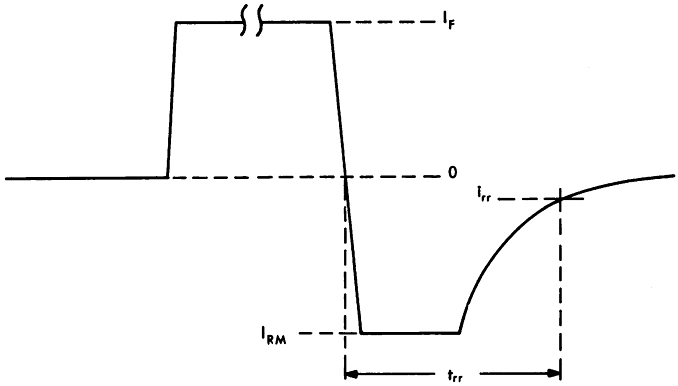
FIGURE 2 — FORWARD RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $Z_{out} = 50\ \Omega$, PW = 150 ns, duty cycle $\leq 2\%$.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 4.5$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT CURRENT WAVEFORM

FIGURE 3 — REVERSE RECOVERY TIME

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $t_f \leq 1$ ns, $Z_{out} = 50\ \Omega$, $t_p = 200$ ns, duty cycle $\leq 1\%$.

d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.4$ ns, $R_{in} = 50\ \Omega$.

TYPES TID25, TID26
BULLETIN NO. DL-S 669403, OCTOBER 1966
REPLACES BULLETIN NO. DL-S 657540, MAY 1965

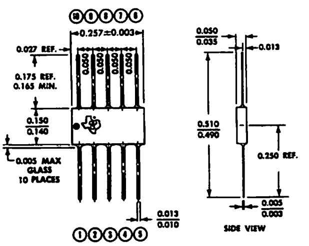
16-DIODE CORE DRIVERS

For Application With
Magnetic Cores • Memory Drums • Memory Tapes
Diode-Capacitor Storage • Magnetic Discs

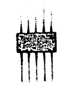
mechanical data

The diode arrays are mounted in a glass-to-metal hermetically sealed, welded package which falls within the JEDEC TO-89 outline. Leads are goldplated F-15† glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic.

ALL LEADS INSULATED FROM CASE

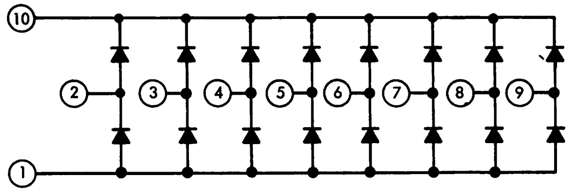


NOTES: a. All dimensions in inches.
b. All decimals ±0.005 except as noted.
c. Lead-spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.
d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.
e. Symbolization denotes orientation of package.



†F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 29% nickel, 17% cobalt, and 53% iron.

schematic diagrams



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH DIODE		TOTAL DEVICE	UNIT
	TID25	TID26	ALL TYPES	
Peak Reverse Voltage (See Note 1)	60	40		V
Steady State Reverse Voltage, V_R	30	15		V
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1, 2, and 3)	500		500	mA
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Notes 2 and 4)	100		200	mA
Storage Temperature Range	–65 to 200			°C
Lead Temperature 1/16 Inch From Case for 10 Seconds	300			°C

NOTES: 1. These values apply for 100-μs pulses, duty cycle ≤ 20%.
2. The values shown for total device apply for any combination provided the ratings of individual diodes are not exceeded.
3. Derate linearly to 150°C free-air temperature at the rate of 4 mA/deg.
4. Derate linearly to 150°C free-air temperature at the rate of 0.8 mA/deg for each diode and 1.6 mA/deg for the total device.

electrical characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS		TID25		TID26		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 10\ \mu A$		60		40		V
I_R	Static Reverse Current	$V_R = 30$ V,	See Note 6		0.1			μA
		$V_R = 15$ V,	See Note 6				0.1	μA
V_F	Static Forward Voltage	$I_F = 100$ mA			1		1.1	V
v_F	Instantaneous Forward Voltage	$I_F = 500$ mA,	See Note 7		1.3		1.5	V
V_{FM}	Peak Forward Voltage	$I_F = 500$ mA,	See Note 8		5		5	V
C_T	Total Capacitance †	$V_R = 0$,	f = 1 MHz		8		8	pF

multiple-diode operatior (see note 9)

PARAMETER		TEST CONDITIONS	TID25		TID26		UNIT
			MIN	MAX	MIN	MAX	
I_{R1}	Static Reverse Current	V_{R1} = rated V_R, $I_{FN} = 25$ mA		10		10	μA
V_{F1}	Static Forward Voltage	$I_{F1} = I_{FN} = 25$ mA		1		1	V

switching characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS	ALL TYPES	UNIT
			MAX	
t_{fr}	Forward Recovery Time	$I_F = 500$ mA, See Figure 3	40	ns
t_{rr}	Reverse Recovery Time	$I_F = 200$ mA, $I_{RM} = 200$ mA, $R_L = 100\ \Omega$, $i_{rr} = 20$ mA, See Figure 4	20	ns

NOTES: 5. Test conditions and limits apply separately to each of the diodes. The diodes not under test are open-circuited during the measurement of these characteristics, except for I_R as shown in figures 1 and 2.

6. See figures 1 and 2, Parameter Measurement Information section.

7. This parameter is measured using pulse techniques. $t_p = 100\ \mu s$, duty cycle = 2%. Read time is 90 μs from leading edge of the pulse.

8. The initial instantaneous value is measured using pulse techniques. $t_p = 150\ \mu s$, duty cycle $\leq$ 2%, pulse rise time $\leq$ 10 ns. The total diode shunt capacitance is 19 pF max and the equipment bandwidth is 80 MHz.

9. Test conditions apply separately to the common-anode and common-cathode sections. Subscript numerial 1 refers to the diode under test; subscript N refers simultaneously to each of the other diodes in the section. Each diode is individually tested after the device reaches operating thermal equilibrium.

†C_T is the total pin-to-pin capacitance measured across any of the diodes. The interaction of the other diodes cannot easily be separated out unless three-terminal guarded measurement techniques are used. The actual capacitance of a single, isolated diode will typically be 30% of the measured pin-to-pin value for the common-cathode diodes, and 75% of the measured value for the common-anode diodes.

PARAMETER MEASUREMENT INFORMATION

When measuring the reverse current of an individual diode the current meter must be placed so that the shunt current through the other diodes is bypassed around the meter. To obtain accurate readings, the voltage drop across the current meter must be less than 10 mV.

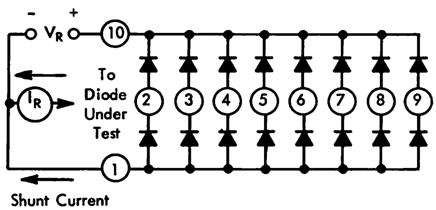


FIGURE 1 - TEST CIRCUIT FOR COMMON-CATHODE DIODE

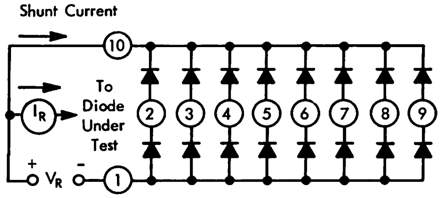
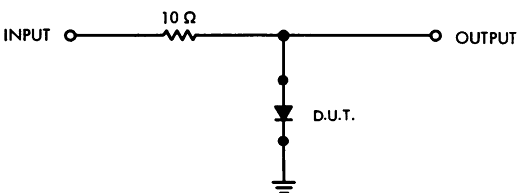
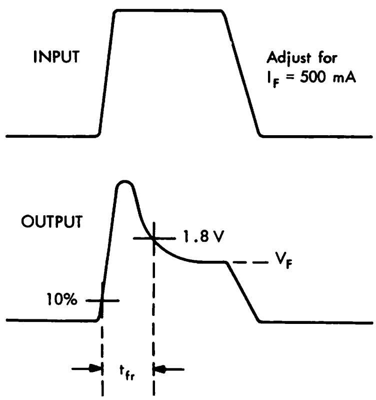


FIGURE 2 - TEST CIRCUIT FOR COMMON-ANODE DIODE



TEST CIRCUIT



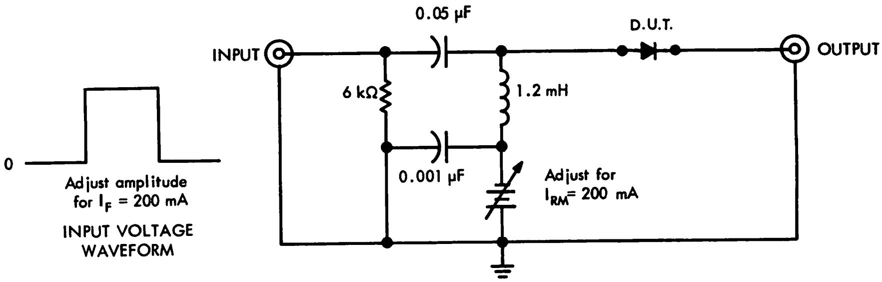
VOLTAGE WAVEFORMS

FIGURE 3 — FORWARD RECOVERY TIME

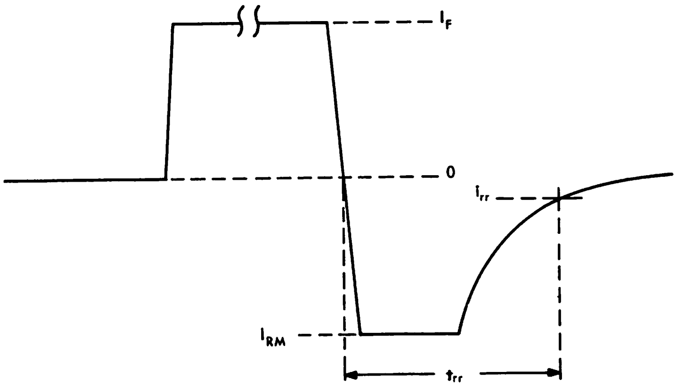
NOTES: a. The input pulse is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 150$ ns, duty cycle $\leq 2\%$.

b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 4.5$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT CURRENT WAVEFORM

FIGURE 4 — REVERSE RECOVERY TIME

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $t_f \leq 1$ ns, $Z_{out} = 50\ \Omega$, $t_p = 200$ ns, duty cycle $\leq 1\%$.
d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.4$ ns, $R_{in} = 50\ \Omega$.

EPITAXIAL PLANAR SILICON DUAL 10-DIODE ARRAYS

TYPES TID29, TID30
BULLETIN NO. DL-S 669404, OCTOBER 1966
REPLACES BULLETIN NO. DL-S 658007, AUGUST 1965

20-DIODE CORE DRIVERS

For Application With

Magnetic Cores • Memory Drums • Memory Tapes

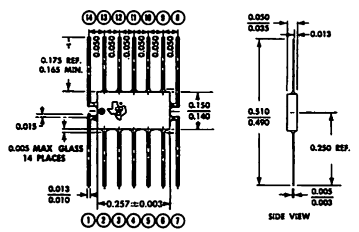
Diode-Capacitor Storage • Magnetic Discs

Convenient Input/Output Lead Arrangement

mechanical data

The diode arrays are mounted in a glass-to-metal hermetically sealed, welded package which falls within the JEDEC TO-84 outline. Leads are goldplated F-15† glass-sealing alloy. Approximate weight is 0.1 gram. All external surfaces are metallic.

ALL LEADS INSULATED FROM CASE



NOTES: a. All dimensions in inches.

b. All decimals ±0.005 except as noted.

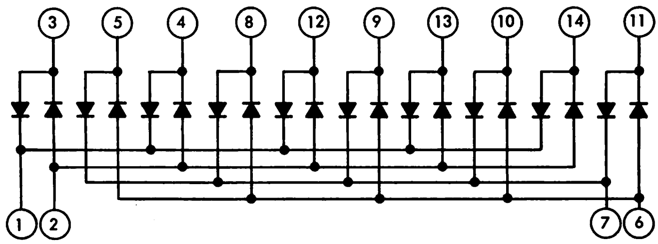
c. Lead-spacing tolerance is ±0.015 at extremities and ±0.005 at package, nonaccumulative.

d. Lead centerlines are located within ±0.005 of their true positions relative to body centerlines.

e. Symbolization denotes orientation of package.

†F-15 is the ASTM designation for an iron-nickel-cobalt alloy containing nominally 29% nickel, 17% cobalt, and 53% iron.

schematic diagrams



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	EACH DIODE		TOTAL DEVICE	UNIT
	TID29	TID30	ALL TYPES	
Peak Reverse Voltage (See Note 1)	60	40		V
Steady State Reverse Voltage, V_R	30	15		V
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1, 2, and 3)	500		500	mA
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Notes 2 and 4)	100		200	mA
Storage Temperature Range	–65 to 200			°C
Lead Temperature 1/16 Inch From Case for 10 Seconds	300			°C

NOTES: 1. These values apply for 100-μs pulses, duty cycle ≤ 20%.

2. The values shown for total device apply for any combination provided the ratings of individual diodes are not exceeded.

3. Derate linearly to 150°C free-air temperature at the rate of 4 mA/deg.

4. Derate linearly to 150°C free-air temperature at the rate of 0.8 mA/deg for each diode and 1.6 mA/deg for the total device.

TYPES TID29, TID30
EPITAXIAL PLANAR SILICON DUAL 10-DIODE ARRAYS

electrical characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS		TID29		TID30		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)}$	Reverse Breakdown Voltage	$I_R = 10\ \mu A$		60		40		V
I_R	Static Reverse Current	$V_R = 30\ V$,	See Note 6		0.1			μA
		$V_R = 15\ V$,	See Note 6				0.1	μA
V_F	Static Forward Voltage	$I_F = 100\ mA$			1		1.1	V
v_F	Instantaneous Forward Voltage	$I_F = 500\ mA$,	See Note 7		1.3		1.5	V
V_{FM}	Peak Forward Voltage	$I_F = 500\ mA$,	See Note 8		5		5	V
C_T	Total Capacitance †	$V_R = 0$,	$f = 1\ MHz$		8		8	pF

multiple-diode operation (see note 9)

PARAMETER		TEST CONDITIONS	TID29		TID30		UNIT
			MIN	MAX	MIN	MAX	
I_{R1}	Static Reverse Current	$V_{R1} = \text{rated } V_R$, $I_{FN} = 25\ mA$		10		10	μA
V_{F1}	Static Forward Voltage	$I_{F1} = I_{FN} = 25\ mA$		1		1	V

switching characteristics at 25°C free-air temperature

single-diode operation (see note 5)

PARAMETER		TEST CONDITIONS	ALL TYPES MAX	UNIT
t_{fr}	Forward Recovery Time	$I_F = 500\ mA$, See Figure 3	40	ns
t_{rr}	Reverse Recovery Time	$I_F = 200\ mA$, $I_{RM} = 200\ mA$, $i_{rr} = 20\ mA$, $R_L = 100\ \Omega$, See Figure 4	20	ns

NOTES: 5. Test conditions and limits apply separately to each of the diodes. The diodes not under test are open-circuited during the measurement of these characteristics, except for I_R as shown in figures 1 and 2.

6. See figures 1 and 2, Parameter Measurement Information section.

7. This parameter is measured using pulse techniques. $t_p = 100\ \mu s$, duty cycle = 2%. Read time is 90 μs from leading edge of the pulse.

8. The initial instantaneous value is measured using pulse techniques. $t_p = 150\ \mu s$, duty cycle ≤ 2%, pulse rise time ≤ 10 ns. The total diode shunt capacitance is 19 pF max and the equipment bandwidth is 80 MHz.

9. Test conditions apply separately to the common-anode and common-cathode sections. Subscript numerial 1 refers to the diode under test; subscript N refers simultaneously to each of the other diodes in the section. Each diode is individually tested after the device reaches operating thermal equilibrium.

†C_T is the total pin-to-pin capacitance measured across any of the diodes. The interaction of the other diodes cannot easily be separated out unless three-terminal guarded measurement techniques are used. The actual capacitance of a single, isolated diode will typically be 30% of the measured pin-to-pin value for the common-cathode diodes, and 75% of the measured value for the common-anode diodes.

PARAMETER MEASUREMENT INFORMATION

When measuring the reverse current of an individual diode the current meter must be placed so that the shunt current through the other diodes is bypassed around the meter. To obtain accurate readings, the voltage drop across the current meter must be less than 10 mV.

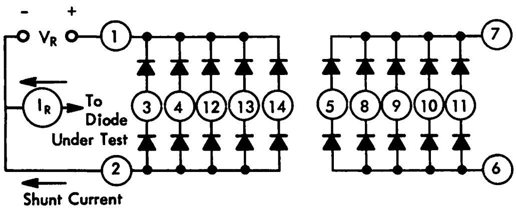


FIGURE 1 — TEST CIRCUIT FOR COMMON-CATHODE DIODES

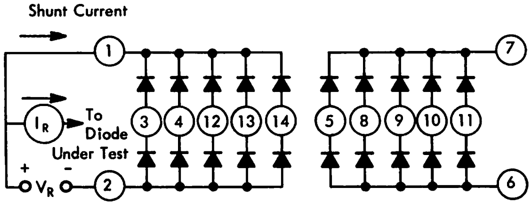
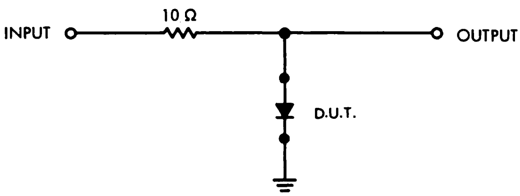
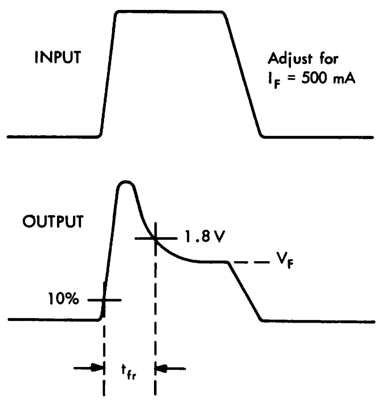


FIGURE 2 — TEST CIRCUIT FOR COMMON-ANODE DIODES



TEST CIRCUIT

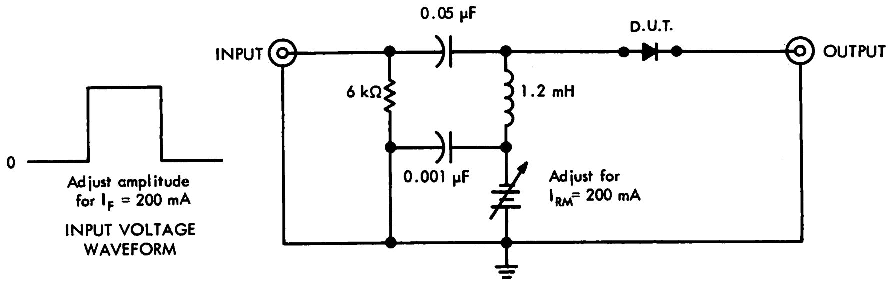


VOLTAGE WAVEFORMS

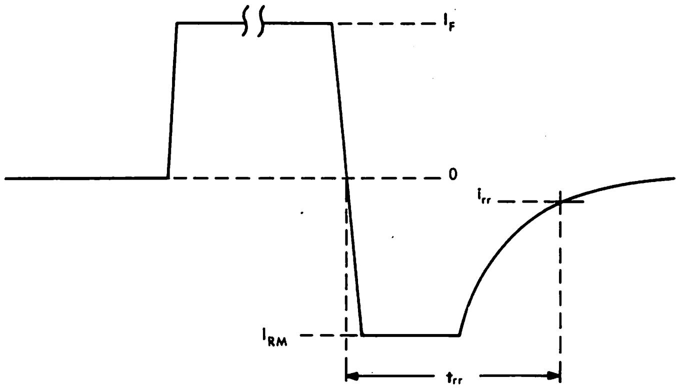
FIGURE 3 — FORWARD RECOVERY TIME

NOTES: a. The input pulse is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 150$ ns, duty cycle $\leq 2\%$.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 4.5$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT CURRENT WAVEFORM

FIGURE 4 — REVERSE RECOVERY TIME

NOTES: c. The input pulse is supplied by a generator with the following characteristics: $t_f \leq 1$ ns, $Z_{out} = 50\ \Omega$, $t_p = 200$ ns, duty cycle $\leq 1\%$.
d. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 0.4$ ns, $R_{in} = 50\ \Omega$.

PLANAR SILICON VOLTAGE-VARIABLE-CAPACITANCE DIODES

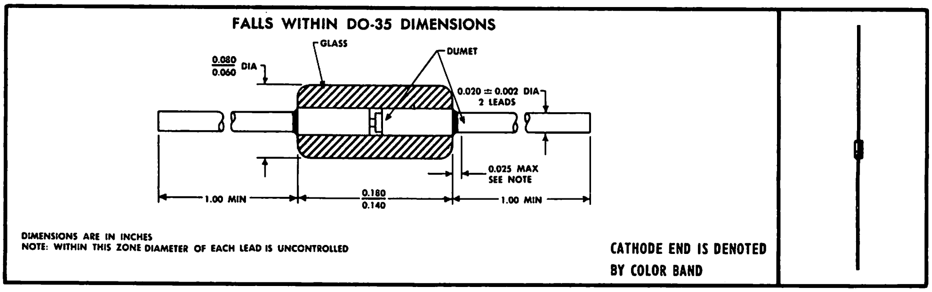
TYPES TIV306, TIV307, TIV308
BULLETIN NO. DL-S 6810196, MAY 1968
REPLACES BULLETIN NO. DL-S 6710196, JUNE 1967

FOR USE IN AUTOMATIC FREQUENCY CONTROL AND VOLTAGE-VARIABLE TUNING

- **Small Size, Whiskerless, Double-Plug Construction**
- **High Q, High Capacitance Ratio**
- **Replaces TIV300 and TIV301**

mechanical data

The glass-passivated silicon wafer is encased in a hermetically sealed glass package. High-temperature bond between wafer and leads ensures integral positive contact under extreme environmental conditions.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Peak Reverse Voltage . . . . 20 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1) . . . . 250 mW
Operating Free-Air Temperature Range . . . . −65°C to 150°C
Storage Temperature Range . . . . −65°C to 200°C

electrical characteristics at 25°C free-air temperature

	PARAMETER	TEST CONDITIONS	TIV306 MIN	TIV306 MAX	TIV307 MIN	TIV307 MAX	TIV308 MIN	TIV308 MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	$I_R = 100\ \mu A$	20		20		20		V
I_R	Reverse Current	$V_R = 15$ V		50		50		50	nA
C_T	Total Capacitance	$V_R = 4$ V, $f = 1$ MHz	5	9	7	11	9	14	pF
Q	Figure of Merit (Note 2)	$V_R = 4$ V, $f = 50$ MHz	200		200		200		
$\frac{C_{V1}}{C_{V2}}$	Capacitance Ratio	$V_1 = 1$ V, $V_2 = 5$ V, $f = 1$ MHz	1.5		1.5		1.5		

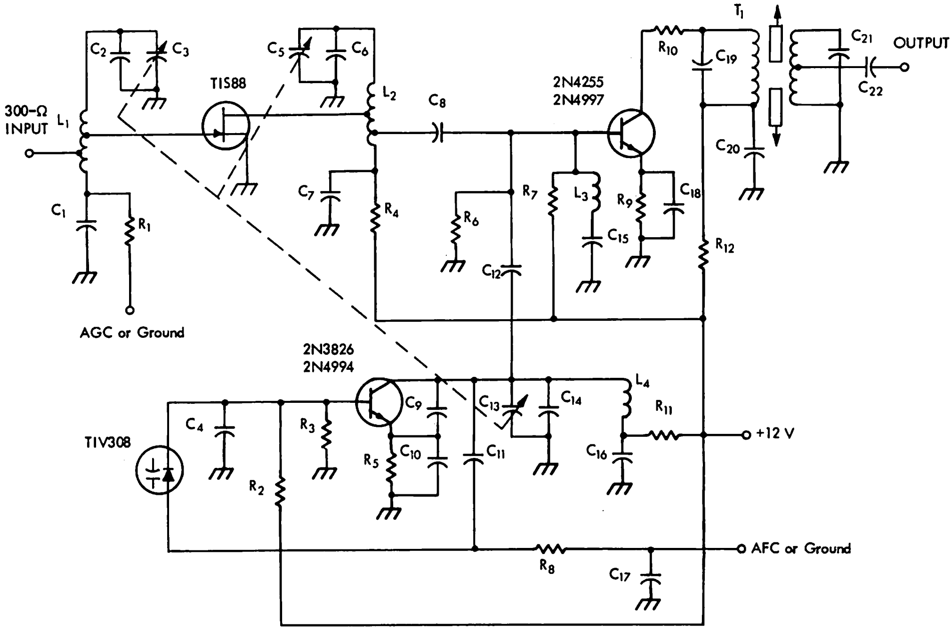
NOTES: 1. Derate linearly to 150°C free-air temperature at the rate of 2 mW/deg.

2. Figure of Merit, Q, is defined by the equation $Q = \frac{1}{2\pi f C_T r_s}$ where r_s is Equivalent Series Resistance, as measured on a Boonton RF Admittance Bridge, Model 33A or equivalent.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIV306, TIV307, TIV308
PLANAR SILICON VOLTAGE-VARIABLE-CAPACITANCE DIODES

TYPICAL APPLICATION DATA



TYPICAL TUNER PERFORMANCE AT $f_0 = 98$ MHz	
Image Rejection (119.4 MHz) $f_0 + \frac{1}{2}$ IF Rejection (103.35 MHz)	47 dB 73 dB
Sensitivity for 30-dB $\frac{S+N}{N}$ (±75-kHz deviation)	2.3 μV
Sensitivity for 30-dB $\frac{S+N}{N}$ (±22.5-kHz deviation)	3.4 μV
Voltage Gain from Input to Primary of IF Transformer	37 dB

CIRCUIT COMPONENT INFORMATION

CAPACITORS

C_1: 0.001 μF
C_2: 10 pF
C_3: †
C_4: 0.001 μF
C_5: †
C_6: 10 pF
C_7: 0.001 μF
C_8: 12 pF
C_9: 4.7 pF
C_{10}: 6.8 pF
C_{11}: 4.7 pF
C_{12}: 1.2 pF
C_{13}: †
C_{14}: 10 pF
C_{15}: 240 pF
C_{16}: 0.001 μF
C_{17}: 0.1 μF
C_{18}: 0.01 μF
C_{19}: 47 pF
C_{20}: 0.01 μF
C_{21}: 100 pF
C_{22}: 0.01 μF

†Three-gang, 6–21 pF each, with trimmers.

RESISTORS

R_1: 27 kΩ
R_2: 10 kΩ
R_3: 2.7 kΩ
R_4: 330 Ω
R_5: 1 kΩ
R_6: 2.7 kΩ
R_7: 10 kΩ
R_8: 330 kΩ
R_9: 820 Ω
R_{10}: 120 Ω
R_{11}: 330 Ω
R_{12}: 330 Ω

All resistors ½ W, ten percent tolerance

TRANSFORMER

T_1: 10.7 MHz IF transformer

COILS

L_1: 2.5 T, #16 bus, ¼″ ID, carbonyl "E" core, tapped at 1 T and 2 T from bottom
L_2: 4 T, #16 bus, ¼″ ID, air core, tapped at 1.3 T and 1 T from bottom
L_3: 1 μH
L_4: 3 T, #16 bus, ¼″ ID, carbonyl "E" core

FIGURE 19 — TYPICAL FM TUNER

TYPES 1N746 THRU 1N759, 1N746A THRU 1N759A SILICON VOLTAGE REGULATOR DIODES

TYPES 1N746 THRU 1N759, 1N746A THRU 1N759A
BULLETIN NO. DL-S 681008, MARCH 1959
REVISED MAY 1968

3.3 TO 12 VOLTS • 400 mw

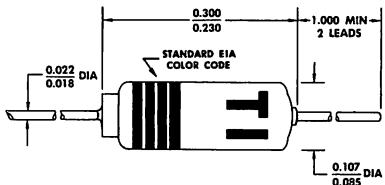
GUARANTEED DYNAMIC ZENER IMPEDANCE

Available in 5% and 10% tolerances

-65 to 175°C operation & storage

mechanical data

The diode is encased in a hermetically sealed hard-glass package which falls within the JEDEC DO-7 outline. Unit weight is typically 0.195 gram.



ALL DIMENSIONS IN INCHES

REGISTERED BODY DIMENSIONS *

	MAX
LENGTH	0.300
DIAMETER	0.125

CATHODE END IS DENOTED BY COLOR BANDS

*absolute maximum ratings

Average Rectified Forward Current at (or below) 25°C Free-Air Temperature	230 ma
Average Rectified Forward Current at 150°C Free-Air Temperature	85 ma
Continuous Power Dissipation at (or below) 50°C Free-Air Temperature	400 mw
Continuous Power Dissipation at 150°C Free-Air Temperature	100 mw
Operating Free-Air Temperature Range	–65°C to 175°C
Storage Temperature Range	–65°C to 175°C

*Indicates JEDEC registered data

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

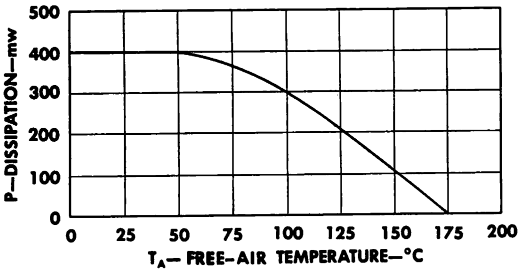
TYPES 1N746 THRU 1N759, 1N746A THRU 1N759A
SILICON VOLTAGE REGULATOR DIODES

***electrical characteristics at 25°C free-air temperature (unless otherwise noted)**

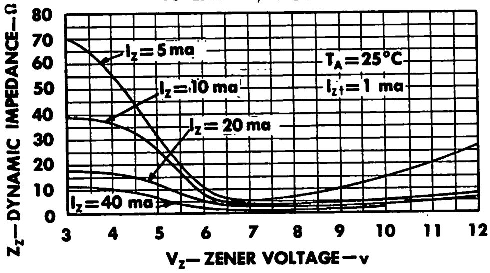
PARAMETER	V_Z Zener Breakdown Voltage					α_Z Temperature Coefficient of Breakdown Voltage	Z_Z Small-Signal Breakdown Impedance	I_R Static Reverse Current	
TEST CONDITIONS	I_{ZT} = 20 ma					I_{ZT} = 20 ma	I_{ZT} = 20 ma, I_{zt} = 1 ma	V_R = 1 v	V_R = 1 v, T_A = 150°C
LIMIT →	NOM	1N746-1N759 MIN	1N746-1N759 MAX	1N746A-1N759A MIN	1N746A-1N759A MAX	TYP	MAX	MAX	MAX
UNIT →	v	v	v	v	v	%/°C	Ω	μa	μa
1N746	3.3	2.97	3.63	3.135	3.465	−0.062	28	10	30
1N747	3.6	3.24	3.96	3.420	3.780	−0.055	24	10	30
1N748	3.9	3.51	4.29	3.705	4.095	−0.049	23	10	30
1N749	4.3	3.87	4.73	4.085	4.515	−0.036	22	2	30
1N750	4.7	4.23	5.17	4.465	4.935	−0.018	19	2	30
1N751	5.1	4.59	5.61	4.845	5.355	−0.008	17	1	20
1N752	5.6	5.04	6.16	5.320	5.880	+0.006	11	1	20
1N753	6.2	5.58	6.82	5.890	6.510	+0.022	7	0.1	20
1N754	6.8	6.12	7.48	6.460	7.140	+0.035	5	0.1	20
1N755	7.5	6.75	8.25	7.125	7.875	+0.045	6	0.1	20
1N756	8.2	7.38	9.02	7.790	8.610	+0.052	8	0.1	20
1N757	9.1	8.19	10.01	8.645	9.555	+0.056	10	0.1	20
1N758	10.0	9.00	11.00	9.500	10.500	+0.060	17	0.1	20
1N759	12.0	10.80	13.20	11.400	12.000	+0.060	30	0.1	20

*Indicates JEDEC registered data

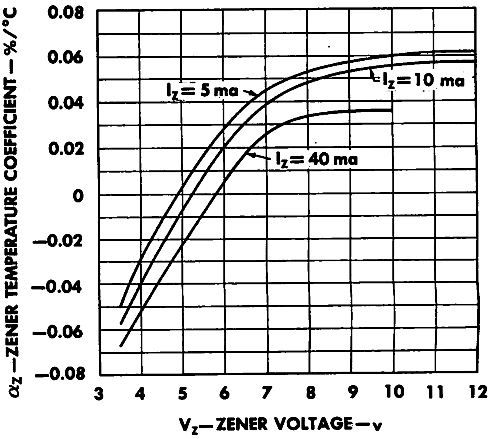
MAXIMUM POWER DISSIPATION



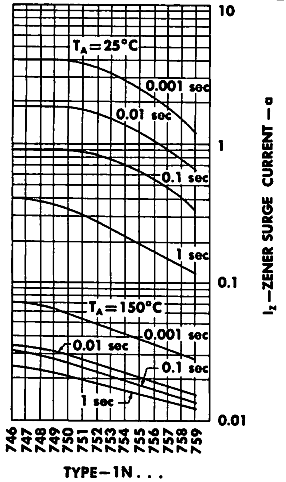
TYPICAL DYNAMIC IMPEDANCE vs ZENER VOLTAGE



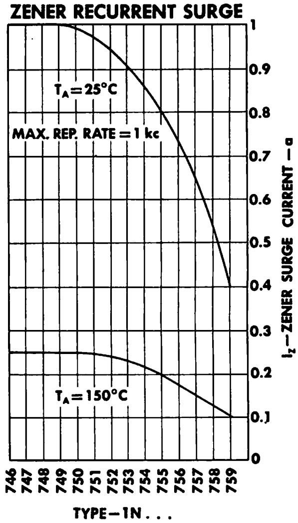
TYPICAL ZENER TEMPERATURE COEFFICIENT vs ZENER VOLTAGE



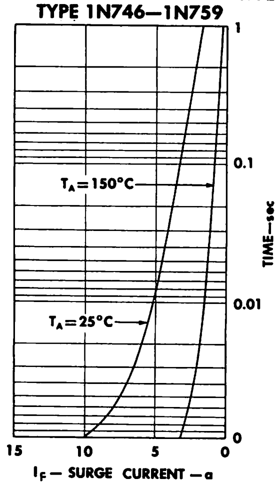
ZENER SURGE CURRENT
SINGLE SURGE—NONREPETITIVE



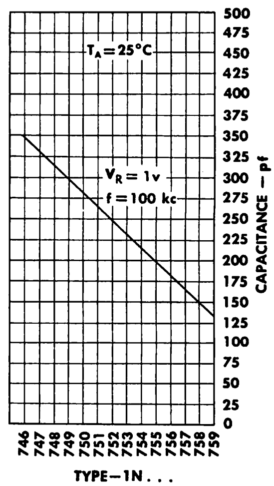
ZENER RECURRENT SURGE



FORWARD SURGE CURRENT
SINGLE SURGE—NONREPETITIVE
TYPE 1N746—1N759

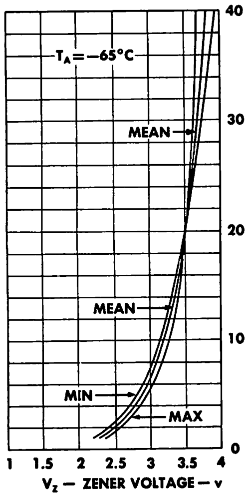


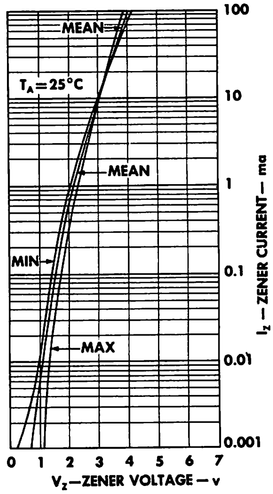
TYPICAL CAPACITANCE

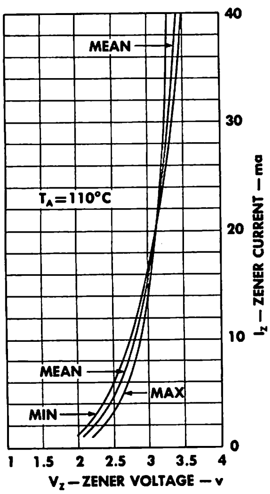


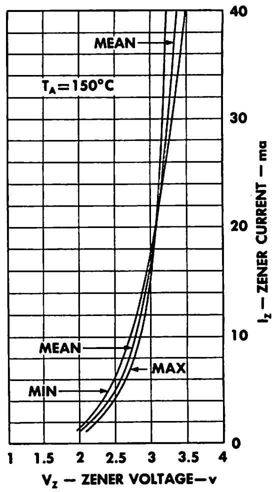
TYPICAL CHARACTERISTICS

V_Z vs I_Z TYPE 1N746







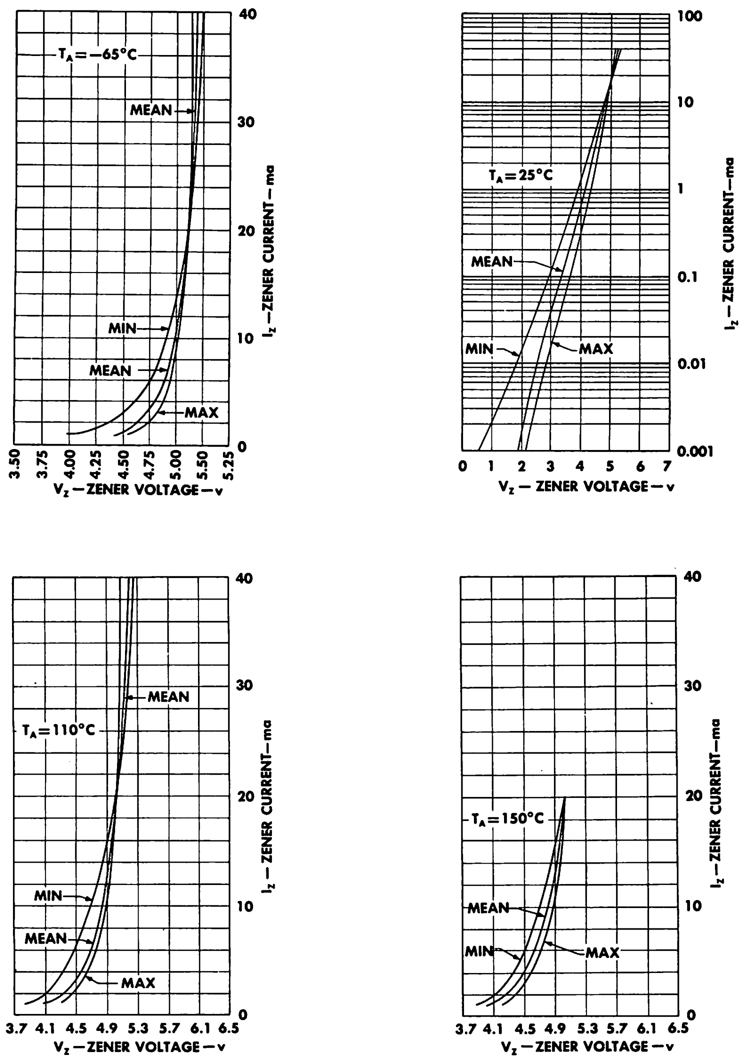


An individual diode will have voltage characteristics which vary with reverse current as shown on all curves.

When a diode has a zener voltage at 20 ma different from the value shown, translate the curves to this new value or shift the voltage axis to correspond to the translation. The max-min curves will now give the individual diode zener voltage spread at different current levels.

TYPICAL CHARACTERISTICS

V_Z vs I_Z TYPE 1N751

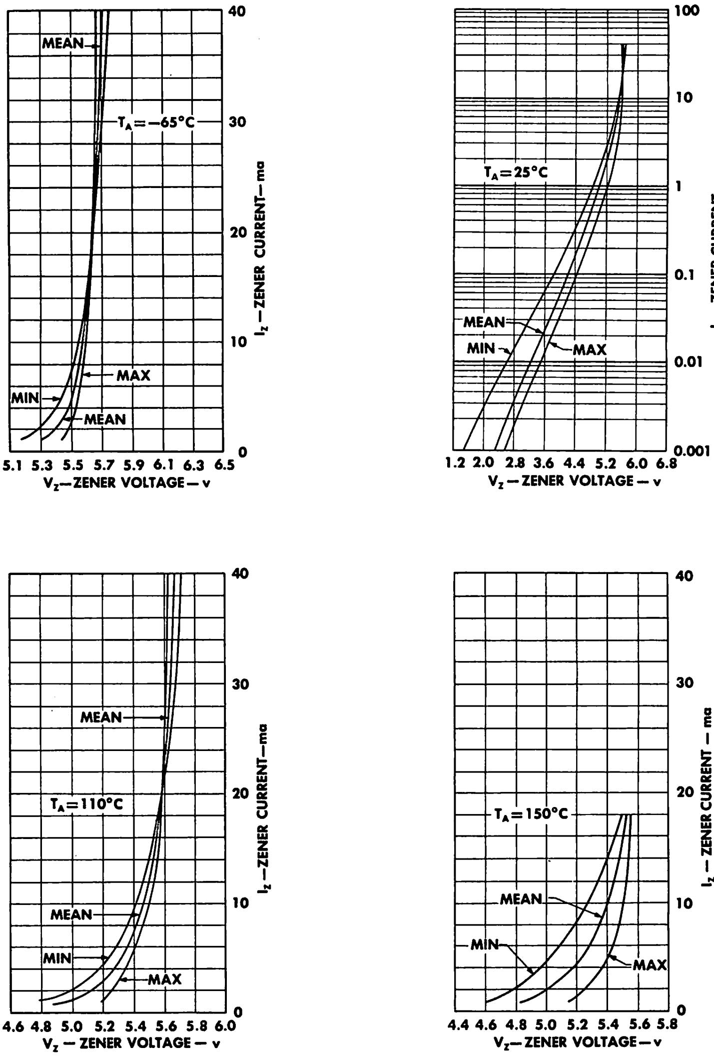


An individual diode will have voltage characteristics which vary with reverse current as shown on all curves.

When a diode has a zener voltage at 20 ma different from the value shown, translate the curves to this new value or shift the voltage axis to correspond to the translation. The max-min curves will now give the individual diode zener voltage spread at different current levels.

TYPICAL CHARACTERISTICS

V_Z vs I_Z TYPE 1N752

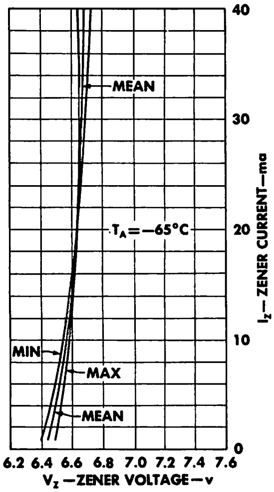


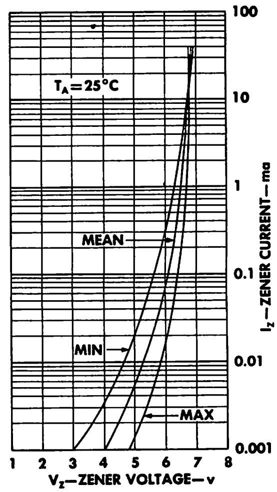
An individual diode will have voltage characteristics which vary with reverse current as shown on all curves.

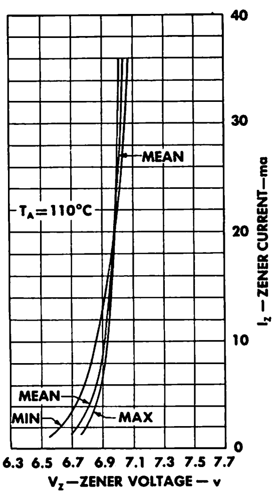
When a diode has a zener voltage at 20 ma different from the value shown, translate the curves to this new value or shift the voltage axis to correspond to the translation. The max-min curves will now give the individual diode zener voltage spread at different current levels.

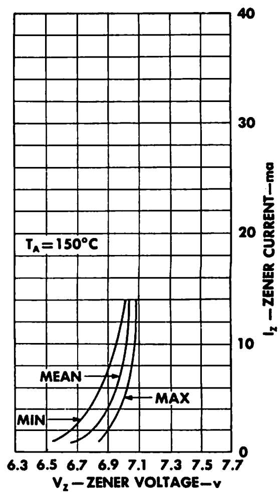
TYPICAL CHARACTERISTICS

V_Z vs I_Z TYPE 1N754







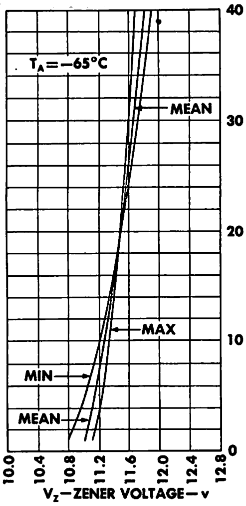


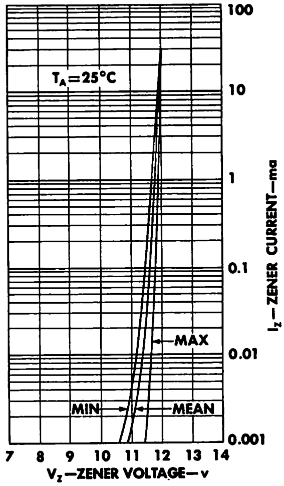
An individual diode will have voltage characteristics which vary with reverse current as shown on all curves.

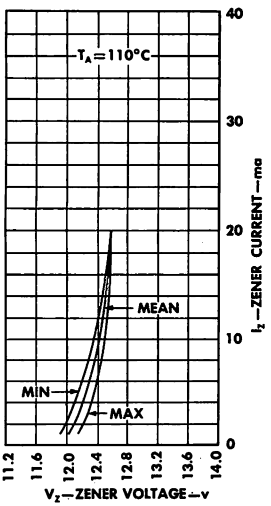
When a diode has a zener voltage at 20 ma different from the value shown, translate the curves to this new value or shift the voltage axis to correspond to the translation. The max-min curves will now give the individual diode zener voltage spread at different current levels.

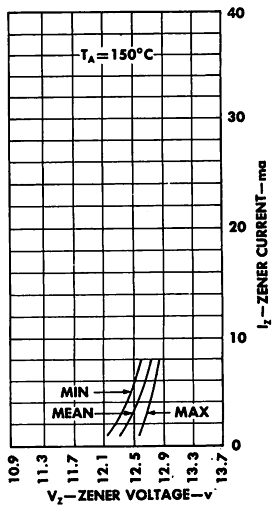
TYPICAL CHARACTERISTICS

V_Z vs I_Z TYPE 1N759









An individual diode will have voltage characteristics which vary with reverse current as shown on all curves.

When a diode has a zener voltage at 20 ma different from the value shown, translate the curves to this new value or shift the voltage axis to correspond to the translation. The max-min curves will now give the individual diode zener voltage spread at different current levels.

TYPES 1N4370 THRU 1N4372, 1N4370A THRU 1N4372A
ALLOY-JUNCTION SILICON VOLTAGE REGULATOR DIODES

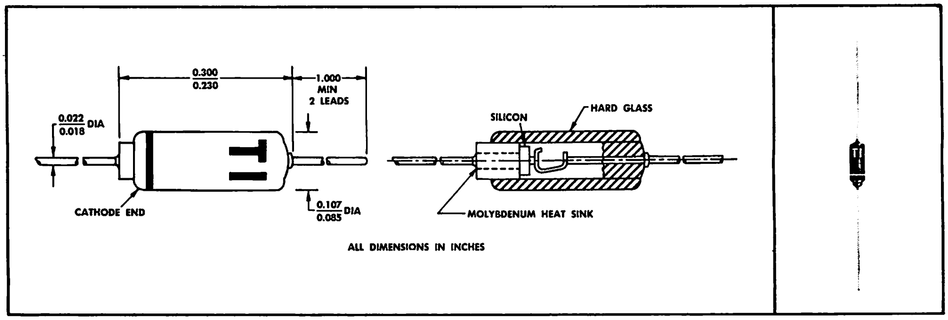
TYPES 1N4370 THRU 1N4372, 1N4370A THRU 1N4372A
BULLETIN NO. DL-S 668111, JANUARY 1966

400 mW — 2.4 V to 3 V

1N4370A Thru 1N4372A Can Be Supplied in Accordance with MIL-S-19500/127
Low Noise Density: 20 $\mu V/\sqrt{Hz}$ Typical
Very Low Dynamic Zener Impedance

mechanical data

The diode is encased in a hermetically sealed hard-glass package. The outline drawing meets JEDEC DO-7 outline*. Unit weight is 0.195 gram.



*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

TYPE	I_{ZM} Steady-State Reverse Current (See Note 1)	P Dissipation $T_A \leq 50°C$ (See Note 2)	T_{stg} Storage Temperature Range	Lead Temperature (See Note 3)
1N4370	150 mA	400 mW	−55°C to 175°C	230°C
1N4370A				
1N4371	135 mA			
1N4371A				
1N4372	120 mA			
1N4372A				

NOTES: 1. The nominal I_{ZM} currents shown are applicable to devices having regulator voltages 10% above the nominal V_Z values. These values do not represent absolute limits. The actual steady-state current-voltage product must not exceed 400 mW.

2. Derate linearly to 175°C free-air temperature at the rate of 3.2 mW/deg.

3. This value applies 1/16 inch from the case for 10 seconds.

*Indicates JEDEC registered data.

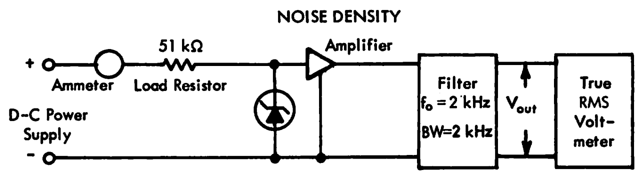
TYPES 1N4370 THRU 1N4372, 1N4370A THRU 1N4372A
ALLOY-JUNCTION SILICON VOLTAGE REGULATOR DIODES

***electrical characteristics at 25°C free-air temperature**

PARAMETER	V_Z Zener Breakdown Voltage			Z_Z Small-Signal Breakdown Impedance	I_R Static Reverse Current	V_F Static Forward Voltage
TEST CONDITIONS	$I_{ZT} = 20$ mA (See Note 4)			$I_{ZT} = 20$ mA, $I_{zt} = 2$ mA, $f = 60$ Hz	$V_R = 1$ V	$I_F = 200$ mA
LIMIT	MIN	NOM†	MAX	MAX	MAX	MAX
UNIT		V		Ω	μA	V
1N4370	2.16	2.4	2.64	30	100	1.5
1N4370A	2.28	2.4	2.52	30	100	1.5
1N4371	2.43	2.7	2.97	30	75	1.5
1N4371A	2.57	2.7	2.84	30	75	1.5
1N4372	2.70	3	3.30	29	50	1.5
1N4372A	2.85	3	3.15	29	50	1.5

NOTE 4: This parameter is measured after the device reaches operating thermal equilibrium.
*Indicates JEDEC registered data.
†Tolerance is ±10% for the 1N4370 thru 1N4372 series; ±5% for the 1N4370A thru 1N4372A series.

PARAMETER MEASUREMENT INFORMATION



$$\text{ND in } \mu V/\sqrt{Hz} = \frac{V_{out}}{\text{Overall Gain}\sqrt{BW}}$$

FIGURE 1 — NOISE DENSITY TEST CIRCUIT

STANDARD MOUNTING HARDWARE FOR SILICON THYRISTORS

STANDARD MOUNTING HARDWARE FOR SILICON THYRISTORS
BULLETIN NO. DL-S 688866, MAY 1968

This data sheet identifies those standard hardware kits which are supplied with each device. At additional cost, nonstandard hardware items will be supplied.

The mounting hardware assembly drawings of Section A (Figures 1 and 2) specify the individual hardware items that are included in each mounting hardware kit. Section A also references the package outlines for which each kit is designed and shows the typical thermal resistance associated with the mounting hardware.

Section B contains mechanical drawings of the individual hardware items that are referenced in Figures 1 and 2.

TABLE A
SILICON THYRISTORS

DEVICE TYPES	KIT
TIC20-TIC21	*
TIC22-TIC23	10
TI40A0-TI40A4	9
TIC44-TIC47	*
TI145A0-TI145A4	*
2N681,A-2N689,A	10
2N876-2N881	*
2N884-2N889	*
2N1595-2N1599	*
2N1600-2N1604	9
2N1770,A-2N1777,A	9
2N1778	9
2N1842B-2N1850B	10
2N2322-2N2326	*
2N2653	9
2N2687-2N2690	*
2N3001-2N3004	*
2N3005-2N3008	*
TI3037-TI3042	10
2N3555-2N3558	*
2N3559-2N3562	*
2N3936-2N3940	9
2N5273-2N5275	10

*No hardware furnished with these devices.

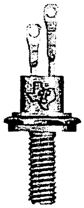
Texas Instruments reserves the right to substitute similar parts at any time in order to expedite delivery or improve design.

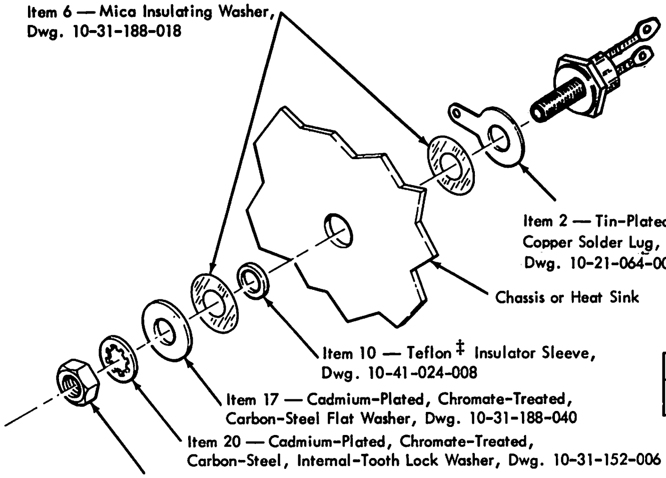
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

STANDARD MOUNTING HARDWARE FOR SILICON THYRISTORS

SECTION A — MOUNTING HARDWARE ASSEMBLY DRAWINGS AND PHOTOGRAPHS

MOUNTING KIT 9 for TO-64 PACKAGE OUTLINE

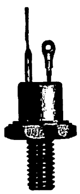


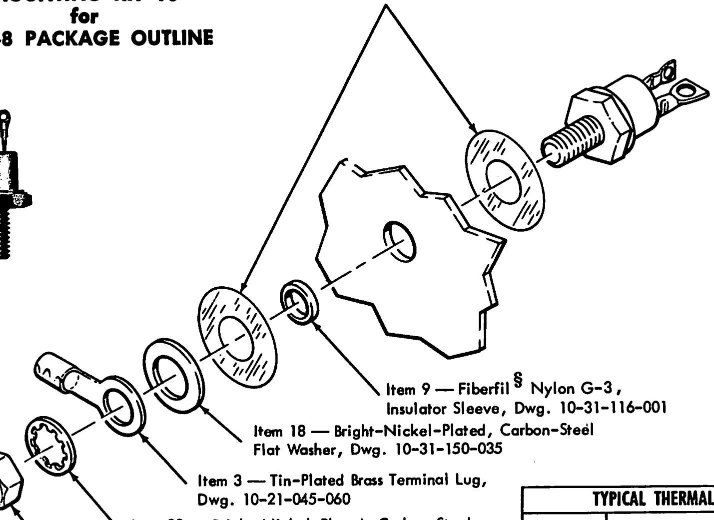


TYPICAL THERMAL RESISTANCE†		
$\theta_{C\text{-}HS}$	4	deg/W

FIGURE 1

MOUNTING KIT 10 for TO-48 PACKAGE OUTLINE





TYPICAL THERMAL RESISTANCE†		
$\theta_{C\text{-}HS}$	1.2	deg/W

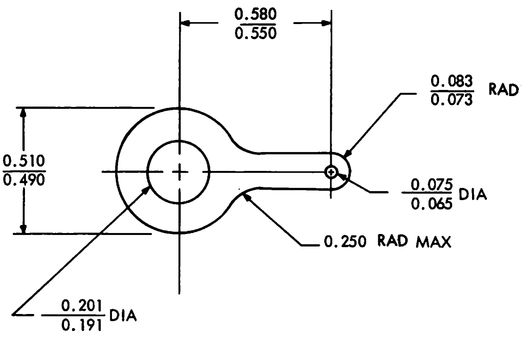
FIGURE 2

†$\theta_{C\text{-}HS}$ is the thermal resistance from the mounting base of the semiconductor-device case to the mounting surface of the heat sink. The heat sink used to determine this value was a smooth, flat, copper plate, with the thermocouple mounted 0.05 inch below the mounting surface in an area beneath the device. The device was mounted directly to a clean, dry, heat-sink surface, without the use of a thermal compound and a torque of ten inch-pounds was applied to the stud or each of the mounting screws.

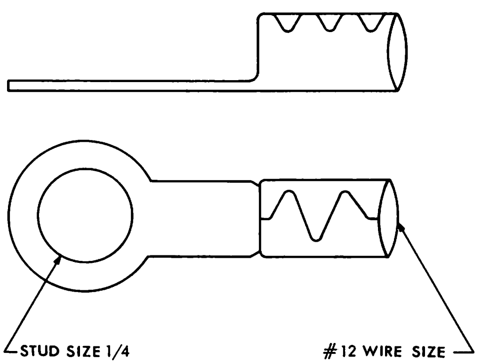
‡Trademark of E.I. du Pont

§Trademark of Cedar Plastics

SECTION B — MECHANICAL DRAWINGS OF HARDWARE ITEMS

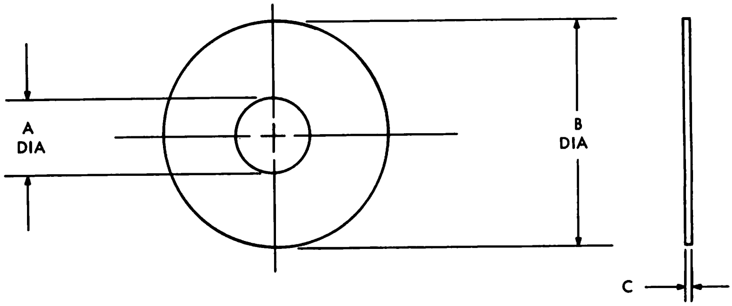


SOLDER LUG
Item 2



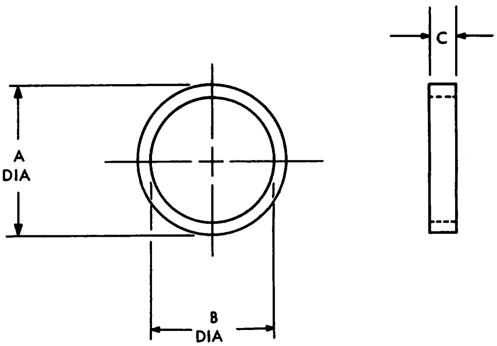
TERMINAL LUG
Item 3

SECTION B — MECHANICAL DRAWINGS OF HARDWARE ITEMS



Item	A	B	C
6	0.205 / 0.195	0.536 / 0.526	0.005 / 0.001
7	0.270 / 0.260	0.885 / 0.865	0.0025 / 0.0015

INSULATING WASHER
Items 6 and 7

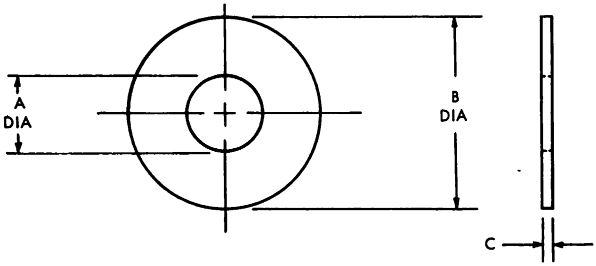


Item	A	B	C
9	0.340 / 0.330	0.270 / 0.260	0.072 / 0.052
10	0.271 / 0.251	0.203 / 0.191	0.050 / 0.035

INSULATING SLEEVE
Items 9 and 10

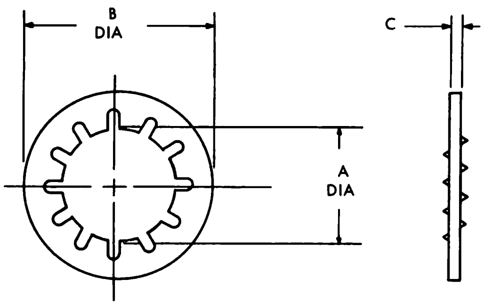
STANDARD MOUNTING HARDWARE FOR SILICON THYRISTORS

SECTION B — MECHANICAL DRAWINGS OF HARDWARE ITEMS



Item	A	B	C
17	0.208 / 0.198	0.505 / 0.495	0.051 / 0.041
18	0.276 / 0.255	0.635 / 0.615	0.069 / 0.034

FLAT WASHER
Items 17 and 18

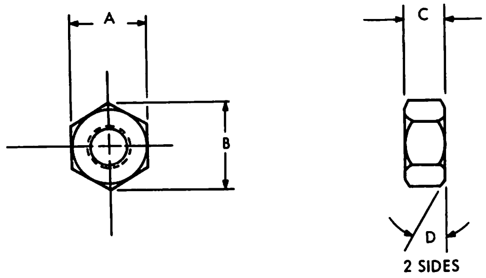


Item	A	B	C
20	0.204 / 0.195	0.381 / 0.365	0.025 / 0.020
22	0.267 / 0.256	0.478 / 0.466	0.027 / 0.023

INTERNAL-TOOTH LOCK WASHER
Items 20 and 22

STANDARD MOUNTING HARDWARE FOR SILICON THYRISTORS

SECTION B — MECHANICAL DRAWINGS OF HARDWARE ITEMS



Item	Thread	A	B	C	D
25	10-32 UNF-2B	0.375 / 0.362	0.433 / 0.413	0.130 / 0.117	30°
27	¼-28 UNF-2B	0.438 / 0.423	0.506 / 0.488	0.193 / 0.178	30°

HEXAGONAL NUT
Items 25 and 27

TYPES TIC20, TIC21, TIC22, TIC23
BULLETIN NO. DL-S 657400, MARCH 1965

GATED SYMMETRICAL SWITCHES

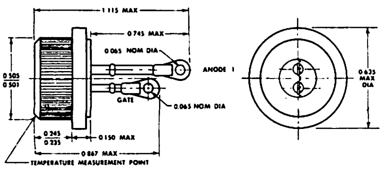
200 and 300 VOLTS — 6 AMPS

description

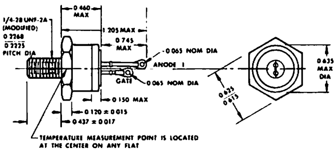
The TIC20 through TIC23 are bidirectional triode semiconductor switches which may be triggered from the blocking state to the conducting state by either polarity of gate signal with either polarity of anode-2 voltage.

mechanical data

ANODE 2 IS IN ELECTRICAL CONTACT WITH THE CASE

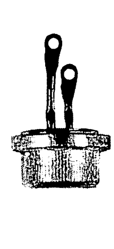


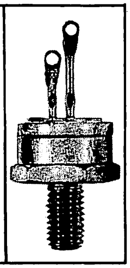
OUTLINE — TIC20, TIC21



OUTLINE — TIC22, TIC23

ALL DIMENSIONS ARE IN INCHES





absolute maximum ratings over operating case temperature range (unless otherwise noted)

	TIC20 TIC22	TIC21 TIC23	UNIT
Peak Blocking Voltage (See Note 1)	200	300	v
Full-Cycle RMS Anode Current at (or below) 75°C Case Temperature (See Note 2)	6		a
Peak Anode Surge Current (See Note 3)	50		a
Average Gate Power Dissipation	0.5		w
Peak Gate Power Dissipation for 5 msec	5		w
Operating Case Temperature Range	–25 to +100		°C
Storage Temperature Range	–25 to +100		°C
Terminal Temperature 1/16 Inch from Case for 10 Seconds	230		°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	TYP	MAX	UNIT
I_{AOM}	Peak Anode Blocking Current	$V_{AAM} = 200$ v, $I_G = 0$, $T_C = 100°C$	TIC20 TIC22		1	ma
		$V_{AAM} = 300$ v, $I_G = 0$, $T_C = 100°C$	TIC21 TIC23			
I_{GT}	Gate Trigger Current	$V_{A2\text{-}A1} = +12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		+50	ma
		$V_{A2\text{-}A1} = +12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		–50	
		$V_{A2\text{-}A1} = -12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL	+100		
		$V_{A2\text{-}A1} = -12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		–50	
V_{GT}	Gate Trigger Voltage	$V_{A2\text{-}A1} = +12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		+3	v
		$V_{A2\text{-}A1} = +12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		–3	
		$V_{A2\text{-}A1} = -12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL	+3		
		$V_{A2\text{-}A1} = -12$ v, $R_L = 12\,\Omega$, $PW_G \geq 20\ \mu$sec	ALL		–3	
V_{AAM}	Peak "On" Voltage	$I_{A2M} = \pm 10$ a, See Note 4	ALL		1.9	v

NOTES: 1. These values apply bidirectionally when the gate—anode-1 resistance $R_{GA1} \leq \infty$.

2. This value applies for 60-cps full-sine-wave operation with resistive load. Above 75°C derate according to Figure 3.

3. This value applies for one 60-cps full sine wave when the device is operating at (or below) the rated value of anode current. Surge may be repeated after the device has returned to original thermal equilibrium.

4. The initial instantaneous value is measured using pulse techniques. Anode-pulse width = 300 μsec, Duty Cycle $\leq$ 1%.

TYPICAL APPLICATION DATA

The two power terminals are designated as Anode 1 (A1) and Anode 2 (A2).
The gate signal is referenced to Anode 1, see Figure 1.

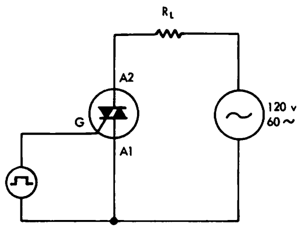


FIGURE 1

TYPICAL ANODE
VOLTAGE-CURRENT CHARACTERISTICS

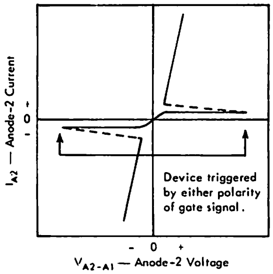


FIGURE 2

LETTER SYMBOLS

Standard symbology has not as yet been developed for bidirectional thyristors. The following tentative list has been compiled by Texas Instruments.

I_{AOM}, I_{ARM}, I_{ASM}, I_{AXM} — The peak value of anode blocking current with the gate terminal returned to the anode-1 terminal through a resistance R_{GA1} or bias network as indicated by the second subscript. "O" indicates $R_{GA1} = \infty$ (gate open-circuited). "R" indicates R_{GA1} = a finite specified value. "S" indicates $R_{GA1} = 0$ (gate short-circuited to anode-1). "X" indicates a bias which may be expressed as V_{GG} = a finite specified value in series with R_{GA1} = a finite specified value. The third subscript, "M" for peak value, may be replaced by "rms" to indicate total rms value.

$I_{A2\text{-}A1O}$, $I_{A2\text{-}A1R}$ — The steady-state current into the anode-2 terminal when it has positive polarity with respect to the anode-1 terminal and the device is blocking. Reversed polarity is indicated by a negative value of current. The final subscript indicates the gate-to-anode-1 termination as explained above.

I_{A1M}, I_{A2M}, I_{GM} — The peak value of current into the anode-1, anode-2, or gate terminal as indicated by the first letter or letter-numeral subscript.

PW_G — The width of the gate pulse.

I_{A1}, I_{A2}, I_G — The steady-state current into the terminal indicated by the subscript.

V_{AAM} — The peak value of anode-to-anode voltage. Numerals may be added to the "A" subscripts if desirable to indicate relative anode polarity.

$V_{A2\text{-}A1}$ — Steady-state anode-2 voltage with respect to anode 1.

THERMAL INFORMATION

FULL-CYCLE RMS ANODE CURRENT DERATING CURVE

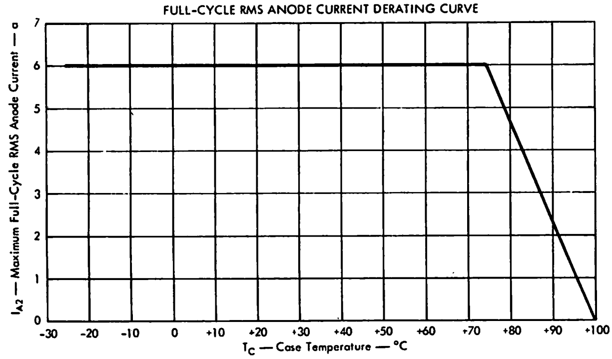


FIGURE 3

TYPES TI42A, TI43A, TIC54, TIC55, TIC56, TIC57
BULLETIN NO. DL-S 6810686, MAY 1968
REPLACES BULLETIN NO. DL-S 622311, MARCH 1962 AND
BULLETIN NO. 622644, MAY 1962

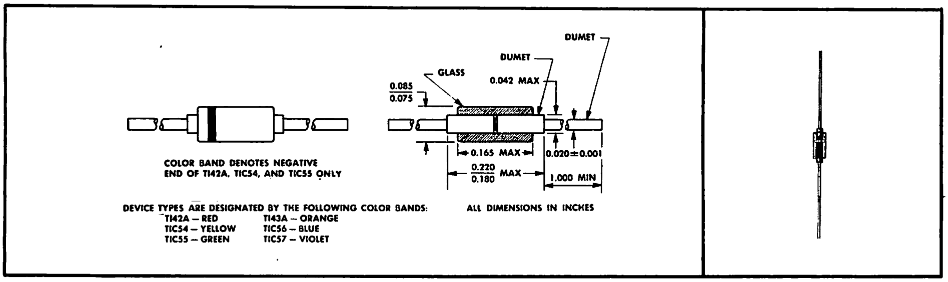
AVALANCHE SWITCHING DEVICES USED FOR FIRING SCRs AND TRIACS

description

Types TI42A, TIC54, and TIC55 guarantee the stated values of breakdown and breakback voltages only when the marked end is negative with respect to the unmarked end.

Types TI43A, TIC56, and TIC57 are electrically symmetrical trigger diacs that have guaranteed breakdown voltage and negative resistance characteristics in both directions. The breakdown voltage in either direction is guaranteed to be within two volts of the breakdown voltage in the other direction.

mechanical data



absolute maximum ratings at 100°C free-air temperature (unless otherwise noted)

Average Power Dissipation (See Note 1) . . . . 100 mW

Nonrepetitive Peak Current for 10 μs . . . . 1 A

Storage Temperature Range . . . . −65°C to 150°C

electrical characteristics at 25°C free-air temperature†

PARAMETER		TEST CONDITIONS	TYPE	MIN	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	dv/dt = 12 V/ms, See Figure 1	TI42A	28	36	V
			TIC54	26	38	
			TIC55	22	38	
			TI43A	28	36	
			TIC56	26	38	
			TIC57	22	38	
$V_{(BR)1}$-$V_{(BR)2}$	Breakdown Voltage Differential‡	dv/dt = 12 V/ms, See Figure 1	TI43A		2	V
			TIC56			
			TIC57			
$\triangle V$	Breakback Voltage	dv/dt = 12 V/ms, See Figure 1	ALL	8		V

NOTE 1: Derate linearly to 150°C free-air temperature at the rate of 2 mW/deg.

†Breakdown and breakback voltage characteristics apply unilaterally to the TI42A, TIC54, and TIC55; bilaterally to the TI43A, TIC56, and TIC57. See *Description*.

‡Breakdown Voltage Differential is the difference between the two breakdown voltages measured in the two directions.

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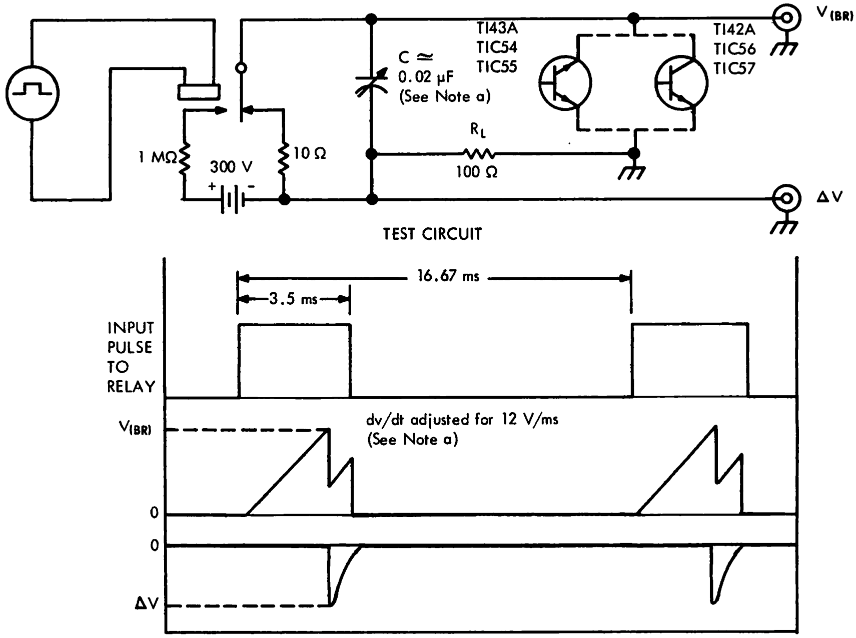
TYPES TI42A, TI43A, TIC54, TIC55, TIC56, TIC57
N-P-N DIFFUSED SILICON BREAKDOWN DIODES

PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS

NOTE a: Capacitor C is adjusted until dv/dt across DUT is 12 V/ms.

FIGURE 1

TYPICAL CHARACTERISTICS

It is of special importance to recognise the fact that the breakdown voltage decreases in magnitude as the voltage rate of rise, dv/dt, is increased. This characteristic is illustrated by Figure 2.

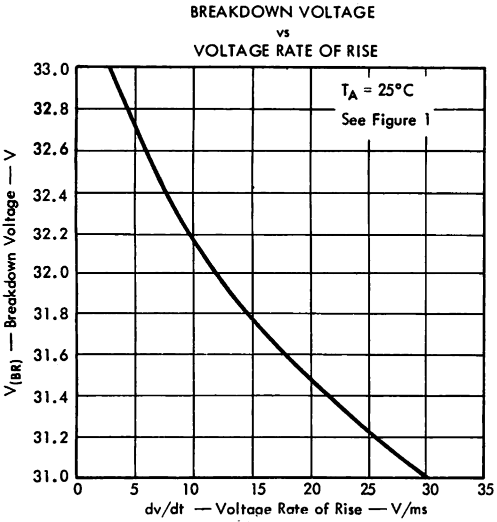


FIGURE 2

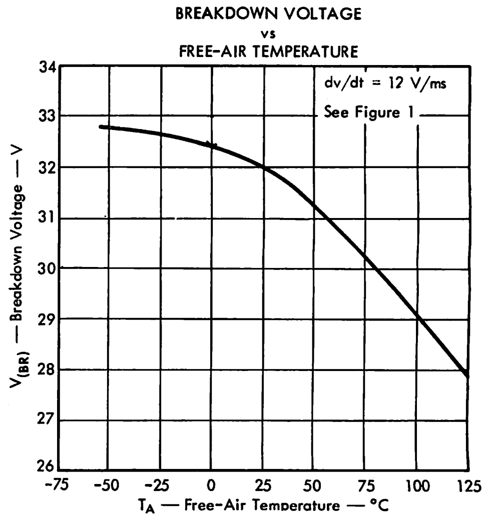
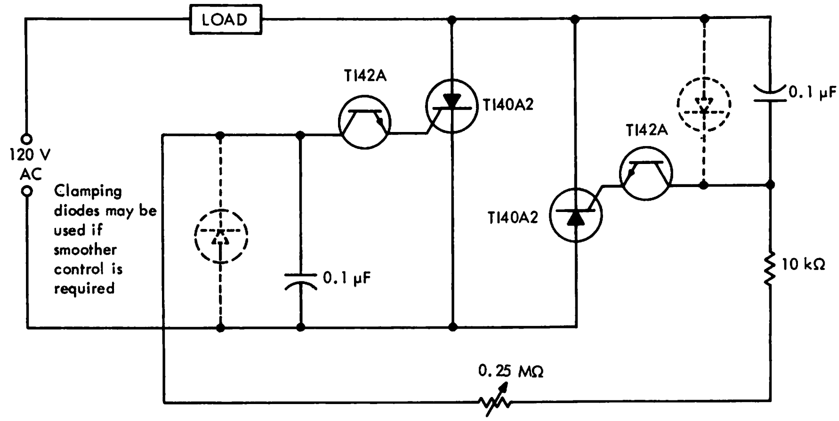


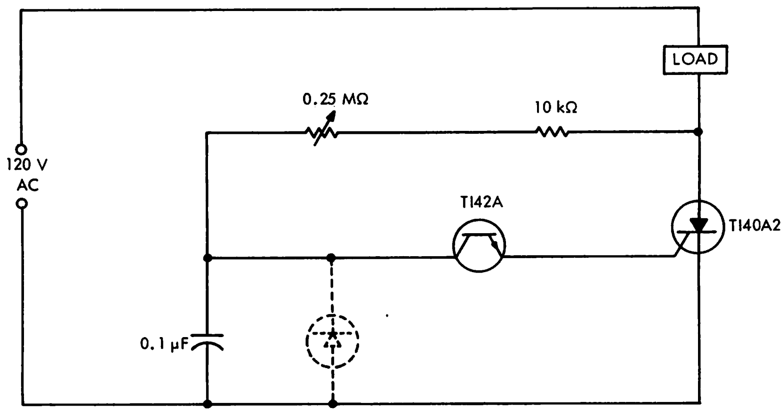
FIGURE 3

TYPICAL APPLICATION DATA



SYMMETRICAL CONTROL CIRCUIT

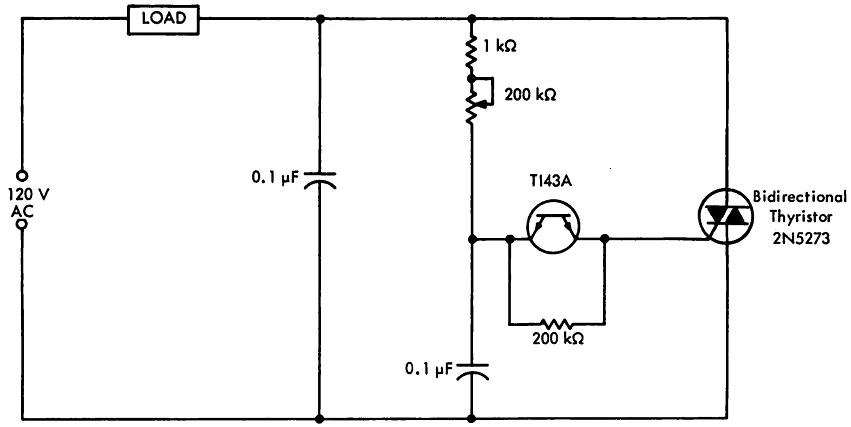
FIGURE 4



HALF-WAVE CONTROL CIRCUIT

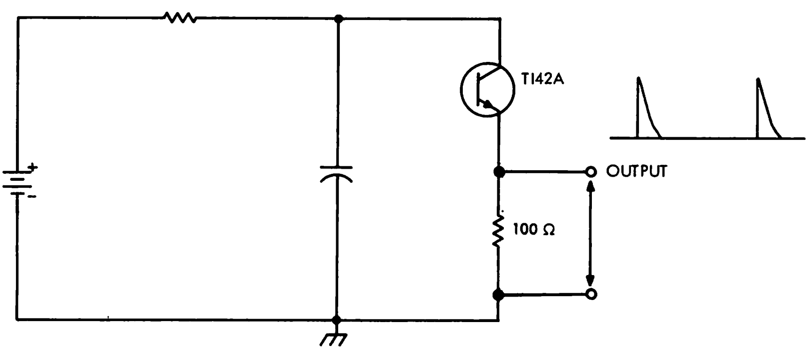
FIGURE 5

TYPICAL APPLICATION DATA



SYMMETRICAL CONTROL CIRCUIT

FIGURE 6



RELAXATION OSCILLATOR

FIGURE 7

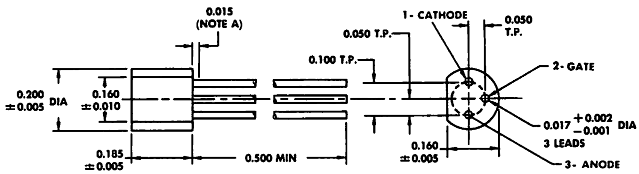
TYPES TIC44, TIC45, TIC46, TIC47
BULLETIN NO. DL-S 669051, SEPTEMBER 1966

SILECT† THYRISTORS

600 mA DC • 30 thru 200 VOLTS
Rugged, One-Piece Construction with Standard TO-18 100-mil Pin Circle

mechanical data

These thyristors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The thyristors are insensitive to light.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.019) shall be within 0.007 of their true positions measured in the gaging plane 0.054 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in inches.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TIC44	TIC45	TIC46	TIC47	UNIT
Continuous Forward Blocking Voltage, V_{FO} (See Note 1)	30	60	100	200	V
Peak Forward Blocking Voltage (See Note 1)	30	60	100	200	V
Continuous Reverse Blocking Voltage, V_{RO} (See Note 1)	30	60	100	200	V
Peak Reverse Blocking Voltage (See Note 1)	30	60	100	200	V
Continuous Anode Forward Current at (or below) 55°C Case Temperature (See Note 2)	600				mA
Continuous Anode Forward Current at (or below) 25°C Free-Air Temperature (See Note 3)	300				mA
Average Anode Forward Current (180° Conduction Angle) at (or below) 55°C Case Temperature (See Note 4)	430				mA
Peak Anode Surge Current (See Note 5)	6				A
Peak Gate Reverse Voltage	8				V
Peak Gate Forward Current (Pulse Width ≤ 300 μs)	1				A
Peak Gate Power Dissipation (Pulse Width ≤ 300 μs)	4				W
Operating Free-Air Temperature Range	−55 to 125				°C
Storage Temperature Range	−55 to 150				°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260				°C

NOTES: 1. These values apply when the gate-cathode resistance $R_{GK} \leq 1\ k\Omega$.
2. These values apply for continuous d-c operation with resistive load. Above 55°C derate according to Figure 5.
3. These values apply for continuous d-c operation with resistive load. Above 25°C derate according to Figure 6.
4. This value may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 55°C derate according to Figure 5.
5. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse blocking voltage and anode forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

†Trademark of Texas Instruments.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
I_{FR}	Static Anode Forward Blocking Current	V_F = Rated V_{FR}, $R_{GK} = 1\ k\Omega$, $T_A = 125°C$		50	μA
I_{RR}	Static Anode Reverse Blocking Current	V_R = Rated V_{RR}, $R_{GK} = 1\ k\Omega$, $T_A = 125°C$		50	μA
I_{GT}	Gate Trigger Current (See Note 6)	$V_{AA} = 6\ V$, $R_L = 100\ \Omega$, $t_{p(g)} \geq 20\ \mu s$		200	μA
V_{GT}	Gate Trigger Voltage (See Note 6)	$V_{AA} = 6\ V$, $R_L = 100\ \Omega$, $t_{p(g)} \geq 20\ \mu s$		0.8	V
		$V_{AA} = 6\ V$, $R_L = 100\ \Omega$, $t_{p(g)} \geq 20\ \mu s$, $T_A = 125°C$	0.2		
I_{HR}	Holding Current	$R_L = 100\ \Omega$, $R_{GK} = 1\ k\Omega$		5	mA
V_F	Static Forward Voltage	$I_F = 300\ mA$, $R_{GK} \geq 1\ k\Omega$, See Note 7		1.4	V

NOTES: 6. When measuring these parameters, a 1 kΩ resistor should be used between gate and cathode to prevent triggering by random noise.

7. This parameter is measured using pulse techniques. $t_p = 1$ ms, duty cycle $\leq 1\%$.

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	75	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	275	

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_{on}	Turn-On Time	$V_{AA} = 30\ V$, $R_L = 50\ \Omega$, $R_G = 20\ k\Omega$, $V_{in} = 20\ V$, See Figure 1	3.5	μs
t_{off}	Commutating Turn-Off Time	$V_{AA} = 30\ V$, $R_L = 50\ \Omega$, $I_R = 1\ A$, See Figure 2	6.8	μs

PARAMETER MEASUREMENT INFORMATION

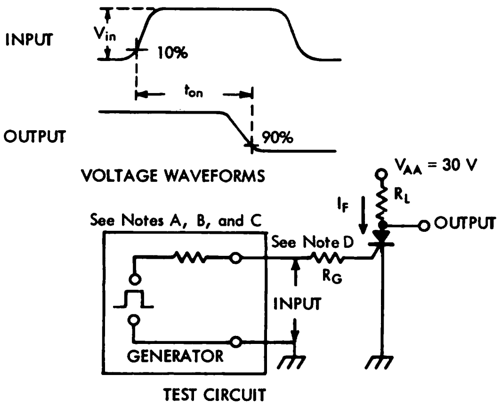


FIGURE 1 — TURN-ON TIME

NOTES: A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.

B. The input waveform of Figure 1 has the following characteristics: $t_r \leq 40$ ns, $t_p \geq 20$ μs.

C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 14$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 12$ pF.

D. R_G includes the total resistance of the generator and the external resistor.

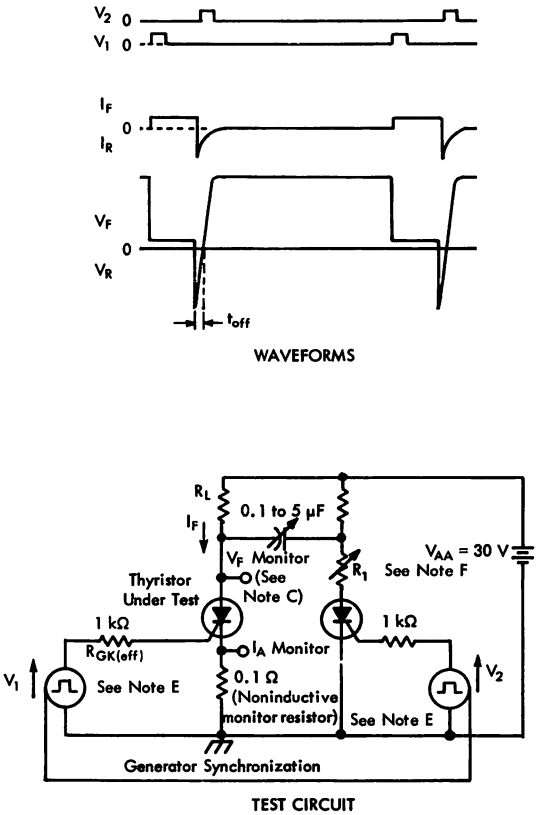


FIGURE 2 — COMMUTATING TURN-OFF TIME

NOTES: E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: $t_p = 50$ to 300 μs, duty cycle = 1%. The pulse widths of V_1 and V_2 are ≥ 10 μs.

F. Resistor R_1 is adjusted for $I_R = 1$ A.

THERMAL INFORMATION

The minimum heat-sink requirements may be calculated for any anode-current, heat-sink combination by the following procedure:

1. Determine worst-case power dissipation from figure 3.
2. Calculate maximum allowable case-to-free-air thermal resistance by use of the equation:

$$\theta_{C\text{-}A} = \frac{T_J - T_A}{P_{A(av)}} - \theta_{J\text{-}C}$$

where: T_J = Junction temperature
T_A = Free-air temperature
$P_{A(av)}$ = Average anode power dissipation (see figure 3 for worst-case values)
$\theta_{J\text{-}C}$ = Junction-to-case thermal resistance = 75 deg/W maximum.

3. Determine area of heat sink from figure 4.

EXAMPLE

Determine: Minimum size of 1/16″-thick aluminum heat sink for safe operation of thyristor at an average current of 0.4 A with a conduction angle of 180°.

Given: Maximum T_J = 125°C
T_A = 35°C
$\theta_{J\text{-}C}$ = 75 deg/W

Solution: From figure 3, $P_{A(av)}$ = 0.84 W for 0.4 A with 180° conduction angle. Using the equation of step 2 above:

$$\theta_{C\text{-}A} = \frac{125°C - 35°C}{0.84\ W} - 75\ \text{deg/W} = 32\ \text{deg/W}$$

Figure 4 shows that for $\theta_{C\text{-}A}$ of 32 deg/W, the area is 18 sq. in. The minimum dimensions of the sides should be:

$$\sqrt{\frac{area}{2}} \times \sqrt{\frac{area}{2}} = \sqrt{\frac{18}{2}} \times \sqrt{\frac{18}{2}} = 3'' \times 3''$$

NOTES: 8. The thyristor is mounted in the center of a square heat sink vertically positioned in still free air with both sides exposed. The heat-sink area is twice the area of one side.

9. $\theta_{C\text{-}A}$ includes the case-to-heat sink thermal resistance, $\theta_{C\text{-}HS}$, in addition to the heat-sink-to-free-air thermal resistance, $\theta_{HS\text{-}A}$, and is defined by the equation, $\theta_{C\text{-}A} = \theta_{C\text{-}HS} + \theta_{HS\text{-}A}$.

MAXIMUM AVERAGE ANODE POWER DISSIPATED
vs
AVERAGE ANODE FORWARD CURRENT

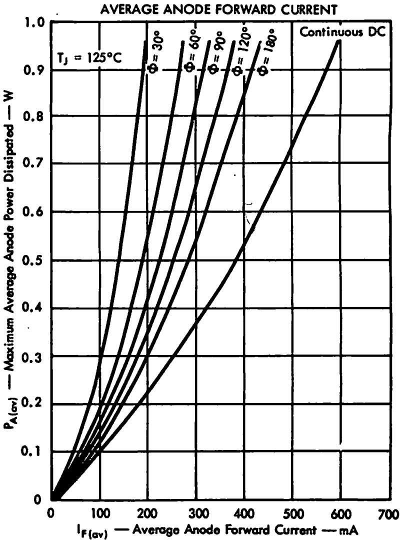


FIGURE 3

TYPICAL HEAT-SINK AREA
vs
CASE-TO-FREE-AIR THERMAL RESISTANCE
1/16" - THICK ALUMINUM HEAT SINK

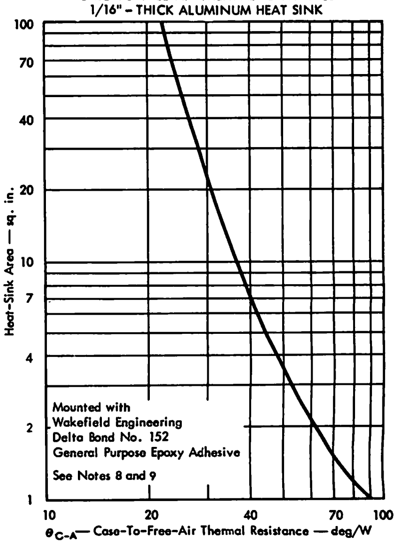


FIGURE 4

THERMAL INFORMATION

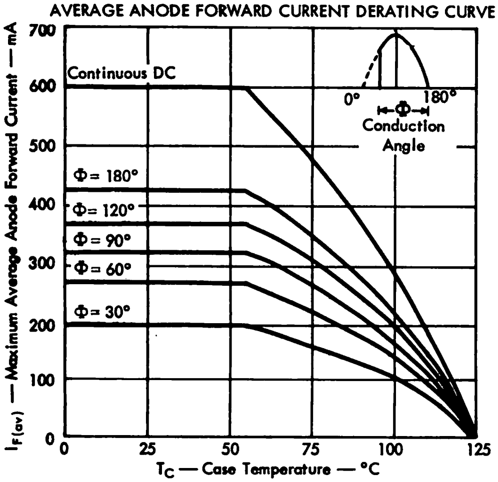


FIGURE 5

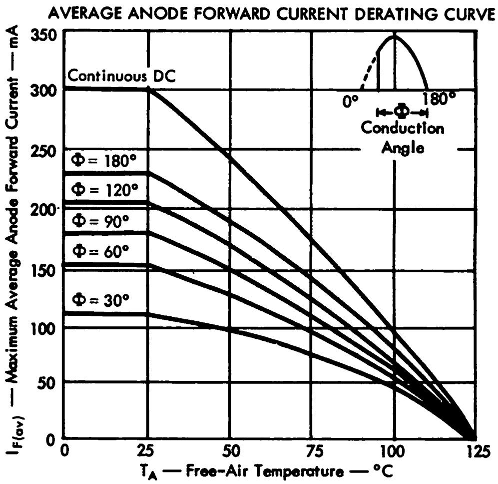


FIGURE 6

TYPICAL CHARACTERISTICS

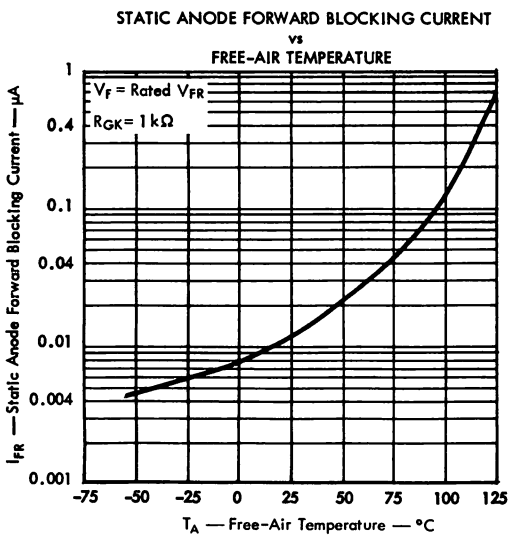


FIGURE 7

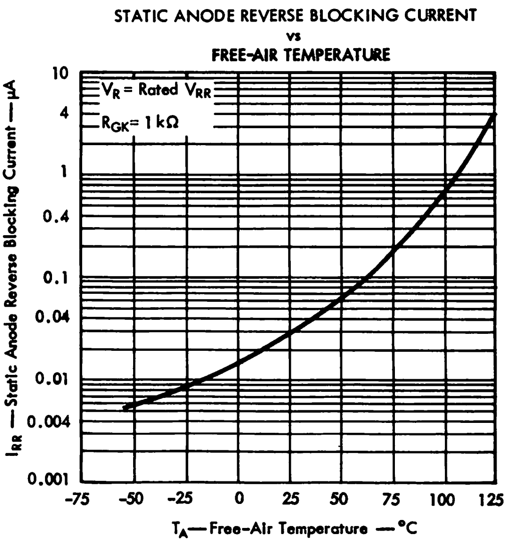


FIGURE 8

TYPICAL CHARACTERISTICS

GATE TRIGGER CURRENT vs FREE-AIR TEMPERATURE

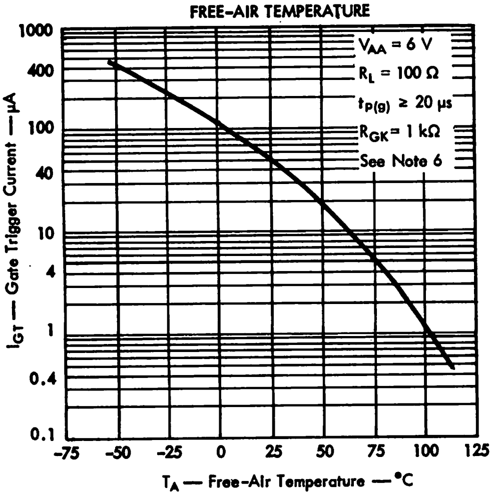


FIGURE 9

GATE TRIGGER VOLTAGE vs FREE-AIR TEMPERATURE

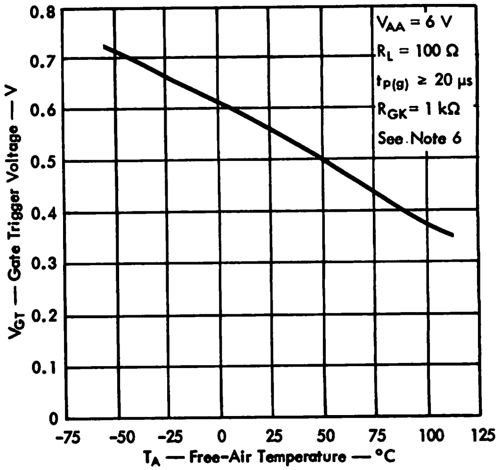


FIGURE 10

NOTE 6: When measuring these parameters, a 1 kΩ resistor should be used between gate and cathode to prevent triggering by random noise.

HOLDING CURRENT vs FREE-AIR TEMPERATURE

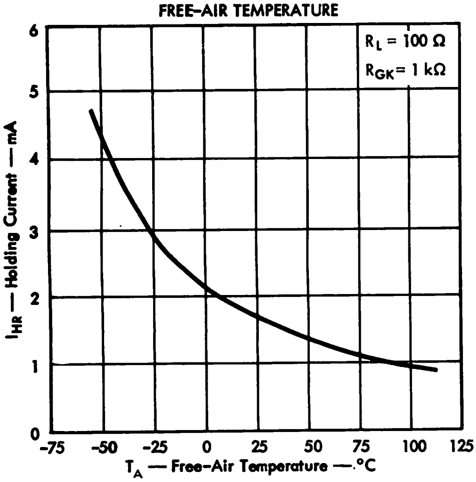


FIGURE 11

TURN-ON TIME vs GATE CURRENT

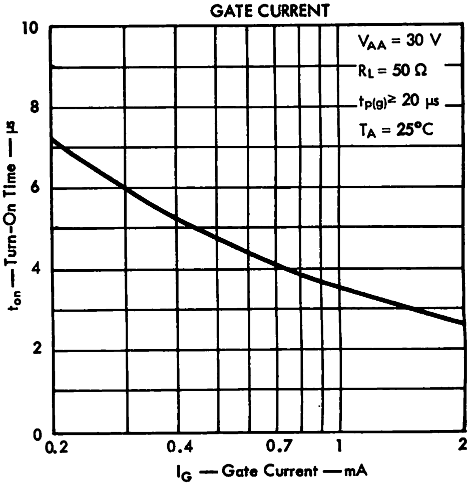
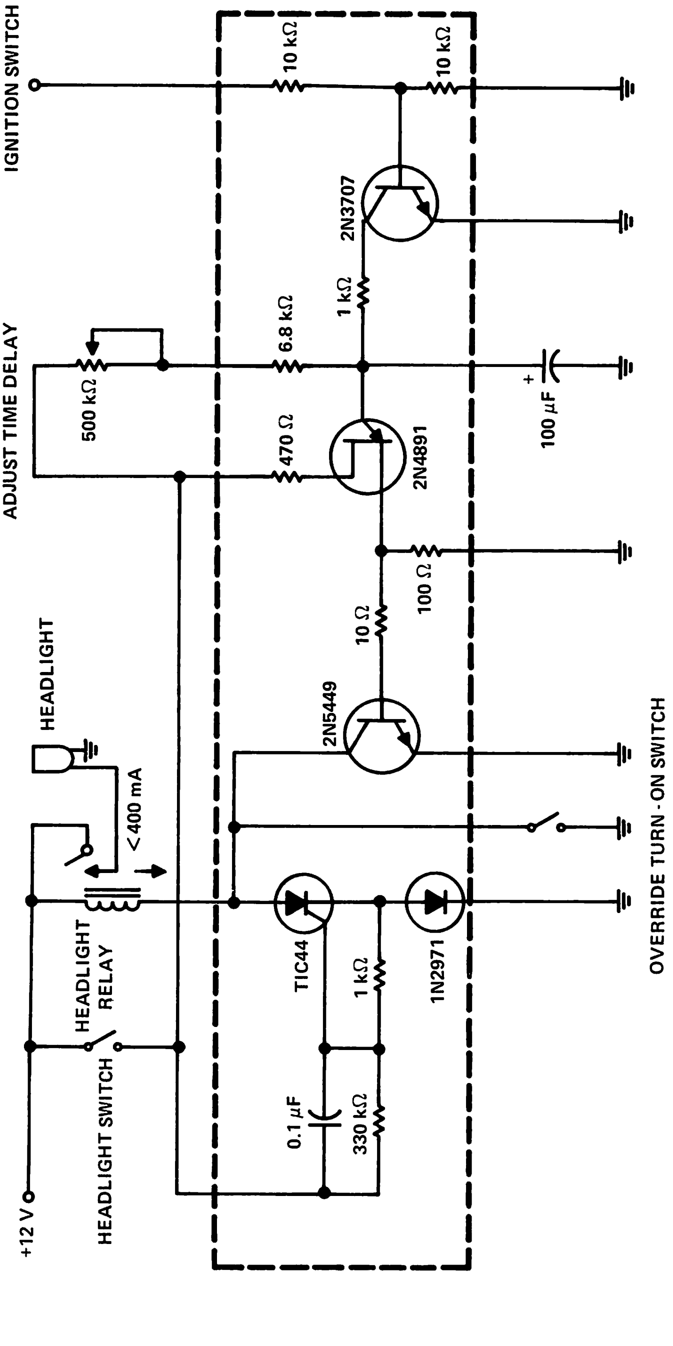


FIGURE 12

TYPICAL APPLICATION DATA

AUTOMATIC TURN-OFF CONTROL FOR HEADLIGHTS



- Lights turn on with light switch.
- Lights turn off 1 second to 15 minutes (adjustable) after ignition is turned off.
- 2N4891 unijunction used as variable timer.

CA17110

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Chiyoda-du, Tokyo, Japan

TYPES 2N3001, 2N3002, 2N3003, 2N3004
P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

TYPES 2N3001, 2N3002, 2N3003, 2N3004
BULLETIN NO. DL-S 634260, AUGUST 1963

350 ma — 30 to 200 VOLTS — 20 μa GATE SENSITIVITY

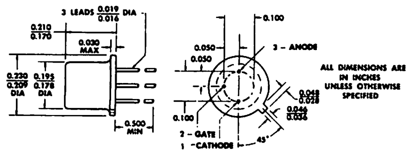
ALL PLANAR, OXIDE-PASSIVATED JUNCTIONS

NO SOLDER OR FLUXES

- **High Operating Temperatures**
- **High Surge Current Capability**
- **Fast Switching Speeds**
- **Low Forward Voltage Drop**

mechanical data

The devices are in a hermetically sealed welded case with a glass-to-metal seal between case and leads. Approximate weight is 0.35 gram.



* THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

* ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	2N3001	2N3002	2N3003	2N3004	UNIT
*Continuous Forward Blocking Voltage, V_{FB} (See Note 1)	30	60	100	200	v
*Continuous Reverse Blocking Voltage, V_R	30	60	100	200	v
*Peak Forward Blocking Voltage (See Note 1)	30	60	100	200	v
*Peak Reverse Blocking Voltage	30	60	100	200	v
Peak Gate Reverse Voltage	8				v
*Continuous Anode Forward Current at (or below) 55°C Free-Air Temperature (See Note 2)	350				ma
*Continuous Anode Forward Current at 130°C Free-Air Temperature (See Note 2)	75				ma
*Average Anode Forward Current (180° Conduction Angle) at (or below) 55°C Free-Air Temperature (See Note 2)	250				ma
*Anode Surge Current (See Note 3)	6				a
*Peak Gate Forward Current (Pulse width $\leq$ 8 msec)	250				ma
*Average Gate Power Dissipation	100				mw
*Operating Free-Air Temperature Range	-65 to $+150$				°C
*Storage Temperature Range	-65 to $+200$				°C

NOTES: 1. This value applies when the Gate-Cathode Resistance, $R_{GK} \leq 1\,k\Omega$.

2. For operation above 55°C free-air temperature, refer to Anode Forward Current Derating Curve, Figure 1.

3. This rating applies for one half-cycle sine wave, 60 cps, when the device is conducting maximum rated current immediately before and after the surge. Surge may be repeated after the device has returned to original thermal equilibrium conditions.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_F	Anode Forward Blocking Current†	V_{AK} = Rated V_{FB}, R_{GK} = 1 kΩ			20	na
		V_{AK} = Rated V_{FB}, R_{GK} = 1 kΩ, T_A = 150°C			20	μa
I_R	Anode Reverse Blocking Current†	V_{KA} = Rated V_R, R_{GK} = ∞			0.1	μa
		V_{KA} = Rated V_R, R_{GK} = ∞, T_A = 150°C			100	μa
I_{GR}	Gate Reverse Current	V_{KG} = 5 v, R_L = ∞			0.1	μa
$I_{GT(on)}$	Gate Trigger Current†	V_{AA} = 5 v, R_L = 12 Ω		5.0	20	μa
$V_{GT(on)}$	Gate Trigger Voltage†	V_{AA} = 5 v, R_L = 12 Ω, T_A = −65°C			0.9	v
		V_{AA} = 5 v, R_L = 12 Ω		0.55	0.7	v
		V_{AA} = 5 v, R_L = 12 Ω, T_A = 150°C	0.2			v
I_H	Holding Current	R_{GK} = 1k Ω		1.2	3.0	ma
		R_{GK} = 1k Ω, T_A = −65°C			4.0	ma
V_F	Peak Instantaneous Fwd. Voltage	I_F = 350 ma, (See Note 4)			1.1	v
dV/dt	Critical Rate of Anode Voltage Rise	V_{KG} = 1.0 v		400		v/μsec

†For additional TI guaranteed characteristics, see Figures 2, 3, 6, and 7.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N3004 TYP	UNIT
t_{on}	Turn-On Time	V_{AA} = 200 v, R_L = 2.2 kΩ, R_G = 100 Ω, V_{in} = 3.0 v, (See Fig. 14)	0.3	μsec
t_{off}	Commutating Turn-Off Time	V_{AA} = 50 v, R_L = 140 Ω, 1N645 between gate and cathode, (See Fig. 15)	3.5	μsec

thermal characteristics

PARAMETER		TYP	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	75	C°/watt
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	275	C°/watt

NOTE 4: These parameters must be measured using pulse techniques. Anode pulse width = 300 μsec, PRR = 10 pps.

* Indicates JEDEC registered data (typical data excluded).

ANODE FORWARD CURRENT DERATING CURVES

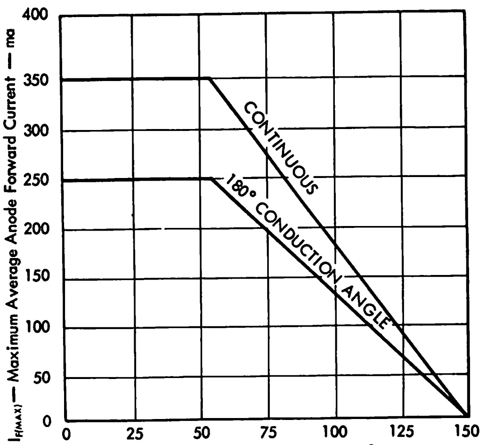


FIGURE 1

ANODE CHARACTERISTICS

ANODE FORWARD BLOCKING CURRENT
vs
FREE-AIR TEMPERATURE

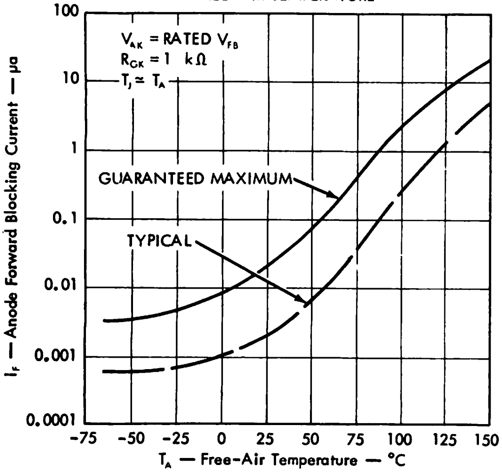


FIGURE 2

ANODE REVERSE BLOCKING CURRENT
vs
FREE-AIR TEMPERATURE

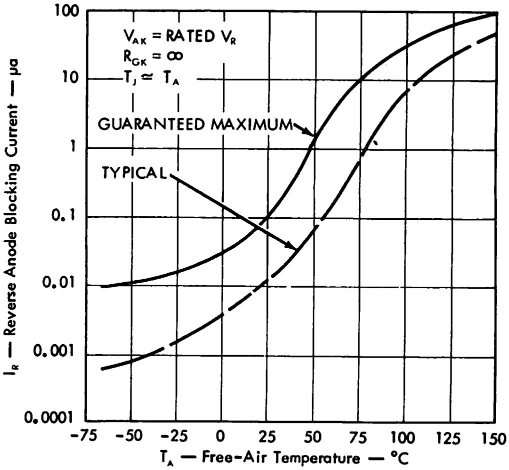


FIGURE 3

TYPICAL
PEAK INSTANTANEOUS FORWARD VOLTAGE
vs
ANODE FORWARD CONDUCTION CURRENT

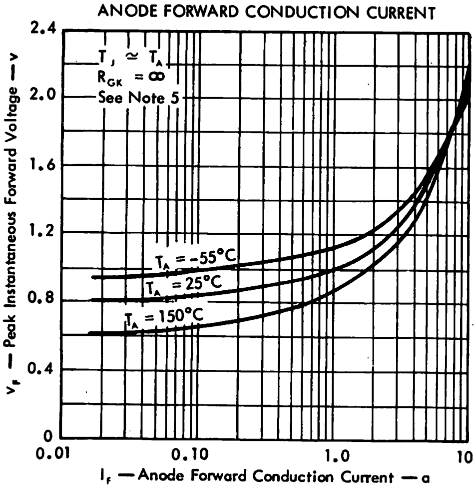


FIGURE 4

TYPICAL HOLDING CURRENT
vs
FREE-AIR TEMPERATURE

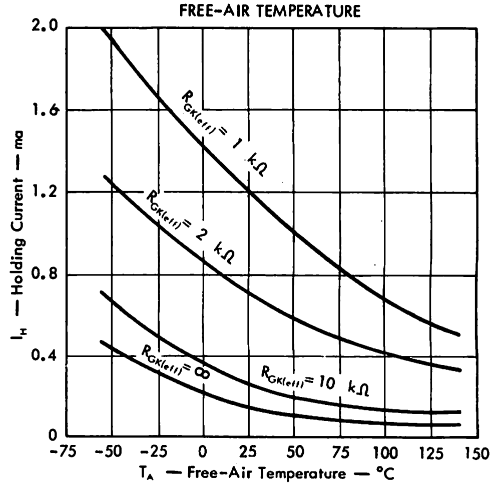


FIGURE 5

NOTE: 5. These parameters were measured using pulse techniques. Anode pulse width = 300 μsec, PRR = 10 pps.

GATE CHARACTERISTICS

GATE TRIGGER CURRENT
vs
FREE-AIR TEMPERATURE

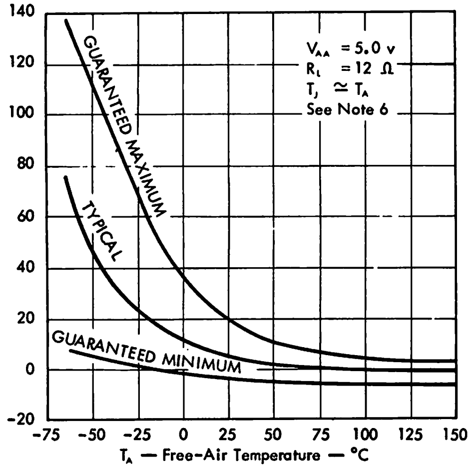


FIGURE 6

GATE TRIGGER VOLTAGE
vs
FREE-AIR TEMPERATURE

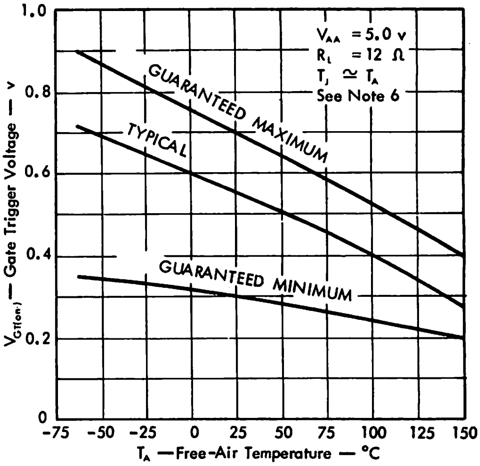


FIGURE 7

TYPICAL GATE - CATHODE VOLTAGE
vs
GATE FORWARD CONDUCTION CURRENT

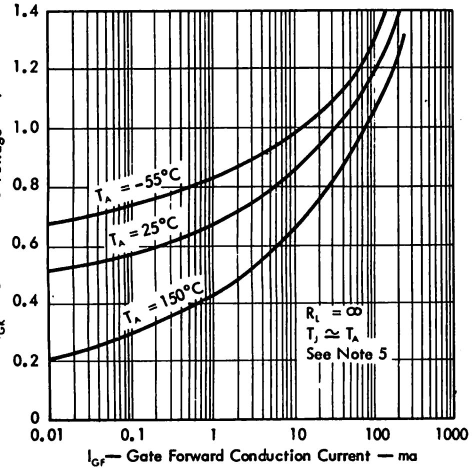


FIGURE 8

TYPICAL GATE TRIGGER VOLTAGE
vs
GATE PULSE WIDTH

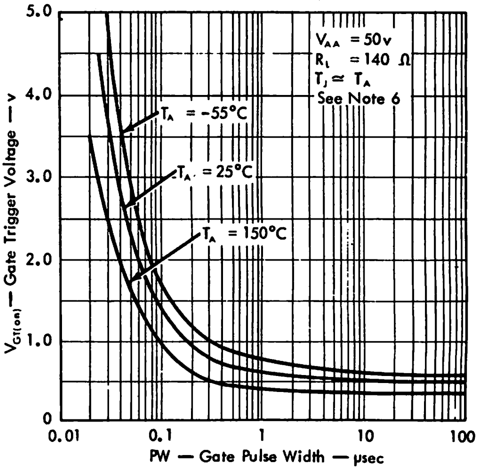


FIGURE 9

NOTE: 6. These parameters were measured using single pulse techniques. Anode pulse width = 300 μsec, Duty Cycle = 0.

TYPICAL SWITCHING CHARACTERISTICS, $T_A = 25°C$

TURN-ON TIME vs GATE INPUT PULSE AMPLITUDE

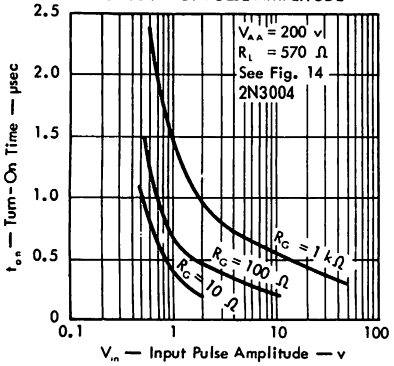


FIGURE 10

TURN-ON TIME vs ANODE SUPPLY VOLTAGE

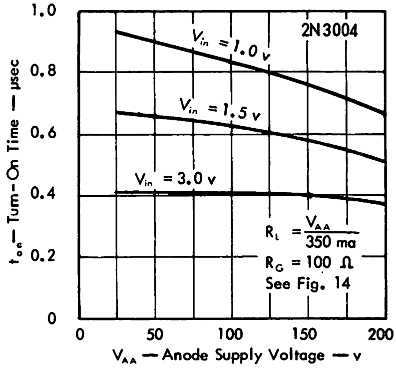


FIGURE 11

TURN-ON TIME vs ANODE FORWARD CURRENT

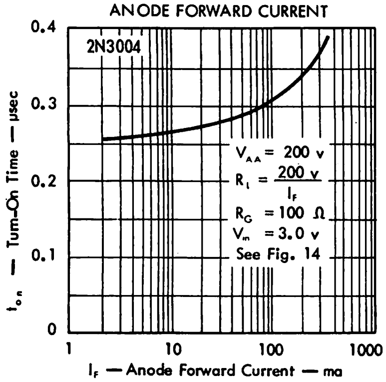


FIGURE 12

COMMUTATING TURN-OFF TIME vs ANODE FORWARD CURRENT

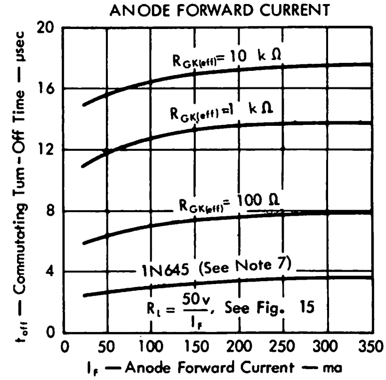


FIGURE 13

PARAMETER MEASUREMENT INFORMATION

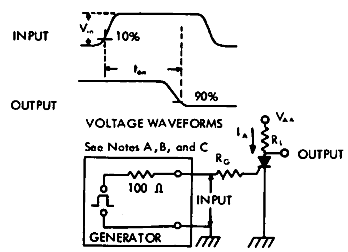


FIGURE 14 — TURN-ON TIME TEST CIRCUIT

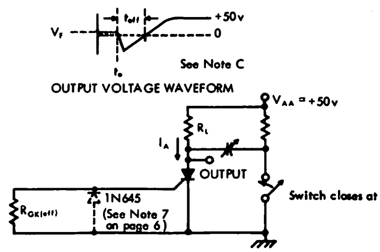


FIGURE 15 — TURN-OFF TIME TEST CIRCUIT

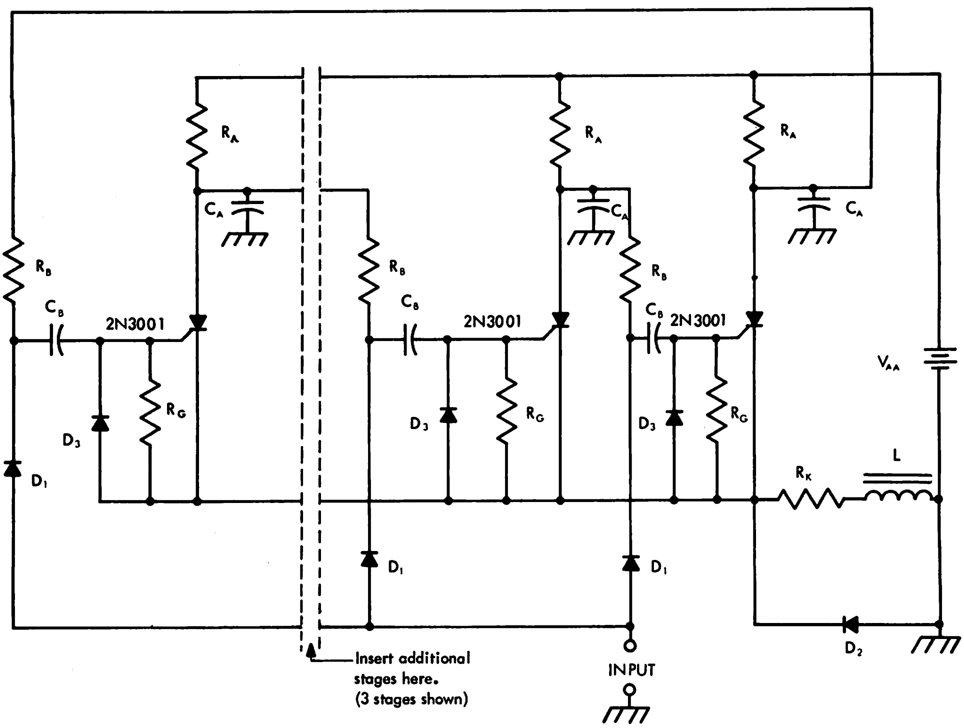
NOTES: A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.

B. The input waveform has the following characteristics: $t_r \leq 40$ nsec, PW $\geq$ device turn-on time at the operating point.

C. Waveforms are monitored on an oscilloscope with following characteristics $t_r \leq 14$ nsec, $R_{in} \geq 10$ MΩ, $C_{in} \leq 12$ pf.

TYPICAL APPLICATION DATA

20-kc RING COUNTER



CIRCUIT PERFORMANCE CHARACTERISTICS FOR 10 STAGE OPERATION AT $T_A = 25°C$

a. V_{AA} Range for 20kc Operation: 6 v to 30 v (Rated V_{FB})
b. V_{AA} Range for 10kc Operation: 2.75 v to 30 v (Rated V_{FB})
c. Range of Input Amplitude for 10kc operation: 3 v to 8 v

CIRCUIT COMPONENT INFORMATION

R_A : 330 Ω	C_A : 0.06 μf ± 20%
R_B : 33 kΩ	C_B : 0.001 μf ± 20%
R_G : 1 kΩ	L : 40 mh
R_K : 33 Ω	D_1, D_2, and D_3 : 1N914

All Resistors, ± 5% tolerance, ½ w

NOTE: 7. The commutating turn-off time of the 2N3001 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Fig. 13. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Fig. 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

TYPES 2N3005, 2N3006, 2N3007, 2N3008
P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

TYPES 2N3005, 2N3006, 2N3007, 2N3008
BULLETIN NO. DL-S 634267, SEPTEMBER 1963

350 ma — 30 to 200 VOLTS — 200 μa GATE SENSITIVITY

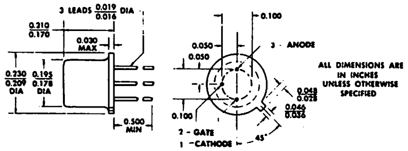
ALL PLANAR, OXIDE-PASSIVATED JUNCTIONS

NO SOLDER OR FLUXES

- **High Operating Temperatures**
- **Fast Switching Speeds**
- **High Surge Current Capability**
- **Low Forward Voltage Drop**
- **Gate Turn-Off Capability**

mechanical data

The devices are in a hermetically sealed welded case with a glass-to-metal seal between case and leads. Approximate weight is 0.35 gram.



• THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

• ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	2N3005	2N3006	2N3007	2N3008	UNIT
*Continuous Forward Blocking Voltage, V_{FB} (See Note 1)	30	60	100	200	v
*Continuous Reverse Blocking Voltage, V_R	30	60	100	200	v
*Peak Forward Blocking Voltage (See Note 1)	30	60	100	200	v
*Peak Reverse Blocking Voltage	30	60	100	200	v
Peak Gate Reverse Voltage	8				v
*Continuous Anode Forward Current at (or below) 55°C Free-Air Temperature (See Note 2)	350				ma
*Continuous Anode Forward Current at 130°C Free-Air Temperature (See Note 2)	75				ma
*Average Anode Forward Current (180° Conduction Angle) at (or below) 55°C Free-Air Temperature (See Note 2)	250				ma
*Anode Surge Current (See Note 3)	6				a
*Peak Gate Forward Current (Pulse width $\leq$ 8 msec)	250				ma
*Average Gate Power Dissipation	100				mw
*Operating Free-Air Temperature Range	−65 to + 150				°C
*Storage Temperature Range	−65 to + 200				°C

NOTES: 1. This value applies when the Gate-Cathode Resistance, $R_{GK} \leq 1\ k\Omega$.

2. For operation above 55°C free-air temperature, refer to Anode Forward Current Derating Curve, Figure 1.

3. This rating applies for one half-cycle sine wave, 60 cps, when the device is conducting maximum rated current immediately before and after the surge. Surge may be repeated after the device has returned to original thermal equilibrium conditions.

*Indicates JEDEC registered data.

TYPES 2N3005, 2N3006, 2N3007, 2N3008
P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_F	Anode Forward Blocking Current†	V_{AK} = Rated V_{FB}, $R_{GK} = 1\,k\Omega$			20	na
		V_{AK} = Rated V_{FB}, $R_{GK} = 1\,k\Omega$, $T_A = 150°C$			20	μa
I_R	Anode Reverse Blocking Current†	V_{KA} = Rated V_R, $R_{GK} = \infty$			0.1	μa
		V_{KA} = Rated V_R, $R_{GK} = \infty$, $T_A = 150°C$			100	μa
I_{GR}	Gate Reverse Current	$V_{KG} = 5\,v$, $R_L = \infty$			0.1	μa
$I_{GT(on)}$	Gate Trigger Current†	$V_{AA} = 5\,v$, $R_L = 12\,\Omega$		90	200	μa
$V_{GT(on)}$	Gate Trigger Voltage†	$V_{AA} = 5\,v$, $R_L = 12\,\Omega$, $T_A = -65°C$			0.9	v
		$V_{AA} = 5\,v$, $R_L = 12\,\Omega$		0.6	0.8	v
		$V_{AA} = 5\,v$, $R_L = 12\,\Omega$, $T_A = 150°C$	0.2			v
I_H	Holding Current	$R_{GK} = 1k\Omega$		1.8	5.0	ma
		$R_{GK} = 1k\Omega$, $T_A = -65°C$			8.0	ma
V_F	Peak Instantaneous Fwd. Voltage	I_F = 350 ma, (See Note 4)			1.1	v
dV/dt	Critical Rate of Anode Voltage Rise	$V_{KG} = 1.0\,v$		400		v/μsec

†For additional TI guaranteed characteristics, see Figures 2, 3, 6, and 7.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	2N3008 TYP	UNIT
t_{on}	Turn-On Time	$V_{AA} = 200\,v$, $R_L = 2.2\,k\Omega$, $R_G = 100\,\Omega$, $V_{in} = 3.0\,v$, (See Fig. 14)	0.55	μsec
t_{off}	Commutating Turn-Off Time	$V_{AA} = 50\,v$, $R_L = 140\,\Omega$, 1N645 between gate and cathode, (See Fig. 15)	2.2	μsec
$I_{GT(off)}$	Gate Turn-Off Current	I_F = 200 ma (See Note 5)	40	ma
$V_{GT(off)}$	Gate Turn-Off Voltage	$V_{AA} \leq 100\,v$ (Not to exceed Rated V_{FB})	4.0	v

thermal characteristics

PARAMETER		TYP	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	75	C°/watt
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	275	C°/watt

NOTE 4: These parameters must be measured using pulse techniques. Anode pulse width = 300 μsec, PRR = 10 pps.

NOTE 5: Anode current not to exceed 200 ma for gate turn-off applications.

* Indicates JEDEC registered data (typical data excluded).

ANODE FORWARD CURRENT DERATING CURVES

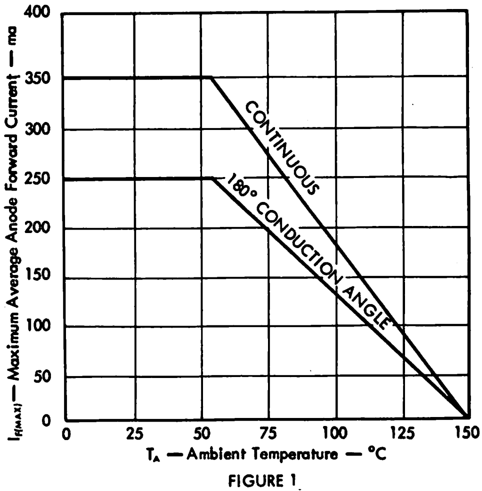


FIGURE 1

ANODE CHARACTERISTICS

ANODE FORWARD BLOCKING CURRENT
vs
FREE-AIR TEMPERATURE

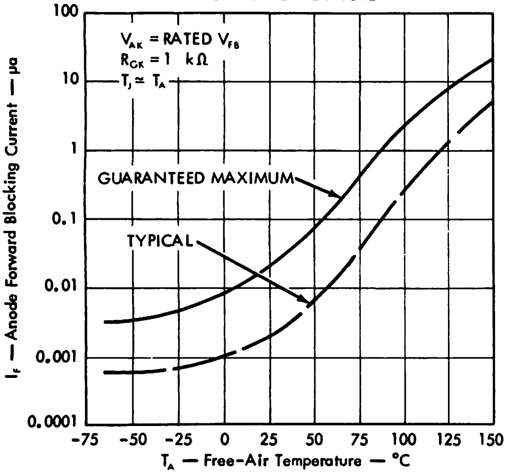


FIGURE 2

ANODE REVERSE BLOCKING CURRENT
vs
FREE-AIR TEMPERATURE

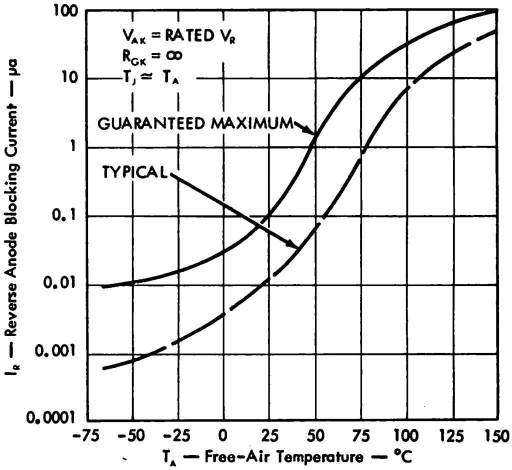


FIGURE 3

TYPICAL PEAK INSTANTANEOUS FORWARD VOLTAGE
vs
ANODE FORWARD CONDUCTION CURRENT

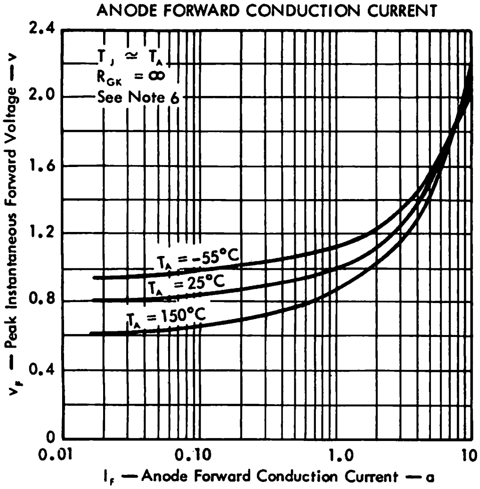


FIGURE 4

TYPICAL HOLDING CURRENT
vs
FREE-AIR TEMPERATURE

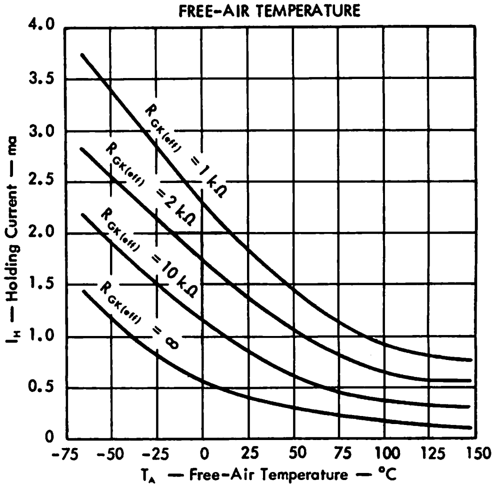


FIGURE 5

NOTE 6: These parameters were measured using pulse techniques. Anode pulse width = 300 μsec, PRR = 10 pps.

GATE CHARACTERISTICS

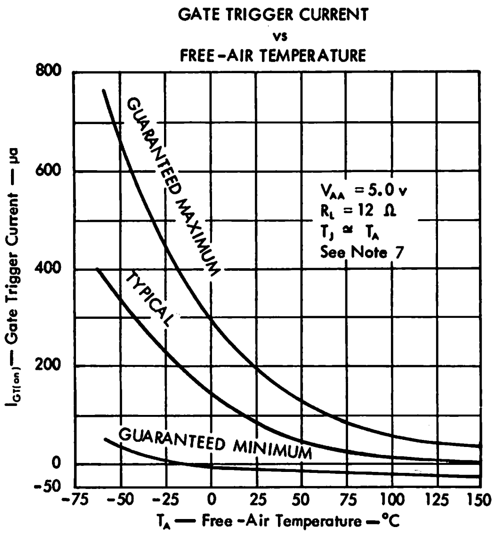


FIGURE 6

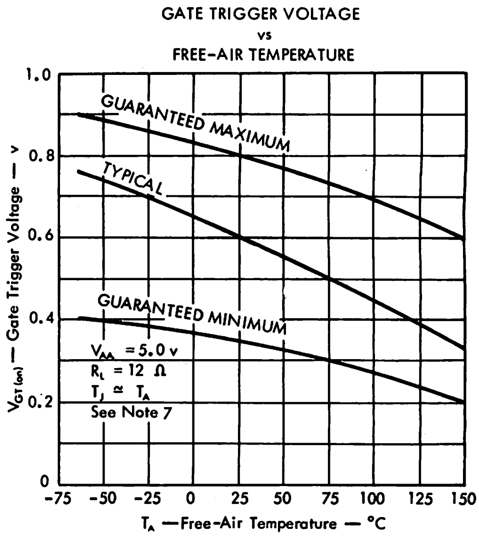


FIGURE 7

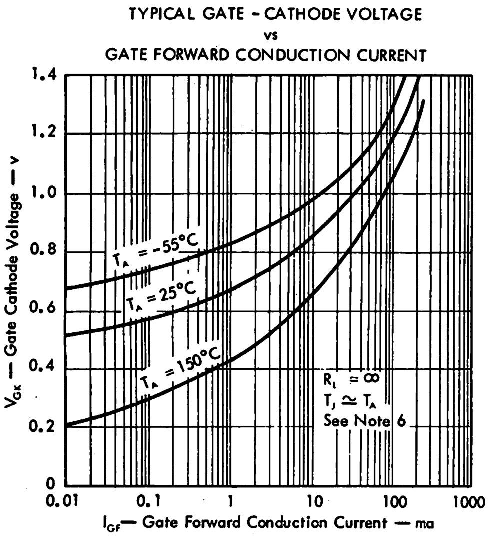


FIGURE 8

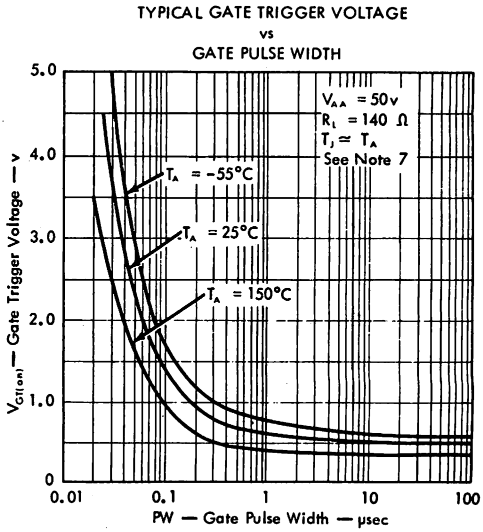


FIGURE 9

NOTE 7: These parameters were measured using single pulse techniques. Anode pulse width = 300 μsec, Duty Cycle = 0.

TYPICAL SWITCHING CHARACTERISTICS, $T_A = 25°C$

TURN-ON TIME
vs
GATE INPUT PULSE AMPLITUDE

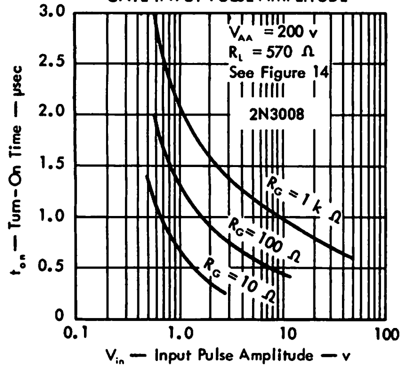


FIGURE 10

TURN-ON TIME
vs
ANODE SUPPLY VOLTAGE

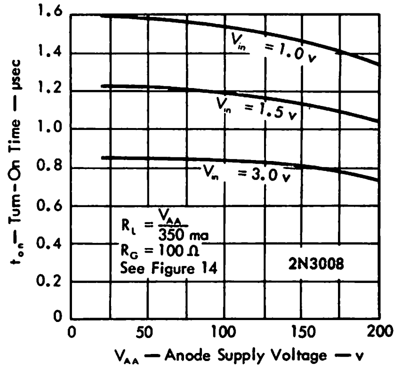


FIGURE 11

TURN-ON TIME
vs
ANODE FORWARD CURRENT

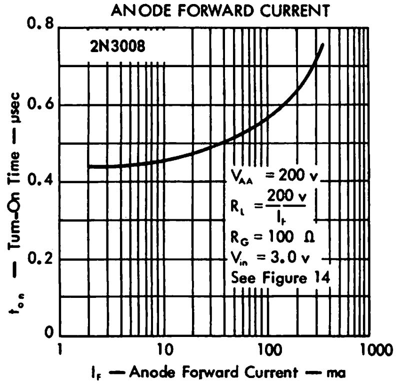


FIGURE 12

COMMUTATING TURN-OFF TIME
vs
ANODE FORWARD CURRENT

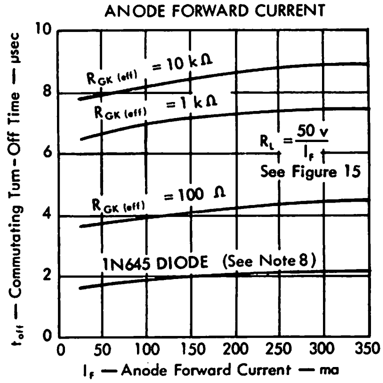


FIGURE 13

PARAMETER MEASUREMENT INFORMATION

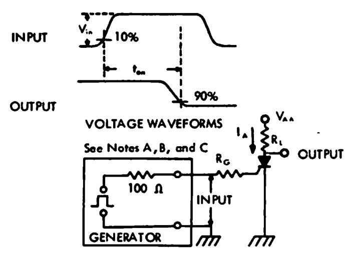


FIGURE 14 — TURN-ON TIME TEST CIRCUIT

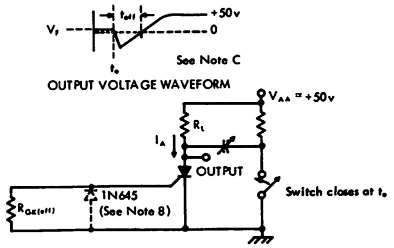


FIGURE 15 — TURN-OFF TIME TEST CIRCUIT

NOTES: A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.
B. The input waveform has the following characteristics: $t_r \leq 40$ nsec, PW $\geq$ device turn-on time at the operating point.
C. Waveforms are monitored on an oscilloscope with following characteristics $t_r \leq 14$ nsec, $R_{in} \geq 10$ MΩ, $C_{in} \leq 12$ pf.

TYPICAL GATE TURN-OFF CHARACTERISTICS

The 2N3005 series thyristors exhibit gate turn-off gain, in addition to the standard controlled switch characteristics. Figure 16 shows the typical gate turn-off gain as a function of anode current. This characteristic offers increased flexibility in the design of pulse-width modulators, pulse-forming networks, static switches, choppers, bistable-circuits and inverters.

TYPICAL GATE TURN-OFF GAIN
vs
ANODE FORWARD CURRENT

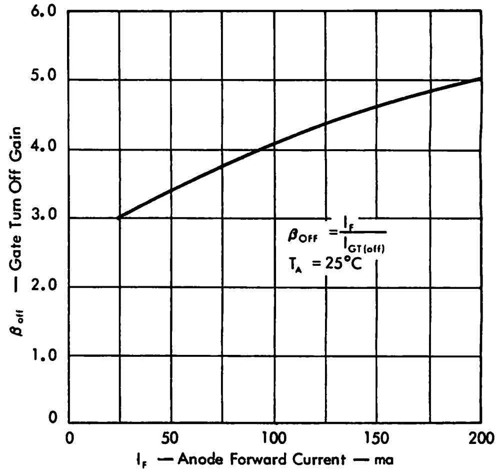
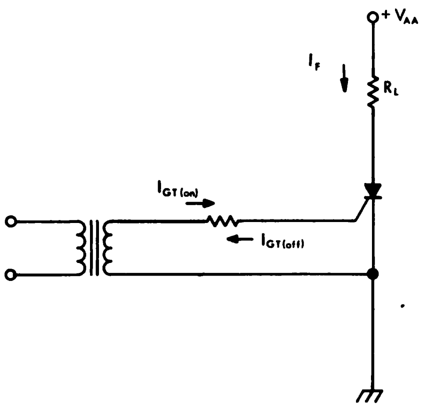
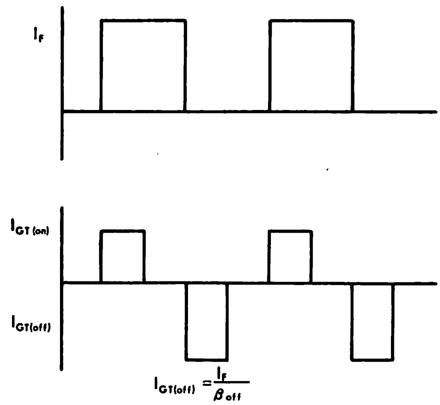


FIGURE 16



TYPICAL GATE TURN-OFF CIRCUIT



TYPICAL WAVEFORMS

Improved turn-off time may be realized using the gate turn-off method. A combination of gate turn-off and standard commutating turn-off will further improve the turn-off time. For applications requiring a guaranteed β_{OFF}, contact your nearest TI Sales Office for information on special types.

NOTE 8: The commutating turn-off time of the 2N3005 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Fig. 13. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Fig. 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

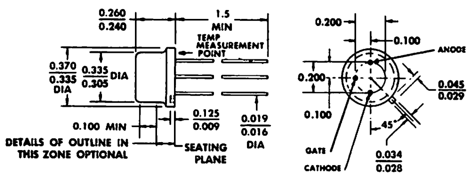
TYPES 2N3555, 2N3556, 2N3557, 2N3558
BULLETIN NO. DL-S 645905, AUGUST 1964

1 AMP AVG — 30 to 200 VOLTS — 20 μa GATE SENSITIVITY
ALL PLANAR, OXIDE-PASSIVATED JUNCTIONS
NO SOLDER OR FLUXES

- **High Operating Temperatures**
- **High Surge Current Capability**
- **Fast Switching Speeds**
- **Low Forward Voltage Drop**

mechanical data

These devices are in precision welded, hermetically sealed enclosures. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate unit weight is 1.8 grams.

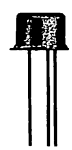


*THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

*THE GATE TERMINAL IS CONNECTED TO A P REGION.

*ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings over operating case temperature range (unless otherwise noted)

	2N3555	2N3556	2N3557	2N3558	UNIT
Continuous Forward Blocking Voltage, V_{FR} (See Note 1)	30	60	100	200	v
Peak Forward Blocking Voltage (See Note 1)	30	60	100	200	v
Continuous Reverse Blocking Voltage, V_{RO} (See Note 2)	30	60	100	200	v
Peak Reverse Blocking Voltage (See Note 2)	30	60	100	200	v
Continuous or RMS Anode Forward Current at (or below) 100°C Case Temperature (See Note 3)	1.6				a
Average Anode Forward Current (180° Conduction Angle) at (or below) 100°C Case Temperature (See Note 4)	1				a
Peak Anode Surge Current (See Note 5)	18				a
Peak Gate Reverse Voltage	8				v
Peak Gate Forward Current (Pulse width ≤ 8 msec)	250				ma
Average Gate Power Dissipation	100				mw
Operating Case Temperature Range	−65 to +150				°C
Storage Temperature Range	−65 to +200				°C

NOTES:
1. These values apply when the gate-cathode resistance $R_{GK} \leq 1\ k\Omega$.
2. These values apply when the gate-cathode resistance $R_{GK} = \infty$.
3. This value applies for continuous d-c or single-phase, 60-cps, half-sine-wave operation with resistive load. Above 100°C, derate according to Figure 13.
4. This value may be applied continuously under single-phase, 60-cps, half-sine-wave operation with resistive load. Above 100°C, derate according to Figure 13.
5. This value applies for one 60-cps half sine wave when the device is operating at (or below) rated values of peak reverse blocking voltage and anode forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

*Indicates JEDEC registered data

TYPES 2N3555, 2N3556, 2N3557, 2N3558
P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

***electrical characteristics at 25°C case temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{FR}	Static Anode Forward Blocking Current	V_{AK} = Rated V_{FR}, R_{GK} = 1 kΩ			20	na
		V_{AK} = Rated V_{FR}, R_{GK} = 1 kΩ, T_C = 150°C			20	μa
I_{RO}	Static Anode Reverse Blocking Current	V_{KA} = Rated V_{RO}, I_G = 0			0.1	μa
		V_{KA} = Rated V_{RO}, I_G = 0, T_C = 150°C			100	μa
I_{GKO}	Gate Reverse Current	V_{KG} = 5 v, I_A = 0			–0.1	μa
I_{GT}	Gate Trigger Current	V_{AA} = 5 v, R_L = 12 Ω, $PW_G \geq$ 10 μsec		5	20	μa
V_{GT}	Gate Trigger Voltage	V_{AA} = 5 v, R_L = 12 Ω, $PW_G \geq$ 10 μsec, T_C = –65°C			0.9	v
		V_{AA} = 5 v, R_L = 12 Ω, $PW_G \geq$ 10 μsec		0.55	0.7	v
		V_{AA} = 5 v, R_L = 12 Ω, $PW_G \geq$ 10 μsec, T_C = 150°C	0.2			v
I_{HR}	Holding Current	R_{GK} = 1 kΩ, R_L = 2 kΩ		1.2	3	ma
		R_{GK} = 1 kΩ, R_L = 2 kΩ, T_C = –65°C			4	ma
V_F	Forward Voltage	I_F = 1.6 a, $R_{GK} \geq$ 1 kΩ, See Note 6			1.4	v
dv/dt	Critical Rate of Anode Voltage Rise	V_{KG} = 1 v		400		v/μsec

switching characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3558 TYP	UNIT
t_{on}	Turn-On Time	V_{AA} = 200 v, R_L = 2.2 kΩ, R_G = 100 Ω, V_{in} = 3 v, See Fig. 14	0.3	μsec
t_{off}	Commutating Turn-Off Time	V_{AA} = 50 v, R_L = 140 Ω, 1N645 between gate and cathode, See Fig 15	3.5	μsec

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	35	C°/w

NOTE 6: The initial instantaneous value is measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.

*Indicates JEDEC registered data (typical data excluded).

ANODE CHARACTERISTICS

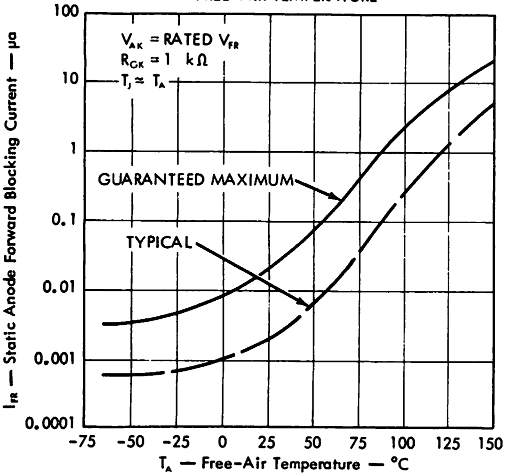


FIGURE 1

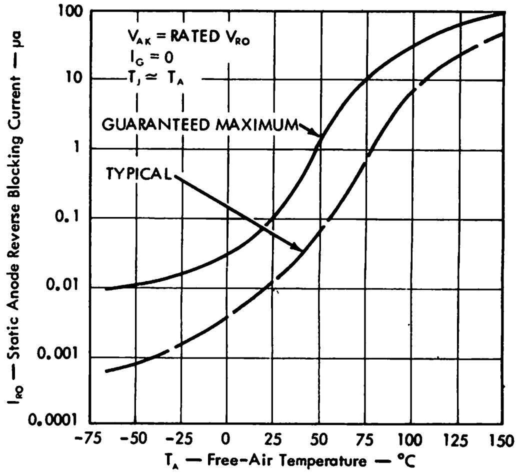


FIGURE 2

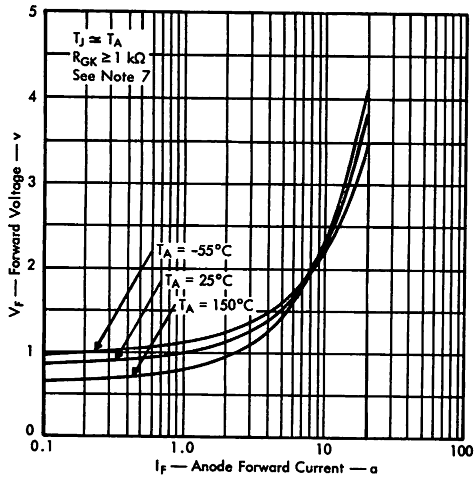


FIGURE 3

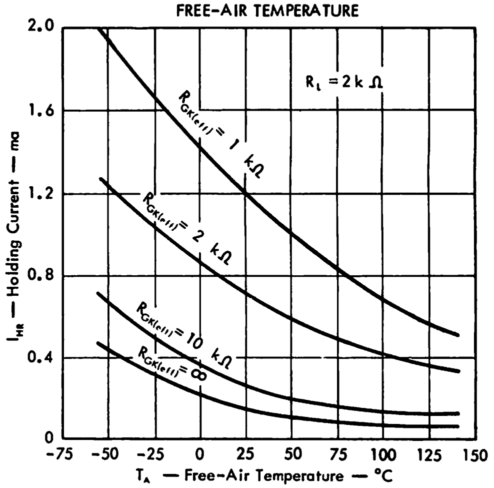


FIGURE 4

NOTE 7: These parameters were measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.

GATE CHARACTERISTICS

GATE TRIGGER CURRENT
vs
FREE-AIR TEMPERATURE

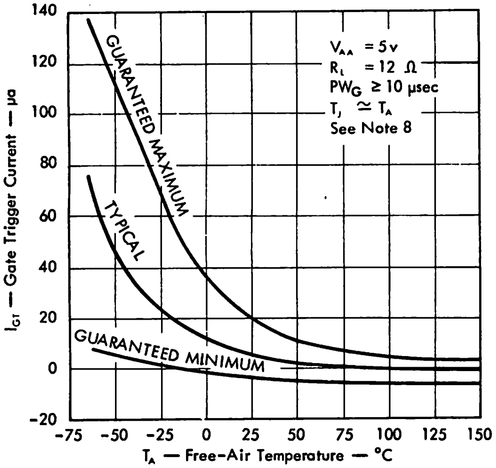


FIGURE 5

GATE TRIGGER VOLTAGE
vs
FREE-AIR TEMPERATURE

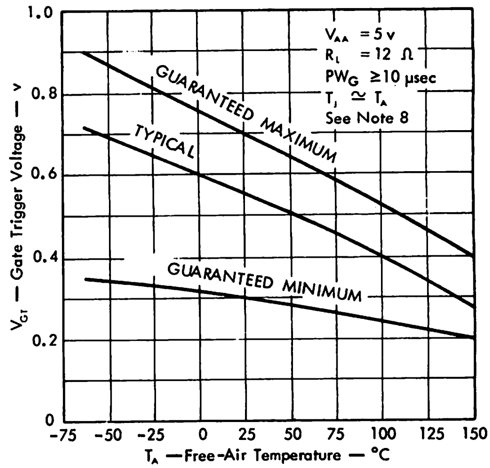


FIGURE 6

TYPICAL GATE - CATHODE VOLTAGE
vs
GATE FORWARD CURRENT

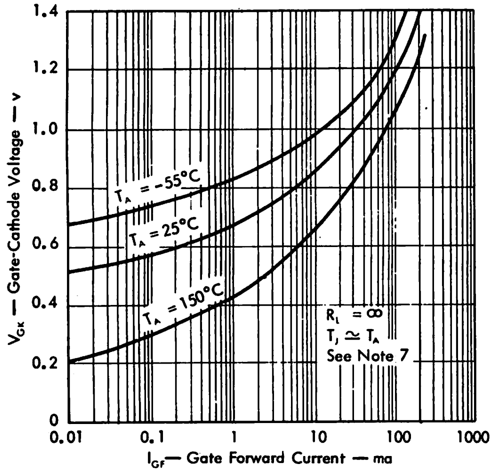


FIGURE 7

TYPICAL GATE TRIGGER VOLTAGE
vs
GATE PULSE WIDTH

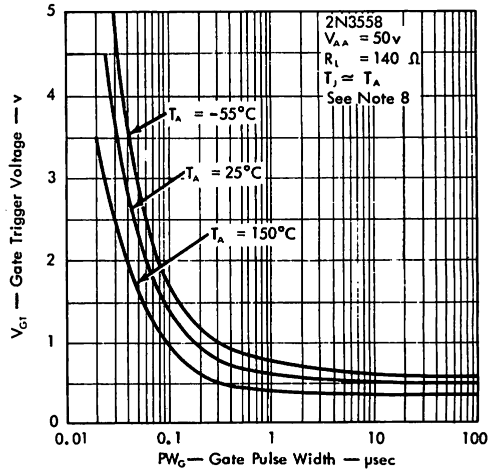


FIGURE 8

NOTES: 7. These parameters were measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.
8. These parameters were measured using single pulse techniques. Anode-pulse width = 300 μsec, Duty Cycle = 0.

TYPICAL SWITCHING CHARACTERISTICS, $T_A = 25°C$

TURN-ON TIME
vs
GATE INPUT PULSE AMPLITUDE

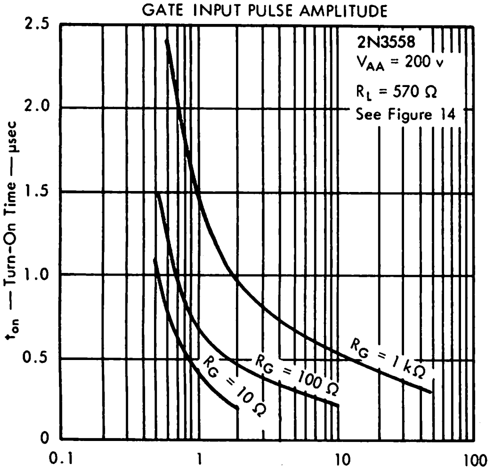


FIGURE 9

TURN-ON TIME
vs
ANODE SUPPLY VOLTAGE

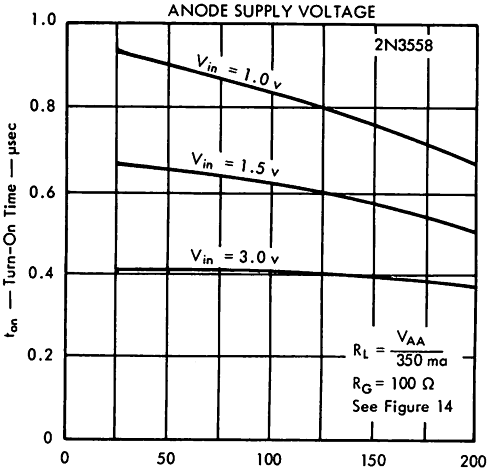


FIGURE 10

TURN-ON TIME
vs
ANODE FORWARD CURRENT

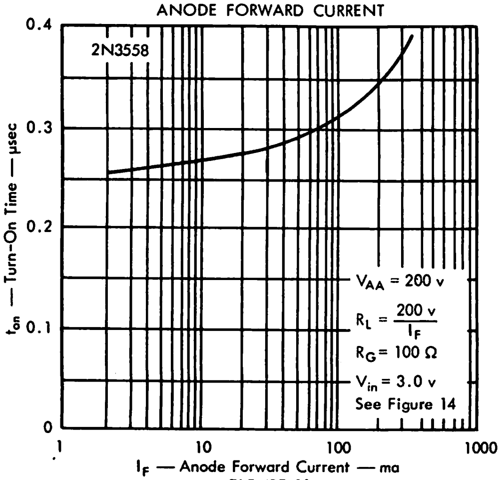


FIGURE 11

COMMUTATING TURN-OFF TIME
vs
ANODE FORWARD CURRENT

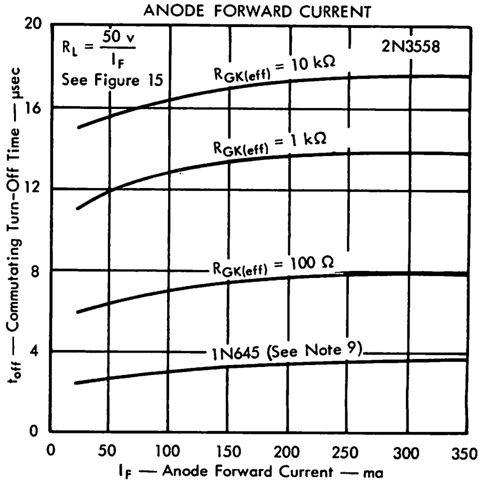


FIGURE 12

NOTE 9: The commutating turn-off time of the 2N3555 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Figure 12. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Figure 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

ANODE FORWARD CURRENT DERATING CURVE

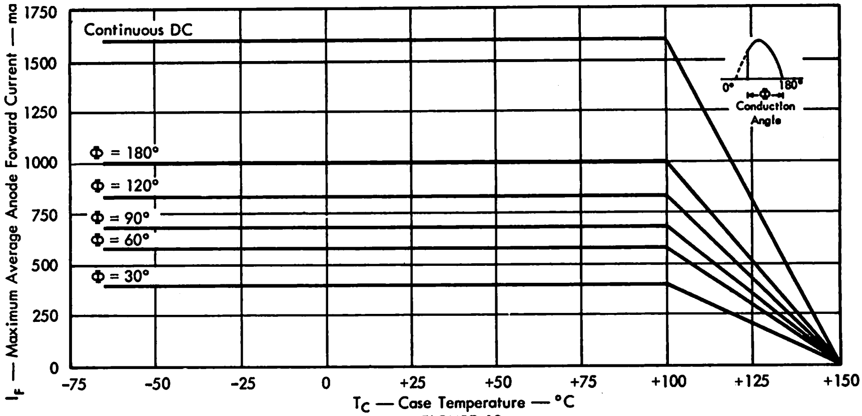


FIGURE 13

PARAMETER MEASUREMENT INFORMATION

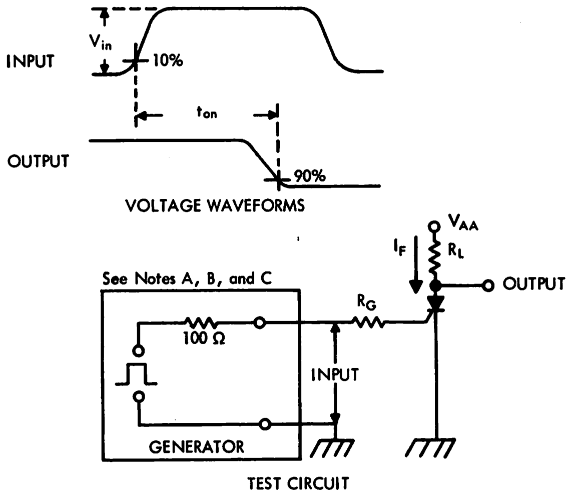


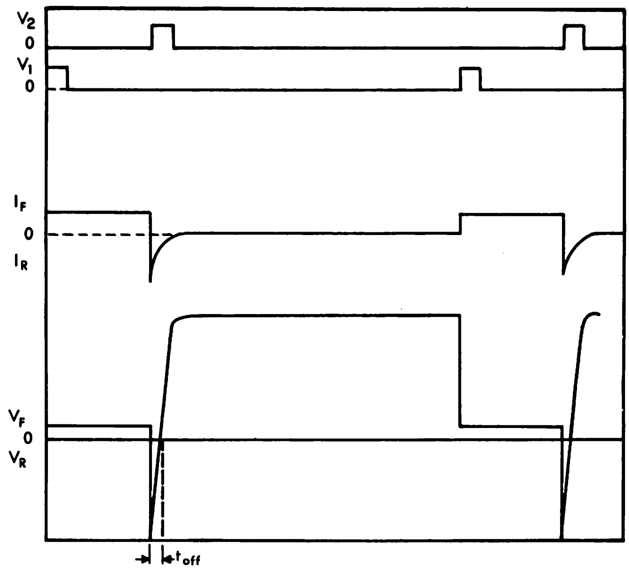
FIGURE 14 — TURN-ON TIME

NOTES: A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.

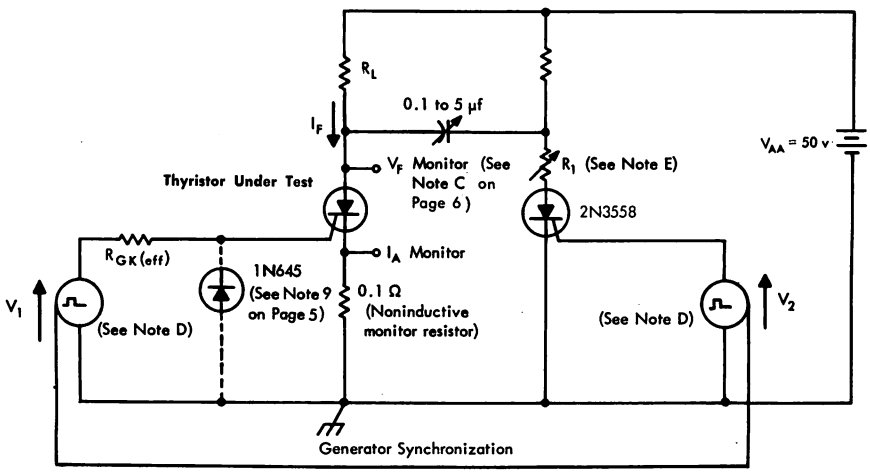
B. The input waveform of Figure 14 has the following characteristics: $t_r \leq 40$ nsec, PW $\geq$ device turn-on time at the operating point.

C. Waveforms are maintained on an oscilloscope with following characteristics: $t_r \leq 14$ nsec, $R_{in} \geq 10$ MΩ, $C_{in} \leq 12$ pf.

PARAMETER MEASUREMENT INFORMATION



WAVEFORMS



TEST CIRCUIT

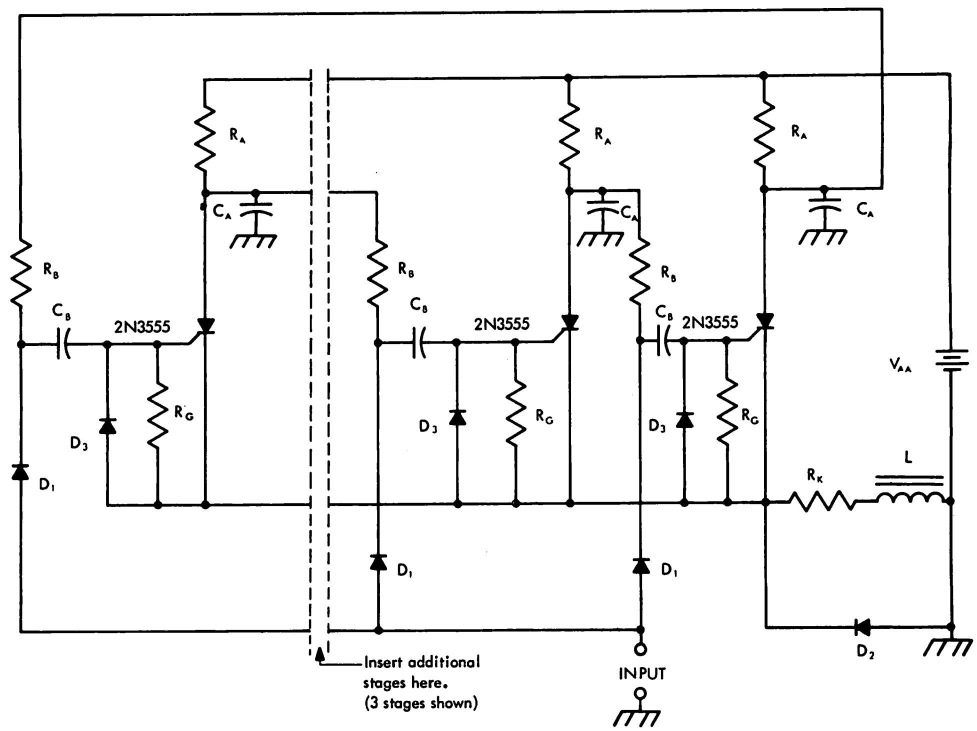
FIGURE 15 — COMMUTATING TURN-OFF TIME

D. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: PW = 50 to 300 μsec, Duty Cycle = 1%. The pulse widths of V_1 and V_2 are ≥ 10 μsec.

E. Resistor R_1 is adjusted for $I_R = 1$ a.

TYPICAL APPLICATION DATA

20-kc RING COUNTER



CIRCUIT PERFORMANCE CHARACTERISTICS FOR 10-STAGE OPERATION AT $T_A = 25°C$

a. V_{AA} Range for 20-kc Operation: 6 v to 30 v (Rated V_{FR})
b. V_{AA} Range for 10-kc Operation: 2.75 v to 30 v (Rated V_{FR})
c. Range of Input Amplitude for 10-kc operation: 3 v to 8 v

CIRCUIT COMPONENT INFORMATION

R_A : 330 Ω	C_A : 0.06 μf ± 20%
R_B : 33 k Ω	C_B : 0.001 μf ± 20%
R_G : 1 k Ω	L : 40 mh
R_K : 33 Ω	D_1, D_2, and D_3 : 1N914

All Resistors, ± 5% tolerance, ½ w

P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

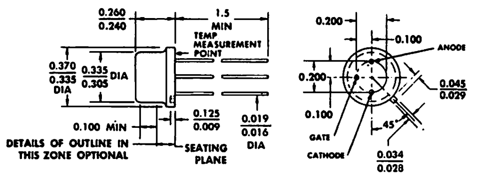
TYPES 2N3559, 2N3560, 2N3561, 2N3562
BULLETIN NO. DL-S 645906, AUGUST 1964

1 AMP AVG — 30 to 200 VOLTS — 200 μa GATE SENSITIVITY
ALL PLANAR, OXIDE-PASSIVATED JUNCTIONS
NO SOLDER OR FLUXES

- **High Operating Temperatures**
- **High Surge Current Capability**
- **Fast Switching Speeds**
- **Low Forward Voltage Drop**

mechanical data

These devices are in precision welded, hermetically sealed enclosures. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate unit weight is 1.8 grams.

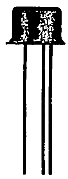


*THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

*THE GATE TERMINAL IS CONNECTED TO A P REGION.

*ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



*absolute maximum ratings over operating case temperature range (unless otherwise noted)

	2N3559	2N3560	2N3561	2N3562	UNIT
Continuous Forward Blocking Voltage, V_{FR} (See Note 1)	30	60	100	200	v
Peak Forward Blocking Voltage (See Note 1)	30	60	100	200	v
Continuous Reverse Blocking Voltage, V_{RO} (See Note 2)	30	60	100	200	v
Peak Reverse Blocking Voltage (See Note 2)	30	60	100	200	v
Continuous or RMS Anode Forward Current at (or below) 100°C Case Temperature (See Note 3)	1.6				a
Average Anode Forward Current (180° Conduction Angle) at (or below) 100°C Case Temperature (See Note 4)	1				a
Peak Anode Surge Current (See Note 5)	18				a
Peak Gate Reverse Voltage	8				v
Peak Gate Forward Current (Pulse width $\leq$ 8 msec)	250				ma
Average Gate Power Dissipation	100				mw
Operating Case Temperature Range	−65 to +150				°C
Storage Temperature Range	−65 to +200				°C

NOTES:
1. These values apply when the gate-cathode resistance $R_{GK} \leq 1\ k\Omega$.
2. These values apply when the gate-cathode resistance $R_{GK} = \infty$.
3. This value applies for continuous d-c or single-phase, 60-cps, half-sine-wave operation with resistive load. Above 100°C, derate according to Figure 13.
4. This value may be applied continuously under single-phase, 60-cps, half-sine-wave operation with resistive load. Above 100°C derate according to Figure 13.
5. This value applies for one 60-cps half sine wave when the device is operating at (or below) rated values of peak reverse blocking voltage and anode forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{FR}	Static Anode Forward Blocking Current	V_{AK} = Rated V_{FR}, $R_{GK} = 1\ k\Omega$			20	na
		V_{AK} = Rated V_{FR}, $R_{GK} = 1\ k\Omega$, $T_C = 150°C$			20	μa
I_{RO}	Static Anode Reverse Blocking Current	V_{KA} = Rated V_{RO}, $I_G = 0$			0.1	μa
		V_{KA} = Rated V_{RO}, $I_G = 0$, $T_C = 150°C$			100	μa
I_{GKO}	Gate Reverse Current	$V_{KG} = 5\ v$, $I_A = 0$			−0.1	μa
I_{GT}	Gate Trigger Current	$V_{AA} = 5\ v$, $R_L = 12\ \Omega$, $PW_G \geq 10\ \mu sec$		90	200	μa
V_{GT}	Gate Trigger Voltage	$V_{AA} = 5\ v$, $R_L = 12\ \Omega$, $PW_G \geq 10\ \mu sec$, $T_C = -65°C$			0.9	v
		$V_{AA} = 5\ v$, $R_L = 12\ \Omega$, $PW_G \geq 10\ \mu sec$		0.6	0.8	v
		$V_{AA} = 5\ v$, $R_L = 12\ \Omega$, $PW_G \geq 10\ \mu sec$, $T_C = 150°C$	0.2			v
I_{HR}	Holding Current	$R_{GK} = 1\ k\Omega$, $R_L = 2\ k\Omega$		1.8	5	ma
		$R_{GK} = 1\ k\Omega$, $R_L = 2\ k\Omega$, $T_C = -65°C$			8	ma
V_F	Forward Voltage	$I_F = 1.6\ a$, $R_{GK} \geq 1\ k\Omega$, See Note 6			1.4	v
I_{GQ}	Gate Turn-Off Current	$I_F = 200\ ma$ (See Note 7),		−40		ma
V_{GQ}	Gate Turn-Off Voltage	$V_{AA} \leq 100\ v$ (Not to exceed Rated V_{FR})		−4		v
dv/dt	Critical Rate of Anode Voltage Rise	$V_{KG} = 1\ v$		400		v/μsec

switching characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3562 TYP	UNIT
t_{on}	Turn-On Time	$V_{AA} = 200\ v$, $R_L = 2.2k\Omega$, $R_G = 100\Omega$, $V_{in} = 3\ v$, See Fig. 14	0.55	μsec
t_{off}	Commutating Turn-Off Time	$V_{AA} = 50\ v$, $R_L = 140\Omega$, 1N645 between gate and cathode, See Fig. 15	2.2	μsec

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	35	C°/w

NOTES: 6. The initial instantaneous value is measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.

7. Anode current not to exceed 200 ma for gate turn-off applications.

*Indicates JEDEC registered data (typical data excluded).

ANODE CHARACTERISTICS

STATIC ANODE FORWARD BLOCKING CURRENT vs FREE-AIR TEMPERATURE

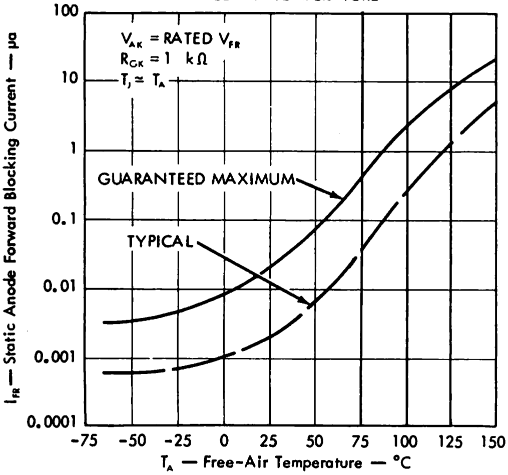


FIGURE 1

STATIC ANODE REVERSE BLOCKING CURRENT vs FREE-AIR TEMPERATURE

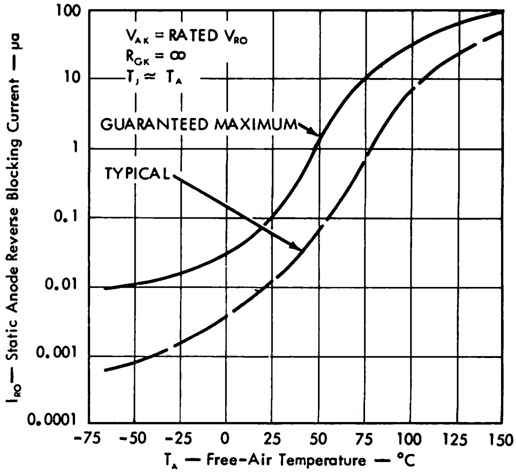


FIGURE 2

TYPICAL FORWARD VOLTAGE vs ANODE FORWARD CURRENT

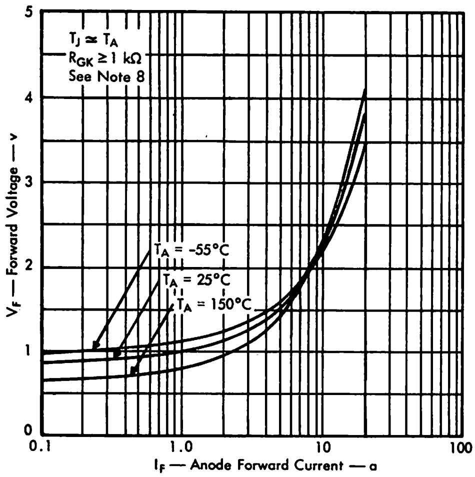


FIGURE 3

TYPICAL HOLDING CURRENT vs FREE-AIR TEMPERATURE

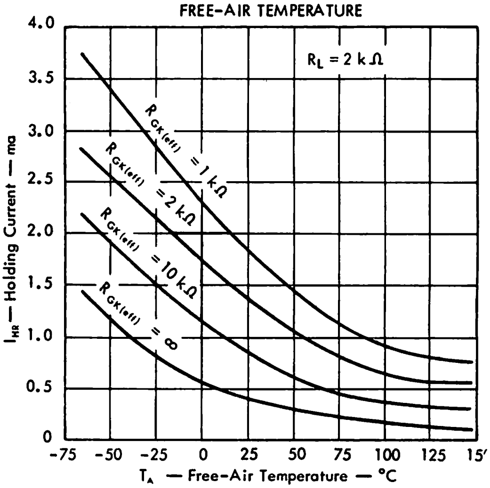


FIGURE 4

NOTE 8: These parameters were measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.

GATE CHARACTERISTICS

GATE TRIGGER CURRENT
vs
FREE-AIR TEMPERATURE

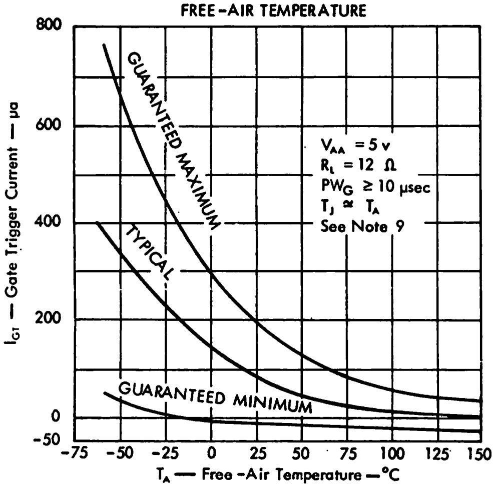


FIGURE 5

GATE TRIGGER VOLTAGE
vs
FREE-AIR TEMPERATURE

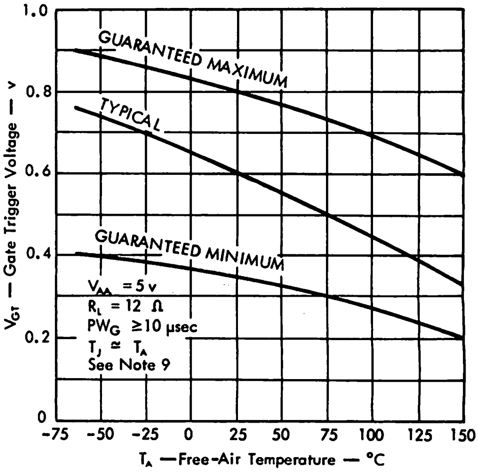


FIGURE 6

TYPICAL GATE - CATHODE VOLTAGE
vs
GATE FORWARD CURRENT

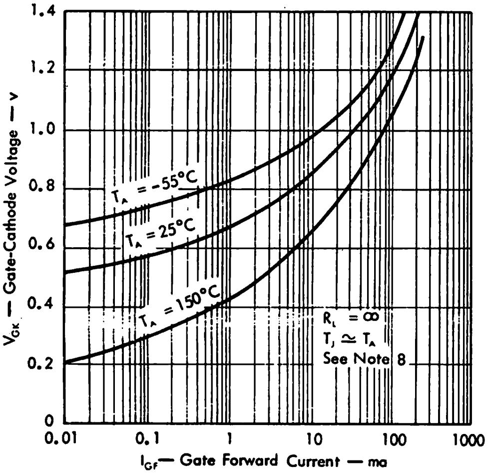


FIGURE 7

TYPICAL GATE TRIGGER VOLTAGE
vs
GATE PULSE WIDTH

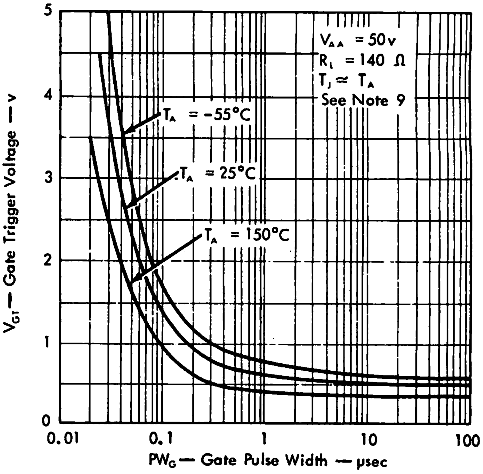


FIGURE 8

NOTES: 8. These parameters were measured using pulse techniques. Anode-pulse width = 300 μsec, PRR = 10 pps.

9. These parameters were measured using single pulse techniques. Anode-pulse width = 300 μsec, Duty Cycle = 0.

TYPICAL SWITCHING CHARACTERISTICS, $T_A = 25°C$

TURN-ON TIME
vs
GATE INPUT PULSE AMPLITUDE

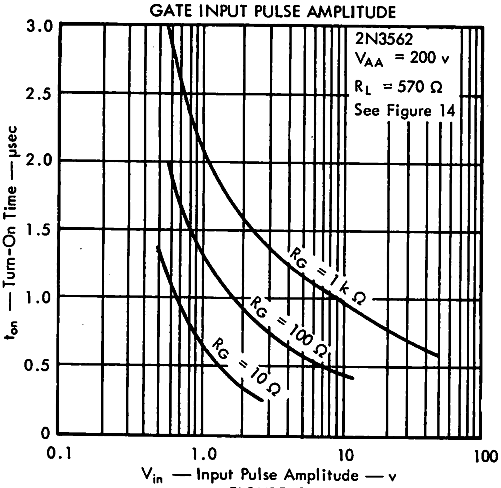


FIGURE 9

TURN-ON TIME
vs
ANODE SUPPLY VOLTAGE

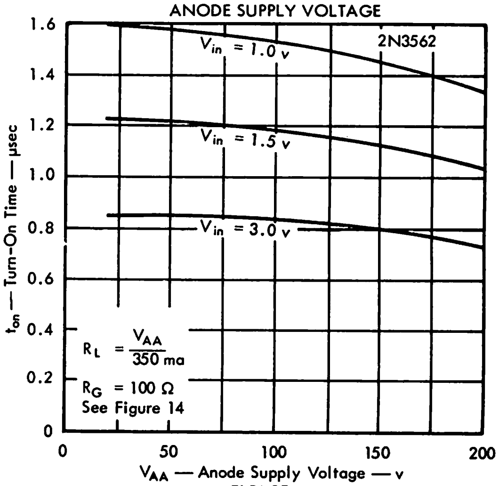


FIGURE 10

TURN-ON TIME
vs
ANODE FORWARD CURRENT

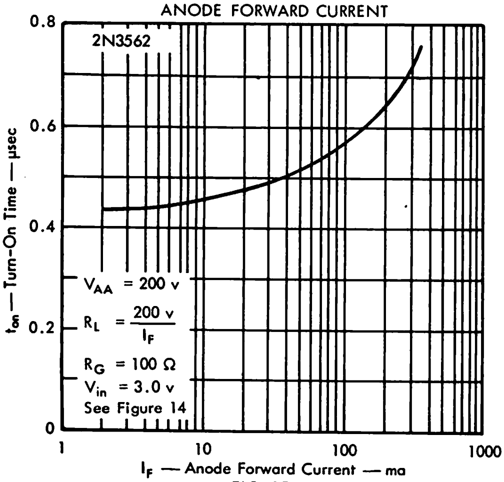


FIGURE 11

COMMUTATING TURN-OFF TIME
vs
ANODE FORWARD CURRENT

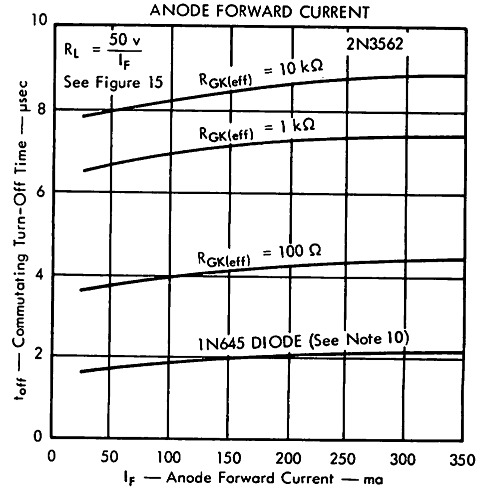


FIGURE 12

NOTE 10: The commutating turn-off time of the 2N3559 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Fig. 12. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Fig. 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

ANODE FORWARD CURRENT DERATING CURVE

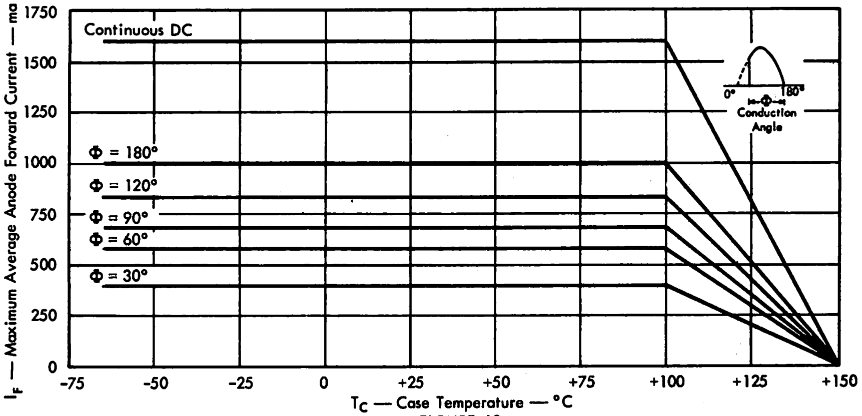
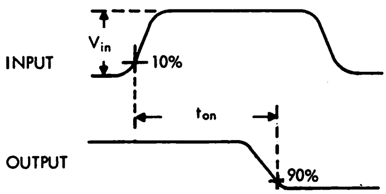
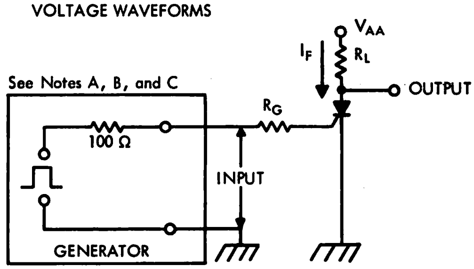


FIGURE 13

PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS



TEST CIRCUIT

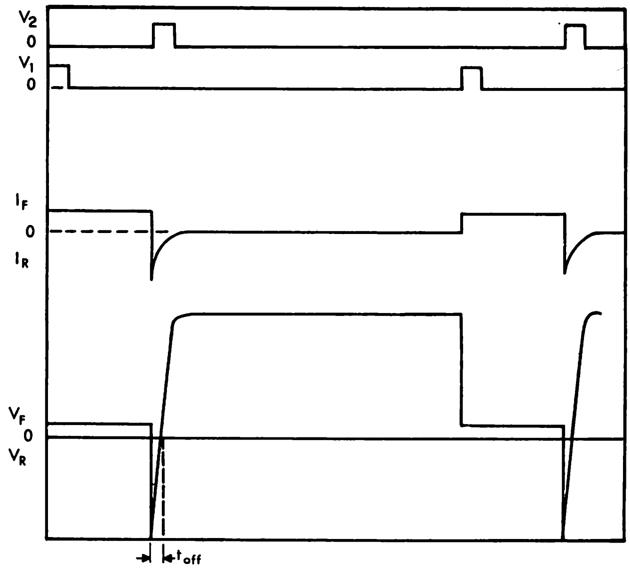
FIGURE 14 — TURN-ON TIME

NOTES: A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.

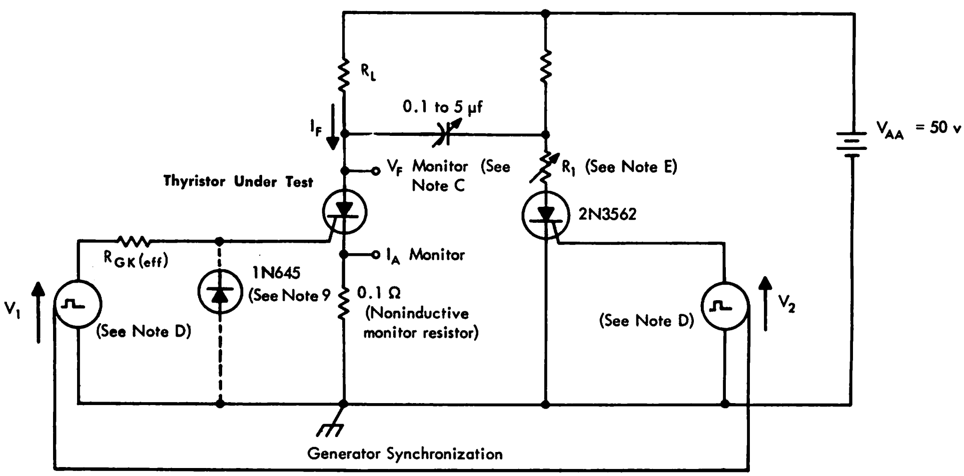
B. The input waveform of Figure 14 has the following characteristics: $t_r \leq 40$ nsec, PW $\geq$ device turn-on time at the operating point.

C. Waveforms are monitored on an oscilloscope with following characteristics $t_r \leq 14$ nsec, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 12$ pf.

PARAMETER MEASUREMENT INFORMATION



WAVEFORMS



TEST CIRCUIT

FIGURE 15 — COMMUTATING TURN-OFF TIME

D. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: PW = 50 to 300 µsec, duty cycle = 1%. The pulse widths of V_1 and V_2 are $\geq$ 10 µsec.

E. Resistor R_1 is adjusted for $I_R = 1$ a.

TYPICAL GATE TURN-OFF CHARACTERISTICS

The 2N3559 series thyristors exhibit gate-turn-off gain, in addition to the standard controlled switch characteristics. Figure 16 shows the typical gate-turn-off gain as a function of anode current. This characteristic offers increased flexibility in the design of pulse-width modulators, pulse-forming networks, static switches, choppers, bistable circuits and inverters.

TYPICAL GATE-TURN-OFF GAIN
vs
ANODE FORWARD CURRENT

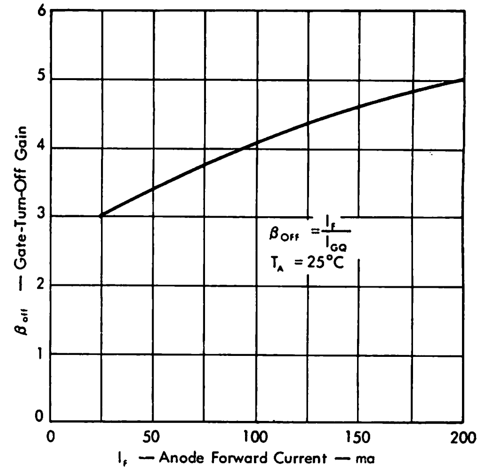
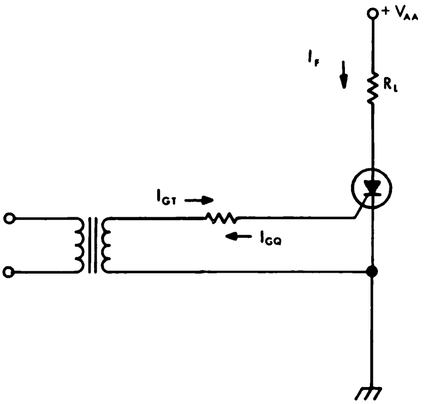
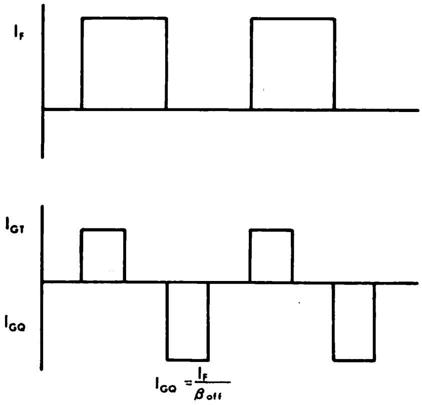


FIGURE 16



TYPICAL GATE-TURN-OFF CIRCUIT



TYPICAL WAVEFORMS

Improved turn-off time may be realized using the gate-turn-off method. A combination of gate-turn-off and standard commutating turn-off will further improve the turn-off time. For applications requiring a guaranteed β_{off}, contact your nearest TI Sales Office for information on special types.

TYPES 2N5273, 2N5274, 2N5275
SILICON BIDIRECTIONAL TRIODE THYRISTORS

TYPES 2N5273, 2N5274, 2N5275
BULLETIN NO. DL-S 6810499, MARCH 1968

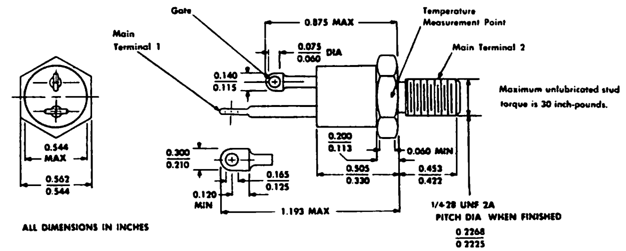
FORMERLY L140A, L140B, L140C

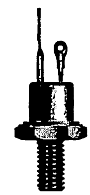
- HIGH TEMPERATURE • HIGH CURRENT • HIGH VOLTAGE
- GATED, SYMMETRICAL SWITCHES
- 200, 400, AND 600 VOLTS
- 25 AMPS RMS

description

The 2N5273 through 2N5275 are bidirectional triode thyristors (triacs) which may be triggered from the off-state to the on-state by either polarity of gate signal with Main Terminal 2 positive, or by a negative gate signal with Main Terminal 2 negative.

*mechanical data





*ALL JEDEC TO-48 DIMENSIONS AND NOTES ARE APPLICABLE

*absolute maximum ratings over operating case temperature range (unless otherwise noted)

	2N5273	2N5274	2N5275	UNIT
Continuous Off-State Voltage, V_D (See Note 1)	200	400	600	V
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	200	400	600	V
Full-Cycle RMS On-State Current at (or below) 60°C Case Temperature, $I_{T(rms)}$ (See Note 2)		25		A
Peak On-State Surge Current, I_{TSM} (See Note 3)		400		A
Peak Gate Voltage, V_{GM}		±10		V
Peak Gate Current, I_{GM}		±2		A
Peak Gate Power Dissipation, P_{GM}, at (or below) 60°C Case Temperature (Pulse Width $\leq$ 200 μs)		10		W
Average Gate Power Dissipation, $P_{G(av)}$, at (or below) 60°C Case Temperature (See Note 4)		2		W
Operating Case Temperature Range		−40 to 125		°C
Storage Temperature Range		−65 to 150		°C
Terminal Temperature 1/16 Inch from Case for 10 Seconds		260		°C

NOTES: 1. These values apply bidirectionally when the resistance between the gate and Main Terminal 1, R_{G}, $\leq \infty$.
2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 60°C derate according to figure 2.
3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) the rated value of on-state current. Surge may be repeated after the device has returned to original thermal equilibrium. During the surge, gate control may be lost.
4. This value applies for a maximum averaging time of 16.6 ms.

*Indicates JEDEC registered data

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TYPES 2N5273, 2N5274, 2N5275
SILICON BIDIRECTIONAL TRIODE THYRISTORS

*electrical characteristics

PARAMETER		TEST CONDITIONS				TYPE	TYP	MAX	UNIT
I_{DRM}	Repetitive Peak Off-State Current	$V_{DRM} = \pm 200$ V,	$I_G = 0$,		$T_C = 125°C$	2N5273		±1	mA
		$V_{DRM} = \pm 400$ V,	$I_G = 0$,		$T_C = 125°C$	2N5274		±1	
		$V_{DRM} = \pm 600$ V,	$I_G = 0$,		$T_C = 125°C$	2N5275		±1	
I_{GTM}	Peak Gate Trigger Current	$V_{supply} = +12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$	ALL		+150	mA
		$V_{supply} = +12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$			−150	
		$V_{supply} = -12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$			−150	
V_{GTM}	Peak Gate Trigger Voltage	$V_{supply} = +12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$	ALL		+3.5	V
		$V_{supply} = +12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$			−3.5	
		$V_{supply} = -12$ V†,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 50\ \mu s$,	$T_C = -40°C$			−3.5	
I_H	Holding Current	$V_{supply} = \pm 12$ V†, Initiating $I_{TM} = \pm 500$ mA	$I_G = 0$,		$T_C = -40°C$	ALL	±12	±100	mA
I_L	Latching Current	$V_{supply} = \pm 12$ V†,	See Note 5,		$T_C = -40°C$	ALL	±23		mA
dV/dt	Critical Rate of Rise of Off-State Voltage	$V_{DRM} = \pm 200$ V,	$I_G = 0$,		$T_C = 125°C$	2N5273	300		V/μs
		$V_{DRM} = \pm 400$ V,	$I_G = 0$,		$T_C = 125°C$	2N5274	300		
		$V_{DRM} = \pm 600$ V,	$I_G = 0$,		$T_C = 125°C$	2N5275	300		
V_{TM}	Peak On-State Voltage	$I_{TM} = \pm 35$ A,	$I_G = 150$ mA, See Note 6,		$T_C = 25°C$	ALL		±1.7	V

†The supply voltage is called positive when it causes Main Terminal 2 to be positive with respect to Main Terminal 1.

NOTES: 5. The triacs are triggered by a 15-V (open-circuit amplitude) pulse supplied by a generator with the following characteristics: $R_G = 100\ \Omega$, $t_p = 50\ \mu s$, $t_r \leq 15$ ns, $t_f \leq 15$ ns, PRR = 1 kHz.

6. The initial instantaneous value is measured using pulse techniques. $t_p \leq 1$ ms, duty cycle $\leq 2\%$.

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.75	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

*Indicates JEDEC registered data (typical values excluded)

switching characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_{gt}	Gate-Controlled Turn-On Time	$V_{supply} = 25$ V, $R_L = 25\ \Omega$, $R_{G(off)} = 60\ \Omega$, $V_{in} = 18$ V, See Figure 1	0.3	μs

PARAMETER MEASUREMENT INFORMATION

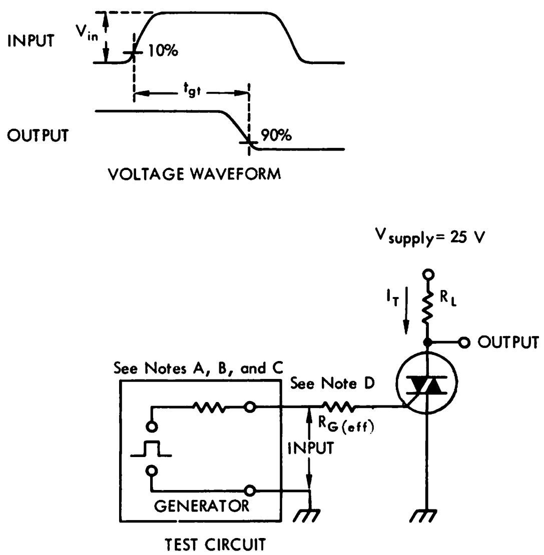


FIGURE 1 — GATE-CONTROLLED TURN-ON TIME

NOTES:
A. V_{in} is measured with gate terminal open.
B. The input waveform of figure 1 has the following characteristics: $t_r \leq 40$ ns, $t_p \geq 20\ \mu s$.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 14$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 12$ pF.
D. $R_{G(off)}$ includes the total resistance of the generator and the external resistor.

THERMAL INFORMATION

RMS ON-STATE CURRENT DERATING CURVE

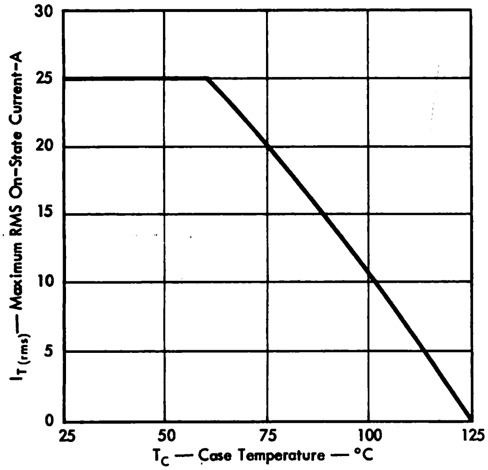


FIGURE 2

MAXIMUM AVERAGE POWER DISSIPATED
vs
RMS ON-STATE CURRENT

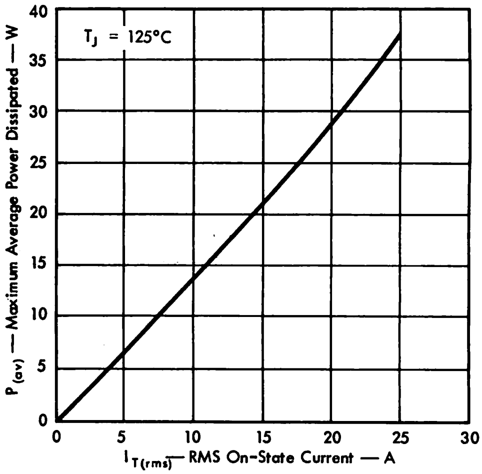


FIGURE 3

TYPICAL HEAT-SINK AREA
vs
CASE-TO-FREE-AIR THERMAL RESISTANCE
1/32"-THICK ALUMINUM HEAT SINK

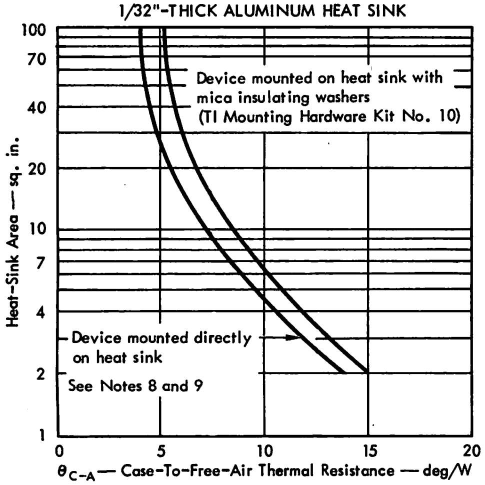


FIGURE 4

CASE-TO-MOVING-AIR THERMAL RESISTANCE
vs
COOLING-AIR VELOCITY

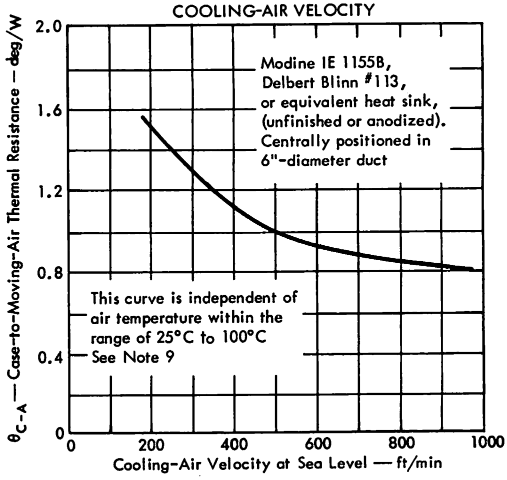


FIGURE 5

NOTES: 8. The thyristor is mounted in the center of a square heat sink vertically-positioned in still free air with both sides exposed. The heat-sink area is twice the area of one side.

9. θ_{C-A} includes the case-to-heat-sink thermal resistance, θ_{C-HS}, in addition to the heat-sink-to-air thermal resistance, θ_{HS-A}, and is defined by the equation $\theta_{C-A} = \theta_{C-HS} + \theta_{HS-A}$.

THERMAL INFORMATION

The minimum heat-sink requirements may be calculated for any on-state current, heat-sink combination by the following procedure:

1. Determine worst-case power dissipation from figure 3.
2. Calculate maximum allowable case-to-free-air thermal resistance by use of the equation:

$$\theta_{C\text{-}A} = \frac{T_J - T_A}{P_{(av)}} - \theta_{J\text{-}C}$$

where: T_J = Junction temperature
T_A = Free-air temperature
$P_{(av)}$ = Average power dissipation
(see figure 3 for worst-case values)
$\theta_{J\text{-}C}$ = Junction-to-case thermal resistance = 1.75 deg/W maximum.

3. If possible, determine area of heat sink from figure 4. If figure 4 cannot be used, a forced-air-cooling heat-sink system must be used, see figure 5.

EXAMPLE NO. 1

Determine minimum size of 1/32″-thick aluminum heat sink for safe operation of the thyristor at an rms current of 10 A, with device mounted directly on heat sink.

Given: Maximum T_J = 125°C
T_A = 35°C
$\theta_{J\text{-}C}$ = 1.75 deg/W

Solution: From figure 3, $P_{(av)}$ = 13 W for 10 A rms. Using the equation of step 2 above:

$$\theta_{C\text{-}A} = \frac{125°C - 35°C}{13\,W} - 1.75\ \text{deg/W} = 5.1\ \text{deg/W}$$

Figure 4 is applicable and shows that for $\theta_{C\text{-}A}$ of 5.1 deg/W, the area is 24 sq. in. The minimum dimensions of the sides should be:

$$\sqrt{\frac{\text{area}}{2}} \times \sqrt{\frac{\text{area}}{2}} = \sqrt{\frac{24}{2}} \times \sqrt{\frac{24}{2}} = 3.5'' \times 3.5''$$

EXAMPLE NO. 2

Determine minimum heat sink requirements for safe operation of the thyristor at an rms current of 25 A.

Given: Maximum T_J = 125°C
T_A = 25°C
$\theta_{J\text{-}C}$ = 1.75 deg/W

Solution: From figure 5, $P_{(av)}$ = 37.5 W for 25 A rms. Using the equation of step 2 above:

$$\theta_{C\text{-}A} = \frac{125°C - 25°C}{37.5\ W} - 1.75\ \text{deg/W} = 0.92\ \text{deg/W}$$

Figure 5 is applicable and shows for $\theta_{C\text{-}A}$ = 0.92 deg/W, a Modine IE 1155B, Delbert Blinn #113 or equivalent heat sink should be used and be cooled by an air velocity of 630 ft/min.

TYPICAL CHARACTERISTICS

PEAK GATE TRIGGER CURRENT
vs
CASE TEMPERATURE

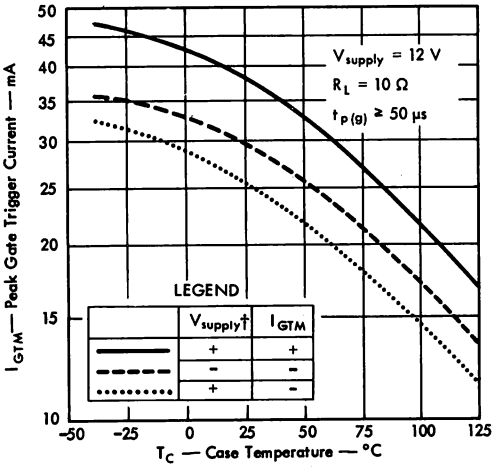


FIGURE 6

PEAK GATE TRIGGER VOLTAGE
vs
CASE TEMPERATURE

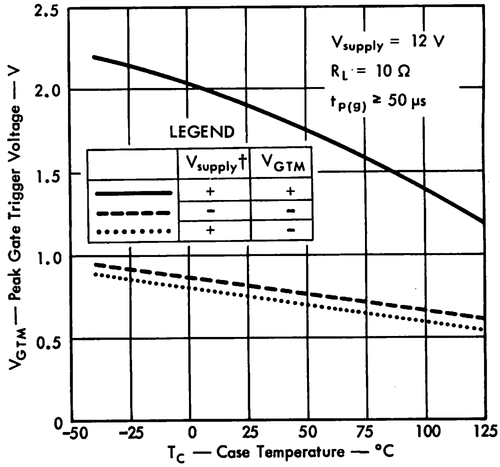


FIGURE 7

GATE VOLTAGE
vs
GATE CURRENT

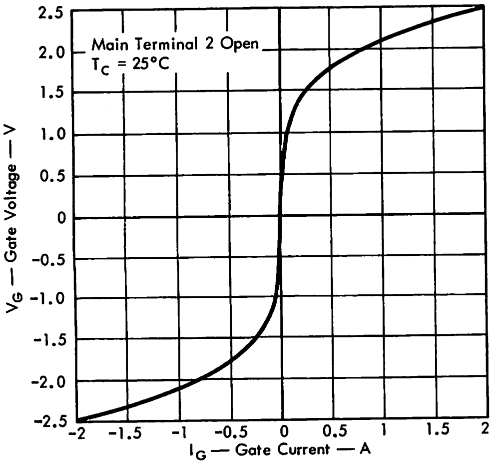


FIGURE 8

GATE-CONTROLLED TURN-ON TIME
vs
GATE CURRENT

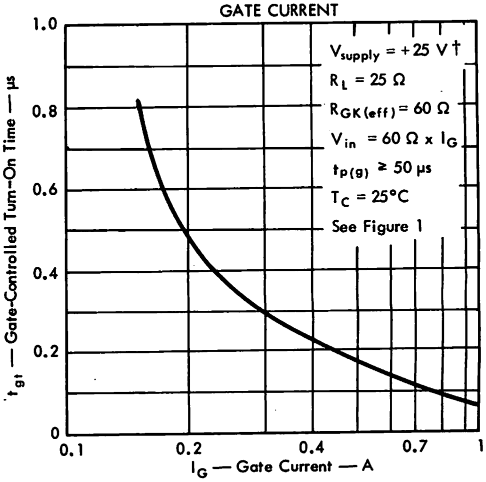


FIGURE 9

†The supply voltage is called positive when it causes Main Terminal 2 to be positive with respect to Main Terminal 1.

TYPICAL CHARACTERISTICS

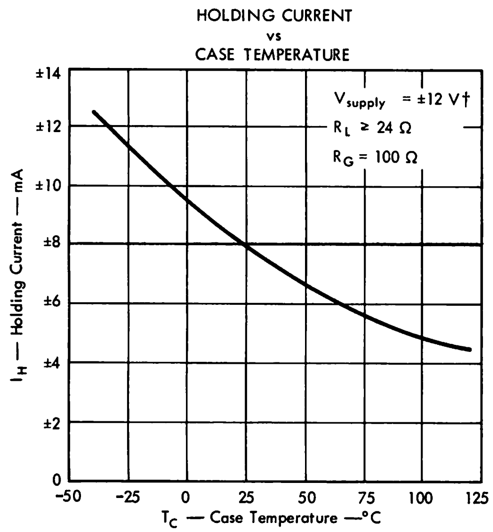


FIGURE 10

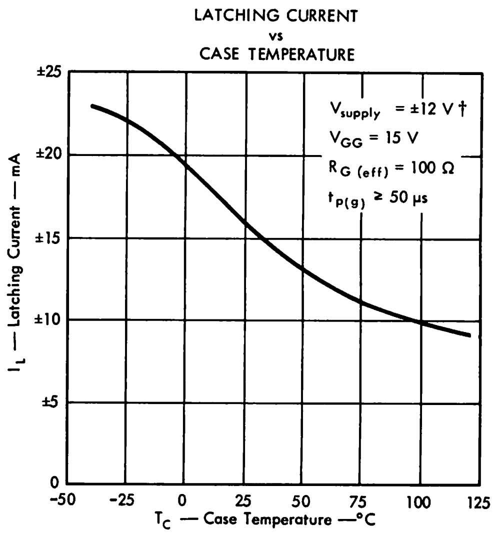


FIGURE 11

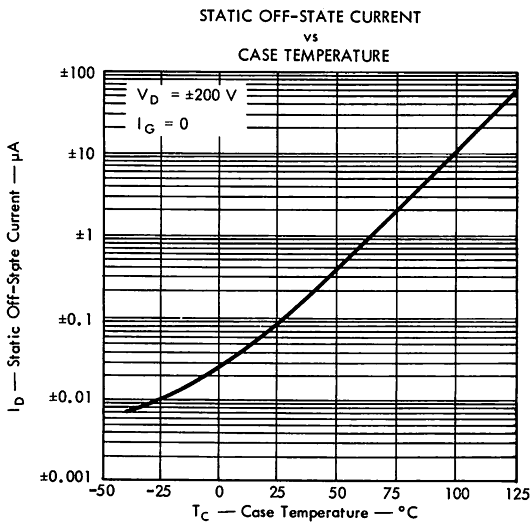


FIGURE 12

†The supply voltage is called positive when it causes Main Terminal 2 to be positive with respect to Main Terminal 1.

TYPICAL CHARACTERISTICS

PEAK ON-STATE VOLTAGE
vs
PEAK ON-STATE CURRENT

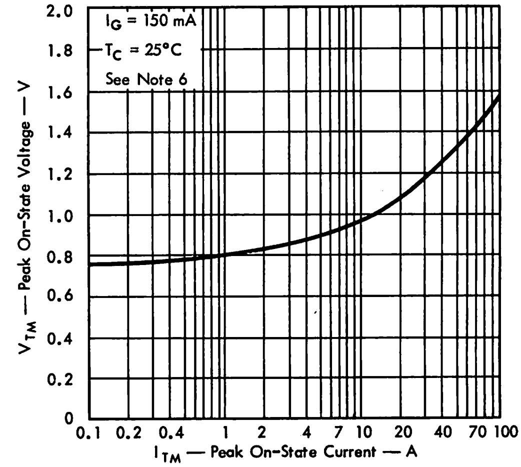
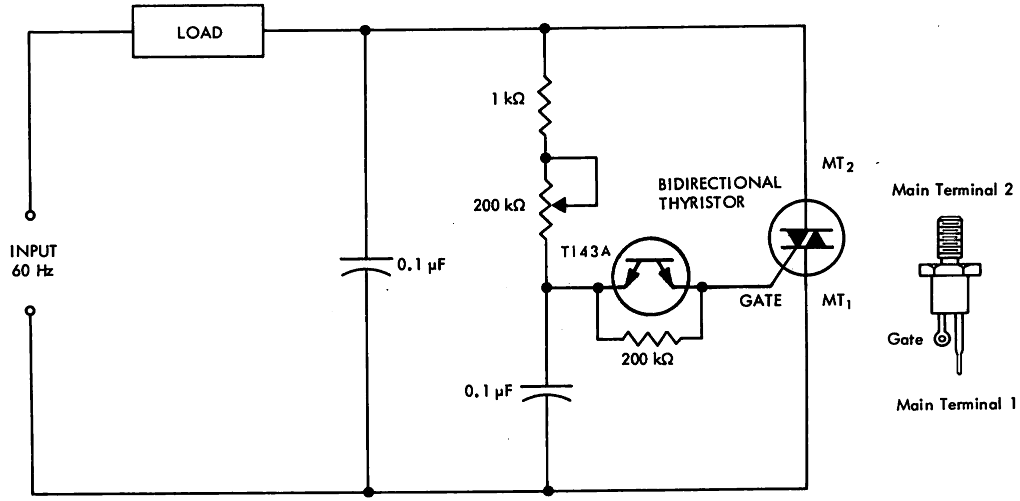


FIGURE 13

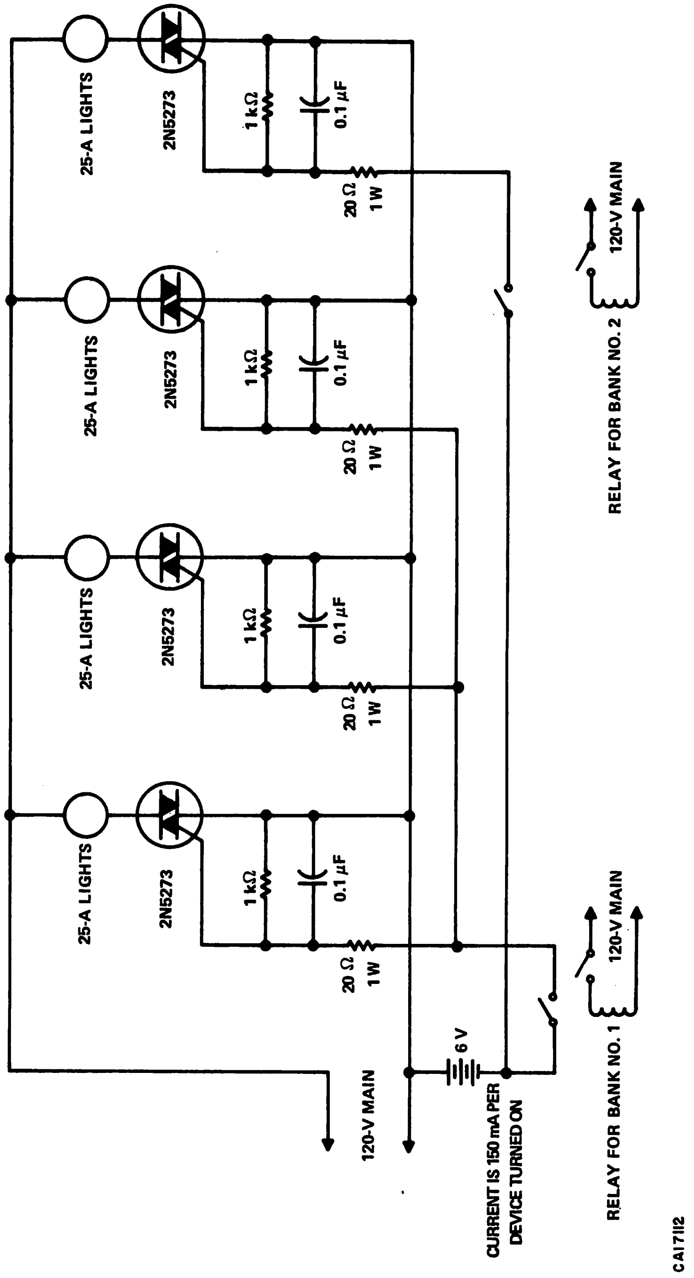
NOTE 6: The initial instantaneous value is measured using pulse techniques. $t_p \leq 1$ ms, duty cycle $\leq$ 2%.

TYPICAL APPLICATION DATA



SYMMETRICAL CONTROL CIRCUIT

TYPICAL APPLICATION DATA



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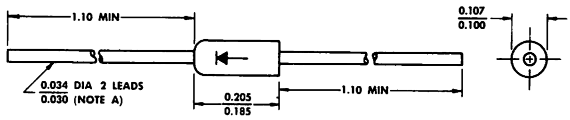
*mechanical data



NOTE A: The specified lead diameter applies in the zone between 0.050" and 1.00" from the rectifier body. Outside of this zone the lead diameter is not controlled.

ALL DIMENSIONS ARE IN INCHES

THE LEADS ARE ELECTRICALLY INSULATED FROM THE CASE

*absolute maximum ratings at specified ambient† temperature

		1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNIT
V_{RM}	Peak Reverse Voltage from −65°C to +175°C (See Note 1)	50	100	200	400	600	800	1000	v
V_R	Steady State Reverse Voltage from 25°C to 75°C	50	100	200	400	600	800	1000	v
I_O	Average Rectified Forward Current from 25°C to 75°C (See Notes 1 and 2)	1							a
$I_{FM(rep)}$	Repetitive Peak Forward Current, 10 cycles, at (or below) 75°C (See Note 3)	10							a
$I_{FM(surge)}$	Peak Surge Current, One Cycle, at (or below) 75°C (See Note 3)	30							a
$T_{A(opr)}$	Operating Ambient Temperature Range	−65 to +175							°C
T_{stg}	Storage Temperature Range	−65 to +200							°C
	Lead Temperature 3/8 Inch from Case for 10 Seconds	350							°C

NOTES: 1. These values may be applied continuously under single-phase, 60-cps, half-sine-wave operation with resistive load. Above 75°C derate I_O according to Figure 1.

2. This rectifier is a lead-conduction-cooled device. At (or above) ambient temperatures of 75°C, the lead temperature 3/8 inch from case must be no higher than 5°C above the ambient temperature for these ratings to apply.

3. These values apply for 60-cps half sine waves when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

* Indicates JEDEC registered data.

† The ambient temperature is measured at a point 2 inches below the device. Natural air cooling shall be used.

TYPES 1N4001 THROUGH 1N4007
DIFFUSED-JUNCTION SILICON RECTIFIERS

***electrical characteristics at specified ambient† temperature**

PARAMETER		TEST CONDITIONS	MAX	UNIT
I_R	Static Reverse Current	V_R = Rated V_R, T_A = 25°C	10	μa
		V_R = Rated V_R, T_A = 100°C	50	μa
$I_{R(avg)}$	Average Reverse Current	V_{RM} = Rated V_{RM}, I_O = 1 a, f = 60 cps, T_A = 75°C	30	μa
V_F	Static Forward Voltage	I_F = 1 a, T_A = 25°C to 75°C	1.1	v
$V_{F(avg)}$	Average Forward Voltage	V_{RM} = Rated V_{RM}, I_O = 1 a, f = 60 cps, T_A = 25°C to 75°C	0.8	v
V_{FM}	Peak Forward Voltage	V_{RM} = Rated V_{RM}, I_O = 1 a, f = 60 cps, T_A = 25°C to 75°C	1.6	v

*Indicates JEDEC registered data.

THERMAL INFORMATION

FORWARD CURRENT DERATING CURVE

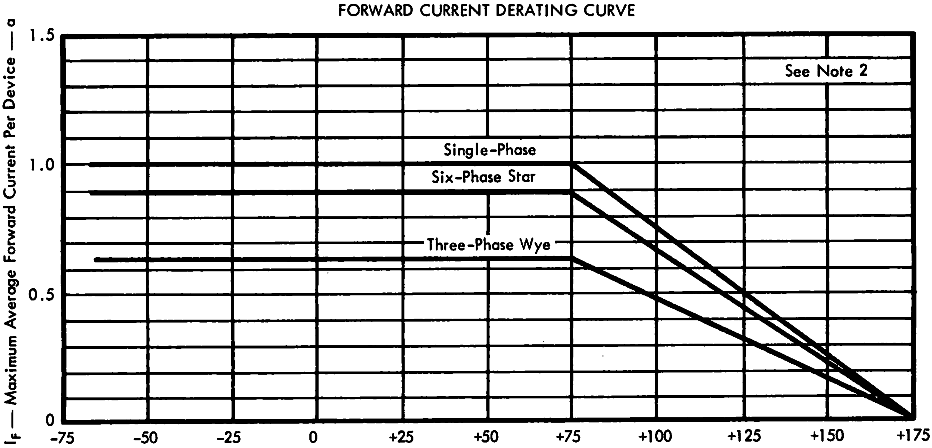


FIGURE 1

†The ambient temperature is measured at a point 2 inches below the device. Natural air cooling shall be used.

NOTE 2: This rectifier is a lead-conduction-cooled device. At (or above) ambient temperatures of 75°C, the lead temperature ⅜ inch from case must be no higher than 5°C above the ambient temperature for these ratings to apply.

TYPE LS 400
N-P-N PLANAR SILICON PHOTO DEVICE

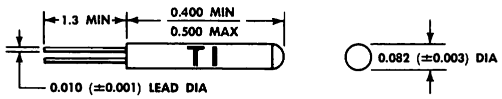
TYPE LS 400
BULLETIN NO. DL-S 682721, JUNE 1962
REVISED MAY 1968

For Application in:
- Character Recognition,
- Tape Read-out, Photo Switching,
- Proportional Control,
- Differential Amplifiers

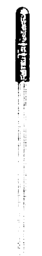
30 VOLTS 50 MILLIWATTS
Operation to 125° C
Designed for High Sensitivity, Fast Response

mechanical data

Hard glass, hermetically sealed case. Unit weight 0.1 gram.



DIMENSIONS ARE IN INCHES



ratings — conditions at 25°C (unless otherwise noted)

	symbol	min	typical	max	unit
Power dissipation	P			50	mw
Reverse voltage	V_R			30	v
Operating temperature	T_A			125	°C
Forward breakdown @ 100 μa	BV_F		8		v
Reverse breakdown @ 100 μa	BV_R		50		v

electrical specifications

	symbol	min	typical	max	unit
Light current @ 5 v*	I_L	1.0	3.0		ma
Dark current @ 30 v	I_d		0.01	0.025	μa
Dark current @ 30 v @ 125°C	I_d		10		μa
Rise time**	t_r		1.5		μs
Fall time**	t_f		15		μs
Light current sensitivity between 300 and 600 foot candles @ 5 v			7		μa/foot candle

*Measured with radiation of 9 mw/cm^2 in wavelengths from 0.7 to 1.0 microns.
**Measured with 1000 ohm series resistance in wavelengths from 0.7 to 1.0 microns.

TEXAS INSTRUMENTS
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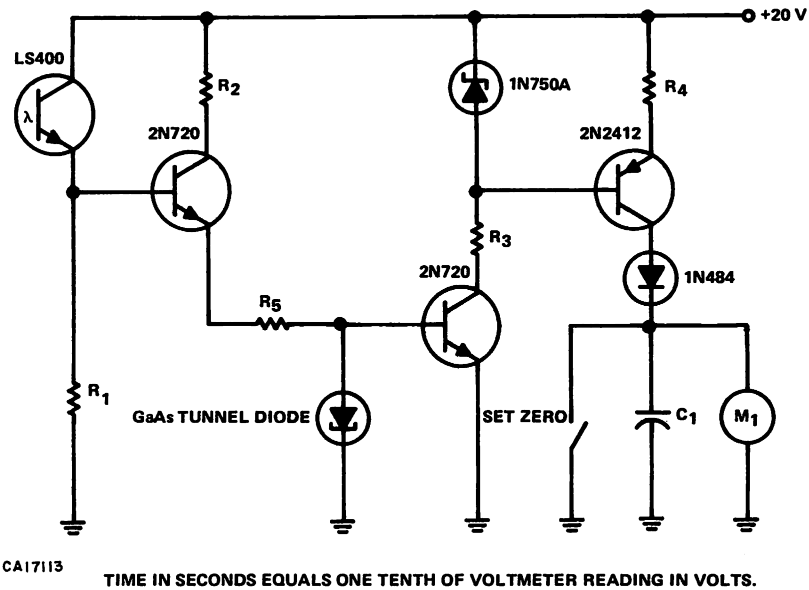
TYPE LS400
N-P-N PLANAR SILICON PHOTO DEVICE

TYPICAL APPLICATION DATA

LIGHT-PULSE-DURATION INDICATOR



TIME IN SECONDS EQUALS ONE TENTH OF VOLTMETER READING IN VOLTS.

TYPICAL PERFORMANCE	
Maximum Pulse Width	1 s
Minimum Pulse Width	1 μs
Operating Temperature Range	0°C to 70°C

CIRCUIT COMPONENT INFORMATION

R_1: 4.7 kΩ
R_2: 1 kΩ
R_3: 1.5 kΩ
R_4: 3.6 kΩ
R_5: 500 Ω

C_1: 100 μF, Mylar†

M_1: VTVM, 10-MΩ input impedance

†Trademark of E. I. duPont

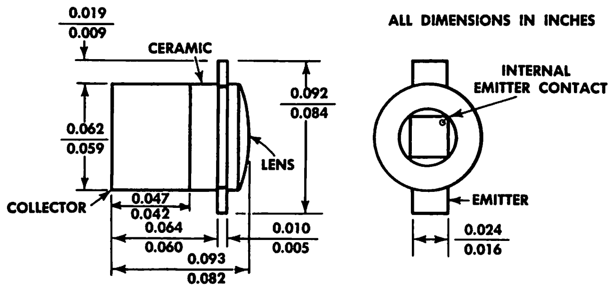
N-P-N PLANAR SILICON LIGHT SENSOR

TYPE LS 600
BULLETIN NO. DL-S 633820, JUNE 1963
REVISED OCTOBER 1965

MICRO SENSOR DESIGNED FOR HIGH-DENSITY MATRIX AND LINE READ-OUT EQUIPMENT

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Unique Package Design Allows for Assembly into Printed Circuit Boards
- Small Diameter Reduces Optical "Cross-Talk"
- Power Dissipation 50 mw

mechanical data



FOUR TIMES ACTUAL SIZE

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 v
Emitter-Collector Voltage	7 v
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mw
Operating Free-Air Temperature Range	−65°C to +125°C
Storage Temperature Range	−65°C to +150°C
Soldering Temperature (3 minutes)	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 0.5 mw/C°

TYPE LS 600
N-P-N PLANAR SILICON LIGHT SENSOR

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

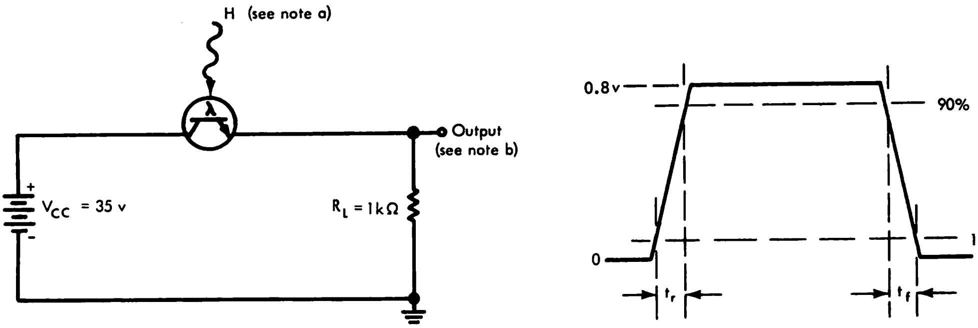
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_L	Light Current	$V_{CE} = 5$ v, $H = 20$ mw/cm^2 (See Note 2)	0.8	1.0		ma
I_D	Dark Current	$V_{CE} = 30$ v, $H = 0$		0.01	0.025	μa
I_D	Dark Current	$V_{CE} = 30$ v, $H = 0$ $T_A = 100°C$		10		μa
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_L = 0.4$ ma, $H = 20$ mw/cm^2 (See Note 2)		0.3		v

NOTE 2. Irradiance (H) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear filament bulb operating at a 2870°K color temperature.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 35$ v, $I_L = 800\ \mu$a	1.5	μsec
t_f	Fall Time	$R_L = 1\text{k}\Omega$, (See Figure 1)	15	μsec

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irridation is adjusted for $I_L = 800\mu$a.

b. Output waveform is monitored on an oscilloscope with the following characteristics:

$t_r \leq 12$ nsec; $R_{in} \geq 1$ megohm, $C_{in} \leq 20$ pf.

TYPE 1N2175
N-P-N DIFFUSED SILICON PHOTO-DUO-DIODE

TYPE 1N2175
BULLETIN NO. DL-S 623313, DECEMBER 1962
REPLACES BULLETIN NO. DL-S 1044, FEBRUARY 1959

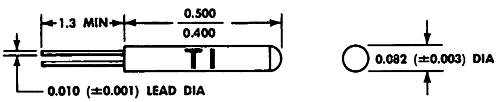
FOR APPLICATION IN:

Tape readout
Card readout
Light switching
Measurement indicators

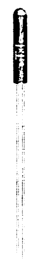
50 VOLTS
250 MILLIWATTS
Designed for 125°C operation
Unlimited altitude range

mechanical data

Hermetically sealed case. Unit weight 0.16 gram.



DIMENSIONS ARE IN INCHES



ratings

conditions	min	typical	max	unit
Bias Voltage @25°C			±50	v
Power Dissipation @25°C			250	mw
Operating Temperature	—65		125	°C
Storage Temperature	—65		125	°C

specifications

‡Dark Current @25°C @±50 v		0.01	0.5	μa
Dark Current @100°C @±50 v		20	100	μa
†Light Current @25°C @±10 v	100	200		μa
* Typical Photocurrent Rise Time		2		μs
Typical Photocurrent Fall Time		45		μs
Typical Sensitivity		22.3		μa/mw/cm²

NOTES:

‡ Dark current is leakage current across diode with no incident irradiation.

† Light current is measured for a value of irradiance. Irradiance = 9 mw/cm² in a wave length range of .7 to 1.1 microns as defined by a Corning CS 7-69 filter.

* Rise time is the time required for the photocurrent ** to rise from 10% to 90% of its final value after instantaneous application of excitation. Fall time is the time for the photocurrent to decay from 90% to 10% of its initial value after instantaneous removal of excitation.

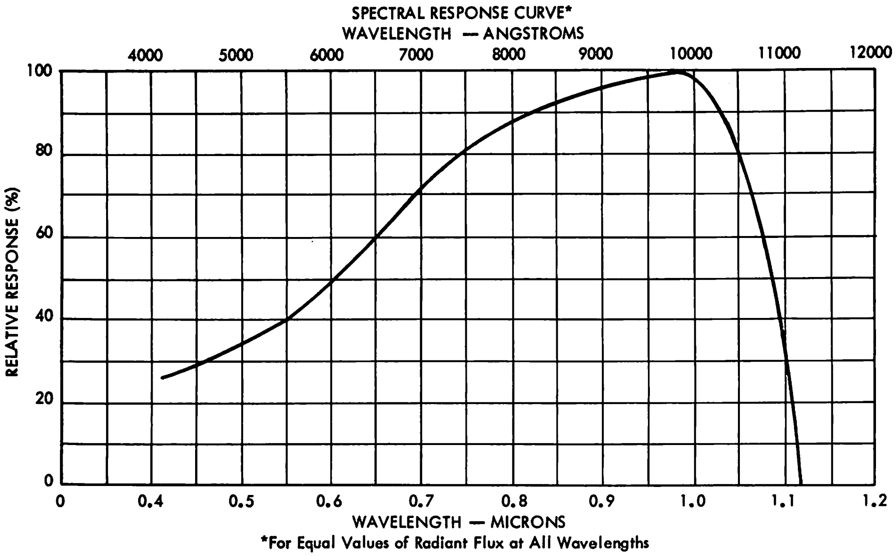
**Photocurrent is the difference between Light Current and Dark Current.

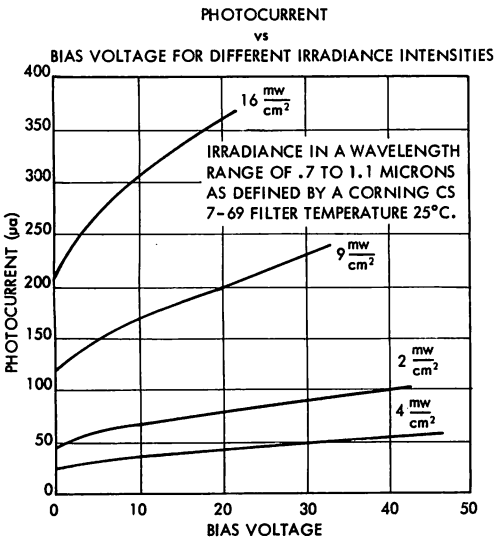
APPLICATION NOTES:

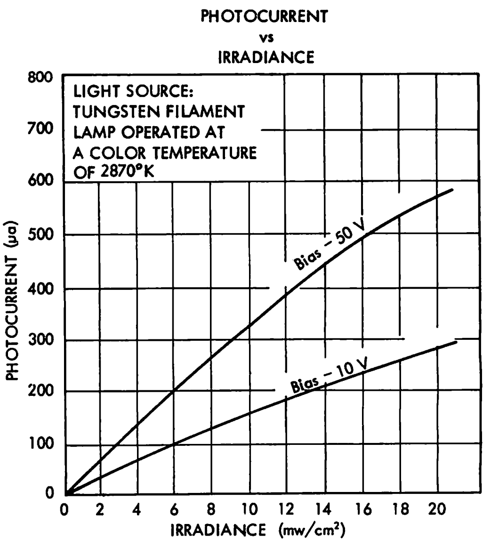
The 1N2175 is a subminiature symmetrically diffused silicon unit. The two junctions are symmetrical so either diode terminal can be biased positively or negatively. Because of this unique design, AC or DC bias voltage can be used. The small size and high light sensitivity of this unit makes it particularly useful in high speed reading of punched cards and tapes, light detection systems, and in production line screening or counting. Numerous other commercial and military applications exist.

TYPE 1N2175
N-P-N DIFFUSED SILICON PHOTO-DUO-DIODE

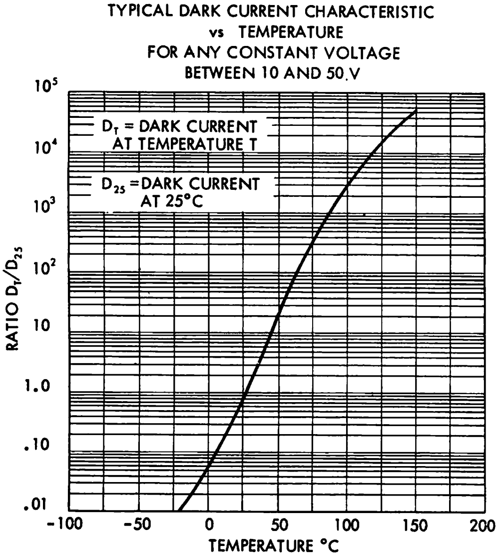
TYPICAL CHARACTERISTICS

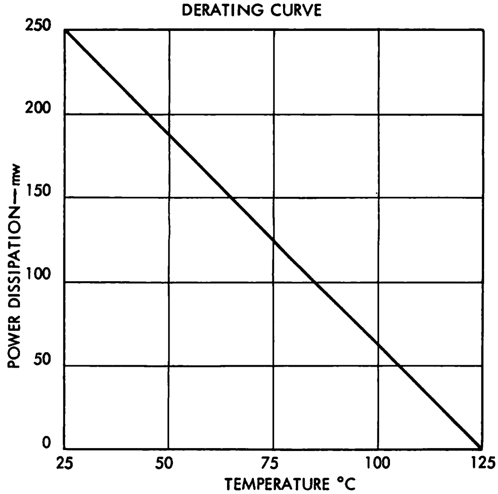


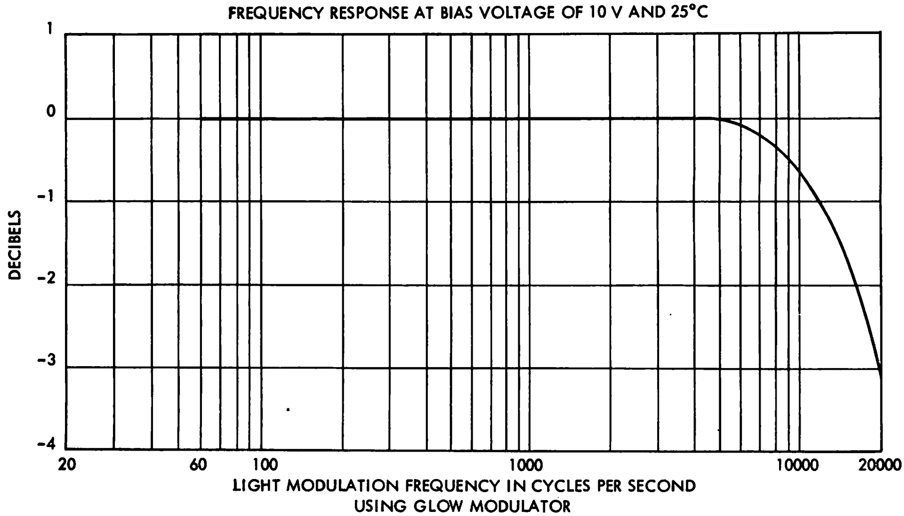




TYPICAL CHARACTERISTICS



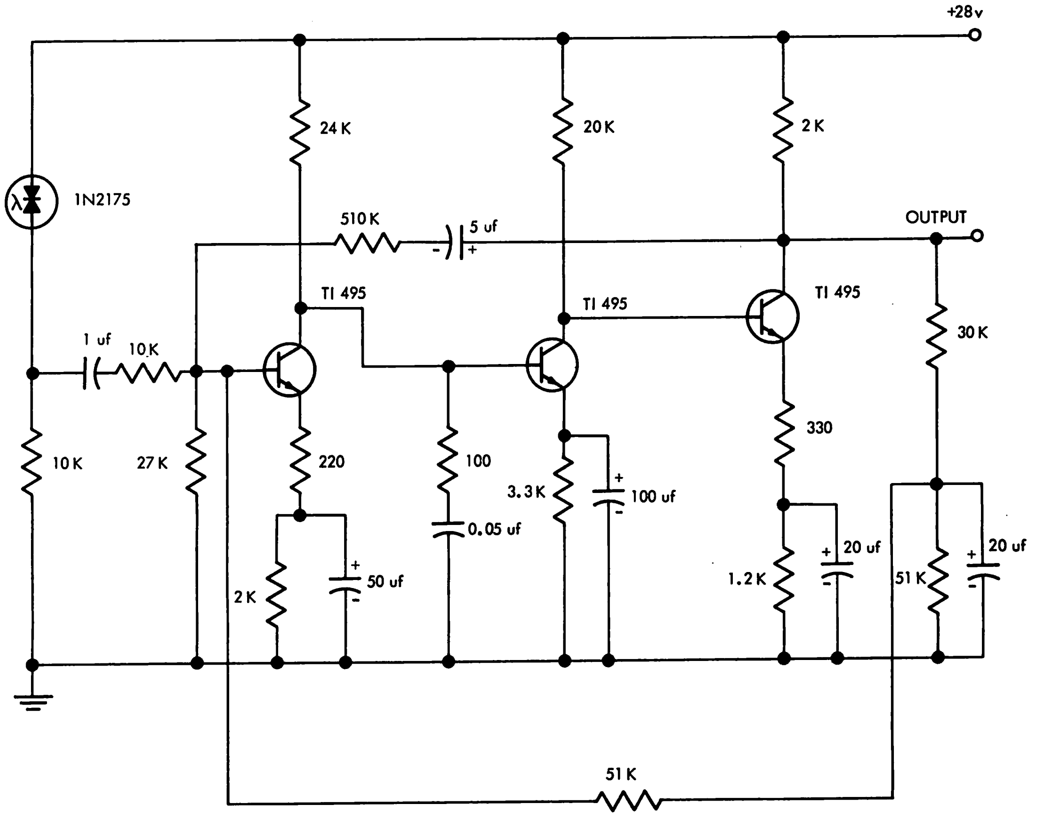




TYPICAL APPLICATION DATA

PHOTO DUO-DIODE PREAMPLIFIER

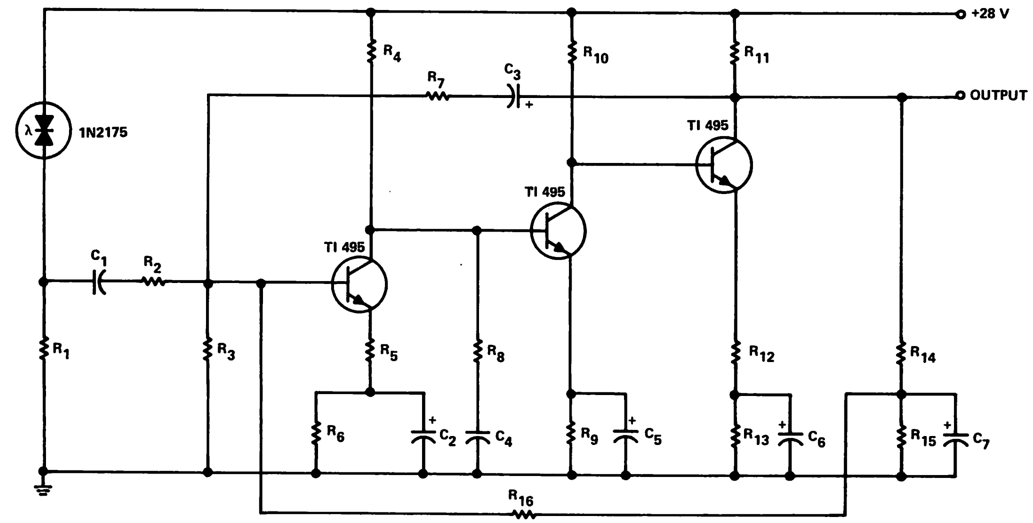
This circuit was designed for use with the TI 1N2175 photo duo-diode. A voltage amplification of 30 db was obtained. This varied less than 1 db changing from low h_{FE} units at -40°C to high h_{FE} units at 100°C. An output of 4 volts peak to peak can be obtained across a 1 kΩ load resistor. The amplifier response is ±1 db from 10 cps to 10 kc.



Resistor values are in ohms.

TYPICAL APPLICATION DATA

LOW-NOISE PHOTODIODE PREAMPLIFIER



CAI7114

CIRCUIT COMPONENT INFORMATION

RESISTORS

R_1: 10 kΩ	R_9: 3.3 kΩ
R_2: 10 kΩ	R_{10}: 20 kΩ
R_3: 27 kΩ	R_{11}: 2 kΩ
R_4: 24 kΩ	R_{12}: 330 Ω
R_5: 220 Ω	R_{13}: 1.2 kΩ
R_6: 2 kΩ	R_{14}: 30 kΩ
R_7: 510 Ω	R_{15}: 51 kΩ
R_8: 100 Ω	R_{16}: 51 kΩ

CAPACITORS

C_1: 1 μF
C_2: 50 μF
C_3: 5 μF
C_4: 0.05 μF
C_5: 100 μF
C_6: 20 μF
C_7: 20 μF

TYPICAL PERFORMANCE DATA	
Voltage Gain	30 dB
Output Voltage	4 V
Frequency Response	1 Hz to 10 kHz
Operating Temperature Range	−40°C to 100°C

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JAPAN

Texas Instruments Asia Limited
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Chiyoda-du, Tokyo, Japan

TYPES CG⅛, CG¼ AND CG½
PRECISION, CARBON-FILM, GLASS-ENCAPSULATED HERMETIC RESISTORS

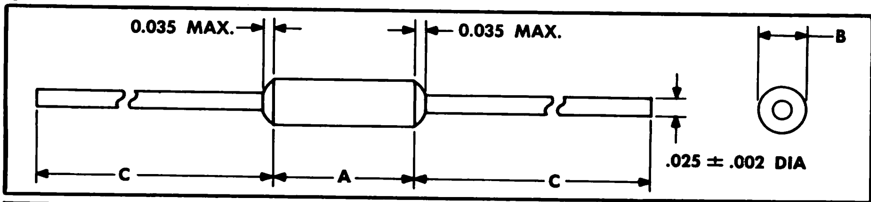
TYPES CG1/8, CG1/4, CG1/2
BULLETIN NO. DL-S 634364, SEPTEMBER 1963
REPLACES BULLETIN NO. DL-S 633484, MARCH 1963

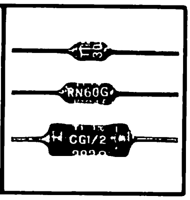
- **Proven high reliability — >40,000,000 test data hours**
- **-65°C to 175°C storage temperature**
- **Hermetically sealed in hard glass**
- **Meet or exceed all requirements of Specification MIL-R-10509D for Characteristics B, D & G**
- **Leads welded to end caps**
- **±1% ohmic tolerance**

environmental tests

To achieve maximum reliability, all TI glass resistors are 100% inspected for hermetic seal as a continuous process control. Tests are conducted to all electrical, environmental, and mechanical specifications to insure full and continuous compliance with Mil-R-10509D, Characteristics B,D, and G.

specifications





TI type number	wattage rating ($T_A \leq 70°C$)* TI	MIL B	MIL D	MIL G	MIL designation	standard resistance ranges	maximum working voltage**	body length*** (A)	body diameter (B)	lead length (C)	lead size	avg. weight per 100 unpacked units
—					—	—	volts	inches	inches	inches	awg #	lbs.
CG⅛	⅛	—	⅛	1/10	RN55	10Ω to 100KΩ	250	0.240($^{+.010}_{-.020}$)	0.125(±0.015)	1.500(±0.125)	22	0.076
CG¼	¼	⅛	¼	⅛	RN60	10Ω to 1 MegΩ	350	0.360($^{+.025}_{-.015}$)	0.140(±0.020)	1.500(±0.125)	22	0.09
CG½	½	¼	½	¼	RN65	10Ω to 2 MegΩ	500	0.560(±.025)	0.225(±0.020)	1.500(±0.125)	22	0.228

*For operation at higher temperature, see Dissipation Derating Curves, Page 2.
Critical ohmic value and above. For lower values use $E = \sqrt{PR}$. See Paragraph 3.6 of **MIL-R-10509D
***Length of glass package. Fillets on leads extend 0.035" max. beyond glass.

symbolization

CG1/8 — Standard stock symbolization includes manufacturer's identification, tolerance and ohmic value (e.g. — TI, 1%, 100 K).

CG1/4 — Standard stock symbolization includes manufacturer's identification, tolerance, mil-type designation and ohmic value (e.g. — TI, 1%, RN60G, 1003F, 100 K).

CG1/2 — Standard stock symbolization includes manufacturer's identification, tolerance, mil-type designation and ohmic value (e.g. — TI, 1%, RN65G, 1003F, 100 K).

modifications available on request

± ½%, 2% or 5% Resistance Tolerance
Resistance Values Outside Published Ranges
Special symbolization

performance characteristics †

test	average performance of TI CG ¼ resistors	limits: MIL Char D	limits: TI and MIL Char G
Temperature Cycling per MIL-R-10509D (4.6.4)	less than ± 0.05%	±0.50%	± 0.25%
Low Temperature Operation per MIL-R-10509D (4.6.5)	less than ± 0.05%	±0.50%	± 0.25%
Short Time Overload per MIL-R-10509D (4.6.6)	less than ± 0.05%	±0.50%	± 0.25%
Effect of Soldering per MIL-R-10509D (4.6.10)	less than ± 0.03%	±0.50%	± 0.10%
Insulation Resistance per MIL-R-10509D (4.6.9)	greater than 1,000,000 megohms	greater than 10,000 megohms	
Moisture Resistance per MIL-R-10509D (4.6.11)	less than ± 0.08%	±1.50%	± 0.50%
Shock per MIL-R-10509D (4.6.15)	less than ± 0.05%	±0.50%	± 0.25%
Vibration, High Frequency per MIL-R-10509D (4.6.16)	less than ± 0.05%	±0.50%	±0.25%
Shelf Life, Change per Year	less than ± 0.04%	no requirement	no requirement
Voltage Coefficient	less than 0.002%/volt	no requirement	no requirement

†Unless otherwise noted, data is % change in initial resistance. The two-sigma limits were used as the range indications for average performance.

TEXAS INSTRUMENTS
INCORPORATED
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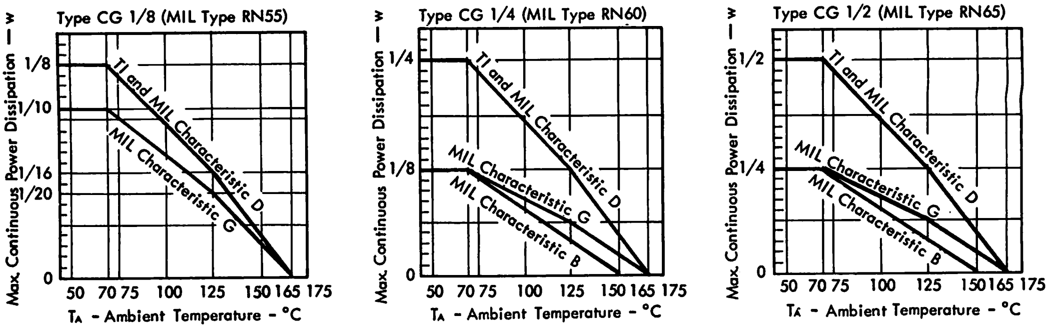
TYPES CG⅛, CG¼ AND CG½
PRECISION, CARBON-FILM, GLASS-ENCAPSULATED HERMETIC RESISTORS

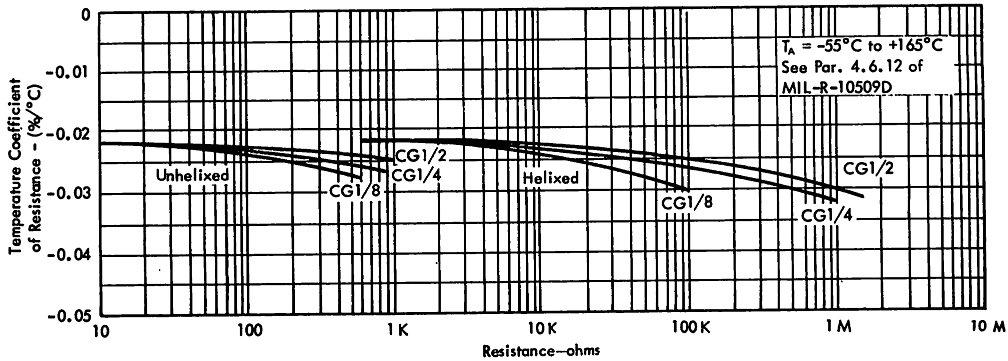
THERMAL INFORMATION

DISSIPATION DERATING CURVES

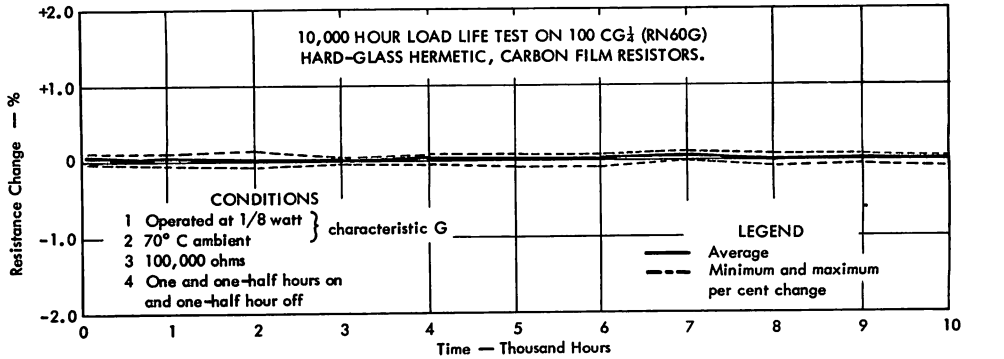


TYPICAL CHARACTERISTICS

TEMPERATURE COEFFICIENT vs RESISTANCE



LOAD LIFE PERCENT CHANGE vs TIME



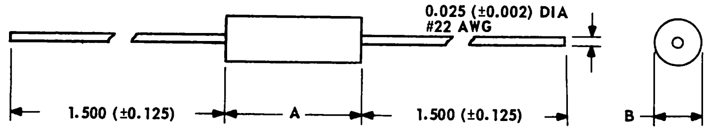
TYPES MC55, MC60, MC65, MC55D, MC60D, MC65D
EPOXY-ENCAPSULATED PRECISION METAL-FILM RESISTORS

TYPES MC55, MC60, MC65, MC55D, MC60D, MC65D
BULLETIN NO. DL-S 685630, JULY 1964
REVISED MAY 1968

Designed to meet or exceed all requirements of Specification MIL-R-10509F for Characteristic C, D, E, & F.

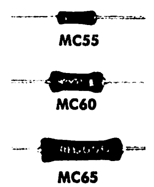
- **Load-rated for 125°C or 70°C applications**
- **High degree of stability and reliability**
- **Precision resistance tolerances**
- **Rugged cap-and-lead construction**
- **Temperature Coefficients ±10, ±25, ±50 and ±100 ppm/°C**
- **Tough Epoxy coating • Fully insulated**

specifications



ALL DIMENSIONS IN INCHES

Body length is measured between the points where body diameter is 0.038″. The lead is solderable up to 0.062″ from the body..



MIL-R-10509F DESIGNATION				ELECTRICAL RATINGS AND CHARACTERISTICS			MECHANICAL DATA		
type	applicable characteristic	power rating†	TI TYPE	power rating‡	maximum working voltage	resistance value range§ ($T_A = 25°C$)	body size length — A	body size diameter — B	average weight for 100 unpacked units
		W		W	V		inch	inch	lb
RN55	C & E	1/10	MC55	1/8	250	24.9 Ω to 100 kΩ	0.250 (±0.031)	0.095 (±0.015)	0.075
	D	1/8	MC55D	1/4					
RN60	C & E	1/8	MC60	1/4	300	49.9 Ω to 499 kΩ	0.375 (±0.031)	0.140 (±0.015)	0.101
	D	1/4	MC60D	3/8					
RN65	C & E	1/4	MC65	1/2	350	49.9 Ω to 1 MΩ	0.575 (±0.031)	0.171 (±0.015)	0.198
	F	1/2							
	D	1/2	MC65D	1					

symbolization

Standard stock symbolization includes TI Type Number, Resistance Value, Tolerance, and Temperature Coefficient, depending upon wattage size and space available. Military type symbolization is used when applicable. Resistance values are symbolized to a maximum of three significant figures per Table 1.

military devices

The resistors are available in accordance with the requirements of MIL-R-10509F. For current availability of resistance values, tolerances, and characteristics consult a TI Sales Office.

modifications available upon request

Special testing
"A" nickel weldable leads
Resistance values outside published ranges
Special paint coverage

†These ratings apply at (or below) 125°C ambient temperature for characteristics C, E, and F and at (or below) 70°C ambient temperature for characteristic D. For higher temperatures refer to MIL-R-10509F.

‡These ratings apply at (or below) 125°C ambient temperature for MC55, MC60, and MC65 and at (or below) 70°C ambient temperature for "D" suffix devices. For higher temperatures refer to Power Dissipation Derating Curves Page 2.

§The value ranges shown are for a temperature coefficient of 25 ppm. See "high- and low-value availability" on Page 2.

TEXAS INSTRUMENTS
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POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES MC55, MC60, MC65, MC55D, MC60D, MC65D
EPOXY-ENCAPSULATED PRECISION METAL-FILM RESISTORS

RESISTANCE VALUE

standard values and tolerance

The following resistance values are standard and in most cases are available from stock. Nonstandard values will be manufactured to specific requirements.

TABLE 1 — 1% TOLERANCE

1.00	1.10	1.21	1.33	1.47	1.62	1.78	1.96	2.15	2.37	2.61	2.87	3.16	3.48	3.83	4.22	4.64	5.11	5.62	6.19	6.81	7.50	8.25	9.09
1.02	1.13	1.24	1.37	1.50	1.65	1.82	2.00	2.21	2.43	2.67	2.94	3.24	3.57	3.92	4.32	4.75	5.23	5.76	6.34	6.98	7.68	8.45	9.31
1.05	1.15	1.27	1.40	1.54	1.69	1.87	2.05	2.26	2.49	2.74	3.01	3.32	3.65	4.02	4.42	4.87	5.36	5.90	6.49	7.15	7.87	8.66	9.53
1.07	1.18	1.30	1.43	1.58	1.74	1.91	2.10	2.32	2.55	2.80	3.09	3.40	3.74	4.12	4.53	4.99	5.49	6.04	6.65	7.32	8.06	8.87	9.76

Standard stock tolerance is ±1% (F). Tolerances of ±0.5% (D), ±0.25% (C), and ±0.1% (B) are also available upon request. The MC — D series is also available with ±2% tolerance. The parenthetical letters are equivalent MIL-R-10509F tolerance designations.

temperature coefficient

T-C Code Designation	Comparable MIL-R-10509F Characteristic	T-C Range	Temperature Range
T-1	D	±100 ppm/°C	–55° to +175°C
T-2	C & F	±50 ppm/°C	–55° to +175°C
T-9	E	±25 ppm/°C	–55° to +175°C
T-10		±10 ppm/°C	+25° to +150°C

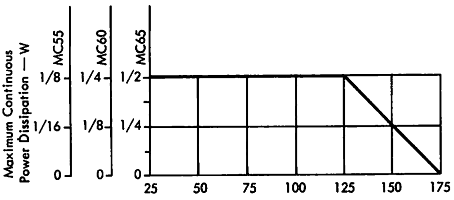
Special tracking requirements, temperature ranges, etc., are available.

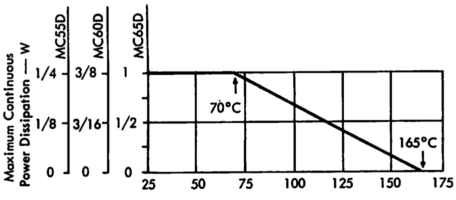
hi- and low-value availability

The range of available resistance values is dependent upon temperature coefficient, e.g., the available range is extended for temperature coefficient of 100 ppm compared to 25 ppm. Contact a TI sales office for extended value ranges currently available in each T-C range.

POWER RATING AND PERFORMANCE CHARACTERISTICS

power dissipation derating curves





performance characteristics

Resistance-value stability is affected by power dissipation in operational-environment tests. Following are two typical examples. In one, the more stable MC series is tested to a low-power MIL-R-10509 application demonstrating maximum stability. In the other example, the lower-cost MC — D series is tested at its maximum TI-rated power to demonstrate its excellent stability under these extreme power conditions.

TEST PER APPLICABLE MIL-R-10509F PROCEDURE	MC55, MC60, MC65		MC55D, MC60D, MC65D	
	MIL-R-10509F Char E LIMITS	TI TYPICAL PERFORMANCE	MIL-R-10509F Char D LIMITS	TI TYPICAL PERFORMANCE
1000-Hour Load Life	±0.50% max	+0.14% avg	±1.0 %	+0.30% avg■
Moisture Resistance	±0.50% max	+0.15% avg	±1.5 %	+0.40% avg■
Low-Temperature Operation	±0.25% max	<±0.05%	±0.50%	+0.10% avg
Temperature Cycling	±0.25% max	<±0.05%	±0.50%	<±0.05%
Short-Time Overload	±0.25% max	<±0.05%	±0.50%	+0.10% avg■
Effect of Soldering	±0.10% max	<±0.05%	±0.50%	<±0.05%
Insulation Resistance	$>10^{10}\ \Omega$	$>10^{12}\ \Omega$	$>10^{10}\ \Omega$	$>10^{12}\ \Omega$ ■
Shock	±0.25% max	<±0.05%	±0.50%	<±0.05%
Vibration	±0.25% max	<±0.05%	±0.50%	<±0.05%

Unless otherwise noted, data is percent change from initial resistance. ■Operated at maximum TI-rated power.

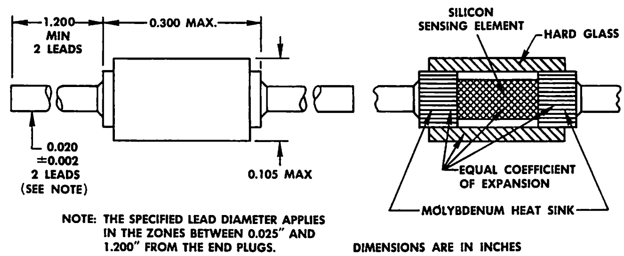
TYPE TG 1/8
BULLETIN NO. DL-S 668132, JUNE 1966

HERMETICALLY SEALED, TEMPERATURE-SENSING, TEMPERATURE-COMPENSATING POSITIVE-TEMPERATURE-COEFFICIENT THERMISTOR

- **Designed to meet or exceed all electrical requirements of MIL-T-23648A for positive-TC thermistors**

mechanical data

The resistors are encapsulated in a hard-glass, hermetically sealed package with welded unborated solder-coated dumet leads.



maximum ratings

Power Dissipation at (or below) 25°C Ambient Temperature (See Figure 1) . . . . 250 mW
Power Dissipation at 100°C Ambient Temperature (See Figure 1) . . . . 125 mW
Operating Ambient Temperature Range . . . . −65°C to 150°C
Storage Temperature Range . . . . −65°C to 150°C

electrical and thermal characteristics

Zero-Power Resistance Ratio, $R_{25°C}/R_{125°C}$	0.55 ± 15%
Thermal Time Constant, τ	60 s max, 35 s typ

standard zero-power resistance values (ohms) at 25°C ambient temperature

10	12	15	18	22	27	33	39	47	50	56	68	82
100	120	150	180	220	270	330	390	470	500	560	680	820
1000	1200	1500	1800	2200	2700							

Standard stock tolerances are ±5% and ±10%

TYPE TG 1/8
SOLID-STATE TEMPERATURE-SENSING RESISTOR

performance characteristics

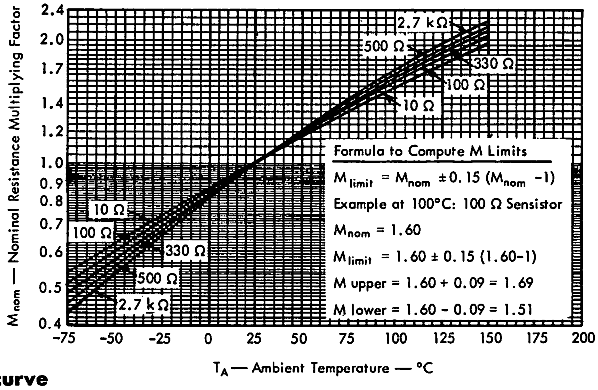
TEST PER APPLICABLE MIL-T-23648A PROCEDURE	MAXIMUM RESISTANCE CHANGE, T_A=25°C
Short-Time Overload	±1%
Dielectric Withstanding Voltage	±1%
Low-Temperature Storage	±1%
High-Temperature Storage	±2%
Terminal Strength	±1%
Thermal Shock	±2%
Resistance to Soldering Heat	±1%
Moisture Resistance	±2%
1000-Hour Load Life, T_A = 100°C	±2%
Vibration, High-Frequency	±1%
Shock	±1%
Immersion	±1%

military applications

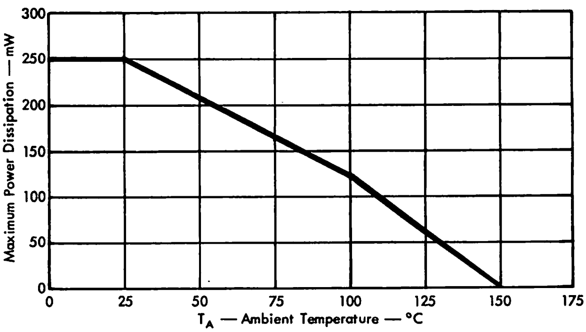
The SENSISTOR silicon resistor has been designed to operate under military test conditions as stated above. Production lots are regularly tested to these criteria as part of TI's continuing process-control testing program.

Special methods have been developed for load-life and temperature-coefficient testing. Test details, recommended test parameters, and test results are available upon request.

nominal resistance multiplying factor vs ambient temperature



dissipation derating curve



TYPES TM 1/8, TM 1/4, TC 1/8 AND P-100 PROBE SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

TYPES TM ⅛, TM ¼, TC ⅛ AND P-100 PROBE
BULLETIN NO. DL-S 679254, JANUARY 1967
REPLACES BULLETIN NO. DL-S 611284

Temperature Compensating • Temperature Sensing

POSITIVE-TEMPERATURE-COEFFICIENT THERMISTORS

Amplifiers • Power Supplies • Servos • Thermometry

Mag Amps • Computers • Telemetering

Large positive temperature coefficient of resistance (approx. 0.7%/deg)

mechanical data

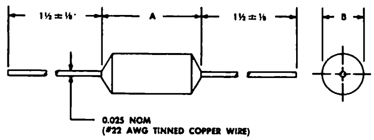
sensistor

Molded
Silicon Types TM ¼ & TM ⅛

Axial Leads

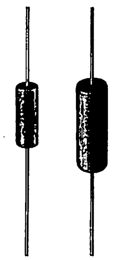
Full Load at 100°C

Derated Linearly to 150°C



COLOR: GREEN
ALL DIMENSIONS IN INCHES

TYPE	A	B
TM ¼	0.585 ± 0.015	0.200 ± 0.015
TM ⅛	0.406 ± 0.015	0.140 ± 0.015



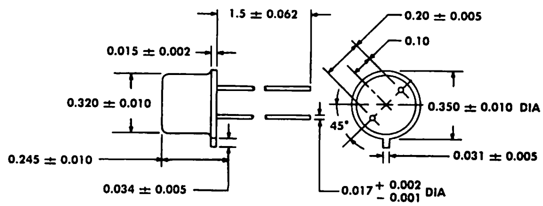
sensistor

Round Welded Case
Silicon Type TC ⅛

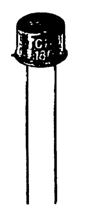
Glass-to-Metal Hermetic Seal Between Case and Leads

Full Load at 100°C

Derated Linearly to 150°C



UNIT IS ENCASED IN A GOLD-PLATED CAN.
ALL DIMENSIONS IN INCHES

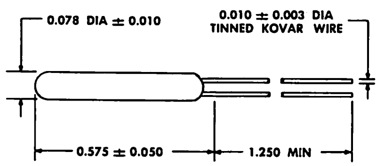


sensistor

Glass-Encased
Silicon Type P-100 Probe

All Glass Package
Glass-to-Metal Hermetic Seal at Leads

Accurate Resistance–Temperature Relationship From −180°C to + 200°C



ALL DIMENSIONS IN INCHES

TEXAS INSTRUMENTS
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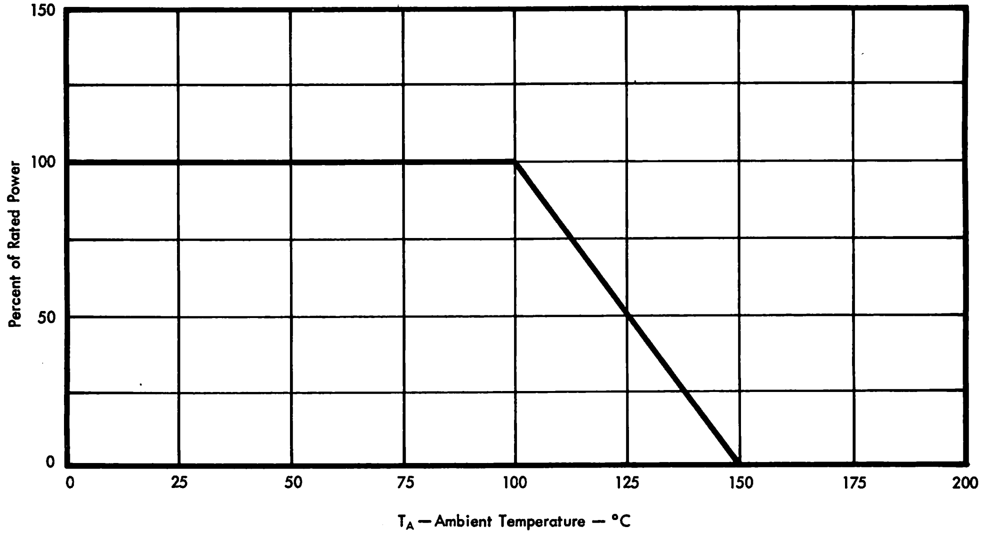
TYPES TM 1/8, TM 1/4, TC 1/8 AND P-100 PROBE
SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

TM 1/8, TM 1/4, & TC 1/8

POWER DERATING CURVE



performance characteristics

TEST PER APPLICABLE MIL-T-23648A PROCEDURE	MAXIMUM RESISTANCE CHANGE, $T_A = 25°C$
Short-Time Overload	±1%
Dielectric Withstanding Voltage	±1%
Low-Temperature Storage	±1%
High-Temperature Storage	±2%
Terminal Strength	±1%
Thermal Shock	±2%
Resistance to Soldering Heat	±1%
Moisture Resistance	±2%
1000-Hour Load Life, $T_A = 100°C$	±2%
Vibration, High-Frequency	±1%
Shock	±1%
Immersion	±1%

military applications

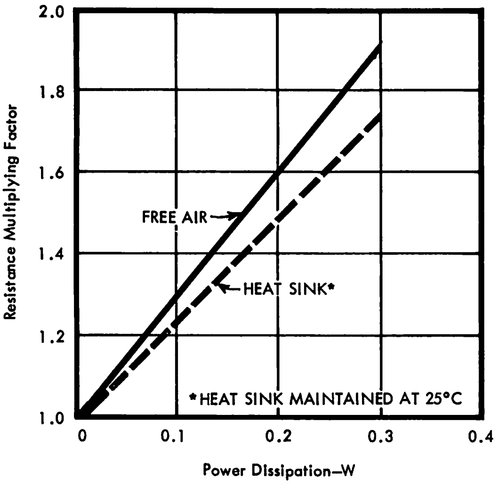
The SENSISTOR silicon resistor has been designed to operate under military test conditions as stated above. Production lots are regularly tested to these criteria as part of TI's continuing process-control testing program.

Special methods have been developed for load-life and temperature-coefficient testing. Test details, recommended test parameters, and test results are available upon request.

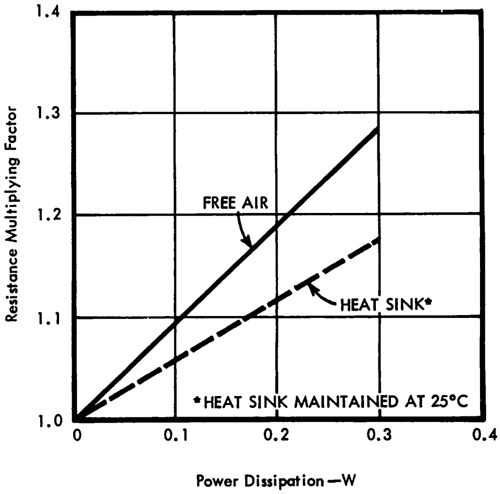
TYPES TM 1/8, TM 1/4, TC 1/8 AND P-100 PROBE SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

TYPICAL CHARACTERISTICS

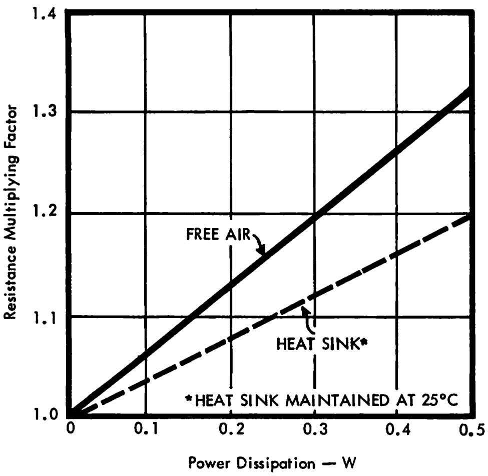
TC 1/8
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION



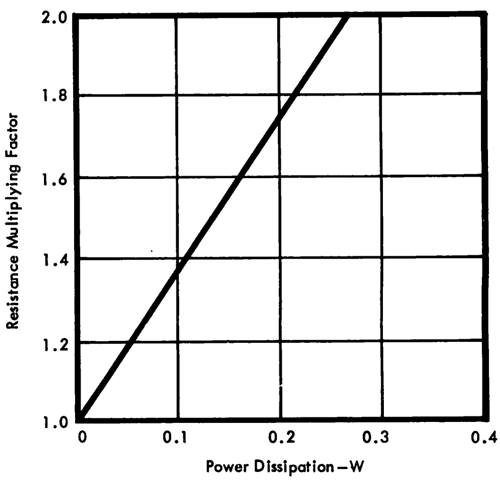
TM 1/8
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION



TM 1/4
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION



P-100 PROBE
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION



To correct resistance value for self-heating effect, determine correction factor from the above curve. Choose the nearest approximate heat-dissipation condition (free still air or strapped to the chassis or heat sink). Multiply the factor thus obtained by resistor value which has been corrected for no-load ambient temperature if necessary.

TYPES TM 1/8, TM 1/4, TC 1/8 AND P-100 PROBE
SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

electrical specifications

	TC ⅛	TM ⅛	TM ¼	P-100	UNIT
Wattage Rating	⅛	⅛	¼	not applicable	W
Standard Resistance Range*	10 - 5600	10 - 5600	10 - 10.000	100 - 4000	Ω
Maximum Thermal Time Constant	60	40	60	11	s

*Resistances calibrated at 25°C ± 0.20°C; resistance tolerance ± 10%.

standard resistance values (ohms) for 1 to 10 decade† — TM ⅛, TM ¼, and TC ⅛

1.0	1.2	1.5	1.8	2.2	2.7	3.3
3.9	4.7	5.0	5.6	6.8	8.2	

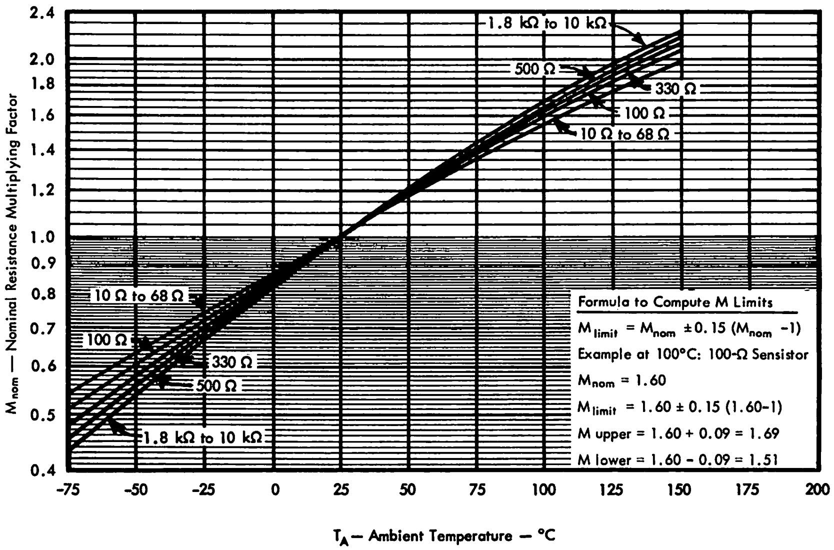
†Resistance values not listed will be considered nonstandard.

standard resistance values (ohms) — P-100 Probe

100	500	1000	2000	4000

± 5% tolerances, matched pairs, and other resistance values available as special devices.

nominal resistance multiplying factor vs ambient temperature



NOTES

NOTES

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NOTES

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