

The Engineering Staff of  
**TEXAS INSTRUMENTS INCORPORATED**  
Semiconductor Group



**The  
Linear  
Control Circuits  
Data Book**  
for  
**Design Engineers**

**Second Edition**

**TEXAS INSTRUMENTS**  
INCORPORATED

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#### **IMPORTANT NOTICES**

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## INTRODUCTION

In this 416-page data book, Texas Instruments is pleased to present important technical information on a broad line of linear control integrated circuits that includes operational amplifiers, voltage comparators, analog switches, timers, analog-to-digital converters, Hall-effect devices, and many others.

You will find specifications on device types initiated by TI (TL series) and on plug-in replacements for many competitive types. The functional indexes and selection guides provide the designer with rapid access to data sheets for specific applications, and the interchangeability guides show both direct and nearest replacement devices for many competitive parts. There are margin tabs to guide you quickly to general circuit categories, and the alphanumeric index lets you locate particular type numbers quickly.

The section on military products describes process and screening requirements for JAN, JAN-processed, /883B Class B, and standard device types.

This volume offers design data and specifications only for linear control integrated circuits, but complete technical data on any Texas Instruments semiconductor component is available from your nearest TI field sales office or authorized distributor and from: Marketing and Information Services, Texas Instruments Incorporated, P.O. Box 225012, MS 308, Dallas, Texas 75265.

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INCORPORATED

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# General Information





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# FUNCTIONAL INDEX

## SINGLE UNCOMPENSATED OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

I <sub>IB</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
75	2	10	50	1	0.5	3	±5	±22	High Performance	LM101A	J, JG, U, W	59
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060M	JG	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070M	JG	131
0.2	6	1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080M	JG	139
10,000	5	2,000	1.4	0.5	1.7	6.7		–7, +14	General Purpose	TL702M	J, U, W	157
5,000	2	500	2.5	0.5	1.7	6.7		–7, +14	General Purpose	uA702M	J, JG, U, W	163
200	2	50	25	1	0.3	3.6		±18	General Purpose	uA709AM	J, JG, U	167
500	5	200	25	1	0.3	5.5		±18	General Purpose	uA709M	J, JG	167
500	5	200	50	1	0.5	2.8	±2	±22	General Purpose	uA748M	J, JG, U, W	181

### Industrial Temperature Range (–25°C to 85°C)

75	2	10	50	1	0.5	3	±5	±22	High Performance	LM201A	J, JG, N, P	59
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060I	JG, P	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070I	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080I	JG, P	115

### Commercial Temperature Range (0°C to 70°C)

250	7.5	50	25	1	0.5	3	±5	±18	High Performance	LM301A	J, JG, N, P	59
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060C	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060AC	JG, P	115
0.4	15	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070C	JG, P	131
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070AC	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080AC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080C	JG, P	139
15,000	10	5,000	1	0.5	1.7	7		–7, +14	General Purpose	TL702C	J, JG, N	163
1,500	7.5	500	12	1	0.3	5.5		±18	General Purpose	uA709C	J, JG, N, P	167
500	6	200	20	1	0.5	2.8	±2	±18	General Purpose	uA748C	J, JG, N, P	181
100	5	20	25	1	0.5	3.3	±5	±22	High Performance	uA777C	J, JG, N, P	185



# FUNCTIONAL INDEX

## SINGLE INTERNALLY COMPENSATED OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

$I_{IB}$ nA	$V_{IO}$ mV	$I_{IO}$ nA	$A_{VD}$ V/mV	$B_1$ MHz	SR V/ $\mu$ s	$I_{CC}$ mA	$V_{CC}$ V		DESCRIPTION	DEVICE	PACKAGE	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
75	2	10	50	1	0.5	3	$\pm 2$	$\pm 22$	High Performance	LM107	J, JG, U, W	62
800	2	200	50	10	13	6.5	$\pm 3$	$\pm 22$	Low Noise $V_n = 4 \text{ nV}/\sqrt{\text{Hz}}$ Typ	SE5534	JG	105
800	2	200	50	10	13	6.5	$\pm 3$	$\pm 22$	Low Noise $V_n = 4.5 \text{ nV}/\sqrt{\text{Hz}}$ Max	SE5534A	JG	
0.2	6	0.1	4	1	3.5	0.2	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL061M	JG, U	105
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL071M	JG	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL081M	JG	139
0.2	2	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low $V_{IO}$	TL088M	JG, U	
150	5	30	50	1	0.5	1.0	+3	+32	General Purpose,	TL321M	JG	151
500	5	200	50	1	0.5	2.8	$\pm 2$	$\pm 22$	General Purpose	uA741M	J, JG, U, W	173

### Industrial Temperature Range (–25°C to 85°C)

75	2	10	50	1	0.5	3	$\pm 2$	$\pm 22$	High Performance	LM207	N	62
250	4	50	50	15	70	8	$\pm 20$		High Performance	LM218I	JG, P	73
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL061I	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL066I	JG, P	123
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise	TL071I	JG, P	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL081I	JG, P	139
0.4	0.5	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low Offset	TL087I	JG, P	147
0.4	3	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low Offset	TL088I	JG, P	147
150	5	30	50	1	0.5	1	+3	+32	General Purpose	TL321I	JG, P	151

# FUNCTIONAL INDEX

## SINGLE INTERNALLY COMPENSATED OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>B</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
250	7.5	50	25	1	0.5	3	±2	±18	High Performance	LM307	J, JG, N, P	62
500	10	200	25	15	70	10		±20	High Performance	LM318	JG, N, P	73
1,500	4	300	25	10	13	8	±3	±22	Low Noise V <sub>n</sub> = 4 nV/√Hz Typ	NE5534	JG, P	105
1,500	4	300	25	10	13	8	±3	±22	Low Noise V <sub>n</sub> = 4.5 nV/√Hz Max	NE5534A	JG, P	105
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061AC	JG, P	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061BC	JG, P	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061C	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power with Power Control	TL066AC	JG, P	123
0.2	3	1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power with Power Control	TL066BC	JG, P	123
0.4	15	2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power with Power Control	TL066C	JG, P	123
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise V <sub>n</sub> = 18 nV/√Hz Typ	TL071AC	JG, P	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise V <sub>n</sub> = 18 nV/√Hz Typ	TL071BC	JG, P	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise V <sub>n</sub> = 18 nV/√Hz Typ	TL071C	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081AC	JG, P	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081BC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081C	JG, P	139
0.4	0.5	0.2	25	3	13	2.8	±4	±18	BIFET, Low V <sub>IO</sub>	TL087C	JG, P	147
0.4	2	0.2	25	3	13	2.8	±4	±18	BIFET, Low V <sub>IO</sub>	TL088C	JG, P	147
250	7	50	25	1	0.5	1.0	+3	+32	General Purpose,	TL321C	JG, P	151
500	6	200	20	1	0.5	2.8	±2	±18	General Purpose	uA741C	J, JG, N, P	173

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# FUNCTIONAL INDEX

## DUAL OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

$I_B$ nA	$V_{IO}$ mV	$I_{IO}$ nA	$A_{VD}$ V/mV	$B_1$ MHz	SR V/ $\mu$ s	$I_{CC}$ mA	$V_{CC}$ V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
150	5	30	50	1	0.3	0.6	+3	+32	General Purpose	LM158	JG	71
500	5	200	50	1	0.6	2.8	$\pm 2$	$\pm 22$	General Purpose	MC1558	JG, U	85
500	5	200	50	3	1.5	2.8		$\pm 22$	High Performance	RM4558	JG	103
100	5	40	4	0.5	0.5	0.1	$\pm 2$	$\pm 22$	Low Power	TL022M	JG, U	109
0.2	6	0.1	4	1	3.5	0.2	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL062M	JG, U	115
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise			
									$V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL072M	JG	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL082M	JG	139
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL083M	J	139
500	5	50	50	1	0.6	4	+3	+36	General Purpose	TL322M	JG	153
500	5	200	50	1	0.5	2.8	$\pm 2$	$\pm 22$	General Purpose	uA747M	J, W	177

### Automotive Temperature Range (–40°C to 85°C)

500	10	50	100	1	0.3	0.6	$\pm 3$	$\pm 26$	General Purpose	LM2904	JG, P, U	83
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### Industrial Temperature Range (–25°C to 85°C)

150	5	30	50	1	0.3	0.6	+3	+32	General Purpose,	LM258	JG, P, U	71
500	8	75	20	1	0.6	4	+3	+36	General Purpose	TL322I	JG, P	153
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL062I	JG, P	115
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise	TL072I	JG, P	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL082I	JG, P	139
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL083I	J, N	139
0.4	0.5	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, Low Offset	TL287I	JG, P	147
0.4	3	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL288I	JG, P	147

## DUAL OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>IB</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
250	7	50	25	1	0.3	0.6	+3	+32	General Purpose	LM358	JG, P	71
500	6	200	20	1	0.6	2.8	±2	±18	General Purpose	MC1458	JG, P	85
800	4	150	25	10	9	8		±22	Low Noise			
									V <sub>n</sub> = 5 nV/√Hz Typ	NE5532	JG, P	93
800	4	150	25	10	9	8		±22	Low Noise			
									V <sub>n</sub> = 5 nV/√Hz Typ	NE5532A	JG, P	93
1500	4	300	25	10	13	8		±22	Low Noise			
									V <sub>n</sub> = 4 nV/√Hz Typ	NE5533	J, N	97
1500	4	300	25	10	13	8		±22	Low Noise			
									V <sub>n</sub> = 3.5 nV/√Hz Typ	NE5533A	J, N	97
500	6	200	20	3	1	2.8		±18	High Performance	RC4558	JG, P	103
250	5	80	1	0.5	0.5	0.125	±2	±18	Low Power	TL022C	JG, P	109
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062AC	JG, P	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062BC	JG, P	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062C	JG, P	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072AC	JG, P	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072BC	JG, P	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072C	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082AC	JG, P	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082BC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082C	JG, P	139
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL083AC	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL083C	J, N	139
0.4	0.5	0.1	25	3	13	2.8	±4	±18	BIFET, Low Offset	TL287C	JG, P	147
0.4	3	0.1	25	3	13	2.8	±4	±18	BIFET, General Purpose	TL288C	JG, P	147
500	10	50	20	1	0.6	4	+3	+36	General Purpose	TL322C	JG, P	153
500	6	200	25	1	0.5	2.8	±2	±18	General Purpose	uA747C	J, N	177

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# FUNCTIONAL INDEX

## QUADRUPLE OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

I <sub>IB</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
150	5	30	50	1	0.5	0.5	+3	+32	General Purpose	LM124	J, U	65
500	5	200	50	3.5	1.5	2.8	±4	±22	High Performance	RM4136	J, U	101
100	5	40	4	0.5	0.5	0.1	±2	±22	Low Power	TL044M	J, U	112
0.2	9	0.1	4	1	3.5	0.2	±1.5	±18	BIFET, Low Power	TL064M	J, W	115
0.2	9	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise V <sub>n</sub> = 18 nV/√Hz Typ	TL074M	J, W	131
0.2	9	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084M	J, W	139
100	5	25	50	1	0.5	3.6		±22	General Purpose	LM148	J	67
100			2	2.5	0.5	12	+4.5	+36	General Purpose	LM1900	J	77
500	5	50	50	1	0.6	4	+3	+36	General Purpose	MC3503	J	89

### Automotive Temperature Range (–40°C to 85°C)

200			1.2	2.5	0.5	10	+4.5	+32	General Purpose	LM2900	J, N	77
500	10	50	100	5	1	5	+3	+26	General Purpose	LM2902	J, N	81
500	8	75	20	1	0.6	7	+3	+36	General Purpose	MC3303	J, N	89

### Industrial Temperature Range (–25°C to 85°C)

250	7	50	25	1	0.5	3	+3	+32	General Purpose,	LM224	J, N	65
200	6	50	25	1	0.5	4.5		±18	General Purpose	LM248	J, N	67
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064I	J, N	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL074I	J, N	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084I	J, N	139

## QUADRUPLE OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>B</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
250	7	50	25	1	0.5	0.5	+3	+32	General Purpose	LM324	J, N	65
200	6	50	25	1	0.5	4.5		±18	General Purpose	LM348	J, N	67
200			1.2	2.5	0.5	10	+4.5	+32	General Purpose	LM3900	J, N	77
500	10	50	20	1	0.6	7	+3	+36	General Purpose	MC3403	J, N	89
500	6	200	20	3	1	2.8	±4	±18	High Performance	RC4136	J, N	101
250	5	80	1	0.5	0.5	0.125	±2	±18	Low Power	TL044C	J, N	112
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064AC	J, N	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064BC	J, N	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064C	J, N	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL074AC	J, N	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL074BC	J, N	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL074C	J, N	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL075C	N	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084AC	J, N	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084BC	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084C	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL085C	N	139

# FUNCTIONAL INDEX

## VOLTAGE COMPARATORS

### Military Temperature Range (–55°C to 125°C)

	I <sub>B</sub> μA MAX	V <sub>IO</sub> mV MAX	I <sub>IO</sub> μA MAX	A <sub>VD</sub>	I <sub>OL</sub> mA MIN	RESPONSE TIME ns	POWER SUPPLIES	DEVICE	PACKAGE	PAGE
Single	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	LM106	J, JG, W	195
	0.15	4	0.02	200,000 TYP	8	140 TYP	15 V, –15 V	LM111	J, JG	201
	0.05	4	0.02	200,000 TYP	8	210 TYP	15 V, –15 V	TL111	J, JG, N, P	219
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL331M	JG	223
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL510M	J, JG, U	233
	150	6	20	500 MIN	1.6	40 TYP	12 V, –6 V	TL710M	J, JG, U	239
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL810M	J, JG, U	245
Dual	20	2	3	1250 MIN	2	40 TYP	12 V, –6 V	uA710M	J, JG, U	259
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	LM193†	JG, U	211
	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	TL506M	J, W	227
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL514M	J, W	237
Dual-Channel	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL820M	J	255
	30	6	5	8,000 MIN	0.5	80 MAX	12 V, –6 V	TL811M	J, U	249
Quad	150	6	20	500 MIN	0.5	80 MAX	12 V, –6 V	uA711M	J, U	263
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	LM139†	J, W	209
Hex	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL336M†	J	225

### Automotive Temperature Range (–40°C to 85°C)

Dual	0.25	7	0.05	100,000 TYP	6	1300 TYP	2 V to 36 V	LM2903†	JG, P	215
Quad	0.25	7	0.05	100,000 TYP	6	1300 TYP	2 V to 36 V	LM2901†	J, N	213
	0.5	20	0.1	30,000 TYP	6	1300 TYP	2 V to 28 V	LM3302†	J, N	217

†Capable of operating with a single 5-volt supply.

## VOLTAGE COMPARATORS

### Industrial Temperature Range (–25°C to 85°C)

	I <sub>B</sub> μA MAX	V <sub>IO</sub> mV MAX	I <sub>IO</sub> μA MAX	A <sub>VD</sub>	I <sub>OL</sub> mA MIN	RESPONSE TIME ns	POWER SUPPLIES	DEVICE	PACKAGE	PAGE
Single	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	LM206	J, JG, N, P	195
	0.15	4	0.2	200,000 TYP	8	140 TYP	15 V, –15 V	LM211†	J, JG, P	201
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3111†	JG, P	223
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3311†	JG, P	223
Dual	0.25	5	0.005	200,000 TYP	6	1300 TYP	2 V to 36 V	LM293†	JG, P	211
Quad	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM239†	J, N	209
Hex	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3361†	J, N	225

### Commercial Temperature Range (0°C to 70°C)

Single	40	6.5	7.5	40,000 TYP	16	28 TYP	12 V, –3 V to –12 V	LM306	J, JG, N, P	195
	0.3	10	0.07	200,000 TYP	8	165 TYP	15 V, –15 V	LM311†	J, JG, N, P	201
	0.01	13	0.004	200,000 TYP	8	210 TYP	15 V, –15 V	TL311†	N, P	219
	0.01	10	0.004	200,000 TYP	8	210 TYP	15 V, –15 V	TL311A†	N, P	219
	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	TL331C†	JG, P	223
	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL510C	J, JG, N, P	233
	150	10	25	500 MIN		40 MAX	12 V, –6 V	TL710C	J, JG, N, P	239
	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL810C	J, JG, N, P	245
	25	5	5	1000 MIN	1.6	40 TYP	12 V, –6 V	uA710C	J, JG, N, P	259
	Dual	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM393†	JG, P
40		6.5	7.5	40,000 TYP	16	28 TYP	12 V, –3 V to –12 V	TL506C	J, N	227
30		4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL514C	J, N	237
30		4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL820C	J, N	255
Dual Channel	50	10	10	5000 MIN	0.5	33 TYP	12 V, –6 V	TL810C	J, JG, N, P	245
	150	10	25	500 MIN	0.5	40 TYP	12 V, –6 V	uA711C	J, N	263
Quad	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM339†	J, N	209
Hex	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	TL336C†	N	225

†Capable of operating with a single 5-volt supply.

# FUNCTIONAL INDEX

## SPECIAL FUNCTIONS

PAGE

### Timers

SE555	: General-purpose timers adjustable from 1 microsecond to 1 second	281
NE555	: Commercial-temperature version of SE555	281
SE556	: Dual version of SE555	291
NE556	: Commercial-temperature version of SE556	291
uA2240	: Programmable timer and 8-bit counter specially designed for delays greater than 1 second	401

### Amplifiers

MC1445	: 2-channel-multiplexed video amplifier	277
TL441	: Logarithmic amplifier with 80-dB input range	325
uA733	: Differential video amplifier with 200-MHz bandwidth	393

### Voltage-Level Detectors

TL480	: 10-level logarithmic converter in the J or N package	339
TL481	: 10-level logarithmic converter in the J or N package	341
TL487	: 5-level linear converter in the P or JG package	343
TL489	: 5-level logarithmic converter in the P or JG package	345
TL490	: 10-level linear converter in the J or N package	349
TL491	: 10-level linear converter in the J or N package	353

### Analog-to-Digital Converter Components

ADC0808	: Successive-approximation converter	270
ADC0809	: Successive-approximation converter	270
ADC0816	: Successive-approximation converter	272
ADC0817	: Successive-approximation converter with 8-bit resolution	272
TL500	: Dual-slope-converter analog processor with 14-bit resolution	357
TL501	: Dual-slope-converter analog processor with 13-bit resolution	357
TL502	: Dual-slope-converter digital processor with 4½-digit capability, seven-segment-display outputs	357
TL503	: Dual-slope-converter digital processor with 4½-digit capability, BCD outputs	357
TL505	: Dual-slope-converter analog processor with 10-bit resolution	369
TL507	: Pulse-width modulator with 7-bit resolution	377

### Zero-Crossing Detector

TL440		319
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### Doubly-Balanced Mixer

TL442		333
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### Precision Level Detector

TL560		381
-------	--	-----

### Overvoltage Sensing Circuits

MC3423		279
MC3523		279

### 3-Channel Stepper-Motor Controller

TL376		315
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## SPECIAL FUNCTIONS

### Analog Switches With 30-mA Capability (Bi-MOS)

DEVICE	FUNCTION	$Z_{sw}$ (TYP)	ANALOG RANGE	SUPPLIES	PAGE
TL182	Twin SPST	100 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	303
TL185	Twin DPST	150 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	306
TL188	Dual Complementary SPST	100 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	309
TL191	Twin Dual Complementary SPST	150 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	312

### Analog Switches With 10-mA Capability (P-MOS)

DEVICE	FUNCTION	$Z_{sw}$ (TYP)	ANALOG RANGE	SUPPLIES	PAGE
TL601	SPDT	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL604	Complementary SPST	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL607	SPDT	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL610	SPST	100 $\Omega$	$\pm 10$ V	+10, -20	387

### Hall-Effect Devices

DEVICE	DESCRIPTION	ON	OFF	HYSTERESIS	PAGE
TL170	General purpose switch	$>+350$ G	$<-350$ G	200 G	293
TL172	Normally-off switch	$>+600$ G	$<+100$ G	230 G	295
TL175	Latch	$>+350$ G	$<-350$ G	400 G	299
TL176	Normally-off switch (Automotive Temp. Range)	$>+500$ G	$<+100$ G	75 G	301
TL173	Linear sensor	1.5 mV/G Sensitivity			297

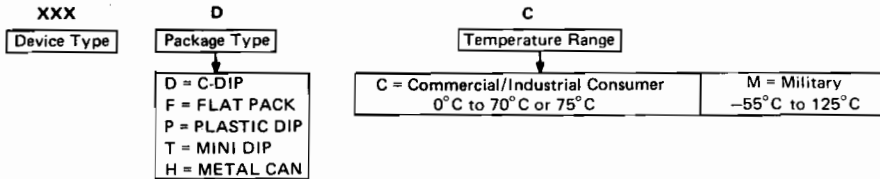
## INTERCHANGEABILITY GUIDE (ALPHABETICALLY BY MANUFACTURERS)

Direct replacements were based on similarity of electrical and mechanical characteristics as shown in currently published data. Interchangeability in particular applications is not guaranteed. Before using a device as a substitute, the user should compare the specifications of the substitute device with the specifications of the original.

Texas Instruments 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.

### FAIRCHILD ORDER INFORMATION

EXAMPLE OF ORDER CODE:

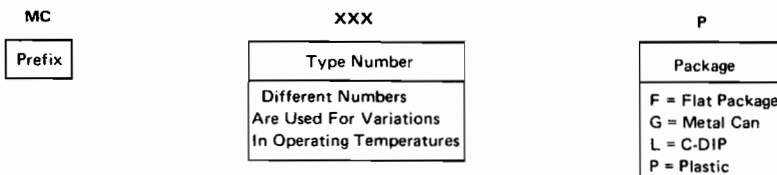


FAIRCHILD	TI DIRECT REPLACEMENT	TI CLOSEST REPLACEMENT	FAIRCHILD	TI DIRECT REPLACEMENT	TI CLOSEST REPLACEMENT
$\mu$ A101A	LM101A		$\mu$ A710	$\mu$ A710	
$\mu$ A107	LM107		$\mu$ A711	$\mu$ A711	
$\mu$ A111	LM111		$\mu$ A733	$\mu$ A733	
$\mu$ A139	LM139		$\mu$ A734		LM111
$\mu$ A201A	LM201A		$\mu$ A741	$\mu$ A741	
$\mu$ A207	LM207		$\mu$ A742		TL440
$\mu$ A301A	LM301A		$\mu$ A747	$\mu$ A747	
$\mu$ A304	LM304		$\mu$ A748	$\mu$ A748	
$\mu$ A307	LM307		$\mu$ A776		$\mu$ A777
$\mu$ A311	LM311		$\mu$ A777	$\mu$ A777	
$\mu$ A555	SE555		$\mu$ A2240C	$\mu$ A2240C	
$\mu$ A556C	NE556		$\mu$ A3302C	LM3302	
$\mu$ A556M	SE556		$\mu$ A3403	MC3403	
$\mu$ A702	$\mu$ A702		$\mu$ A4136C	RC4136	
$\mu$ A709	$\mu$ A709		$\mu$ A4136M	RM4136	
$\mu$ A709A	$\mu$ A709A				



## MOTOROLA ORDER INFORMATION

**EXAMPLE OF ORDER CODE:**

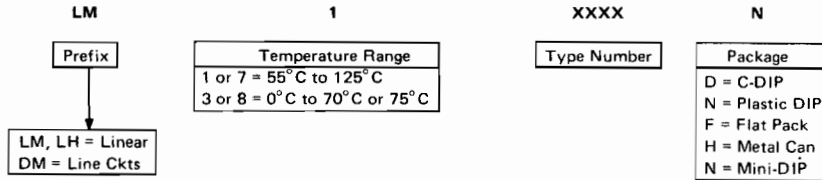


1

MOTOROLA	TI DIRECT REPLACEMENT	TI CLOSEST REPLACEMENT	MOTOROLA	TI DIRECT REPLACEMENT	TI CLOSEST REPLACEMENT
MLM101A	LM101A		MC1545	MC1545	
MLM107	LM107		MC1539		LM101A
MLM111	LM111		MC1555	SE555	
MLM201A	LM201A		MC1558	MC1558	
MLM207	LM207		MC1709	uA709	
MLM211	LM211		MC1710	uA710	
MLM301A	LM301A		MC1711	uA711	
MLM307	LM307		MC1712	uA702	
MLM311	LM311		MC1733	uA733	
MC1414	TL514		MC1741	uA741	
MC1420		uA733	MC1747	uA747	
MC1430		uA702	MC1748	uA748	
MC1431		uA702	MC3302	LM3302	
MC1433		LM301A	MC3302P	LM339	
MC1439		LM301A	MC3303	MC3303	
MC1445	MC1445		MC3403	MC3403	
MC1455	NE555		MC3423	MC3423	
MC1458	MC1458		MC3503	MC3503	
MC1514	TL442		MC3523	MC3523	
MC1530		uA702	MC4558	RM4558	
MC1531		uA702	MC4558C	RC4558	
MC1533		LM101A			

## NATIONAL ORDER INFORMATION

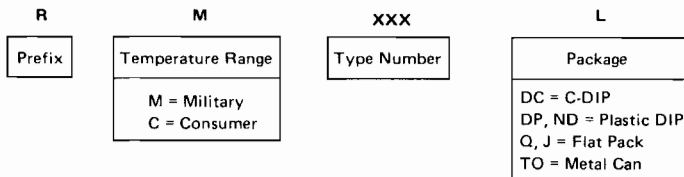
**EXAMPLE OF ORDER CODE:**



NATIONAL	<u>TI DIRECT REPLACEMENT</u>	<u>TI CLOSEST REPLACEMENT</u>	NATIONAL	<u>TI DIRECT REPLACEMENT</u>	<u>TI CLOSEST REPLACEMENT</u>
ADC0808	ADC0808		LM348	LM348	
ADC0809	ADC0809		LM358	LM358	
ADC0816	ADC0816		LM393	LM393	
ADC0817	ADC0817		LM555C	NE555	
DS5534	NE5534		LM555M	SE555	
LM101A	LM101A		LM556	SE556	
LM102	LM102		LM556C	NE556	
LM106	LM106		LM709	uA709	
LM107	LM107		LM709A	uA709A	
LM110	LM110		LM709C	uA709C	
LM111	LM111		LM710	uA710	
LM112	LM112		LM710C	uA710C	
LM118		LM218	LM711	uA711	
LM124	LM124		LM711C	uA711C	
LM139	LM139		LM733	uA733	
LM148	LM148		LM733C	uA733C	
LM158	LM158		LM741	uA741	
LM193	LM193		LM741C	uA741C	
LM201A	LM201A		LM747	uA747	
LM206	LM206		LM747C	uA747C	
LM207	LM207		LM748	uA748	
LM211	LM211		LM748C	uA748C	
LM218	LM218		LM1414N	TL514C	
LM224	LM224		LM1458	MC1558	
LM239	LM239		LM1514	TL514M	
LM248	LM248		LM1558	MC1558	
LM258	LM258		LM1900	LM1900	
LM293	LM293		LM2900	LM2900	
LM301A	LM301A		LM2901	LM2901	
LM306	LM306		LM2902	LM2902	
LM307	LM307		LM2903	LM2903	
LM311	LM311		LM2904	LM2904	
LM318	LM318		LM3302	LM3302	
LM324	LM324		LM3900	LM3900	
LM339	LM339		LM3905		NE555

## RAYTHEON ORDER INFORMATION

**EXAMPLE OF ORDER CODE:**

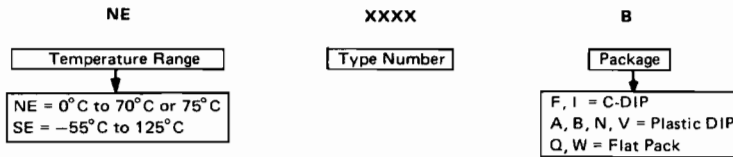


1

RAYTHEON	<u>TI DIRECT</u> <u>REPLACEMENT</u>	<u>TI CLOSEST</u> <u>REPLACEMENT</u>	RAYTHEON	<u>TI DIRECT</u> <u>REPLACEMENT</u>	<u>TI CLOSEST</u> <u>REPLACEMENT</u>
LM101A	LM101A		RC556	NE556	
LM106	LM106		RC702	uA702C	
LM107	LM107		RC709	uA709C	
LM111	LM111		RC710	uA710C	
LM118		LM218	RC711	uA711C	
LM124	LM124		RC733	uA733C	
LM139	LM139		RC741	uA741C	
LM158	LM158		RC747	uA747C	
LM201A	LM201A		RC748	uA748C	
LM206	LM206		RC1458	MC1458	
LM207	LM207		RC3302	LM3302	
LM211	LM211		RC3403	MC3403	
LM218	LM218		RC4136	RC4136	
LM224	LM224		RC4558	RC4558	
LM239	LM239		RM555	SE555	
LM258	LM258		RM556	SE556	
LM301A	LM301A		RM702	uA702M	
LM306	LM306		RM709	uA709M	
LM307	LM307		RM710	uA710M	
LM311	LM311		RM711	uA711M	
LM318	LM318		RM733	uA733M	
LM324	LM324		RM741	uA741M	
LM339	LM339		RM747	uA747M	
LM358	LM358		RM748	uA748M	
LM1900	LM1900		RM1514	TL514M	
LM2900	LM2900		RM1558	MC1558	
LM3900	LM3900		RM4136	RM4136	
RC555	NE555		RM4558	RM4558	

## SIGNETICS ORDER INFORMATION

**EXAMPLE OF ORDER CODE:**



<u>SIGNETICS</u>	<u>TI DIRECT REPLACEMENT</u>	<u>TI CLOSEST REPLACEMENT</u>	<u>SIGNETICS</u>	<u>TI DIRECT REPLACEMENT</u>	<u>TI CLOSEST REPLACEMENT</u>
LM101A	LM101A		NE5533	NE5533	
LM107	LM107		NE5533A	NE5533A	
LM111	LM111		NE5534	NE5534	
LM124	LM124		NE5534A	NE5534A	
LM139	LM139		SE532	LM158	
LM201A	LM201A		SE555	SE555	
LM207	LM207		SE556	SE556	
LM211	LM211		SE5534	SE5534	
LM224	LM224		SE5534A	SE5534A	
LM239	LM239		SE5733	uA733M	
LM301A	LM301A		uA709	uA709	
LM307	LM307		uA709A	uA709A	
LM311	LM311		uA710	uA710M	
LM324	LM324		uA710C	uA710C	
LM339	LM339		uA711	uA711M	
MC3302	LM3302		uA711C	uA711C	
NE532	LM358		uA741	uA741M	
NE555	NE555		uA741C	uA741C	
NE556	NE556		uA747C	uA747C	
NE5532	NE5532		uA748	uA748M	
NE5532A	NE5532A		uA748C	uA748C	

# Thermal Information

# THERMAL INFORMATION

---

## THERMAL CONSIDERATIONS

The power dissipation capability of semiconductor devices is limited by the maximum allowable virtual junction temperature, the ambient temperature, and the thermal resistance between the virtual junction and the ambient environment.

The temperature difference between the junction and the ambient environment is

$$T_J - T_A = P_D R_{\theta JA} \quad (1)$$

where  $T_J$  = virtual junction temperature, °C  
 $T_A$  = ambient temperature, °C  
 $P_D$  = power dissipated in the device, W  
 $R_{\theta JA}$  = thermal resistance, junction to ambient, °C/W

Solving for  $T_J$ ,

$$T_J = T_A + P_D R_{\theta JA} \quad (2)$$

The rating curves that follow assume the ambient environment is still air, that no heat sink is used, and that the junction temperature should not exceed 150°C.

$R_{\theta JA}$  may be reduced by the use of a heat sink.

$$R_{\theta JA} = R_{\theta JC} + R_{\theta CA} \quad (3)$$

where  $R_{\theta JC}$  = thermal resistance, junction to case, and  $R_{\theta CA}$  = thermal resistance, case to ambient.  $R_{\theta CA}$  is a function of the heat sink, mounting technique, and air velocity.

Substituting equation (3) into equation (1) and solving for  $P_D$ ,

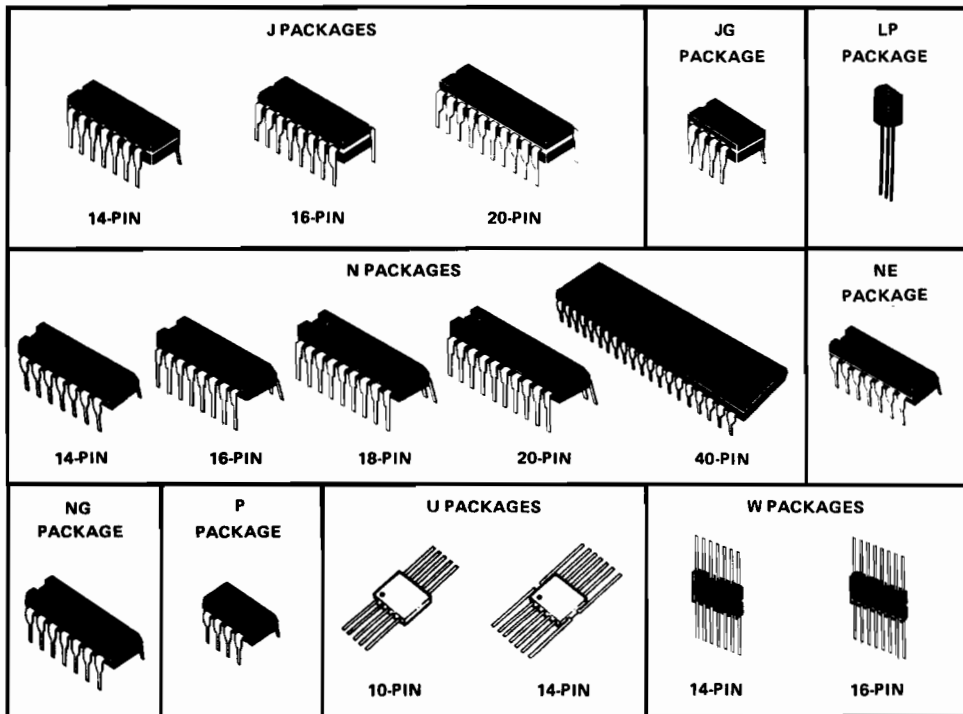
$$P_D = \frac{T_J - T_A}{R_{\theta JC} + R_{\theta CA}} \quad (4)$$

# THERMAL INFORMATION

## THERMAL RESISTANCE

PACKAGE	PINS	JUNCTION-TO-CASE THERMAL RESISTANCE $R_{\theta JC}$ ( $^{\circ}C/W$ )	JUNCTION-TO-AMBIENT THERMAL RESISTANCE $R_{\theta JA}$ ( $^{\circ}C/W$ )
J ceramic dual-in-line (glass-mounted chips)	14 thru 20	60	122
J ceramic dual-in-line <sup>†</sup> (alloy-mounted chips)	14 thru 20	29 <sup>†</sup>	91 <sup>†</sup>
JG ceramic dual-in-line (glass-mounted chips)	8	58	151
JG ceramic dual-in-line <sup>†</sup> (alloy-mounted chips)	8	26 <sup>†</sup>	119 <sup>†</sup>
LP plastic plug-in	3	35	160
N plastic dual-in-line	14 thru 20	44	108
	40	36	76
NE plastic dual-in-line	14	10	60
NG plastic dual-in-line	14	12.5	60
P plastic dual-in-line	8	45	125
U ceramic flat	10, 14	55	185
W ceramic flat	14, 16	60	126

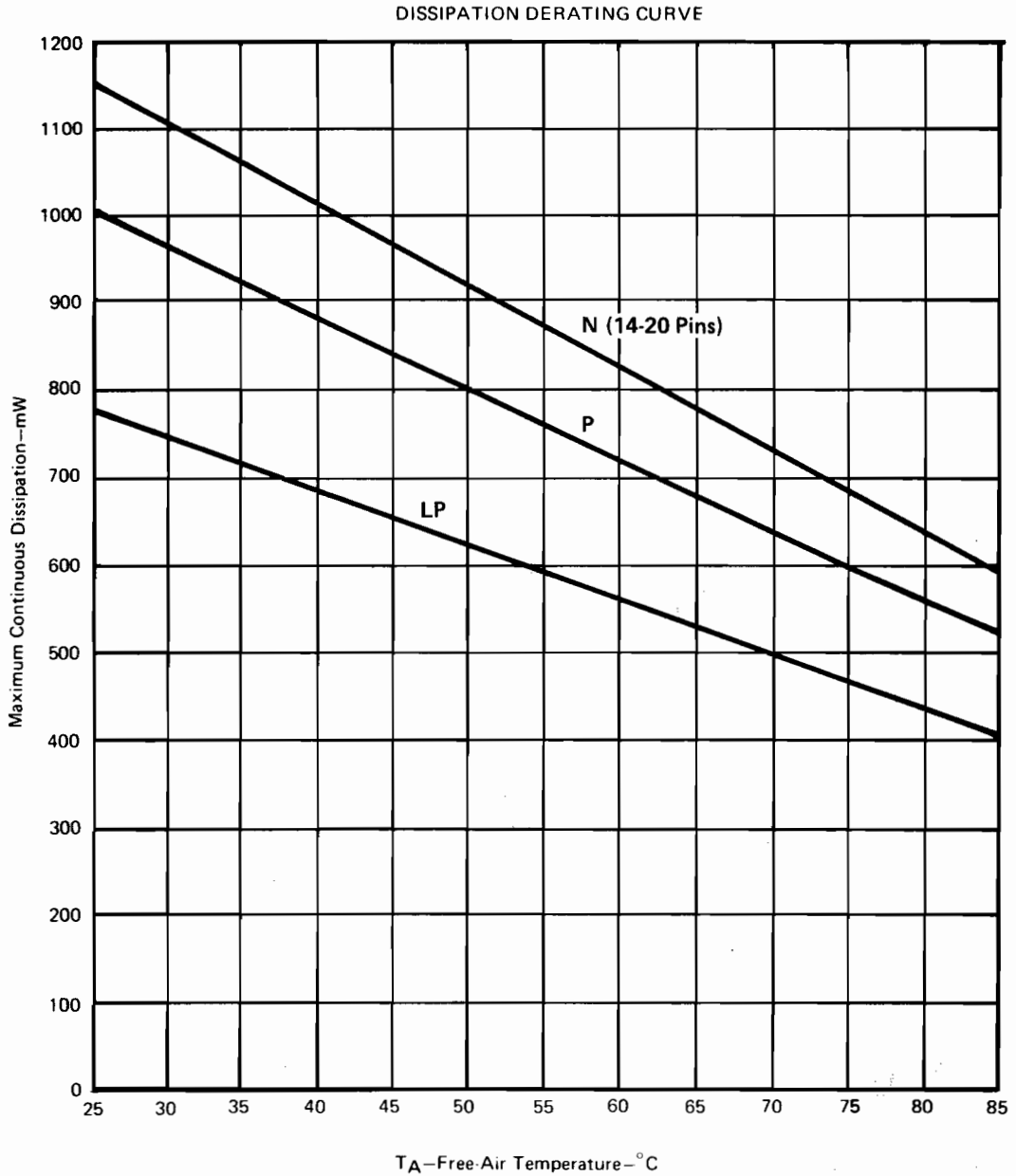
<sup>†</sup> In addition to those products so designated on their data sheets, all devices having a type number prefix of "SNC" or "SNM," or a suffix of "/883B" have alloy-mounted chips.



# THERMAL INFORMATION

## PLASTIC PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

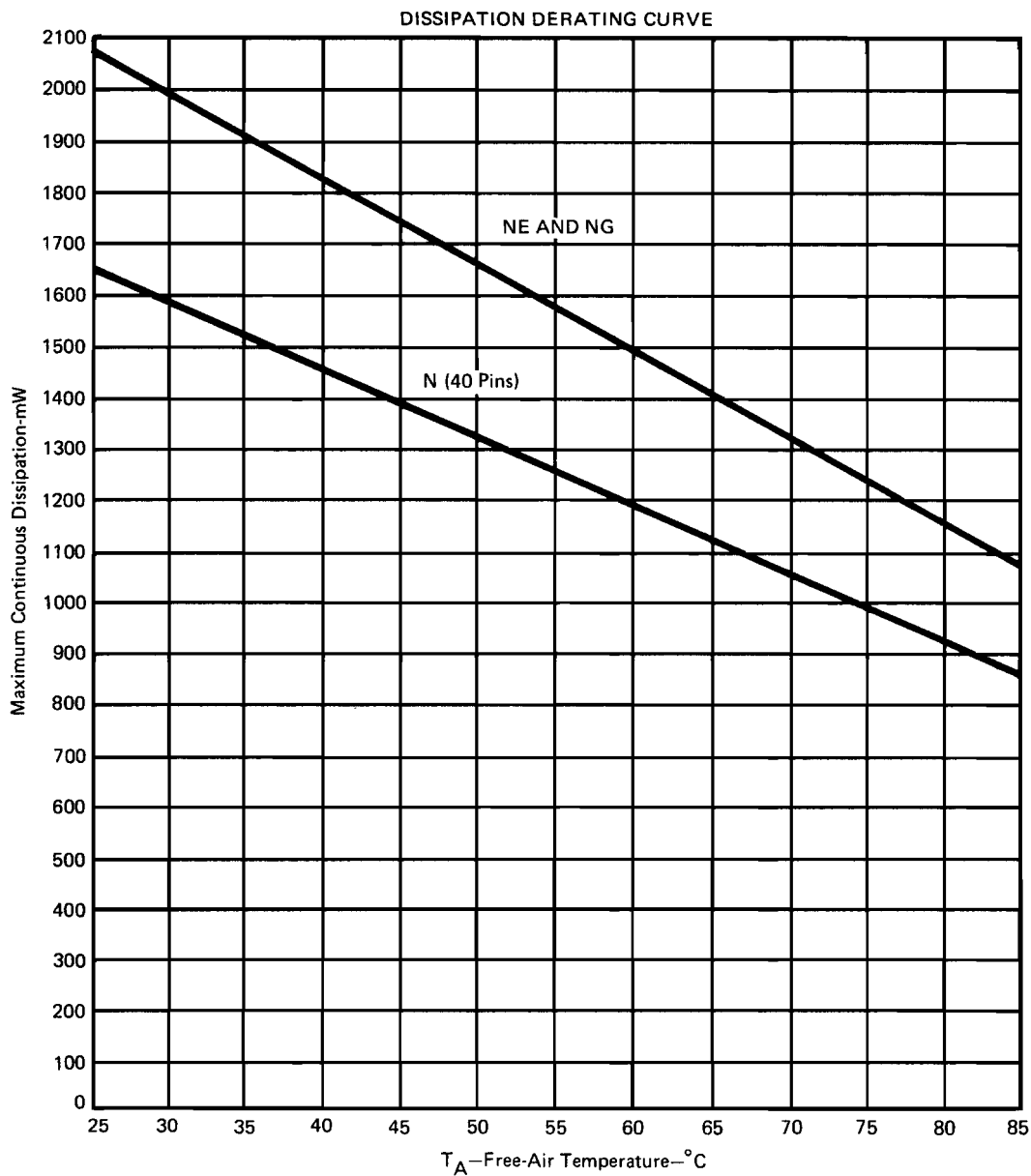




# THERMAL INFORMATION

## PLASTIC PACKAGES (CONTINUED)

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

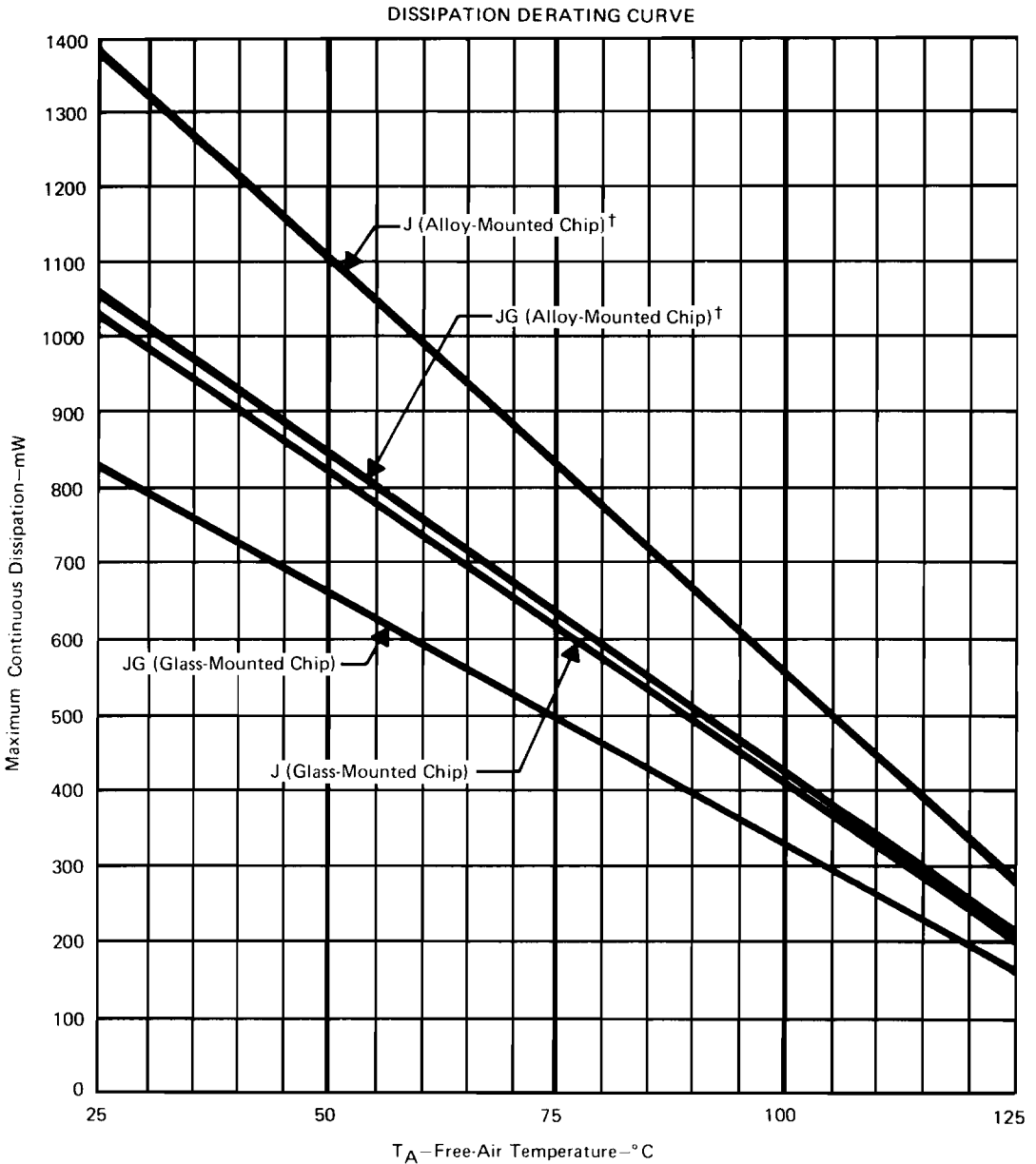


2

# THERMAL INFORMATION

## CERAMIC DUAL-IN-LINE PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

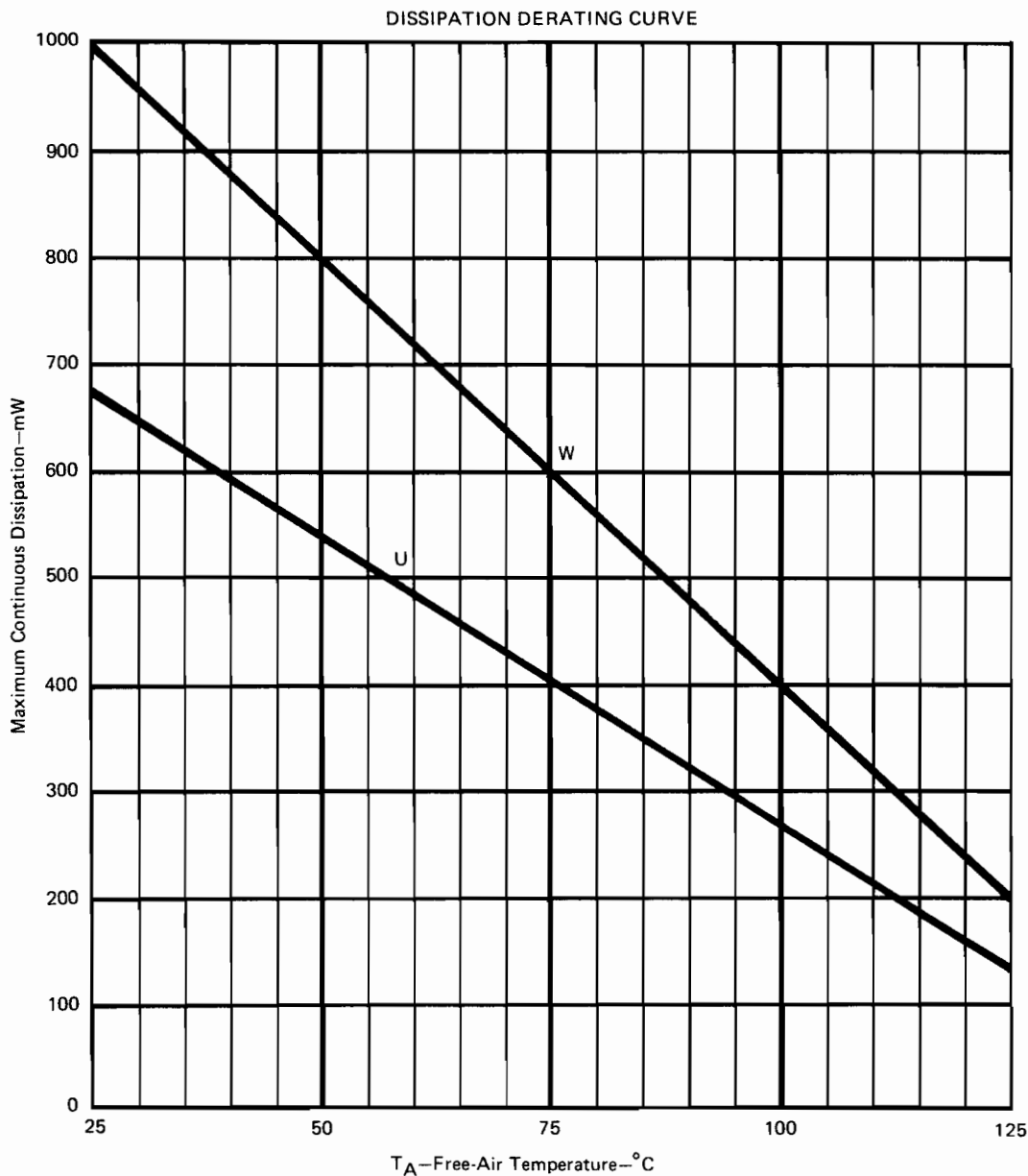


† In addition to those products so designated on their data sheets, all devices having a type number prefix of "SNC" or "SNM", or a suffix of "1883B" have alloy-mounted chips.

# THERMAL INFORMATION

## FLAT PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.



2



# **Ordering Instructions and Mechanical Data**

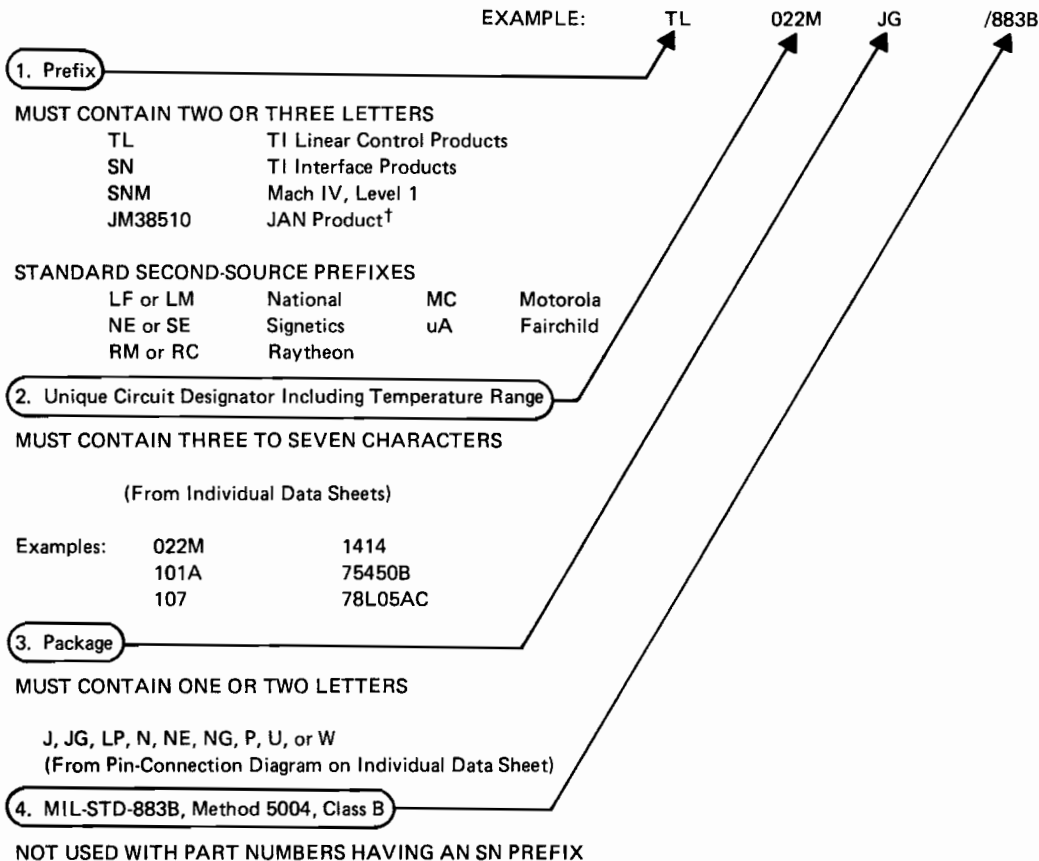


# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## ORDERING INSTRUCTIONS

Electrical characteristics presented in this data book, unless otherwise noted, apply for the circuit type(s) listed in the page heading regardless of package. The availability of a circuit function in a particular package is denoted by an alphabetical reference above the pin-connection diagram(s). These alphabetical references refer to mechanical outline drawing shown in this section.

Factory orders for circuits described should include a four-part type number as explained in the following example.



3

Circuits are shipped in one of the carriers shown below. Unless a specific method of shipment is specified by the customer (with possible additional costs), circuits will be shipped in the most practical carrier.

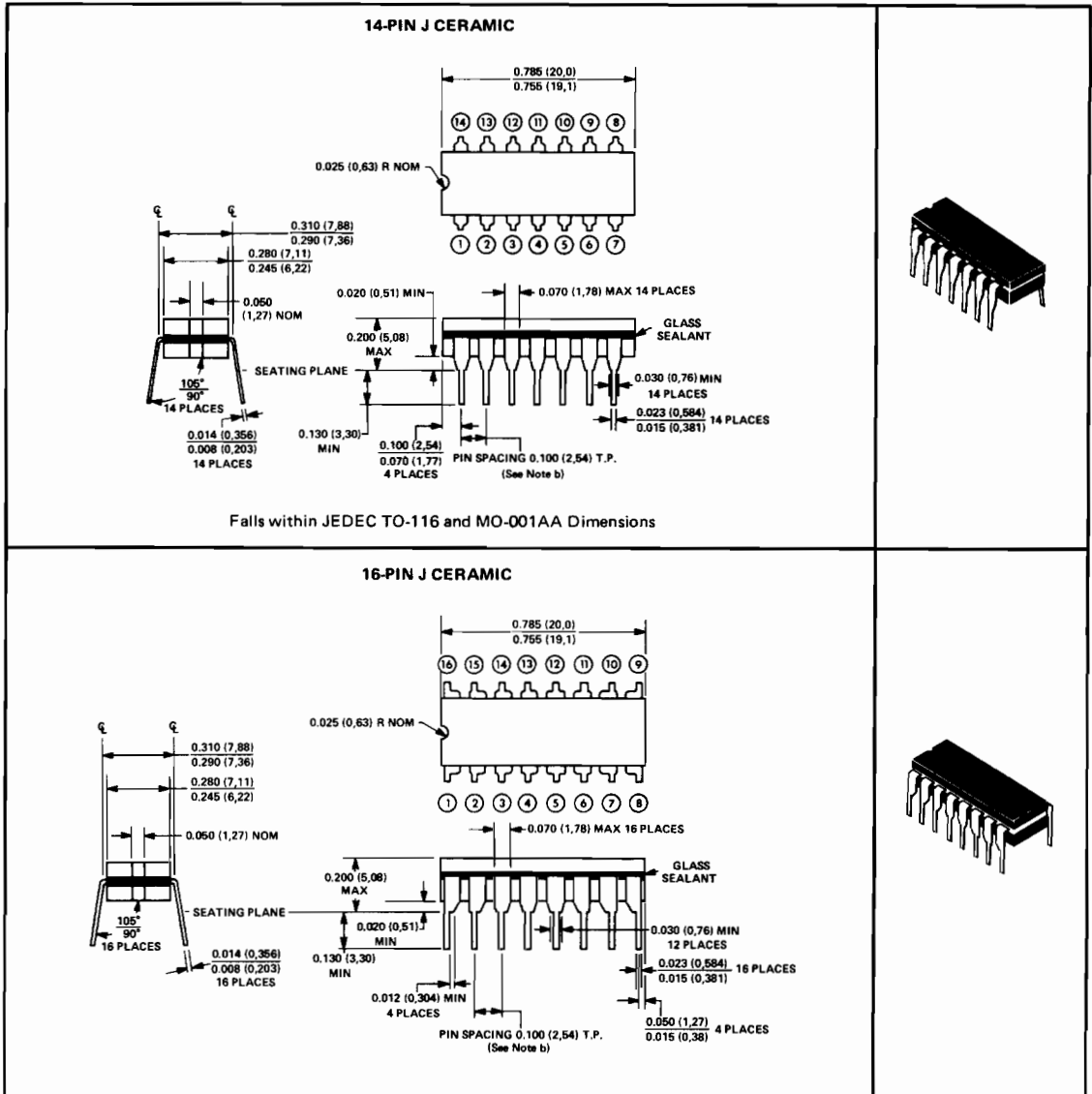
Dual-In-Line (J, JG, N, NE, NG, P)	Plug-In (LP)	Fiat (U, W)
—Slide Magazines	—Barnes Carrier	—Barnes Carrier
—A-Channel Plastic Tubing	—Sectioned Cardboard Box	—Milton Ross Carrier
—Barnes Carrier	—Individual Cardboard Box	
—Sectioned Cardboard Box		
—Individual Plastic Box		

<sup>†</sup>For ordering instruction on JAN Products, see Section 8, page 409.

# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## J ceramic dual-in-line package

These hermetically sealed dual-in-line packages consist of a ceramic base, ceramic cap, and a 14-, 16-, or 20-lead frame. Hermetic sealing is accomplished with glass. The packages are intended for insertion in mounting-hole rows on 0.300 (7,62) centers (see Note a). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly.

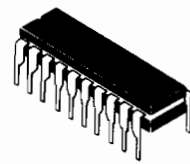
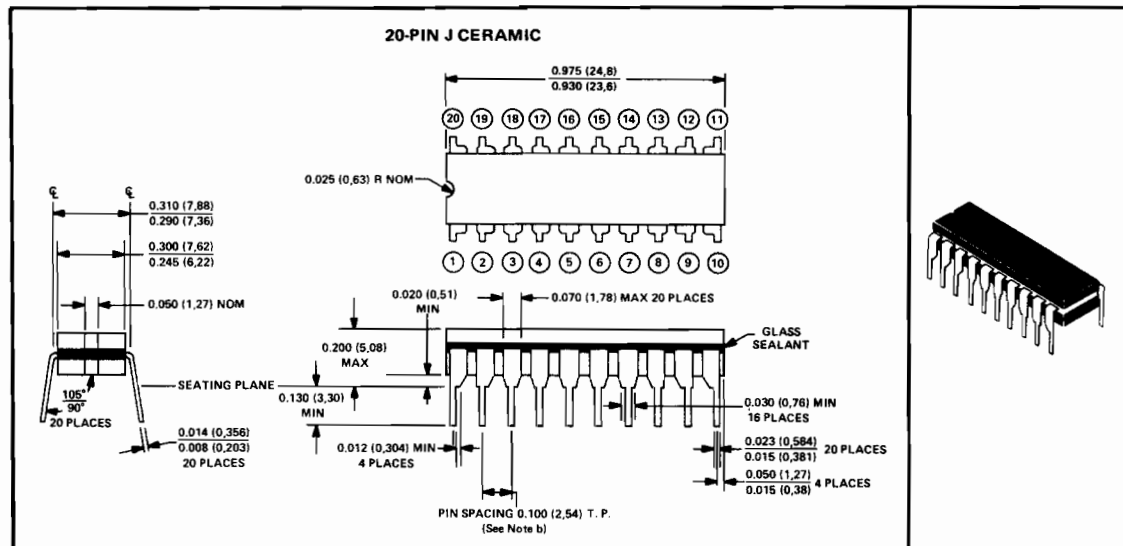


- NOTES: a. All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.  
 b. Each pin centerline is located within 0.010 (0,26) of its true longitudinal position.



# ORDERING INSTRUCTIONS AND MECHANICAL DATA

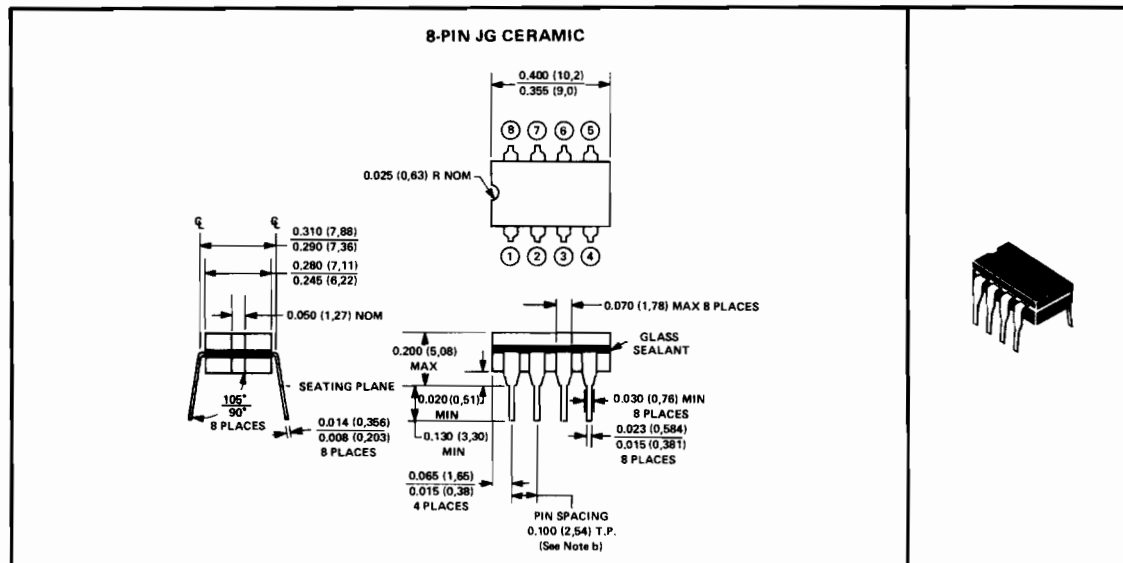
## J ceramic dual-in-line packages (continued)



3

## JG ceramic dual-in-line package

This hermetically sealed dual-in-line package consists of a ceramic base, ceramic cap, and 8-lead frame. Hermetic sealing is accomplished with glass. The package is intended for insertion in mounting-hole rows on 0.300 (7,62) centers (see Note a). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly.

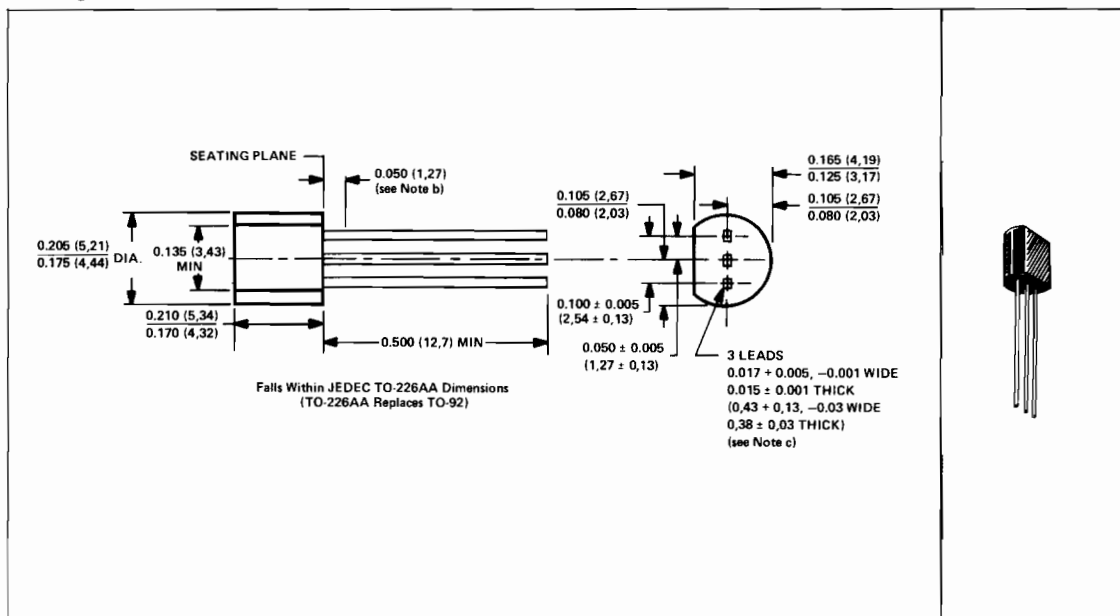


NOTES: a. All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.  
b. Each pin centerline is located within 0.010 (0,26) of its true longitudinal position.

# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## LP Silect<sup>‡</sup> plastic package

The Silect<sup>‡</sup> package is an encapsulation in a plastic compound specifically designed for this purpose. The package will withstand soldering temperature without deformation. The package exhibits stable performance characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C, Method 106B requirements.



<sup>‡</sup>Trade Mark of Texas Instruments Incorporated.

NOTES: a. Dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.

b. Lead dimensions are not controlled in this area.

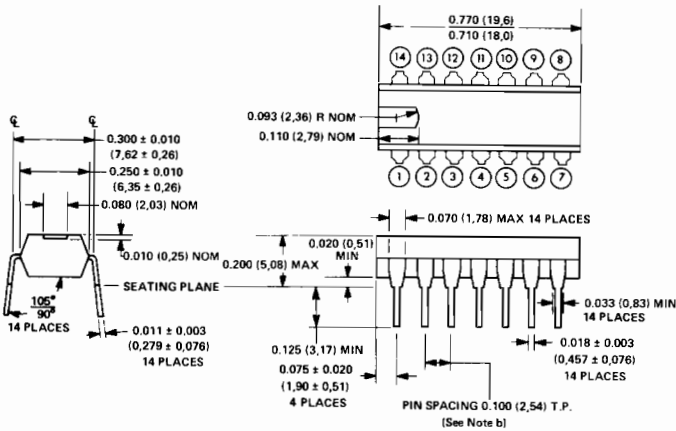
c. Beyond 0.100 (2,54) below seating plane, tolerance on lead width reduces to ±0.001 (0,03).

# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## N, NE, and NG plastic dual-in-line packages

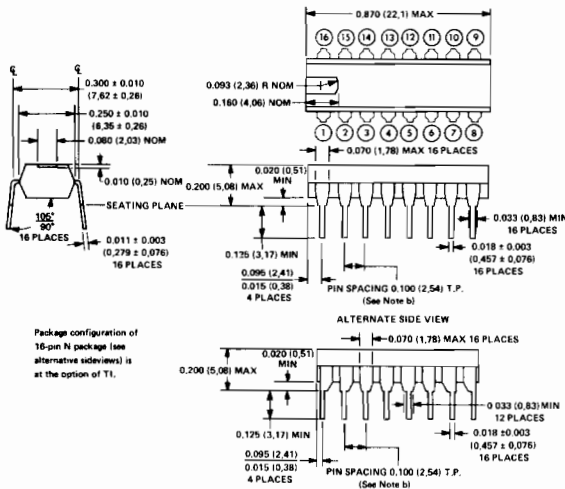
These dual-in-line packages consist of a circuit mounted on a 14-, 16-, 18-, 20-, or 40-lead frame and encapsulated within an electrically nonconductive plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. The packages are intended for insertion in mounting-hole rows on 0.300 (7,62) centers (see Note a). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tinned (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly. The NE package is available only in a 14-pin version and has internal metal tabs connecting the center three leads on each side for better heat dissipation. The NG package is available in either 14- or 16-pin versions and is intrinsically similar to the N package but provides better heat dissipation.

### 14-PIN N, NE, AND NG PLASTIC

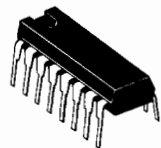
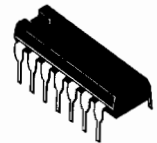


Falls Within JEDEC TO-116 and EIA MD-001AA Dimensions

### 16-PIN N AND NG PLASTIC

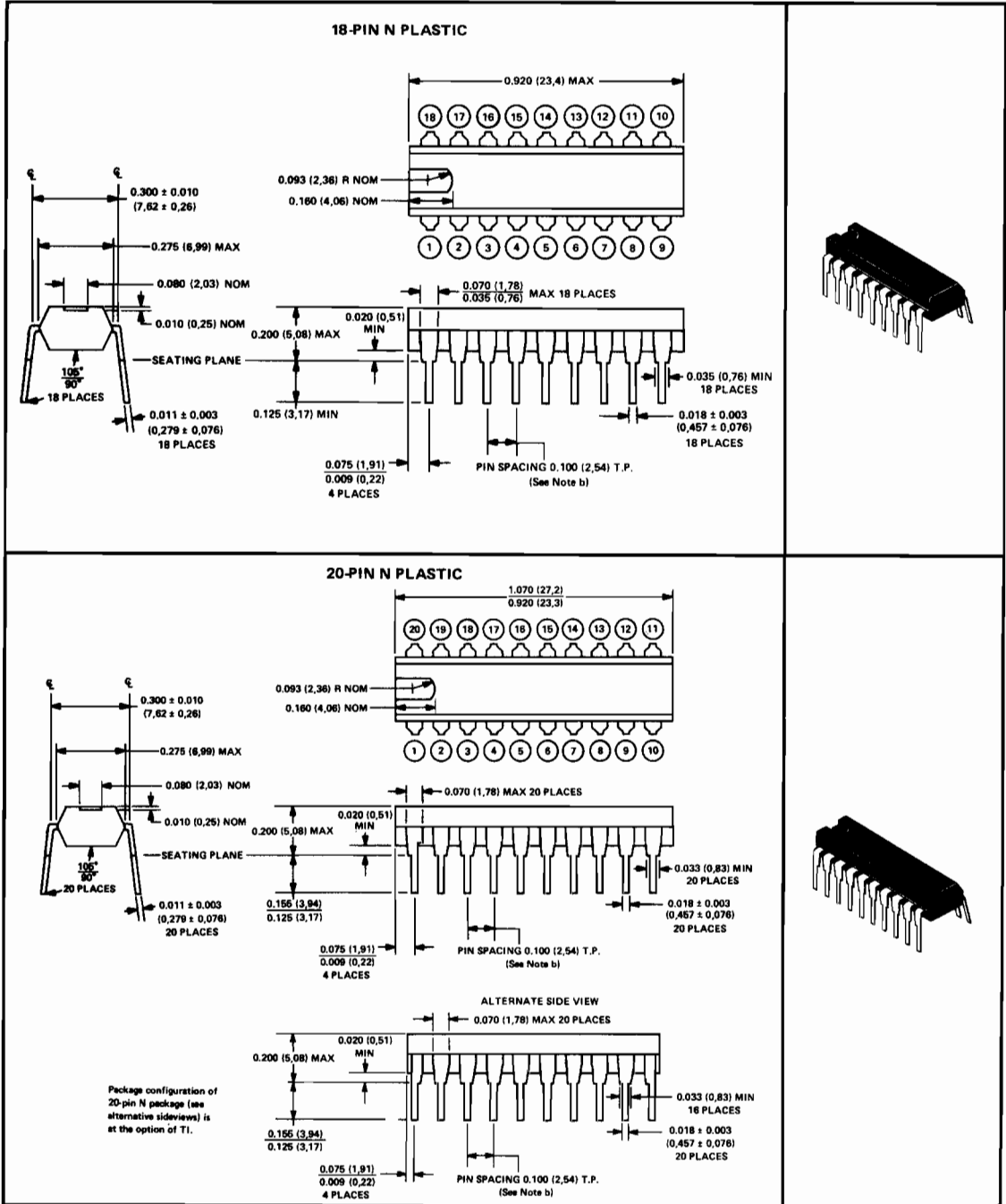


Package configuration of 16-pin N package (see alternate sideviews) is at the option of TI.



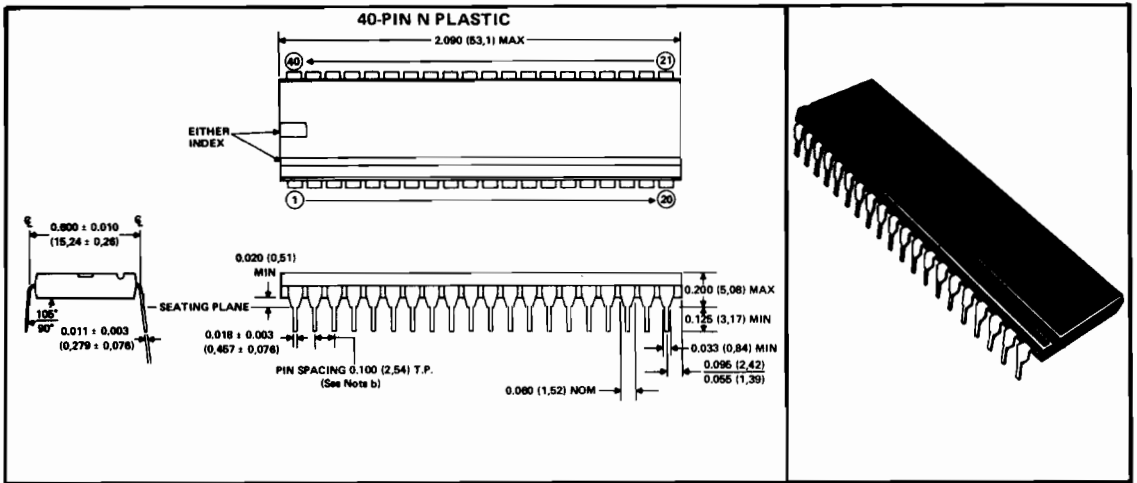
# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## N plastic dual-in-line packages (continued)



# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## N plastic dual-in-line packages (continued)

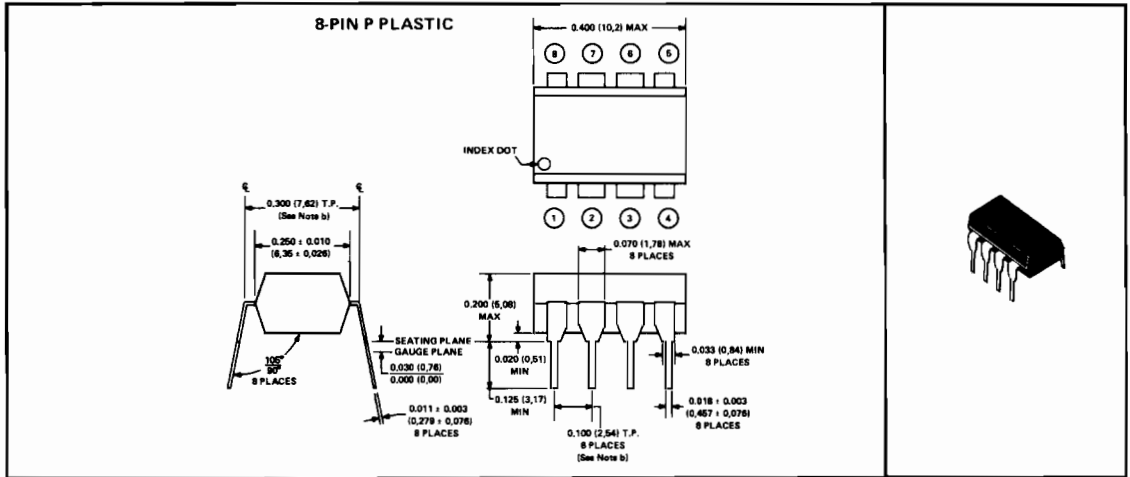


- NOTES: a. All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.  
 b. Leads are within 0.005 (0,127) radius of true position (TP) at maximum material condition.

# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## P plastic dual-in-line package

This dual-in-line package consists of a circuit mounted on an 8-lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics remain stable when operated in high-humidity conditions. The package is intended for insertion in mounting-hole rows on 0.300-inch (7,62) centers (see Note a). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly.

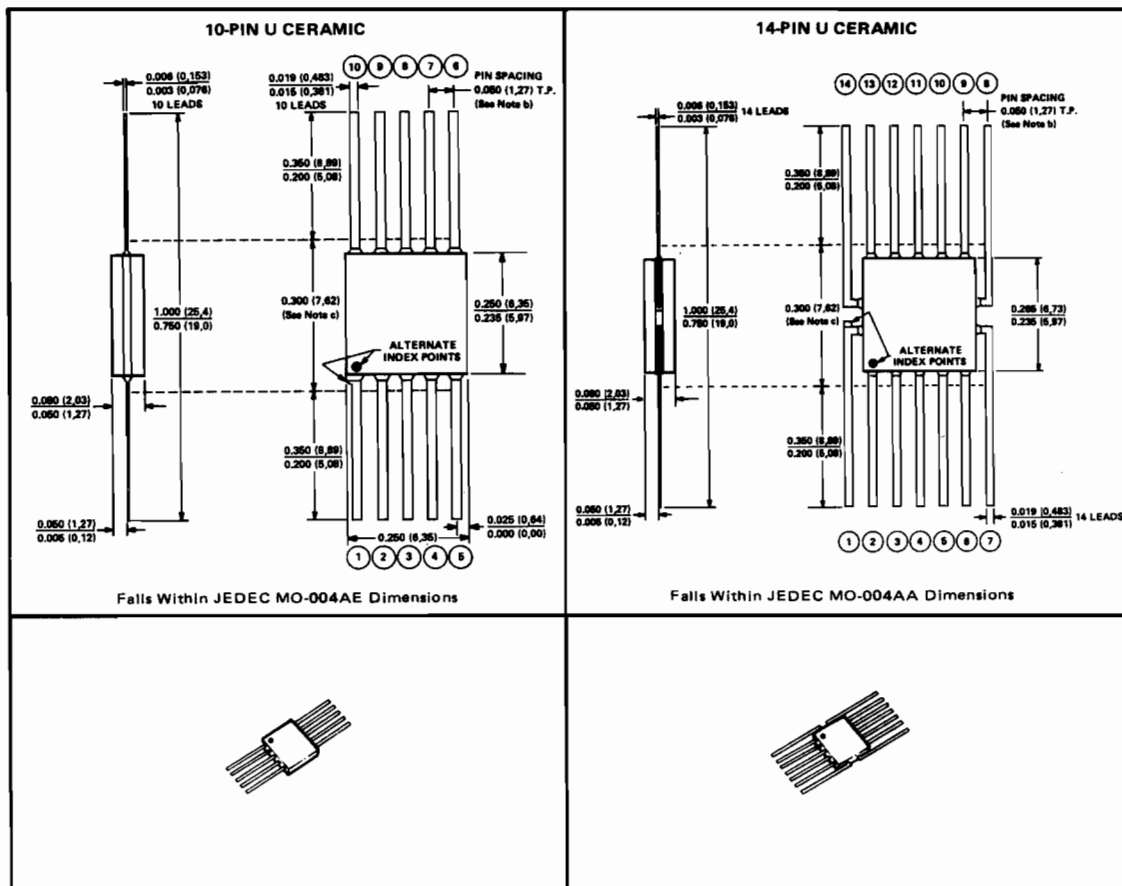


- NOTES: a. All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.  
 b. Each pin is within 0,005 (0,127) radius of true position (TP) at the gauge plane with maximum material condition and unit installed.

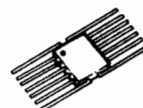
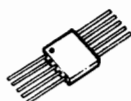
# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## U ceramic flat packages

These flat packages consist of a ceramic base, ceramic cap, and 10- or 14- lead frame. Circuit bars are alloy-mounted. Hermetic sealing is accomplished with glass. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly.



- NOTES:
- All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.
  - Leads are within 0.005 (0,127) radius of true position (TP) at maximum material condition.
  - This dimension determines a zone within which all body and lead irregularities lie.

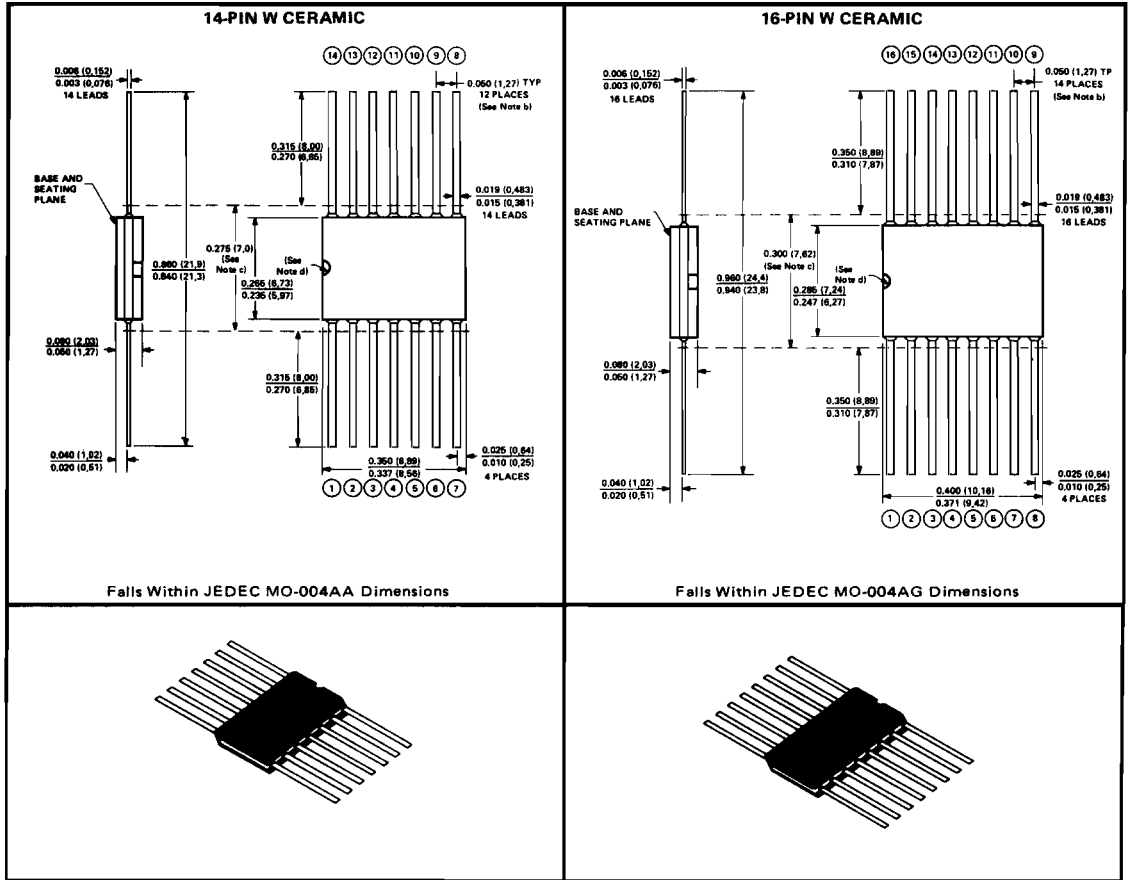


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# ORDERING INSTRUCTIONS AND MECHANICAL DATA

## W ceramic flat packages

These hermetically sealed flat packages consist of an electrically nonconductive ceramic base and cap and a 14- or 16-lead frame. Hermetic sealing is accomplished with glass. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: a. All dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.  
 b. Leads are within 0.005 (0.127) radius of true position (TP) at maximum material condition.  
 c. This dimension determines a zone within which all body and lead irregularities lie.  
 d. Index point is provided on cap for terminal identification only



# Operational Amplifiers

# SELECTION GUIDE

## SINGLE UNCOMPENSATED OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

I <sub>IB</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
75	2	10	50	1	0.5	3	±5	±22	High Performance	LM101A	J, JG, U, W	59
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060M	JG	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070M	JG	131
0.2	6	1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080M	JG	139
10,000	5	2,000	1.4	0.5	1.7	6.7		–7, +14	General Purpose	TL702M	J, U, W	157
5,000	2	500	2.5	0.5	1.7	6.7		–7, +14	General Purpose	uA702M	J, JG, U, W	163
200	2	50	25	1	0.3	3.6		±18	General Purpose	uA709AM	J, JG, U	167
500	5	200	25	1	0.3	5.5		±18	General Purpose	uA709M	J, JG	167
500	5	200	50	1	0.5	2.8	±2	±22	General Purpose	uA748M	J, JG, U, W	181

### Industrial Temperature Range (–25°C to 85°C)

75	2	10	50	1	0.5	3	±5	±22	High Performance	LM201A	J, JG, N, P	59
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060I	JG, P	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070I	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080I	JG, P	115

### Commercial Temperature Range (0°C to 70°C)

250	7.5	50	25	1	0.5	3	±5	±18	High Performance	LM301A	J, JG, N, P	59
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060C	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL060AC	JG, P	115
0.4	15	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070C	JG, P	131
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise	TL070AC	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080AC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL080C	JG, P	139
15,000	10	5,000	1	0.5	1.7	7		–7, +14	General Purpose	TL702C	J, JG, N	163
1,500	7.5	500	12	1	0.3	5.5		±18	General Purpose	uA709C	J, JG, N, P	167
500	6	200	20	1	0.5	2.8	±2	±18	General Purpose	uA748C	J, JG, N, P	181
100	5	20	25	1	0.5	3.3	±5	±22	High Performance	uA777C	J, JG, N, P	185

## SINGLE INTERNALLY COMPENSATED OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

$I_{IB}$ nA	$V_{IO}$ mV	$I_{IO}$ nA	$A_{VD}$ V/mV	$B_1$ MHz	$SR$ V/ $\mu$ s	$I_{CC}$ mA	$V_{CC}$ V		DESCRIPTION	DEVICE	PACKAGE	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
75	2	10	50	1	0.5	3	$\pm 2$	$\pm 22$	High Performance	LM107	J, JG, U, W	62
800	2	200	50	10	13	6.5	$\pm 3$	$\pm 22$	Low Noise $V_n = 4 \text{ nV}/\sqrt{\text{Hz}}$ Typ	SE5534	JG	105
800	2	200	50	10	13	6.5	$\pm 3$	$\pm 22$	Low Noise $V_n = 4.5 \text{ nV}/\sqrt{\text{Hz}}$ Max	SE5534A	JG	105
0.2	6	0.1	4	1	3.5	0.2	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL061M	JG, U	
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL071M	JG	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL081M	JG	139
0.2	2	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low $V_{IO}$	TL088M	JG; U	151
150	5	30	50	1	0.5	1.0	+3	+32	General Purpose,	TL321M	JG	
500	5	200	50	1	0.5	2.8	$\pm 2$	$\pm 22$	General Purpose	uA741M	J, JG, U, W	173

### Industrial Temperature Range (–25°C to 85°C)

75	2	10	50	1	0.5	3	$\pm 2$	$\pm 22$	High Performance	LM207	N	62
250	4	50	50	15	70	8		$\pm 20$	High Performance	LM218I	JG, P	73
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL061I	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL066I	JG, P	123
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise	TL071I	JG, P	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL081I	JG, P	139
0.4	0.5	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low Offset	TL087I	JG, P	147
0.4	3	0.1	50	3	13	2.8	$\pm 4$	$\pm 18$	BIFET, Low Offset	TL088I	JG, P	147
150	5	30	50	1	0.5	1	+3	+32	General Purpose	TL321I	JG, P	151

# SELECTION GUIDE

## SINGLE INTERNALLY COMPENSATED OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>B</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
250	7.5	50	25	1	0.5	3	±2	±18	High Performance	LM307	J, JG, N, P	62
500	10	200	25	15	70	10		±20	High Performance	LM318	JG, N, P	73
1,500	4	300	25	10	13	8	±3	±22	Low Noise			
									V <sub>n</sub> = 4 nV/√Hz Typ	NE5534	JG, P	105
1,500	4	300	25	10	13	8	±3	±22	Low Noise			
									V <sub>n</sub> = 4.5 nV/√Hz Max	NE5534A	JG, P	105
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061AC	JG, P	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061BC	JG, P	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL061C	JG, P	115
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power			
									with Power Control	TL066AC	JG, P	123
0.2	3	1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power			
									with Power Control	TL066BC	JG, P	123
0.4	15	2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power			
									with Power Control	TL066C	JG, P	123
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL071AC	JG, P	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL071BC	JG, P	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL071C	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081AC	JG, P	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081BC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL081C	JG, P	139
0.4	0.5	0.2	25	3	13	2.8	±4	±18	BIFET, Low V <sub>IO</sub>	TL087C	JG, P	147
0.4	2	0.2	25	3	13	2.8	±4	±18	BIFET, Low V <sub>IO</sub>	TL088C	JG, P	147
250	7	50	25	1	0.5	1.0	+3	+32	General Purpose,	TL321C	JG, P	151
500	6	200	20	1	0.5	2.8	±2	±18	General Purpose	uA741C	J, JG, N, P	173

## DUAL OPERATIONAL AMPLIFIERS

## Military Temperature Range (–55°C to 125°C)

$I_{IB}$ nA	$V_{IO}$ mV	$I_{IO}$ nA	$A_{VD}$ V/mV	$B_1$ MHz	$SR$ V/ $\mu$ s	$I_{CC}$ mA	$V_{CC}$ V		DESCRIPTION	DEVICE	PACKAGES	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
150	5	30	50	1	0.3	0.6	+3	+32	General Purpose	LM158	JG	71
500	5	200	50	1	0.6	2.8	$\pm 2$	$\pm 22$	General Purpose	MC1558	JG, U	85
500	5	200	50	3	1.5	2.8		$\pm 22$	High Performance	RM4558	JG	103
100	5	40	4	0.5	0.5	0.1	$\pm 2$	$\pm 22$	Low Power	TL022M	JG, U	109
0.2	6	0.1	4	1	3.5	0.2	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL062M	JG, U	115
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL072M	JG	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL082M	JG	139
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL083M	J	139
500	5	50	50	1	0.6	4	+3	+36	General Purpose	TL322M	JG	153
500	5	200	50	1	0.5	2.8	$\pm 2$	$\pm 22$	General Purpose	uA747M	J, W	177

## Automotive Temperature Range (–40°C to 85°C)

500	10	50	100	1	0.3	0.6	$\pm 3$	$\pm 26$	General Purpose	LM2904	JG, P, U	83
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## Industrial Temperature Range (–25°C to 85°C)

150	5	30	50	1	0.3	0.6	+3	+32	General Purpose,	LM258	JG, P, U	71
500	8	75	20	1	0.6	4	+3	+36	General Purpose	TL322I	JG, P	153
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL062I	JG, P	115
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise	TL072I	JG, P	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL082I	JG, P	139
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL083I	J, N	139
0.4	0.5	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, Low Offset	TL287I	JG, P	147
0.4	3	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL288I	JG, P	147

# SELECTION GUIDE

## DUAL OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>IB</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
							MIN	MAX				
250	7	50	25	1	0.3	0.6	+3	+32	General Purpose	LM358	JG, P	71
500	6	200	20	1	0.6	2.8	±2	±18	General Purpose	MC1458	JG, P	85
800	4	150	25	10	9	8		±22	Low Noise			
									V <sub>n</sub> = 5 nV/√Hz Typ	NE5532	JG, P	93
800	4	150	25	10	9	8		±22	Low Noise			
									V <sub>n</sub> = 5 nV/√Hz Typ	NE5532A	JG, P	93
1500	4	300	25	10	13	8		±22	Low Noise			
									V <sub>n</sub> = 4 nV/√Hz Typ	NE5533	J, N	97
1500	4	300	25	10	13	8		±22	Low Noise			
									V <sub>n</sub> = 3.5 nV/√Hz Typ	NE5533A	J, N	97
500	6	200	20	3	1	2.8		±18	High Performance	RC4558	JG, P	103
250	5	80	1	0.5	0.5	0.125	±2	±18	Low Power	TL022C	JG, P	109
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062AC	JG, P	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062BC	JG, P	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL062C	JG, P	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072AC	JG, P	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072BC	JG, P	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL072C	JG, P	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082AC	JG, P	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082BC	JG, P	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL082C	JG, P	139
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL083AC	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL083C	J, N	139
0.4	0.5	0.1	25	3	13	2.8	±4	±18	BIFET, Low Offset	TL287C	JG, P	147
0.4	3	0.1	25	3	13	2.8	±4	±18	BIFET, General Purpose	TL288C	JG, P	147
500	10	50	20	1	0.6	4	+3	+36	General Purpose	TL322C	JG, P	153
500	6	200	25	1	0.5	2.8	±2	±18	General Purpose	uA747C	J, N	177

## QUADRUPLE OPERATIONAL AMPLIFIERS

### Military Temperature Range (–55°C to 125°C)

$I_{IB}$ nA	$V_{IO}$ mV	$I_{IO}$ nA	$A_{VD}$ V/mV	$B_1$ MHz	SR V/ $\mu$ s	$I_{CC}$ mA	$V_{CC}$ V		DESCRIPTION	DEVICE	PACKAGES	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
150	5	30	50	1	0.5	0.5	+3	+32	General Purpose	LM124	J, U	65
500	5	200	50	3.5	1.5	2.8	$\pm 4$	$\pm 22$	High Performance	RM4136	J, U	101
100	5	40	4	0.5	0.5	0.1	$\pm 2$	$\pm 22$	Low Power	TL044M	J, U	112
0.2	9	0.1	4	1	3.5	0.2	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL064M	J, W	115
0.2	9	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ	TL074M	J, W	131
0.2	9	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL084M	J, W	139
100	5	25	50	1	0.5	3.6		$\pm 22$	General Purpose	LM148	J	67
100	5	25	2	2.5	0.5	12	$+4.5$	$+36$	General Purpose	LM1900	J	77
500	5	50	50	1	0.6	4	+3	+36	General Purpose	MC3503	J	89

### Automotive Temperature Range (–40°C to 85°C)

200			1.2	2.5	0.5	10	$+4.5$	$+32$	General Purpose	LM2900	J, N	77
500	10	50	100	5	1	5	+3	+26	General Purpose	LM2902	J, N	81
500	8	75	20	1	0.6	7	+3	+36	General Purpose	MC3303	J, N	89

### Industrial Temperature Range (–25°C to 85°C)

250	7	50	25	1	0.5	3	+3	+32	General Purpose,	LM224	J, N	65
200	6	50	25	1	0.5	4.5		$\pm 18$	General Purpose	LM248	J, N	67
0.2	6	0.1	4	1	3.5	0.25	$\pm 1.5$	$\pm 18$	BIFET, Low Power	TL064I	J, N	115
0.2	6	0.05	50	3	13	2.5	$\pm 3.5$	$\pm 18$	BIFET, Low Noise	TL074I	J, N	131
0.2	6	0.1	50	3	13	2.8	$\pm 3.5$	$\pm 18$	BIFET, General Purpose	TL084I	J, N	139

# SELECTION GUIDE

## QUADRUPLE OPERATIONAL AMPLIFIERS

Commercial Temperature Range (0°C to 70°C)

I <sub>B</sub> nA	V <sub>IO</sub> mV	I <sub>IO</sub> nA	A <sub>VD</sub> V/mV	B <sub>1</sub> MHz	SR V/μs	I <sub>CC</sub> mA	V <sub>CC</sub> V		DESCRIPTION	DEVICE	PACKAGES	PAGE
MAX	MAX	MAX	MIN	TYP	TYP	MAX	MIN	MAX				
250	7	50	25	1	0.5	0.5	+3	+32	General Purpose	LM324	J, N	65
200	6	50	25	1	0.5	4.5		±18	General Purpose	LM348	J, N	67
200			1.2	2.5	0.5	10	+4.5	+32	General Purpose	LM3900	J, N	77
500	10	50	20	1	0.6	7	+3	+36	General Purpose	MC3403	J, N	89
500	6	200	20	3	1	2.8	±4	±18	High Performance	RC4136	J, N	101
250	5	80	1	0.5	0.5	0.125	±2	±18	Low Power	TL044C	J, N	112
0.2	6	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064AC	J, N	115
0.2	3	0.1	4	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064BC	J, N	115
0.4	15	0.2	3	1	3.5	0.25	±1.5	±18	BIFET, Low Power	TL064C	J, N	115
0.2	6	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL074AC	J, N	131
0.2	3	0.05	50	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL074BC	J, N	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL074C	J, N	131
0.2	10	0.05	25	3	13	2.5	±3.5	±18	BIFET, Low Noise			
									V <sub>n</sub> = 18 nV/√Hz Typ	TL075C	N	131
0.2	6	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084AC	J, N	139
0.2	3	0.1	50	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084BC	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL084C	J, N	139
0.4	15	0.2	25	3	13	2.8	±3.5	±18	BIFET, General Purpose	TL085C	N	139



# GLOSSARY

## OPERATIONAL AMPLIFIER TERMS AND DEFINITIONS

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### Input Offset Voltage ( $V_{IO}$ )

The d-c voltage that must be applied between the input terminals to force the quiescent d-c output voltage to zero.

NOTE: The input offset voltage may also be defined for the case where two equal resistances ( $R_S$ ) are inserted in series with the input leads.

### Average Temperature Coefficient of Input Offset Voltage ( $\alpha_{VIO}$ )

The ratio of the change in input offset voltage to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{VIO} = \left| \frac{(V_{IO} @ T_{A(1)}) - (V_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right| \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

### Input Offset Current ( $I_{IO}$ )

The difference between the currents into the two input terminals with the output at zero volts.

### Average Temperature Coefficient of Input Offset Current ( $\alpha_{IIO}$ )

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{IIO} = \left| \frac{(I_{IO} @ T_{A(1)}) - (I_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right| \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

### Input Bias Current ( $I_{IB}$ )

The average of the currents into the two input terminals with the output at zero volts.

### Common-Mode Input Voltage ( $V_{IC}$ )

The average of the two input voltages.

### Common-Mode Input Voltage Range ( $V_{ICR}$ )

The range of common-mode input voltage that if exceeded will cause the amplifier to cease functioning properly.

### Differential Input Voltage ( $V_{ID}$ )

The voltage at the noninverting input with respect to the inverting input.

### Maximum Peak Output Voltage Swing ( $V_{OM}$ )

The maximum positive or negative peak output voltage that can be obtained without waveform clipping when the quiescent d-c output voltage is zero.

### Maximum Peak-to-Peak Output Voltage Swing ( $V_{OPP}$ )

The maximum peak-to-peak output voltage that can be obtained without waveform clipping when the quiescent d-c output voltage is zero.

# GLOSSARY

## OPERATIONAL AMPLIFIER TERMS AND DEFINITIONS

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### Large-Signal Voltage Amplification ( $A_V$ )

The ratio of the peak-to-peak output voltage swing to the change in input voltage required to drive the output.

### Differential Voltage Amplification ( $A_{VD}$ )

The ratio of the change in output voltage to the change in differential input voltage producing it.

### Maximum-Output-Swing Bandwidth ( $B_{OM}$ )

The range of frequencies within which the maximum output voltage swing is above a specified value.

### Unity-Gain Bandwidth ( $B_1$ )

The range of frequencies within which the open-loop voltage amplification is greater than unity.

### Phase Margin ( $\phi_m$ )

The absolute value of the open-loop phase shift between the output and the inverting input at the frequency at which the modulus of the open-loop amplification is unity.

### Gain Margin ( $A_m$ )

The reciprocal of the open-loop voltage amplification at the lowest frequency at which the open-loop phase shift is such that the output is in phase with the inverting input.

### Input Resistance ( $r_i$ )

The resistance between the input terminals with either input grounded.

### Differential Input Resistance ( $r_{id}$ )

The small-signal resistance between the two ungrounded input terminals.

### Output Resistance ( $r_o$ )

The resistance between the output terminal and ground.

### Input Capacitance ( $C_i$ )

The capacitance between the input terminals with either input grounded.

### Common-Mode Input Impedance ( $z_{ic}$ )

The parallel sum of the small-signal impedance between each input terminal and ground.

### Output Impedance ( $z_o$ )

The small-signal impedance between the output terminal and ground.

# GLOSSARY

## OPERATIONAL AMPLIFIER TERMS AND DEFINITIONS

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### Common-Mode Rejection Ratio ( $k_{CMR}$ , CMRR)

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

### Supply Voltage Sensitivity ( $k_{SVS}$ , $\Delta V_{IO}/\Delta V_{CC}$ )

The absolute value of the ratio of the change in input offset voltage to the change in supply voltages producing it.

NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.  
2. This is the reciprocal of supply voltage rejection ratio.

### Supply Voltage Rejection Ratio ( $k_{SVR}$ , $\Delta V_{CC}/\Delta V_{IO}$ )

The absolute value of the ratio of the change in supply voltages to the change in input offset voltage.

NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.  
2. This is the reciprocal of supply voltage sensitivity.

### Equivalent Input Noise Voltage ( $V_n$ )

The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

### Equivalent Input Noise Current ( $I_n$ )

The current of an ideal current source (having an internal impedance equal to infinity) in parallel with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a current source.

### Average Noise Figure ( $\bar{F}$ )

The ratio of (1) the total output noise power within a designated output frequency band when the noise temperature of the input termination(s) is at the reference noise temperature,  $T_0$ , at all frequencies to (2) that part of (1) caused by the noise temperature of the designated signal-input termination within a designated signal-input frequency band.

### Short-Circuit Output Current ( $I_{OS}$ )

The maximum output current available from the amplifier with the output shorted to ground, to either supply, or to a specified point.

### Supply Current ( $I_{CC}$ )

The current into the  $V_{CC}$  or  $V_{CC+}$  terminal of an integrated circuit.

### Total Power Dissipation ( $P_D$ )

The total d-c power supplied to the device less any power delivered from the device to a load.

NOTE: At no load:  $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$ .

### Channel Separation ( $V_{O1}/V_{O2}$ )

The ratio of the change in output voltage of a driven channel to the resulting change in output voltage of another channel.

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# GLOSSARY

## OPERATIONAL AMPLIFIER TERMS AND DEFINITIONS

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### Rise Time ( $t_r$ )

The time required for an output voltage step to change from 10% to 90% of its final value.

### Total Response Time (Settling Time) ( $t_{tot}$ )

The time between a step-function change of the input signal level and the instant at which the magnitude of the output signal reaches for the last time a specified level range ( $\pm\epsilon$ ) containing the final output signal level.

### Overshoot Factor

The ratio of (1) the largest deviation of the output signal value from its final steady-state value after a step-function change of the input signal, to (2) the absolute value of the difference between the steady-state output signal values before and after the step-function change of the input signal.

### Slew Rate (SR)

The average time rate of change of the closed-loop amplifier output voltage for a step-signal input.

# LINEAR INTEGRATED CIRCUITS

# TYPES LM101A, LM201A, LM301A HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 11432, JANUARY 1971—REVISED OCTOBER 1979

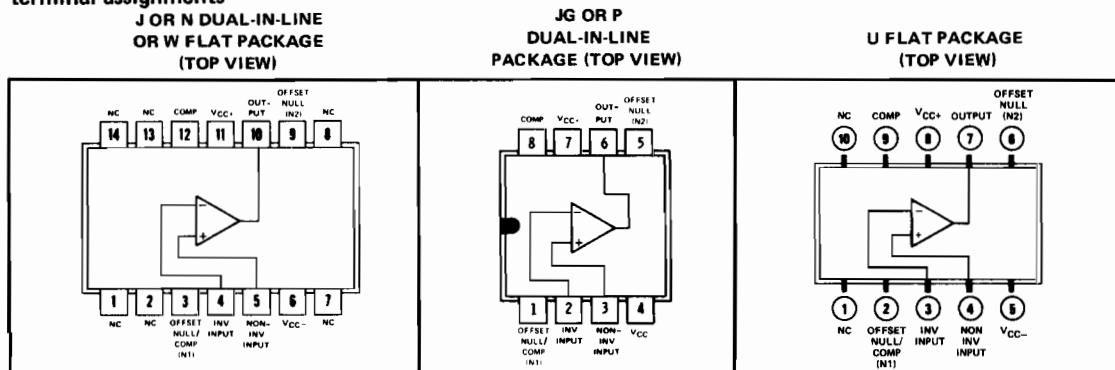
- Low Input Currents
- Low Input Offset Parameters
- Frequency and Transient Response Characteristics Adjustable
- Short-Circuit Protection
- Offset-Voltage Null Capability
- Designed to be Interchangeable with National Semiconductor LM101A and LM301A
- No Latch-Up
- Wide Common-Mode and Differential Voltage Ranges
- Same Pin Assignments as uA709

## description

The LM101A, LM201A, and LM301A are high-performance operational amplifiers featuring very low input bias current and input offset voltage and current to improve the accuracy of high-impedance circuits using these devices. The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are protected to withstand short-circuits at the output. The external compensation of these amplifiers allows the changing of the frequency response (when the closed-loop gain is greater than unity) for applications requiring wider bandwidth or higher slew rate. A potentiometer may be connected between the offset-null inputs (N1 and N2), as shown in Figure 7, to null out the offset voltage.

The LM101A is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM201A is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM301A is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM101A	LM201A	LM301A	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$	-0.5 to 2	-0.5 to 2	-0.5 to 2	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	500	500	500	mW
Operating free-air temperature range	$-55$ to $125$	$-25$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	300	300	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds		260	260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the LM101A only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature. For the LM201A only, the unlimited duration of the short-circuit applies at (or below)  $85^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, LM101A chips are alloy-mounted; LM201A and LM301A chips are glass-mounted.

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# TYPES LM101A, LM201A, LM301A

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	500 mW	11.0 mW/°C	105°C
J (Glass-Mounted Chip)	500 mW	8.2 mW/°C	89°C
JG (Alloy-Mounted Chip)	500 mW	8.4 mW/°C	90°C
JG (Glass-Mounted Chip)	500 mW	6.6 mW/°C	74°C
N	500 mW	9.2 mW/°C	96°C
P	500 mW	8.0 mW/°C	87°C
U	500 mW	5.4 mW/°C	57°C
W	500 mW	8.0 mW/°C	87°C

Also see Dissipation Derating Curves, Section 2.

electrical characteristics at specified free-air temperature,  $C_C = 30$  pF (see note 6)

PARAMETER	TEST CONDITIONS†	LM101A, LM201A			LM301A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50$ k $\Omega$	25°C	0.6	2	2.0	7.5	mV	
		Full range	3			10		
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage		Full range	3	15	6	30	$\mu V/^\circ C$	
$I_{IO}$ Input offset current		25°C	1.5	10	3	50	nA	
		Full range	20			70		
$\alpha_{IIO}$ Average temperature coefficient of input offset current		$T_A = -55^\circ C$ to $25^\circ C$	0.02	0.2			nA/°C	
		$T_A = 25^\circ C$ to MAX	0.01	0.1				
		$T_A = 0^\circ C$ to $25^\circ C$				0.02		0.6
		$T_A = 25^\circ C$ to $70^\circ C$				0.01		0.3
$I_{IB}$ Input bias current		25°C	30	75	70	250	nA	
		Full range	100			300		
$V_{ICR}$ Common-mode input voltage range	See Note 7	Full range	±15		±12		V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15$ V, $R_L = 10$ k $\Omega$	25°C	24	28	24	28	V	
		Full range	24					
		$V_{CC\pm} = \pm 15$ V, $R_L = 2$ k $\Omega$	20	26	20	26		
		Full range	20					
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15$ V, $V_O = \pm 10$ V, $R_L \geq 2$ k $\Omega$	25°C	50	200	25	200	V/mV	
		Full range	25			15		
$r_i$ Input resistance		25°C	1.5	4	0.5	2	M $\Omega$	
CMRR Common-mode rejection ratio	$R_S = 50$ k $\Omega$	25°C	80	98	70	90	dB	
		Full range	80			70		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$R_S = 50$ k $\Omega$	25°C	80	98	70	96	dB	
		Full range	80			70		
$I_{CC}$ Supply current	No load, No signal, See Note 7	25°C	1.8	3	1.8	3	mA	
		MAX	1.2	2.5				

†All characteristics are specified under open-loop operation. Full range for LM101A is  $-55^\circ C$  to  $125^\circ C$ , for LM201A is  $-25^\circ C$  to  $85^\circ C$ , and for LM301A is  $0^\circ C$  to  $70^\circ C$ .

NOTES: 6. Unless otherwise noted,  $V_{CC\pm} = \pm 5$  V to  $\pm 20$  V for LM101A and LM201A, and  $V_{CC\pm} = \pm 5$  V to  $\pm 15$  V for LM301A. All typical values are at  $V_{CC\pm} = \pm 15$  V.

7. For LM101A and LM201A,  $V_{CC\pm} = \pm 20$  V. For LM301A,  $V_{CC\pm} = \pm 15$  V.

# TYPES LM101A, LM201A, LM301A HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

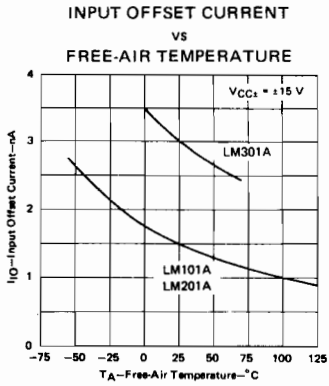


FIGURE 1

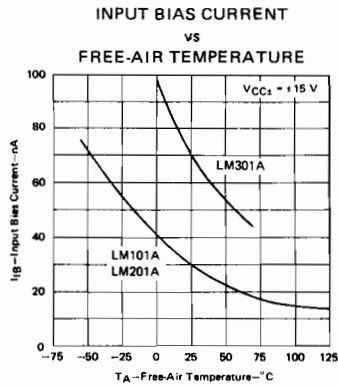


FIGURE 2

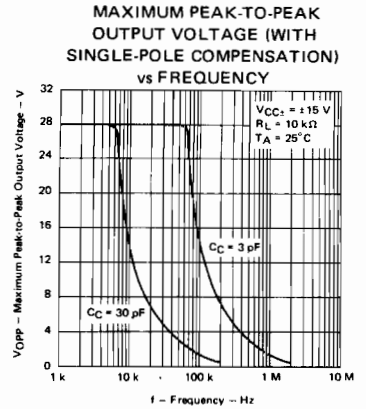


FIGURE 3

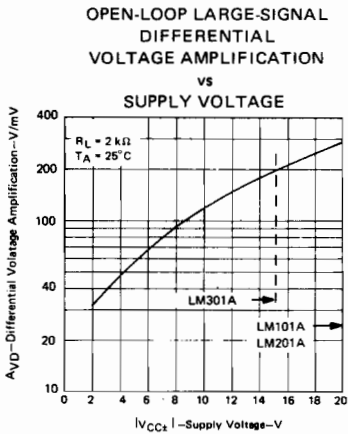


FIGURE 4

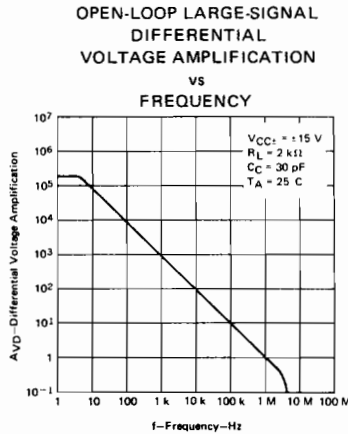


FIGURE 5

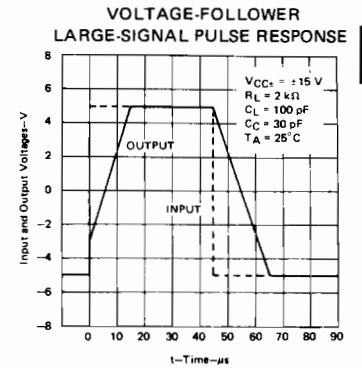
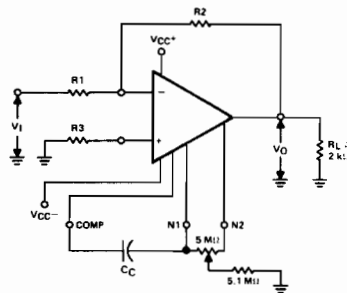


FIGURE 6

## TYPICAL APPLICATION DATA



$$\frac{V_O}{V_I} = -\frac{R_2}{R_1}$$

$$C_C \geq \frac{R_1 \cdot 30 \text{ pF}}{R_1 + R_2}$$

$$R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

FIGURE 7—INVERTING CIRCUIT WITH ADJUSTABLE GAIN,  
SINGLE-POLE COMPENSATION, AND OFFSET ADJUSTMENT

- Low Input Currents
- No Frequency Compensation Required
- Low Input Offset Parameters
- Short-Circuit Protection
- No Latch-Up
- Wide Common-Mode and Differential Voltage Ranges

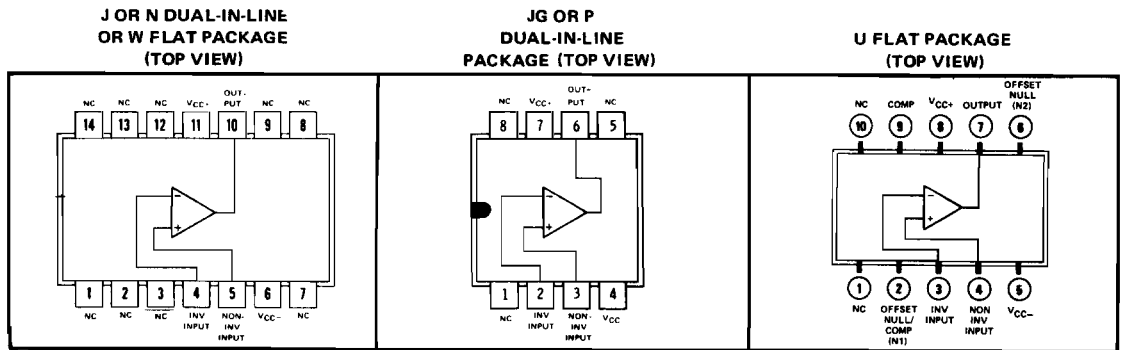
## description

The LM107, LM207, and LM307 are high-performance operational amplifiers featuring very low input bias current and input offset voltage and current to improve the accuracy of high-impedance circuits using these devices.

The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The LM107 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM207 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM307 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM107	LM207	LM307	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	500	500	500	mW
Operating free-air temperature range	$-55$ to $125$	$-25$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J, JG, U, or W package		300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package		260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the LM107 only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature. For the LM207 only, the unlimited duration of the short-circuit applies at (or below)  $85^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, LM107 chips are alloy-mounted; LM207 and LM307 chips are glass-mounted.



# TYPES LM107, LM207, LM307 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	500 mW	11.0 mW/°C	105°C
J (Glass-Mounted Chip)	500 mW	8.2 mW/°C	89°C
JG (Alloy-Mounted Chip)	500 mW	8.4 mW/°C	90°C
JG (Glass-Mounted Chip)	500 mW	6.6 mW/°C	74°C
N	500 mW	9.2 mW/°C	96°C
P	500 mW	8.0 mW/°C	87°C
U	500 mW	5.4 mW/°C	57°C
W	500 mW	8.0 mW/°C	87°C

Also see Dissipation Derating Curves, Section 2.

electrical characteristics at specified free-air temperature (see note 6)

PARAMETER		TEST CONDITIONS†	LM107, LM207			LM307			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$R_S = 50\text{ k}\Omega$	25°C	0.6	2	2	7.5	mV	
			Full range	3		10			
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage		Full range	3	15	6	30	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current		25°C	1.5	10	3	50	nA	
			Full range	20		70			
$\alpha I_{IO}$	Average temperature coefficient of input offset current		$T_A = -55^\circ\text{C}$ to $25^\circ\text{C}$	0.02	0.2			nA/°C	
			$T_A = 25^\circ\text{C}$ to MAX	0.01	0.1				
			$T_A = 0^\circ\text{C}$ to $25^\circ\text{C}$			0.02	0.6		
			$T_A = 25^\circ\text{C}$ to $70^\circ\text{C}$			0.01	0.3		
$I_{IB}$	Input bias current		25°C	30	75	70	250	nA	
			Full range	100		300			
$V_{ICR}$	Common-mode input voltage range	See Note 7	Full range	$\pm 15$		$\pm 12$		V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15\text{ V}$ , $R_L = 10\text{ k}\Omega$	25°C	24	28	24	28	V	
			Full range	24		24			
		$V_{CC\pm} = \pm 15\text{ V}$ , $R_L = 2\text{ k}\Omega$	25°C	20	26	20	26		
			Full range	20		20			
$AVD$	Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15\text{ V}$ , $V_O = \pm 10\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	200	25	200	V/mV	
			Full range	25		15			
$r_i$	Input resistance		25°C	1.5	4	0.5	2	M $\Omega$	
$CMRR$	Common-mode rejection ratio	$R_S = 50\text{ k}\Omega$	25°C	80	98	70	90	dB	
			Full range	80		70			
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$R_S = 50\text{ k}\Omega$	25°C	80	98	70	96	dB	
			Full range	80		70			
$I_{CC}$	Supply current	No load, No signal, See Note 7	25°C	1.8	3	1.8	3	mA	
			MAX	1.2	2.5				

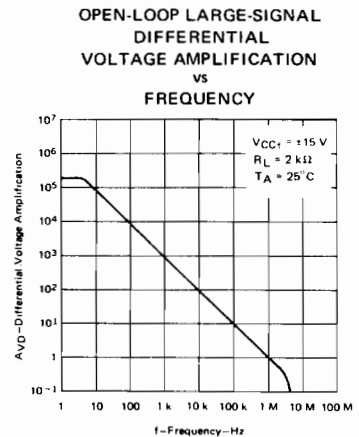
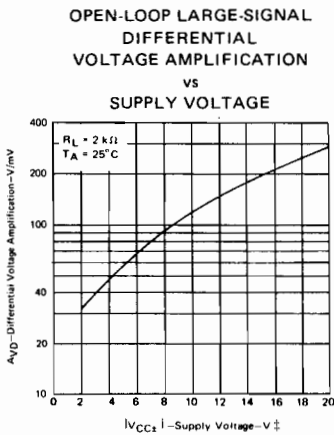
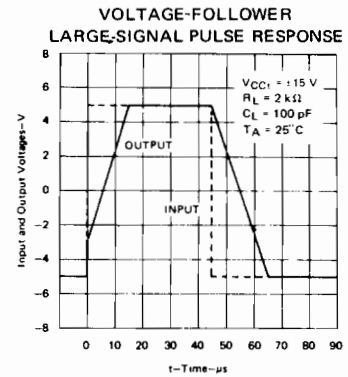
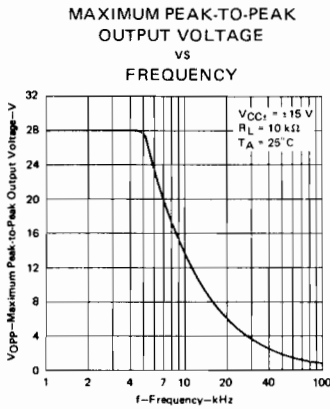
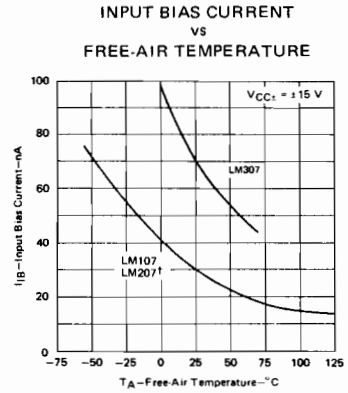
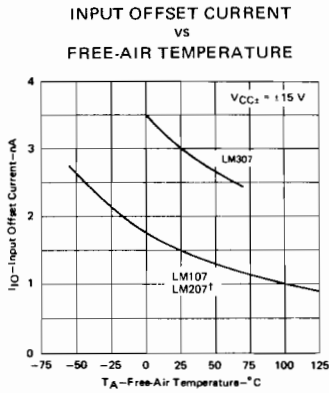
† All characteristics are specified under open-loop operation. Full range for LM107 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for LM207 is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and for LM307 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTES: 6. Unless otherwise noted  $V_{CC\pm} = \pm 5\text{ V}$  to  $\pm 20\text{ V}$  for LM107 and LM207, and  $V_{CC\pm} = \pm 5\text{ V}$  to  $\pm 15\text{ V}$  for LM307. All typical values are at  $V_{CC\pm} = \pm 15\text{ V}$ .

7. For LM107 and LM207,  $V_{CC\pm} = \pm 20\text{ V}$ . For LM307,  $V_{CC\pm} = \pm 15\text{ V}$ .

# TYPES LM107, LM207, LM307 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS



† Data for free-air temperatures below  $-25^{\circ}\text{C}$  and above  $85^{\circ}\text{C}$  is applicable for LM107 only.

‡ Data for supply voltages greater than 15 V is applicable to LM107 and LM207 circuits only.

# LINEAR INTEGRATED CIRCUITS

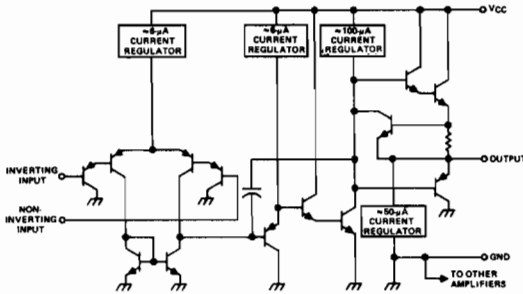
# TYPES LM124, LM224, LM324 QUADRUPLE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12248, SEPTEMBER 1975 — REVISED OCTOBER 1979

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 30 V  
or Dual Supplies
- Low Supply Current Drain  
Independent of Supply Voltage  
. . . 0.8 mA Typ
- Common-Mode Input Voltage  
Range Includes Ground Allowing  
Direct Sensing near Ground

- Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 3 nA Typ (LM124)  
Input Bias Current . . . 45 nA Typ
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage . . .  $\pm 32$  V
- Open-Loop Differential Voltage  
Amplification . . . 100 V/mV Typ
- Internal Frequency Compensation

schematic (each amplifier)



## description

These devices consist of four independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts and Pin 4 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

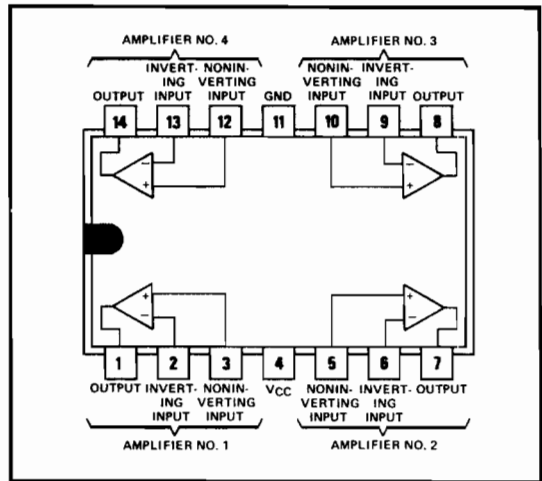
Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	32 V
Differential input voltage (see Note 2)	$\pm 32$ V
Input voltage range (either input)	-0.3 V to 32 V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	900 mW
Operating free-air temperature range:	
LM124	-55°C to 125°C
LM224	-25°C to 85°C
LM324	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM124 chips are alloy-mounted; LM224 and LM324 chips are glass-mounted.

J OR N DUAL-IN-LINE OR  
W FLAT PACKAGE (TOP VIEW)



# TYPES LM124, LM224, LM324

## QUADRUPLE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

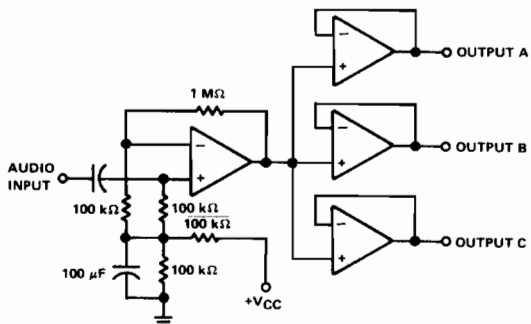
PARAMETER	TEST CONDITIONS†	LM124, LM224			LM324			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage $V_O = 1.4\text{ V}$ , $V_{CC} = 5\text{ V to }30\text{ V}$	25°C	2	5	2	7	mV	
		Full range		7		9		
$I_{IO}$	Input offset current $V_O = 1.4\text{ V}$	25°C	3	30	5	50	nA	
		Full range		100		150		
$I_{IB}$	Input bias current $V_O = 1.4\text{ V}$ , See Note 5	25°C	-45	-150	-45	-250	nA	
		Full range		-300		-500		
$V_{ICR}$	Common-mode input voltage range $V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$V_{OH}$	High-level output voltage $V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$ $V_{CC} = 30\text{ V}$ , $R_L \geq 10\text{ k}\Omega$	Full range	26		26		V	
		Full range	27	28	27	28		
$V_{OL}$	Low-level output voltage $R_L \leq 10\text{ k}\Omega$	Full range		5 20		5 20	mV	
$A_{VD}$	Large-signal differential voltage amplification $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100	V/mV	
		Full range	25		15			
CMRR	Common-mode rejection ratio $R_S \leq 10\text{ k}\Omega$	25°C	70	85	65	85	dB	
$k_{SVR}^*$	Supply voltage rejection ratio $R_S \leq 10\text{ k}\Omega$	25°C	65	100	65	100	dB	
$V_{O1} / V_{O2}$	Channel separation $f = 1\text{ kHz to }20\text{ kHz}$	25°C		120		120	dB	
$I_O$	Output current $V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0\text{ V}$	25°C	-20	-40	-20	-40	mA	
		Full range	-10	-20	-10	-20		
		25°C	$V_{CC} = 15\text{ V}$ , $V_{ID} = -1\text{ V}$ , $V_O = 5\text{ V}$	10	20	10	20	
				Full range	5	8	5	8
$I_{CC}$	Supply current (four amplifiers) No load, No signal	25°C		0.8		0.8	mA	
		Full range		1.2		1.2		

\* $k_{SVR} = \Delta V_{CC} / \Delta V_{IO}$

†All characteristics are specified under open-loop conditions. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM124,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM224, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM324.

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

### TYPICAL APPLICATION DATA



AUDIO DISTRIBUTION AMPLIFIER

### THERMAL INFORMATION

#### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	900 mW	11.0 mW/°C	68°C
J (Glass-Mounted Chip)	900 mW	8.2 mW/°C	40°C
N	900 mW	9.2 mW/°C	52°C
W	900 mW	8.0 mW/°C	37°C

Also see Dissipation Derating Curves, Section 2.

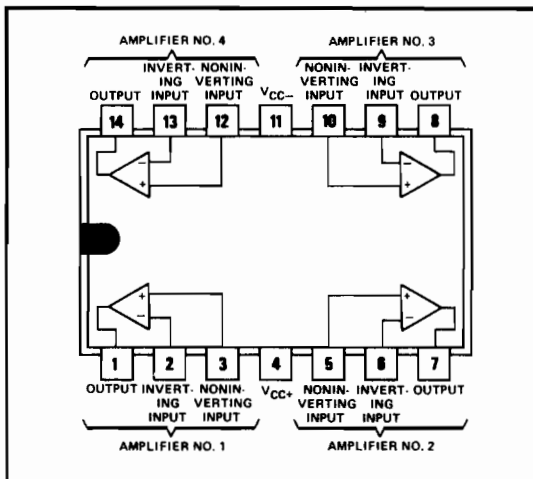
- uA741 Operating Characteristics
- Low Supply Current Drain. . . 0.6 mA Typ
- Low Input Offset Voltage
- Low Input Offset Current
- Class AB Output Stage
- Input/Output Overload Protection

**description**

The LM148, LM248, and LM348 are quadruple, independent, high-gain, internally compensated operational amplifiers designed to have operating characteristics similar to the uA741. These amplifiers exhibit low supply current drain, and input bias and offset currents that are much less than for the uA741.

The LM148 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM248 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM348 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

LM148 . . . J  
LM248, LM348 . . . J OR N  
DUAL-IN-LINE PACKAGE (TOP VIEW)



4

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	LM148	LM248	LM348	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	-18	V
Differential input voltage (see Note 2)	44	36	36	V
Input voltage (either input; see Notes 1 and 3)	$\pm 22$	$\pm 18$	$\pm 18$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	J package	1375	1025	mW
	N package		1150	
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J package	300	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM148 chips are alloy-mounted; LM248 and LM348 chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25°C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

# TYPES LM148, LM248, LM348

## QUADRUPLE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS†	LM148			LM248			LM348			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 10\text{ k}\Omega$ $T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	1	5		1	6		1	6		mV
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	4	25		4	50		4	50		nA
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	30	100		30	200		30	200		nA
$V_{ICR}$ Common-mode input voltage range	$T_A = \text{full range}$	$\pm 12$			$\pm 12$			$\pm 12$			V
$V_{OPP}$ Maximum peak-to-peak Output voltage swing	$R_L = 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $R_L \geq 10\text{ k}\Omega$ , $T_A = \text{full range}$ $R_L = 2\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $R_L \geq 2\text{ k}\Omega$ , $T_A = \text{full range}$	24	26		24	26		24	26		V
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$ $T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	50	160		25	160		25	160		V/mV
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$	0.8	2.5		0.8	2.5		0.8	2.5		M $\Omega$
$B_1$ Unity-gain bandwidth	$A_{VD} = 1$ , $T_A = 25^\circ\text{C}$	1			1			1			MHz
$\phi_M$ Phase margin	$A_{VD} = 1$ , $T_A = 25^\circ\text{C}$	$60^\circ$			$60^\circ$			$60^\circ$			
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$ $T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	70	90		70	90		70	90		dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S \leq 10\text{ k}\Omega$ $T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	77	96		77	96		77	96		dB
$I_{OS}$ Short-circuit output current	$T_A = 25^\circ\text{C}$	$\pm 25$			$\pm 25$			$\pm 25$			mA
$I_{CC}$ Supply current (four amplifiers)	No load, $T_A = 25^\circ\text{C}$ No signal, $T_A = 25^\circ\text{C}$	2.4	3.6		2.4	4.5		2.4	4.5		mA
$V_{O1}/V_{O2}$ Channel separation	$f = 1\text{ Hz to } 20\text{ kHz}$ , $T_A = 25^\circ\text{C}$	120			120			120			dB

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM148,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM248; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM348.

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	0.5			V/ $\mu\text{s}$

### PARAMETER MEASUREMENT INFORMATION

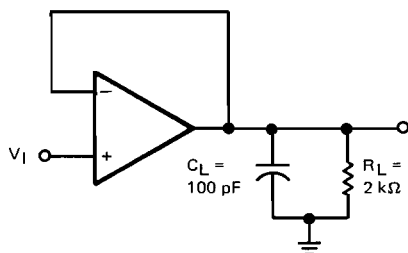


FIGURE 1—UNITY-GAIN AMPLIFIER

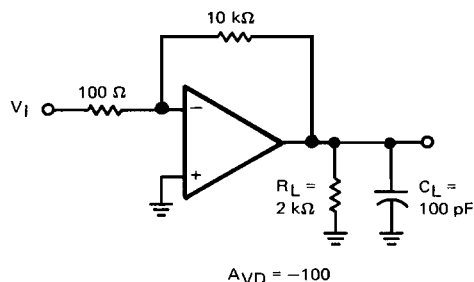


FIGURE 2—INVERTING AMPLIFIER

# TYPES LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

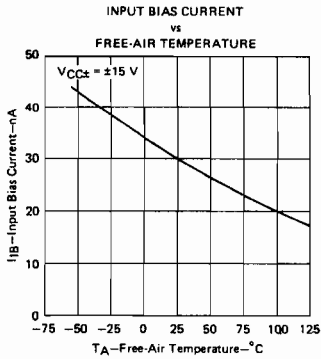


FIGURE 3

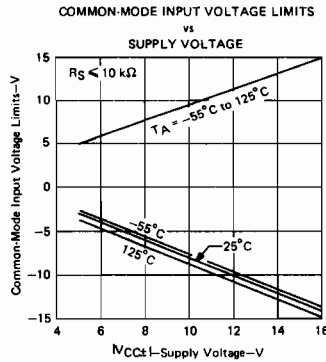


FIGURE 4

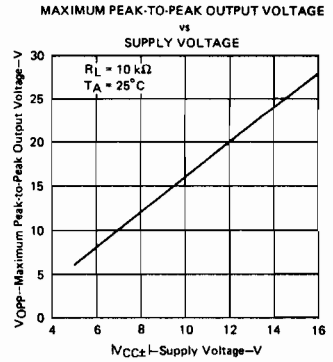


FIGURE 5

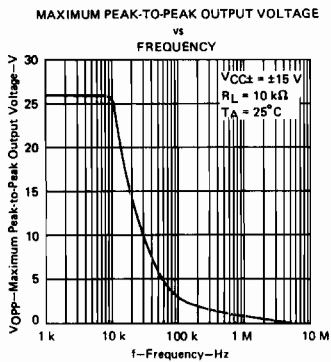


FIGURE 6

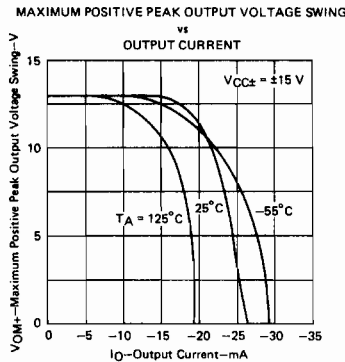


FIGURE 7

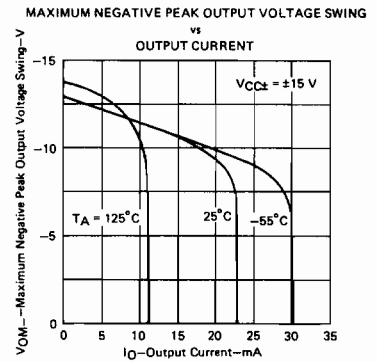


FIGURE 8

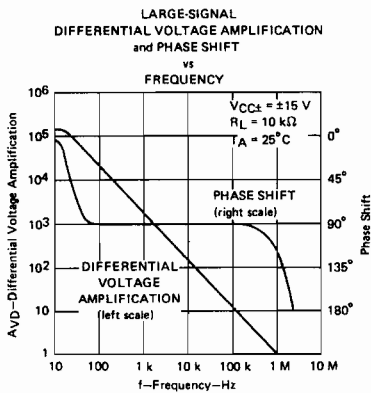


FIGURE 9

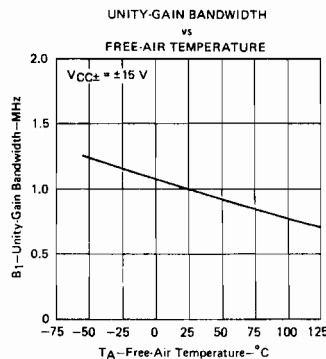


FIGURE 10

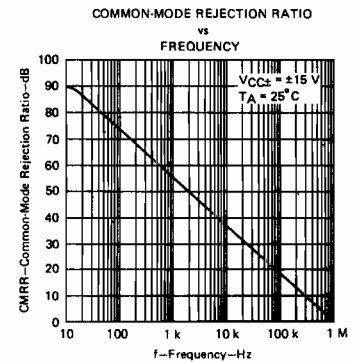


FIGURE 11

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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# TYPES LM148, LM248, LM348

## QUADRUPLE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

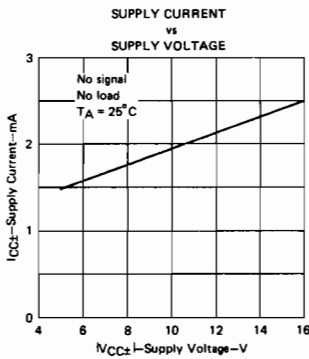


FIGURE 12

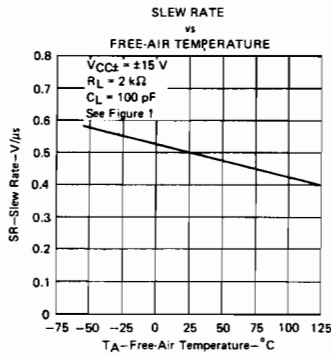


FIGURE 13

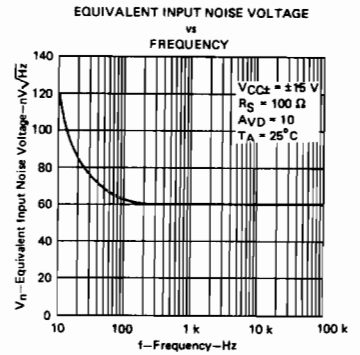


FIGURE 14

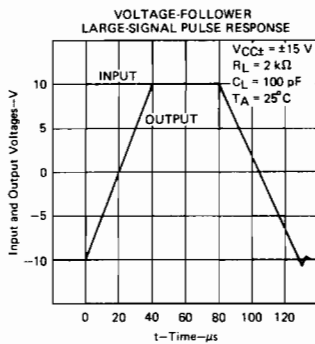


FIGURE 15

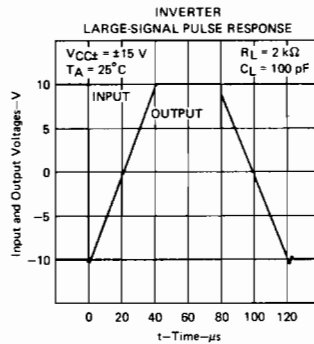


FIGURE 16

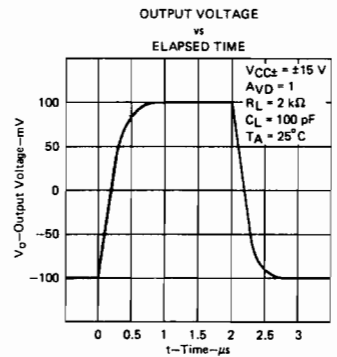


FIGURE 17

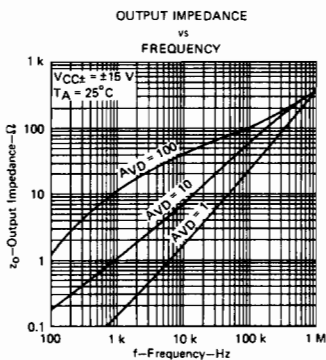
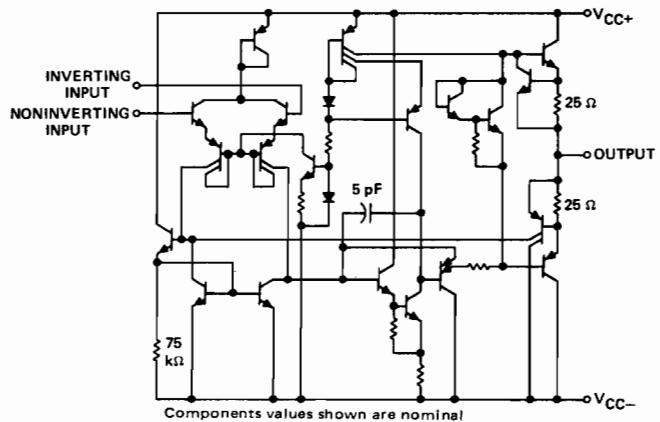


FIGURE 18

### schematic (each amplifier)



†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



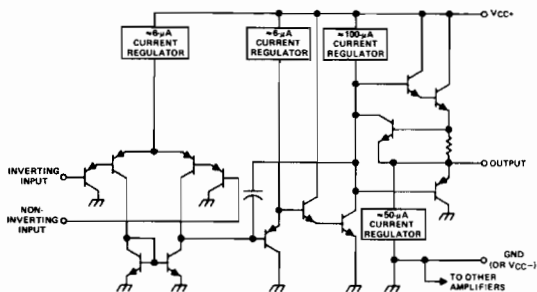
# LINEAR INTEGRATED CIRCUITS

# TYPES LM158, LM258, LM358 DUAL OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12413, JUNE 1976 - REVISED OCTOBER 1979

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 30 V  
or Dual Supplies
- Low Supply Current Drain  
Independent of Supply Voltage  
. . . 0.5 mA Typ
- Common-Mode Input Voltage  
Range Includes Ground Allowing  
Direct Sensing near Ground
- Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 3 nA Typ (LM158)  
Input Bias Current . . . 45 nA Typ
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage . . .  $\pm 32$  V
- Open-Loop Differential Voltage  
Amplification . . . 100 V/mV Typ
- Internal Frequency Compensation

### schematic (each amplifier)



### description

These devices consist of two independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts and Pin 4 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

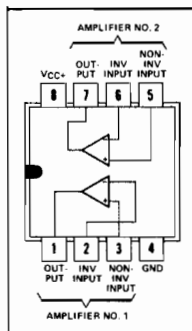
Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

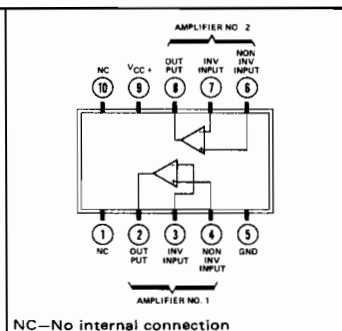
Supply voltage, $V_{CC}$ (see Note 1)	32 V
Differential input voltage (see Note 2)	$\pm 32$ V
Input voltage range (either input)	-0.3 V to 32 V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
LM258JG, LM358JG	825 mW
LM158JG, LM258P, LM358P	900 mW
LM158U, LM258U, LM358U	675 mW
Operating free-air temperature range:	
LM158	-55°C to 125°C
LM258	-25°C to 85°C
LM358	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG or U package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, LM158 chips are alloy-mounted; LM258 and LM358 chips are glass-mounted.

JG OR P  
DUAL-IN-LINE  
PACKAGE (TOP VIEW)



U  
FLAT PACKAGE  
(TOP VIEW)



# TYPES LM158, LM258, LM358

## DUAL OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM158, LM258			LM358			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 1.4\text{ V}$ , $V_{CC} = 5\text{ V to } 30\text{ V}$	25°C	2	5	2	7	mV	
		Full range	7			9		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage		Full range	7			$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	30	5	50	nA	
		Full range	100			150		
$\alpha I_{IO}$ Average temperature coefficient of input offset current		Full range	10			$\text{pA}/^\circ\text{C}$		
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$ , See Note 5	25°C	-45	-150	-45	-250	nA	
		Full range	-300			-500		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$V_{OH}$ High-level output voltage	$V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$	Full range	26			V		
	$V_{CC} = 30\text{ V}$ , $R_L \geq 10\text{ k}\Omega$	Full range	27	28	27		28	
$V_{OL}$ Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5			20	mV	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 2\text{ k}\Omega$	25°C	$V_{CC}-1.5$		$V_{CC}-1.5$		V	
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to } 11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100	V/mV	
		Full range	25			15		
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	70	85	70	85	dB	
$k_{SVR}^*$ Supply voltage rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	65	100	65	100	dB	
$V_{O1}/V_{O2}$ Channel separation	$f = 1\text{ kHz to } 20\text{ kHz}$	25°C	120			120	dB	
$I_O$ Output current	$V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0\text{ V}$	25°C	-20	-40	-20	-40	mA	
		Full range	-10	-20	-10	-20		
	$V_{CC} = 15\text{ V}$ , $V_{ID} = -1\text{ V}$ , $V_O = 5\text{ V}$	25°C	10	20	10	20		
		Full range	5	8	5	8		
$I_{CC}$ Supply current (two amplifiers)	No load, No signal	25°C	0.7			0.7	mA	
		Full range	1.2			1.2		

\* $k_{SVR} = \Delta V_{CC}/\Delta V_{IO}$

† All characteristics are specified under open-loop conditions. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM158,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM258, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM358.

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	900 mW	8.4 mW/ $^\circ\text{C}$	43°C
JG (Glass-Mounted Chip)	825 mW	6.6 mW/ $^\circ\text{C}$	25°C
P	900 mW	8.0 mW/ $^\circ\text{C}$	37°C
U	675 mW	5.4 mW/ $^\circ\text{C}$	25°C

Also see Dissipation Derating Curves, Section 2.

# LINEAR INTEGRATED CIRCUITS

# TYPES LM218, LM318 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12410, JUNE 1976 — REVISED OCTOBER 1979

- Small-Signal Bandwidth . . . 15 MHz Typ
- Slewing Rate . . . 50 V/ $\mu$ s Min
- Bias Current . . . 250 nA Max (LM218)
- Supply Voltage Range . . .  $\pm 5$  V to  $\pm 20$  V
- Internal Frequency Compensation
- Input and Output Overload Protection
- Same Pin Assignments as General Purpose Operational Amplifiers

## description

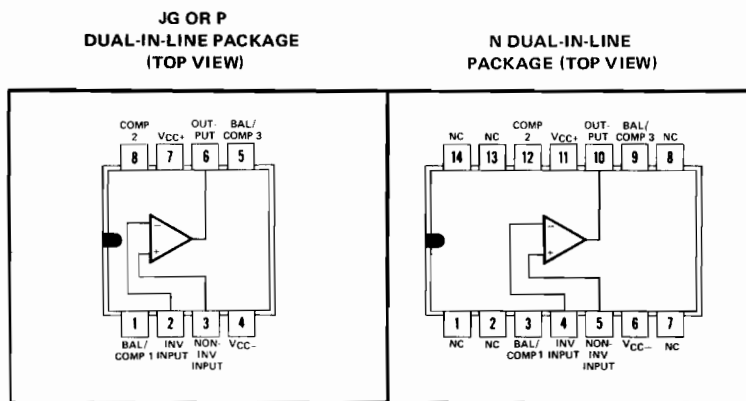
The LM218 and LM318 are precision, high-speed operational amplifiers designed for applications requiring wide bandwidth and high slewing rate. They feature a factor-of-ten increase in speed over general purpose devices without sacrificing dc performance.

These operational amplifiers have internal unity-gain frequency compensation. This considerably simplifies their application since no external components are necessary for operation. However, unlike most internally compensated amplifiers, external frequency compensation may be added for optimum performance. For inverting applications, feed-forward compensation will boost the slewing rate to over 150 V/ $\mu$ s and almost double the bandwidth. Overcompensation may be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor may be added to reduce the settling time for  $\epsilon < 0.1\%$  to under 1  $\mu$ s.

The high speed and fast settling time of these operational amplifiers make them useful in A/D converters, oscillators, active filters, sample and hold circuits, and general purpose amplifiers.

The LM218 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM318 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments



NC—No internal connection

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	500 mW	6.6 mW/ $^{\circ}\text{C}$	74 $^{\circ}\text{C}$
N	500 mW	9.2 mW/ $^{\circ}\text{C}$	96 $^{\circ}\text{C}$
P	500 mW	8.0 mW/ $^{\circ}\text{C}$	87 $^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPES LM218, LM318

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM218	LM318	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	20	20	V
Supply voltage, $V_{CC-}$ (see Note 1)	-20	-20	V
Input voltage (either input, see Notes 1 and 2)	$\pm 15$	$\pm 15$	V
Differential input current (see Note 3)	$\pm 10$	$\pm 10$	mA
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or JG package	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
3. The inputs are shunted with two opposite-facing base-emitter diodes for over voltage protection. Therefore, excessive current will flow if a differential input voltage in excess of approximately 1 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. For the LM218 only, the unlimited duration of the short-circuit applies at (or below) 85°C case temperature or 75°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, LM218 and LM318 chips are glass-mounted.

electrical characteristics at specified free-air temperature (see note 6)

PARAMETER	TEST CONDITIONS†	LM218			LM318			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage		25°C	2	4	4	10	mV	
		Full range		6		15		
$I_{IO}$ Input offset current		25°C	6	50	30	200	nA	
		Full range		100		300		
$I_{IB}$ Input bias current		25°C	120	250	150	500	nA	
		Full range		500		750		
$V_{ICR}$ Common-mode input voltage range	$V_{CC\pm} = \pm 15$ V	Full range	$\pm 11.5$		$\pm 11.5$		V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15$ V, $R_L = 2$ k $\Omega$	Full range	24	26	24	26	V	
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15$ V, $V_O = \pm 10$ V, $R_L \geq 2$ k $\Omega$	25°C	50	200	25	200	V/mV	
		Full range	25		20			
$B_1$ Unity-gain bandwidth	$V_{CC\pm} = \pm 15$ V	25°C	15		15		MHz	
$r_i$ Input resistance		25°C	1	3	0.5	3	M $\Omega$	
CMRR Common-mode rejection ratio		Full range	80	100	70	100	dB	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )		Full range	70	80	65	80	dB	
$I_{CC}$ Supply current	No load	25°C	5	8	5	10	mA	
		MAX	4.5	7				

†All characteristics are specified under open-loop operation. Full range for LM218 is -25° to 85°C and for LM318 is 0°C to 70°C.

NOTE 6: Unless otherwise noted,  $V_{CC\pm} = \pm 5$  V to  $\pm 20$  V. All typical values are at  $V_{CC\pm} = \pm 15$  V. Throughout this data sheet, supply voltages are specified either as a range or as a specific value. A positive voltage within the specified range (or of the specified value) is applied to  $V_{CC+}$ , and an equal negative voltage is applied to  $V_{CC-}$ .

# TYPES LM218, LM318 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $\Delta V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , See Figure 1	50	70		$\text{V}/\mu\text{s}$

## parameter measurement information

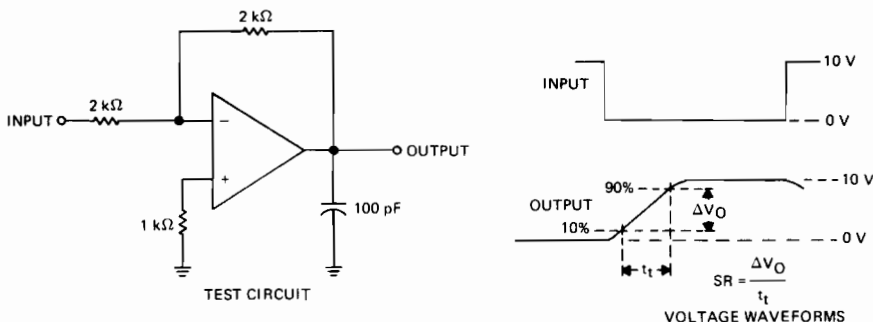
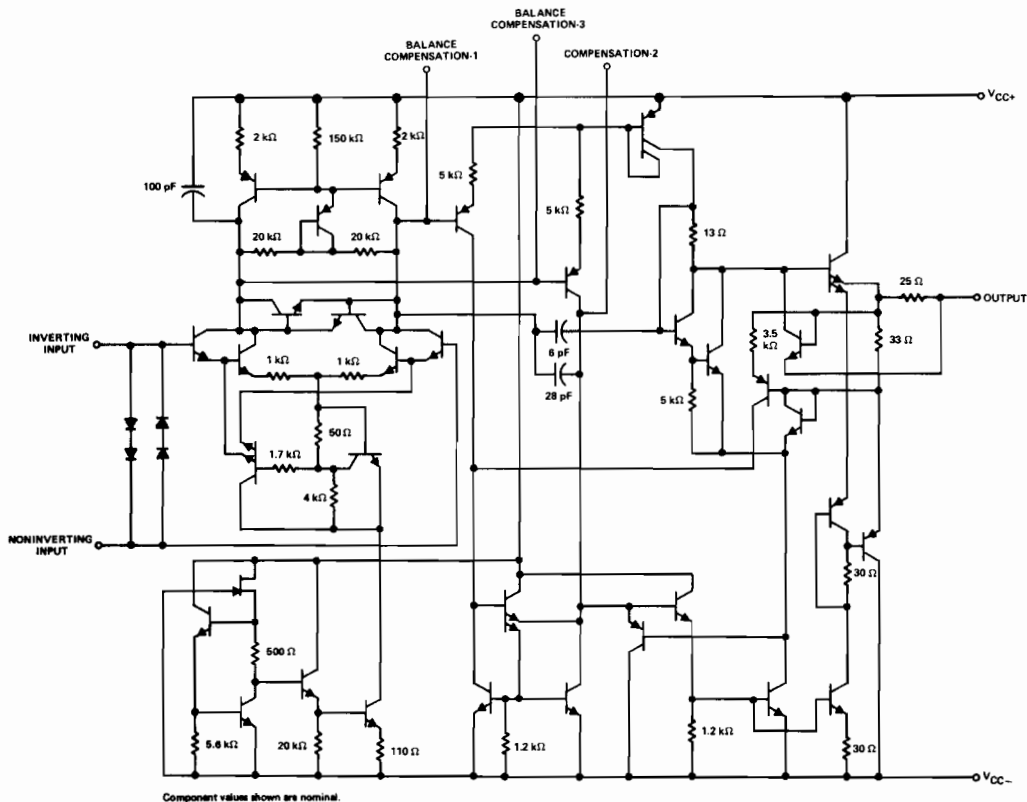


FIGURE 1—SLEW RATE

## schematic





# LINEAR INTEGRATED CIRCUITS

# TYPES LM1900, LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12682, JULY 1979—REVISED DECEMBER 1979

- Wide Range of Supply Voltages, Single or Dual Supplies
- Wide Bandwidth
- Large Output Voltage Swing
- Output Short-Circuit Protection
- Internal Frequency Compensation
- Low Input Bias Current
- Designed to be Interchangeable with National Semiconductor LM1900, LM2900, and LM3900, Respectively

## description

These devices consist of four independent, high-gain, frequency-compensated Norton operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible. The low supply current drain is essentially independent of the magnitude of the supply voltage. These devices provide wide bandwidth and large output voltage swing.

The LM1900 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM2900 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM3900 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

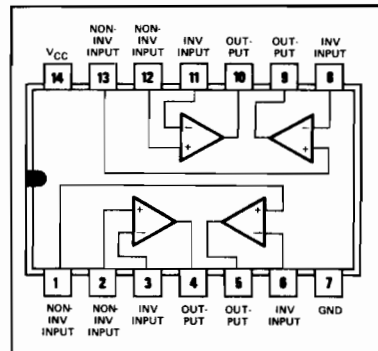
## operating characteristics

Norton (or current-differencing) amplifiers can be used in most standard general purpose op-amp applications. Performance as a dc amplifier in a single-power-supply mode is not as precise as a standard integrated-circuit operational amplifier operating from dual supplies. Operation of the amplifier can best be understood by noting that input currents are differenced at the inverting input terminal and this current then flows through the external feedback resistor to produce the output voltage. Common-mode current biasing is generally useful to allow operating with signal levels near (or even below) ground.

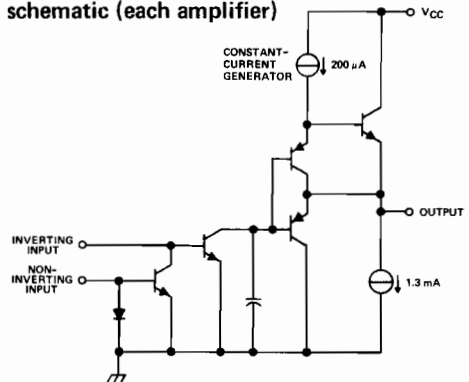
Internal transistors (see Note 5) clamp negative input voltages at approximately  $-0.3$  volt but the magnitude of current flow has to be limited by the external input network. For operation at high temperature, this limit should be approximately  $-100$  microamperes.

Noise immunity of a Norton amplifier is less than that of standard bipolar amplifiers. Circuit layout is more critical since coupling from the output to the noninverting input can cause oscillations. Care must also be exercised when driving either input from a low-impedance source. A limiting resistor should be placed in series with the input lead to limit the peak input current. Current up to 20 milliamperes will not damage the device but the current mirror on the noninverting input will saturate and cause a loss of mirror gain at higher current levels, especially at high operating temperatures.

J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



schematic (each amplifier)



4

# TYPES LM1900, LM2900, LM3900

## QUADRUPLE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM1900	LM2900	LM3900	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	36	32	32	V
Input current	20	20	20	mA
Duration of output short circuit (one amplifier) to ground at (or below) 25°C free-air temperature (see Note 2) <sup>1</sup>	Unlimited	Unlimited	Unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 3)	J Package	1375	1025	mW
	N Package		1150	
Operating free-air temperature range	-55 to 125	-40 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J Package	300	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N Package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 3. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM1900 chips are alloy-mounted; LM2900 and LM3900 chips are glass-mounted.

electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		LM1900			LM2900			LM3900			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$I_{IB}$ Input bias current (inverting input)	$I_{I+} = 0$	$T_A = 25^\circ\text{C}$	25	100		30	200		30	200	nA	
		$T_A = \text{full range}$		150								
$I_{I-}$ Mirror gain	$I_{I+} = 20\ \mu\text{A}$ to $200\ \mu\text{A}$ , $T_A = \text{full range}$ , See Note 4		0.95	1.05	0.9	1.1	0.9	1.1	$\mu\text{A}/\mu\text{A}$			
$I_{I+}$ Change in mirror gain			1	2	2	5	2	5	%			
Mirror current	$V_{I+} = V_{I-}$ , See Note 4	$T_A = \text{full range}$ ,	10	500	10	500	10	500	$\mu\text{A}$			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 10\text{ V}$ , $f = 100\text{ Hz}$	$R_L = 10\text{ k}\Omega$ ,	2	3	1.2	2.8	1.2	2.8	V/mV			
$r_i$ Input resistance (inverting input)			1		1		1	M $\Omega$				
$r_o$ Output resistance			8		8		8	k $\Omega$				
$B_1$ Unity-gain bandwidth (inverting input)			2.5		2.5		2.5	MHz				
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IQ}$ )			50	70	70		70	dB				
$V_{OH}$ High-level output voltage	$I_{I+} = 0$ , $I_{I-} = 0$	$R_L = 2\text{ k}\Omega$	13.5	14.2	13.5		13.5	V				
		$V_{CC} = 30\text{ V}$ , No load	28	29.5	29.5		29.5					
$V_{OL}$ Low-level output voltage	$I_{I+} = 0$ , $R_L = 2\text{ k}\Omega$	$I_{I-} = 10\ \mu\text{A}$ ,	0.09	0.2	0.09	0.2	0.09	0.2	V			
$I_{OHS}$ Short-circuit output current (output internally high)	$I_{I+} = 0$ , $V_O = 0$	$I_{I-} = 0$ ,	-10	-15	-6	-18	-6	-10	mA			
Pull-down current			1	1.3	0.5	1.3	0.5	1.3	mA			
$I_{OL}$ Low-level output current <sup>‡</sup>	$I_{I-} = 5\ \mu\text{A}$ ,	$V_{OL} = 1\text{ V}$	4	5	5		5	mA				
$I_{CC}$ Supply current (four amplifiers)	No Load		6.2	12	6.2	10	6.2	10	mA			

<sup>†</sup>All characteristics are specified under open-loop conditions. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM1900,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for LM2900, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM3900.

<sup>‡</sup>The output current-sink capability can be increased for large-signal conditions by overdriving the inverting input.

NOTE 4: These parameters are measured with the output balanced midway between  $V_{CC}$  and ground.



# TYPES LM1900, LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

## recommended operating conditions

	LM1900		LM2900		LM3900		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Input current (see Note 5)		-1		-1		-1	mA
Operating free-air temperature, $T_A$	-55	125	-40	85	0	70	$^{\circ}\text{C}$

NOTE 5: Clamp transistors are included that prevent the input voltages from swinging below ground more than approximately  $-0.3$  volt. The negative input currents that may result from large signal overdrive with capacitive input coupling must be limited externally to values of approximately  $-1$  mA. Negative input currents in excess of  $-4$  mA will cause the output voltage to drop to a low voltage. These values apply for any one of the input terminals. If more than one of the input terminals are simultaneously driven negative, maximum currents are reduced. Common-mode current biasing can be used to prevent negative input voltages.

## operating characteristics, $V_{CC\pm} = \pm 15$ V, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	Low-to-high output	$V_O = 10$ V,	$C_L = 100$ pF,		0.5		V/ $\mu\text{s}$
	High-to-low output	$R_L = 2$ k $\Omega$			20		

## TYPICAL CHARACTERISTICS†

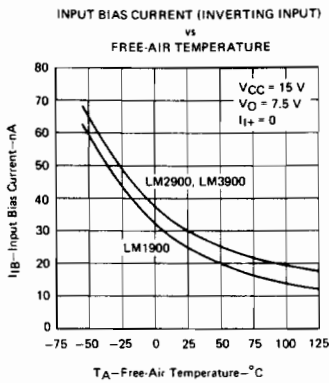


FIGURE 1

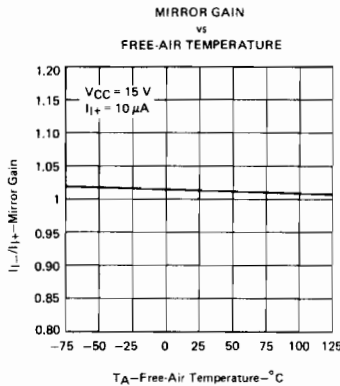


FIGURE 2

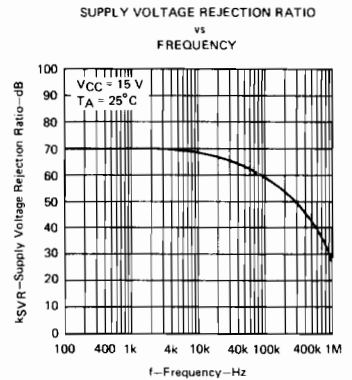


FIGURE 3

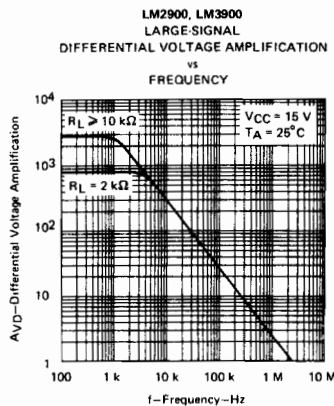


FIGURE 4

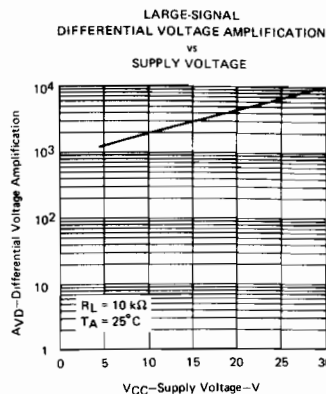


FIGURE 5

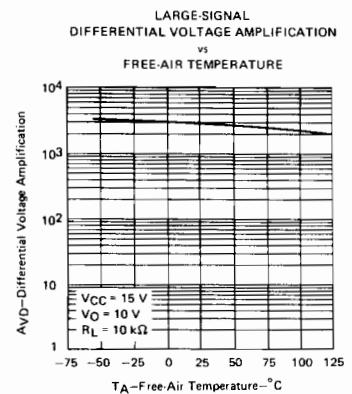


FIGURE 6

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TYPES LM1900, LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

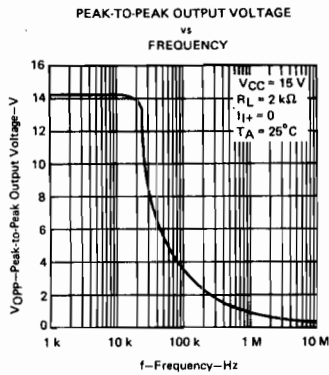


FIGURE 7

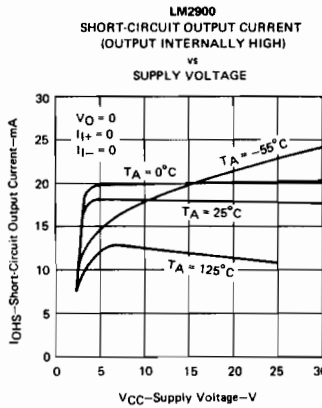


FIGURE 8

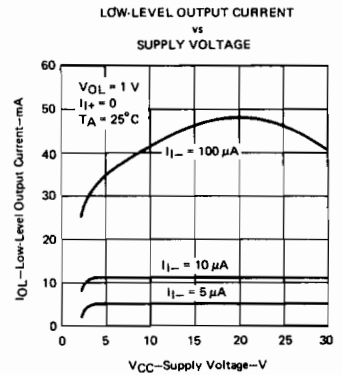


FIGURE 9

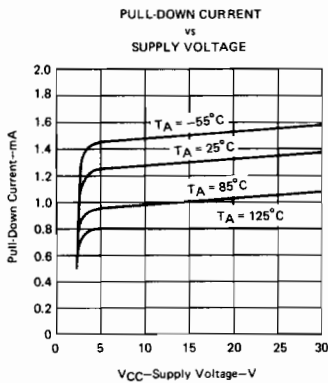


FIGURE 10

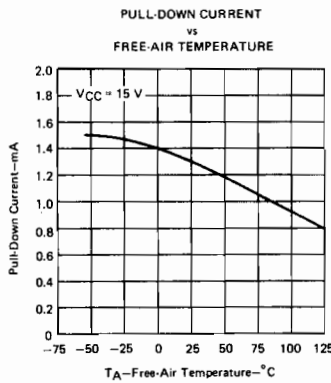


FIGURE 11

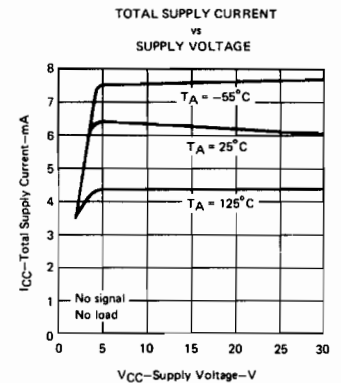


FIGURE 12

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL APPLICATION DATA

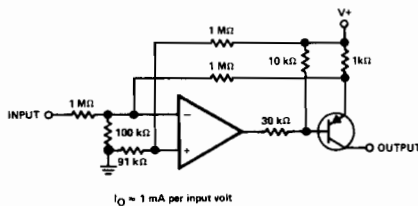


FIGURE 13—VOLTAGE-CONTROLLED CURRENT SOURCE

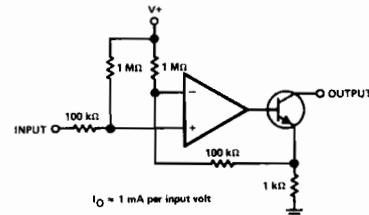


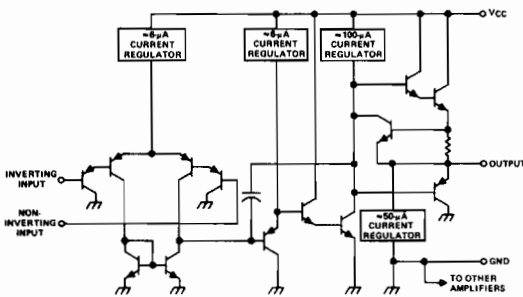
FIGURE 14—VOLTAGE-CONTROLLED CURRENT SINK

### DISSIPATION DERATING TABLE

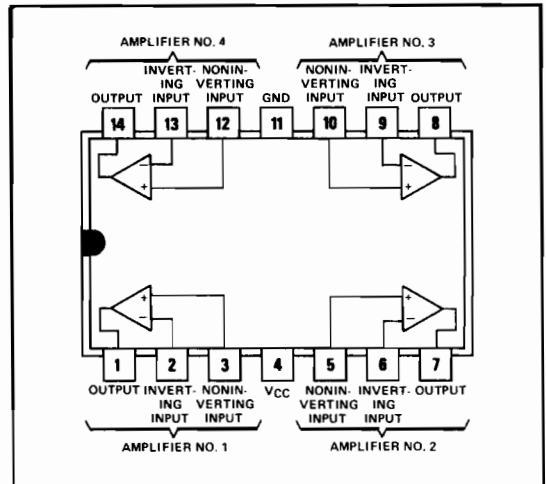
PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25° C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25° C
N	1150 mW	9.2 mW/°C	25° C

- **Wide Range of Supply Voltages**  
Single Supply . . . 3 V to 26 V  
or Dual Supplies
- **Low Supply Current Drain**  
Independent of Supply Voltage  
. . . 0.8 mA Typ
- **Common-Mode Input Voltage**  
Range Includes Ground Allowing  
Direct Sensing near Ground
- **Low Input Bias and Offset Parameters**  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 5 nA Typ  
Input Bias Current . . . 45 nA Typ
- **Differential Input Voltage Range**  
Equal to Maximum-Rated  
Supply Voltage . . .  $\pm 26$  V
- **Open-Loop Differential Voltage**  
Amplification . . . 100 V/mV Typ
- **Maximum Peak-to-Peak Output**  
Voltage Swing . . .  $V_{CC}-1.5$  V Typ
- **Internal Frequency Compensation**

schematic (each amplifier)



J OR N DUAL-IN-LINE OR  
W FLAT PACKAGE (TOP VIEW)



4

**description**

This device consists of four independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply as in automotive systems. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 26 volts and Pin 4 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM2902 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	26 V
Differential input voltage (see Note 2)	$\pm 26$ V
Input voltage range (either input)	-0.3 V to 26 V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	900 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, the LM2902 chips are glass-mounted.

# TYPE LM2902

## QUADRUPLE OPERATIONAL AMPLIFIER

electrical characteristics at 25°C free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

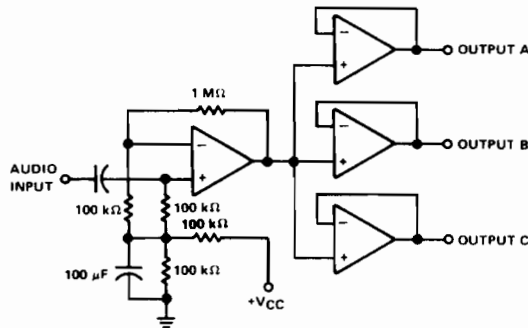
PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage $V_O = 1.4\text{ V}$		2	10	mV	
$I_{IO}$	Input offset current $V_O = 1.4\text{ V}$		5	50	nA	
$I_{IB}$	Input bias current $V_O = 1.4\text{ V}$	See Note 5		-45	-500	nA
$V_{ICR}$	Common-mode input voltage range $V_{CC} = 24\text{ V}$	0 to $V_{CC}-1.5$			V	
$V_{OH}$	High-level output voltage $V_{CC} = 24\text{ V}, R_L = 2\text{ k}\Omega$	20			V	
	$V_{CC} = 24\text{ V}, R_L \geq 10\text{ k}\Omega$	21				
$V_{OL}$	Low-level output voltage $R_L \leq 10\text{ k}\Omega$	5		20	mV	
AVD	Large-signal differential voltage amplification $V_{CC} = 15\text{ V}, R_L \geq 2\text{ k}\Omega, V_O = 1\text{ V to }11\text{ V}$	100			V/mV	
CMRR	Common-mode rejection ratio $R_S \leq 10\text{ k}\Omega$	85			dB	
$k_{SVR}^*$	Supply voltage rejection ratio $R_S \leq 10\text{ k}\Omega$	100			dB	
$V_{O1} / V_{O2}$	Channel separation $f = 1\text{ kHz to }20\text{ kHz}$	120			dB	
$I_O$	Output current $V_{CC} = 15\text{ V}, V_{ID} = 1\text{ V}, V_O = 0\text{ V}$	-20	-40		mA	
	$V_{CC} = 15\text{ V}, V_{ID} = -1\text{ V}, V_O = 2.5\text{ V}$	12	30			
	$V_{ID} = -1\text{ V}, V_O = 5\text{ V}$	8	20			
$I_{CC}$	Supply current (four amplifiers) No load, No signal	0.8		2	mA	

\* $k_{SVR} = \Delta V_{CC} / \Delta V_{IO}$

†All characteristics are specified under open-loop conditions.

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

### TYPICAL APPLICATION DATA



AUDIO DISTRIBUTION AMPLIFIER

### THERMAL INFORMATION

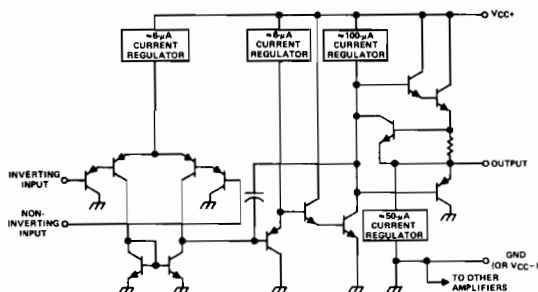
DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	900 mW	11.0 mW/°C	68°C
N	900 mW	9.2 mW/°C	52°C
W	900 mW	8.0 mW/°C	37°C

Also see Dissipation Derating Curves, Section 2.

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 26 V  
or Dual Supplies
- Low Supply Current Drain  
Independent of Supply Voltage  
. . . 0.5 mA Typ
- Common-Mode Input Voltage  
Range Includes Ground Allowing  
Direct Sensing near Ground
- Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 5 nA Typ  
Input Bias Current . . . 45 nA Typ
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage . . .  $\pm 26$  V
- Open-Loop Differential Voltage  
Amplification . . . 100 V/mV Typ
- Maximum Peak-to-Peak Output  
Voltage Swing . . .  $V_{CC}-1.5$  V Typ
- Internal Frequency Compensation

schematic (each amplifier)



## description

This device consists of two independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply as in automotive systems. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 26 volts and Pin 8 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

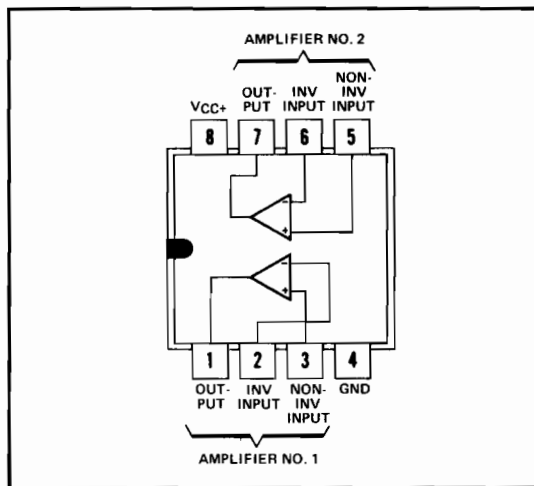
Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM2904 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

DISSIPATION DERATING TABLE

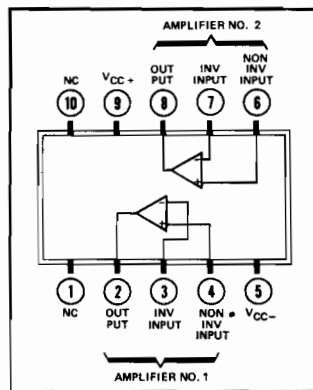
PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	680 mW	$6.6 \text{ mW}/^\circ\text{C}$	$41^\circ\text{C}$
P	680 mW	$8.0 \text{ mW}/^\circ\text{C}$	$65^\circ\text{C}$
U	675 mW	$5.4 \text{ mW}/^\circ\text{C}$	$25^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

# TYPE LM2904

## OPERATIONAL AMPLIFIER

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	26 V
Differential input voltage (see Note 2)	$\pm 26$ V
Input voltage range (either input)	$-0.3$ V to 26 V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4): JG or P package	680 mW
U package	675 mW
Operating free-air temperature range	$-40^\circ\text{C}$ to $85^\circ\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG or U package	$300^\circ\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	$260^\circ\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, the LM2904 chips are glass-mounted.

### electrical characteristics at 25°C free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

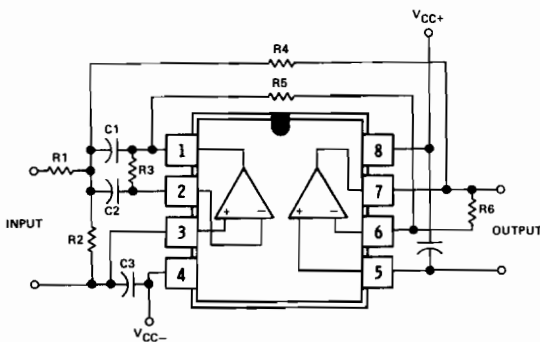
PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = 1.4$ V	2	10	mV
$I_{IO}$	Input offset current	$V_O = 1.4$ V	5	50	nA
$I_{IB}$	Input bias current	$V_O = 1.4$ V	See Note 5	-45 -500	nA
$V_{ICR}$	Common-mode input voltage range	$V_{CC} = 24$ V	0 to $V_{CC}-1.5$		V
$V_{OH}$	High-level output voltage	$V_{CC} = 24$ V, $R_L = 2$ k $\Omega$ $V_{CC} = 24$ V, $R_L \geq 10$ k $\Omega$	20		V
$V_{OL}$	Low-level output voltage	$R_L \leq 10$ k $\Omega$	5	20	mV
$A_{VD}$	Large-signal differential voltage amplification	$V_{CC} = 15$ V, $R_L \geq 2$ k $\Omega$ , $V_O = 1$ V to 11 V	100		V/mV
CMRR	Common-mode rejection ratio	$R_S \leq 10$ k $\Omega$	85		dB
$k_{SVR}^*$	Supply voltage rejection ratio	$R_S \leq 10$ k $\Omega$	100		dB
$V_{O1} / V_{O2}$	Channel separation	$f = 1$ kHz to 20 kHz	120		dB
$I_O$	Output current	$V_{CC} = 15$ V, $V_{ID} = 1$ V, $V_O = 0$ V $V_{CC} = 15$ V, $V_{ID} = -1$ V, $V_O = 2.5$ V $V_{ID} = -1$ V, $V_O = 5$ V	-20	-40	mA
$I_{CC}$	Supply current (both amplifiers)	No load, No signal	0.5	1.2	

\* $k_{SVR} = \Delta V_{CC} / \Delta V_{IO}$

† All characteristics are specified under open-loop conditions.

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

### TYPICAL APPLICATION DATA



#### SELECT VALUES FOR:

$Q$   
 $C1$  and  $C2$   
 where  $C1 = C2$   
 $\omega_0 = 2\pi f_0$

$K$

$K$  is selected to optimize sensitivity and is typically between 1 and 10.

#### CALCULATE:

$$R1 = R3 = R5 = \frac{Q}{\omega_0 C}$$

$$R2 = \frac{R1}{Q - 1 - \frac{2}{K} + \frac{1}{K \cdot Q}}$$

$$R4 = \frac{R1 \cdot K \cdot Q}{2Q - 1}$$

$$R6 = K \cdot R1$$

### MULTIPLE-FEEDBACK ACTIVE BANDPASS FILTER

- Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Designed to be Interchangeable with Motorola MC1558/MC1458 and Signetics S5558/N5558

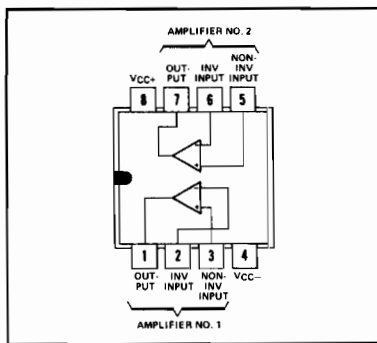
## description

The MC1558 and MC1458 are dual general-purpose operational amplifiers with each half electrically similar to uA741 except that offset null capability is not provided.

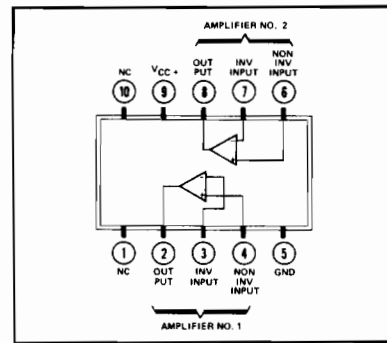
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The MC1558 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the MC1458 is characterized for operation from  $0^{\circ}\text{C}$  to  $75^{\circ}\text{C}$ .

JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	MC1558	MC1458	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V	
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V	
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V	
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V	
Duration of output short-circuit (see Note 4)	unlimited	unlimited		
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	Each amplifier	500	500	
	Total package	JG or P package	680	680
		U Package	675	675
Operating free-air temperature range	$-55$ to $125$	$0$ to $75$	$^{\circ}\text{C}$	
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$	
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	JG or U package	300	$^{\circ}\text{C}$	
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	P package	260	$^{\circ}\text{C}$	

- NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
  4. The output may be shorted to ground or either power supply. For the MC1558 only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
  5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the JG package, MC1558 chips are alloy-mounted; MC1458 chips are glass-mounted.

# TYPES MC1558, MC1458

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER		TEST CONDITIONS†	MC1558			MC1458			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$R_S < 10\text{ k}\Omega$	25°C	1	5	1	6	mV	
			Full range		6	7.5			
$I_{IO}$	Input offset current		25°C	20	200	20	200	nA	
			Full range		500	300			
$I_{IB}$	Input bias current		25°C	80	500	80	500	nA	
			Full range		1500	800			
$V_{ICR}$	Common-mode input voltage range		25°C	±12	±13	±12	±13	V	
			Full range	±12		±12			
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	24	28	24	28	V	
		$R_L > 10\text{ k}\Omega$	Full range	24		24			
		$R_L = 2\text{ k}\Omega$	25°C	20	26	20	26		
		$R_L > 2\text{ k}\Omega$	Full range	20		20			
$A_{VD}$	Large-signal differential voltage amplification	$R_L > 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	50	200	20	200	V/mV	
			Full range	25		15			
$B_{OM}$	Maximum-output-swing bandwidth (closed-loop)	$R_L = 2\text{ k}\Omega$ , $V_O > \pm 10\text{ V}$ , $A_{VD} = 1$ , $THD < 5\%$	25°C	14		14		kHz	
$B_1$	Unity-gain bandwidth		25°C	1		1		MHz	
$\phi_m$	Phase margin	$A_{VD} = 1$	25°C	65°		65°			
$A_m$	Gain margin		25°C	11		11		dB	
$r_i$	Input resistance		25°C	0.3	2	0.3	2	MΩ	
$r_o$	Output resistance	$V_O = 0$ , See Note 6	25°C	75		75		Ω	
$C_i$	Input capacitance		25°C	1.4		1.4		pF	
$z_{ic}$	Common-mode input impedance	$f = 20\text{ Hz}$	25°C	200		200		MΩ	
CMRR	Common-mode rejection ratio	$R_S < 10\text{ k}\Omega$	25°C	70	90	70	90	dB	
			Full range	70		70			
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S < 10\text{ k}\Omega$	25°C	30	150	30	150	μV/V	
			Full range		150		150		
$V_n$	Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $R_S = 0$ , $f = 1\text{ kHz}$ , $BW = 1\text{ Hz}$	25°C	45		45		nV/√Hz	
$I_{OS}$	Short-circuit output current		25°C	±25	±40	±25	±40	mA	
$I_{CC}$	Supply current (Both amplifiers)	No load,	25°C	3.4	5	3.4	5.6	mA	
			Full range		6.6		6.6		
$P_D$	Total power dissipation (Both amplifiers)	No load,	25°C	100	150	100	170	mW	
			Full range		200		200		
$V_{O1}/V_{O2}$	Channel separation		25°C	120		120		dB	

† All characteristics are specified under open-loop operation, unless otherwise noted. Full range for MC1558 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for MC1458 is  $0^\circ\text{C}$  to  $75^\circ\text{C}$ .

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MC1558			MC1458			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$	Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$						μs
	Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1						
SR	Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1						V/μs



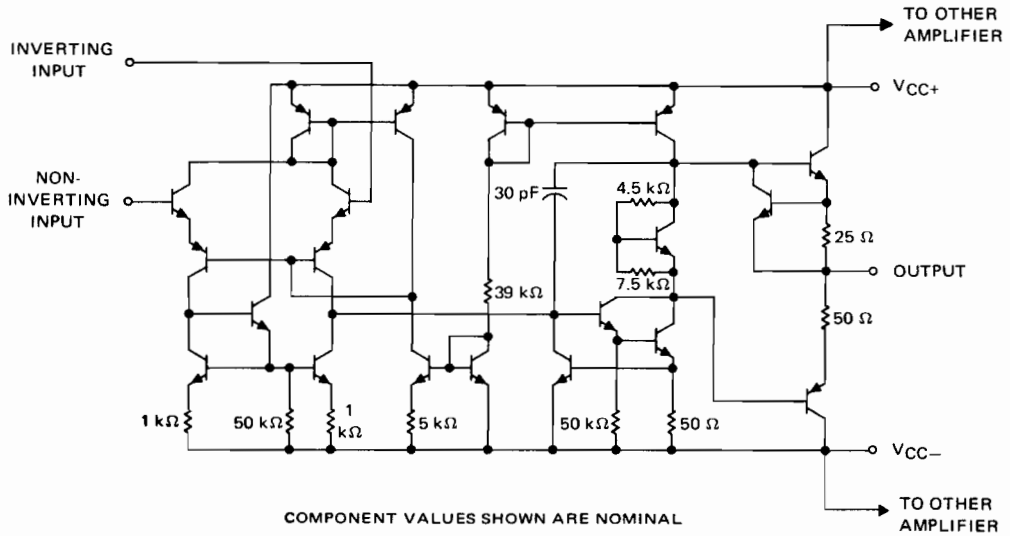
# TYPES MC1558, MC1458 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	$8.4 \text{ mW}/^\circ\text{C}$	$69^\circ\text{C}$
JG (Glass-Mounted Chip)	680 mW	$6.6 \text{ mW}/^\circ\text{C}$	$47^\circ\text{C}$
P	680 mW	$8.0 \text{ mW}/^\circ\text{C}$	$65^\circ\text{C}$
U	675 mW	$5.4 \text{ mW}/^\circ\text{C}$	$25^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

schematic (each amplifier)



4

## PARAMETER MEASUREMENT INFORMATION

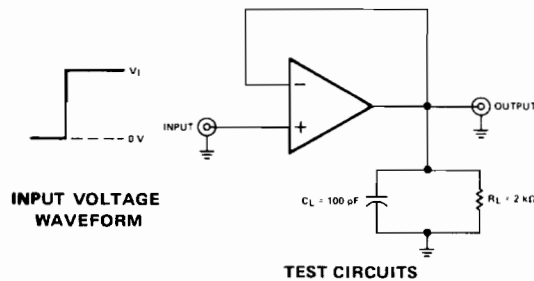


FIGURE 1—RISE TIME, OVERSHOOT,  
AND SLEW RATE

# TYPES MC1558, MC1458

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS

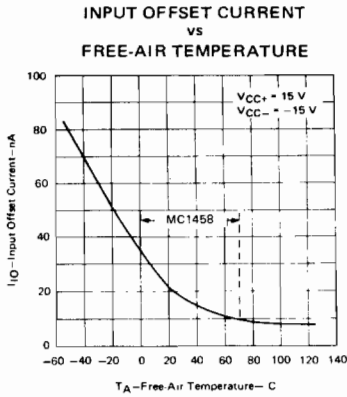


FIGURE 2

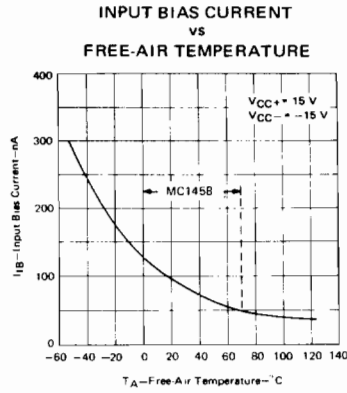


FIGURE 3

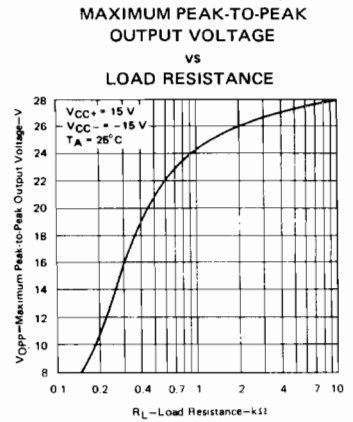


FIGURE 4

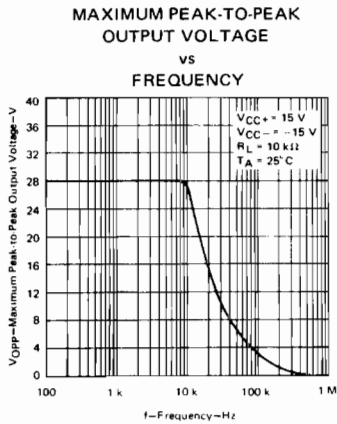


FIGURE 5

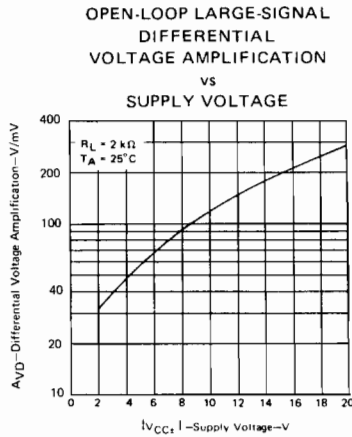


FIGURE 6

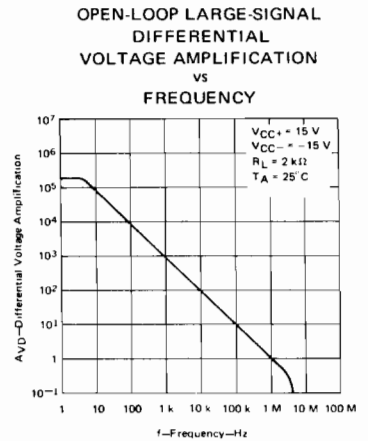


FIGURE 7

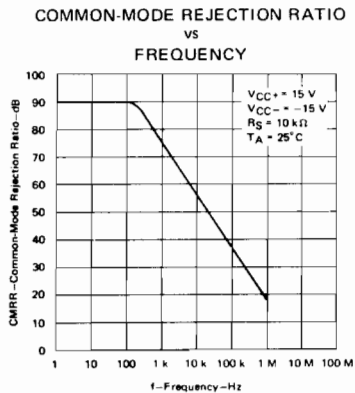


FIGURE 8

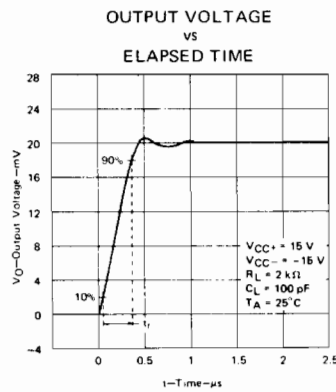


FIGURE 9

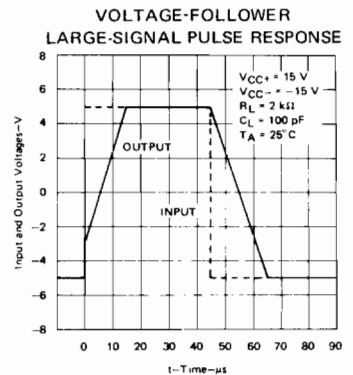


FIGURE 10

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 36 V  
or Dual Supplies
- Class AB Output Stage
- True Differential Input Stage
- Low Input Bias Current
- Internal Frequency Compensation
- Short-Circuit Protection
- Designed to be Interchangeable with  
Motorola MC3503, MC3303, MC3403

**description**

The MC3503, MC3303, and the MC3403 are quadruple operational amplifiers similar in performance to the uA741 but with several distinct advantages. They are designed to operate from a single supply over a range of voltages from 3 volts to 36 volts. Operation from split supplies is also possible provided the difference between the two supplies is 3 volts to 36 volts. The common-mode input range includes the negative supply. Output range is from the negative supply to  $V_{CC} - 1.5$  V. Quiescent supply currents are less than one-half those of the uA741.

The MC3503 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The MC3303 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The MC3403 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	MC3503	MC3303	MC3403	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Supply voltage $V_{CC+}$ with respect to $V_{CC-}$	36	36	36	V
Differential input voltage (see Note 2)	$\pm 36$	$\pm 36$	$\pm 36$	V
Input voltage (see Notes 1 and 3)	$\pm 18$	$\pm 18$	$\pm 18$	V
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 4)	J Package	1375	1025	mW
	N Package		1150	
Operating free-air temperature range	$-55$ to $125$	$-40$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J Package	300	300	$^{\circ}\text{C}$
	N Package		260	
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds				$^{\circ}\text{C}$

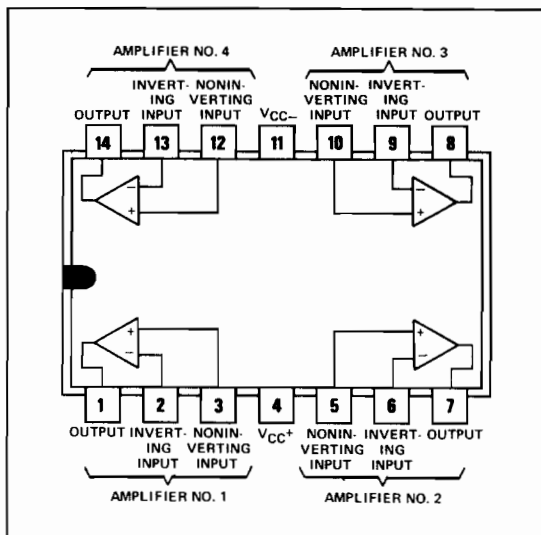
- NOTES: 1. These voltage values are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Neither input must ever be more positive than  $V_{CC+}$  or more negative than  $V_{CC-}$ .  
 4. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, MC3503 chips are alloy-mounted; MC3303 and MC3403 chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/ $^{\circ}\text{C}$	$25^{\circ}\text{C}$
J (Glass-Mounted Chip)	1025 mW	8.2 mW/ $^{\circ}\text{C}$	$25^{\circ}\text{C}$
N	1150 mW	9.2 mW/ $^{\circ}\text{C}$	$25^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

**J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



# TYPES MC3503, MC3303, MC3403

## QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature:  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for MC3303;  $V_{CC\pm} = \pm 15\text{ V}$  for MC3403 and MC3503

PARAMETER	TEST CONDITIONS†	MC3503		MC3303		MC3403		UNIT
		MIN	TYP MAX	MIN	TYP MAX	MIN	TYP MAX	
$V_{IO}$ Input offset voltage	$T_A = 25^\circ\text{C}$ , See Note 5 $T_A = \text{full range}$ , See Note 5	2 5		2 8		2 10		mV
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$T_A = 25^\circ\text{C}$	10		10		10		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$ , See Note 5 $T_A = \text{full range}$ , See Note 5	30 50		30 75		30 50		nA
$\alpha I_{IO}$ Temperature coefficient of input offset current	$T_A = 25^\circ\text{C}$	50		50		50		$\text{pA}/^\circ\text{C}$
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	-0.2 -0.5		-0.2 -0.5		-0.2 -0.5		$\mu\text{A}$
$V_{ICR}$ Common-mode input voltage range‡	$T_A = 25^\circ\text{C}$	$V_{CC-} - V_{CC-}$ to to 13 13.5		$V_{CC-} - V_{CC-}$ to to 12 12.5		$V_{CC-} - V_{CC-}$ to to 13 13.5		V
$V_{OM}$ Peak output voltage swing	$R_L = 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $R_L = 2\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $R_L = 2\text{ k}\Omega$ , $T_A = \text{full range}$	$\pm 12 \pm 13.5$		12 12.5		$\pm 12 \pm 13.5$		V
$A_{VD}$ Large-signal differential voltage amplification	$R_L = 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$ $T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	50 200		20 200		20 200		V/mV
$B_{OM}$ Maximum-output-swing bandwidth	$V_{OPP} = 20\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $A_{VD} = 1$ , $T_A = 25^\circ\text{C}$ , $\text{THD} \leq 5\%$	9		9		9		kHz
$B_1$ Unity-gain bandwidth	$R_L = 10\text{ k}\Omega$ , $V_O = 50\text{ mV}$ , $T_A = 25^\circ\text{C}$	1		1		1		MHz
$\phi_m$ Phase margin	$C_L = 200\text{ pF}$ , $R_L = 2\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$60^\circ$		$60^\circ$		$60^\circ$		
$r_i$ Input resistance	$f = 20\text{ Hz}$ , $T_A = 25^\circ\text{C}$	0.3 1		0.3 1		0.3 1		M $\Omega$
$r_o$ Output resistance	$f = 20\text{ Hz}$ , $T_A = 25^\circ\text{C}$	75		75		75		$\Omega$
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	70 90		70 90		70 90		dB
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$T_A = 25^\circ\text{C}$	30 150		30 150		30 150		$\mu\text{V}/\text{V}$
$I_{OS}$ Short-circuit output current §	$T_A = 25^\circ\text{C}$	$\pm 10 \pm 30 \pm 45$		$\pm 10 \pm 30 \pm 45$		$\pm 10 \pm 30 \pm 45$		mA
$I_{CC}$ Total supply current	No load, $V_O = 0\text{ V}$ , $T_A = 25^\circ\text{C}$	2.8 4		2.8 7		2.8 7		mA

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for MC3503;  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for MC3303; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for MC3403.

‡ The  $V_{ICR}$  limits are directly linked volt-for-volt to supply voltage, viz the positive limit is 2 volts less than  $V_{CC+}$ .

§ Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

NOTE 5:  $V_{IO}$  and  $I_{IO}$  are defined at  $V_O = 0\text{ V}$  for MC3503 and MC3403, and  $V_O = 7\text{ V}$  for MC3303.

# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MC3503			MC3303			MC3403			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 2.5\text{ V}$		2	5		10		2	10	mV	
$I_{IO}$ Input offset current	$V_O = 2.5\text{ V}$		30	50		75		30	50	nA	
$I_{IB}$ Input bias current			-0.2	-0.5		-0.5		-0.2	-0.5	uA	
$V_{OM}$ Peak output voltage swing‡	$R_L = 10\text{ k}\Omega$	3.3	3.5		3.3	3.5		3.3	3.5	V	
	$R_L = 10\text{ k}\Omega$ , $V_{CC+} = 5\text{ V to }30\text{ V}$	$V_{CC+} - 1.7$			$V_{CC+} - 1.7$			$V_{CC+} - 1.7$			
$A_{VD}$ Large-signal differential voltage amplification	$R_L = 2\text{ k}\Omega$ , $\Delta V_O = 2\text{ V}$	20	200		20	200		20	200	V/mV	
$k_{SVS}$ Power supply sensitivity ( $\Delta V_{IO}/\Delta V_{CC+}$ )			150		150		150		150	$\mu\text{V/V}$	
$I_{CC}$ Supply current	No Load, $V_O = 2.5\text{ V}$		2.5	4		2.5	7		2.5	7	mA
$V_{O1}/V_{O2}$ Channel separation	$f = 1\text{ kHz to }20\text{ kHz}$		120		120		120		120	dB	

† All characteristics are specified under open-loop conditions.

‡ Output will swing essentially to ground.

operating characteristics:  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for MC3303;  $V_{CC\pm} = \pm 15\text{ V}$  for MC3403 and MC3503;  $T_A = 25^\circ\text{C}$ ,  $A_{VD} = 1$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = \pm 10\text{ V}$ ,	$C_L = 100\text{ pF}$ ,	See Figure 1		0.6		V/ $\mu\text{s}$
$t_r$ Rise time	$\Delta V_O = 50\text{ mV}$ , See Figure 1	$C_L = 100\text{ pF}$ ,	$R_L = 10\text{ k}\Omega$ ,		0.35		$\mu\text{s}$
$t_f$ Fall time					0.35		$\mu\text{s}$
Overshoot factor					20%		
Crossover distortion	$V_{IP} = 30\text{ mV}$ ,	$V_{OPP} = 2\text{ V}$ ,	$f = 10\text{ kHz}$		1%		

4

## PARAMETER MEASUREMENT INFORMATION

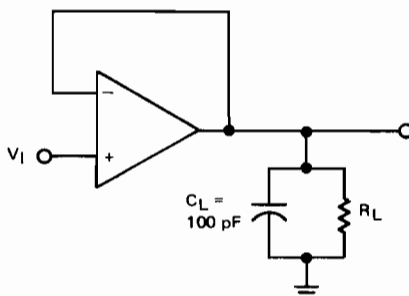


FIGURE 1—UNITY-GAIN AMPLIFIER

# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

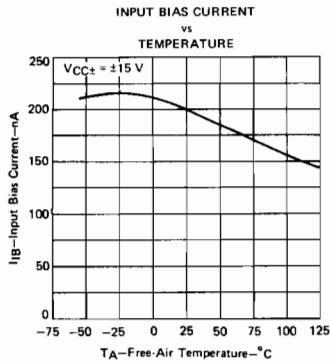


FIGURE 2

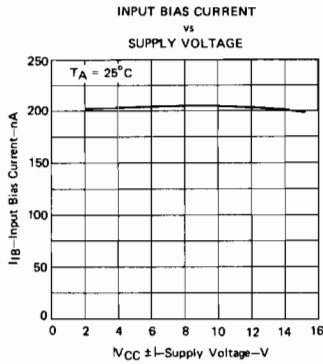


FIGURE 3

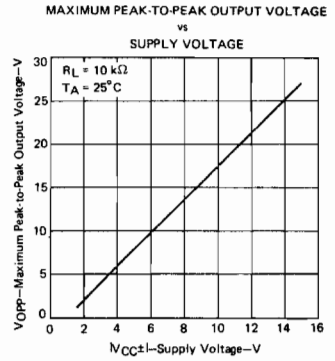


FIGURE 4

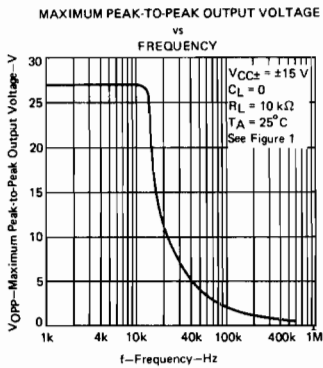


FIGURE 5

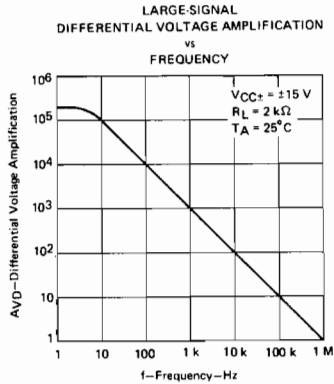


FIGURE 6

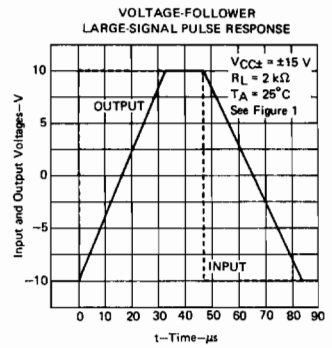
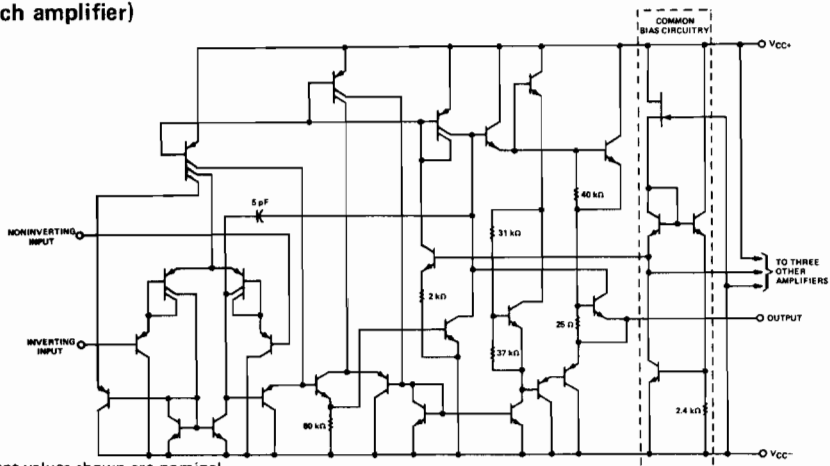


FIGURE 7

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

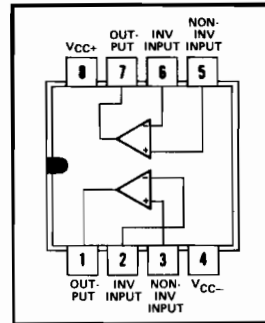
## schematic (each amplifier)



All component values shown are nominal

- Equivalent Input Noise Voltage . . . 5 nV/ $\sqrt{\text{Hz}}$  Typ at 1 kHz
- Unity-Gain Bandwidth . . . 10 MHz Typ
- Common-Mode Rejection Ratio . . . 100 dB Typ
- High DC Voltage Gain . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing . . . 32 V Typ with  $V_{CC\pm} = \pm 18$  V and  $R_L = 600 \Omega$
- High Slew Rate . . . 9 V/ $\mu\text{s}$  Typ
- Wide Supply Voltage Range . . .  $\pm 3$  V to  $\pm 20$  V
- Designed to be Interchangeable with Signetics NE5532 and NE5532A

NE5532, NE5532A . . . JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)

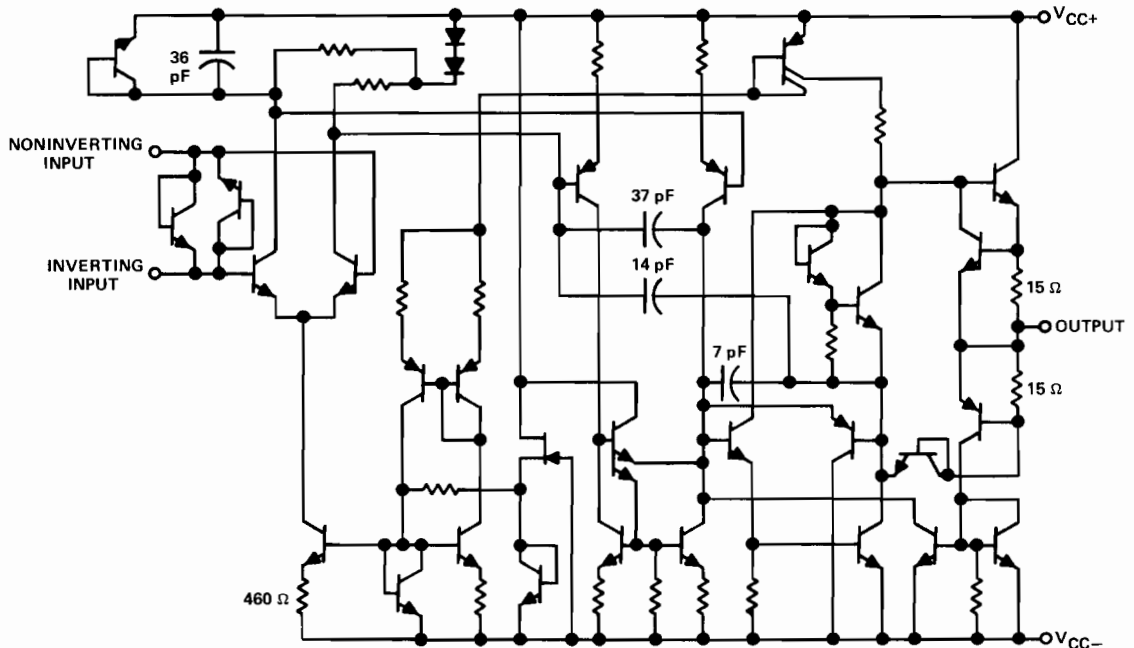


**description**

The NE5532 and NE5532A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. They feature very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, high slew rate, input-protection diodes, and output short-circuit protection. These operational amplifiers are internally compensated for unity gain operation. The NE5532A has guaranteed maximum limits for equivalent input noise voltage.

The NE5532 and NE5532A are characterized for operation from 0°C to 70°C.

**schematic (each amplifier)**



All component values shown are nominal.

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

# TYPES NE5532, NE5532A

## DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	22 V
Supply voltage, $V_{CC-}$ (see Note 1)	-22 V
Input voltage, either input (see Notes 1 and 2)	$V_{CC\pm}$
Input current (see Note 3)	$\pm 10$ mA
Duration of output short-circuit (see Note 4)	unlimited
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5):	
JG package	825 mW
P package	1000 mW
Operating free-air temperature range: NE5532, NE5532A	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
3. Excessive current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table. In the JG package, chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted chip)	825 mW	6.6 mW/°C	25°C
P	1000 mW	8.0 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.



# TYPES NE5532, NE5532A DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	NE5532, NE5532A			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$T_A = 25^\circ\text{C}$	0.5 4			mV
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	5			
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$	10 150			nA
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	200			
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$	200 800			nA
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	1000			
$V_{ICR}$ Common-mode input voltage range		$\pm 12$	$\pm 13$		V
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 600\ \Omega$	$V_{CC\pm} = \pm 15\text{ V}$	24	26	V
		$V_{CC\pm} = \pm 18\text{ V}$	30	32	
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 600\ \Omega$ , $V_O = \pm 10\text{ V}$	$T_A = 25^\circ\text{C}$	15	50	V/mV
		$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	10		
	$R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	$T_A = 25^\circ\text{C}$	25	100	
		$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	15		
$A_{vd}$ Small-signal differential voltage amplification	$f = 10\text{ kHz}$		2.2		V/mV
$B_{OM}$ Maximum-output-swing bandwidth	$R_L = 600\ \Omega$ , $V_O = \pm 10\text{ V}$	140			kHz
	$R_L = 600\ \Omega$ , $V_{CC\pm} = \pm 18\text{ V}$ , $V_O = \pm 14\text{ V}$	100			
$B_1$ Unity-gain bandwidth	$R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$	10			MHz
$r_i$ Input resistance		30	300		k $\Omega$
$z_o$ Output impedance	$A_{VD} = 30\text{ dB}$ , $R_L = 600\ \Omega$ , $f = 10\text{ kHz}$	0.3			$\Omega$
CMRR Comm-mode rejection ratio		70	100		dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )		80	100		dB
$I_{OS}$ Output short-circuit current		38			mA
$I_{CC}$ Total supply current	No load	8	16		mA
$V_{O1}/V_{O2}$ Channel separation	$V_{O1} = 10\text{ V peak}$ , $f = 1\text{ kHz}$	110			dB

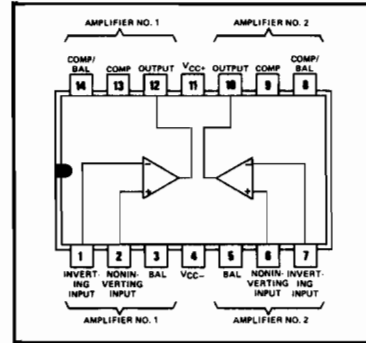
operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	NE5532		NE5532A		UNIT
		MIN	TYP	MAX	MIN	
SR Slew rate at unity gain		9		9		V/ $\mu\text{s}$
Overshoot factor	$V_I = 100\text{ mV}$ , $A_{VD} = 1$ , $R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$	10%		10%		
$V_n$ Equivalent input noise voltage	$f = 30\text{ Hz}$	8		8	10	nV/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$	5		5	6	
$I_n$ Equivalent input noise current	$f = 30\text{ Hz}$	2.7		2.7		pA/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$	0.7		0.7		



- Equivalent Input Noise Voltage . . .  
3.5 nV/√Hz Typ (NE5533A at 1 kHz)
- Unity-Gain Bandwidth . . . 10 MHz Typ
- Common-Mode Rejection Ratio . . .  
100 dB Typ
- High DC Voltage Gain . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing . . .  
32 V Typ with  $V_{CC\pm} = \pm 18$  V and  
 $R_L = 600 \Omega$
- High Slew Rate . . . 13 V/μs Typ
- Wide Supply Voltage Range . . . ±3 V to ±20 V
- Low Harmonic Distortion
- Designed to be Interchangeable with Signetics  
NE5533 and NE5533A

NE5533, NE5533A . . . J OR N  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

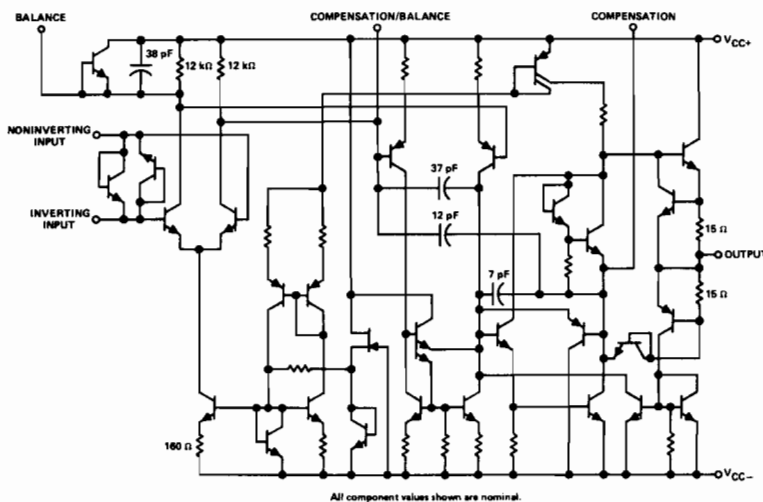
The NE5533 and NE5533A are dual monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. Some of the features include very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, and high slew rate.

These operational amplifiers are internally compensated for a gain equal to or greater than three. Optimization of the frequency response for various applications can be obtained by use of an external compensation capacitor between the compensation terminals. The devices feature input-protection diodes, output short-circuit protection, and offset-voltage nulling capability.

The NE5533A has guaranteed maximums on equivalent input noise voltage.

The NE5533 and NE5533A are characterized for operation from 0°C to 70°C.

**schematic (each amplifier)**



# TYPES NE5533, NE5533A

## DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	22 V
Supply voltage, $V_{CC-}$ (see Note 1)	-22 V
Input voltage either input (see Notes 1 and 2)	$V_{CC\pm}$
Input current (see Note 3)	$\pm 10$ mA
Duration of output short-circuit (see Note 4)	unlimited
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5):	
J package	1025 mW
N package	1150 mW
Operating free-air temperature range: NE5533, NE5533A	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
3. Excessive current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table. In the J package, these chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

# TYPES NE5533, NE5533A DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS		NE5533, NE5533A			UNIT
			MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$T_A = 25^\circ\text{C}$		0.5	4		mV
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$		5			
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$		20	300		nA
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$		400			
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$		500	1500		nA
	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$		2000			
$V_{ICR}$ Common-mode input voltage range			$\pm 12$	$\pm 13$		V
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 600\ \Omega$	$V_{CC\pm} = \pm 15\text{ V}$	24	26		V
		$V_{CC\pm} = \pm 18\text{ V}$	30	32		
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 600\ \Omega$ $V_O = \pm 10\text{ V}$	$T_A = 25^\circ\text{C}$	25	100		V/mV
		$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	15			
$A_{vd}$ Small-signal differential voltage amplification	$f = 10\text{ kHz}$	$C_C = 0$	6			V/mV
		$C_C = 22\text{ pF}$	2.2			
$B_{OM}$ Maximum-output-swing bandwidth	$V_O = \pm 10\text{ V}$ , $V_O = \pm 10\text{ V}$ , $V_{CC\pm} = \pm 18\text{ V}$ , $C_C = 22\text{ pF}$	$C_C = 0$	200			kHz
		$C_C = 22\text{ pF}$	95			
		$V_O = \pm 14\text{ V}$ , $R_L = 600\ \Omega$ , $C_C = 22\text{ pF}$	70			
$B_1$ Unity-gain bandwidth	$C_C = 22\text{ pF}$	$C_L = 100\text{ pF}$	10			MHz
$r_i$ Input resistance			30	100		k $\Omega$
$z_o$ Output impedance	$A_{VD} = 30\text{ dB}$ , $f = 10\text{ kHz}$	$R_L = 600\ \Omega$	$C_C = 22\text{ pF}$ ,	0.3		$\Omega$
CMRR Common-mode rejection ratio			70	100		dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )			80	100		dB
$I_{OS}$ Output short-circuit current			38			mA
$I_{CC}$ Total supply current	No load		8	16		mA
$V_{O1}/V_{O2}$ Channel Separation	$R_S = 5\text{ k}\Omega$ , $f = 1\text{ kHz}$ , $A_{VD} = 100$		110			dB

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operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	NE5533		NE5533A		UNIT
		MIN	TYP	MIN	TYP	
SR Slew rate at unity gain	$C_C = 0$	13		13		V/ $\mu\text{s}$
	$C_C = 22\text{ pF}$	6		6		
$t_r$ Rise time	$V_I = 50\text{ mV}$ , $R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$	$A_{VD} = 1$ , $C_C = 22\text{ pF}$ ,	20		20	ns
			20%		20%	
$t_r$ Rise time	$V_I = 50\text{ mV}$ , $R_L = 600\ \Omega$ , $C_L = 500\text{ pF}$	$A_{VD} = 1$ , $C_C = 47\text{ pF}$ ,	50		50	ns
			35%		35%	
$V_n$ Equivalent input noise voltage	$f = 30\text{ Hz}$	7	5.5	7	nV/ $\sqrt{\text{Hz}}$	
	$f = 1\text{ kHz}$	4	3.5	4.5		
$I_n$ Equivalent input noise current	$f = 30\text{ Hz}$	2.5	1.5		pA/ $\sqrt{\text{Hz}}$	
	$f = 1\text{ kHz}$	0.6	0.4			
$\bar{F}$ Average noise figure	$R_S = 5\text{ k}\Omega$ , $f = 10\text{ Hz to } 20\text{ kHz}$	0.9			dB	

# TYPES NE5533, NE5533A

## DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS

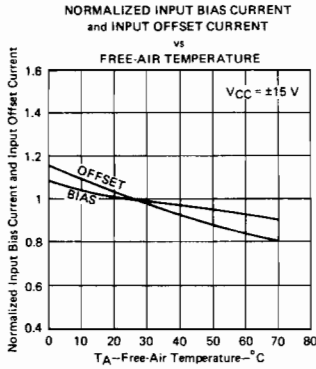


FIGURE 1

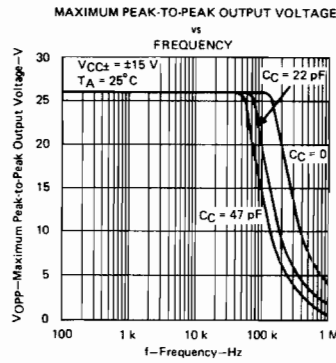


FIGURE 2

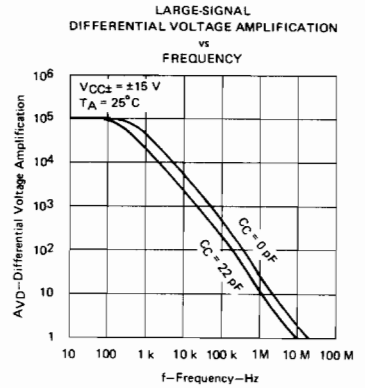


FIGURE 3

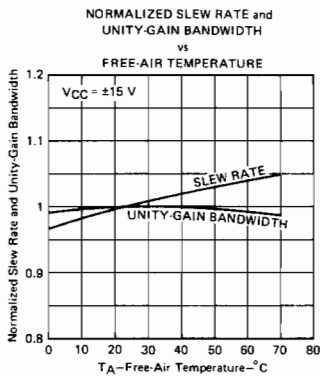


FIGURE 4

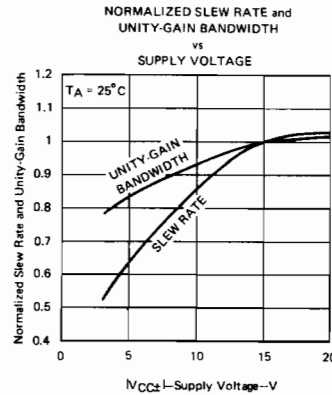


FIGURE 5

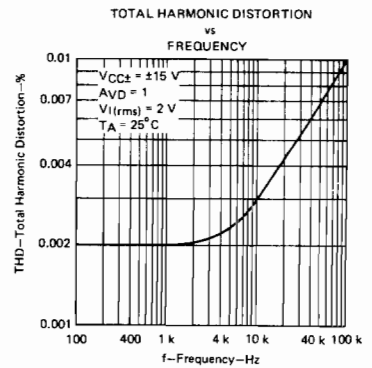


FIGURE 6

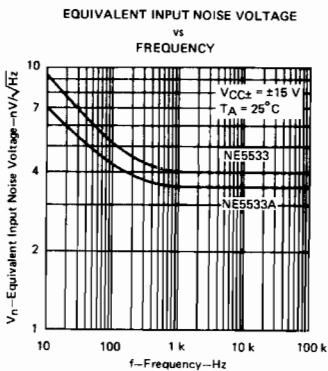


FIGURE 7

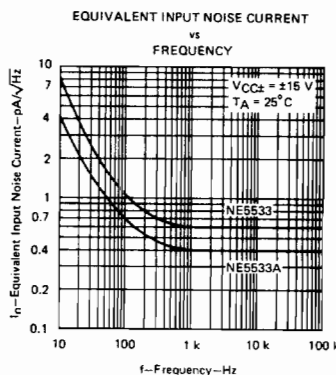


FIGURE 8

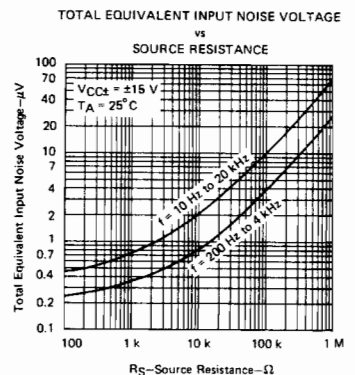


FIGURE 9

# LINEAR INTEGRATED CIRCUITS

# TYPES RM4136, RC4136 QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12368, MARCH 1976 — REVISED OCTOBER 1979

- Continuous-Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Unity Gain Bandwidth 3 MHz Typical
- Gain and Phase Match Between Amplifiers
- Designed to be Interchangeable with Raytheon RM4136 and RC4136

## description

The RM4136 and RC4136 are quad high-performance operational amplifiers with each amplifier electrically similar to uA741 except that offset null capability is not provided.

The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The RM4136 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the RC4136 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	RM4136	RC4136	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Duration of output short-circuit to ground, one amplifier at a time (See Note 4)	unlimited	unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	800	800	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or W package	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N package	260	$^{\circ}\text{C}$

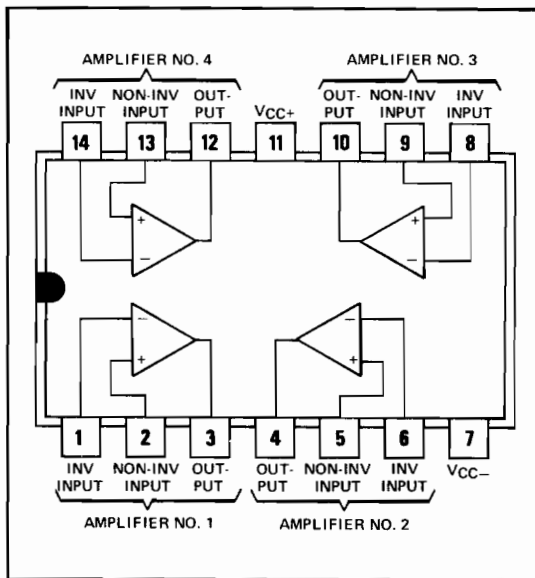
- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, RM4136 chips are alloy-mounted; RC4136 chips are glass-mounted.

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	800 mW	$11.0 \text{ mW}/^{\circ}\text{C}$	$77^{\circ}\text{C}$
J (Glass-Mounted Chip)	800 mW	$8.2 \text{ mW}/^{\circ}\text{C}$	$52^{\circ}\text{C}$
N	800 mW	$9.2 \text{ mW}/^{\circ}\text{C}$	$63^{\circ}\text{C}$
W	800 mW	$8.0 \text{ mW}/^{\circ}\text{C}$	$50^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)



# TYPES RM4136, RC4136

## QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	RM4136			RC4136			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 10\text{ k}\Omega$	25°C	0.5	5	0.5	6	mV	
		Full range		6		7.5		
$I_{IO}$ Input offset current		25°C	5	200	5	200	nA	
		Full range		500		300		
$I_{IB}$ Input bias current		25°C	40	500	40	500	nA	
		Full range		1500		800		
$V_{ICR}$ Common-mode input voltage range		25°C	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	24	28	24	28	V	
	$R_L = 2\text{ k}\Omega$	25°C	20	26	20	26		
	$R_L \geq 2\text{ k}\Omega$	Full range	20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	50	350	20	300	V/mV	
		Full range	25		15			
$B_1$ Unity-gain bandwidth		25°C	2	3.5	3		MHz	
$r_i$ Input resistance		25°C	0.3	5	0.3	5	M $\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	70	90	70	90	dB	
$k_{SVS}^*$ Supply voltage sensitivity	$R_S \leq 10\text{ k}\Omega$	25°C	30	150	30	150	$\mu\text{V/V}$	
$V_n$ Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $R_S = 1\text{ k}\Omega$ , $f = 1\text{ kHz}$ , $BW = 1\text{ Hz}$	25°C	10		10		nV/ $\sqrt{\text{Hz}}$	
$I_{CC}$ Supply current (All four amplifiers)	No load, No signal	25°C	5	11.3	5	11.3	mA	
		MIN $T_A$	6	13.3	6	13.7		
		MAX $T_A$	4.5	10	4.5	10		
$P_D$ Total power dissipation (All four amplifiers)	No load, No signal	25°C	150	340	150	340	mW	
		MIN $T_A$	180	400	180	400		
		MAX $T_A$	135	300	135	300		
$V_{O1}/V_{O2}$ Channel separation	Open loop	$R_S = 1\text{ k}\Omega$ , $f = 10\text{ kHz}$	25°C	105		105	dB	
	$A_{VD} = 100$		25°C	105		105		

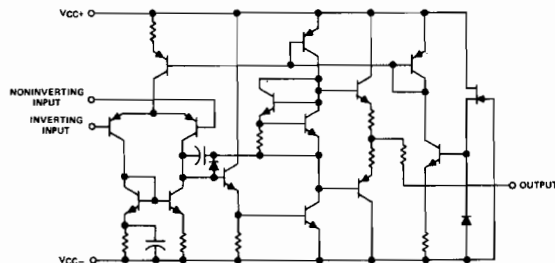
\* $k_{SVS} = \Delta V_{IO} / \Delta V_{CC}$

† All characteristics are specified under open-loop operation, unless otherwise noted. Full range for RM4136 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for RC4136 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	RM4136			RC4136			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		0.13			0.13		$\mu\text{s}$
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.5			1.0		V/ $\mu\text{s}$

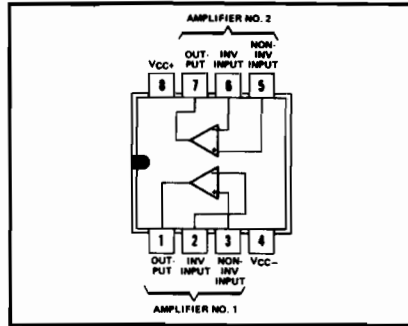
schematic (each amplifier)





- Continuous-Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Unity Gain Bandwidth 3 MHz Typical
- Gain and Phase Match Between Amplifiers
- Designed to be Interchangeable with Raytheon RM4558 and RC4558

JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The RM4558 and RC4558 are dual general-purpose operational amplifiers with each half electrically similar to uA741 except that offset null capability is not provided.

The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The RM4558 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the RC4558 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

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**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	RM4558	RC4558	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Duration of output short-circuit to ground, one amplifier at a time (see Note 4)	unlimited	unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	680	680	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	JG package	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	P package	260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the JG packages, RM4558 chips are alloy-mounted; RC4558 chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	$8.4 \text{ mW}/^{\circ}\text{C}$	$69^{\circ}\text{C}$
JG (Glass-Mounted Chip)	680 mW	$6.6 \text{ mW}/^{\circ}\text{C}$	$47^{\circ}\text{C}$
P	680 mW	$8.0 \text{ mW}/^{\circ}\text{C}$	$65^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPES RM4558, RC4558

## DUAL HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	RM4558			RC4558			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage $R_S < 10\text{ k}\Omega$	25°C	0.5	5	0.5	6	mV	
		Full range		6		7.5		
$I_{IO}$	Input offset current	25°C	5	200	5	200	nA	
		Full range		500		300		
$I_{IB}$	Input bias current	25°C	40	500	40	500	nA	
		Full range		1500		800		
$V_{ICR}$	Common-mode input voltage range	25°C	±12	±14	±12	±14	V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	24	28	24	28	V
		$R_L = 2\text{ k}\Omega$	25°C	20	26	20	26	
		$R_L \geq 2\text{ k}\Omega$	Full range	20		20		
$A_{VD}$	Large-signal differential voltage amplification $R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	50	350	20	300	V/mV	
		Full range	25		15			
$B_1$	Unity-gain bandwidth	25°C	2	3.5	3		MHz	
$r_i$	Input resistance	25°C	0.3	5	0.3	5	MΩ	
$CMRR$	Common-mode rejection ratio	$R_S < 10\text{ k}\Omega$	25°C	70	90	70	90	dB
$k_{SVS}^*$	Supply voltage sensitivity	$R_S < 10\text{ k}\Omega$	25°C	30	150	30	150	μV/V
$V_n$	Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $R_S = 1\text{ k}\Omega$ , $f = 1\text{ kHz}$ , $BW = 1\text{ Hz}$	25°C	10		10		nV/√Hz
$I_{CC}$	Supply current (Both amplifiers)	No load, No signal	25°C	2.5	5.6	2.5	5.6	mA
			MIN $T_A$	3.0	6.6	3.0	6.6	
			MAX $T_A$	2.0	5	2.3	5	
$P_D$	Total power dissipation (Both amplifiers)	No load, No signal	25°C	75	170	75	170	mW
			MIN $T_A$	90	200	90	200	
			MAX $T_A$	60	150	70	150	
$V_{O1}/V_{O2}$	Channel separation	Open loop	$R_S = 1\text{ k}\Omega$ , $f = 10\text{ kHz}$	25°C	105	105	dB	
		$A_{VD} = 100$		25°C	105	105		

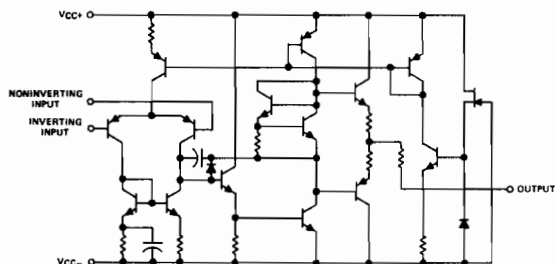
\* $k_{SVS} = \Delta V_{IO}/\Delta V_{CC}$

† All characteristics are specified under open-loop operation, unless otherwise noted. Full range for RM4558 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for RC4558 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	RM4558			RC4558			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$	Rise time $V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$		0.13			0.13		μs
	Overshoot $C_L = 100\text{ pF}$		5%			5%		
SR	Slew rate at unity gain $V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.5			1.0		V/μs

schematic (each amplifier)



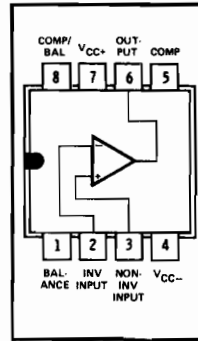
# LINEAR INTEGRATED CIRCUITS

# TYPES SE5534, SE5534A, NE5534, NE5534A LOW-NOISE OPERATIONAL AMPLIFIERS

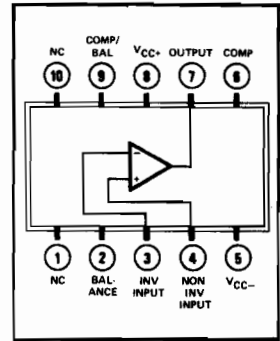
BULLETIN NO. DL-S 12680, JULY 1979—REVISED OCTOBER 1979

- Equivalent Input Noise Voltage . . . 3.5 nV/√Hz Typ
- Unity-Gain Bandwidth . . . 10 MHz Typ
- Common-Mode Rejection Ratio . . . 100 dB Typ
- High DC Voltage Gain . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing . . . 32 V Typ with  $V_{CC\pm} = \pm 18$  V and  $R_L = 600 \Omega$
- High Slew Rate . . . 13 V/μs Typ
- Wide Supply Voltage Range . . .  $\pm 3$  V to  $\pm 20$  V
- Low Harmonic Distortion
- Designed to be Interchangeable with Signetics SE5534, SE5534A, NE5534, and NE5534A

SE5534, SE5534A . . . JG  
NE5534, NE5534A . . . JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



SE5534, SE5534A  
U FLAT PACKAGE  
(TOP VIEW)



NC — No connection

## description

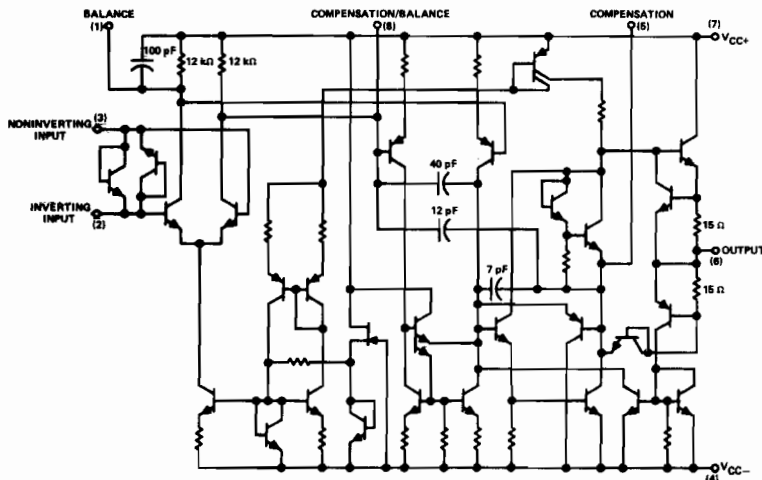
The SE5534, SE5534A, NE5534, and NE5534A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. Some of the features include very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, and high slew rate.

These operational amplifiers are internally compensated for a gain equal to or greater than three. Optimization of the frequency response for various applications can be obtained by use of an external compensation capacitor between pins 5 and 8. The devices feature input-protection diodes, output short-circuit protection, and offset-voltage nulling capability.

The SE5534A and NE5534A have guaranteed maximums on equivalent input noise voltage.

The SE5534 and SE5534A are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the NE5534 and NE5534A are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## schematic



All component values shown are nominal.

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# TYPES SE5534, SE5534A, NE5534, NE5534A

## LOW-NOISE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	22 V
Supply voltage, $V_{CC-}$ (see Note 1)	-22 V
Input voltage either input (see Notes 1 and 2)	$V_{CC\pm}$
Input current (see Note 3)	$\pm 10$ mA
Duration of output short-circuit (see Note 4)	unlimited
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5):	
SE5534, SE5534A in JG package	1050 mW
NE5534, NE5534A in JG package	825 mW
P package	1000 mW
U package	675 mW
Operating free-air temperature range: SE5534, SE5534A	-55°C to 125°C
NE5534, NE5534A	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG or U package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
3. Excessive current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, SE5534 and SE5534A chips are alloy-mounted; NE5534 and NE5534A chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	1050 mW	8.4 mW/°C	25°C
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	1000 mW	8.0 mW/°C	25°C
U	675 mW	5.4 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

# TYPES SE5534, SE5534A, NE5534, NE5534A

## LOW-NOISE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	SE5534, SE5534A			NE5534, NE5534A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$T_A = 25^\circ\text{C}$	0.5			0.5			mV
	$T_A = \text{full range}$	3			5			
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$	10			20			nA
	$T_A = \text{full range}$	500			400			
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$	400			500			nA
	$T_A = \text{full range}$	800			1500			
$V_{ICR}$ Common-mode input voltage range		±12	±13		±12	±13	V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 600\ \Omega$	$V_{CC\pm} = \pm 15\text{ V}$		24	26	24	26	V
		$V_{CC\pm} = \pm 18\text{ V}$		30	32	30	32	
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 600\ \Omega$ , $V_O = \pm 10\text{ V}$	$T_A = 25^\circ\text{C}$		50	100	25	100	V/mV
		$T_A = \text{full range}$		25		15		
$A_{vd}$ Small-signal differential voltage amplification	$f = 10\text{ kHz}$	$C_C = 0$		6			V/mV	
		$C_C = 22\text{ pF}$		2.2				
$B_{OM}$ Maximum-output-swing bandwidth	$V_O = \pm 10\text{ V}$ , $C_C = 0$	200			200			kHz
	$V_O = \pm 10\text{ V}$ , $C_C = 22\text{ pF}$	95			95			
	$V_{CC\pm} = \pm 18\text{ V}$ , $V_O = \pm 14\text{ V}$ , $R_L = 600\ \Omega$ , $C_C = 22\text{ pF}$	70			70			
$B_1$ Unity-gain bandwidth	$C_C = 22\text{ pF}$ , $C_L = 100\text{ pF}$	10			10			MHz
$r_i$ Input resistance		50	100		30	100	k $\Omega$	
$z_o$ Output impedance	$A_{VD} = 30\text{ dB}$ , $R_L = 600\ \Omega$ , $C_C = 22\text{ pF}$ , $f = 10\text{ kHz}$	0.3			0.3			$\Omega$
CMRR Comm-mode rejection ratio		80	100		70	100	dB	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )		86	100		80	100	dB	
$I_{OS}$ Output short-circuit current		38			38			mA
$I_{CC}$ Supply current	No load	$T_A = 25^\circ\text{C}$		4	6.5	4	8	mA
		$T_A = \text{full range}$		9				

† Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for SE5534 and SE5534A; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for NE5534 and NE5534A.

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	SE5534, NE5534			SE5534A, NE5534A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$C_C = 0$	13			13			V/ $\mu\text{s}$
	$C_C = 22\text{ pF}$	6			6			
$t_r$ Rise Time	$V_I = 50\text{ mV}$ , $A_{VD} = 1$ , $R_L = 600\ \Omega$ , $C_C = 22\text{ pF}$ ,	20			20			ns
Overshoot factor	$C_L = 100\text{ pF}$	20%			20%			
$t_r$ Rise time	$V_I = 50\text{ mV}$ , $A_{VD} = 1$ , $R_L = 600\ \Omega$ , $C_C = 47\text{ pF}$ ,	50			50			ns
Overshoot factor	$C_L = 500\text{ pF}$	35%			35%			
$V_n$ Equivalent input noise voltage	$f = 30\text{ Hz}$	7			5.5	7	nV/ $\sqrt{\text{Hz}}$	
	$f = 1\text{ kHz}$	4			3.5	4.5		
$I_n$ Equivalent input noise current	$f = 30\text{ Hz}$	2.5			1.5			pA/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$	0.6			0.4			
$\bar{F}$ Average noise figure	$R_S = 5\text{ k}\Omega$ , $f = 10\text{ Hz to } 20\text{ kHz}$	0.9			0.9			dB

# TYPES SE5534, SE5534A, NE5534, NE5534A

## LOW-NOISE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

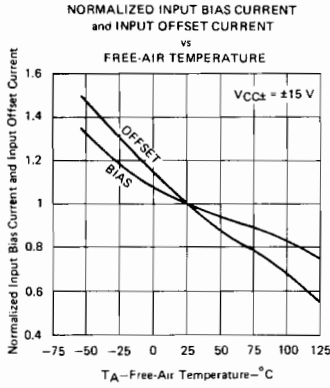


FIGURE 1

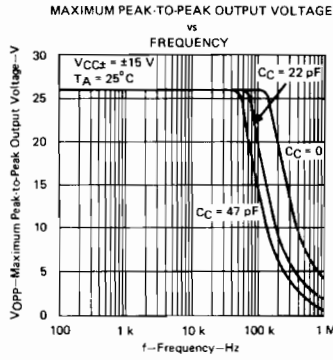


FIGURE 2

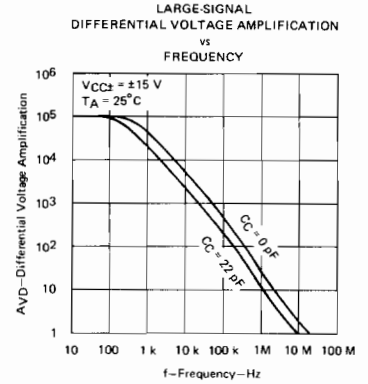


FIGURE 3

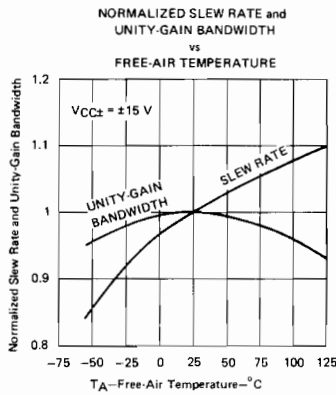


FIGURE 4

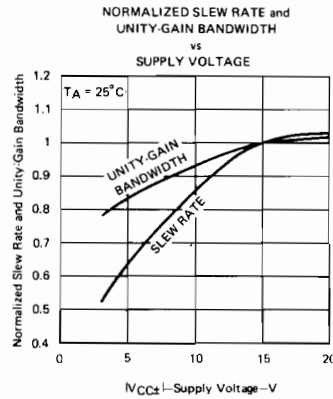


FIGURE 5

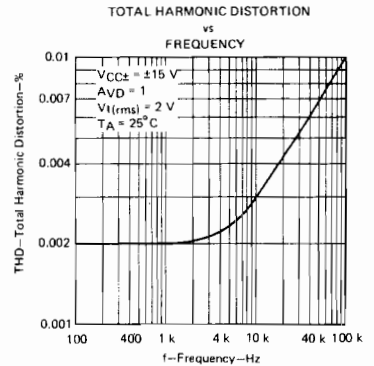


FIGURE 6

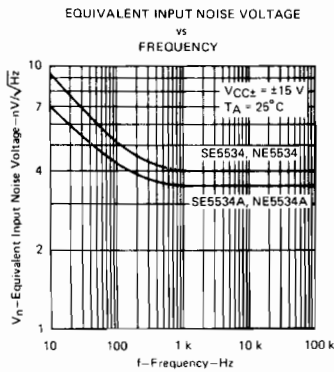


FIGURE 7

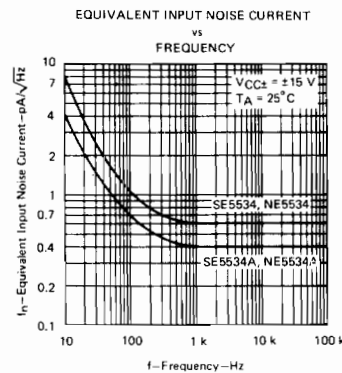


FIGURE 8

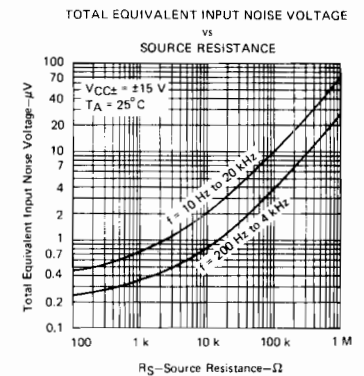


FIGURE 9

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

- Very Low Power Consumption
- Typical Power Dissipation with  $\pm 2$ -V Supplies . . .  $170 \mu W$
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Input Offset Voltage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- Popular Dual Op Amp Pin-Out

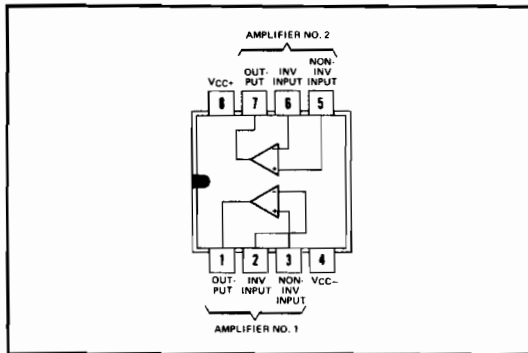
**description**

The TL022 is a dual low-power operational amplifier designed to replace higher-power devices in many applications without sacrificing system performance. High input impedance, low supply currents, and low equivalent input noise voltage over a wide range of operating supply voltages result in an extremely versatile operational amplifier for use in a variety of analog applications including battery-operated circuits. Internal frequency compensation, absence of latch-up, high slew rate, and output short-circuit protection assure ease of use.

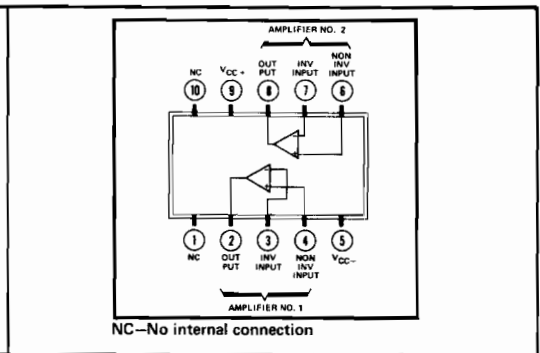
The TL022M is characterized for operation over the full military temperature range of  $-55^{\circ}C$  to  $125^{\circ}C$ ; the TL022C is characterized for operation from  $0^{\circ}C$  to  $70^{\circ}C$ .

**terminal assignments**

**JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)**



**U FLAT PACKAGE  
(TOP VIEW)**



**4**

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	TL022M	TL022C	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V	
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V	
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V	
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V	
Duration of output short-circuit (see Note 4)	unlimited	unlimited		
Continuous total dissipation at (or below) $25^{\circ}C$ free-air temperature range (see Note 5)	Each amplifier	500	500	
	Total package	JG or P package	680	680
		U package	675	675
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}C$	
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}C$	
Lead temperature $1/16$ inch (1,6 mm) from case for 60 seconds	JG or U package	300	$^{\circ}C$	
Lead temperature $1/16$ inch (1,6 mm) from case for 10 seconds	P package		$^{\circ}C$	

- NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
  4. The output may be shorted to ground or either power supply. For the TL022M only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}C$  case temperature or  $75^{\circ}C$  free-air temperature.
  5. For operation above  $25^{\circ}C$  free-air temperature, refer to Dissipation Derating Table. In the JG package, TL022M chips are alloy-mounted; TL022C chips are glass-mounted.

# TYPES TL022M, TL022C

## DUAL LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	TL022M			TL022C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 10\text{ k}\Omega$	25°C	1	5	1	5	mV	
		Full range		6		7.5		
$I_{IO}$ Input offset current		25°C	5	40	15	80	nA	
		Full range		100		200		
$I_{IB}$ Input bias current		25°C	50	100	100	250	nA	
		Full range		250		400		
$V_{ICR}$ Common-mode input voltage range		25°C	±12	±13	±12	±13	V	
		Full range		±12		±12		
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	20	26	20	26	V	
	$R_L \geq 10\text{ k}\Omega$	Full range		20		20		
AVD Large-signal differential voltage amplification	$R_L \geq 10\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	72	86	60	80	dB	
		Full range		72		60		
$B_1$ Unity-gain bandwidth		25°C		0.5		0.5	MHz	
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	60	72	60	72	dB	
		Full range		60		60		
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 10\text{ k}\Omega$	25°C	30	150	30	200	$\mu\text{V}/\text{V}$	
		Full range		150		200		
$V_n$ Equivalent input noise voltage	AVD = 20 dB, B = 1 Hz, f = 1 kHz	25°C		50		50	nV/ $\sqrt{\text{Hz}}$	
$I_{OS}$ Short-circuit output current		25°C		±6		±6	mA	
$I_{CC}$ Supply current (Both amplifiers)	No load,	25°C	130	200	130	250	$\mu\text{A}$	
	No signal	Full range		200		250		
$P_D$ Total dissipation (Both amplifiers)	No load,	25°C	3.9	6	3.9	7.5	mW	
	No signal	Full range		6		7.5		

† All characteristics are specified under open-loop operation, unless otherwise noted. Full range for TL022M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for TL022C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL022M			TL022C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$ ,		0.3			0.3	$\mu\text{s}$	
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		5%			5%		
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1		0.5			0.5	$\text{V}/\mu\text{s}$	

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/ $^\circ\text{C}$	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/ $^\circ\text{C}$	47°C
P	680 mW	8.0 mW/ $^\circ\text{C}$	65°C
U	675 mW	5.4 mW/ $^\circ\text{C}$	25°C

Also see Dissipation Derating Curves, Section 2.



# TYPES TL022M, TL022C DUAL LOW-POWER OPERATIONAL AMPLIFIERS

## PARAMETER MEASUREMENT INFORMATION

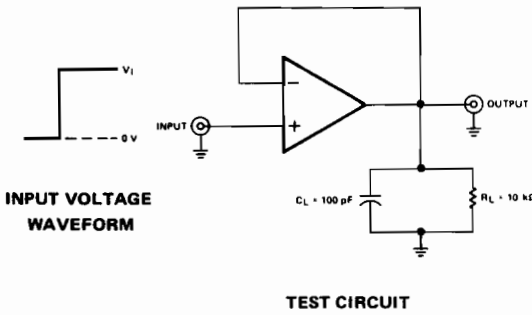


FIGURE 1—RISE TIME, OVERSHOOT FACTOR, AND SLEW RATE

## TYPICAL CHARACTERISTICS

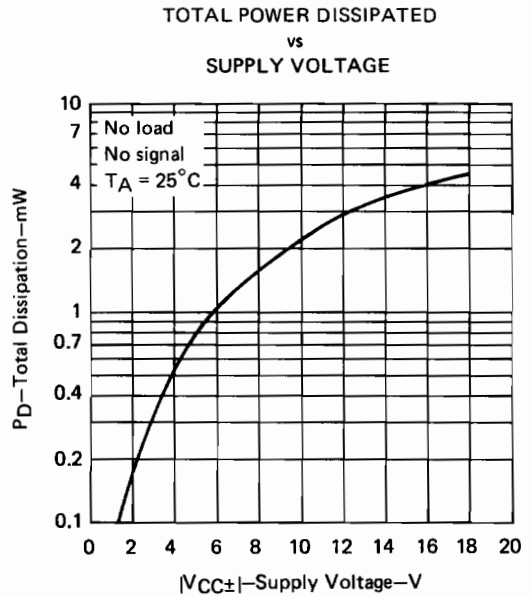
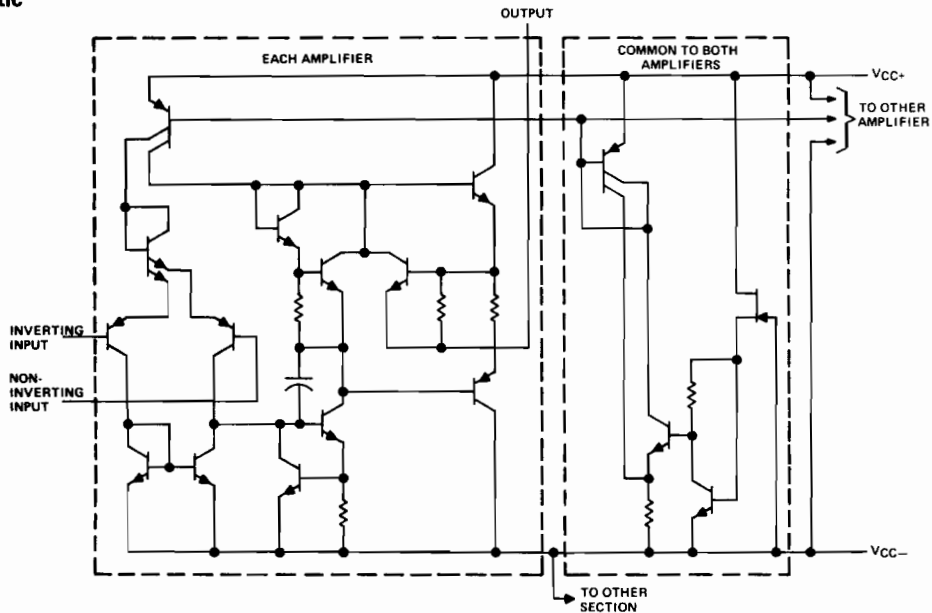


FIGURE 2

4

## schematic



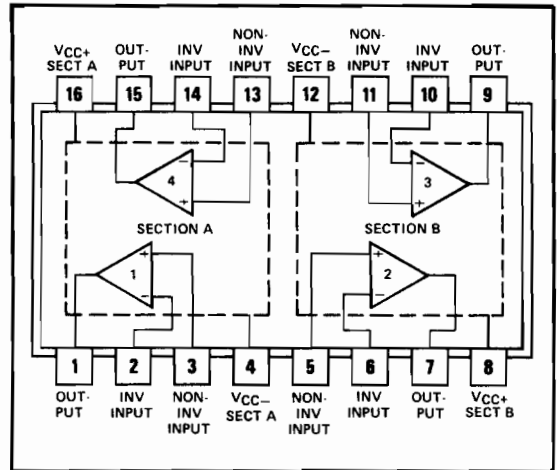
- Very Low Power Consumption
- Typical Power Dissipation with  $\pm 2$ -V Supplies . . . 340  $\mu$ W
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Input Offset Voltage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- Power Applied in Pairs

**description**

The TL044 is a quad low-power operational amplifier designed to replace higher-power devices in many applications without sacrificing system performance. High input impedance, low supply currents, and low equivalent input noise voltage over a wide range of operating supply voltages result in an extremely versatile operational amplifier for use in a variety of analog applications including battery-operated circuits. Internal frequency compensation, absence of latch-up, high slew rate, and output short-circuit protection assure ease of use. Power may be applied separately to Section A (amplifiers 1 and 4) or Section B (amplifiers 2 and 3) while the other pair remains unpowered.

The TL044M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL044C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)**



Pins 4 and 12 are internally connected together in the N package only.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	TL044M	TL044C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature range (see Note 5)	Each amplifier	500	mW
	Total package	680	
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or W Package	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N Package	260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the TL044M only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, TL044M chips are alloy-mounted; TL044C chips are glass-mounted.

# TYPES TL044M, TL044C QUAD LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	TL044M			TL044C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 10\text{ k}\Omega$	25°C	1	5	1	5	mV	
		Full range	6		7.5			
$I_{IO}$ Input offset current		25°C	5	40	15	80	nA	
		Full range	100		200			
$I_{IB}$ Input bias current		25°C	50	100	100	250	nA	
		Full range	250		400			
$V_{ICR}$ Common-mode input voltage range		25°C	±12	±13	±12	±13	V	
		Full range	±12		±12			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	20	26	20	26	V	
	$R_L \geq 10\text{ k}\Omega$	Full range	20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 10\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	72	86	60	80	dB	
	Full range	72		60				
$B_1$ Unity-gain bandwidth		25°C	0.5		0.5		MHz	
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	60	72	60	72	dB	
		Full range	60		60			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 10\text{ k}\Omega$	25°C	30		150	30	200	$\mu\text{V}/\text{V}$
		Full range			150	200		
$V_n$ Equivalent input noise voltage	$A_{VD} = 20\text{ dB}$ , $B = 1\text{ Hz}$ , $f = 1\text{ kHz}$	25°C	50		50		$\text{nV}/\sqrt{\text{Hz}}$	
$I_{OS}$ Short-circuit output current		25°C	±6		±6		mA	
$I_{CC}$ Supply current (Four amplifiers)	No load,	25°C	250	400	250	500	$\mu\text{A}$	
	No signal	Full range	400		500			
$P_D$ Total dissipation (Four amplifiers)	No load,	25°C	7.5	12	7.5	15	mW	
	No signal	Full range	12		15			

†All characteristics are specified under open-loop operation, unless otherwise noted. Full range for TL044M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for TL044C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL044M			TL044C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$ ,	0.3			0.3			$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1	5%			5%			
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	0.5			0.5			$\text{V}/\mu\text{s}$

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	680 mW	11.0 mW/ $^\circ\text{C}$	88°C
J (Glass-Mounted Chip)	680 mW	8.2 mW/ $^\circ\text{C}$	67°C
N	680 mW	9.2 mW/ $^\circ\text{C}$	76°C
W	680 mW	8.0 mW/ $^\circ\text{C}$	65°C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL044M, TL044C

## QUAD LOW-POWER OPERATIONAL AMPLIFIERS

### PARAMETER MEASUREMENT INFORMATION

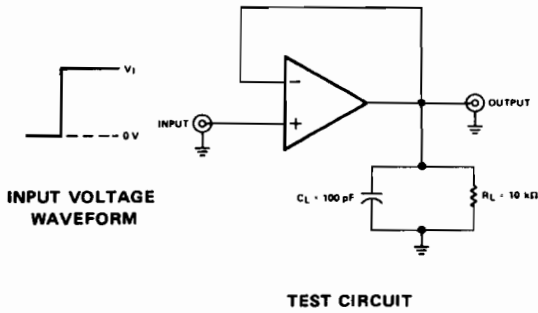


FIGURE 1—RISE TIME, OVERSHOOT FACTOR, AND SLEW RATE

### TYPICAL CHARACTERISTICS

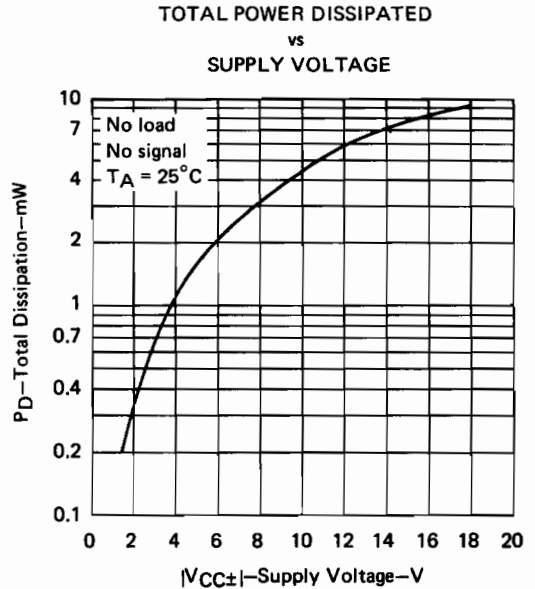
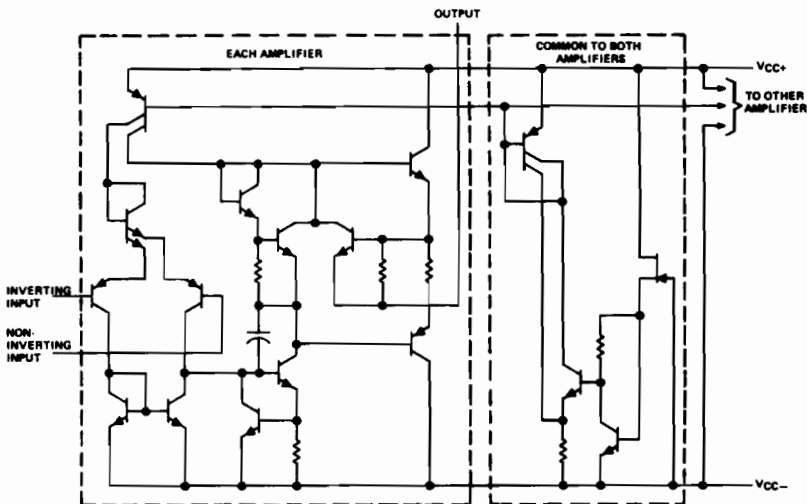


FIGURE 2

schematic (each section)



# LINEAR INTEGRATED CIRCUITS

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12647, NOVEMBER 1978—REVISED OCTOBER 1979

## 19 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES

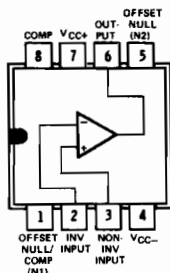
- Very Low Power Consumption
- Typical Supply Current . . . 200  $\mu$ A
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 3.5 V/ $\mu$ s Typ

### description

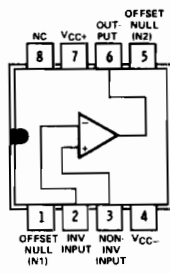
The JFET-input operational amplifiers of the TL061 series are designed as low-power versions of the TL081 series amplifiers. They feature high input impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The TL061 series features the same terminal assignments as the TL071 and TL081 series. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

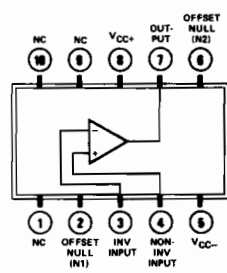
TL060, TL060A  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



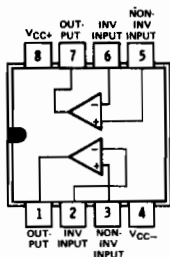
TL061, TL061A, TL061B  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



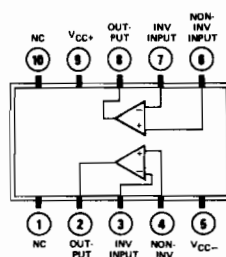
TL061  
U FLAT PACKAGE  
(TOP VIEW)



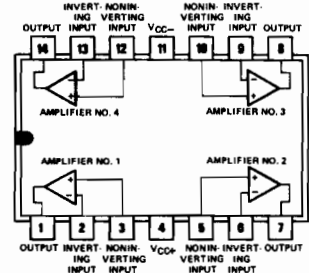
TL062, TL062A, TL062B  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



TL062  
U FLAT PACKAGE  
(TOP VIEW)



TL064 . . . J, N, OR W PACKAGE  
TL064A, TL064B . . . J OR N PACKAGE  
(TOP VIEW)

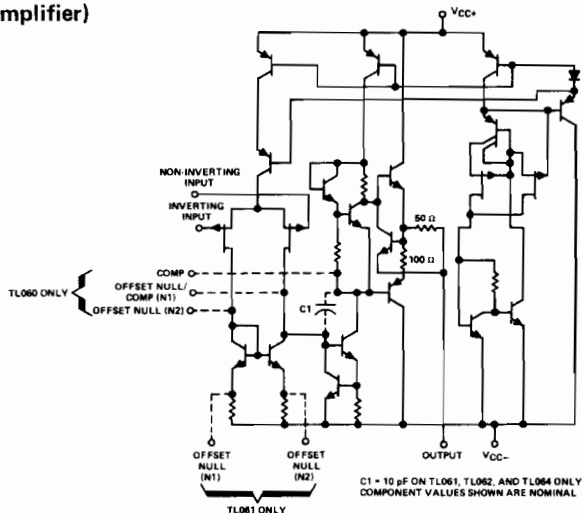


NC—No internal connection

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# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL06_M	TL06_I	TL06_C TL06_AC TL06_BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short circuit (see Note 4)	Unlimited	Unlimited	Unlimited	
Continuous total dissipation at (or below)	J, JG, N, P, or W package			mW
25°C free-air temperature (see Note 5)	U package			
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J, JG, U, or W package			°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package			°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C, free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL06\_M chips are alloy-mounted; TL06\_I, TL06\_C, TL06\_AC, and TL06\_BC chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	680 mW	11.0 mW/°C	88°C
J (Glass-Mounted Chip)	680 mW	8.2 mW/°C	67°C
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/°C	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/°C	47°C
N	680 mW	9.2 mW/°C	76°C
P	680 mW	8.0 mW/°C	65°C
U	675 mW	5.4 mW/°C	25°C
W	680 mW	8.0 mW/°C	65°C

DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL060	TL061	TL062	TL064
TL06_M	JG	JG, U	JG, U	J, W
TL06_I	JG, P	JG, P	JG, P	J, N
TL06_C	JG, P	JG, P	JG, P	J, N
TL06_AC	JG, P	JG, P	JG, P	J, N
TL06_BC		JG, P	JG, P	J, N

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC+} = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS†		TL06_M		TL06_I		TL06_C TL06_AC TL06_BC		UNIT		
			MIN	TYP MAX	MIN	TYP MAX	MIN	TYP MAX			
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$	'60, '61, '62	3	6	3	6	3	15	mV		
		'64	3	9	3	6	3	15			
		'60A, '61A, '62A, '64A '61B, '62B, '64B					3	6			
	$R_S = 50\ \Omega$ , $T_A = \text{full range}$	'60, '61, '62		9		9		20			
		'64		15		9		20			
		'60A, '61A, '62A, '64A '61B, '62B, '64B						7.5 5			
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , $T_A = \text{full range}$		10		10		10	$\mu\text{V}/^\circ\text{C}$			
$I_{IO}$ Input offset current‡	$T_A = 25^\circ\text{C}$	'60, '61, '62, '64	5	100	5	100	5	200	pA		
		'60A, '61A, '62A, '64A '61B, '62B, '64B					5	100			
		'60, '61, '62, '64		20		10		5			
	$T_A = \text{full range}$	'60A, '61A, '62A, '64A '61B, '62B, '64B						3 3	nA		
		'60, '61, '62, '64		30	200	30	200	30		400	
		'60A, '61A, '62A, '64A '61B, '62B, '64B					30	200		30	200
$I_{IB}$ Input bias current‡	$T_A = 25^\circ\text{C}$	'60, '61, '62, '64		50		20		10	pA		
		'60A, '61A, '62A, '64A '61B, '62B, '64B						7 7		nA	
		'60, '61, '62, '64		30	200	30	200	30			400
	$T_A = \text{full range}$	'60A, '61A, '62A, '64A '61B, '62B, '64B						$\pm 11$ $\pm 12$ $\pm 11.5$ $\pm 12$ $\pm 11.5$ $\pm 12$	V		
		'60, '61, '62, '64		20	27	20	27	20		27	
		'60A, '61A, '62A, '64A '61B, '62B, '64B								20 20	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10\ \text{k}\Omega$	'60, '61, '62, '64	4	6	4	6	3	6	V		
		'60A, '61A, '62A, '64A '61B, '62B, '64B					4	6			
	$T_A = \text{full range}$ , $R_L \geq 10\ \text{k}\Omega$	'60, '61, '62, '64		4	6		4	6			
		'60A, '61A, '62A, '64A '61B, '62B, '64B					4	6			
		'60, '61, '62, '64		4		4		3			
		'60A, '61A, '62A, '64A '61B, '62B, '64B					4	4			
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$ , $R_L = 10\ \text{k}\Omega$	'60, '61, '62, '64	1		1		1		MHz		
		'60A, '61A, '62A, '64A '61B, '62B, '64B									
		'60, '61, '62, '64		80	86		80	86		70	76
		'60A, '61A, '62A, '64A '61B, '62B, '64B								80	86
		'60, '61, '62, '64		80	95		80	95		70	95
		'60A, '61A, '62A, '64A '61B, '62B, '64B								80	95
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S \leq 10\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	'60, '61, '62, '64	80	95	80	95	70	95	dB		
		'60A, '61A, '62A, '64A '61B, '62B, '64B					80	95			
		'60, '61, '62, '64		6	7.5		6	7.5		6	7.5
		'60A, '61A, '62A, '64A '61B, '62B, '64B								200	250
		'60, '61, '62, '64		200	250		200	250		200	250
		'60A, '61A, '62A, '64A '61B, '62B, '64B								200	250
$V_{O1}/V_{O2}$ Channel separation	$AV_D = 100$ , $T_A = 25^\circ\text{C}$		120		120		120		dB		

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL06\_M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL06\_I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL06\_C, TL06\_AC, and TL06\_BC.

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as is possible.

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL06_M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	2	3.5			3.5		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1		0.2			0.2		$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		10%			10%		
$V_n$ Equivalent input noise voltage	$R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		42			42		$\text{nV}/\sqrt{\text{Hz}}$

## PARAMETER MEASUREMENT INFORMATION

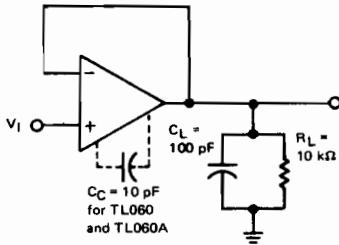


FIGURE 1—UNITY-GAIN AMPLIFIER

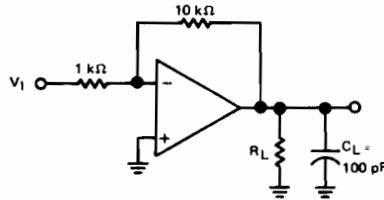


FIGURE 2—GAIN-OF-10  
INVERTING AMPLIFIER

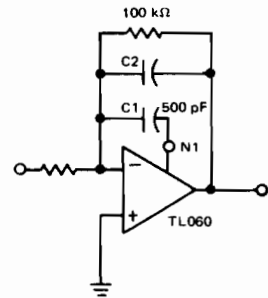
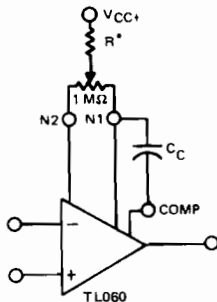


FIGURE 3—FEED-FORWARD  
COMPENSATION

## INPUT OFFSET VOLTAGE NULL CIRCUITS



\*For best results use  $R = 20\text{ M}\Omega$  for  $V_{CC\pm} = \pm 15\text{ V}$  to  $R = 5\text{ M}\Omega$  for  $V_{CC\pm} = \pm 3\text{ V}$ .

FIGURE 4

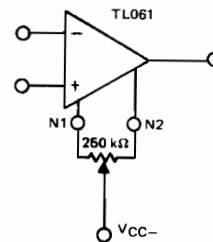


FIGURE 5



# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

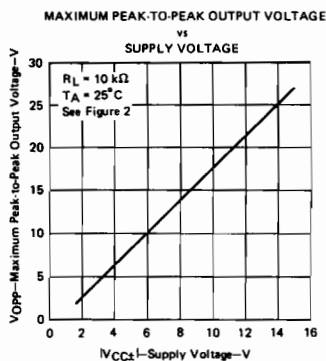


FIGURE 6

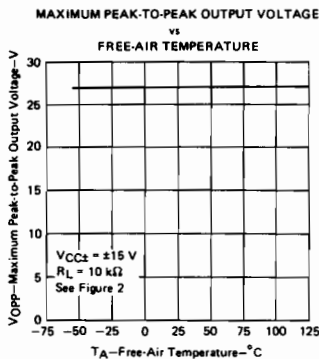


FIGURE 7

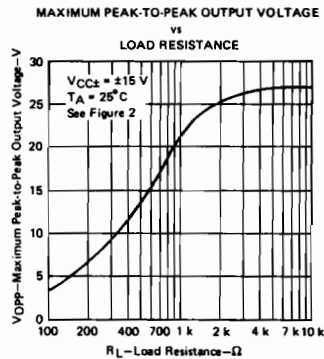


FIGURE 8

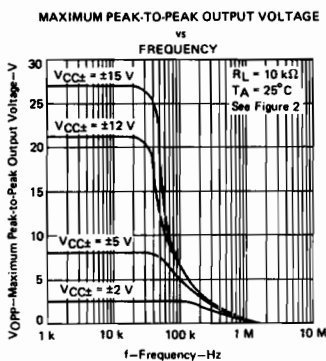


FIGURE 9

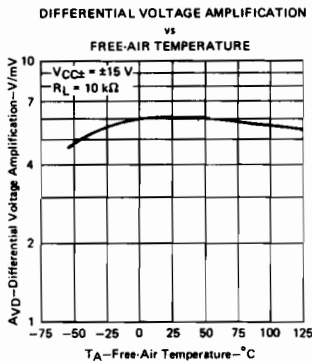


FIGURE 10

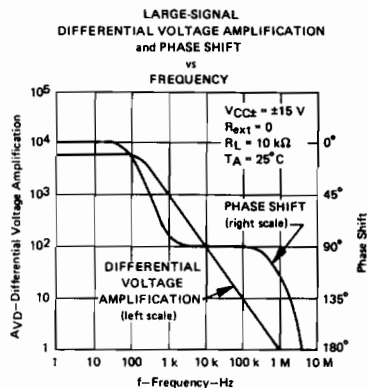


FIGURE 11

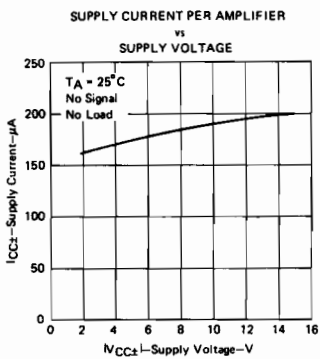


FIGURE 12

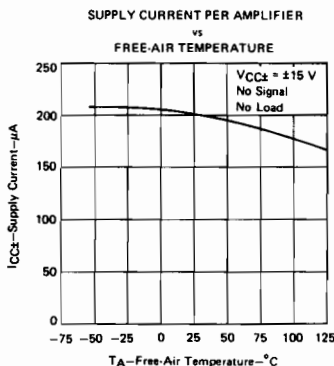


FIGURE 13

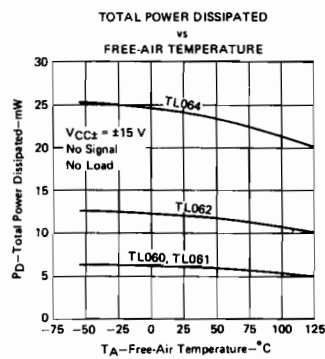


FIGURE 14

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

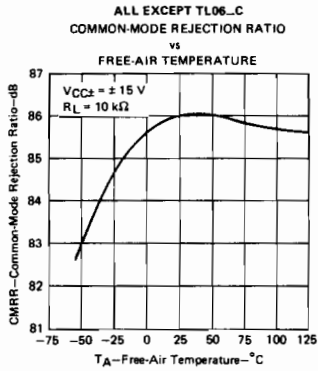


FIGURE 15

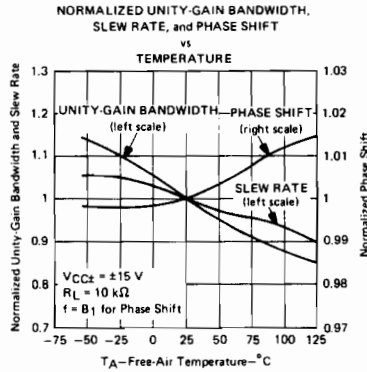


FIGURE 16

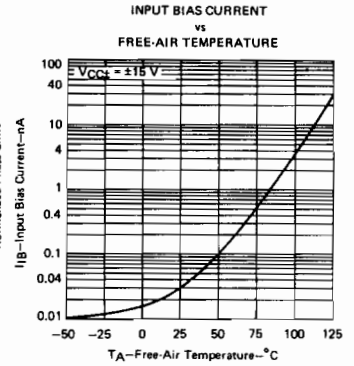


FIGURE 17

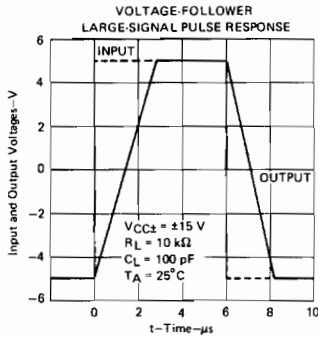


FIGURE 18

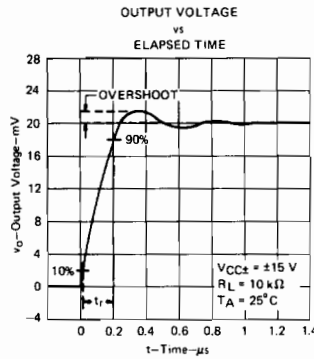


FIGURE 19

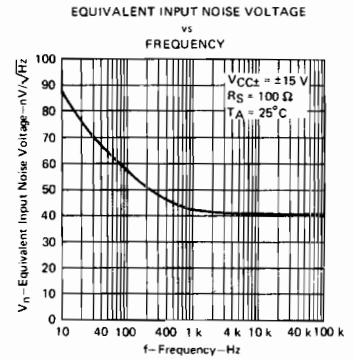


FIGURE 20

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

## TYPICAL APPLICATION DATA

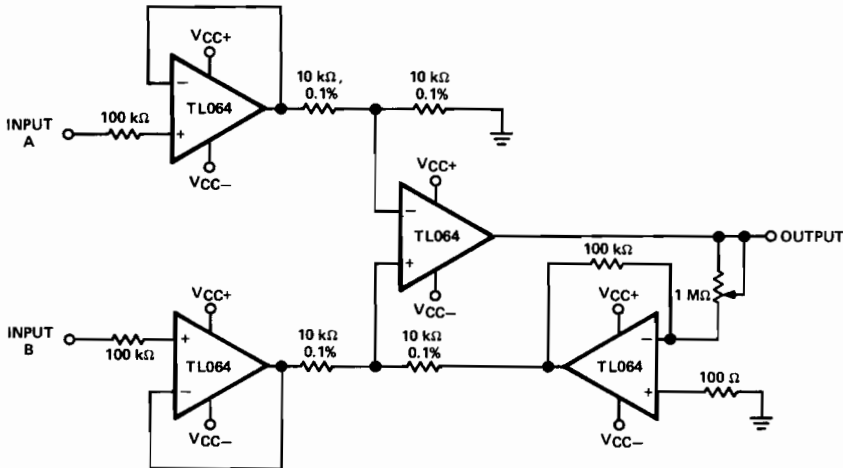


FIGURE 21—INSTRUMENTATION AMPLIFIER

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA

0.5-Hz SQUARE-WAVE OSCILLATOR

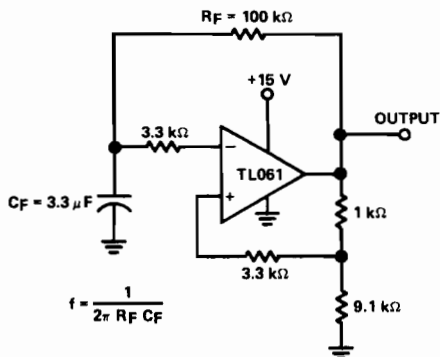


FIGURE 22—0.5-Hz SQUARE-WAVE OSCILLATOR

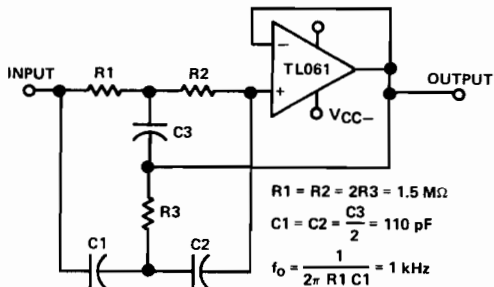


FIGURE 23—HIGH-Q NOTCH FILTER

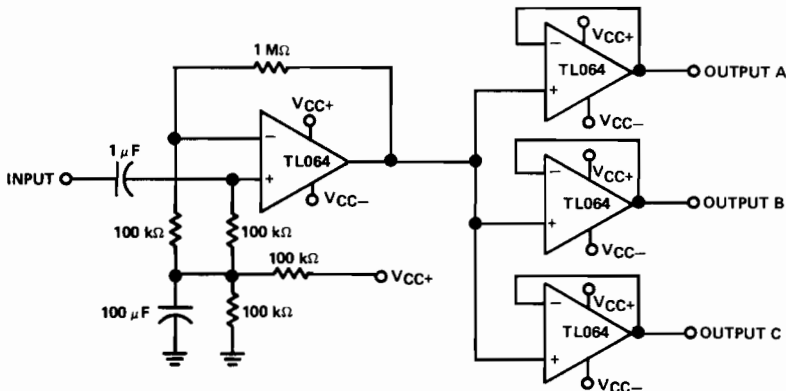


FIGURE 24—AUDIO DISTRIBUTION AMPLIFIER

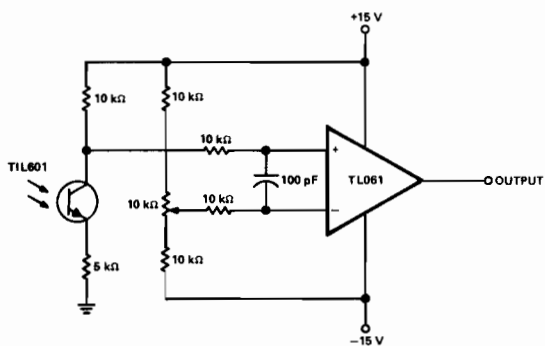


FIGURE 25—LOW-LEVEL LIGHT DETECTOR PREAMPLIFIER

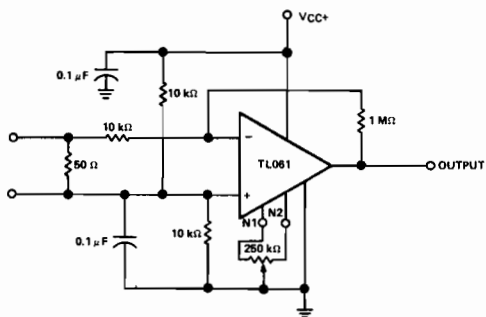


FIGURE 26—AC AMPLIFIER

# TYPES TL060, TL060A, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B, LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA

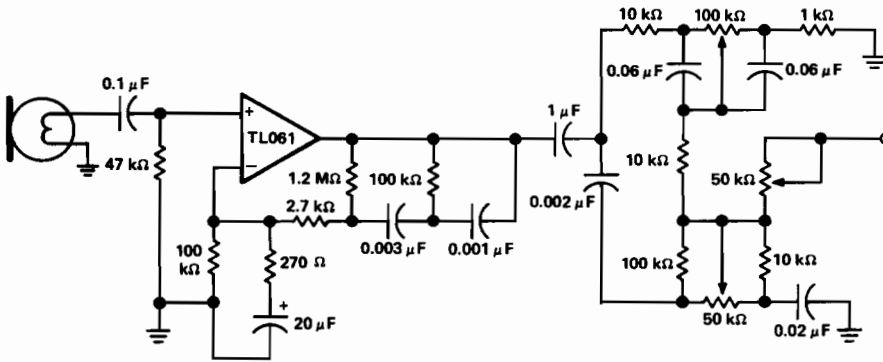


FIGURE 27—MICROPHONE PREAMPLIFIER WITH TONE CONTROL

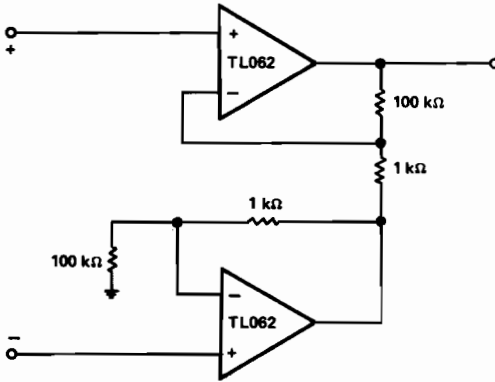


FIGURE 28—INSTRUMENTATION AMPLIFIER

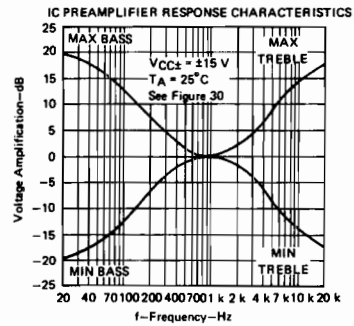


FIGURE 29

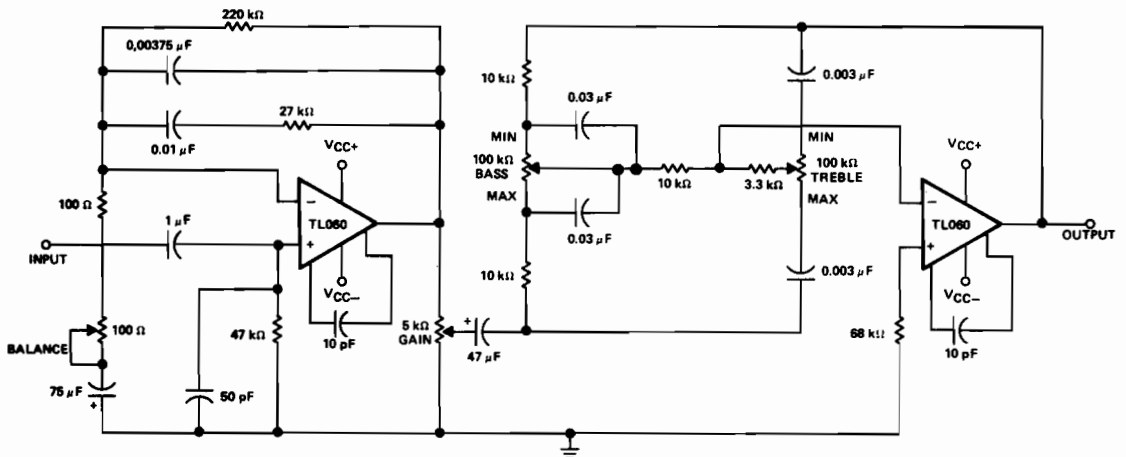
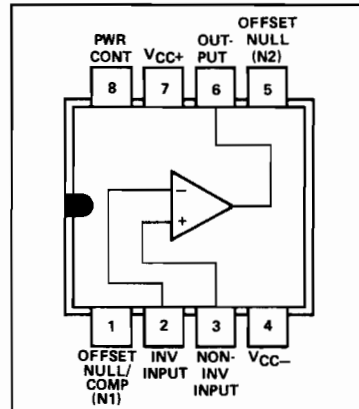


FIGURE 30—IC PREAMPLIFIER

**5 DEVICES COVER COMMERCIAL,  
INDUSTRIAL, AND MILITARY  
TEMPERATURE RANGES**

- Very Low, Adjustable ("Programmable") Power Consumption
- Adjustable Supply Current . . . 5 to 200  $\mu$ A
- Very Low Input Bias and Offset Currents
- Wide Supply Range . . .  $\pm 1.2$  V to  $\pm 18$  V
- Wide Common-Mode and Differential Voltage Ranges
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Typ Unity-Gain Bandwidth . . . 1 MHz (100 kHz at 25  $\mu$ W)
- High Slew Rate . . . 3.5 V/ $\mu$ s Typ
- Internal Frequency Compensation
- Latch-Up-Free Operation

TL066, TL066A, TL066B  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



**description**

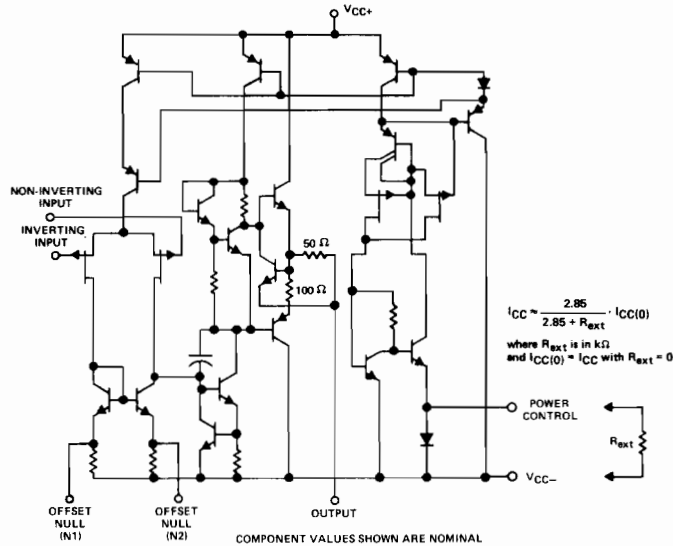
The TL066, TL066A, and TL066B are JFET-input operational amplifiers similar to the TL061 with the additional feature of being power-adjustable. They feature very low input offset and bias currents, high input impedance, wide bandwidth, and high slew rate. The power-control feature permits the amplifiers to be adjusted to require as little as 25 microwatts of power. This type of amplifier, which provides for changing several characteristics by varying one external element, is sometimes referred to as being "programmable". The JFET input stage combined with the adjustable-low-power feature results in superior bandwidth and slew rate performance compared to low-power bipolar-input devices.

The TL066I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL066C, TL066AC, and TL066BC are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL066I	TL066C TL066AC TL066BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Voltage between power-control terminal and $V_{CC-}$	$\pm 0.5$	$\pm 0.5$	V
Duration of output short circuit (see Note 4)	Unlimited	Unlimited	mW
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	680	680	
Operating free-air temperature range	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	JG Package	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	P Package	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, the TL066I, TL066C, TL066AC, and TL066BC chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	680 mW	6.6 mW/°C	47°C
P	680 mW	8.0 mW/°C	65°C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15$  V

PARAMETER	TEST CONDITIONS†		TL066I			TL066C TL066AC TL066BC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$	TL066		3	6		3	15	mV
		TL066A					3	6	
		TL066B					2	3	
	$R_S = 50 \Omega$ , $T_A = \text{full range}$	TL066			9			20	
		TL066A						7.5	
		TL066B						5	
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$R_S = 50 \Omega$	$T_A = \text{full range}$		10		10		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current‡	$T_A = 25^\circ\text{C}$	TL066		5	100		5	200	pA
		TL066A					5	100	
		TL066B					5	100	
	$T_A = \text{full range}$	TL066			10			5	nA
		TL066A						3	
		TL066B						3	
$I_{IB}$ Input bias current‡	$T_A = 25^\circ\text{C}$	TL066		30	200		30	400	pA
		TL066A					30	200	
		TL066B					30	200	
	$T_A = \text{full range}$	TL066			20			10	nA
		TL066A						7	
		TL066B						7	
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$	TL066		$\pm 12$			$\pm 10$	V	
		TL066A					$\pm 12$		
		TL066B					$\pm 12$		
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$		20	27		20	27	V	
	$T_A = \text{full range}$ , $R_L \geq 10 \text{ k}\Omega$		20			20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L > 10 \text{ k}\Omega$ , $V_O = \pm 10 \text{ V}$ , $T_A = 25^\circ\text{C}$	TL066		4	6		3	6	V/mV
		TL066A					4	6	
		TL066B					4	6	
	$R_L > 10 \text{ k}\Omega$ , $V_O = \pm 10 \text{ V}$ , $T_A = \text{full range}$	TL066		4			3		
		TL066A					4		
		TL066B					4		
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$			1		1		MHz	
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$			$10^{12}$		$10^{12}$		$\Omega$	
$r_o$ Output resistance	$T_A = 25^\circ\text{C}$ , $f = 1 \text{ kHz}$			220		220		$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	TL066	80	86		70	76	dB	
		TL066A				80	86		
		TL066B				80	86		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S \leq 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	TL066	80	95		70	95	dB	
		TL066A				80	95		
		TL066B				80	95		
$P_D$ Total power dissipation	No load, $T_A = 25^\circ\text{C}$	No signal,		6	7.5		6	7.5	mW
$I_{CC}$ Supply current	No load, $T_A = 25^\circ\text{C}$	No signal,		200	250		200	250	$\mu\text{A}$

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL066I and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL066C, TL066AC, and TL066BC. The electrical parameters are measured with the power-control terminal (pin 8) connected to  $V_{CC-}$ .

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as is possible.

# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_{ext} = 0$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $V_I = 10\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1		3.5		$\text{V}/\mu\text{s}$
$t_r$	Rise time $V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$		0,2		$\mu\text{s}$
	Overshoot factor $C_L = 100\text{ pF}$ , See Figure 1		10%		
$V_n$	Equivalent input noise voltage $R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		42		$\text{nV}/\sqrt{\text{Hz}}$

### PARAMETER MEASUREMENT INFORMATION

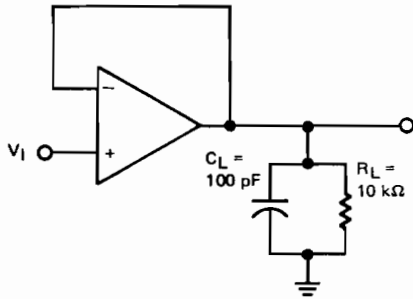


FIGURE 1—UNITY-GAIN AMPLIFIER

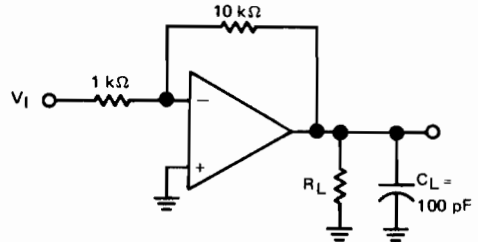


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

### INPUT OFFSET VOLTAGE NULL CIRCUIT

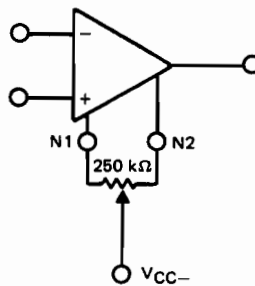


FIGURE 3



# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

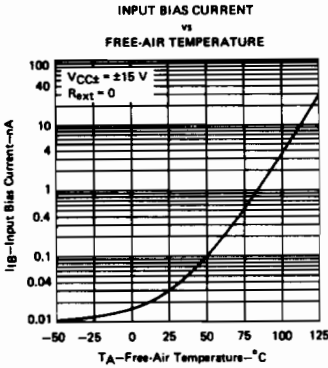


FIGURE 4

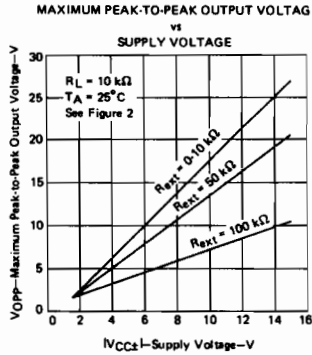


FIGURE 5

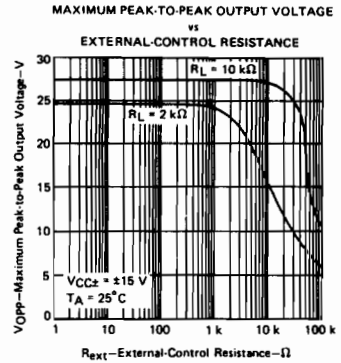


FIGURE 6

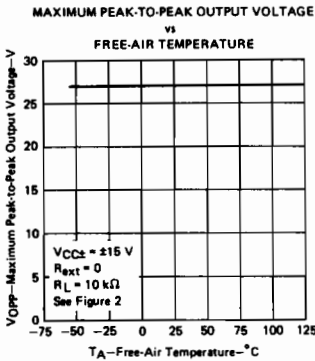


FIGURE 7

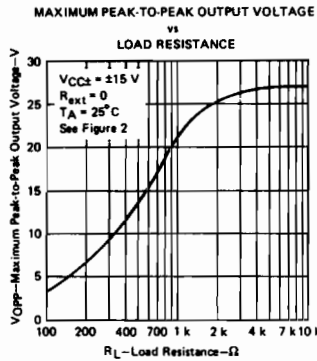


FIGURE 8

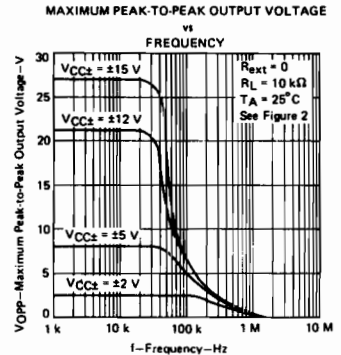


FIGURE 9

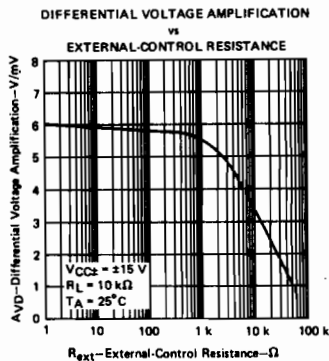


FIGURE 10

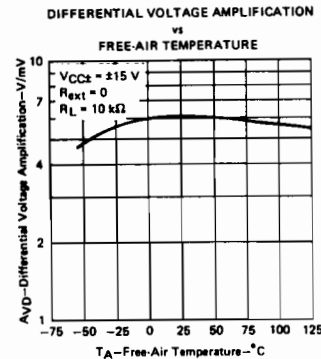


FIGURE 11

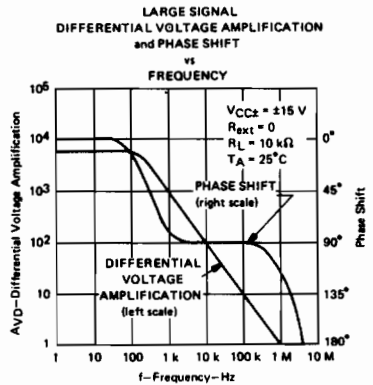


FIGURE 12

† Data at high and low temperatures are applicable only within the rated free-air temperature ranges of the various devices.

# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

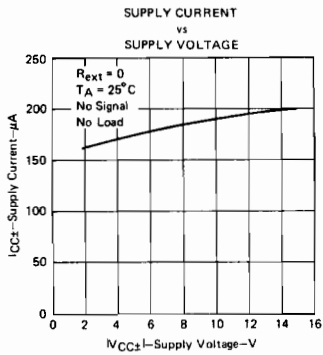


FIGURE 13

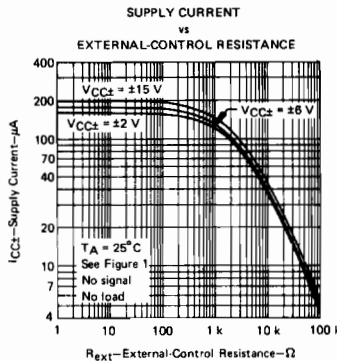


FIGURE 14

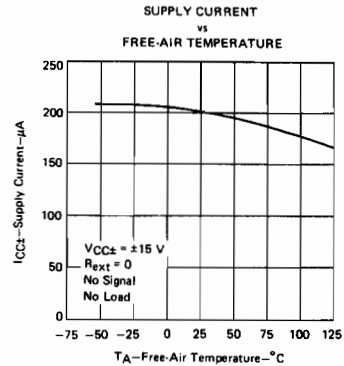


FIGURE 15

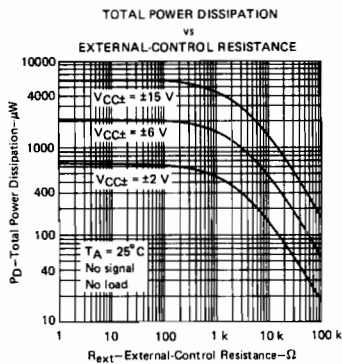


FIGURE 16

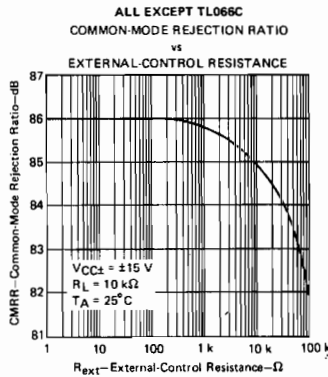


FIGURE 17

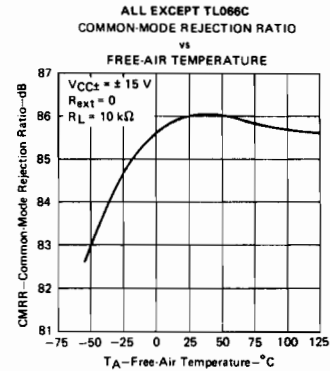


FIGURE 18

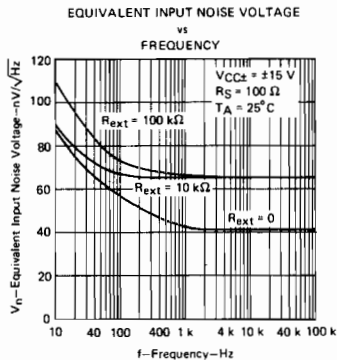


FIGURE 19

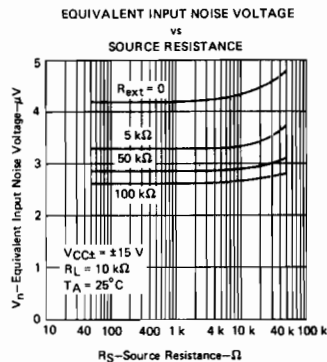


FIGURE 20

†Data at high and low temperatures are applicable only within the rated free-air temperature ranges of the various devices.

# TYPES TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

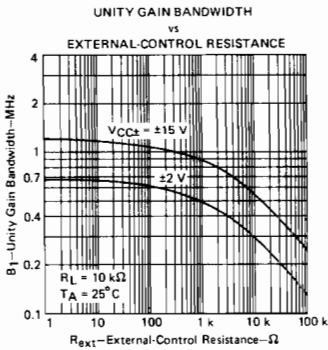


FIGURE 21

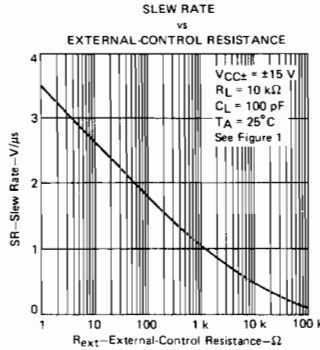


FIGURE 22

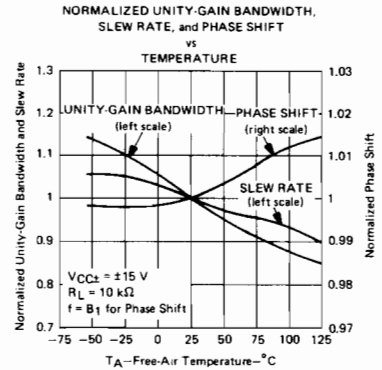


FIGURE 23

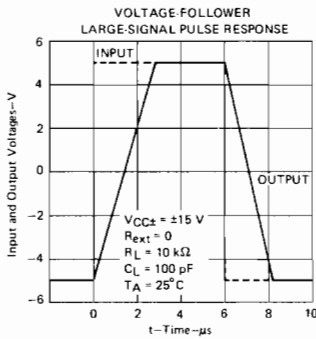


FIGURE 24

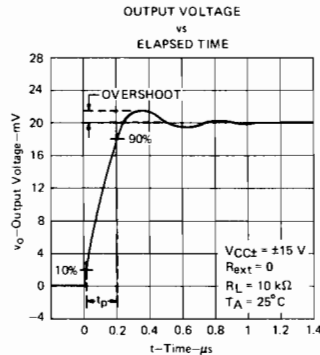


FIGURE 25

†Data at high and low temperatures are applicable only within the rated free-air temperature ranges of the various devices.

### TYPICAL APPLICATION DATA

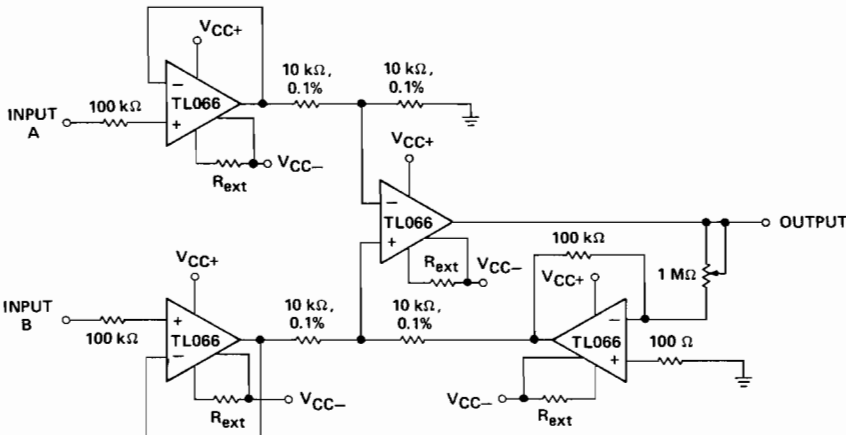


FIGURE 26—INSTRUMENTATION AMPLIFIER

# TYPES TL066I, TL066C, TL066AC, TL066BC ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA

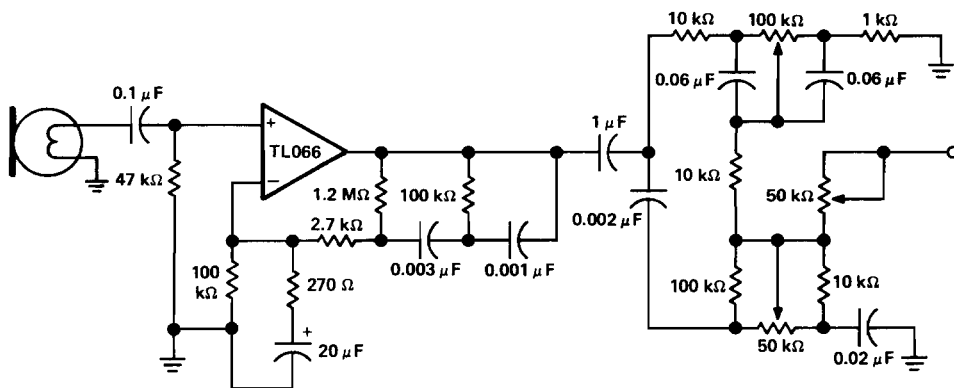


FIGURE 27—MICROPHONE PREAMPLIFIER WITH TONE CONTROL

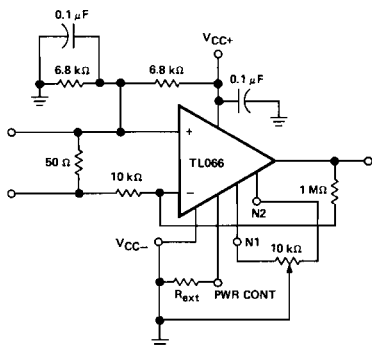


FIGURE 28—AC AMPLIFIER

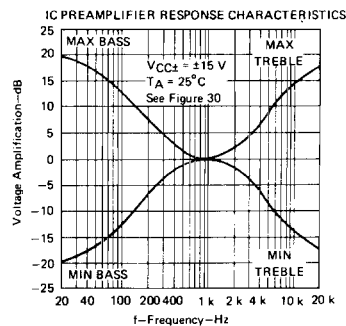


FIGURE 29

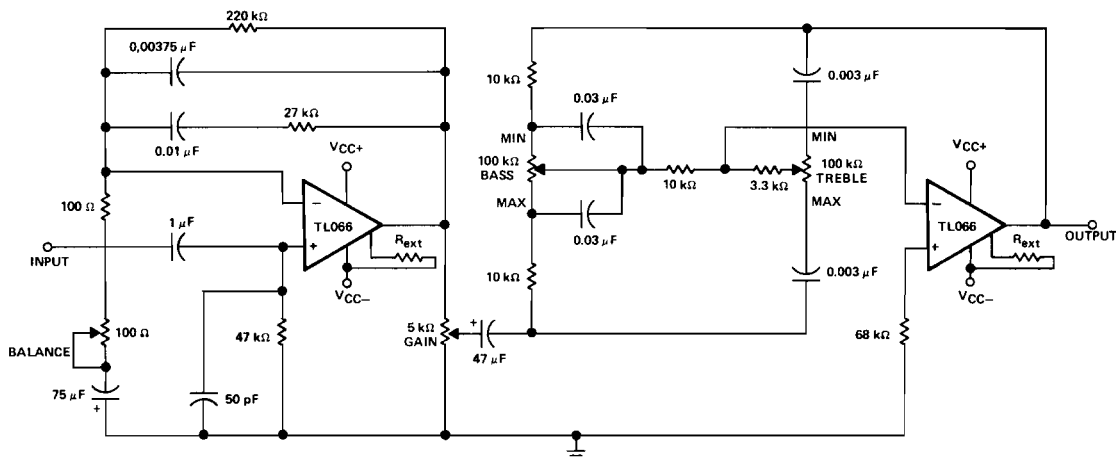


FIGURE 30—IC PREAMPLIFIER

# LINEAR INTEGRATED CIRCUITS

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12640, SEPTEMBER 1978—REVISED OCTOBER 1979

20 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES

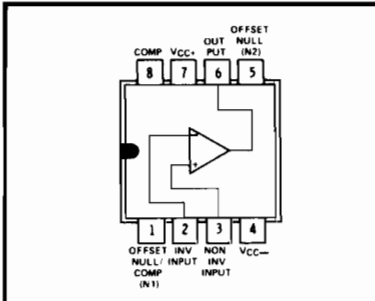
- Low Noise . . .  $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$  Typ
- Low Harmonic Distortion . . . 0.01% Typ
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Low Power Consumption
- Latch-Up-Free Operation
- High Slew Rate . . .  $13 \text{ V}/\mu\text{s}$  Typ

## description

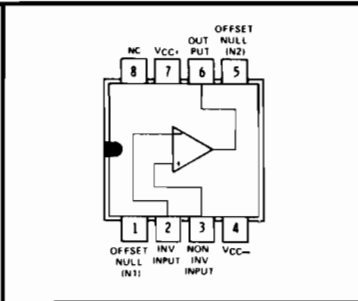
The JFET-input operational amplifiers of the TL071 series are designed as low-noise versions of the TL081 series amplifiers with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL071 series ideally suited as amplifiers for high-fidelity and audio preamplifier applications. Each amplifier features JFET-inputs (for high input impedance) coupled with bipolar output stages all integrated on a single monolithic chip.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

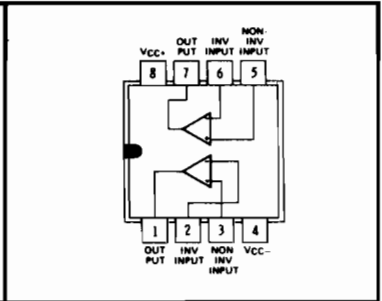
TL070, TL070A  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



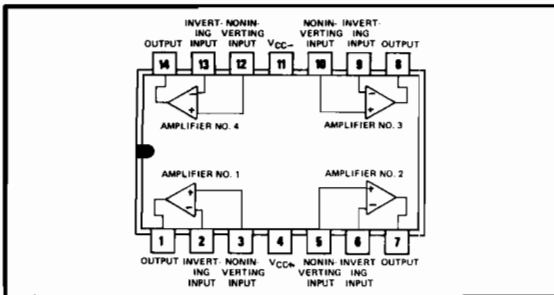
TL071, TL071A, TL071B  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



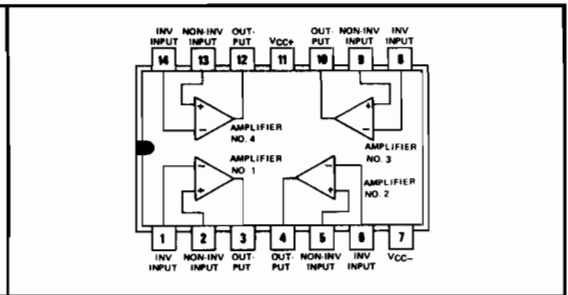
TL072, TL072A, TL072B  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



TL074, TL074A, TL074B  
J OR N DUAL-IN-LINE  
OR W PACKAGE (TOP VIEW)



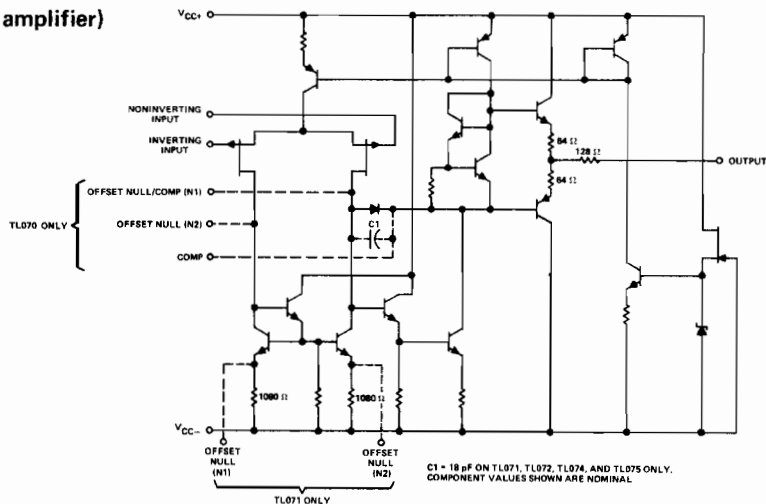
TL075  
N DUAL-IN-LINE  
PACKAGE (TOP VIEW)



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# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL07_C	TL07_I	TL07_C TL07_AC TL07_BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	±30	±30	±30	V
Input voltage (see Notes 1 and 3)	±15	±15	±15	V
Duration of output short circuit (see Note 4)	Unlimited	Unlimited	Unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	680	680	680	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	300	300	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	J, JG or W package N or P package	260	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C, free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL07\_M chips are alloy-mounted; TL07\_I, TL07\_C, TL07\_AC, and TL07\_BC chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	680 mW	11.0 mW/°C	88°C
J (Glass-Mounted Chip)	680 mW	8.2 mW/°C	67°C
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/°C	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/°C	47°C
N	680 mW	9.2 mW/°C	76°C
P	680 mW	8.0 mW/°C	65°C
W	680 mW	8.0 mW/°C	65°C

DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL070	TL071	TL072	TL074	TL075
TL07_M	JG,	JG,	JG,	J, W	*
TL07_I	JG, P	JG, P	JG, P	J, N	*
TL07_C	JG, P	JG, P	JG, P	J, N	N
TL07_AC	JG, P	JG, P	JG, P	J, N	*
TL07_BC	*	JG, P	JG, P	J, N	*

\*These combinations are not defined by this data sheet.

Also see Dissipation Derating Curves, Section 2.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS†		TL07_M		TL07_I		TL07_C TL07_AC TL07_BC		UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$	'70, '71, '72, '75‡	3	6	3	6	3	10	mV
		'74	3	9	3	6	3	10	
		'70A, '71A, '72A, '74A					3	6	
		'71B, '72B, '74B					2	3	
	$R_S = 50\ \Omega$ , $T_A = \text{full range}$	'70, '71, '72, '75‡		9		9		13	
		'74		15		9		13	
		'70A, '71A, '72A, '74A					7.5		
		'71B, '72B, '74B					5		
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , $T_A = \text{full range}$		10		10		10	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current §	$T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	5	50	5	50	5	50	pA
		'70A, '71A, '72A, '74A					5	50	
		'71B, '72B, '74B					5	50	
	$T_A = \text{full range}$	'70, '71, '72, '74, '75‡		20		10		2	nA
		'70A, '71A, '72A, '74A						2	
		'71B, '72B, '74B						2	
$I_{IB}$ Input bias current §	$T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	30	200	30	200	30	200	pA
		'70A, '71A, '72A, '74A					30	200	
		'71B, '72B, '74B					30	200	
	$T_A = \text{full range}$	'70, '71, '72, '74, '75‡		50		20		7	nA
		'70A, '71A, '72A, '74A						7	
		'71B, '72B, '74B						7	
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	$\pm 11$	$\pm 12$	$\pm 11$	$\pm 12$	$\pm 10$	$\pm 11$	V
		'70A, '71A, '72A, '74A					$\pm 11$	$\pm 12$	
		'71B, '72B, '74B					$\pm 11$	$\pm 12$	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10\ \text{k}\Omega$		24	27	24	27	24	27	V
	$T_A = \text{full range}$	$R_L \geq 10\ \text{k}\Omega$		24		24		24	
		$R_L \geq 2\ \text{k}\Omega$		20	24	20	24	20	
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\ \text{k}\Omega$ , $V_O = \pm 10\ \text{V}$ , $T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	35	200	50	200	25	200	V/mV
		'70A, '71A, '72A, '74A					50	200	
		'71B, '72B, '74B					50	200	
	$R_L \geq 2\ \text{k}\Omega$ , $V_O = \pm 10\ \text{V}$ , $T_A = \text{full range}$	'70, '71, '72, '74, '75‡		20		25		15	
		'70A, '71A, '72A, '74A						25	
		'71B, '72B, '74B						25	
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$ , $R_L = 10\ \text{k}\Omega$		3		3		3	MHz	
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$		$10^{12}$		$10^{12}$		$10^{12}$	$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 10\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	80	86	80	86	70	76	dB
		'70A, '71A, '72A, '74A					80	86	
		'71B, '72B, '74B					80	86	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S \leq 10\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	'70, '71, '72, '74, '75‡	80	86	80	86	70	76	dB
		'70A, '71A, '72A, '74A					80	86	
		'71B, '72B, '74B					80	86	
$I_{CC}$ Supply current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	No signal,	1.4	2.5	1.4	2.5	1.4	2.5	mA
$V_{o1}/V_{o2}$ Channel separation	$A_{VD} = 100$ , $T_A = 25^\circ\text{C}$		120		120		120	dB	

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL07\_M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL07\_I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL07\_C, TL07\_AC, and TL07\_BC.

‡ Types TL075I and TL075M are not defined by this data sheet.

§ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as is possible.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075

## LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL07_M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unit gain $V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$ , See Figure 1	10	13		13			$\text{V}/\mu\text{s}$
$t_r$	Rise time $V_I = 20\text{ mV}$ , $C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$ , See Figure 1		0.1		0.1			$\mu\text{s}$
	Overshoot factor		10		10			%
$V_n$	Equivalent input noise voltage $R_S = 100\ \Omega$		18		18			$\text{nV}/\sqrt{\text{Hz}}$
			4		4			$\mu\text{V}$
$I_n$	Equivalent input noise current $R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		0.01		0.01			$\text{pA}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion $V_{O(\text{rms})} = 10\text{ V}$ , $R_L \geq 2\text{ k}\Omega$ , $R_S \leq 1\text{ k}\Omega$ , $f = 1\text{ kHz}$		0.01		0.01			%

### PARAMETER MEASUREMENT INFORMATION

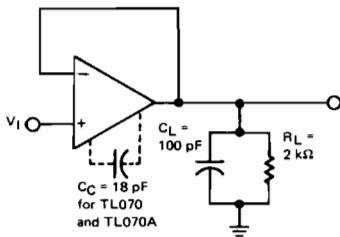


FIGURE 1—UNITY-GAIN AMPLIFIER

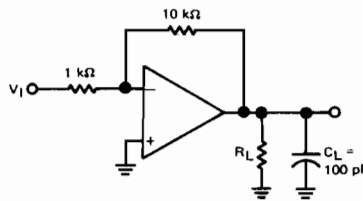


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

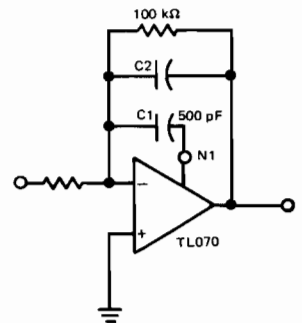


FIGURE 3—FEED-FORWARD COMPENSATION

### INPUT OFFSET VOLTAGE NULL CIRCUITS

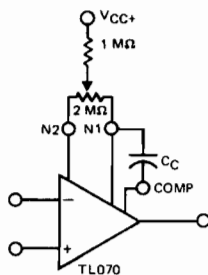


FIGURE 4

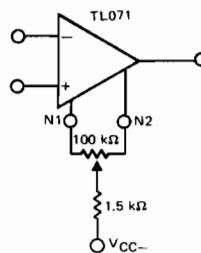


FIGURE 5



# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

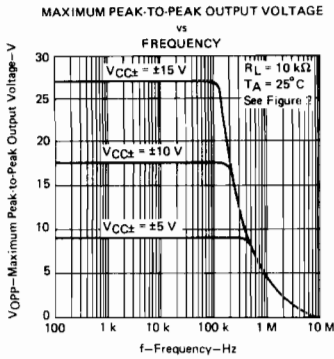


FIGURE 6

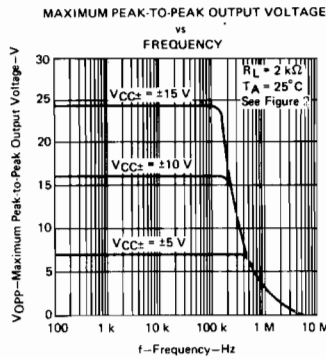


FIGURE 7

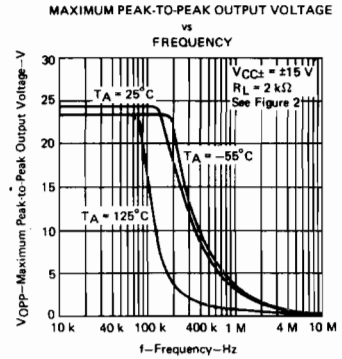


FIGURE 8

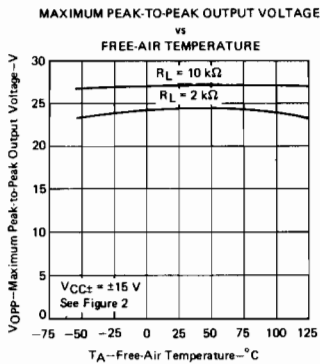


FIGURE 9

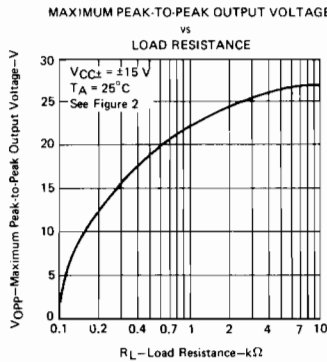


FIGURE 10

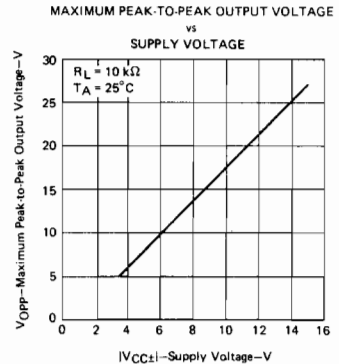


FIGURE 11

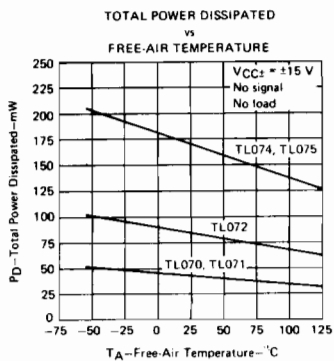


FIGURE 12

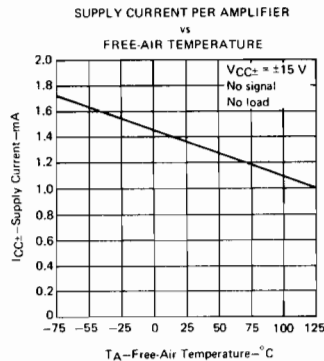


FIGURE 13

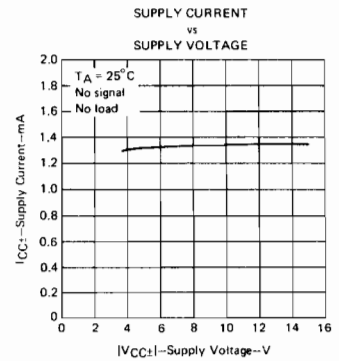


FIGURE 14

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 18-pF compensation capacitor is used with TL070 and TL070A.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075

## LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

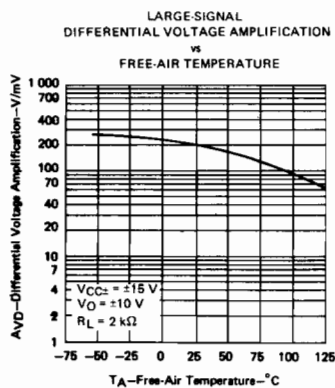


FIGURE 15

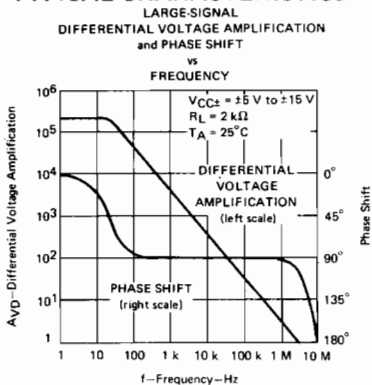


FIGURE 16

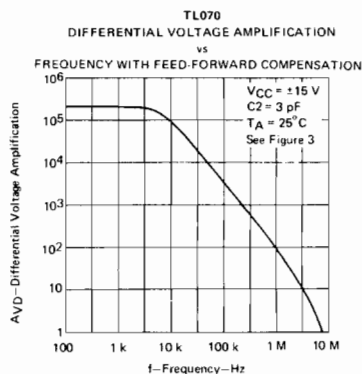


FIGURE 17

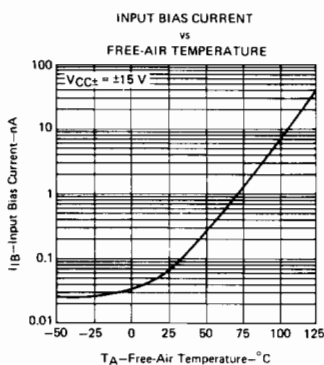


FIGURE 18

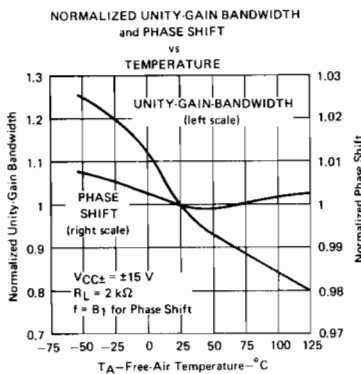


FIGURE 19

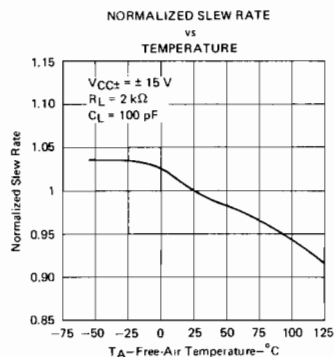


FIGURE 20

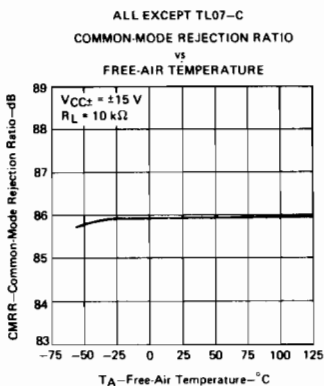


FIGURE 21

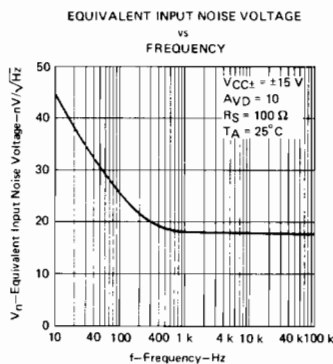


FIGURE 22

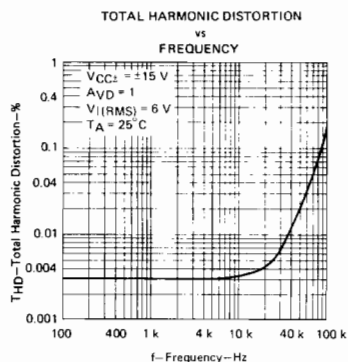


FIGURE 23

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 18-pF compensation capacitor is used with TL070 and TL070A.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

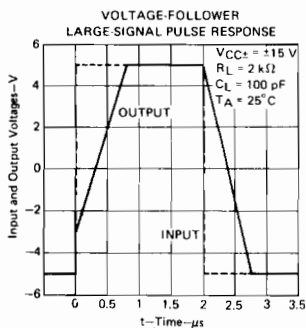


FIGURE 24

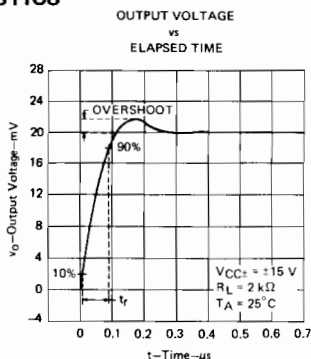


FIGURE 25

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 18-pF compensation capacitor is used with TL070 and TL070A.

## TYPICAL APPLICATION DATA

### 0.5-Hz SQUARE-WAVE OSCILLATOR

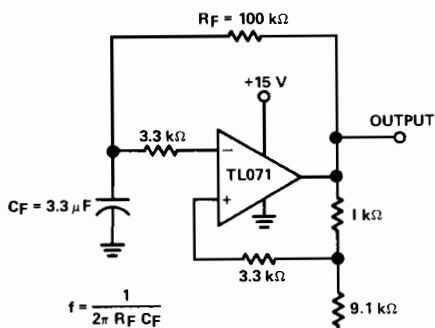


FIGURE 26—0.5-Hz SQUARE-WAVE OSCILLATOR

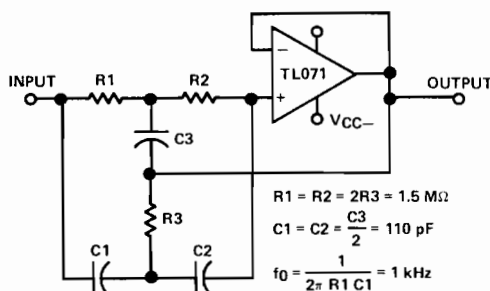


FIGURE 27—HIGH-Q NOTCH FILTER

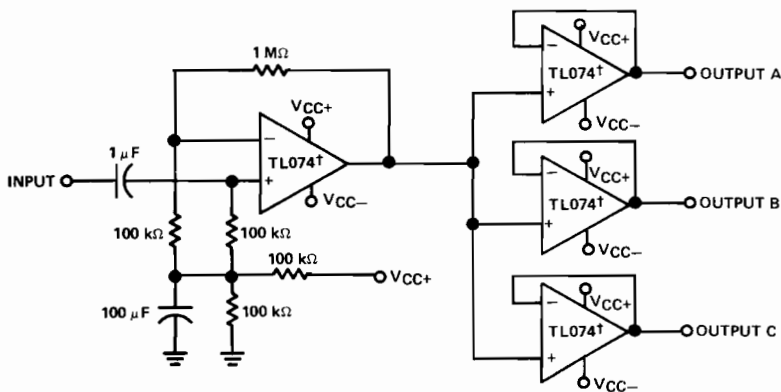
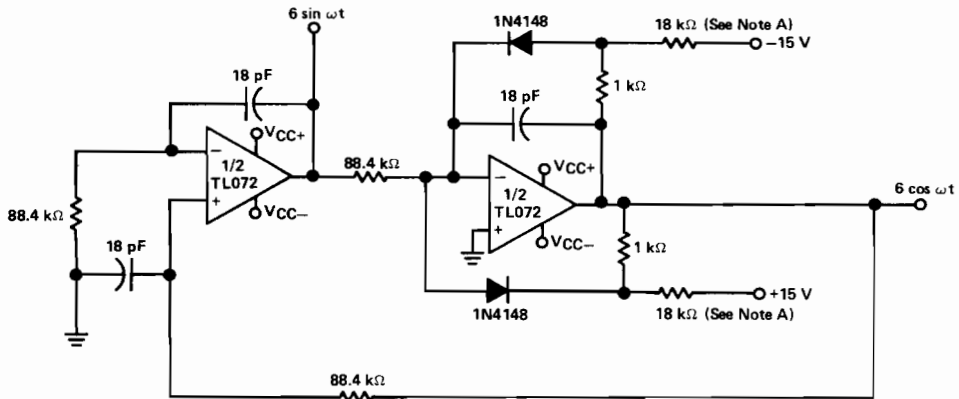


FIGURE 28—AUDIO DISTRIBUTION AMPLIFIER

† or TL075

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA



Note A: These resistor values may be adjusted for a symmetrical output.

FIGURE 29—100-KHz QUADRATURE OSCILLATOR

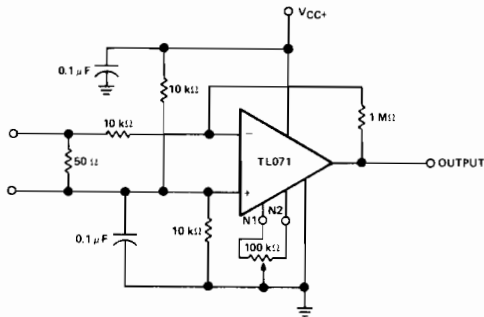


FIGURE 30—AC AMPLIFIER

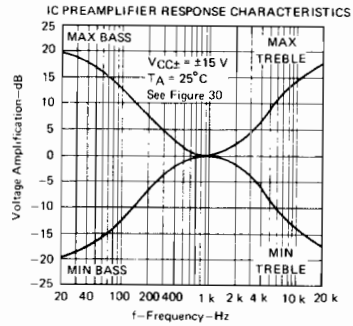


FIGURE 31

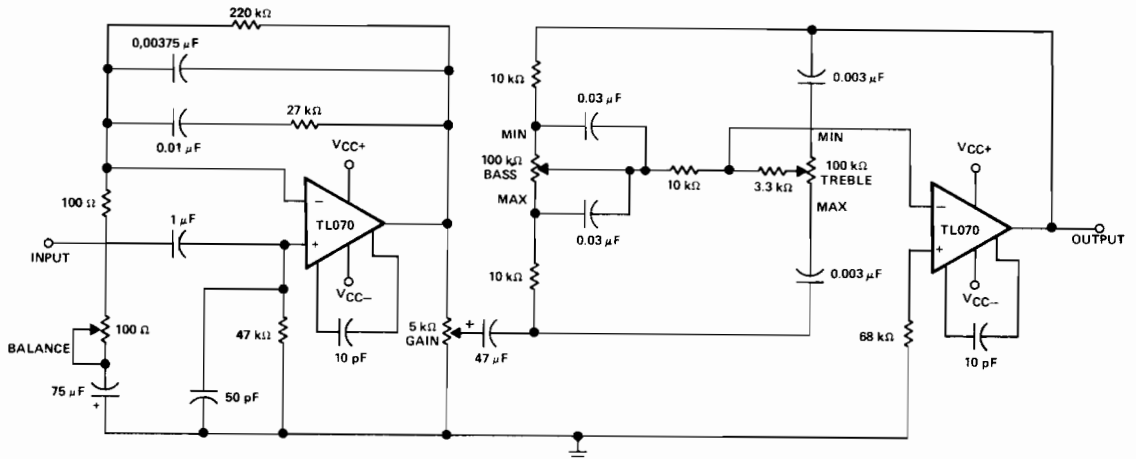


FIGURE 32—IC PREAMPLIFIER

# LINEAR INTEGRATED CIRCUITS

# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12484, FEBRUARY 1977—REVISED OCTOBER 1979

24 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES

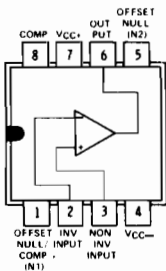
- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL080, TL080A)
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/ $\mu$ s Typ

## description

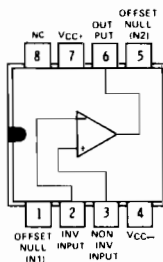
The TL081 JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient. Offset adjustment and external compensation options are available within the TL081 Family.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

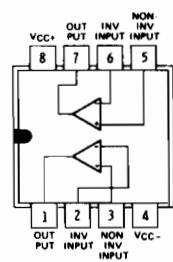
**TL080, TL080A**  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



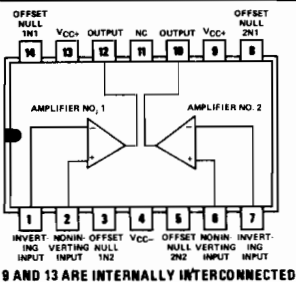
**TL081, TL081A, TL081B**  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



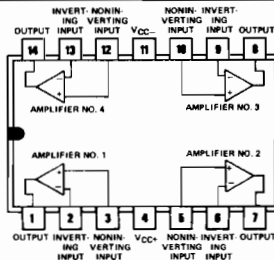
**TL082, TL082A, TL082B**  
JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



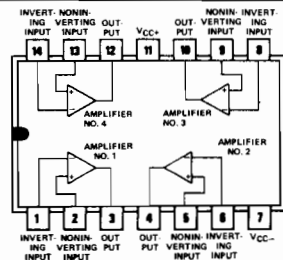
**TL083, TL083A**  
J OR N DUAL-IN-LINE  
PACKAGE (TOP VIEW)



**TL084, TL084A, TL084B**  
J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)



**TL085**  
N DUAL-IN-LINE  
PACKAGE (TOP VIEW)

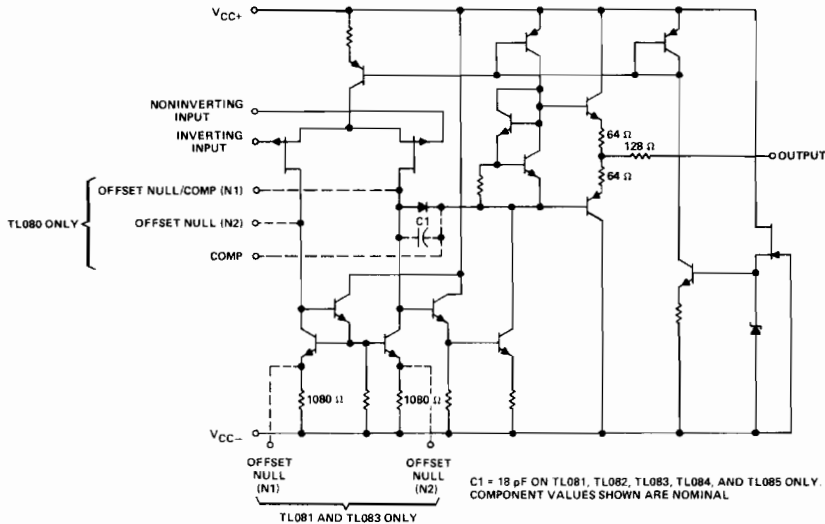


NC—No internal connection

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# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL08_M	TL08_I	TL08_C TL08_AC TL08_BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	±30	±30	±30	V
Input voltage (see Notes 1 and 3)	±15	±15	±15	V
Duration of output short circuit (see Note 4)	Unlimited	Unlimited	Unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (See Note 5)	680	680	680	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J, JG, or W package		300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL08\_M chips are alloy-mounted; TL08\_I, TL08\_C, TL08\_AC, and TL08\_BC chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	680 mW	11.0 mW/°C	88°C
J (Glass-Mounted Chip)	680 mW	8.2 mW/°C	67°C
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/°C	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/°C	47°C
N	680 mW	9.2 mW/°C	76°C
P	680 mW	8.0 mW/°C	65°C
W	680 mW	8.0 mW/°C	65°C

DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL080	TL081	TL082	TL083	TL084	TL085
TL08_M	JG	JG	JG	J	J, W	*
TL08_I	JG, P	JG, P	JG, P	J, N	J, N	*
TL08_C	JG, P	JG, P	JG, P	J, N	J, N	N
TL08_AC	JG, P	JG, P	JG, P	J, N	J, N	*
TL08_BC	*	JG, P	JG, P	*	J, N	*

Also see Dissipation Derating Curves, Section 2.

\*These combinations are not defined by this data sheet.

# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS†		TL08_M			TL08_I			TL08_C TL08_AC TL08_BC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$	'80,'81,'82,'83,'85‡	3	6		3	6		5	15	mV	
		TL084	3	9		3	6		5	15		
		TL08_A							3	6		
	$R_S = 50\ \Omega$ , $T_A = \text{full range}$	'81B,'82B,'84B							2	3		
		'80,'81,'82,'83,'85‡		9			9			20		
		TL084		15			9			20		
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , $T_A = \text{full range}$	TL08_A							7.5			
		'81B,'82B,'84B							5			
			10		10		10					
$I_{IO}$ Input offset current §	$T_A = 25^\circ\text{C}$	TL08_‡	5	100		5	100		5	200	pA	
		TL08_A							5	100		
		'81B,'82B,'84B							5	100		
	$T_A = \text{full range}$	TL08_‡		20			10			5	nA	
		TL08_A								3		
		'81B,'82B,'84B								3		
$I_{IB}$ Input bias current §	$T_A = 25^\circ\text{C}$	TL08_‡	30	200		30	200		30	400	pA	
		TL08_A							30	200		
		'81B,'82B,'84B							30	200		
	$T_A = \text{full range}$	TL08_‡		50			20			10	nA	
		TL08_A								7		
		'81B,'82B,'84B								7		
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$	TL08_‡	±11	±12		±11	±12		±10	±11	V	
		TL08_A							±11	±12		
		'81B,'82B,'84B							±11	±12		
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$	$R_L = 10\ \text{k}\Omega$	24	27		24	27		24	27	V	
		$R_L > 10\ \text{k}\Omega$		24			24			24		
		$R_L > 2\ \text{k}\Omega$	20	24		20	24		20	24		
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\ \text{k}\Omega$ , $V_O = \pm 10\ \text{V}$ , $T_A = 25^\circ\text{C}$	TL08_‡	25	200		50	200		25	200	V/mV	
		TL08_A							50	200		
		'81B,'82B,'84B							50	200		
	$R_L \geq 2\ \text{k}\Omega$ , $V_O = \pm 10\ \text{V}$ , $T_A = \text{full range}$	TL08_‡	15			25			15			
		TL08_A							25			
		'81B,'82B,'84B							25			
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		3			3			3	MHz		
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$		$10^{12}$			$10^{12}$			$10^{12}$	$\Omega$		
CMRR Common-mode rejection ratio	$R_S \geq 10\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	TL08_‡	80	86		80	86		70	76	dB	
		TL08_A							80	86		
		'81B,'82B,'84B							80	86		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S \geq 10\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	TL08_‡	80	86		80	86		70	76	dB	
		TL08_A							80	86		
		'81B,'82B,'84B							80	86		
$I_{CC}$ Supply current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	No signal,	1.4	2.8		1.4	2.8		1.4	2.8	mA	
$V_{O1}/V_{O2}$ Channel separation	$A_{VD} = 100$ , $T_A = 25^\circ\text{C}$		120		120		120		120	dB		

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL08\_M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL08\_I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL08\_C, TL08\_AC, and TL08\_BC.

‡ Types TL085I and TL085M are not defined by this data sheet.

§ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as is possible.

# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL08_M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$ , See Figure 1	8	13			13		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ ,		0.1			0.1		$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		10%			10%		
$V_n$ Equivalent input noise voltage	$R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		25			25		$\text{nV}/\sqrt{\text{Hz}}$

## PARAMETER MEASUREMENT INFORMATION

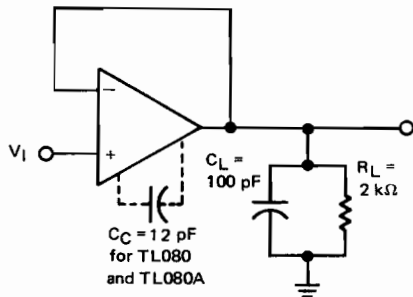


FIGURE 1—UNITY-GAIN AMPLIFIER

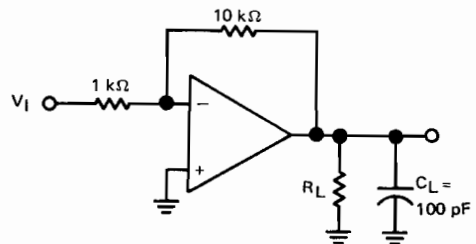


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

## INPUT OFFSET VOLTAGE NULL CIRCUITS

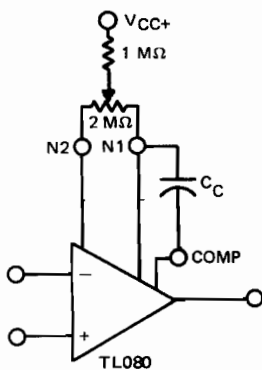


FIGURE 3

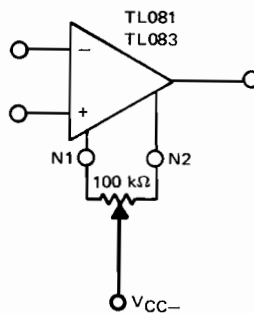
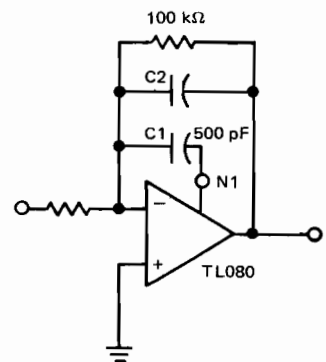


FIGURE 4



FEED-FORWARD COMPENSATION

FIGURE 5



# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B

## JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

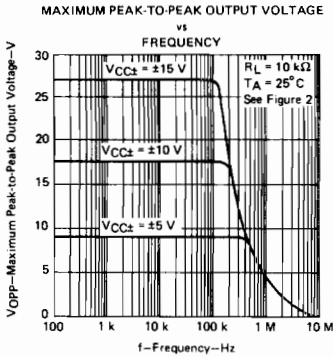


FIGURE 6

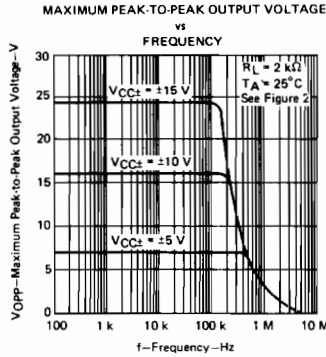


FIGURE 7

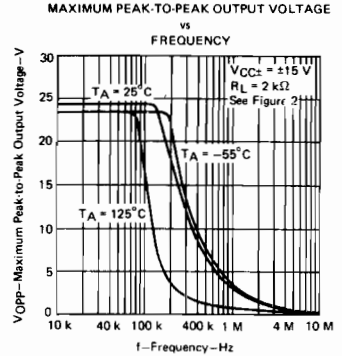


FIGURE 8

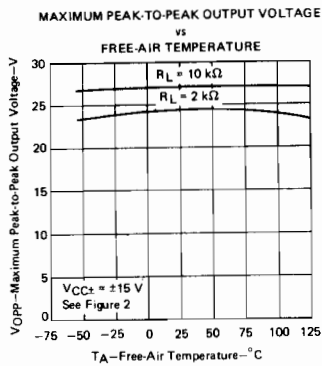


FIGURE 9

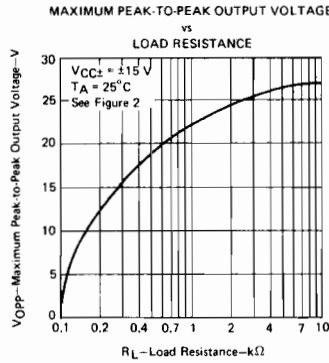


FIGURE 10

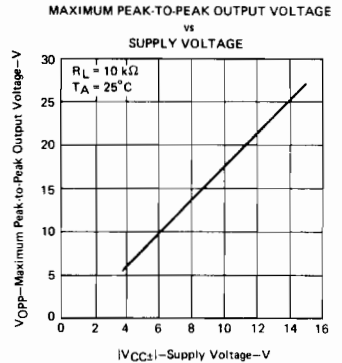


FIGURE 11

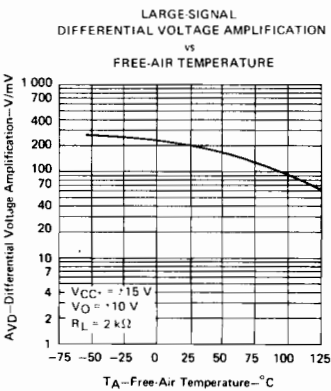


FIGURE 12

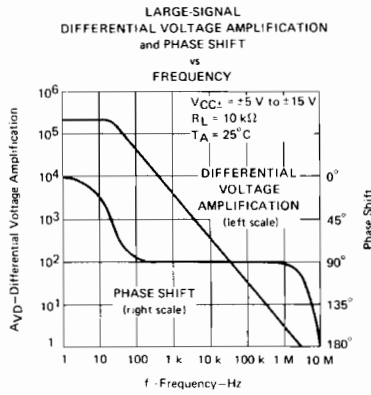


FIGURE 13

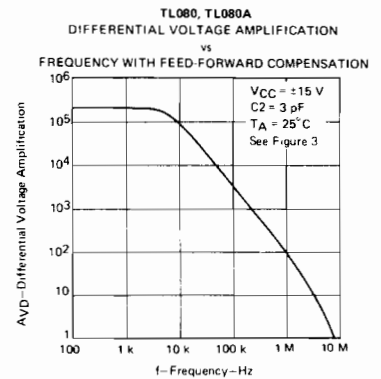


FIGURE 14

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 12-pF compensation capacitor is used with TL080 and TL080A.

# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B

## JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

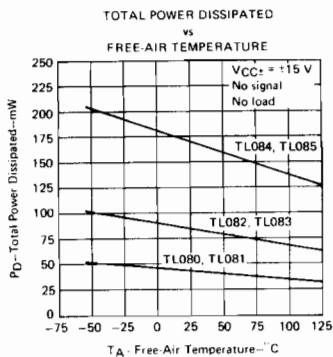


FIGURE 15

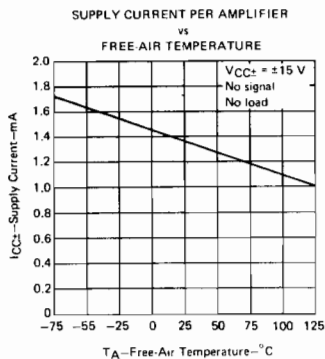


FIGURE 16

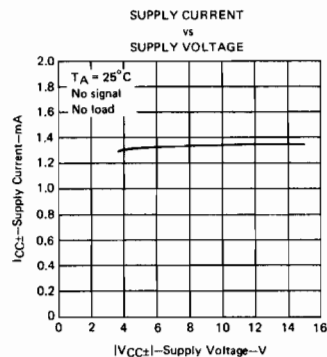


FIGURE 17

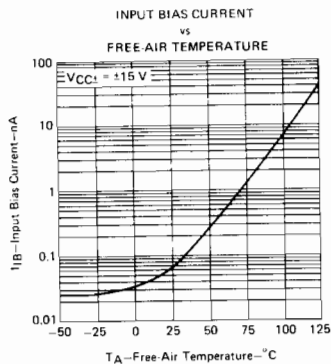


FIGURE 18

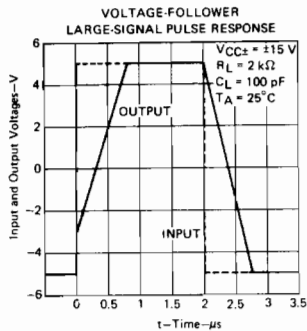


FIGURE 19

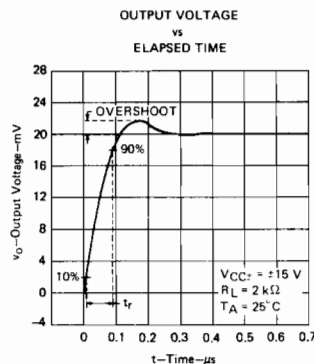


FIGURE 20

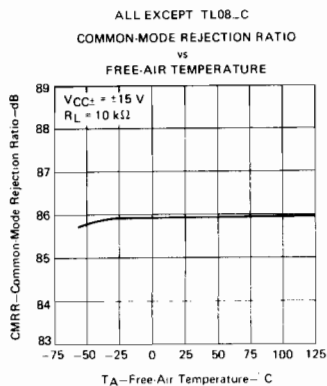


FIGURE 21

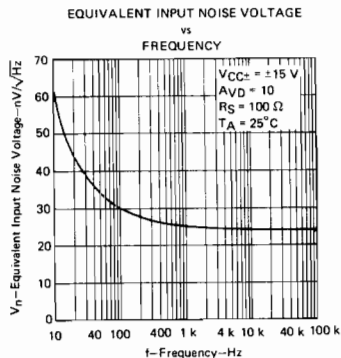


FIGURE 22

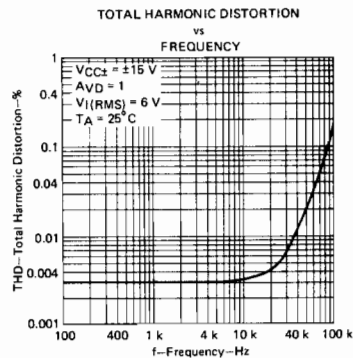


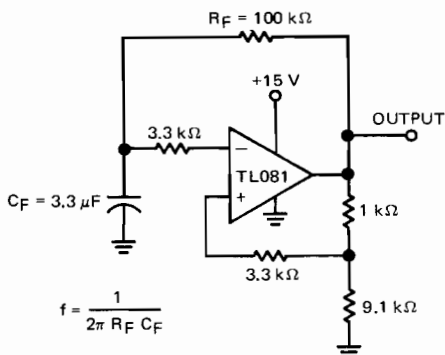
FIGURE 23

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 12-pF compensation capacitor is used with TL080 and TL080A.

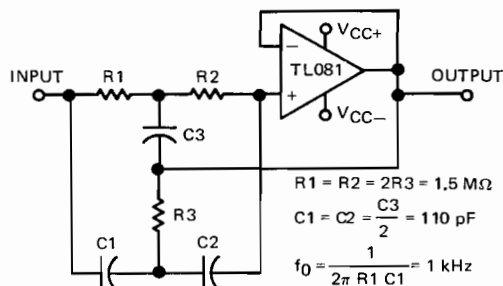
# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA

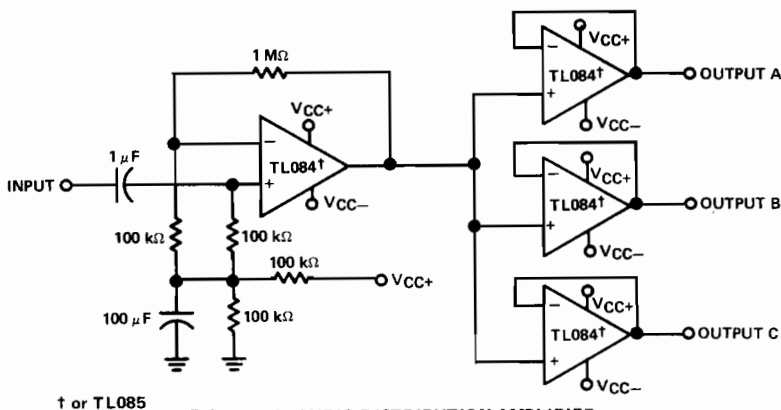
**0.5-Hz SQUARE-WAVE OSCILLATOR**



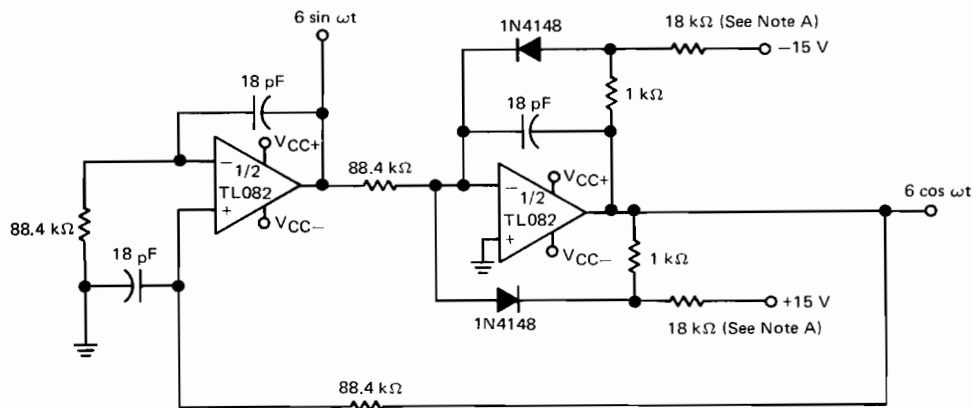
**FIGURE 24—0.5-Hz SQUARE-WAVE OSCILLATOR**



**FIGURE 25—HIGH-Q NOTCH FILTER**



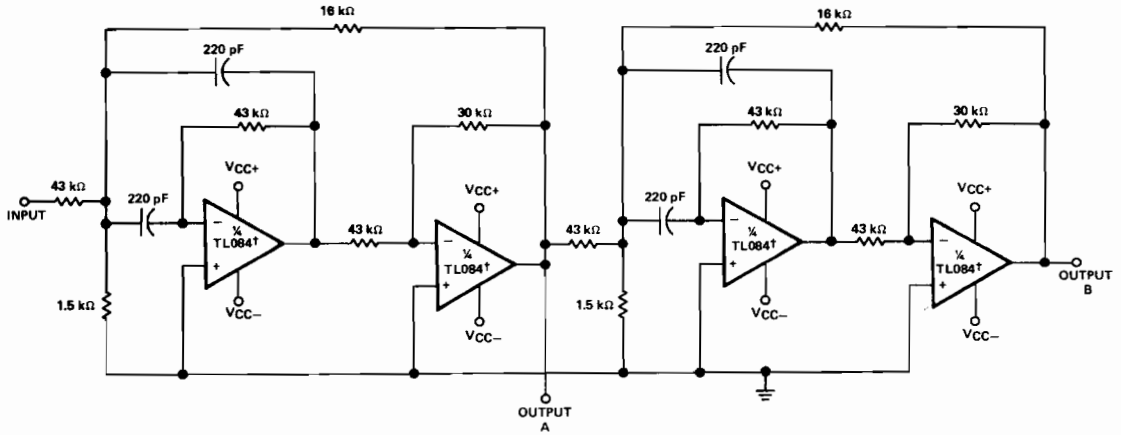
**FIGURE 26—AUDIO DISTRIBUTION AMPLIFIER**



**FIGURE 27—100-kHz QUADRATURE OSCILLATOR**

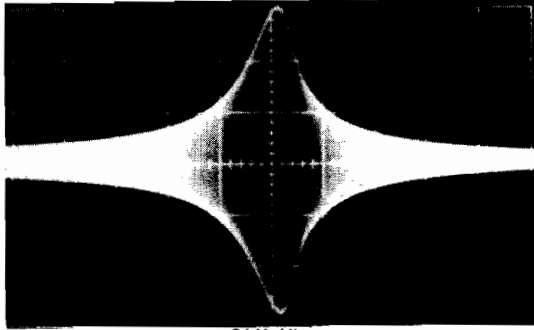
# TYPES TL080 THRU TL085, TL080A THRU TL084A, TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA



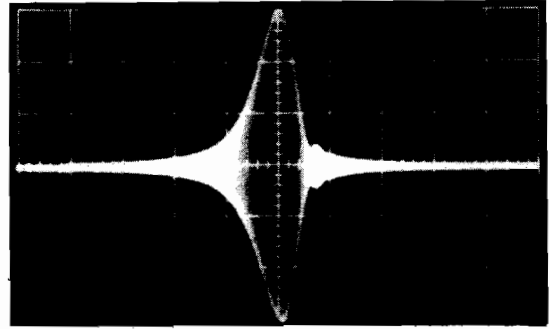
† or TL085

OUTPUT A



2 kHz/div  
SECOND-ORDER BANDPASS FILTER  
 $f_0 = 100 \text{ kHz}$ ,  $Q = 30$ , GAIN = 4

OUTPUT B



2 kHz/div  
CASCADED BANDPASS FILTER  
 $f_0 = 100 \text{ kHz}$ ,  $Q = 69$ , GAIN = 16

FIGURE 28—POSITIVE-FEEDBACK BANDPASS FILTER

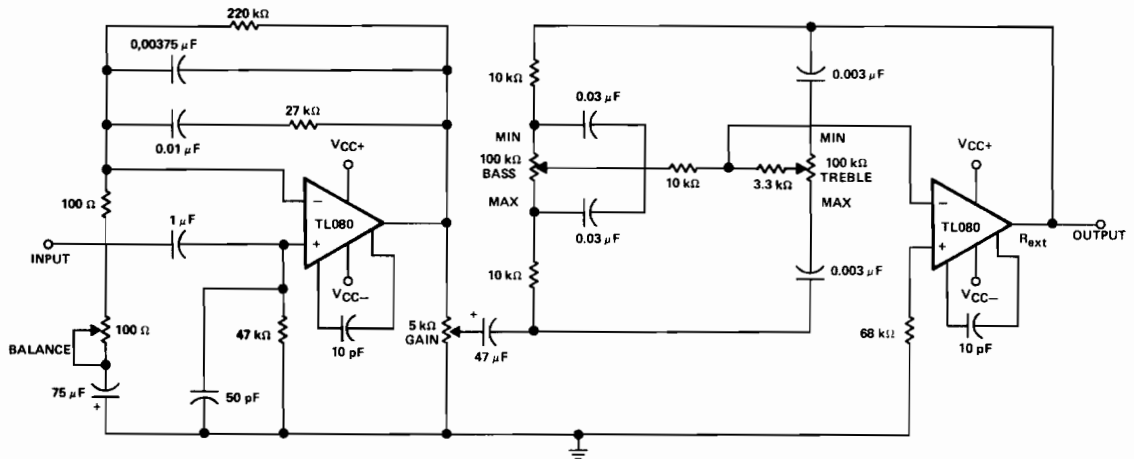


FIGURE 29—IC PREAMPLIFIER

# LINEAR INTEGRATED CIRCUITS

# TYPES TL087, TL088, TL287, TL288 JFET-INPUT OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12642, MARCH 1979 — REVISED OCTOBER 1979

- Low Input Offset Voltage . . . 0.5 mV Max
- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/ $\mu$ s Typ

## description

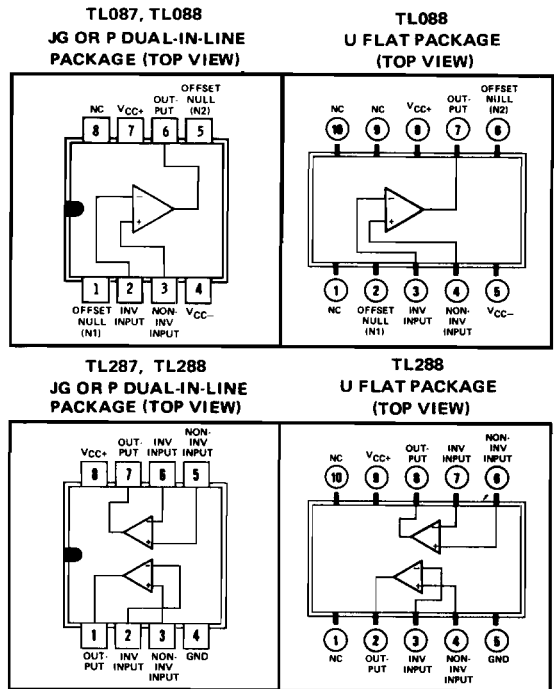
These JFET-input operational amplifiers incorporate well-matched high-voltage JFET and bipolar transistors in a monolithic integrated circuit. They feature low input offset voltage, high slew rate, low input bias and offset current, and low temperature coefficient of input offset voltage. Offset-voltage adjustment is provided for the TL087 and TL088.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL088M TL288M	TL087I TL088I TL287I TL288I	TL087C TL088C TL287C TL288C	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short circuit (see Note 4)	Unlimited	Unlimited	Unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	JG or P package	680	680	mW
	U package	675		
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	$^{\circ}\text{C}$
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	JG or U package	300	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	P package		260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the JG package, TL088M and TL288M chips are alloy-mounted; TL087I, TL088I, TL287I, TL288I, TL087C, TL088C, TL287C and TL288C chips are glass-mounted.



NC—No internal connection

# TYPES TL087, TL088, TL287, TL288

## JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15$  V

PARAMETER	TEST CONDITIONS†		TL088M TL288M			TL087I TL088I TL287I TL288I			TL087C TL088C TL287C TL288C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$	TL087, TL287				0.1	0.5	0.1	0.5		mV	
		TL088, TL288	1	3	1	3	1	3				
	$R_S = 50 \Omega$ , $T_A = \text{full range}$	TL087, TL287				2			1.5			
		TL088, TL288		6		6			5			
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$R_S = 50 \Omega$ , $T_A = \text{full range}$		10		10		10			$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current §	$T_A = 25^\circ\text{C}$		5	100	5	100	5	100	5	100	pA	
	$T_A = \text{full range}$			25		3		2		2	nA	
$I_{IB}$ Input bias current §	$T_A = 25^\circ\text{C}$		60	400	60	400	60	400	60	400	pA	
	$T_A = \text{full range}$			100		20		7		7	nA	
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$		$V_{CC-+4}$ to $V_{CC+}-4$		$V_{CC-+3.5}$ to $V_{CC+}$		$V_{CC-+5}$ to $V_{CC+}$				V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$		24	27	24	27	24	27	24	27	V	
	$T_A = \text{full range}$	$R_L > 10 \text{ k}\Omega$	24		24		24		24			
		$R_L > 2 \text{ k}\Omega$	20		20		20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L > 2 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$V_O = \pm 10 \text{ V}$ ,	50	200	50	200	25	200			V/mV	
		$V_O = \pm 10 \text{ V}$ , $T_A = \text{full range}$	25		25		15					
	$R_L > 2 \text{ k}\Omega$ , $T_A = \text{full range}$											
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		3		3		3			MHz		
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$		$10^{12}$		$10^{12}$		$10^{12}$			$\Omega$		
CMRR Common-mode rejection ratio	$R_S < 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$		80	95	80	95	70	95			dB	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S < 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$		80	95	80	95	70	95			dB	
$I_{CC}$ Supply Current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	No signal,	1.4	2.8	1.4	2.8	1.4	2.8	1.4	2.8	mA	

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL-88M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL-B-I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL-B-C.

§ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

### operating characteristics $V_{CC+} = \pm 15$ V, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL088M, TL288M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_I = 10 \text{ V}$ , $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $A_{VD} = 1$	8	13			13		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$V_I = 20 \text{ mV}$ , $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $A_{VD} = 1$		0.1			0.1		$\mu\text{s}$
			10%			10%		
$V_n$ Equivalent input noise voltage	$R_S = 100 \Omega$ , $f = 1 \text{ kHz}$		18			18		$\text{nV}/\sqrt{\text{Hz}}$

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	8.4 $\text{mW}/^\circ\text{C}$	$69^\circ\text{C}$
JG (Glass-Mounted Chip)	680 mW	6.6 $\text{mW}/^\circ\text{C}$	$47^\circ\text{C}$
P	680 mW	8.0 $\text{mW}/^\circ\text{C}$	$65^\circ\text{C}$
U	675 mW	5.4 $\text{mW}/^\circ\text{C}$	$25^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPES TL087, TL088, TL287, TL288 JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

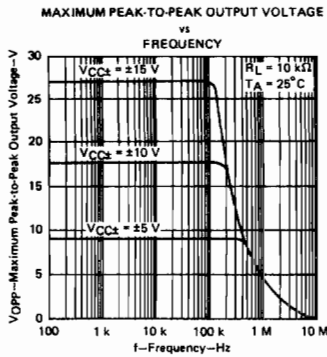


FIGURE 1

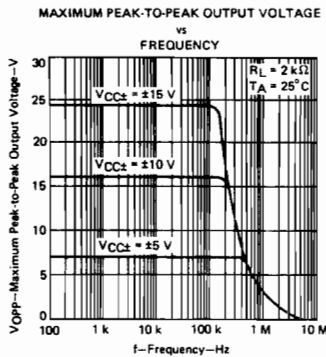


FIGURE 2

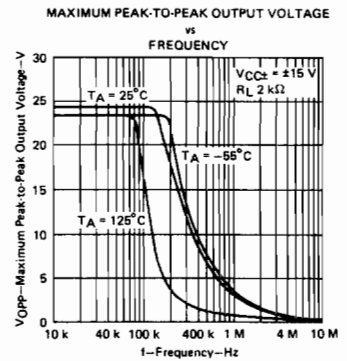


FIGURE 3

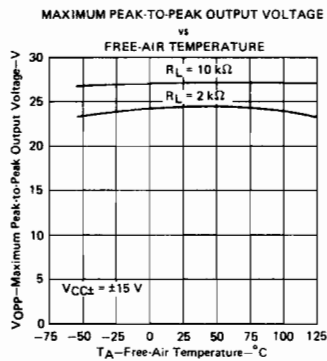


FIGURE 4

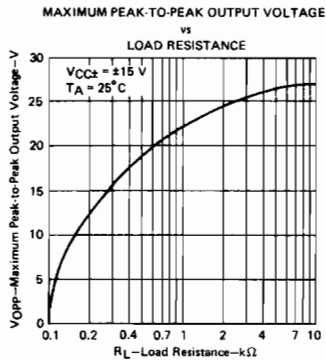


FIGURE 5

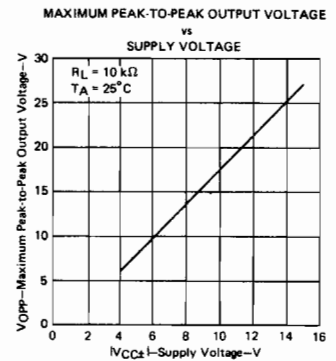


FIGURE 6

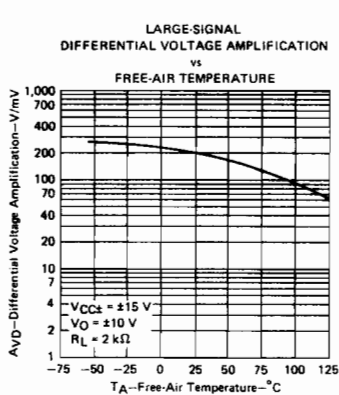


FIGURE 7

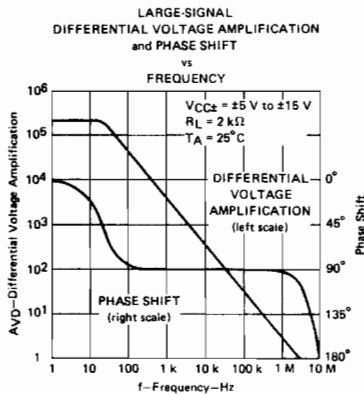


FIGURE 8

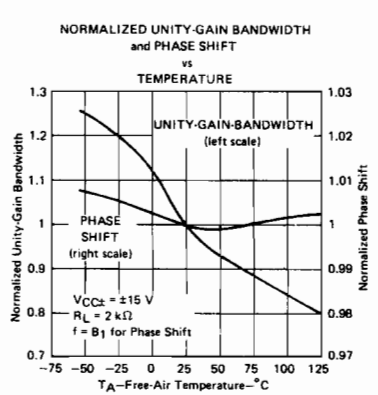


FIGURE 9

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TYPES TL087, TL088, TL287, TL288

## JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

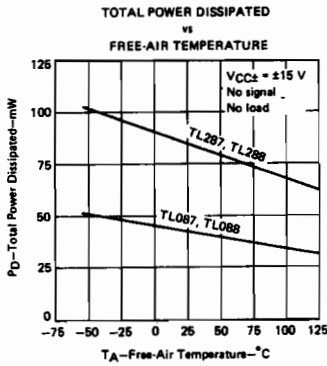


FIGURE 10

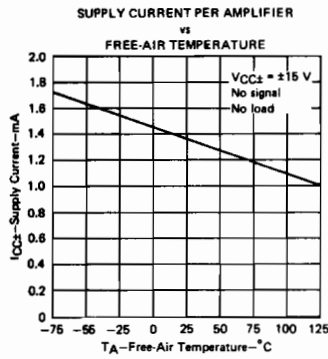


FIGURE 11

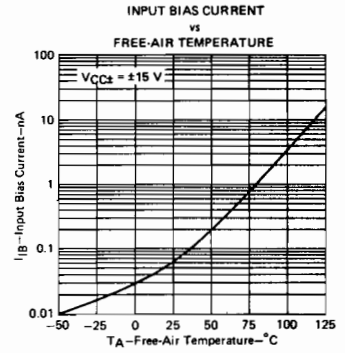


FIGURE 12

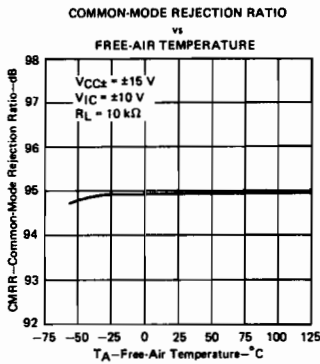


FIGURE 13

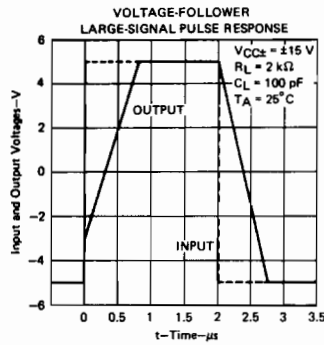


FIGURE 14

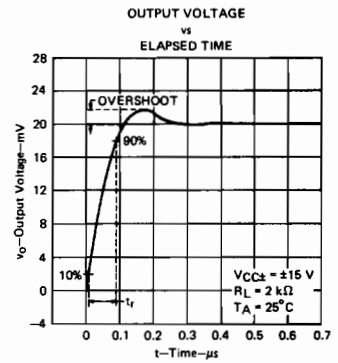


FIGURE 15

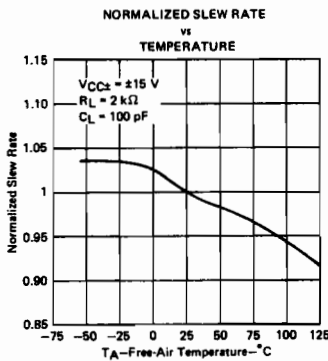


FIGURE 16

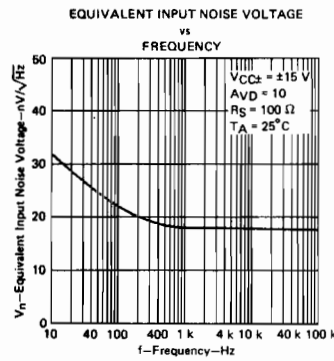


FIGURE 17

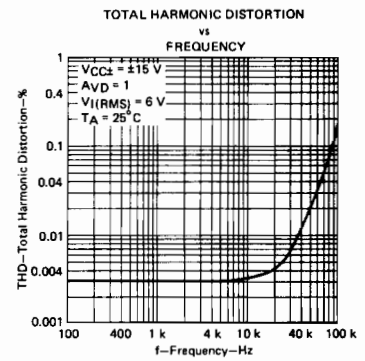


FIGURE 18

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



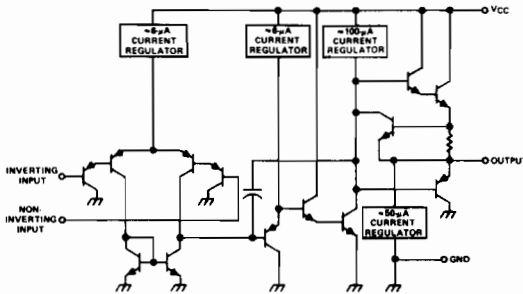
# LINEAR INTEGRATED CIRCUITS

# TYPES TL321M, TL321I, TL321C OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12515, APRIL 1977 — REVISED OCTOBER 1979

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 30 V  
or Dual Supplies
- Low Supply Current Drain  
Independent of Supply Voltage  
. . . 0.8 mA Typ
- Common-Mode Input Voltage  
Range Includes Ground Allowing  
Direct Sensing near Ground
- Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 3 nA Typ (TL321M)  
Input Bias Current . . . 45 nA Typ
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage . . .  $\pm 32$  V
- Open-Loop Differential Voltage  
Amplification . . . 100 V/mV Typ
- Internal Frequency Compensation

schematic

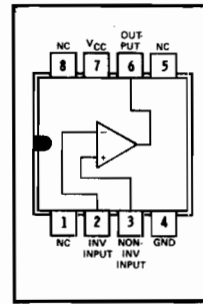


description

The TL321 is a high-gain, frequency-compensated operational amplifier that was designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts and Pin 7 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the TL321 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

JG OR P  
DUAL-IN-LINE  
PACKAGE (TOP VIEW)



NC—No internal connection

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	32 V
Differential input voltage (see Note 2)	$\pm 32$ V
Input voltage range (either input)	-0.3 V to 32 V
Duration of output short-circuit to ground at (or below 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	680 mW
Operating free-air temperature range:	
TL321M	-55°C to 125°C
TL321I	-25°C to 85°C
TL321C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, TL321M chips are alloy-mounted; TL321I and TL321C chips are glass-mounted.

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# TYPES TL321M, TL321I, TL321C

## OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL321M, TL321I			TL321C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 1.4\text{ V}$ , $V_{CC} = 5\text{ V to }30\text{ V}$	25°C	2	5	2	7	mV	
		Full range	7			9		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	30	5	50	nA	
		Full range	100			150		
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$ , See Note 5	25°C	-45	-150	-45	-250	nA	
		Full range	-300			-500		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$V_{OH}$ High-level output voltage	$V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$	Full range	26		26		V	
	$V_{CC} = 30\text{ V}$ , $R_L \geq 10\text{ k}\Omega$	Full range	27	28	27	28		
$V_{OL}$ Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range		5	20	5	20	mV
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100	V/mV	
		Full range	25		15			
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	70	85	65	85	dB	
$k_{SVR}^*$ Supply voltage rejection ratio	$R_S \leq 10\text{ k}\Omega$	25°C	65	100	65	100	dB	
$I_O$ Output current	$V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0\text{ V}$	25°C	-20	-40	-20	-40	mA	
		Full range	-10	-20	-10	-20		
	$V_{CC} = 15\text{ V}$ , $V_{ID} = -1\text{ V}$ , $V_O = 5\text{ V}$	25°C	10	20	10	20		
		Full range	5	8	5	8		
$I_{CC}$ Supply current	No load, No signal	25°C		0.4		0.4	mA	
		Full range		1		1		

\* $k_{SVR} = \Delta V_{CC} / \Delta V_{IO}$

†All characteristics are specified under open-loop conditions. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL321M,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL321I, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL321C.

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/°C	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/°C	47°C
P	680 mW	8.0 mW/°C	65°C

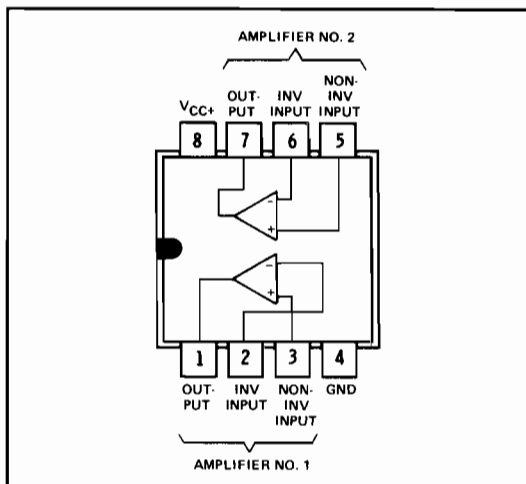
Also see Dissipation Derating Curves, Section 2.

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 36 V  
or Dual Supplies
- Class AB Output Stage
- True Differential Input Stage
- Low Input Bias Current
- Internal Frequency Compensation
- Short-Circuit Protection

**description**

The TL322M, TL322I, and the TL322C are dual operational amplifiers similar in performance to the uA741 but with several distinct advantages. They are designed to operate from a single supply over a range of voltages from 3 volts to 36 volts. Operation from split supplies is also possible provided the difference between the two supplies is 3 volts to 36 volts. The common-mode input range includes the negative supply. Output range is from the negative supply to  $V_{CC} - 1.5$  V. Quiescent supply currents per amplifier are typically less than one-half those of the uA741.

JG OR P  
DUAL-IN-LINE PACKAGE (TOP VIEW)



**4**

The TL322M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL322I is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL322C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	TL322M	TL322I	TL322C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Supply voltage $V_{CC+}$ with respect to $V_{CC-}$	36	36	36	V
Differential input voltage (see Note 2)	$\pm 36$	$\pm 36$	$\pm 36$	V
Input voltage (see Notes 1 and 3)	$\pm 18$	$\pm 18$	$\pm 18$	V
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 4)	JG package	1050	825	mW
	P package		1000	
Operating free-air temperature range	$-55$ to $125$	$-40$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	JG package	300	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	P package		260	$^{\circ}\text{C}$

- NOTES: 1. These voltage values are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Neither input must ever be more positive than  $V_{CC+}$  or more negative than  $V_{CC-}$ .  
 4. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the JG packages, TL322M chips are alloy-mounted; TL322I and TL322C chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	1050 mW	$8.4 \text{ mW}/^{\circ}\text{C}$	$25^{\circ}\text{C}$
JG (Glass-Mounted Chip)	825 mW	$6.6 \text{ mW}/^{\circ}\text{C}$	$25^{\circ}\text{C}$
P	1000 mW	$8.0 \text{ mW}/^{\circ}\text{C}$	$25^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

# TYPES TL322M, TL322I, TL322C

## DUAL LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature:  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for TL322I;  $V_{CC\pm} = \pm 15\text{ V}$  for TL322M and TL322C

PARAMETER	TEST CONDITIONS†	TL322M			TL322I			TL322C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$T_A = 25^\circ\text{C}$ , See Note 5	2 8			2 8			2 10			mV
	$T_A = \text{full range}$ , See Note 5	10			10			12			
$\alpha V_{IO}$ Temperature coefficient of input offset voltage	$T_A = 25^\circ\text{C}$	10			10			10			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$ , See Note 5	30 75			30 75			30 50			nA
	$T_A = \text{full range}$ , See Note 5	250			250			200			
$\alpha I_{IO}$ Temperature coefficient of input offset current	$T_A = 25^\circ\text{C}$	50			50			50			$\text{pA}/^\circ\text{C}$
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$	-0.2 -0.5			-0.2 -0.5			-0.2 -0.5			$\mu\text{A}$
	$T_A = \text{full range}$	-1.5			-1			-0.8			
$V_{ICR}$ Common-mode input voltage range‡	$T_A = 25^\circ\text{C}$	$V_{CC-}$ to $V_{CC-}$ 13 13.5			$V_{CC-}$ to $V_{CC-}$ 12 12.5			$V_{CC-}$ to $V_{CC-}$ 13 13.5			V
$V_{OM}$ Peak output voltage swing	$R_L = 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$\pm 12$ $\pm 13.5$			$\pm 12$ $\pm 12.5$			$\pm 12$ $\pm 13.5$			V
	$R_L = 2\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$\pm 10$ $\pm 13$			$\pm 10$ $\pm 12$			$\pm 10$ $\pm 13$			
	$R_L = 2\text{ k}\Omega$ , $T_A = \text{full range}$	$\pm 10$			$\pm 10$			$\pm 10$			
$A_{VD}$ Large-signal differential voltage amplification	$R_L = 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$ , $T_A = 25^\circ\text{C}$	200			20 200			20 200			V/mV
	$T_A = \text{full range}$	25			15			15			
$B_{OM}$ Maximum-output-swing bandwidth	$V_{OPP} = 20\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $A_{VD} = 1$ , $\text{THD} \leq 5\%$ , $T_A = 25^\circ\text{C}$	9			9			9			kHz
$B_1$ Unity-gain bandwidth	$R_L = 10\text{ k}\Omega$ , $V_O = 50\text{ mV}$ , $T_A = 25^\circ\text{C}$	1			1			1			MHz
$\phi_m$ Phase margin	$C_L = 200\text{ pF}$ , $R_L = 2\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$60^\circ$			$60^\circ$			$60^\circ$			
$r_i$ Input resistance	$f = 20\text{ Hz}$ , $T_A = 25^\circ\text{C}$	0.3 1			0.3 1			0.3 1			$\text{M}\Omega$
$r_o$ Output resistance	$f = 20\text{ Hz}$ , $T_A = 25^\circ\text{C}$	75			75			75			$\Omega$
CMRR Common-mode rejection ratio	$R_S \leq 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	70 90			70 90			70 90			dB
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$T_A = 25^\circ\text{C}$	30 150			30 150			30 150			$\mu\text{V}/\text{V}$
$I_{OS}$ Short-circuit output current §	$T_A = 25^\circ\text{C}$	$\pm 10$ $\pm 30$ $\pm 45$			$\pm 10$ $\pm 30$ $\pm 45$			$\pm 10$ $\pm 30$ $\pm 45$			mA
$I_{CC}$ Total supply current	No load, No signal, $T_A = 25^\circ\text{C}$	1.4 2.5			1.4 4			1.4 4			mA

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL322M;  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for TL322I and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL322C.

‡ The  $V_{ICR}$  limits are directly linked volt-for-volt to supply voltage, viz the positive limit is 2 volts less than  $V_{CC+}$ .

§ Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

NOTE 5:  $V_{IO}$  and  $I_{IO}$  are defined at  $V_O = 0\text{ V}$  for TL322M and TL322C and  $V_O = 7\text{ V}$  for TL322I.

# TYPES TL322M, TL322I, TL322C DUAL LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL322M			TL322I			TL322C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_O = 2.5\text{ V}$		2	8			8		2	10	mV	
$I_{IO}$ Input offset current	$V_O = 2.5\text{ V}$		30	75			75		30	50	nA	
$I_{IB}$ Input bias current			-0.2	-0.5			-0.5		-0.2	-0.5	pA	
$V_{OM}$ Peak output voltage swing §	$R_L = 10\text{ k}\Omega$		3.3	3.5			3.3		3.3	3.5	V	
	$R_L = 10\text{ k}\Omega$ , $V_{CC+} = 5\text{ V to } 30\text{ V}$		$V_{CC+} - 1.7$			$V_{CC+} - 1.7$			$V_{CC+} - 1.7$			
$A_{VD}$ Large-signal differential voltage amplification	$R_L = 2\text{ k}\Omega$ , $\Delta V_O = 2\text{ V}$		20	200			20		20	200	V/mV	
$k_{SVS}$ Power supply sensitivity ( $\Delta V_{IO}/\Delta V_{CC\pm}$ )				150			150			150	$\mu\text{V/V}$	
$I_{CC}$ Supply current	No load, No signal		1.2	2.5			1.2	4		1.2	4	mA
$V_{O1}/V_{O2}$ Channel separation	$f = 1\text{ kHz to } 20\text{ kHz}$		120				120			120	dB	

<sup>†</sup> All characteristics are specified under open-loop conditions.

§ Output will swing essentially to ground.

operating characteristics:  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for TL322I,  $V_{CC\pm} = \pm 15\text{ V}$  for TL322M and TL322C;  $T_A = 25^\circ\text{C}$ ,  $A_{VD} = 1$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = \pm 10\text{ V}$ ,	$C_L = 100\text{ pF}$ ,	See Figure 1		0.6		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$\Delta V_O = 50\text{ mV}$ , See Figure 1	$C_L = 100\text{ pF}$ ,	$R_L = 10\text{ k}\Omega$ ,		0.35		$\mu\text{s}$
$t_f$ Fall time					0.35		$\mu\text{s}$
Overshoot factor					20%		
Crossover distortion	$V_{Ipp} = 30\text{ mV}$ ,	$V_{Opp} = 2\text{ V}$ ,	$f = 10\text{ kHz}$		1%		

4

## PARAMETER MEASUREMENT INFORMATION

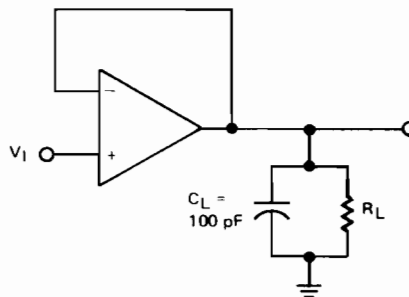


FIGURE 1—UNITY-GAIN AMPLIFIER

# TYPES TL322M, TL322I, TL322C

## DUAL LOW-POWER OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

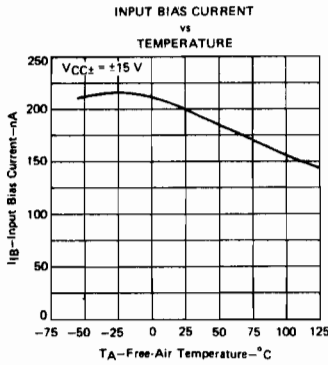


FIGURE 2

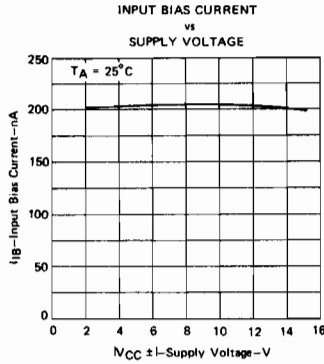


FIGURE 3

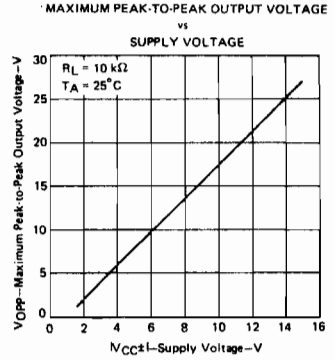


FIGURE 4

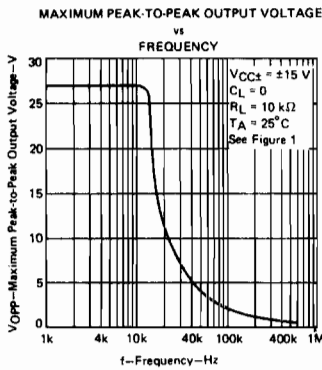


FIGURE 5

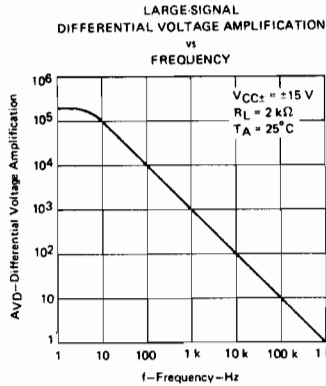


FIGURE 6

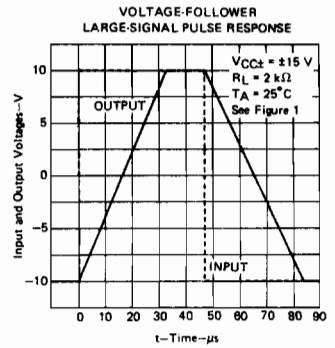
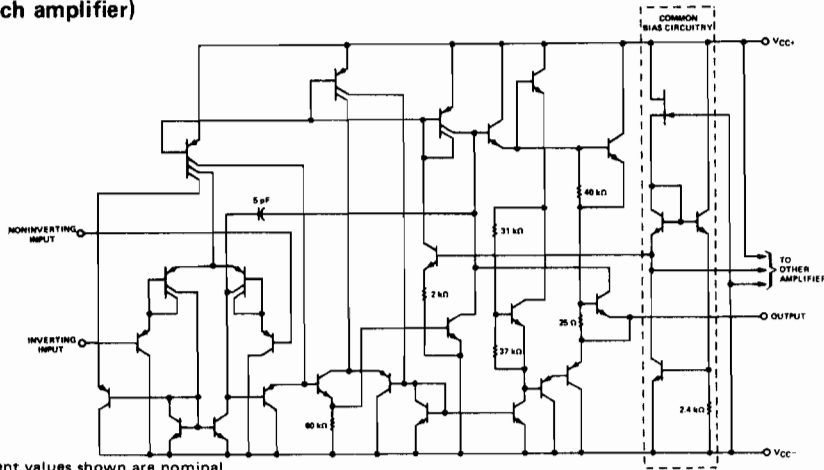


FIGURE 7

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

### schematic (each amplifier)



All component values shown are nominal

# LINEAR INTEGRATED CIRCUITS

# TYPES TL702M, TL702C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 12407, JUNE 1976—REVISED OCTOBER 1979

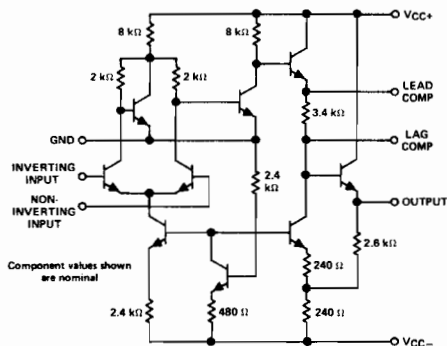
- Open-Loop Voltage Amplification . . . 2600 Typ
- CMRR . . . 80 dB Typ

## description

The TL702 is a high-gain, wideband operational amplifier having differential inputs and single-ended emitter-follower outputs. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. Component matching, inherent in silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. The TL702 is particularly useful for applications requiring transfer or generation of linear and non-linear functions up to a frequency of 30 MHz.

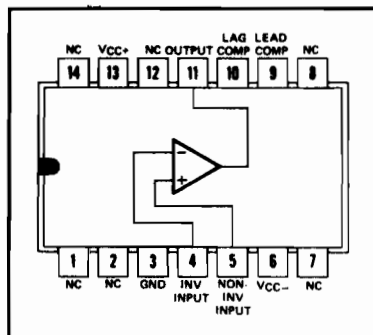
The TL702M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL702C is characterized for operation over the temperature range of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## schematic

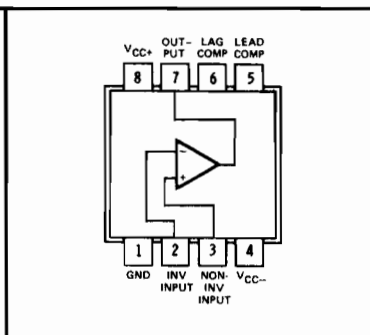


## terminal assignments

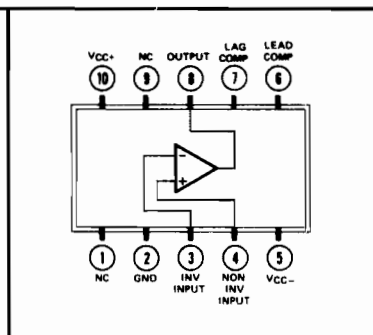
J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE (TOP VIEW)



JG DUAL-IN-LINE  
PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL702M	TL702C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	14	14	V
Supply voltage $V_{CC-}$ (see Note 1)	-7	-7	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (either input, see Notes 1 and 3)	-6 to 1.5	-6 to 1.5	V
Peak output current ( $t_W < 1$ s)	50	50	mA
Continuous total dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 4)	300	300	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature $1/16$ inch (1,6 mm) from case for 60 seconds	J, JG, U, or W package		300
Lead temperature $1/16$ inch (1,6 mm) from case for 10 seconds	N package		260

- NOTES:
1. All voltage values, unless otherwise noted, are with respect to the network ground terminal.
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the lesser of the two supply voltages.
  4. For operation of TL702M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL702M chips are alloy-mounted; TL702C chips are glass-mounted.

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# TYPES TL702M, TL702C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

### TL702M

electrical characteristics at specified free-air temperature

PARAMETER	TEST CONDITIONS†	TL702M						UNIT
		V <sub>CC+</sub> = 12 V V <sub>CC-</sub> = -6 V			V <sub>CC+</sub> = 6 V V <sub>CC-</sub> = -3 V			
		MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>IO</sub>	Input offset voltage	R <sub>S</sub> < 2 kΩ	25°C	2	5	2	5	mV
			Full range		6		6	
α <sub>VIO</sub>	Average temperature coefficient of input offset voltage	R <sub>S</sub> = 50 Ω	-55°C to 25°C	10		10		μV/°C
			25°C to 125°C	5		5		
I <sub>IO</sub>	Input offset current		25°C	0.5	2	0.3	2	μA
			-55°C	1	3		3	
			125°C	0.2	3		3	
α <sub>IIO</sub>	Average temperature coefficient of input offset current		-55°C to 25°C	6		5		nA/°C
			25°C to 125°C	3		2		
I <sub>IB</sub>	Input bias current		25°C	4	10	2.5	7	μA
			-55°C	6.5	20		14	
V <sub>ICR</sub>	Common-mode input voltage range	Positive swing	25°C	0.5	1	0.5	1	V
		Negative swing		-4	-5	-1.5	-2	
V <sub>OPP</sub>	Maximum peak-to-peak output voltage swing	R <sub>L</sub> ≥ 100 kΩ		10	10.6	5	5.4	V
		R <sub>L</sub> = 10 kΩ		8		4		
A <sub>VD</sub>	Large-signal differential voltage amplification	R <sub>L</sub> > 100 kΩ	V <sub>O</sub> = ±5 V	25°C	1400	2600		
				Full range	1000			
			V <sub>O</sub> = ±2.5 V	25°C			380	
r <sub>i</sub>	Input resistance		25°C	8	25	12	40	kΩ
			Full range	3		4		
r <sub>o</sub>	Output resistance	V <sub>O</sub> = 0, See Note 3	25°C	200	500	300	700	Ω
CMRR	Common-mode rejection ratio	R <sub>S</sub> < 2 kΩ	25°C	70	80	70	80	dB
k <sub>SVS</sub> *	Supply voltage sensitivity	R <sub>S</sub> < 2 kΩ	25°C	60	300	60	300	μV/V
I <sub>CC</sub>	Supply current	No load, No signal	25°C	5	6.7	2.1	3.9	mA
P <sub>D</sub>	Total power dissipation	No load, No signal	25°C	90	120	19	35	mW

\*k<sub>SVS</sub> = ΔV<sub>IO</sub>/ΔV<sub>CC</sub>

† All characteristics are specified under open-loop operation. Full range for TL702M is -55°C to 125°C.

NOTE 3: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE T <sub>A</sub>
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
J (Glass-Mounted Chip)	300 mW	8.2 mW/°C	113°C
JG (Alloy-Mounted Chip)	300 mW	8.4 mW/°C	114°C
JG (Glass-Mounted Chip)	300 mW	6.6 mW/°C	104°C
N	300 mW	9.2 mW/°C	117°C
U	300 mW	5.4 mW/°C	94°C
W	300 mW	8.0 mW/°C	112°C

Also see Dissipation Derating Curves, Section 2.



# TYPES TL702M, TL702C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TL702C

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$

PARAMETER	TEST CONDITIONS†	TL702C			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 2\text{ k}\Omega$	25°C	5	10	mV
		Full Range	15		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$	Full Range	5		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current		25°C	0.5	5	$\mu\text{A}$
		Full Range	7.5		
$\alpha I_{IO}$ Average temperature coefficient of input offset current		0°C to 25°C	5		$\text{nA}/^\circ\text{C}$
		25°C to 70°C	3		
$I_{IB}$ Input bias current		25°C	4	15	$\mu\text{A}$
		0°C	4.5	20	
$V_{ICR}$ Common-mode input voltage range	Positive swing	25°C	0.5	1	V
	Negative swing		-4	-5	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 100\text{ k}\Omega$	25°C	10	10.6	V
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 100\text{ k}\Omega$ , $V_O = \pm 5\text{ V}$	25°C	1000	2600	
		Full Range	800		
$r_i$ Input resistance		25°C	6	25	$\text{k}\Omega$
		Full Range	3.5		
$r_o$ Output resistance	$V_O = 0$ , See Note 3	25°C	200	600	$\Omega$
CMRR Common-mode rejection ratio	$R_S \leq 2\text{ k}\Omega$	25°C	65	80	dB
$k_{SVS}^*$ Supply voltage sensitivity	$R_S \leq 2\text{ k}\Omega$	25°C	60	300	$\mu\text{V}/\text{V}$
$I_{CC}$ Supply current	No load, No signal	25°C	5	7	mA
$P_D$ Total power dissipation	No load, No signal	25°C	90	125	mW

\* $k_{SVS} = \Delta V_{IO} / \Delta V_{CC}$

† All characteristics are specified under open-loop operation. Full range for TL702C is 0°C to 70°C.

NOTE 3: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

## TL702M, TL702C

operating characteristics  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	BOTH TYPES			UNIT
			MIN	TYP	MAX	
$t_r$ Rise time	1	$V_I = 10\text{ mV}$ , $C_L = 0$	25	120	ns	
	2	$V_I = 1\text{ mV}$	10	30	ns	
Overshoot factor	1	$V_I = 10\text{ mV}$ , $C_L = 100\text{ pF}$	10%	50%		
	2	$V_I = 1\text{ mV}$	20%	40%		
SR Slew rate	1	$V_I = 6\text{ V}$ , $C_L = 100\text{ pF}$	1.7		$\text{V}/\mu\text{s}$	
	2	$V_I = 100\text{ mV}$	11			

# TYPES TL702M, TL702C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

### PARAMETER MEASUREMENT INFORMATION

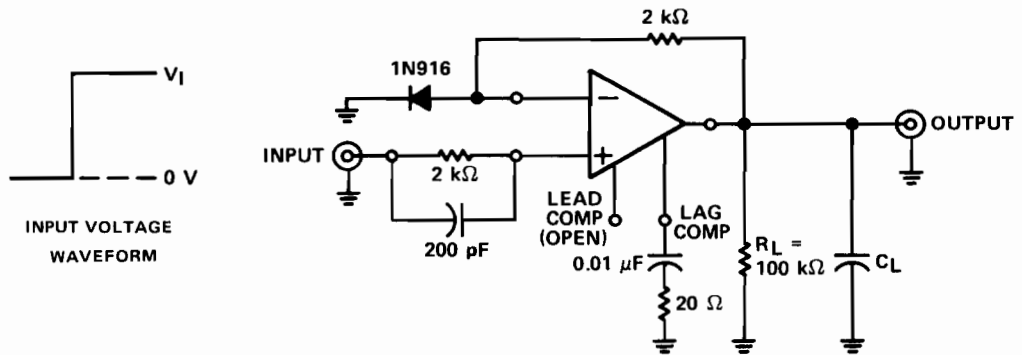


FIGURE 1—UNITY-GAIN AMPLIFIER

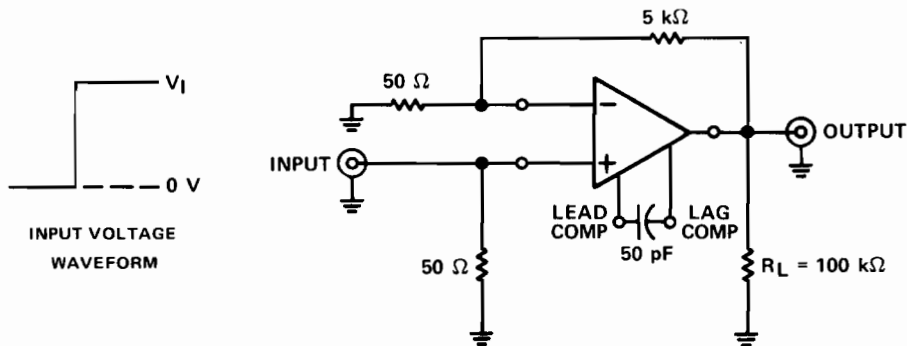
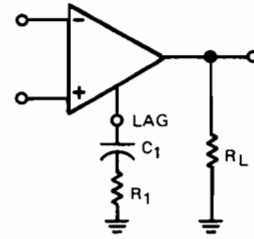
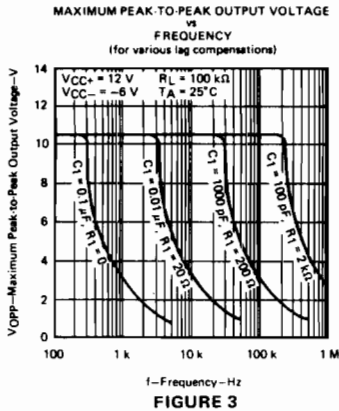


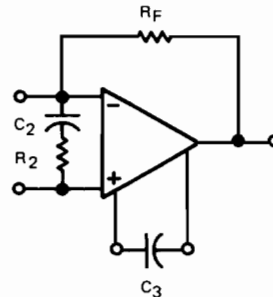
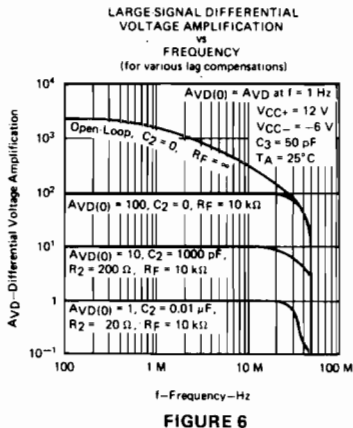
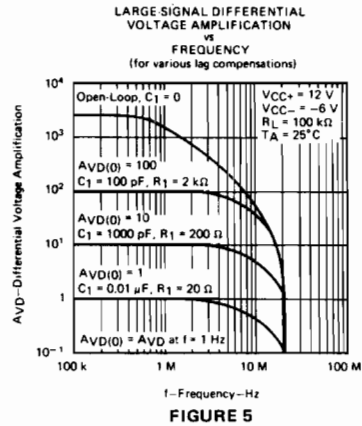
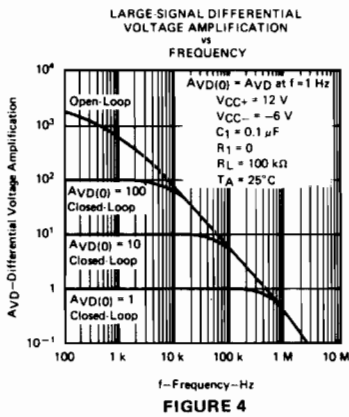
FIGURE 2—GAIN-OF-100 AMPLIFIER

# TYPES TL702M, TL702C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS



LAG COMPENSATION CIRCUIT  
FOR FIGURES 3, 4, AND 5



LEAD-LAG COMPENSATION CIRCUIT  
FOR FIGURE 6



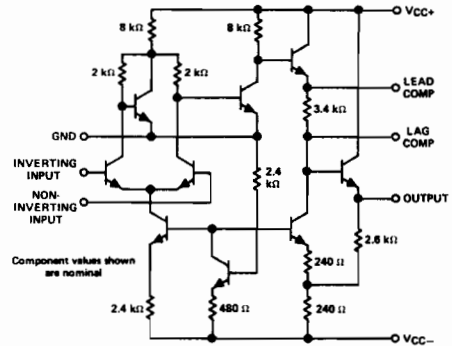
- Open-Loop Voltage Amplification . . . 3600 Typ
- Designed to be Interchangeable With Fairchild  $\mu$ A702
- CMRR . . . 100 dB Typ

**description**

The  $\mu$ A702 is a high-gain, wideband operational amplifier having differential inputs and single-ended emitter-follower outputs. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. Component matching, inherent in silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. The  $\mu$ A702 is particularly useful for applications requiring transfer or generation of linear and non-linear functions up to a frequency of 30 MHz.

The  $\mu$ A702M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**schematic**

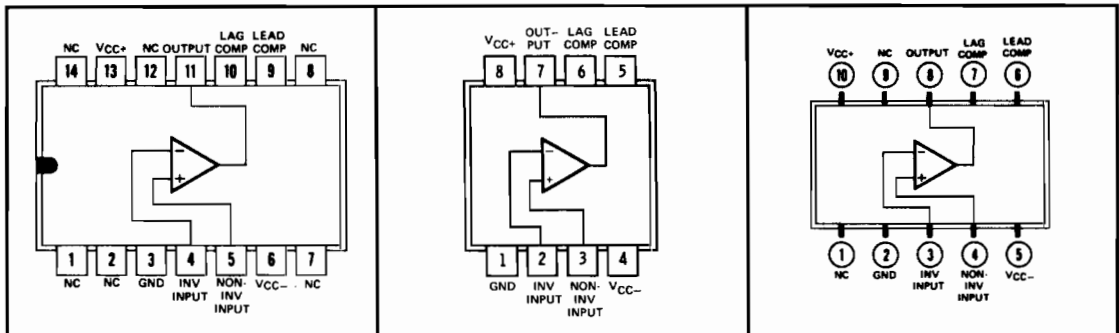


**terminal assignments**

**J DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)**

**JG DUAL-IN-LINE  
PACKAGE (TOP VIEW)**

**U  
FLAT PACKAGE  
(TOP VIEW)**



NC—No Internal connection

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Notes 1 and 3)	-6 V to 1.5 V
Peak output current ( $t_w \leq 1$ s)	50 mA
Continuous total dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 4)	300 mW
Operating free-air temperature range	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	$300^{\circ}\text{C}$

- NOTES:
1. All voltage values, unless otherwise noted, are with respect to the network ground terminal.
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the lesser of the two supply voltages.
  4. For operation above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages,  $\mu$ A702M chips are alloy-mounted.

# TYPE $\mu$ A702M

## GENERAL-PURPOSE OPERATIONAL AMPLIFIER

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
JG (Alloy-Mounted Chip)	300 mW	8.4 mW/°C	114°C
U	300 mW	5.4 mW/°C	94°C
W	300 mW	8.0 mW/°C	112°C

Also see Dissipation Derating Curves, Section 2.

electrical characteristics at specified free-air temperature

PARAMETER	TEST CONDITIONS†		$V_{CC+} = 12\text{ V}$ $V_{CC-} = -6\text{ V}$			$V_{CC+} = 6\text{ V}$ $V_{CC-} = -3\text{ V}$			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 2\text{ k}\Omega$	25°C	0.5 2			0.7 3			mV	
		Full range	3			4				
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$	-55°C to 25°C	2 10			3 15			$\mu\text{V}/^\circ\text{C}$	
		25°C to 125°C	2.5 10			3.5 15				
$I_{IO}$ Input offset current		25°C	0.2 0.5			0.12 0.5			$\mu\text{A}$	
		-55°C	0.4 1.5			0.3 1.5				
		125°C	0.08 0.5			0.05 0.5				
$\alpha_{IIO}$ Average temperature coefficient of input offset current		-55°C to 25°C	3 16			2 13			nA/°C	
		25°C to 125°C	1 5			0.7 4				
$I_{IB}$ Input bias current		25°C	2 5			1.2 3.5			$\mu\text{A}$	
		-55°C	4.3 10			2.6 7.5				
$V_{ICR}$ Common-mode input voltage range	Positive swing	25°C	0.5 1			0.5 1			V	
	Negative swing		-4 -5			-1.5 -2				
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 100\text{ k}\Omega$	25°C	10 10.6			5 5.4			V	
		Full range	10			5				
	$R_L = 10\text{ k}\Omega$	25°C	7 8			3 4				
		Full range	7			3				
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 100\text{ k}\Omega$	$V_O = \pm 5\text{ V}$	25°C	2500 3600 6000						
			Full range	2000 7000						
	$V_O = \pm 2.5\text{ V}$	25°C				600 900 1500				
		Full range				500 1750				
$r_i$ Input resistance		25°C	16 40			22 67			k $\Omega$	
		Full range	6			8				
$r_o$ Output resistance	$V_O = 0$ , See Note 3	25°C	200 500			300 700			$\Omega$	
		Full range	70			70				
CMRR Common-mode rejection ratio	$R_S \leq 2\text{ k}\Omega$	25°C	80 100			80 100			dB	
		Full range	70			70				
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 2\text{ k}\Omega$	25°C	75			75			$\mu\text{V}/\text{V}$	
		Full range	200			200				
$I_{CC}$ Supply current	No load, No signal	25°C	5 6.7			2.1 3.3			mA	
		-55°C	5 7.5			2.1 3.9				
		125°C	4.4 6.7			1.7 3.3				
		Full range	90 120			19 30				
$P_D$ Total power dissipation	No load, No signal	25°C	90 120			19 30			mW	
		-55°C	90 135			19 35				
		125°C	80 120			15 30				
		Full range	80 120			15 30				

† All characteristics are specified under open-loop operation. Full range is -55°C to 125°C.

NOTE 3: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

# TYPE $\mu$ A702M

## GENERAL-PURPOSE OPERATIONAL AMPLIFIER

operating characteristics  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_r$ Rise time	1	$V_I = 10\text{ mV}$ , $C_L = 0$	25	120		ns
	2	$V_I = 1\text{ mV}$	10	30		ns
Overshoot factor	1	$V_I = 10\text{ mV}$ , $C_L = 100\text{ pF}$	10%	50%		
	2	$V_I = 1\text{ mV}$	20%	40%		
SR Slew rate	1	$V_I = 6\text{ V}$ , $C_L = 100\text{ pF}$	1.7			V/ $\mu$ s
	2	$V_I = 100\text{ mV}$	11			

### PARAMETER MEASUREMENT INFORMATION

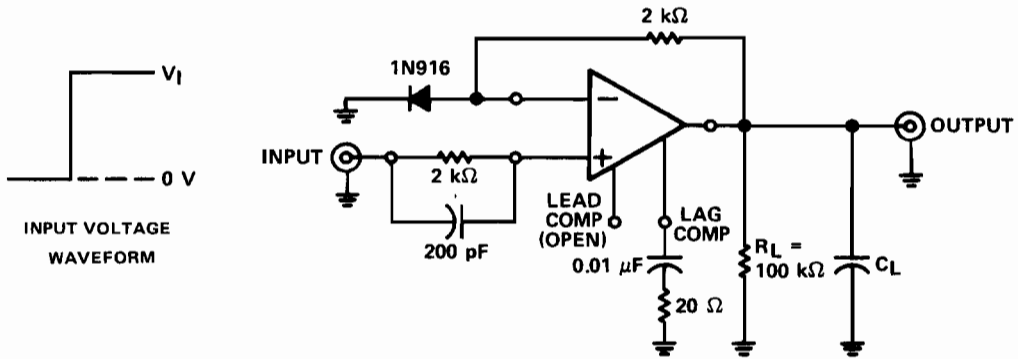


FIGURE 1—UNITY-GAIN AMPLIFIER

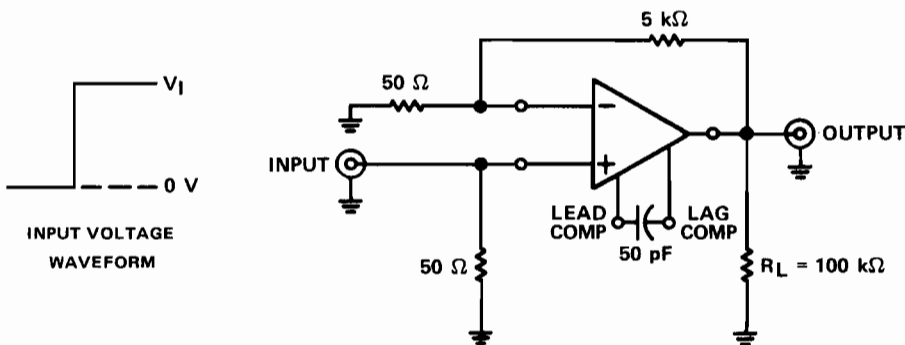


FIGURE 2—GAIN-OF-100 AMPLIFIER

# TYPE $\mu$ A702M GENERAL-PURPOSE OPERATIONAL AMPLIFIER

## TYPICAL CHARACTERISTICS

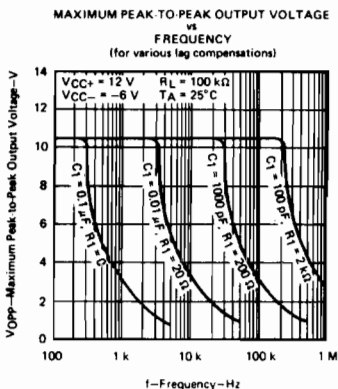
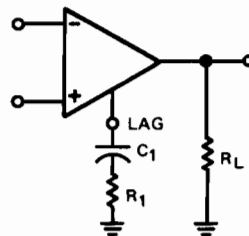


FIGURE 3



LAG COMPENSATION CIRCUIT  
FOR FIGURES 3, 4, AND 5

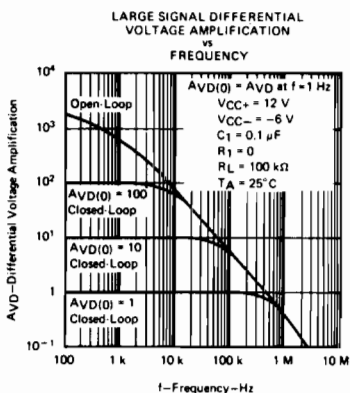


FIGURE 4

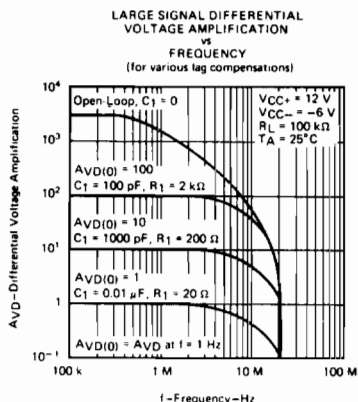


FIGURE 5

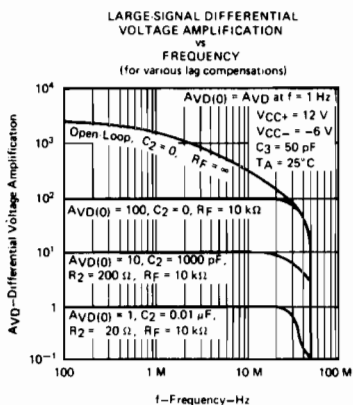
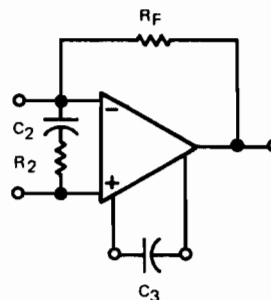


FIGURE 6



LEAD-LAG COMPENSATION CIRCUIT  
FOR FIGURE 6



# LINEAR INTEGRATED CIRCUITS

## TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 11447, FEBRUARY 1971—REVISED OCTOBER 1979

- Common-Mode Input Range . . .  $\pm 10$  V Typical
- Designed to be Interchangeable with Fairchild  $\mu$ A709A,  $\mu$ A709, and  $\mu$ A709C
- Maximum Peak-to-Peak Output Voltage Swing . . . 28 V Typical with 15 V Supplies

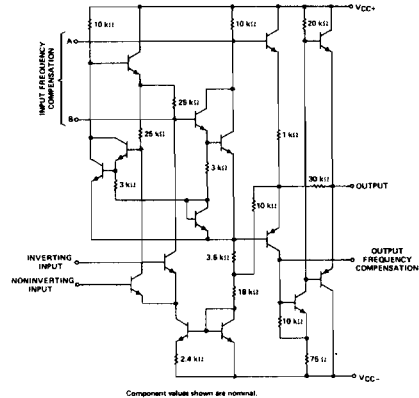
### description

These circuits are general-purpose operational amplifiers, each having high-impedance differential inputs and a low-impedance output. Component matching, inherent with silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. These amplifiers are particularly useful for applications requiring transfer or generation of linear or nonlinear functions.

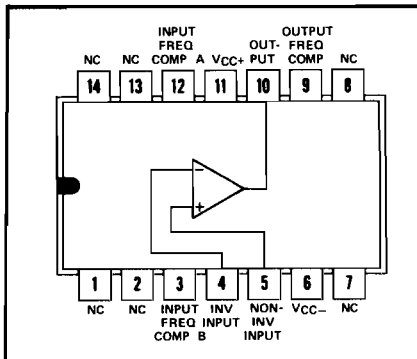
The  $\mu$ A709A circuit features improved offset characteristics, reduced input-current requirements, and lower power dissipation when compared to the  $\mu$ A709 circuit. In addition, maximum values of the average temperature coefficients of offset voltage and current are guaranteed.

The  $\mu$ A709AM and  $\mu$ A709M are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The  $\mu$ A709C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

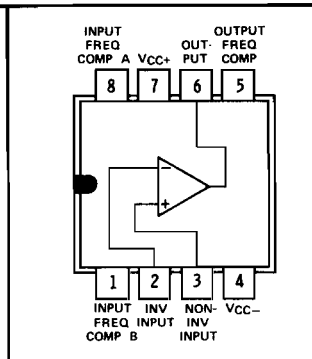
### schematic



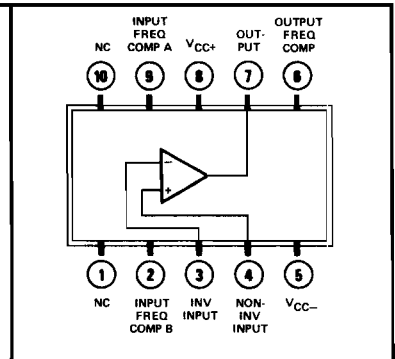
J OR N DUAL-IN-LINE  
OR W FLAT  
PACKAGE (TOP VIEW)



JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

4

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A709AM $\mu$ A709M	$\mu$ A709C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 10$	$\pm 10$	V
Duration of output short-circuit (see Note 4)	5	5	s
Continuous total dissipation at (or below) 70°C free-air temperature (see Note 5)	300	300	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J, JG, U, or W package	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 10 volts, whichever is less.  
 4. The output may be shorted to ground or either power supply.  
 5. For operation of  $\mu$ A709AM and  $\mu$ A709M above 70°C free-air temperature, refer to the Dissipation Derating Curves, Section 2. In the J and JG packages,  $\mu$ A709AM and  $\mu$ A709M chips are alloy-mounted;  $\mu$ A709C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 9$  V to  $\pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	$\mu$ A709AM			$\mu$ A709M			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$	Input offset voltage	$R_S \leq 10$ k $\Omega$	25°C	0.6	2	1	5	mV
			Full range		3		6	
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage	$R_S = 50$ $\Omega$	Full range	1.8	10	3		$\mu$ V/°C
		$R_S = 10$ k $\Omega$	-55°C to 25°C	4.8	25	.6		
			25°C to 125°C	2	15	6		
$I_{IO}$	Input offset current		25°C	10	50	50	200	nA
			-55°C	40	250	100	500	
			125°C	3.5	50	20	200	
$\alpha_{IIO}$	Average temperature coefficient of input offset current		-55°C to 25°C	0.45	2.8			nA/°C
			25°C to 125°C	0.08	0.5			
$I_{IB}$	Input bias current		25°C	0.1	0.2	0.2	0.5	$\mu$ A
			-55°C	0.3	0.6	0.5	1.5	
$V_{ICR}$	Common-mode input voltage range	$V_{CC\pm} = \pm 15$ V	25°C	$\pm 8$	$\pm 10$	$\pm 8$	$\pm 10$	V
			Full range	$\pm 8$		$\pm 8$		
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15$ V, $R_L \geq 10$ k $\Omega$	25°C	24	28	24	28	V
			Full range	24		24		
		$V_{CC\pm} = \pm 15$ V, $R_L = 2$ k $\Omega$	25°C	20	26	20	26	
		$V_{CC\pm} = \pm 15$ V, $R_L \geq 2$ k $\Omega$	Full range	20		20		
$A_{VD}$	Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15$ V, $R_L \geq 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C		45	45		V/mV
			Full range	25	70	25	70	
$r_i$	Input resistance		25°C	350	750	150	400	k $\Omega$
			-55°C	85	185	40	100	
$r_o$	Output resistance	$V_O = 0$ , See Note 6	25°C		150		150	$\Omega$
CMRR	Common-mode rejection ratio	$R_S \leq 10$ k $\Omega$	25°C	80	110	70	90	dB
			Full range	80		70		
$k_{SVS}$	Power supply sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 10$ k $\Omega$	25°C	40	100	25	150	$\mu$ V/V
			Full range		100		150	
$I_{CC}$	Supply current	$V_{CC\pm} = \pm 15$ V, No load, No signal	25°C	2.5	3.6	2.6	5.5	mA
			-55°C	2.7	4.5			
			125°C	2.1	3			
$P_D$	Total power dissipation	$V_{CC\pm} = \pm 15$ V, No load, No signal	25°C	75	108	78	165	mW
			-55°C	81	135			
			125°C	63	90			

† All characteristics are specified under open-loop operation. Full range for  $\mu$ A709AM and  $\mu$ A709M is -55°C to 125°C.

‡ All typical values are at  $V_{CC\pm} = \pm 15$  V.

Note 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature (unless otherwise noted  $V_{CC\pm} = \pm 15$  V)

PARAMETER	TEST CONDITIONS†	$\mu$ A709C			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V, $R_S \leq 10$ k $\Omega$		2	7.5	mV
				10	
$I_{IO}$ Input offset current	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V		100	500	nA
				750	
$I_{IB}$ Input bias current	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V		0.3	1.5	$\mu$ A
				2	
$V_I$ Input voltage range			$\pm 8$	$\pm 10$	V
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 10$ k $\Omega$		24	28	V
			24		
	$R_L = 2$ k $\Omega$		20	26	
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2$ k $\Omega$		20		V/mV
$r_i$ Input resistance			50	250	k $\Omega$
			35		
$r_o$ Output resistance	$V_O = 0$ , See Note 6		150		$\Omega$
CMRR Common-mode rejection ratio	$R_S \leq 10$ k $\Omega$		65	90	dB
$\Delta V_{IO}/\Delta V_{CC}$ Supply voltage sensitivity	$R_S \leq 10$ k $\Omega$		25	200	$\mu$ V/V
$P_D$ Total power dissipation	No load, No signal		80	200	mW

†All characteristics are specified under open-loop operation. Full range for  $\mu$ A709C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics  $V_{CC\pm} = \pm 9$  V to  $\pm 15$  V,  $T_A = 25^\circ$  C

PARAMETER	TEST CONDITIONS	$\mu$ A709AM $\mu$ A709M $\mu$ A709C			UNIT
		MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20$ mV, $R_L = 2$ k $\Omega$ , See Figure 1		0.3	1	$\mu$ s
Overshoot factor			6%	30%	

### PARAMETER MEASUREMENT INFORMATION

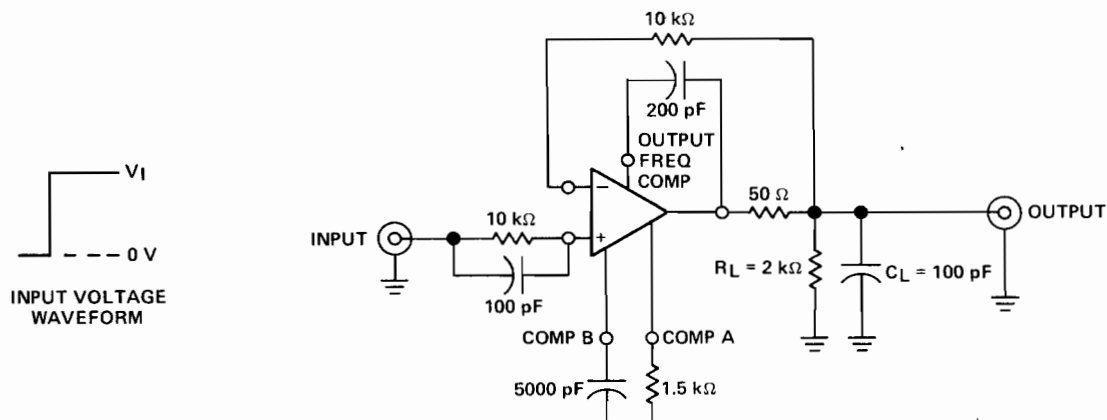


FIGURE 1—RISE TIME AND SLEW RATE

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS (unless designated maximum or minimum)

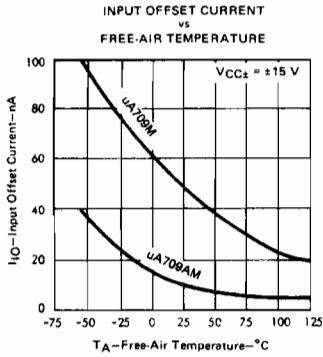


FIGURE 2

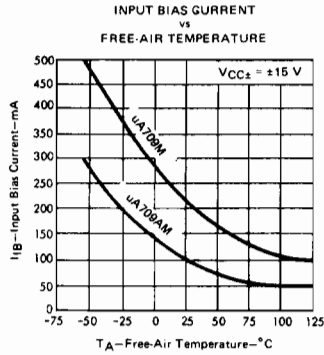


FIGURE 3

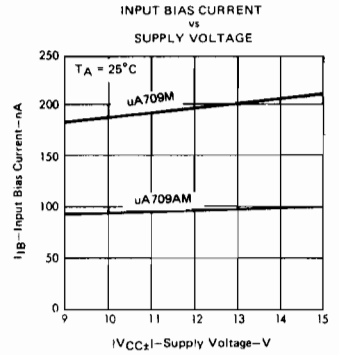


FIGURE 4

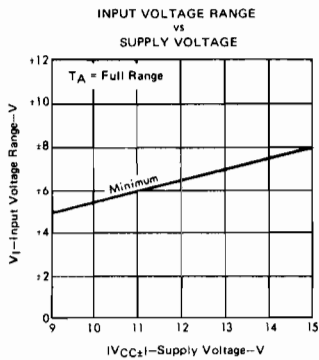


FIGURE 5

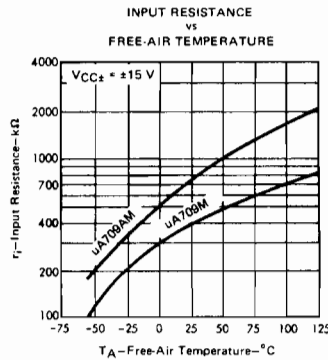


FIGURE 6

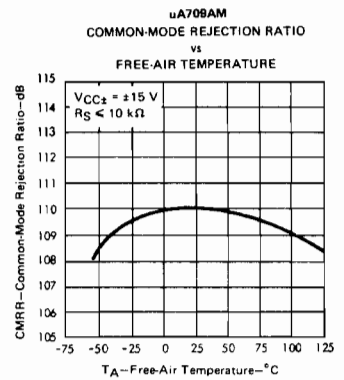


FIGURE 7

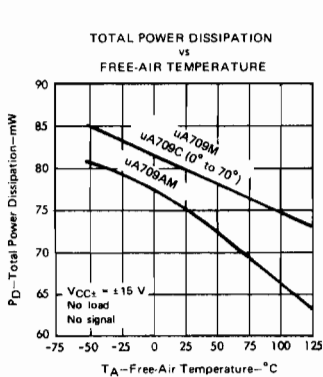


FIGURE 8

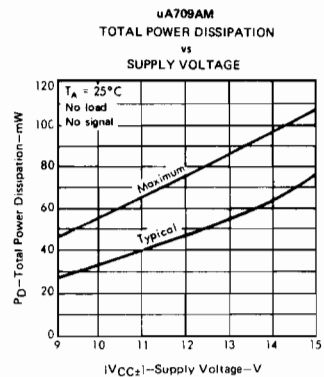


FIGURE 9

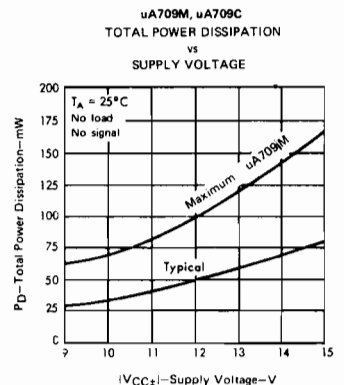


FIGURE 10

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS (unless designated maximum or minimum)

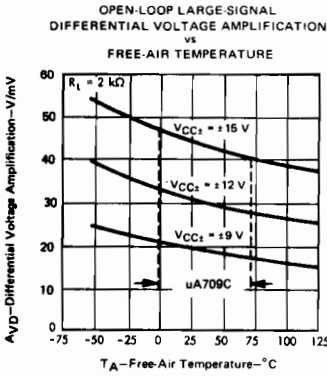


FIGURE 11

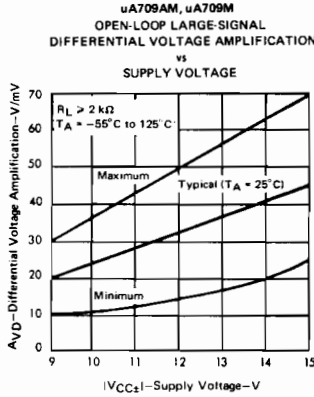


FIGURE 12

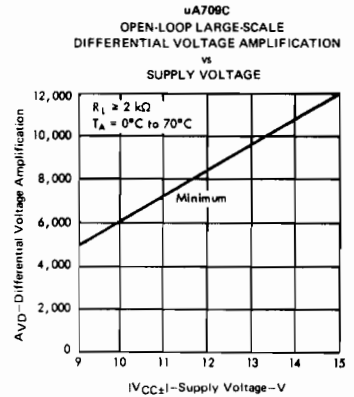


FIGURE 13

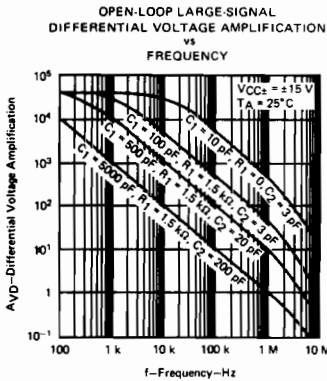


FIGURE 14

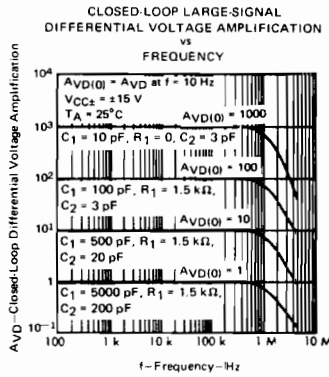
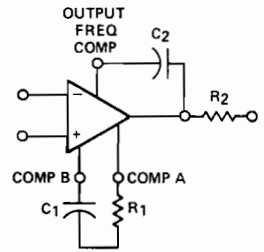


FIGURE 15



When the amplifier is operated with capacitive loading,  $R_2 = 50 \Omega$ .

FREQUENCY  
COMPENSATION CIRCUIT  
FOR FIGURES 14, 15, AND 18

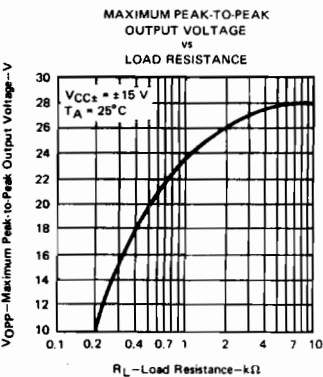


FIGURE 16

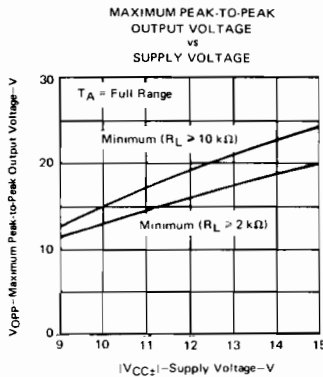


FIGURE 17

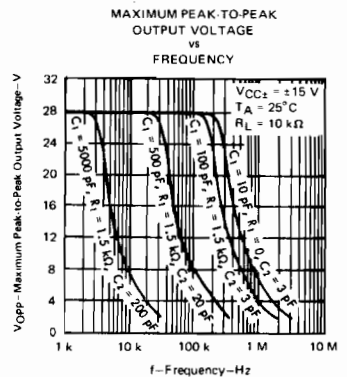


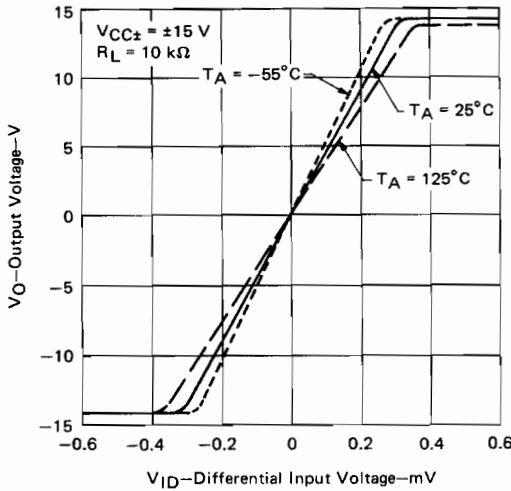
FIGURE 18

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

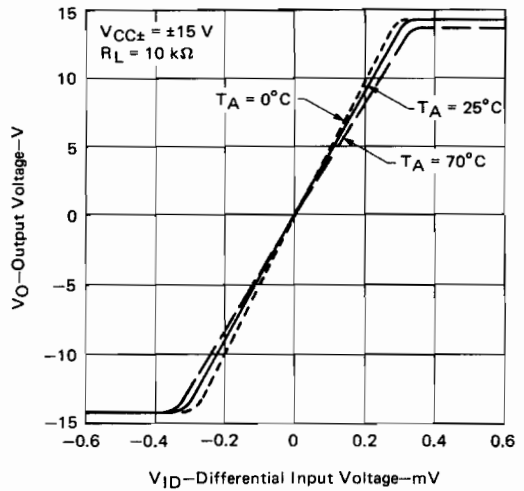
### TYPICAL CHARACTERISTICS

**$\mu$ A709AM,  $\mu$ A709M**  
VOLTAGE TRANSFER  
CHARACTERISTICS

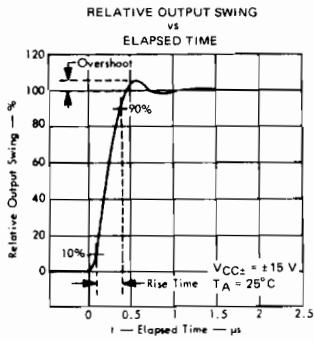


**FIGURE 19**

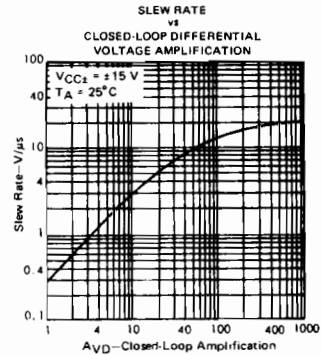
**$\mu$ A709C**  
VOLTAGE TRANSFER  
CHARACTERISTICS



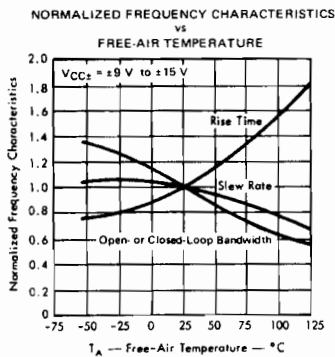
**FIGURE 20**



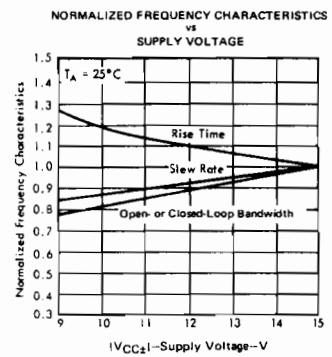
**FIGURE 21**



**FIGURE 22**



**FIGURE 23**



**FIGURE 24**

# LINEAR INTEGRATED CIRCUITS

# TYPES $\mu$ A741M, $\mu$ A741C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 11363, NOVEMBER 1970—REVISED OCTOBER 1979

- Short-Circuit Protection
- Offset-Voltage Null Capability
- Large Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up

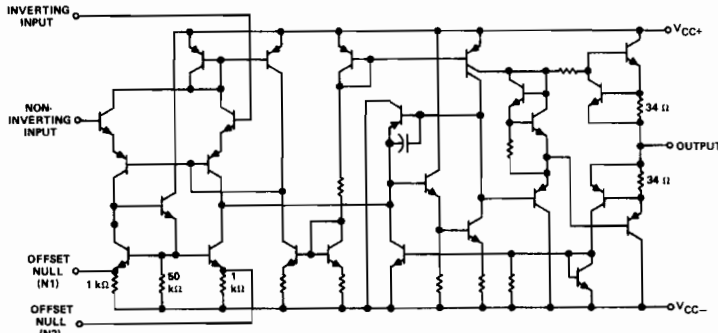
## description

The  $\mu$ A741 is a general-purpose operational amplifier featuring offset-voltage null capability.

The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low-value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The  $\mu$ A741M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A741C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

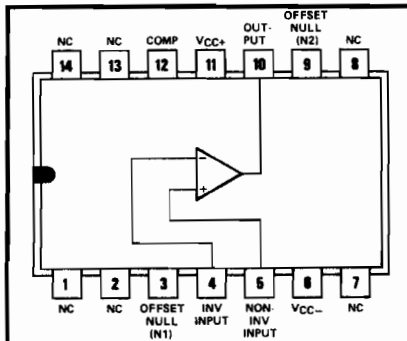
## schematic



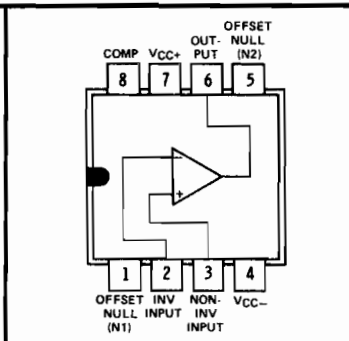
Resistor values shown are nominal

## terminal assignments

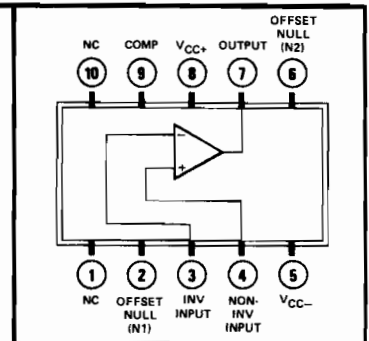
J OR N DUAL-IN-LINE OR  
W FLAT PACKAGE  
(TOP VIEW)



JG OR P DUAL-IN-LINE  
PACKAGE  
(TOP VIEW)



U  
FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

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# TYPES $\mu$ A741M, $\mu$ A741C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A741M	$\mu$ A741C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$	$\pm 0.5$	$\pm 0.5$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1.6 mm) from case for 60 seconds	J, JG, U, or W package		300
Lead temperature 1/16 inch (1.6 mm) from case for 10 seconds	N or P package		260

- NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
  4. The output may be shorted to ground or either power supply. For the  $\mu$ A741M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.
  5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages,  $\mu$ A741M chips are alloy-mounted;  $\mu$ A741C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V

PARAMETER	TEST CONDITIONS†	$\mu$ A741M			$\mu$ A741C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$	Input offset voltage	$R_S < 10$ k $\Omega$	25°C	1	5	1	6	mV	
$\Delta V_{IO(adj)}$	Offset voltage adjust range		25°C	$\pm 15$		$\pm 15$	7.5	mV	
$I_{IO}$	Input offset current		25°C	20	200	20	200	nA	
$I_{IB}$	Input bias current		25°C	80	500	80	500	nA	
$V_{ICR}$	Common-mode input voltage range		25°C	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$R_L = 10$ k $\Omega$	25°C	24	28	24	28	V	
		$R_L > 10$ k $\Omega$	Full range	24		24			
		$R_L = 2$ k $\Omega$	25°C	20	26	20	26		
		$R_L > 2$ k $\Omega$	Full range	20		20			
$A_{VD}$	Large-signal differential voltage amplification	$R_L > 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C	50	200	20	200	V/mV	
			Full range	25		15			
$r_i$	Input resistance		25°C	0.3	2	0.3	2	M $\Omega$	
$r_o$	Output resistance	$V_O = 0$ V, See Note 6	25°C		75		75	$\Omega$	
$C_i$	Input capacitance		25°C		1.4		1.4	pF	
CMRR	Common-mode rejection ratio	$R_S < 10$ k $\Omega$	25°C	70	90	70	90	dB	
			Full range	70		70			
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S < 10$ k $\Omega$	25°C	30	150	30	150	$\mu$ V/V	
			Full range		150		150		
$I_{OS}$	Short-circuit output current		25°C	$\pm 25$	$\pm 40$	$\pm 25$	$\pm 40$	mA	
$I_{CC}$	Supply current	No load, No signal	25°C		1.7	2.8	1.7	2.8	mA
			Full range		3.3		3.3		
$P_D$	Total power dissipation	No load, No signal	25°C		50	85	50	85	mW
			Full range		100		100		

†All characteristics are specified under open-loop operation. Full range for  $\mu$ A741M is -55°C to 125°C and for  $\mu$ A741C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.



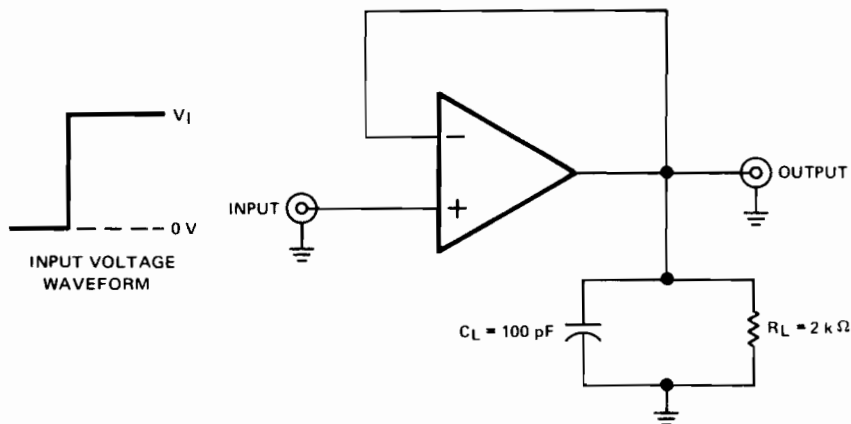
# TYPES $\mu$ A741M, $\mu$ A741C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A741M			$\mu$ A741C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$	Rise time	$V_i = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1						$\mu\text{s}$
	Overshoot factor							
SR	Slew rate at unity gain	$V_i = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1						$\text{V}/\mu\text{s}$

### PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

### TYPICAL APPLICATION DATA

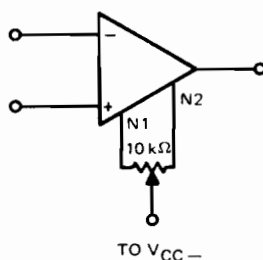


FIGURE 2—INPUT OFFSET VOLTAGE NULL CIRCUIT

# TYPES $\mu$ A741M, $\mu$ A741C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT  
VS  
FREE-AIR TEMPERATURE

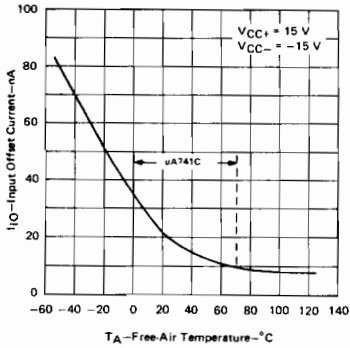


FIGURE 3

INPUT BIAS CURRENT  
VS  
FREE-AIR TEMPERATURE

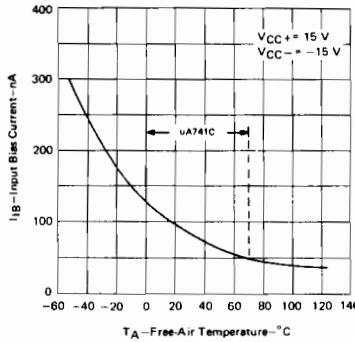


FIGURE 4

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE  
VS  
LOAD RESISTANCE

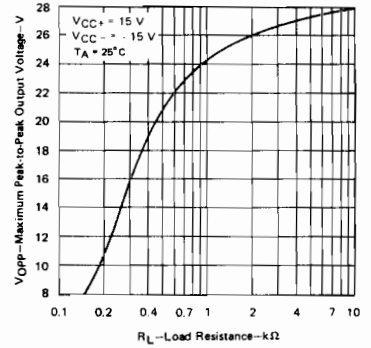


FIGURE 5

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE  
VS  
FREQUENCY

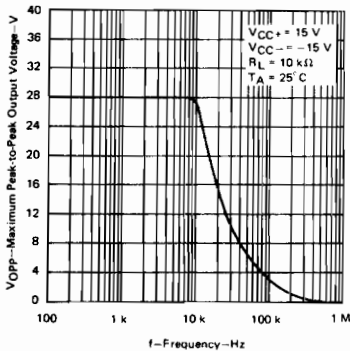


FIGURE 6

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
VS  
SUPPLY VOLTAGE

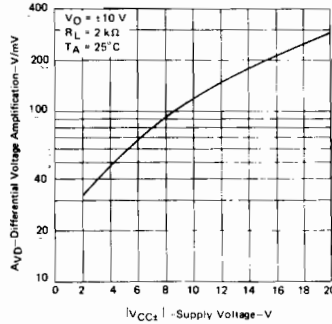


FIGURE 7

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
VS  
FREQUENCY

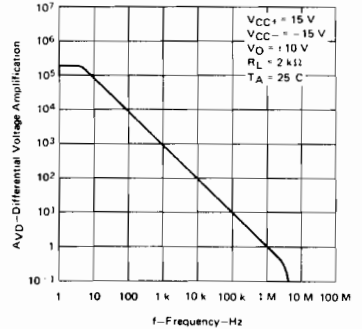


FIGURE 8

COMMON-MODE REJECTION RATIO  
VS  
FREQUENCY

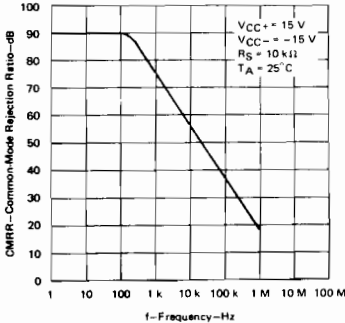


FIGURE 9

OUTPUT VOLTAGE  
VS  
ELAPSED TIME

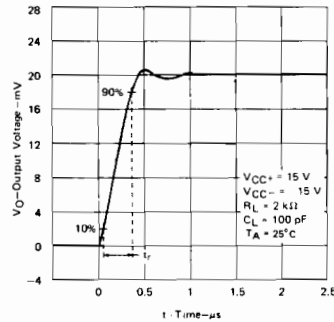


FIGURE 10

VOLTAGE-FOLLOWER  
LARGE-SIGNAL PULSE RESPONSE

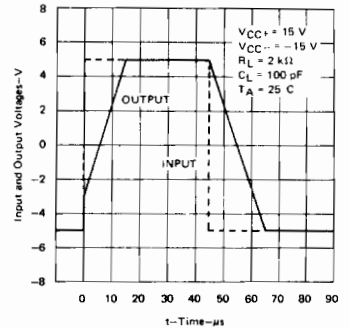


FIGURE 11

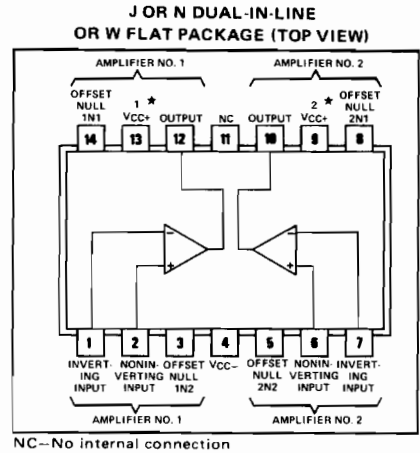
- No Frequency Compensation Required
- Low Power Consumption
- Short-Circuit Protection
- Offset-Voltage Null Capability
- Wide Common-Mode and Differential Voltage Ranges
- No Latch-up
- Designed to be Interchangeable with Fairchild  $\mu$ A747M and  $\mu$ A747C

**description**

The  $\mu$ A747 is a dual general-purpose operational amplifier featuring offset-voltage null capability. Each half is electrically similar to  $\mu$ A741.

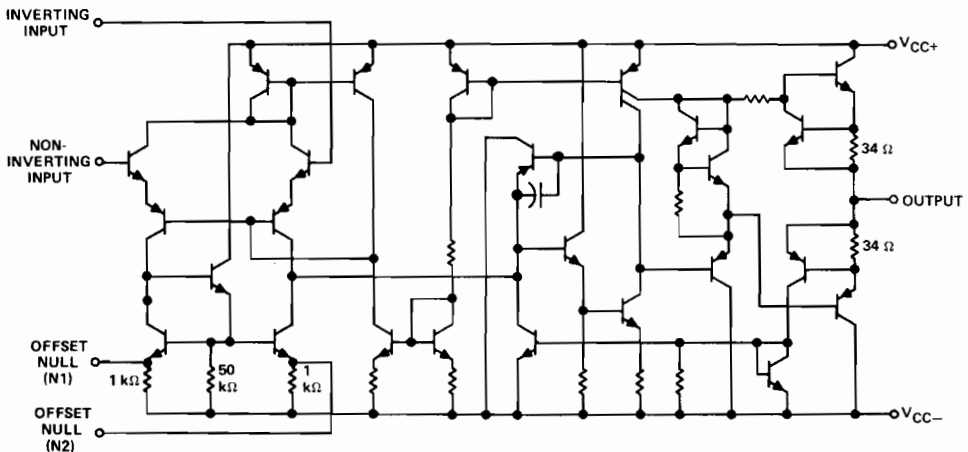
The high common-mode input voltage range and the absence of latch-up make this amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low-value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The  $\mu$ A747M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A747C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



\* On parts date-coded 7701 or higher, the two positive supply terminals (1  $V_{CC+}$  and 2  $V_{CC+}$ ) are connected together internally. For parts without this internal connection, order  $\mu$ A747-1M or  $\mu$ A747-1C.

**schematic (each amplifier)**



Resistor values shown are nominal

# TYPES $\mu$ A747M, $\mu$ A747C

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		$\mu$ A747M	$\mu$ A747C	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)		22	18	V	
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	V	
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	V	
Input voltage any input (see Notes 1 and 3)		$\pm 15$	$\pm 15$	V	
Voltage between any offset null terminal (N1/N2) and $V_{CC-}$		$\pm 0.5$	$\pm 0.5$	V	
Duration of output short-circuit (see Note 4)		unlimited	unlimited		
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	Each amplifier	500	500	mW	
	Total package J, N, or W package	800	800		
Operating free-air temperature range		-55 to 125	0 to 70	°C	
Storage temperature range		-65 to 150	-65 to 150	°C	
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds		J or W package	300	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds		N package		260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or either power supply. For the  $\mu$ A747M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.  
 5. For operation above 25°C free-air temperature and for total package ratings, refer to Dissipation Derating Table. In the J package,  $\mu$ A747M chips are alloy-mounted;  $\mu$ A747C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V

PARAMETER	TEST CONDITIONS†	$\mu$ A747M			$\mu$ A747C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 10$ k $\Omega$	25°C		1	5	1		6	mV
		Full range					7.5		
$\Delta V_{IO}(\text{adj})$ Offset voltage adjust range		25°C		$\pm 15$			$\pm 15$		mV
$I_{IO}$ Input offset current		25°C		20		20		200	nA
		Full range					300		
$I_{IB}$ Input bias current		25°C		80		80		500	nA
		Full range					800		
$V_{ICR}$ Common-mode input voltage range		25°C		$\pm 12$	$\pm 13$	$\pm 12$		$\pm 13$	V
		Full range					$\pm 12$		
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10$ k $\Omega$	25°C		24	28	24		28	V
	$R_L \geq 10$ k $\Omega$	Full range					24		
	$R_L = 2$ k $\Omega$	25°C		20	26	20		26	
	$R_L \geq 2$ k $\Omega$	Full range					20		
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C		50	200	25		200	V/mV
		Full range					15		
$r_i$ Input resistance		25°C		0.3	2	0.3		2	M $\Omega$
$r_o$ Output resistance	$V_O = 0$ V, See Note 6	25°C		75			75		$\Omega$
$C_i$ Input capacitance		25°C		1.4			1.4		pF
CMRR Common-mode rejection ratio	$R_S \leq 10$ k $\Omega$	25°C		70	90	70		90	dB
		Full range					70		
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 10$ k $\Omega$	25°C		30	150	30		150	$\mu$ V/V
		Full range					150		
$I_{OS}$ Short-circuit output current		25°C		$\pm 25$	$\pm 40$	$\pm 25$		$\pm 40$	mA
$I_{CC}$ Supply current (each amplifier)	No load, No signal	25°C		1.7		1.7		2.8	mA
		Full range					3.3		
$P_D$ Power dissipation (each amplifier)	No load, No signal	25°C		50		50		85	mW
		Full range					100		
$V_{O1}/V_{O2}$ Channel separation		25°C		120			120		dB

† All characteristics are specified under open-loop operation. Full range for  $\mu$ A747M is -55°C to 125°C and for  $\mu$ A747C is 0°C to 70°C.  
 NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

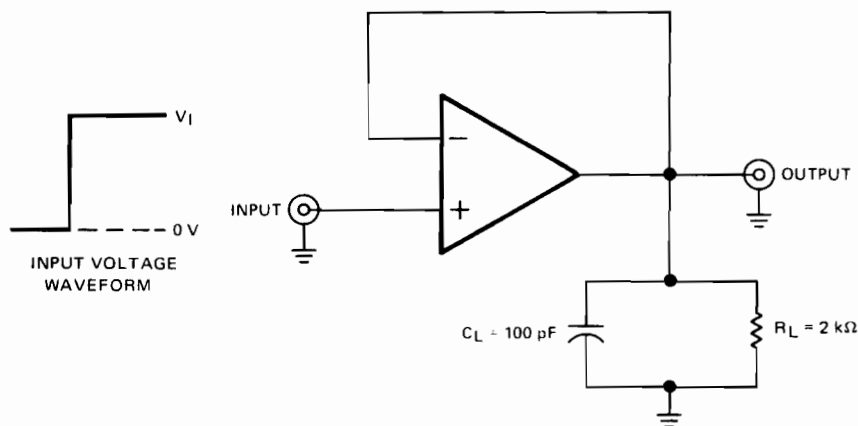
# TYPES $\mu$ A747M, $\mu$ A747C

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A747M			$\mu$ A747C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$	Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1						$\mu\text{s}$
	Overshoot factor	5%						5%
SR	Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1						$\text{V}/\mu\text{s}$

### PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

### TYPICAL APPLICATION DATA

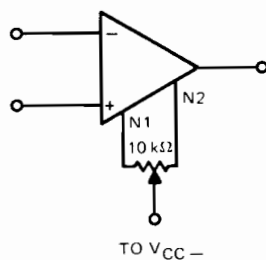


FIGURE 2—INPUT OFFSET VOLTAGE NULL CIRCUIT

#### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	800 mW	$11.0\text{ mW}/^\circ\text{C}$	$77^\circ\text{C}$
J (Glass-Mounted Chip)	800 mW	$8.2\text{ mW}/^\circ\text{C}$	$52^\circ\text{C}$
N	800 mW	$9.2\text{ mW}/^\circ\text{C}$	$63^\circ\text{C}$
W	800 mW	$8.0\text{ mW}/^\circ\text{C}$	$50^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPES $\mu$ A747M, $\mu$ A747C DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

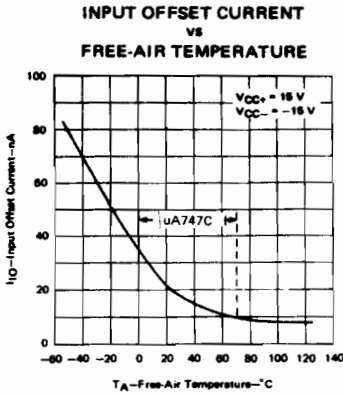


FIGURE 3

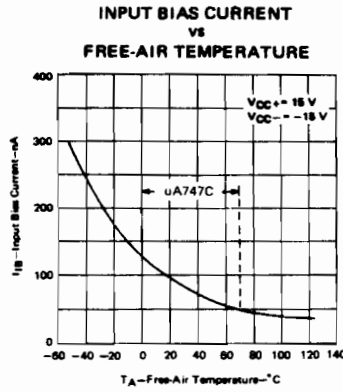


FIGURE 4

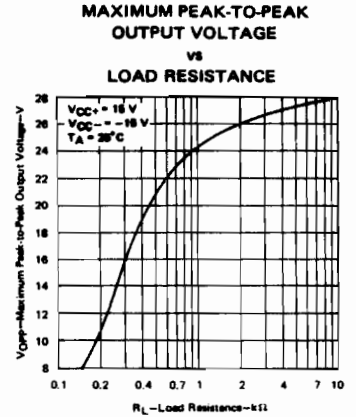


FIGURE 5

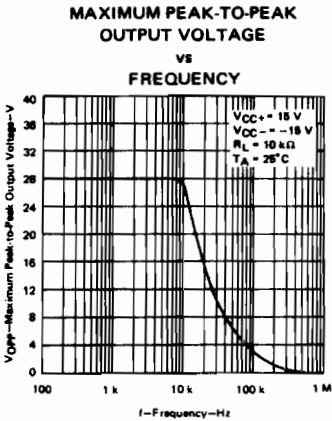


FIGURE 6

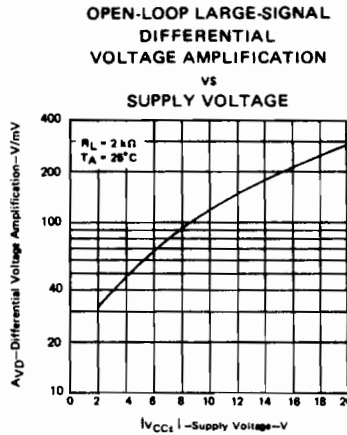


FIGURE 7

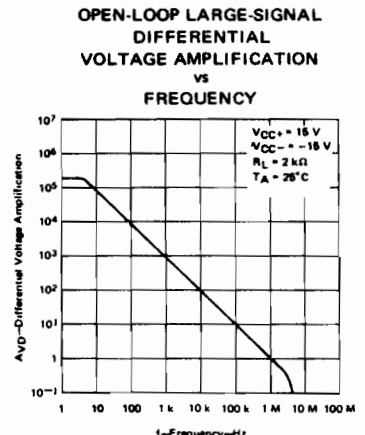


FIGURE 8

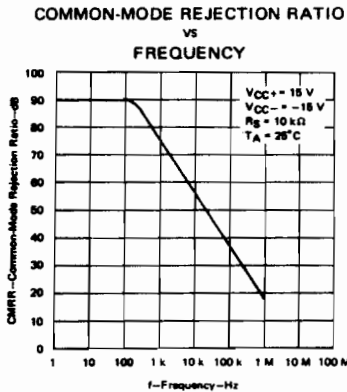


FIGURE 9

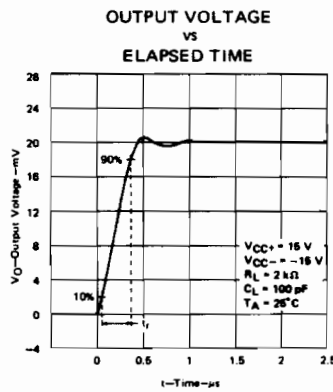


FIGURE 10

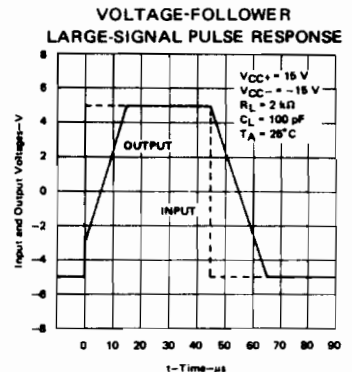


FIGURE 11

# LINEAR INTEGRATED CIRCUITS

# TYPES $\mu$ A748M, $\mu$ A748C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 11418, DECEMBER 1970—REVISED OCTOBER 1979

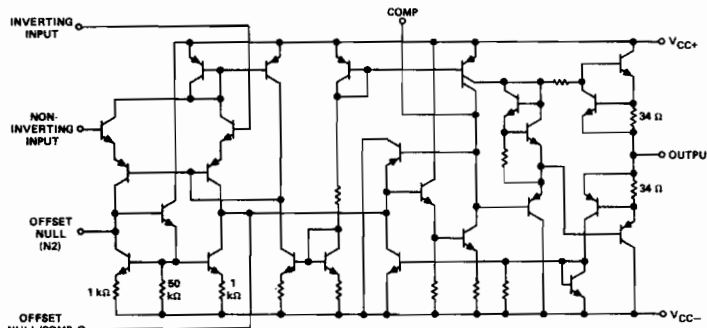
- Frequency and Transient Response Characteristics Adjustable
- Short-Circuit Protection
- Offset-Voltage Null Capability
- Wide Common-Mode and Differential Voltage Ranges
- Low Power Consumption
- No Latch-up
- Same Pin Assignments as  $\mu$ A709

## description

The  $\mu$ A748 is a general-purpose operational amplifier. It offers the same advantages and desirable features as the  $\mu$ A741 with the exception of internal compensation. The external compensation of the  $\mu$ A748 allows the changing of the frequency response (when the closed-loop gain is greater than unity) for applications requiring wider bandwidth or higher slew rate. This circuit features high gain, large differential and common-mode input voltage range, output short-circuit protection, and may be compensated under unity-gain conditions with a single 30-pF capacitor. A potentiometer may be connected between the offset null inputs, as shown in Figure 12, to null out the offset voltage.

The  $\mu$ A748M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A748C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## schematic

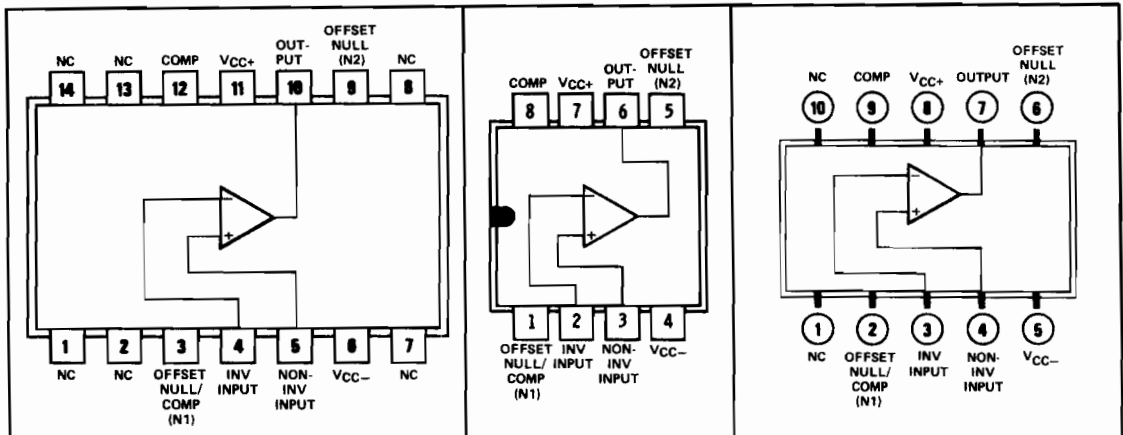


Resistor values shown are nominal.

J OR N DUAL-IN-LINE PACKAGE  
OR W FLAT PACKAGE (TOP VIEW)

JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)

U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

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# TYPES $\mu$ A748M, $\mu$ A748C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A748M	$\mu$ A748C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$	-0.5 to 2	-0.5 to 2	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1, 6 mm) from case for 60 seconds	J, JG, U, or W package		°C
Lead temperature 1/16 inch (1, 6 mm) from case for 10 seconds	N or P package		°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or either power supply. For the  $\mu$ A748M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J and JG package,  $\mu$ A748M chips are alloy-mounted;  $\mu$ A748C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V,  $C_C = 30$  pF

PARAMETER	TEST CONDITIONS†	$\mu$ A748M			$\mu$ A748C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 10$ k $\Omega$	25°C	1	5	1	6	mV	
		Full range		6		7.5		
$I_{IO}$ Input offset current		25°C	20	200	20	200	nA	
		Full range		500		300		
$I_{IB}$ Input bias current		25°C	80	500	80	500	nA	
		Full range		1500		800		
$V_{ICR}$ Common-mode input voltage range		25°C	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V	
		Full range	$\pm 12$		$\pm 12$			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10$ k $\Omega$	25°C	24	28	24	28	V	
	$R_L \geq 10$ k $\Omega$	Full range	24		24			
	$R_L = 2$ k $\Omega$	25°C	20	26	20	26		
	$R_L \geq 2$ k $\Omega$	Full range	20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C	50	200	20	200	V/mV	
		Full range	25		15			
$r_i$ Input resistance		25°C	0.3	2	0.3	2	M $\Omega$	
$r_o$ Output resistance	$V_O = 0$ V, See Note 6	25°C		75		75	$\Omega$	
$C_i$ Input capacitance		25°C		1.4		1.4	pF	
$CMRR$ Common-mode rejection ratio	$R_S \leq 10$ k $\Omega$	25°C	70	90	70	90	dB	
		Full range	70		70			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S \leq 10$ k $\Omega$	25°C	30	150	30	150	$\mu$ V/V	
		Full range		150		150		
$I_{OS}$ Short-circuit output current		25°C	$\pm 25$	$\pm 40$	$\pm 25$	$\pm 40$	mA	
$I_{CC}$ Supply current	No load, No signal	25°C	1.7	2.8	1.7	2.8	mA	
		Full range		3.3		3.3		
$P_D$ Total power dissipation	No load, No signal	25°C	50	85	50	85	mW	
		Full range		100		100		

† All characteristics are specified under open-loop operation. Full range for  $\mu$ A748M is -55°C to 125°C and for  $\mu$ A748C is 0°C to 70°C.  
 NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.



# TYPES $\mu$ A748M, $\mu$ A748C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A748M			$\mu$ A748C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $C_C = 30\text{ pF}$ , See Figure 1		0.3			0.3		$\mu\text{s}$
Overshoot factor	See Figure 1		5%			5%		
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $C_C = 30\text{ pF}$ , See Figure 1		0.5			0.5		$\text{V}/\mu\text{s}$

## PARAMETER MEASUREMENT INFORMATION

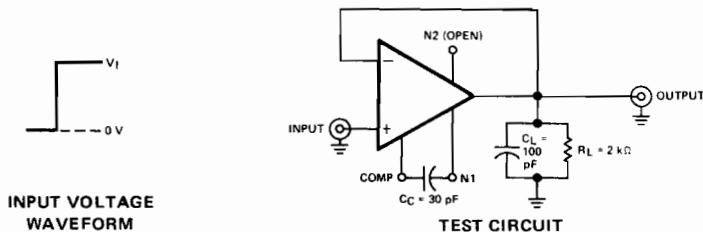


FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

## TYPICAL CHARACTERISTICS

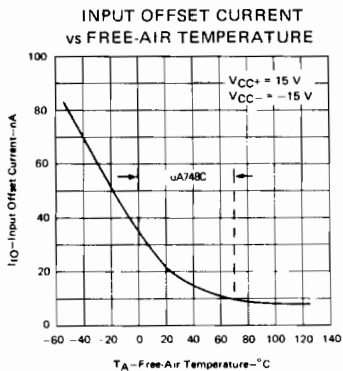


FIGURE 2

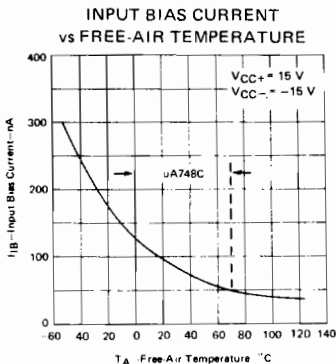


FIGURE 3

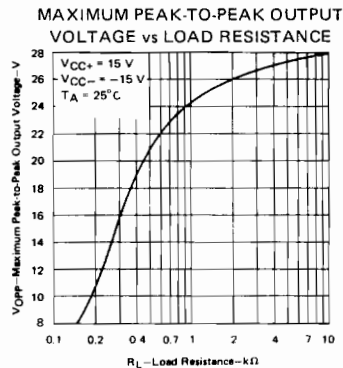


FIGURE 4

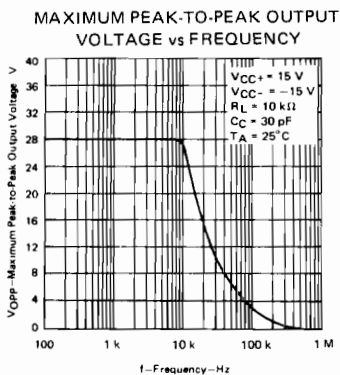


FIGURE 5

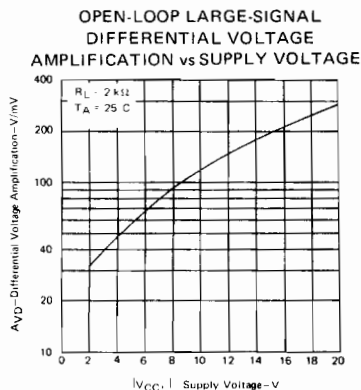


FIGURE 6

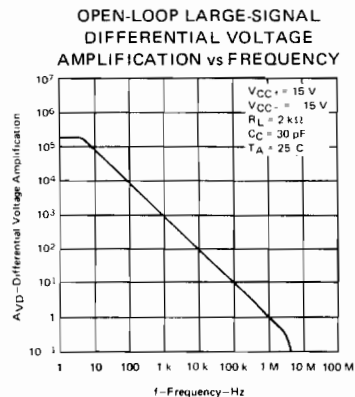


FIGURE 7

# TYPES $\mu$ A748M, $\mu$ A748C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO  
VS  
FREQUENCY

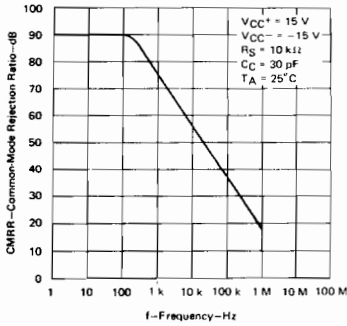


FIGURE 8

OUTPUT VOLTAGE  
VS  
ELAPSED TIME

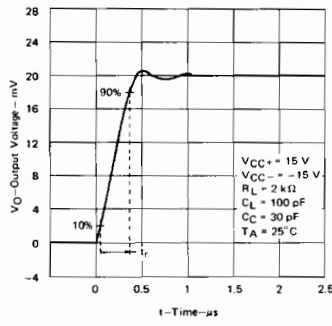


FIGURE 9

VOLTAGE-FOLLOWER  
LARGE-SIGNAL PULSE RESPONSE

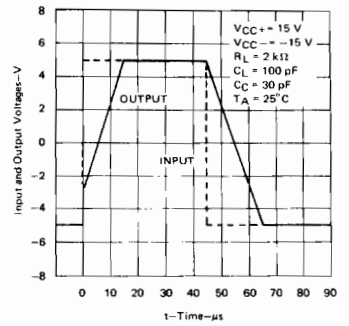
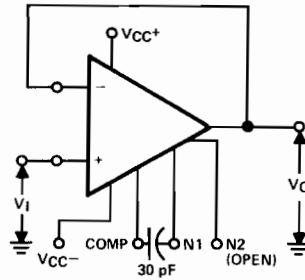


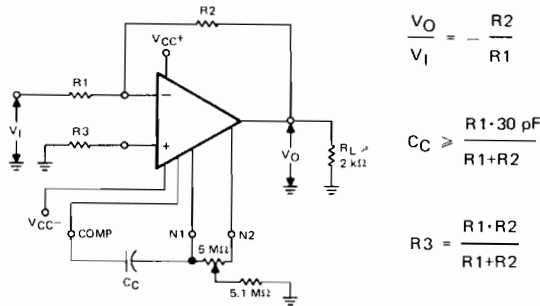
FIGURE 10

### TYPICAL APPLICATION DATA



$r_i = 400 \text{ M}\Omega$ ,  $r_o < 1 \Omega$ ,  
 $C_i = 1 \text{ pF}$ ,  $\text{BW} = 1 \text{ MHz}$

FIGURE 11—UNITY-GAIN VOLTAGE FOLLOWER



$$\frac{V_O}{V_I} = -\frac{R_2}{R_1}$$

$$C_C \approx \frac{R_1 \cdot 30 \text{ pF}}{R_1 + R_2}$$

$$R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

FIGURE 12—INVERTING CIRCUIT WITH ADJUSTABLE GAIN, COMPENSATION, AND OFFSET ADJUSTMENT

# LINEAR INTEGRATED CIRCUITS

# TYPE $\mu$ A777C HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

BULLETIN NO. DL-S 12307, SEPTEMBER 1973—REVISED OCTOBER 1979

- Low Input Currents
- Low Input Offset Parameters
- Frequency and Transient Response Characteristics Adjustable
- Short-Circuit Protection
- Offset-Voltage Null Capability
- No Latch-Up
- Wide Common-Mode and Differential Voltage Ranges
- Same Pin Assignments as  $\mu$ A748,  $\mu$ A709, LM101A/LM301 except U Package

## description

The  $\mu$ A777 is a precision operational amplifier. Low offset and bias currents improve system accuracy when used in applications such as long-term integrators, sample-and-hold circuits, and high-source-impedance summing amplifiers. This device is an excellent choice where a performance between that of super-beta and general purpose operational amplifiers is required.

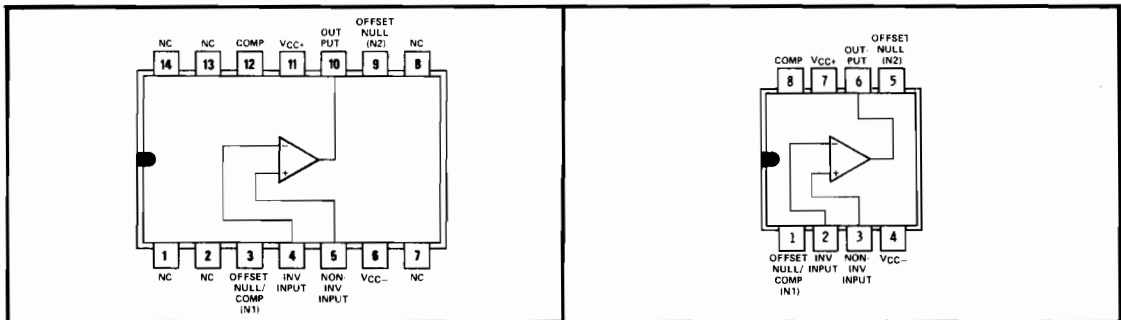
External compensation of the  $\mu$ A777 may be implemented in either normal or feed-forward configuration to satisfy bandwidth and slew-rate requirements. This circuit features high gain, wide differential and common-mode input voltage range, output short-circuit protection, and null capability.

The  $\mu$ A777C is characterized for operation from 0°C to 70°C.

## terminal assignments

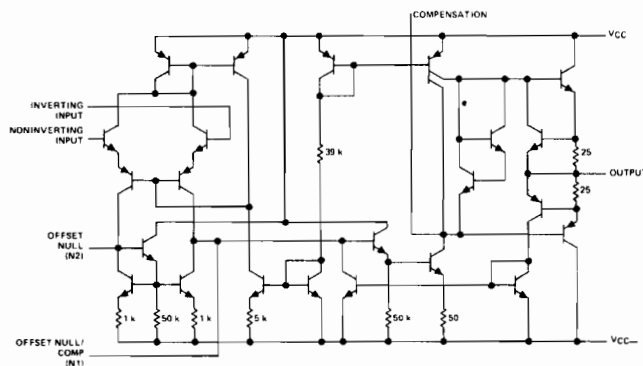
JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW)

J OR N DUAL-IN-LINE PACKAGE (TOP VIEW)



NC—No internal connection.

## schematic



Resistor values shown are nominal and in ohms.

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# TYPE $\mu$ A777C

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		$\mu$ A777C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	V
Differential input voltage (see Note 2)		$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)		$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$		-0.5 to 2	V
Duration of output short-circuit (see Note 4)		unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)		500	mW
Operating free-air temperature range		0 to 70	°C
Storage temperature range		-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or JG package	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or either power supply.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J and JG package,  $\mu$ A777C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V,  $C_C = 30$  pF (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$R_S \leq 50$ k $\Omega$	25°C	0.7	5	mV	
			0°C to 70°C		5		
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	$R_S \leq 50$ k $\Omega$	0°C to 70°C	4	30	$\mu$ V/°C	
$I_{IO}$	Input offset current		25°C	0.7	20	nA	
			0°C to 70°C		40		
$\alpha I_{IO}$	Average temperature coefficient of input offset current		0°C to 25°C	20	600	pA/°C	
			25°C to 70°C	10	300		
$I_{IB}$	Input bias current		25°C	25	100	nA	
			0°C to 70°C		200		
$V_{ICR}$	Common-mode input voltage range		0°C to 70°C	$\pm 12$	$\pm 13$	V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$R_L = 10$ k $\Omega$	0°C to 70°C	24	28	V	
		$R_L = 2$ k $\Omega$	0°C to 70°C	20	26		
$A_{VD}$	Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L \geq 2$ k $\Omega$	25°C	25	250	V/mV	
			0°C to 70°C	15			
$r_i$	Input resistance		25°C	1	2	M $\Omega$	
$r_o$	Output resistance		25°C		100	$\Omega$	
$C_i$	Input capacitance		25°C		3	pF	
CMRR	Common-mode rejection ratio	$R_S = 50$ k $\Omega$	0°C to 70°C	70	95	dB	
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$R_S \leq 50$ k $\Omega$	0°C to 70°C	15	150	$\mu$ V/V	
$I_{OS}$	Short-circuit output current		25°C	$\pm 25$		mA	
$I_{CC}$	Supply current	No load, No signal	25°C	1.9	3.3	mA	
			0°C		3.3		
			70°C		3.3		

† All characteristics are specified under open-loop operation.

# TYPE $\mu$ A777C

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		$\mu$ A777C			UNIT
			MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$A_V = 1$ , $C_C = 30\text{ pF}$	0.3		$\mu\text{s}$	
		$A_V = 10$ , $C_C = 3.5\text{ pF}$	0.2			
Overshoot factor	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$A_V = 1$ , $C_C = 30\text{ pF}$	5%			
		$A_V = 10$ , $C_C = 3.5\text{ pF}$	5%			
SR Slew rate	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$A_V = 1$ , $C_C = 30\text{ pF}$	0.5		$\text{V}/\mu\text{s}$	
		$A_V = 10$ , $C_C = 3.5\text{ pF}$	5.5			

### PARAMETER MEASUREMENT INFORMATION

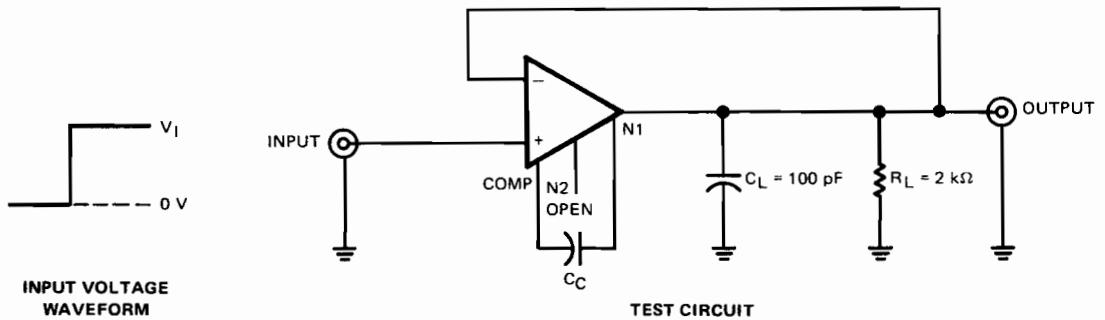


FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	500 mW	$11.0\text{ mW}/^\circ\text{C}$	$105^\circ\text{C}$
J (Glass-Mounted Chip)	500 mW	$8.2\text{ mW}/^\circ\text{C}$	$89^\circ\text{C}$
JG (Alloy-Mounted Chip)	500 mW	$8.4\text{ mW}/^\circ\text{C}$	$90^\circ\text{C}$
JG (Glass-Mounted Chip)	500 mW	$6.6\text{ mW}/^\circ\text{C}$	$74^\circ\text{C}$
N	500 mW	$9.2\text{ mW}/^\circ\text{C}$	$96^\circ\text{C}$
P	500 mW	$8.0\text{ mW}/^\circ\text{C}$	$87^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPE $\mu$ A77C

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

### TYPICAL CHARACTERISTICS

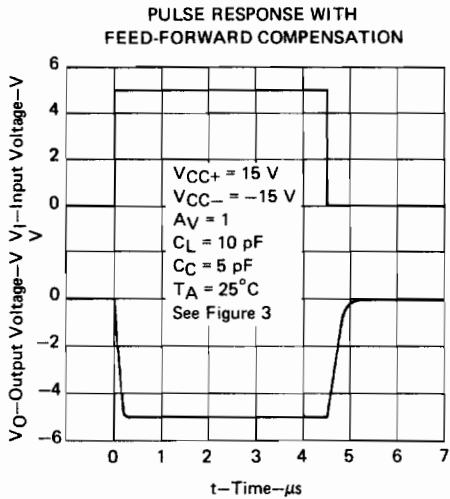


FIGURE 2

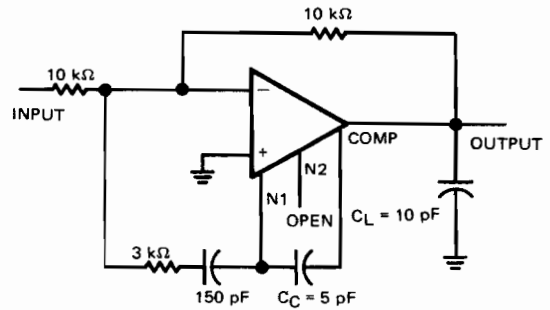


FIGURE 3—INVERTING CIRCUIT WITH UNITY GAIN AND FEED-FORWARD COMPENSATION

### TYPICAL APPLICATION DATA

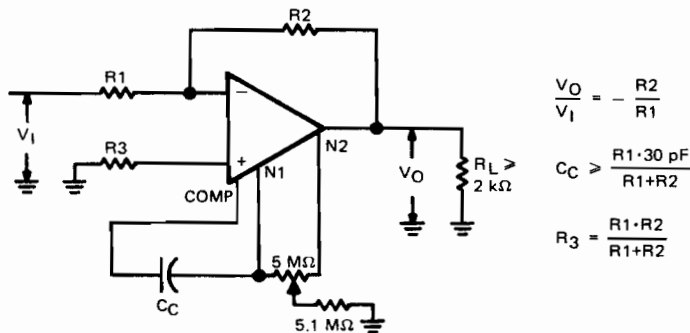


FIGURE 4—INVERTING CIRCUIT WITH ADJUSTABLE GAIN, SINGLE-POLE COMPENSATION, AND OFFSET ADJUSTMENT

# Voltage Comparators

# SELECTION GUIDE

## VOLTAGE COMPARATORS

### Military Temperature Range (–55°C to 125°C)

	$I_{IB}$ $\mu A$ MAX	$V_{IO}$ mV MAX	$I_{IO}$ $\mu A$ MAX	AVD	$I_{OL}$ mA MIN	RESPONSE TIME ns	POWER SUPPLIES	DEVICE	PACKAGE	PAGE
Single	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	LM106	J, JG, W	195
	0.15	4	0.02	200,000 TYP	8	140 TYP	15 V, –15 V	LM111	J, JG	201
	0.05	4	0.02	200,000 TYP	8	210 TYP	15 V, –15 V	TL111	J, JG, N, P	219
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL331M	JG	223
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL510M	J, JG, U	233
	150	6	20	500 MIN	1.6	40 TYP	12 V, –6 V	TL710M	J, JG, U	239
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL810M	J, JG, U	245
	20	2	3	1250 MIN	2	40 TYP	12 V, –6 V	uA710M	J, JG, U	259
Dual	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	LM193 <sup>†</sup>	JG, U	211
	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	TL506M	J, W	227
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL514M	J, W	237
	25	3	7	10,000 MIN	0.5	80 MAX	12 V, –6 V	TL820M	J	255
Dual- Channel	30	6	5	8,000 MIN	0.5	80 MAX	12 V, –6 V	TL811M	J, U	249
	150	6	20	500 MIN	0.5	80 MAX	12 V, –6 V	uA711M	J, U	263
Quad	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	LM139 <sup>†</sup>	J, W	209
Hex	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL336M <sup>†</sup>	J	225

### Automotive Temperature Range (–40°C to 85°C)

Dual	0.25	7	0.05	100,000 TYP	6	1300 TYP	2 V to 36 V	LM2903 <sup>†</sup>	JG, P	215
Quad	0.25	7	0.05	100,000 TYP	6	1300 TYP	2 V to 36 V	LM2901 <sup>†</sup>	J, N	213
	0.5	20	0.1	30,000 TYP	6	1300 TYP	2 V to 28 V	LM3302 <sup>†</sup>	J, N	217

<sup>†</sup> Capable of operating with a single 5-volt supply.



## VOLTAGE COMPARATORS

### Industrial Temperature Range (–25°C to 85°C)

	I <sub>IB</sub> μA MAX	V <sub>IO</sub> mV MAX	I <sub>IO</sub> μA MAX	A <sub>VD</sub>	I <sub>OL</sub> mA MIN	RESPONSE TIME ns	POWER SUPPLIES	DEVICE	PACKAGE	PAGE
Single	45	3	7	40,000 TYP	16	40 MAX	12 V, –3 V to –12 V	LM206	J, JG, N, P	195
	0.15	4	0.2	200,000 TYP	8	140 TYP	15 V, –15 V	LM211†	J, JG, P	201
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3111†	JG, P	223
	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3311†	JG, P	223
Dual	0.25	5	0.005	200,000 TYP	6	1300 TYP	2 V to 36 V	LM293†	JG, P	211
Quad	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM239†	J, N	209
Hex	0.1	5	0.025	200,000 TYP	6	1300 TYP	2 V to 36 V	TL3361†	J, N	225

### Commercial Temperature Range (0°C to 70°C)

Single	40	6.5	7.5	40,000 TYP	16	28 TYP	12 V, –3 V to –12 V	LM306	J, JG, N, P	195
	0.3	10	0.07	200,000 TYP	8	165 TYP	15 V, –15 V	LM311†	J, JG, N, P	201
	0.01	13	0.004	200,000 TYP	8	210 TYP	15 V, –15 V	TL311†	N, P	219
	0.01	10	0.004	200,000 TYP	8	210 TYP	15 V, –15 V	TL311A†	N, P	219
	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	TL331C†	JG, P	223
	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL510C	J, JG, N, P	233
	150	10	25	500 MIN		40 MAX	12 V, –6 V	TL710C	J, JG, N, P	239
	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL810C	J, JG, N, P	245
Dual	25	5	5	1000 MIN	1.6	40 TYP	12 V, –6 V	uA710C	J, JG, N, P	259
	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM393†	JG, P	211
	40	6.5	7.5	40,000 TYP	16	28 TYP	12 V, –3 V to –12 V	TL506C	J, N	227
	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL514C	J, N	237
Dual Channel	30	4.5	7.5	8000 MIN	0.5	80 MAX	12 V, –6 V	TL820C	J, N	255
	50	10	10	5000 MIN	0.5	33 TYP	12 V, –6 V	TL810C	J, JG, N, P	245
Quad	150	10	25	500 MIN	0.5	40 TYP	12 V, –6 V	uA711C	J, N	263
Hex	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	LM339†	J, N	209
	0.25	5	0.05	200,000 TYP	6	1300 TYP	2 V to 36 V	TL336C†	N	225

† Capable of operating with a single 5-volt supply.

# GLOSSARY

## DIFFERENTIAL COMPARATOR TERMS, DEFINITIONS, AND SYMBOLS

---

### Input Offset Voltage ( $V_{IO}$ )

The d-c voltage that must be applied between the input terminals to force the quiescent d-c output voltage to the specified level.

NOTE: The input offset voltage may also be defined for the case where two equal resistances ( $R_S$ ) are inserted in series with the input leads.

### Average Temperature Coefficient of Input Offset Voltage ( $\alpha_{VIO}$ )

The ratio of the change in input offset voltage to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{VIO} = \left| \frac{(V_{IO} @ T_{A(1)}) - (V_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right| \quad \text{where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

### Input Offset Current ( $I_{IO}$ )

The difference between the currents into the two input terminals with the output at the specified level.

### Average Temperature Coefficient of Input Offset Current ( $\alpha_{IIO}$ )

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{IIO} = \left| \frac{(I_{IO} @ T_{A(1)}) - (I_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right| \quad \text{where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

### Input Bias Current ( $I_{IB}$ )

The average of the currents into the two input terminals with the output at the specified level.

### High-Level Strobe Current ( $I_{IH(S)}$ )

The current flowing into or out of\* the strobe at a high-level voltage.

### Low-Level Strobe Current ( $I_{IL(S)}$ )

The current flowing out of\* the strobe at a low-level voltage.

### High-Level Strobe Voltage ( $V_{IH(S)}$ )

For a device having an active-low strobe, a voltage within the range that is guaranteed not to interfere with the operation of the comparator.

### Low-Level Strobe Voltage ( $V_{IL(S)}$ )

For a device having an active-low strobe, a voltage within the range that is guaranteed to force the output high or low, as specified, independently of the differential inputs.

### Input Voltage Range ( $V_I$ )

The range of voltage that if exceeded at either input terminal will cause the comparator to cease functioning properly.

\*Current out of a terminal is given as a negative value.

# GLOSSARY

## DIFFERENTIAL COMPARATOR TERMS, DEFINITIONS, AND SYMBOLS

---

### Common-Mode Input Voltage ( $V_{IC}$ )

The average of the two input voltages.

### Common-Mode Input Voltage Range ( $V_{ICR}$ )

The range of common-mode input voltage that if exceeded will cause the comparator to cease functioning properly.

### Differential Input Voltage ( $V_{ID}$ )

The voltage at the noninverting input with respect to the inverting input.

### Differential Input Voltage Range ( $V_{ID}$ )

The range of voltage between the two input terminals that if exceeded will cause the comparator to cease functioning properly.

### Differential Voltage Amplification ( $A_{VD}$ )

The ratio of the change in output voltage to the change in differential input voltage producing it with the common-mode input voltage held constant.

### High-Level Output Voltage ( $V_{OH}$ )

The voltage at an output with input conditions applied that according to the product specification will establish a high level at the output.

### Low-Level Output Voltage ( $V_{OL}$ )

The voltage at an output with input conditions applied that according to the product specification will establish a low level at the output.

### High-Level Output Current, ( $I_{OH}$ )

The current into\* an output with input conditions applied that according to the product specification will establish a high level at the output.

### Low-Level Output Current, ( $I_{OL}$ )

The current into\* an output with input conditions applied that according to the product specification will establish a low level at the output.

### Output Resistance ( $r_o$ )

The resistance between an output terminal and ground.

### Common-Mode Rejection Ratio ( $k_{CMR}$ , $CMRR$ )

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

---

\* Current out of a terminal is given as a negative value.

# GLOSSARY

## DIFFERENTIAL COMPARATOR TERMS, DEFINITIONS, AND SYMBOLS

---

### Supply Current ( $I_{CC+}$ , $I_{CC-}$ )

The current into\* the  $V_{CC+}$  or  $V_{CC-}$  terminal of an integrated circuit.

### Total Power Dissipation ( $P_D$ )

The total d-c power supplied to the device less any power delivered from the device to a load.

NOTE: At no load:  $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$ .

### Response Time

The interval between the application of an input step function and the instant when the output crosses the logic threshold voltage.

NOTE: The input step drives the comparator from some initial condition sufficient to saturate the output (or in the case of high-to-low-level response time, to turn the output off) to an input level just barely in excess of that required to bring the output back to the logic threshold voltage. This excess is referred to as the voltage overdrive.

### Strobe Release Time

The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from its active logic level to its inactive logic level.

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\*Current out of a terminal is given as a negative value.

# LINEAR INTEGRATED CIRCUITS

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

BULLETIN NO. DL-S 11586, JANUARY 1972—REVISED OCTOBER 1979

- Fast Response Times
- Improved Gain and Accuracy
- Fan-Out to 10 Series 54/74 TTL Loads
- Strobe Capability
- Short-Circuit and Surge Protection
- Designed to be Interchangeable with National Semiconductor LM106, LM206, and LM306

## description

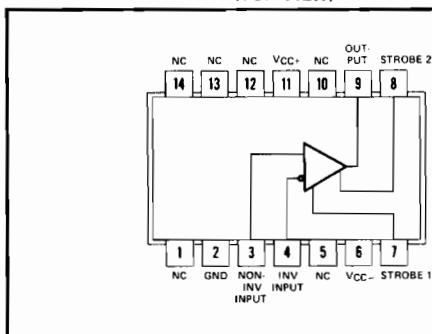
The LM106, LM206, and LM306 are high-speed voltage comparators with differential inputs, a low-impedance high-sink-current (100 mA) output, and two strobe inputs. These devices detect low-level analog or digital signals and can drive digital logic or lamps and relays directly. Short-circuit protection and surge-current limiting is provided.

The circuit is similar to a TL810 with gated output. A low-level input at either strobe causes the output to remain high regardless of the differential input. When both strobe inputs are either open or at a high logic level, the output voltage is controlled by the differential input voltage. The circuit will operate with any negative supply voltage between  $-3\text{ V}$  and  $-12\text{ V}$  with little difference in performance.

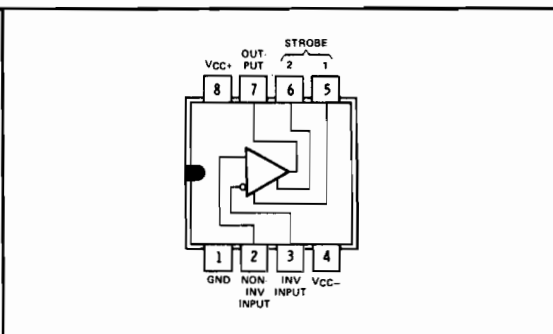
The LM106 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM206 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM306 from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments

J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)



JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	15 V
Supply voltage $V_{CC-}$ (see Note 1)	$-15\text{ V}$
Differential input voltage (see Note 2)	$\pm 5\text{ V}$
Input voltage (either input, see Notes 1 and 3)	$\pm 7\text{ V}$
Strobe voltage range (see Note 1)	$0\text{ V}$ to $V_{CC+}$
Output voltage (see Note 1)	$24\text{ V}$
Voltage from output to $V_{CC-}$	$30\text{ V}$
Duration of output short-circuit (see Note 4)	$10\text{ s}$
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	$600\text{ mW}$
Operating free-air temperature range:	
LM106 Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
LM206 Circuits	$-25^{\circ}\text{C}$ to $85^{\circ}\text{C}$
LM306 Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J, JG, or W package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N or P package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages and the voltage from the output to  $V_{CC-}$ , are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 7 volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, LM106 chips are alloy-mounted; LM206 and LM306 chips are glass-mounted.

# TYPES LM106, LM206, LM306

## DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -3\text{ V}$  to  $-12\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		LM106, LM206			LM306			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ ,	See Note 6	25°C	0.5§ 2		1.6§ 5			mV
			Full range	3		6.5			
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ ,	See Note 6	Full range	3 10		5 20			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current		See Note 6	25°C	0.7§ 3		1.8§ 5			$\mu\text{A}$
			MIN	2 7		1 7.5			
			MAX	0.4 3		0.5 5			
$\alpha_{IIO}$ Average temperature coefficient of input offset current		See Note 6	MIN to 25°C	15 75		24 100			$\text{nA}/^\circ\text{C}$
			25°C to MAX	5 25		15 50			
$I_{IB}$ Input bias current	$V_O = 0.5\text{ V}$ to $5\text{ V}$		MIN to 25°C	45		40			$\mu\text{A}$
			25°C to MAX	7§ 20		16§ 25			
$I_{L(S)}$ Low-level strobe current	$V_{(\text{strobe})} = 0.4\text{ V}$		Full range	-1.7§ -3.2		-1.7§ -3.2			mA
$V_{IH(S)}$ High level strobe voltage			Full range	2.2		2.2			V
$V_{IL(S)}$ Low-level strobe voltage			Full range	0.9		0.9			V
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$ to $-12\text{ V}$		Full range	±5		±5			V
$V_{ID}$ Differential input voltage range			Full range	±5		±5			V
$AVD$ Large-signal differential voltage amplification	No load, $V_O = 0.5\text{ V}$ to $5\text{ V}$		25°C	40 §		40 §			V/mV
$V_{OH}$ High-level output voltage	$I_{OH} = -400\ \mu\text{A}$		$V_{ID} = 5\text{ mV}$	Full range		2.5 5.5		V	
			$V_{ID} = 8\text{ mV}$	Full range		2.5 5.5			
$V_{OL}$ Low-level output voltage	$I_{OL} = 100\text{ mA}$		$V_{ID} = -5\text{ mV}$	25°C		0.8§ 1.5		V	
			$V_{ID} = -7\text{ mV}$	25°C		0.8§ 2			
	$I_{OL} = 50\text{ mA}$		$V_{ID} = -5\text{ mV}$	Full range		1			
			$V_{ID} = -8\text{ mV}$	Full range		1			
	$I_{OL} = 16\text{ mA}$		$V_{ID} = -5\text{ mV}$	Full range		0.4			
			$V_{ID} = -8\text{ mV}$	Full range		0.4			
$I_{OH}$ High-level output current	$V_{OH} = 8\text{ V}$ to $24\text{ V}$		$V_{ID} = 5\text{ mV}$	MIN to 25°C		0.02§ 1		$\mu\text{A}$	
			$V_{ID} = 7\text{ mV}$	25°C to MAX		100			
			$V_{ID} = 8\text{ mV}$	MIN to 25°C		0.02§ 2			
			$V_{ID} = 8\text{ mV}$	25°C to MAX		100			
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , No load		Full range	6.6§ 10		6.6 10		mA	
$I_{CC-}$ Supply current from $V_{CC-}$	No load		Full range	-1.9§ -3.6		-1.9§ -3.6		mA	

† Unless otherwise noted, all characteristics are measured with the strobe open.

§ These typical values are at  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$ . Full range (MIN to MAX) for LM106 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ ; for LM206 is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ ; and for LM306 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 6: The offset voltages and offset currents given are the maximum values required to drive the output down to the low range ( $V_{OL}$ ) or up to the high range ( $V_{OH}$ ). Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

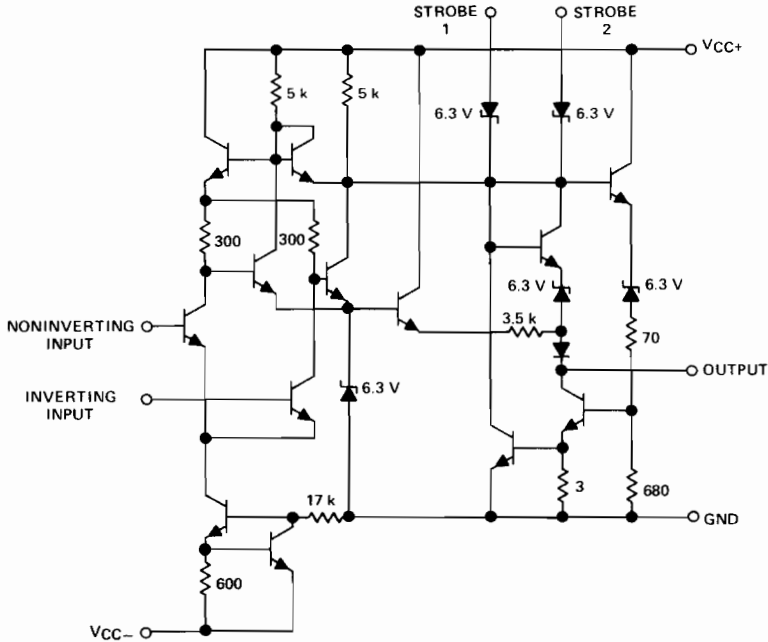
switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS†		LM106, LM206			LM306			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Response time, low-to-high-level output	$R_L = 390\ \Omega$ to $5\text{ V}$ ,	$C_L = 15\text{ pF}$ , See Note 7	28	40		28			ns

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

schematic

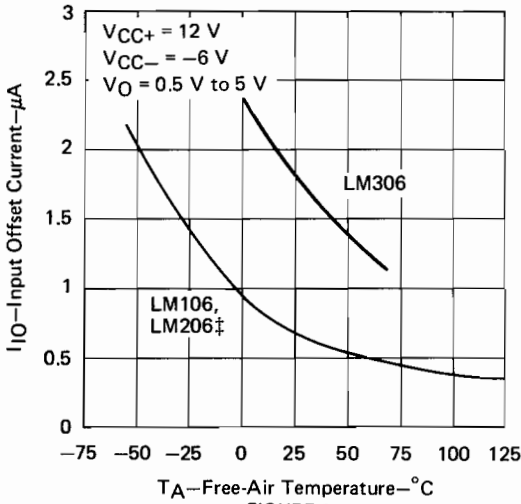


Resistor values are nominal in ohms.

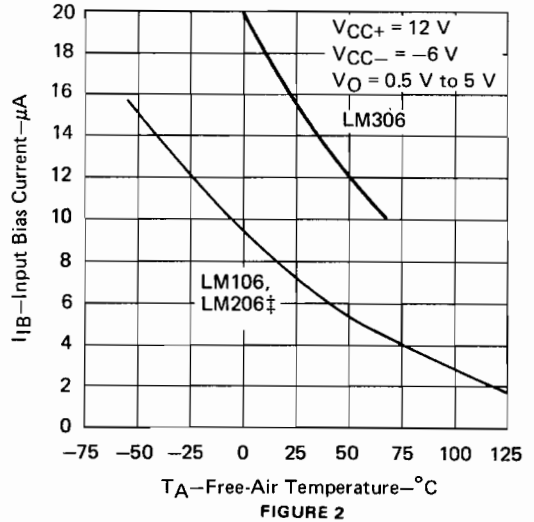
## TYPICAL CHARACTERISTICS

5

INPUT OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE



INPUT BIAS CURRENT  
vs  
FREE-AIR TEMPERATURE



‡ Data for free-air temperatures below -25°C and above 85°C is applicable for LM106 only.

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS ‡

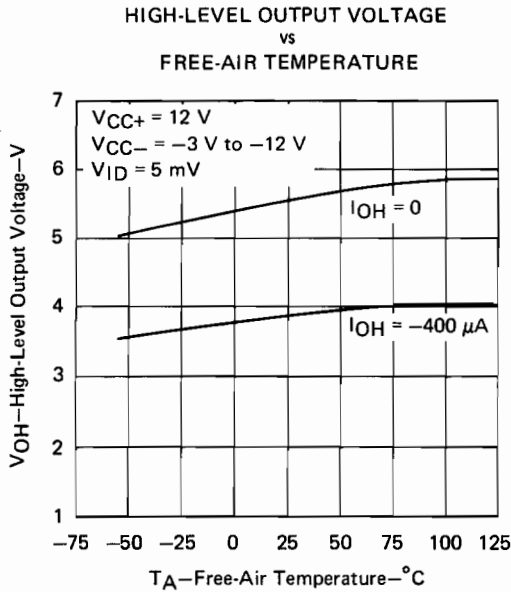


FIGURE 3

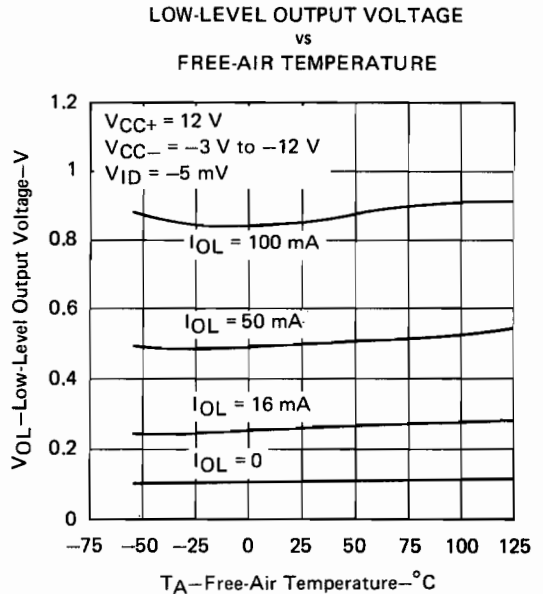


FIGURE 4

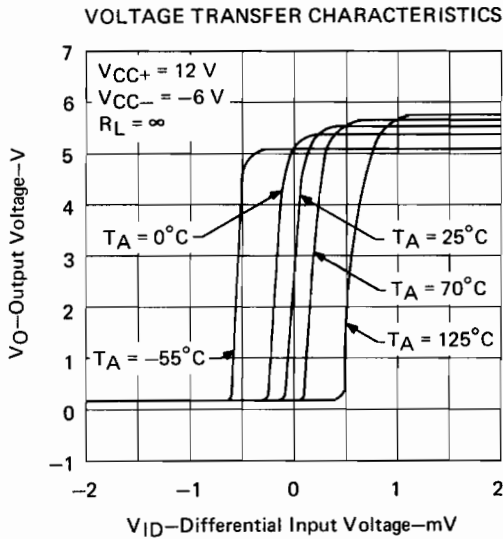


FIGURE 5

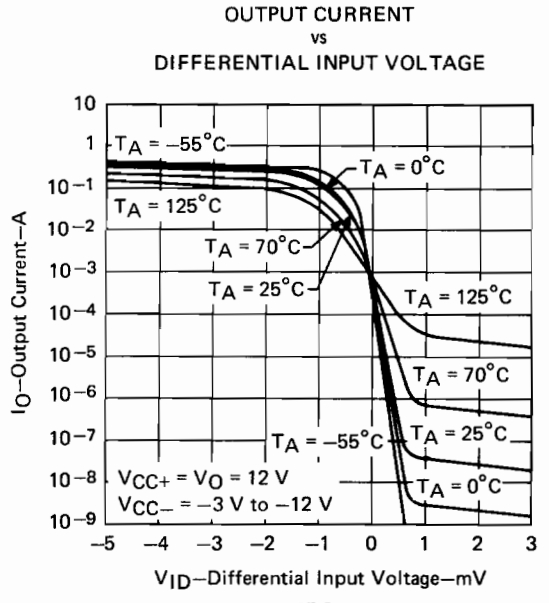


FIGURE 6

‡Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.



# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>‡</sup>

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

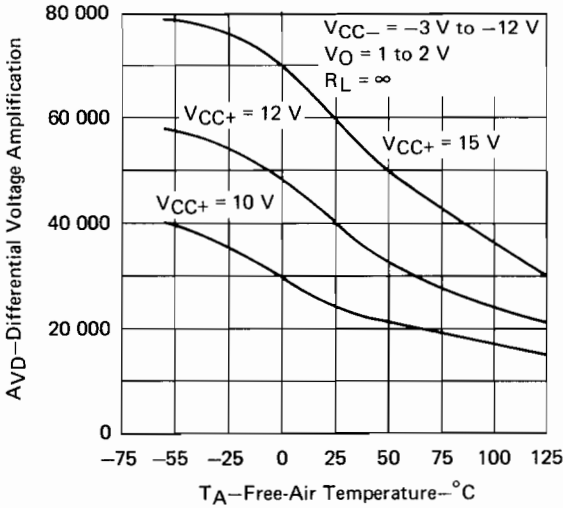


FIGURE 7

SHORT-CIRCUIT OUTPUT CURRENT  
vs  
FREE-AIR TEMPERATURE

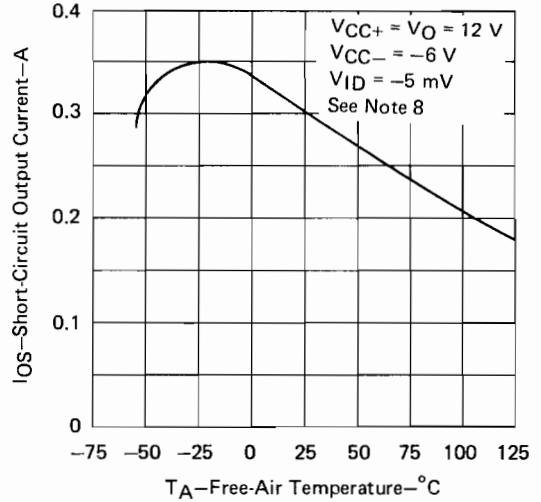


FIGURE 8

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

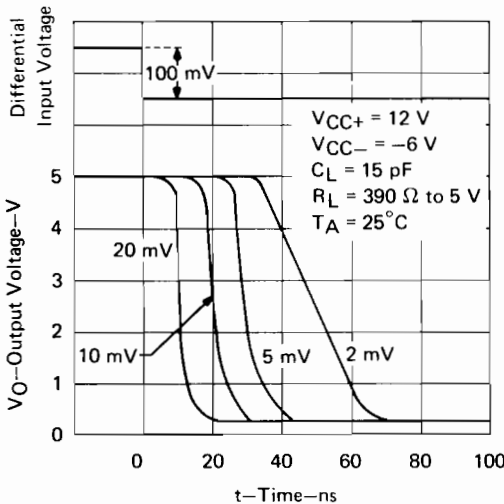


FIGURE 9

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

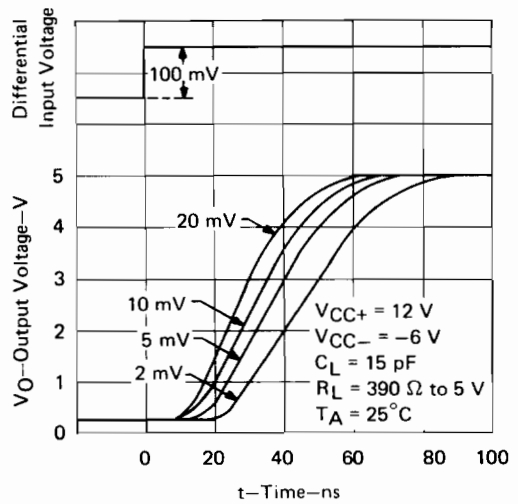


FIGURE 10

<sup>‡</sup>Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.  
NOTE 8: This parameter was measured using a single 5-ms pulse.

# TYPES LM106, LM206, LM306

## DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS ‡

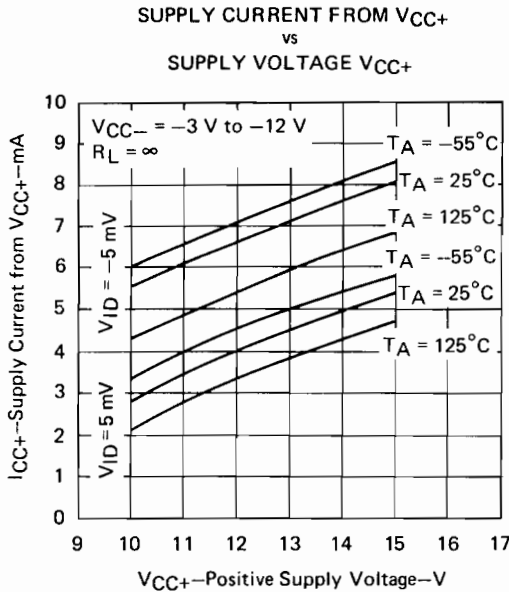


FIGURE 11

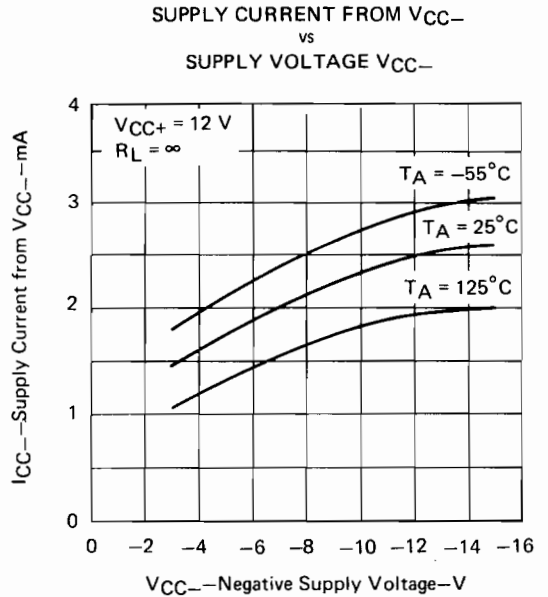


FIGURE 12

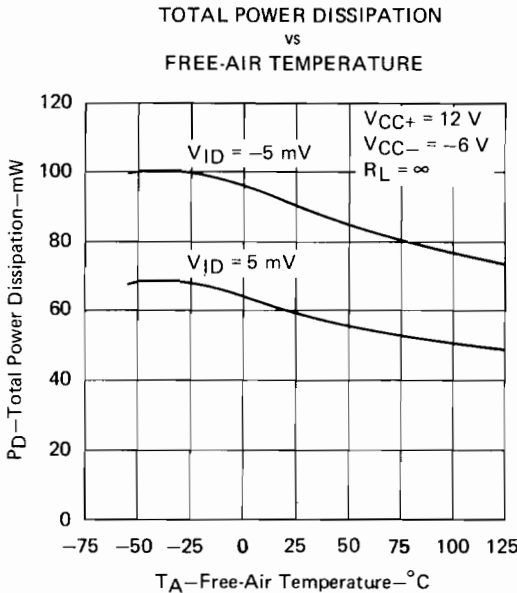


FIGURE 13

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	600 mW	11.0 mW/ $^\circ\text{C}$	95 $^\circ\text{C}$
J (Glass-Mounted Chip)	600 mW	8.2 mW/ $^\circ\text{C}$	77 $^\circ\text{C}$
JG (Alloy-Mounted Chip)	600 mW	8.4 mW/ $^\circ\text{C}$	79 $^\circ\text{C}$
JG (Glass-Mounted Chip)	600 mW	6.6 mW/ $^\circ\text{C}$	59 $^\circ\text{C}$
N	600 mW	9.2 mW/ $^\circ\text{C}$	85 $^\circ\text{C}$
P	600 mW	8.0 mW/ $^\circ\text{C}$	75 $^\circ\text{C}$
W	600 mW	8.0 mW/ $^\circ\text{C}$	75 $^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

‡Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.

# LINEAR INTEGRATED CIRCUITS

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

BULLETIN NO. DL-S 11797, SEPTEMBER 1973—REVISED OCTOBER 1979

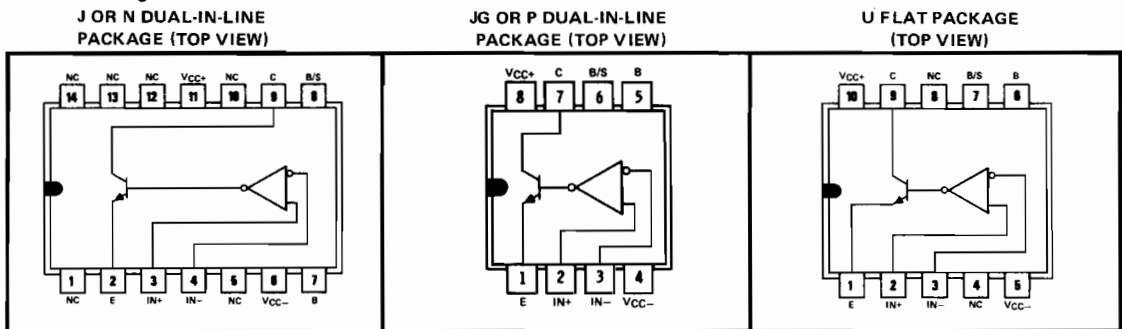
- Fast Response Times
- Strobe Capability
- Designed to be Interchangeable with National Semiconductor LM111, LM211, and LM311
- Maximum Input Bias Current. . . 300 nA
- Maximum Input Offset Current. . . 70 nA
- Can Operate From Single 5-V Supply

## description

The LM111, LM211, and LM311 are single high-speed voltage comparators. These devices are designed to operate from a wide range of power supply voltage, including  $\pm 15$ -volt supplies for operational amplifiers and 5-volt supplies for logic systems. The output levels are compatible with most DTL, TTL, and MOS circuits. These comparators are capable of driving lamps or relays and switching voltages up to 50 volts at 50 milliamperes. All inputs and outputs can be isolated from system ground. The outputs can drive loads referenced to ground,  $V_{CC+}$ , or  $V_{CC-}$ . Offset balancing and strobe capability are available and the outputs can be wire-OR connected. If the strobe input is low, the output will be in the off state regardless of the differential input. Although slower than the TL506 and TL514, these devices are not as sensitive to spurious oscillations.

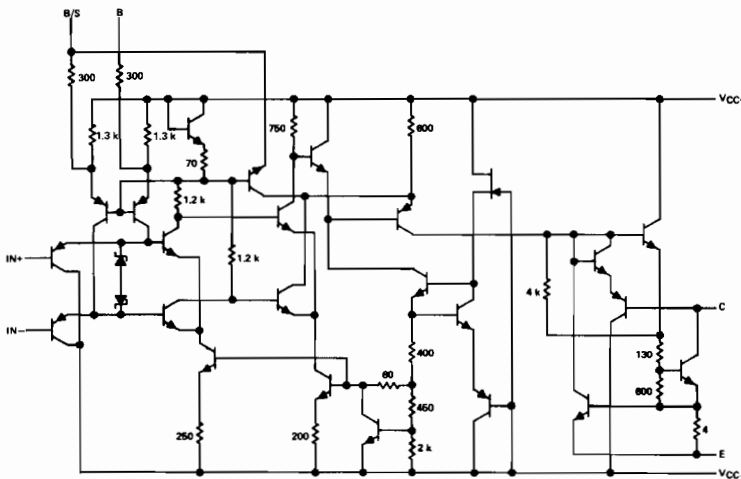
The LM111 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM211 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM311 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments



NC—No internal connection

## schematic



Resistor values shown are nominal and in ohms.

- B Balance
- B/S Balance/Strobe
- C Collector Output
- E Emitter Output
- IN+ Noninverting Input
- IN- Inverting Input
- NC No Internal Connection
- $V_{CC+}$  Positive Supply Voltage
- $V_{CC-}$  Negative Supply Voltage

5

# TYPES LM111, LM211, LM311

## DIFFERENTIAL COMPARATORS WITH STROBES

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM111	LM211	LM311	UNIT	
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V	
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V	
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V	
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V	
Voltage from emitter output to $V_{CC-}$	30	30	30	V	
Voltage from collector output to $V_{CC-}$	50	50	40	V	
Duration of output short-circuit (see Note 4)	10	10	10	s	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	500	mW	
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C	
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C	
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	J, JG, or U package			300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	N or P package			260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or  $\pm 15$  volts, whichever is less.  
 4. The output may be shorted to ground or either power supply.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, LM111 chips are alloy-mounted; LM211 and LM311 chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM111, LM211		LM311		UNIT		
		MIN	TYP‡ MAX	MIN	TYP‡ MAX			
$V_{IO}$ Input offset voltage	$R_S \leq 50$ k $\Omega$ , See Note 6	25°C	0.7	3	2	7.5	mV	
		Full range			10			
$I_{IO}$ Input offset current	See Note 6	25°C	4	10	6	50	nA	
		Full range			70			
$I_{IB}$ Input bias current	$V_O = 1$ V to 14 V	25°C	75	100	100	250	nA	
		Full range			300			
$I_{IL(S)}$ Low-level strobe current	$V_{(strobe)} = 0.3$ V, $V_{ID} \leq -10$ mV	25°C	-3		-3		mA	
$V_{ICR}$ Common-mode input voltage range		Full range	$\pm 14$		$\pm 14$		V	
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5$ V to 35 V, $R_L = 1$ k $\Omega$	25°C	40	200	40	200	V/mV	
$I_{OH}$ High-level (collector) output current	$V_{ID} = 5$ mV, $V_{OH} = 35$ V	25°C	0.2		10		nA	
		Full range			0.5		$\mu$ A	
	$V_{ID} = 10$ mV, $V_{OH} = 35$ V	25°C			0.2		50	nA
$V_{OL}$ Low-level (collector-to-emitter) output voltage	$I_{OL} = 50$ mA	$V_{ID} = -5$ mV	25°C	0.75	1.5		V	
		$V_{ID} = -10$ mV	25°C			0.75		1.5
	$V_{CC+} = 4.5$ V, $V_{CC-} = 0$ V, $I_{OL} = 8$ mA	$V_{ID} = -6$ mV	Full range	0.23	0.4			
		$V_{ID} = -10$ mV	Full range			0.23		0.4
$I_{CC+}$ Supply current from $V_{CC+}$ , output low	$V_{ID} = -10$ mV, No load	25°C	5.1	6		5.1	7.5	mA
$I_{CC-}$ Supply current from $V_{CC-}$ , output high	$V_{ID} = 10$ mV, No load	25°C	-4.1	-5		-4.1	-5	mA

† Unless otherwise noted, all characteristics are measured with the balance and balance/strobe terminals open and the emitter output grounded. Full range for LM111 is -55°C to 125°C, for LM211 is -25°C to 85°C, and for LM311 is 0°C to 70°C.

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 6: The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pull-up resistor of 7.5 k $\Omega$  to  $V_{CC+}$ . Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

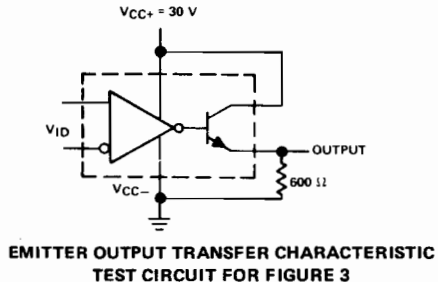
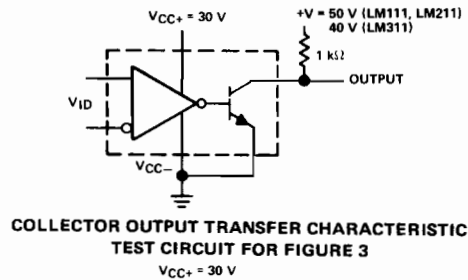
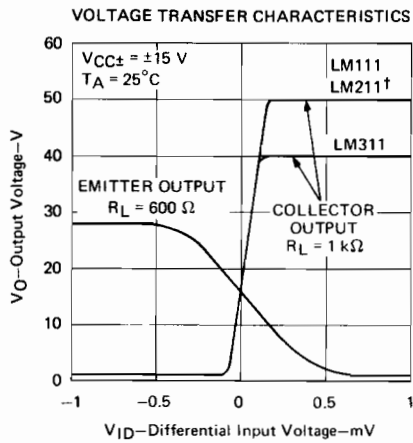
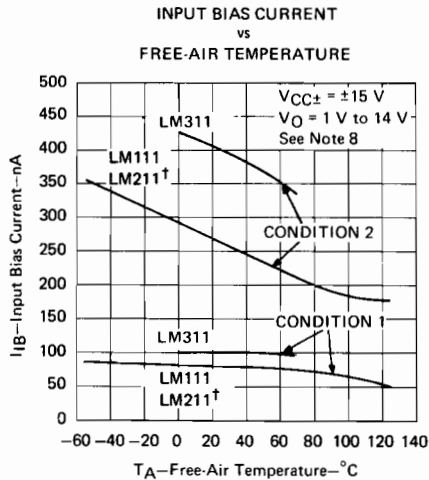
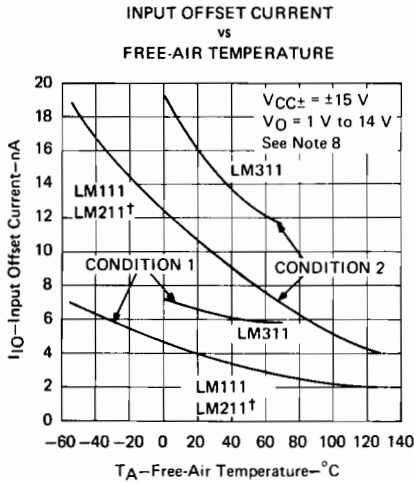
# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

switching characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time, low-to-high-level output	$R_C = 500\ \Omega$ to $5\text{ V}$ , $C_L = 5\text{ pF}$ , See Note 7		115		ns
Response time, high-to-low-level output			165		ns

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

## TYPICAL CHARACTERISTICS



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

NOTE 8: Condition 1 is with the balance and balance/strobe terminals open. Condition 2 is with the balance and balance/strobe terminals connected to  $V_{CC+}$ .

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

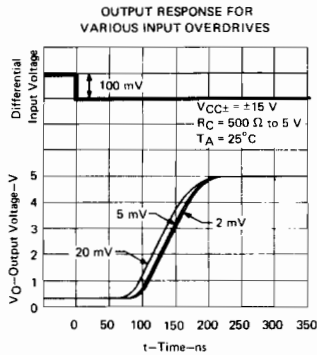
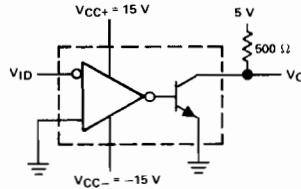


FIGURE 4



TEST CIRCUIT FOR FIGURES 4 AND 5

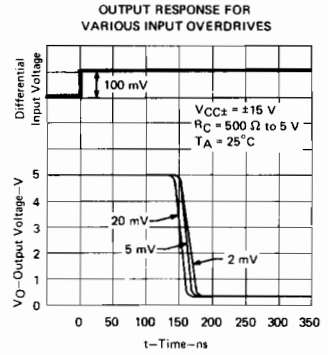


FIGURE 5

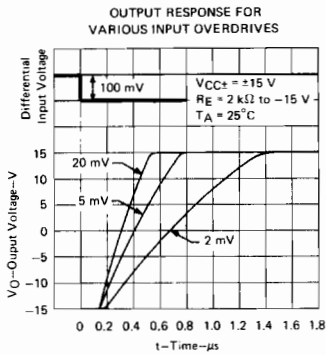
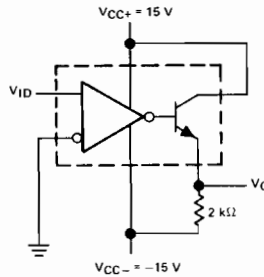


FIGURE 6



TEST CIRCUIT FOR FIGURES 6 AND 7

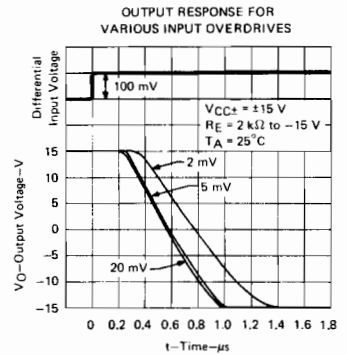


FIGURE 7

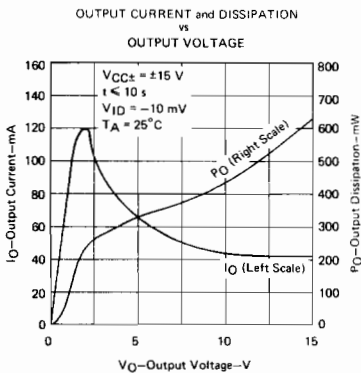


FIGURE 8

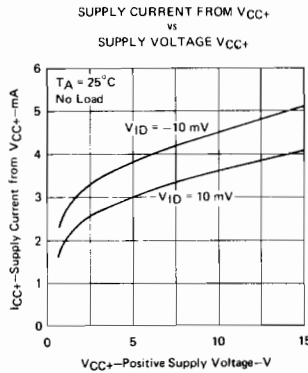


FIGURE 9

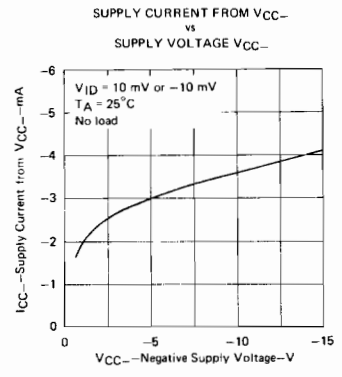


FIGURE 10

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL APPLICATION DATA

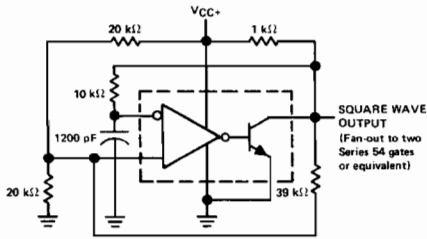


FIGURE 11—100-kHz  
FREE-RUNNING MULTIVIBRATOR

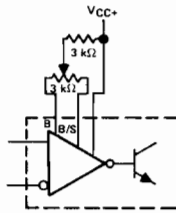


FIGURE 12  
OFFSET BALANCING

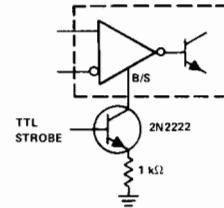


FIGURE 13—STROBING

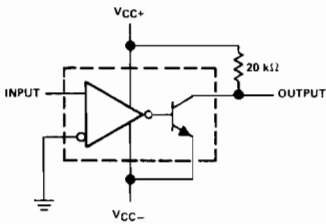
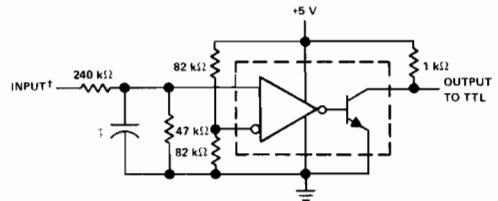


FIGURE 14—ZERO-CROSSING DETECTOR



† Resistor values shown are for a 0-to-30-V logic swing and a 15-V threshold.  
‡ May be added to control speed and reduce susceptibility to noise spikes.

FIGURE 15—TTL INTERFACE WITH HIGH-LEVEL LOGIC

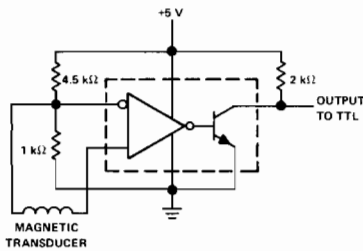


FIGURE 16—DETECTOR FOR MAGNETIC TRANSDUCER

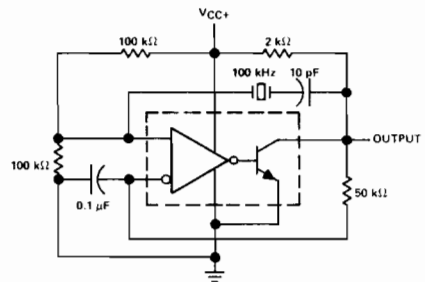


FIGURE 17—100-kHz CRYSTAL OSCILLATOR

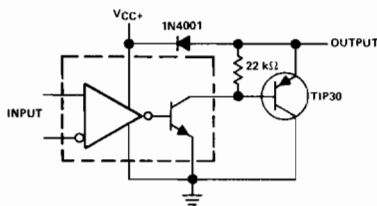
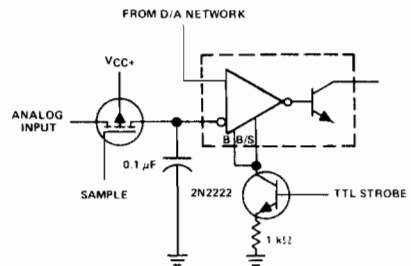


FIGURE 18—COMPARATOR AND SOLENOID DRIVER



Typical input current is 50 pA with inputs strobed off.  
FIGURE 19—STROBING BOTH INPUT AND  
OUTPUT STAGES SIMULTANEOUSLY

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL APPLICATION DATA

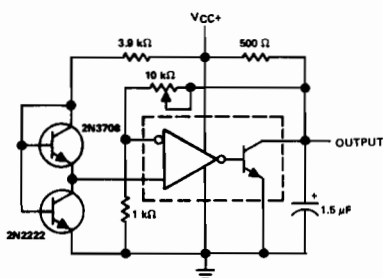


FIGURE 20—LOW-VOLTAGE  
ADJUSTABLE REFERENCE SUPPLY

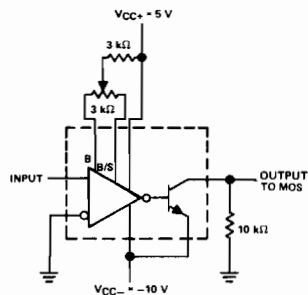
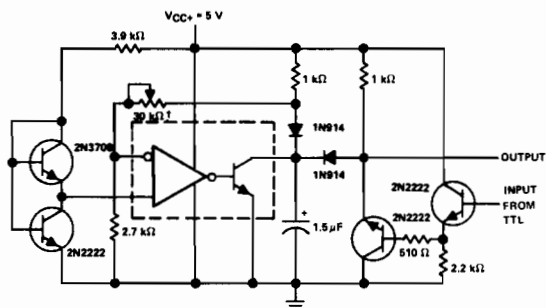


FIGURE 21—ZERO-CROSSING  
DETECTOR DRIVING MOS LOGIC



† Adjust to set clamp level.

FIGURE 22—PRECISION SQUARER

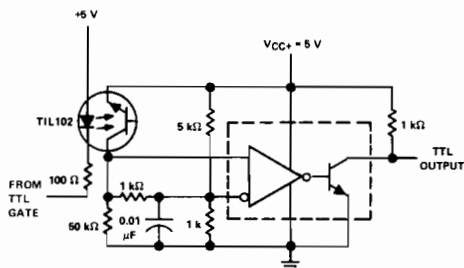


FIGURE 23—DIGITAL TRANSMISSION ISOLATOR

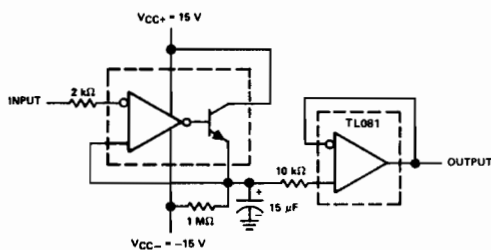


FIGURE 24—POSITIVE-PEAK DETECTOR

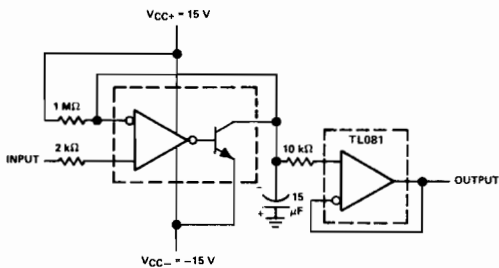
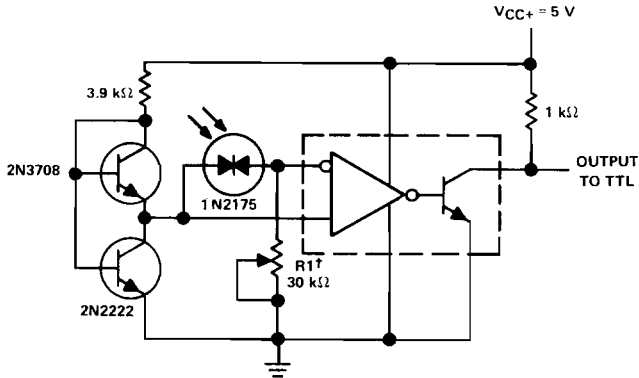


FIGURE 25—NEGATIVE-PEAK DETECTOR



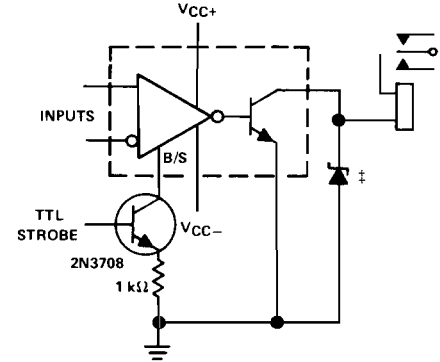
# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL APPLICATION DATA



†R1 sets the comparison level. At comparison, the photodiode has less than 5 mV across it, decreasing dark current by an order of magnitude.

FIGURE 26—PRECISION PHOTODIODE COMPARATOR



‡Transient voltage and inductive kickback protection.

FIGURE 27—RELAY DRIVER WITH STROBE

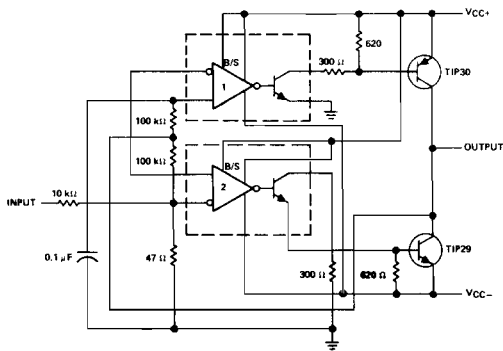


FIGURE 28—SWITCHING POWER AMPLIFIER

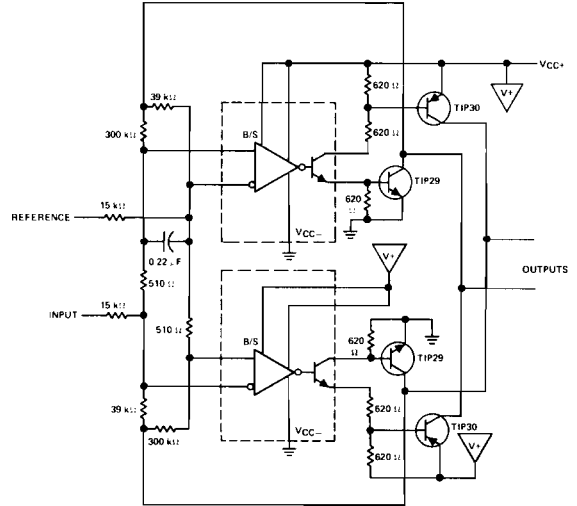


FIGURE 29—SWITCHING POWER AMPLIFIERS



# LINEAR INTEGRATED CIRCUITS

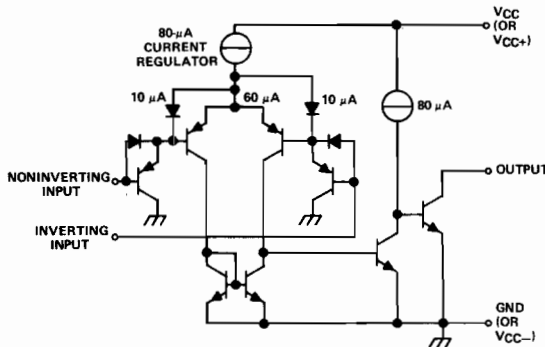
# TYPES LM139, LM239, LM339 QUADRUPLE DIFFERENTIAL COMPARATORS

BULLETIN NO. DL-S 12236, MARCH 1975—REVISED OCTOBER 1979

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (LM139)

- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 36$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, DTL, MOS, and CMOS

schematic (each comparator)



Current values shown are nominal.

## description

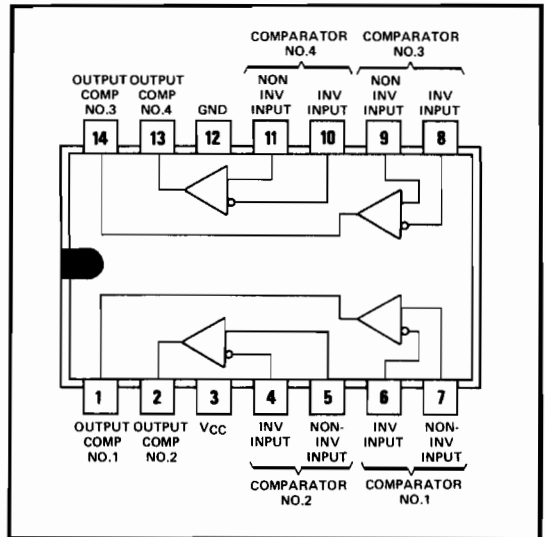
These devices consist of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 3 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	900 mW
Operating free-air temperature range:	
LM139	-55°C to 125°C
LM239	-25°C to 85°C
LM339	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM139 chips are alloy-mounted; LM239 and LM339 chips are glass-mounted.

J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)



5

# TYPES LM139, LM239, LM339

## QUADRUPLE DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM139			LM239, LM339			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$ , $V_{IC} = V_{ICR}$ , $V_O = 1.4\text{ V}$	25°C	2	5	2	5	mV	
		Full range	9					
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	25	5	50	nA	
		Full range	100					
$I_{IB}$ Input bias current	See Note 5	25°C	-25	-100	-25	-250	nA	
		Full range	-300					
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 2\text{ V to }36\text{ V}$	25°C	0 to $V_{CC}-1.5$	0 to $V_{CC}-1.5$	V			
		Full range	0 to $V_{CC}-2$	0 to $V_{CC}-2$				
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ k}\Omega\text{ to }V_{CC}$	25°C	200		200		V/mV	
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$	$V_{OH} = 5\text{ V}$	25°C	0.1		nA		
		$V_{OH} = 30\text{ V}$	Full range	1		1		
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C	250	500	250	500	mV	
		Full range	700					
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16	6	16	mA	
$I_{CC}$ Supply current (four comparators)	No load	25°C	0.8	2	0.8	2	mA	

† Full range (MIN to MAX) for LM139 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for the LM239 is  $-85^\circ\text{C}$  to  $125^\circ\text{C}$ , and for the LM339 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ ‡ See Note 6	100-mV input step with 5-mV overdrive	1.3		$\mu\text{s}$
		TTL-level input step	0.3		

‡  $C_L$  includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	900 mW	11.0 mW/ $^\circ\text{C}$	68°C
J (Glass-Mounted Chip)	900 mW	8.2 mW/ $^\circ\text{C}$	40°C
N	900 mW	9.2 mW/ $^\circ\text{C}$	52°C
W	900 mW	8.0 mW/ $^\circ\text{C}$	37°C

Also see Dissipation Derating Curves, Section 2.

# LINEAR INTEGRATED CIRCUITS

# TYPES LM193, LM293, LM393 DUAL DIFFERENTIAL COMPARATORS

BULLETIN NO. DL-S 12411, JUNE 1976—REVISED OCTOBER 1979

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage  
... 2 to 36 Volts
- Low Supply Current Drain  
Independent of Supply Voltage  
... 0.5 mA Typ
- Low Input Bias Current ... 25 nA Typ
- Low Input Offset Current  
... 3 nA Typ (LM193)
- Low Input Offset Voltage ... 2 mV Typ
- Common-Mode Input Voltage  
Range Includes Ground
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage ...  $\pm 36$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, DTL,  
MOS, and CMOS

## description

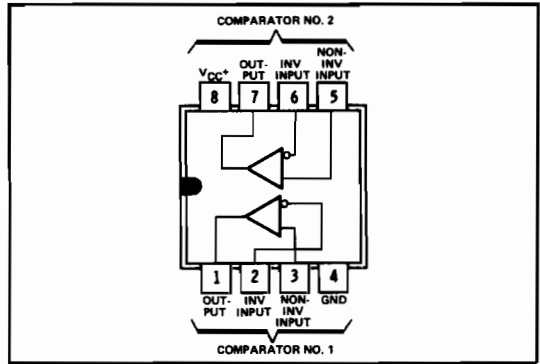
These devices consist of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 8 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

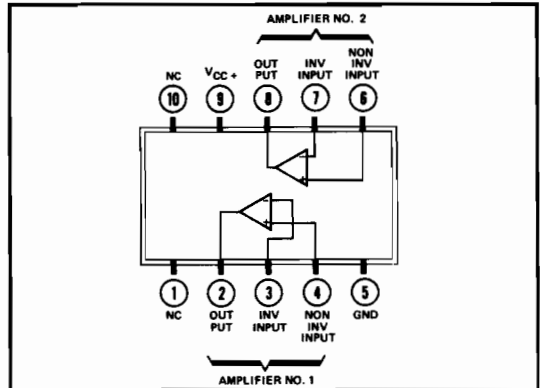
Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
LM293JG, LM393JG	825 mW
LM193JG, LM293P, LM393P	900 mW
LM193U, LM293U, LM393U	675 mW
Operating free-air temperature range:	
LM193	-55°C to 125°C
LM293	-25°C to 85°C
LM393	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG or U package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, LM193 chips are alloy-mounted; LM293 and LM393 chips are glass-mounted.

JG OR P  
DUAL-IN-LINE PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



# TYPES LM193, LM293, LM393

## DUAL DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	LM193			LM293, LM393			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to } 30\text{ V}$ , $V_{IC} = V_{ICR}$ , $V_O = 1.4\text{ V}$	25°C		1	5		1	5	mV	
		Full range			9			9		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C		3	25		5	50	nA	
		Full range			100			150		
$I_{IB}$ Input bias current	See Note 5	25°C		-25	-100		-25	-250	nA	
		Full range			-300			-400		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 2\text{ V to } 36\text{ V}$	25°C		0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$		V	
		Full range		0 to $V_{CC}-2$			0 to $V_{CC}-2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ V to } V_{CC}$	25°C		50	200		50	200	V/mV	
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$ , $V_{OH} = 5\text{ V}$	25°C			0.1			0.1	nA	
	$V_{ID} = 1\text{ V}$ , $V_{OH} = 30\text{ V}$	Full range				1		1	$\mu\text{A}$	
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C		250	400		250	400	mV	
		Full range			700			700		
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_O = 1.5\text{ V}$	25°C		6	16		6	16	mA	
$I_{CC}$ Supply current	No load	$V_{CC} = 5\text{ V}$	25°C		0.8	1		0.8	1	mA
		$V_{CC} = 30\text{ V}$	Full range			2.5			2.5	

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ † See Note 6	100-mV input step with 5-mV overdrive		1.3		$\mu\text{s}$
		TTL-level input step		0.3		

† $C_L$  includes probe and jig capacitance.

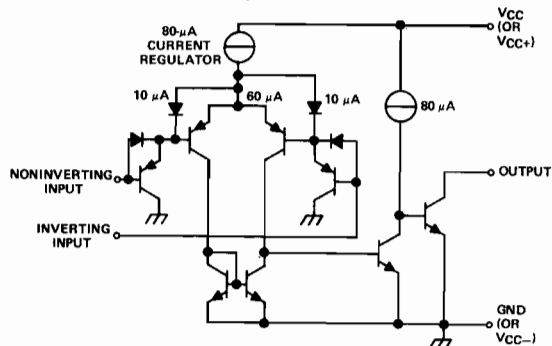
NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	900 mW	8.4 mW/°C	43°C
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	900 mW	8.0 mW/°C	37°C
U	675 mW	5.4 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

schematic (each comparator)

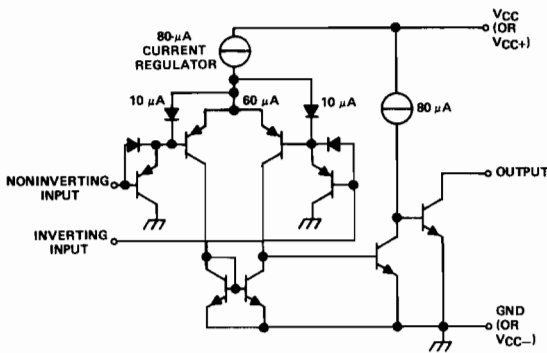


Current values shown are nominal.

- Eliminates Need for Dual Supplies
- Wide Range of Supply Voltages . . . 2 to 36 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV Typ  
Input Offset Current . . . 5 nA Typ  
Input Bias Current . . . -25 nA Typ

- Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing near Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 36$  V
- Low Output Saturation Voltage . . . 1 mV Typ at 5  $\mu$ A . . . 70 mV Typ at 1 mA
- Output Compatible with TTL, DTL, MOS, and CMOS

schematic (each comparator)



Current values shown are nominal.

**description**

The LM2901 consists of four independent voltage comparators designed specifically for automotive and industrial control systems. They operate from a single power supply over a wide range of voltages, and the low supply current drain is independent of the magnitude of the supply voltage. A unique characteristic of these comparators is that the common-mode input voltage range includes ground even when a single supply voltage is used.

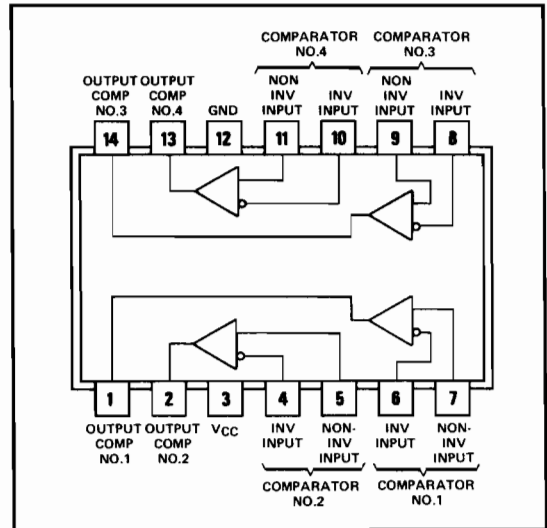
The outputs can be connected to other open-collector outputs to achieve wired-AND relationships. Applications include limit comparators, simple analog-to-digital converters, wide-range VCO's, MOS clock timers, multivibrators, high-voltage digital logic gates, and pulse, square-wave, and time-delay generators. The LM2901 was designed to directly interface with CMOS—where the low power drain of the LM2901 is a large advantage over standard comparators.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, VCC (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	900 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to VCC can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM2901 chips are glass-mounted.

J OR N DUAL-IN-LINE OR  
W FLAT PACKAGE (TOP VIEW)



5

# TYPE LM2901

## QUADRUPLE DIFFERENTIAL COMPARATOR

electrical characteristics at 25°C free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{CC} = 5\text{ V to } 30\text{ V}$ , $V_{IC} = V_{ICR}$ , $V_O = 1.4\text{ V}$	25°C	2	7	mV
			-40°C to 85°C		15	
$I_{IO}$	Input offset current	$V_O = 1.4\text{ V}$	25°C	5	50	nA
			-40°C to 85°C		200	
$I_{IB}$	Input bias current	See Note 5	25°C	-25	-250	nA
			-40°C to 85°C		-500	
$V_{ICR}$	Input common-mode voltage range	$V_{CC} = 2\text{ V to } 36\text{ V}$	25°C	0 to $V_{CC} - 1.5$		V
			-40°C to 85°C	0 to $V_{CC} - 2$		
AVD	Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ k}\Omega$ to $V_{CC}$		25	100	V/mV
$I_{OH}$	High-level output current	$V_{ID} = 1\text{ V}$ $V_O = 5\text{ V}$	25°C	0.1		nA
		$V_{ID} = 1\text{ V}$ $V_O = 30\text{ V}$	-40°C to 85°C		1	$\mu\text{A}$
$V_{OL}$	Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C		400	mV
			-40°C to 85°C		700	
$I_{OL}$	Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16	mA
		$V_{CC} = 5\text{ V}$	25°C	0.4	1	mA
$I_{CC}$	Supply current	No load	-40°C to 85°C		2.5	

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

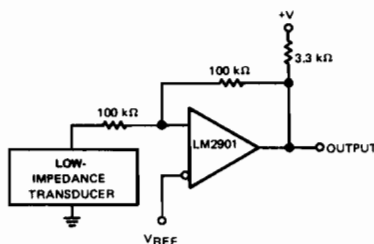
switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	$R_L = 5.1\text{ k}\Omega$ to 5 V $C_L = 15\text{ pF}$ † See Note 6	100-mV input step with 5-mV overdrive		1.5		$\mu\text{s}$
		TTL-level input step		0.3		

†  $C_L$  includes probe and jig capacitance.

NOTE 6: The typical value is for the interval between the input step function and the time when the output crosses 1.4 V.

### TYPICAL APPLICATION DATA



BASIC SINGLE-SUPPLY TRANSLATOR

### THERMAL INFORMATION

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	900 mW	8.2 mW/°C	40°C
N	900 mW	9.2 mW/°C	52°C
W	900 mW	8.0 mW/°C	37°C

Also see Dissipation Derating Curves, Section 2.



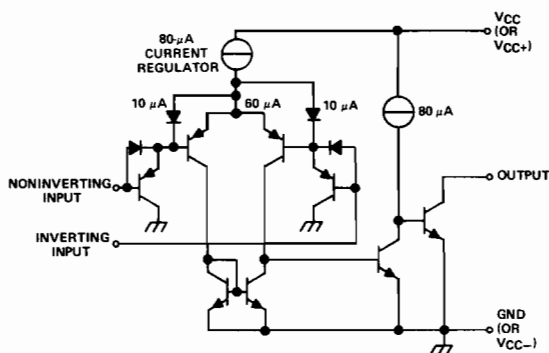
# LINEAR INTEGRATED CIRCUITS

# TYPE LM2903 DUAL DIFFERENTIAL COMPARATOR

BULLETIN NO. DL-S 12412, JUNE 1976—REVISED OCTOBER 1979

- Eliminates Need for Dual Supplies
- Wide Range of Supply Voltages  
... 2 to 36 Volts
- Low Supply Current Drain  
Independent of Supply Voltage  
... 0.5 mA Typ
- Low Input Bias and Offset Parameters  
Input Offset Voltage ... 2 mV Typ  
Input Offset Current ... 5 nA Typ  
Input Bias Current ... -25 nA Typ
- Common-Mode Input Voltage  
Range Includes Ground Allowing  
Direct Sensing near Ground
- Differential Input Voltage Range  
Equal to Maximum-Rated  
Supply Voltage ...  $\pm 36$  V
- Low Output Saturation Voltage  
... 1 mV Typ at 5  $\mu$ A  
... 70 mV Typ at 1 mA
- Output Compatible with TTL,  
DTL, MOS, and CMOS

schematic (each comparator)



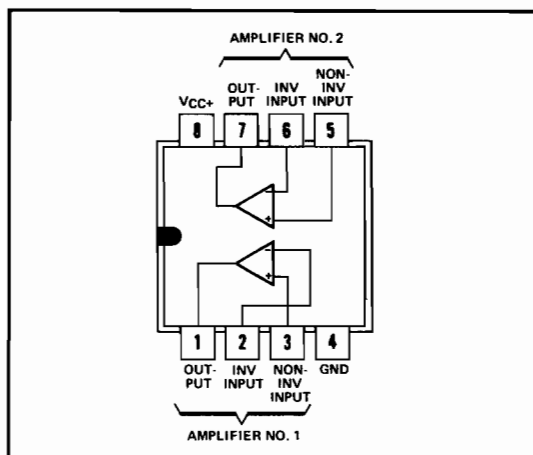
Current values shown are nominal.

## description

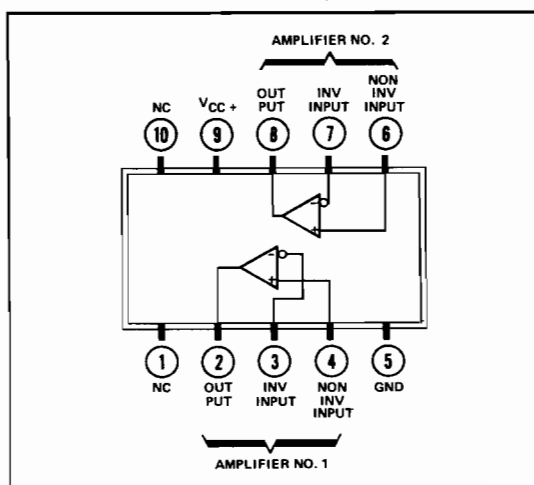
The LM2903 consists of two independent voltage comparators designed specifically for automotive and industrial control systems. They operate from a single power supply over a wide range of voltages and the low supply current drain is independent of the magnitude of the supply voltage. A unique characteristic of these comparators is that the common-mode input voltage range includes ground, even though operated from a single supply voltage. Applications include limit comparators, simple analog-to-digital converters, wide-range VCO's, MOS clock timers, multivibrators, high-voltage digital logic gates, and pulse, square-wave, and time-delay generators. The LM2903 was designed to directly interface with CMOS — where the low power drain of the LM2903 is a large advantage over standard comparators.

The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

JG OR P  
DUAL-IN-LINE PACKAGE (TOP VIEW)



U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

# TYPE LM2903

## DUAL DIFFERENTIAL COMPARATOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
LM2903 JG/883B	900 mW
LM2903 JG	825 mW
P package	900 mW
U package	675 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG or U package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, LM2903/883B chips are alloy-mounted; LM2903 chips are glass-mounted.

### electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
	$V_{CC} = 5$ V to 30 V, $V_{IC} = V_{ICR}$ , $V_O = 1.4$ V	25°C	-40°C to 85°C				
$V_{IO}$ Input offset voltage				2	7		mV
$I_{IO}$ Input offset current	$V_O = 1.4$ V	25°C		5	50		nA
		-40°C to 85°C			200		
$I_{IB}$ Input bias current	See Note 5	25°C		-25	-250		nA
		-40°C to 85°C			-500		
$V_{ICR}$ Input common-mode voltage range	$V_{CC} = 2$ V to 36 V	25°C		0 to $V_{CC} - 1.5$			V
		-40°C to 85°C		0 to $V_{CC} - 2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15$ V, $R_L = 15$ k $\Omega$ to $V_{CC}$			25	100		V/mV
$I_{OH}$ High-level output current	$V_{ID} = 1$ V	$V_O = 5$ V	25°C		0.1		nA
	$V_{ID} = 1$ V	$V_O = 30$ V	-40°C to 85°C			1	$\mu$ A
$V_{OL}$ Low-level output voltage	$V_{ID} = -1$ V, $I_{OL} = 4$ mA	25°C				400	mV
		-40°C to 85°C				700	
$I_{OL}$ Low-level output current	$V_{ID} = -1$ V, $V_{OL} = 1.5$ V		25°C	6	16		mA
$I_{CC}$ Supply current	No load	$V_{CC} = 5$ V	25°C		0.4	1	mA
		$V_{CC} = 30$ V	-40°C to 85°C			2.5	

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

### switching characteristics, $V_{CC} = 5$ V, $T_A = 25^\circ$ C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	$R_L = 15$ k $\Omega$ to 5 V, $C_L = 15$ pF <sup>†</sup> See Note 6	100-mV input step with 5-mV overdrive		1.5		$\mu$ s
		TTL-level input step		0.3		

<sup>†</sup> $C_L$  includes probe and jig capacitance.

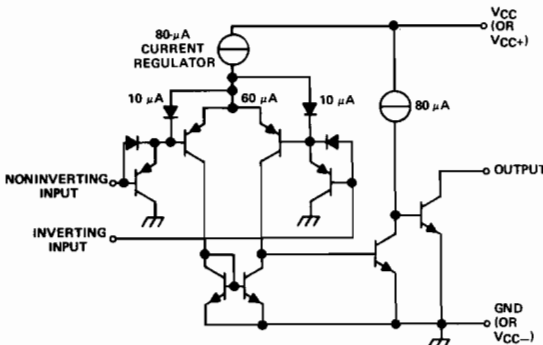
NOTE 6: The typical value is for the interval between the input step function and the time when the output crosses 1.4 V.

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	900 mW	8.4 mW/°C	43°C
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	900 mW	8.0 mW/°C	37°C
U	675 mW	5.4 mW/°C	25°C

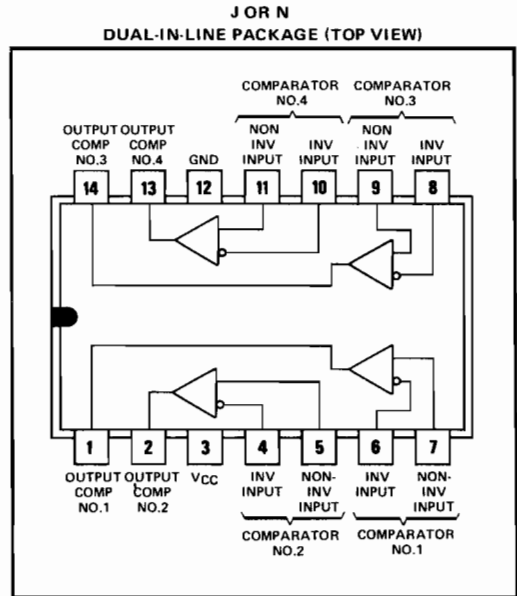
- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 28 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 5 nA Typ
- Low Input Offset Voltage . . . 3 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 28$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, DTL, MOS, and CMOS

schematic (each comparator)



description Current values shown are nominal.

This device consists of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 28 volts and pin 3 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	28 V
Differential input voltage (see Note 2)	$\pm 28$ V
Input voltage range (either input)	-0.3 V to 28 V
Output voltage	28 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	900 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES:**
1. All voltage values, except differential voltages, are with respect to the network ground terminal.
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.
  4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, LM3302 chips are glass-mounted.

# TYPE LM3302

## QUADRUPLE DIFFERENTIAL COMPARATOR

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to } 28\text{ V}$ , $V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR}$	25°C	3	20	mV
		-40°C to 85°C		40	
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	100	nA
		-40°C to 85°C		300	
$I_{IB}$ Input bias current	See Note 5	25°C	-25	-500	nA
		-40°C to 85°C		-1000	
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 2\text{ V to } 28\text{ V}$	25°C	0 to $V_{CC}-1.5$		V
		-40°C to 85°C	0 to $V_{CC}-2$		
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ k}\Omega$ to $V_{CC}$	25°C	2	30	V/mV
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$ , $V_{OH} = 5\text{ V}$	25°C		0.1	nA
		-40°C to 85°C		1	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C	200	500	mV
		-40°C to 85°C		700	
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	2	16	mA
$I_{CC}$ Supply current (four comparators)	No load	25°C	0.8	2	mA

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MIN	UNIT
Response time	$R_L = 5.1\text{ k}\Omega$ to $5\text{ V}$ $C_L = 15\text{ pF}$ ‡ See Note 6	100-mV input step with 5 mV overdrive		1.3	$\mu\text{s}$
		TTL-level input step		0.3	

‡ $C_L$  includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	900 mW	8.2 mW/°C	40°C
N	900 mW	9.2 mW/°C	52°C

Also see Dissipation Derating Curves, Section 2.

# LINEAR INTEGRATED CIRCUITS

# TYPES TL111, TL311, TL311A JFET-INPUT DIFFERENTIAL COMPARATORS WITH STROBES

BULLETIN NO. DL-S 12737, NOVEMBER 1979

- Fast Response Times
- Strobe Capability
- Designed to Replace LM111 and LM311

- Common-Mode Input Voltage Range Includes  $V_{CC-}$
- N-Channel JFET High-Impedance Input
- Can Operate From Single 5-V Supply

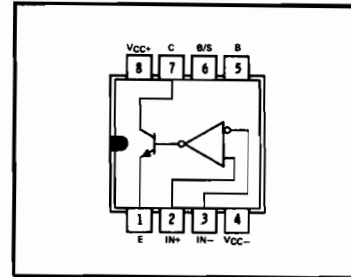
## description

The TL111, TL311, and TL311A are high-speed voltage comparators. These devices use an N-channel JFET high-impedance input structure that extends the operating range of the common-mode input voltage to include the value of the  $V_{CC-}$  supply. Designed for a wide variety of applications, the TL111, TL311, and TL311A can be operated over a wide range of supply voltage, including  $\pm 15$ -volt supplies for operational amplifiers and single 5-volt supplies for logic systems. The uncommitted output transistor can drive loads referenced to ground,  $V_{CC+}$ , or  $V_{CC-}$ . Additionally, it is capable of driving loads that require switching up to 50 volts. Outputs can be wire-OR connected.

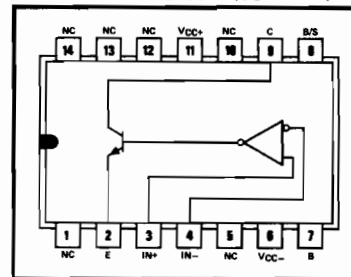
Offset balancing and strobe capability are available. If the strobe input is low (more negative than  $V_{IC} + 0.3$  V), the output will be in the off state regardless of the differential input.

The TL111 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL311 and TL311A are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)



J OR N DUAL-IN-LINE  
OR W FLAT PACKAGE (TOP VIEW)



NC—No internal connection

5

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL111	TL311, TL311A	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage range (either input, see Notes 1 and 3)	$V_{CC-}$ to 15	$V_{CC-}$ to 15	V
Voltage from emitter output to $V_{CC-}$	30	30	V
Voltage from collector output to $V_{CC-}$	50	40	V
Duration of output short-circuit (see Note 4)	10	10	s
Continuous total dissipation at (or below $25^{\circ}\text{C}$ free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	300	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or JG package N or P package	260	$^{\circ}\text{C}$

- NOTES: 1. These voltage values are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The input voltage must never be more positive than  $V_{CC+}$  or 15 volts, whichever is less, or more negative than  $V_{CC-}$ .  
 4. The output may be shorted to ground or either power supply.  
 5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, TL111 chips are alloy-mounted; TL311 and TL311A chips are glass-mounted.

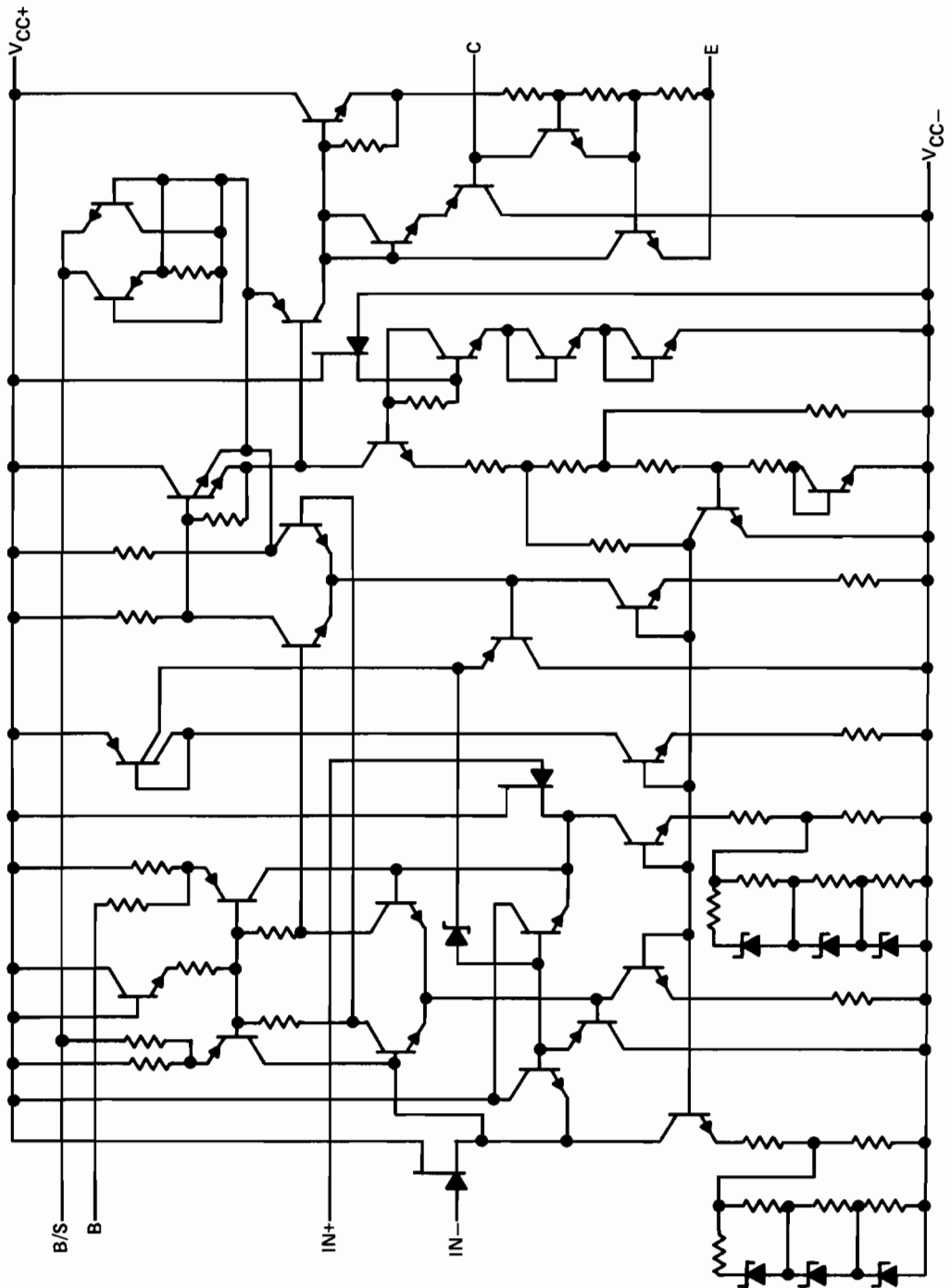
## ADVANCE INFORMATION

This document contains information on a new product. Specifications are subject to change without notice.

TEXAS INSTRUMENTS  
INCORPORATED

POST OFFICE BOX 225012 • DALLAS, TEXAS 75285

# TYPES TL111, TL311, TL311A JFET-INPUT DIFFERENTIAL COMPARATORS WITH STROBES



# TYPES TL111, TL311, TL311A JFET-INPUT DIFFERENTIAL COMPARATORS WITH STROBES

**electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS†		TL111		TL311		TL311A		UNIT	
	MIN	TYP‡ MAX	MIN	TYP‡ MAX	MIN	TYP‡ MAX	MIN	TYP‡ MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 50\text{ k}\Omega$ , See Note 6	See Note 6	25°C Full range	0.5	2	10	2	7.5	mV	
$I_{IO}$ Input offset current	See Note 6		25°C Full range	50	100	100	50	100	pA	
$I_{IB}$ Input bias current	$V_O = 1\text{ V to }14\text{ V}$		25°C Full range	100	250	100	100	250	pA	
$I_{IL(S)}$ Low-level strobe current	$-V_{ID} \geq 10\text{ mV}$ , $V_{I(S)} = V_{IC} + 0.3\text{ V}$		25°C	-3	-3	-3	-3	-3	nA	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -18\text{ V to }0\text{ V}$ , $V_{CC+} = 5\text{ V to }18\text{ V}$ , See Note 7		Full range	$V_{CC-}$ to $V_{CC+} - 3\text{ V}$	$V_{CC-}$ to $V_{CC+} - 3\text{ V}$	$V_{CC-}$ to $V_{CC+} - 3\text{ V}$	$V_{CC-}$ to $V_{CC+} - 3\text{ V}$	$V_{CC-}$ to $V_{CC+} - 3\text{ V}$	V	
$AVD$ Large-signal differential voltage amplification	$V_O = 5\text{ V to }35\text{ V}$ , $R_L = 1\text{ k}\Omega$		25°C	200	200	200	200	200	V/mV	
$I_{OH}$ High-level (collector) output current	$V_{ID} = 5\text{ mV}$ , $V_{OH} = 35\text{ V}$		25°C Full range	0.2	10				nA	
$V_{OL}$ Low-level (collector-to-emitter) output voltage	$V_{ID} = 10\text{ mV}$ , $I_{OL} = 50\text{ mA}$	$V_{OH} = 35\text{ V}$	25°C	0.75	1.5	0.2	50	0.2	50	nA
	$V_{CC+} = 4.5\text{ V}$ , $V_{CC-} = 0\text{ V}$	$V_{ID} = -10\text{ mV}$	25°C			0.75	1.5	0.75	1.5	V
	$I_{OL} = 8\text{ mA}$	$V_{ID} = -6\text{ mV}$	Full range	0.23	0.4					
$I_{CC+}$ Supply current from $V_{CC+}$ , output low	$V_{ID} = -10\text{ mV}$ , No load	No load	25°C	3	5	3	5	3	5	mA
$I_{CC-}$ Supply current from $V_{CC-}$ , output high	$V_{ID} = 10\text{ mV}$ , No load	No load	25°C	-2	-4	-2	-4	-2	-4	mA

† Unless otherwise noted, all characteristics are measured with the balance and balance/strobe terminals open and the emitter output is at 0 volts.

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .

§ Full range for TL111 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , and for TL311 and TL311A is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTES: 6. The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pull-up resistor of 7.5 k $\Omega$  to  $V_{CC+}$ . Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

7. For  $V_{ICR}$ , all voltages are with respect to a common ground (0 V).

# TYPES TL111, TL311, TL311A

## JFET-INPUT DIFFERENTIAL COMPARATORS WITH STROBES

switching characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time, low-to-high-level output	$R_C = 500\ \Omega$ to $5\text{ V}$ , $C_L = 5\text{ pF}$ , See Note 8		115		ns
Response time, high-to-low-level output			165		ns

NOTE 8: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

### TYPICAL CHARACTERISTICS

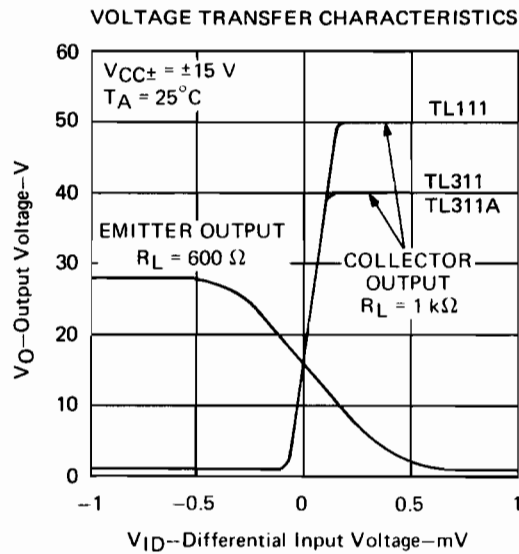
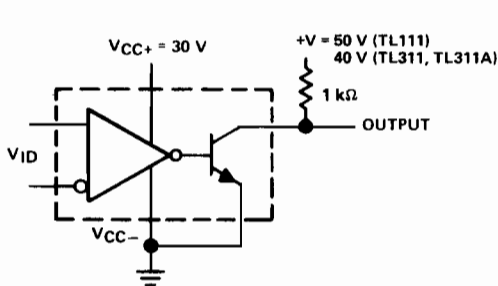
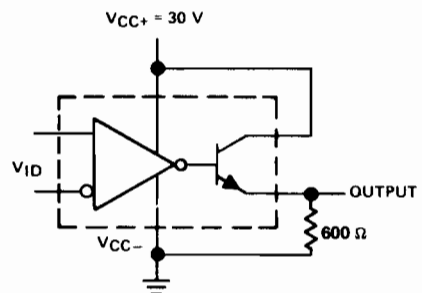


FIGURE 1



COLLECTOR OUTPUT TRANSFER CHARACTERISTIC  
TEST CIRCUIT FOR FIGURE 1



EMITTER OUTPUT TRANSFER CHARACTERISTIC  
TEST CIRCUIT FOR FIGURE 1



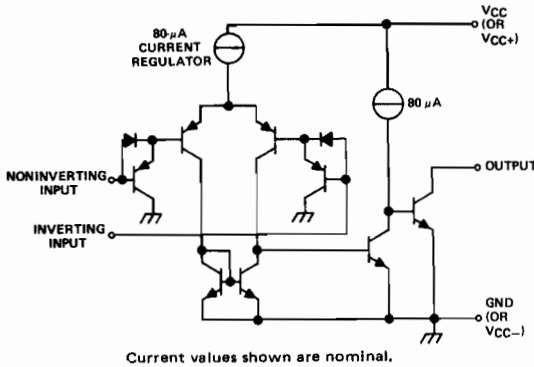
# LINEAR INTEGRATED CIRCUITS

# TYPES TL331M, TL331I, TL331C DIFFERENTIAL COMPARATORS

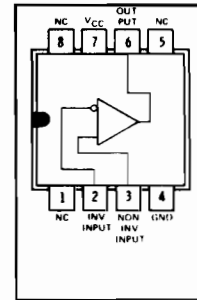
BULLETIN NO. DL-S 12516, APRIL 1977—REVISED OCTOBER 1979

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (TL331M)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 36$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, DTL, MOS, and CMOS

schematic (each comparator)



JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW)



NC—No internal connection

## description

The TL331 is a voltage comparator that is designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 7 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage.

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## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	680 mW
Operating free-air temperature range: TL331M	-55°C to 125°C
TL331I	-25°C to 85°C
TL331C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, TL331M chips are alloy-mounted; TL331I and TL331C chips are glass-mounted.

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# TYPES TL331M, TL331I, TL331C

## DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL331M, TL331I			TL331C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to } 30\text{ V}$ , $V_{IC} = V_{ICR}$ , $V_O = 1.4\text{ V}$	25°C	2	5	2	5	5	mV
		Full range	9			9		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	25	5	50	50	nA
		Full range	100			150		
$I_{IB}$ Input bias current	See Note 5	25°C	-25	-100	-25	-250	-250	nA
		Full range	-300			-400		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 2\text{ V to } 36\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ k}\Omega\text{ to } V_{CC}$	25°C	200			200		V/mV
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$	$V_{OH} = 5\text{ V}$	25°C			0.1		nA
		$V_{OH} = 30\text{ V}$	Full range	1			1	
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C	250	500	250	500	mV	
		Full range	700			700		
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16	6	16	mA	
$I_{CC}$ Supply current	No load	25°C	0.5	0.8	0.5	0.8	mA	

†Full range (MIN to MAX) for TL331M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for the TL331I is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and for the TL331C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ , † See Note 6	100-mV input step with 5-mV overdrive			1.3	$\mu\text{s}$
		TTL-level input step			0.3	

† $C_L$  includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

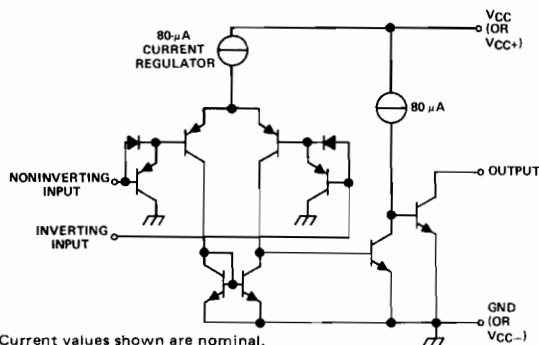
DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	680 mW	8.4 mW/ $^\circ\text{C}$	69°C
JG (Glass-Mounted Chip)	680 mW	6.6 mW/ $^\circ\text{C}$	47°C
P	680 mW	8.0 mW/ $^\circ\text{C}$	65°C

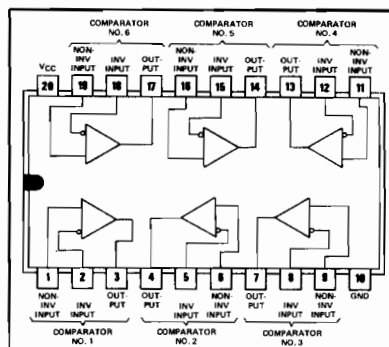
Also see Dissipation Derating Curves, Section 2.

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 1 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (TL336M)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 36$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, DTL, MOS, and CMOS

schematic (each comparator)



J OR N  
DUAL-IN-LINE PACKAGE (TOP VIEW)



## description

The TL336 is a hex voltage comparator that is designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and  $V_{CC}$  is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	680 mW
Operating free-air temperature range: TL336M	-55°C to 125°C
TL336I	-25°C to 85°C
TL336C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, TL336M chips are alloy-mounted; TL336I and TL336C chips are glass-mounted.

# TYPES TL336M, TL336I, TL336C

## HEX DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL336M, TL336I			TL336C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to } 30\text{ V}$ , $V_{IC} = V_{ICR}$ , $V_O = 1.4\text{ V}$	25°C	2	5	2	5	mV	
		Full range	9					
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	25	5	50	nA	
		Full range	100					
$I_{IB}$ Input bias current	See Note 5	25°C	-25	-100	-25	-250	nA	
		Full range	-300					
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 2\text{ V to } 36\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L = 15\text{ k}\Omega$ to $V_{CC}$	25°C	200			V/mV		
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$	$V_{OH} = 5\text{ V}$	0.1			nA		
		$V_{OH} = 30\text{ V}$	1			$\mu\text{A}$		
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C	250	500	250	500	mV	
		Full range	700					
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16	6	16	mA	
$I_{CC}$ Supply current (six comparators)	No load	25°C	1	3	1	3	mA	

† Full range (MIN to MAX) for TL336M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for the TL336I is  $-85^\circ\text{C}$  to  $125^\circ\text{C}$ , and for the TL336C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 5: The direction of the bias current is out of the device due to the P-N-P input stage. This current is essentially constant, regardless of the state of the output, so no loading change is presented to the input lines.

### switching characteristics, $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ ‡ See Note 6	100-mV input step with 5-mV overdrive	1.3		$\mu\text{s}$
		TTL-level input step	0.3		

‡  $C_L$  includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	680 mW	11.0 mW/ $^\circ\text{C}$	88°C
J (Glass-Mounted Chip)	680 mW	8.2 mW/ $^\circ\text{C}$	67°C
N	680 mW	9.2 mW/ $^\circ\text{C}$	76°C

Also see Dissipation Derating Curves, Section 2.

- Each Comparator Identical to LM106 or LM306 with Common  $V_{CC+}$ ,  $V_{CC-}$ , and Ground Connections
- Improved Gain and Accuracy
- Fan-Out to 10 Series 54/74 TTL Loads
- Strobe Capability
- Short-Circuit and Surge Protection
- Fast Response Times

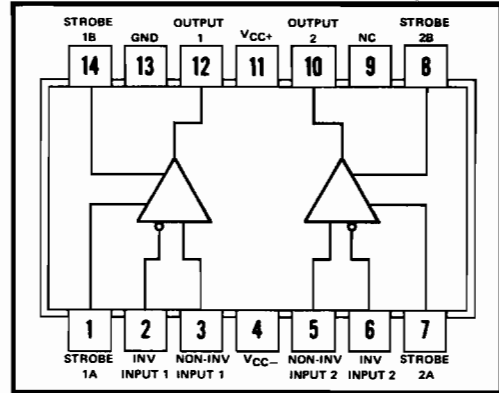
**description**

The TL506 is a dual high-speed voltage comparator, with each half having differential inputs, a low-impedance output with high-sink-current capability (100 mA), and two strobe inputs. This device detects low-level analog or digital signals and can drive digital logic or lamps and relays directly. Short-circuit protection and surge-current limiting is provided.

The circuit is similar to a TL810 with gated output. A low-level input at either strobe causes the output to remain high regardless of the differential input. When both strobe inputs are either open or at a high logic level, the output voltage is controlled by the differential input voltage. The circuit will operate with any negative supply voltage between  $-3\text{ V}$  and  $-12\text{ V}$  with little difference in performance.

The TL506M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL506C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**J OR N DUAL-IN-LINE PACKAGE OR  
W FLAT PACKAGE (TOP VIEW)**



NC—No internal connection

**5**

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	15 V
Supply voltage $V_{CC-}$ (see Note 1)	$-15\text{ V}$
Differential input voltage (see Note 2)	$\pm 5\text{ V}$
Input voltage (any input, see Notes 1 and 3)	$\pm 7\text{ V}$
Strobe voltage range (see Note 1)	0 V to $V_{CC+}$
Output voltage (see Note 1)	24 V
Voltage from output to $V_{CC-}$	30 V
Duration of output short-circuit (see Note 4)	10 s
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5):	
Each amplifier	600 mW
Total package	800 mW
Operating free-air temperature range:	
TL506M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL506C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	$260^{\circ}\text{C}$

- NOTES:
1. All voltage values, except differential voltages and the voltage from the output to  $V_{CC-}$ , are with respect to the network ground terminal.
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 7 volts, whichever is less.
  4. One output at a time may be shorted to ground or either power supply.
  5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, TL506M chips are alloy-mounted; TL506C chips are glass-mounted.

# TYPES TL506M, TL506C

## DUAL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -3\text{ V to } -12\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL506M			TL506C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	See Note 6	25°	0.5§		2		1.6§		mV
		Full range	3			6.5			
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	See Note 6	Full range	3		10		5		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	See Note 6	25° C	0.7§		3		1.8§		$\mu\text{A}$
		MIN	2		7		1		
		MAX	0.4		3		0.5		
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 6	MIN to 25° C	15		75		24		$\text{nA}/^\circ\text{C}$
		25° C to MAX	5		25		15		
$I_{IB}$ Input bias current	$V_O = 0.5\text{ V to } 5\text{ V}$	25° C	7§		20		16§		$\mu\text{A}$
		Full range	45			40			
$I_{IL(S)}$ Low-level strobe current	$V_{(\text{strobe})} = 0.4\text{ V}$	Full range	-1.7§		-3.3		-1.7§		mA
$V_{IH(S)}$ High-level strobe voltage		Full range	2.5		2.5				V
$V_{IL(S)}$ Low-level strobe voltage		Full range			0.9		0.9		V
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V to } -12\text{ V}$	Full range	±5		±5				V
$V_{ID}$ Differential input voltage range		Full range	±5		±5				V
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0.5\text{ V to } 5\text{ V}$	25° C	40 000§		40 000§				
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -400\ \mu\text{A}$	Full range	2.5		5.5		2.5		V
	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 100\text{ mA}$	25° C	0.8§		1.5		0.8§		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 50\text{ mA}$	Full range	1		1		1		V
	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 16\text{ mA}$	Full range	0.4		0.4		0.4		
$I_{OH}$ High-level output current	$V_{ID} = 5\text{ mV}$ , $V_{OH} = 8\text{ V to } 24\text{ V}$	25° C	0.02§		1		0.02§		$\mu\text{A}$
		Full range	100			100			
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , See Note 7	Full range	13.9§		20		13.9§		20
$I_{CC-}$ Supply current from $V_{CC-}$	See Note 7	Full range	3.2§		7.2		3.2§		7.2

† Unless otherwise noted, all characteristics are measured with the strobe open.

§ These typical values are at  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$ . Full range (MIN to MAX) for TL506M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL506C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTES: 6. The offset voltages and offset currents given are the maximum values required to drive the output down to the low range ( $V_{OL}$ ) or up to the high range ( $V_{OH}$ ). Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

7. Power supply currents are measured with the respective non-inverting inputs and inverting inputs of both comparators connected in parallel. The outputs are open.

### switching characteristics, $V_{CC+} = 12\text{ V}$ , $V_{CC-} = -6\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS†	TL506M			TL506C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time, low-to-high-level output	$R_L = 390\ \Omega$ to $5\text{ V}$ , $C_L = 15\text{ pF}$ , See Note 8	28		40		28		ns

NOTE 8: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

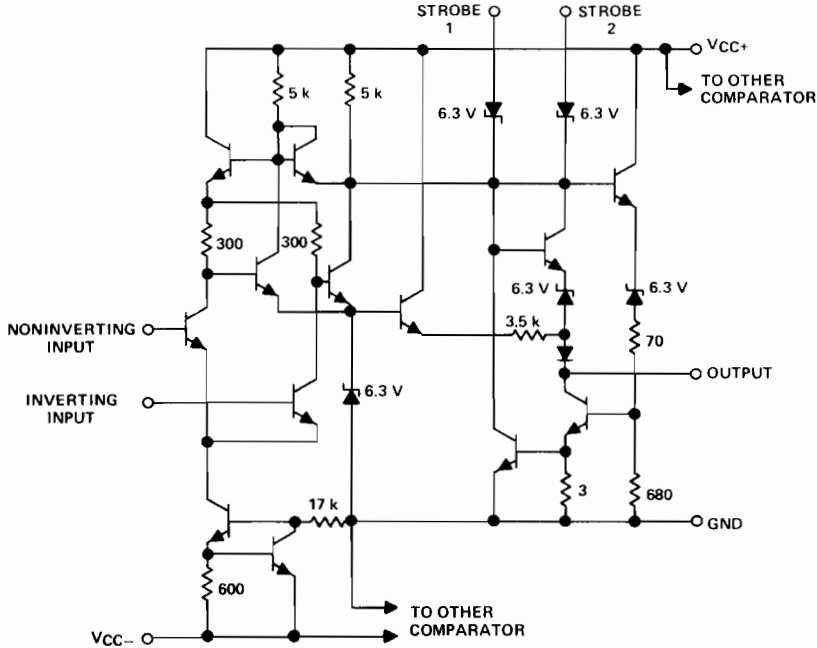
### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	600 mW	11.0 $\text{mW}/^\circ\text{C}$	95° C
J (Glass-Mounted Chip)	600 mW	8.2 $\text{mW}/^\circ\text{C}$	77° C
N	600 mW	9.2 $\text{mW}/^\circ\text{C}$	85° C
W	600 mW	8.0 $\text{mW}/^\circ\text{C}$	75° C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

schematic (each comparator)

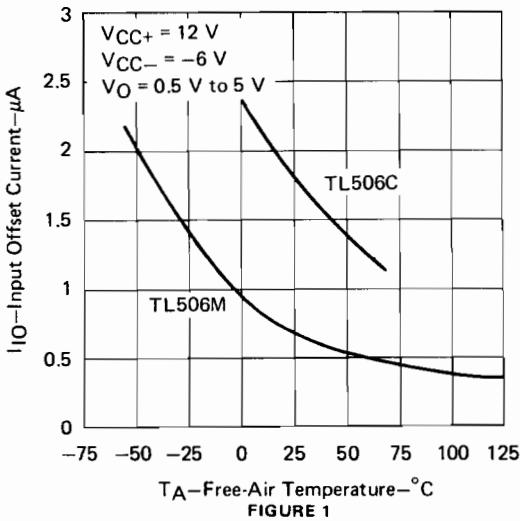


Resistor values are nominal in ohms.

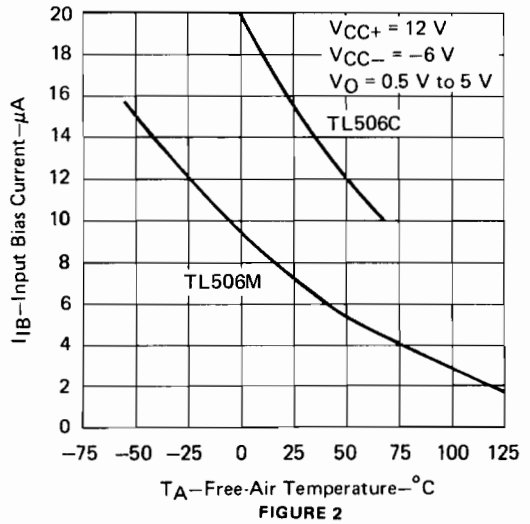
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## TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE



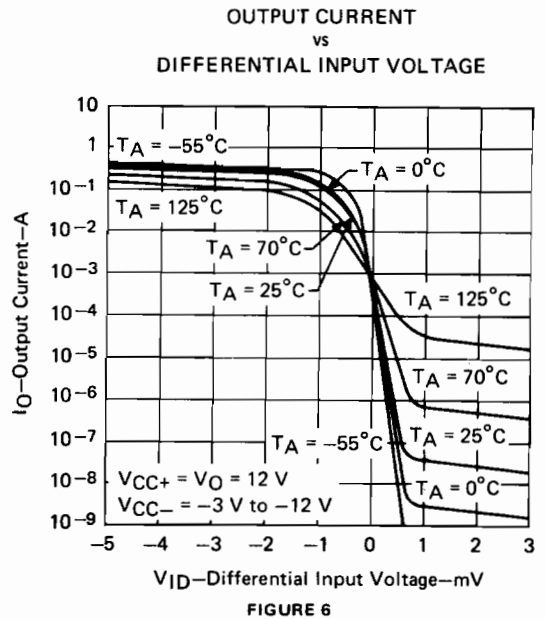
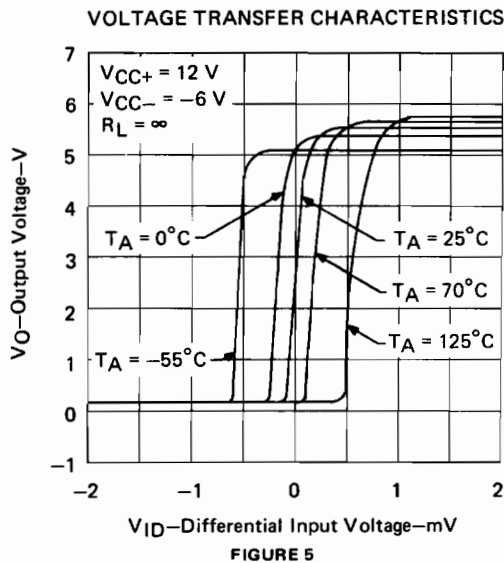
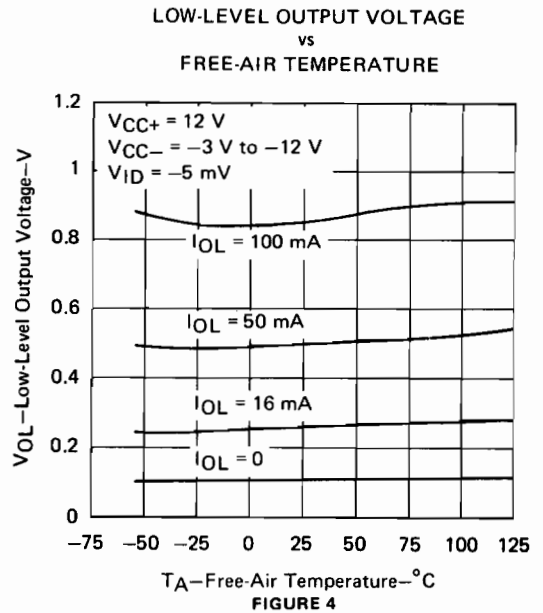
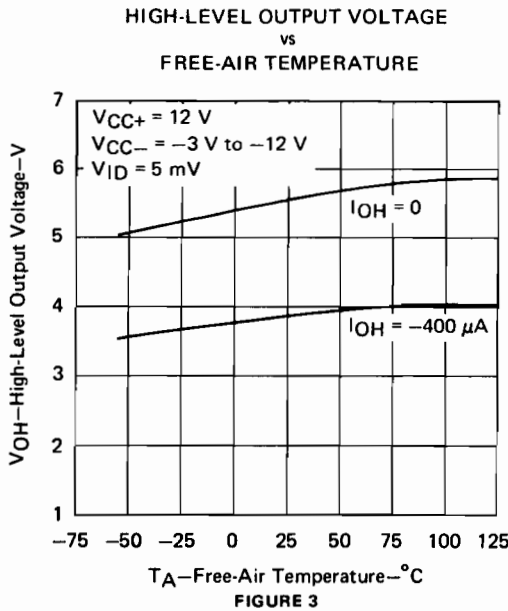
INPUT BIAS CURRENT  
vs  
FREE-AIR TEMPERATURE



# TYPES TL506M, TL506C

## DUAL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS†



†Data for temperatures below  $0^{\circ}\text{C}$  and above  $70^{\circ}\text{C}$  is applicable to TL506M circuits only.



# TYPES TL506M, TL506C

## DUAL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

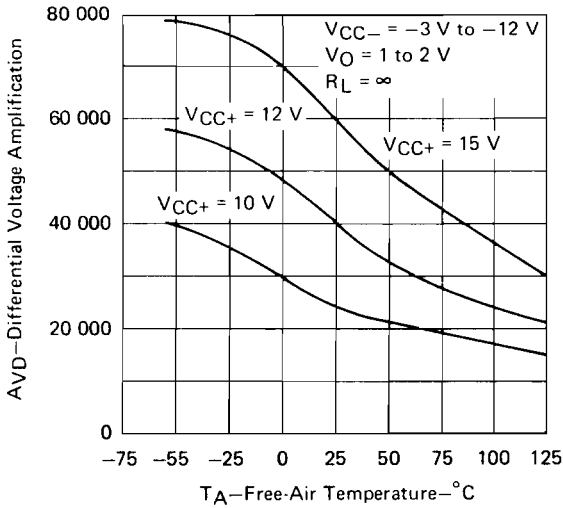


FIGURE 7

SHORT-CIRCUIT OUTPUT CURRENT  
vs  
FREE-AIR TEMPERATURE

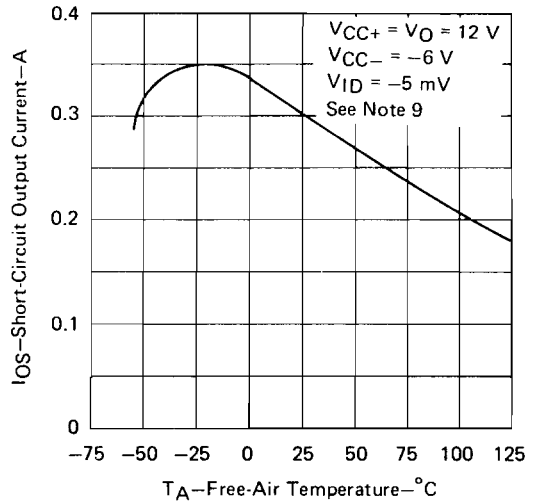


FIGURE 8

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

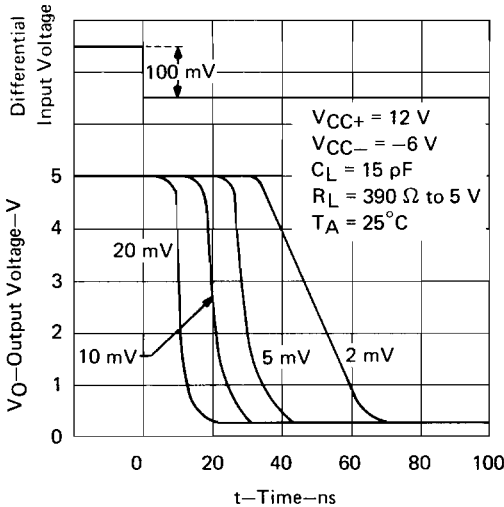


FIGURE 9

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

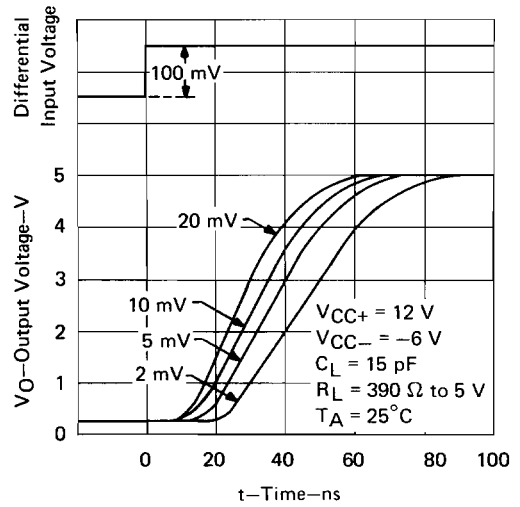


FIGURE 10

†Data for temperatures below  $0^{\circ}C$  and above  $70^{\circ}C$  is applicable to TL506M circuits only.  
NOTE 9: This parameter was measured using a single 5-ms pulse.

# TYPES TL506M, TL506C

## DUAL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS†

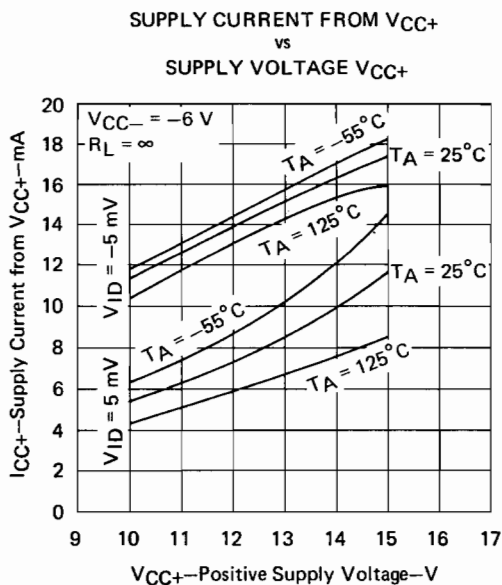


FIGURE 11

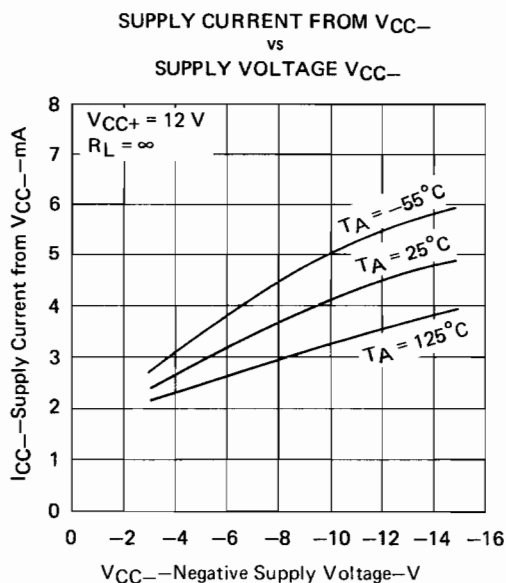


FIGURE 12

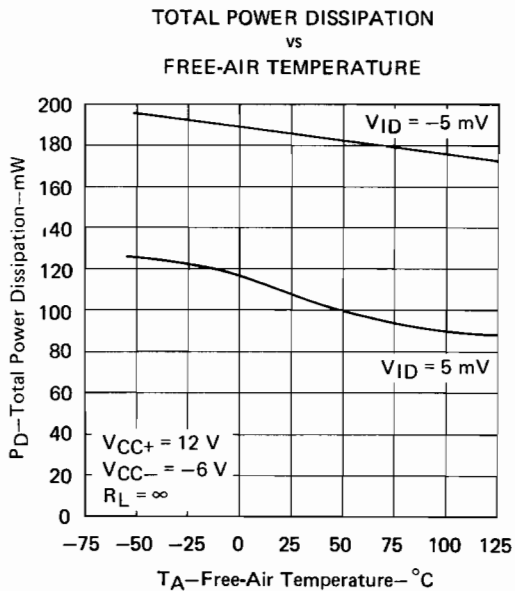


FIGURE 13

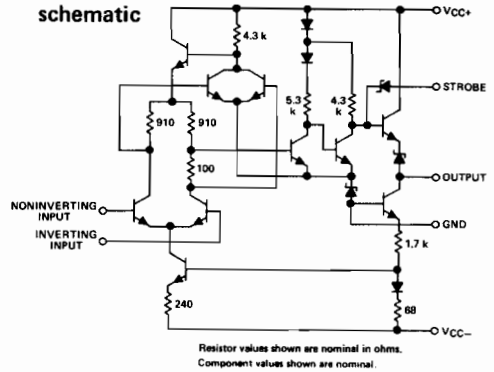
†Data for temperatures below  $0^\circ\text{C}$  and above  $70^\circ\text{C}$  is applicable to TL506M circuits only.

- Low Offset Characteristics
- High Differential Voltage Amplification
- Fast Response Times
- Output Compatible with Most TTL and DTL Circuits

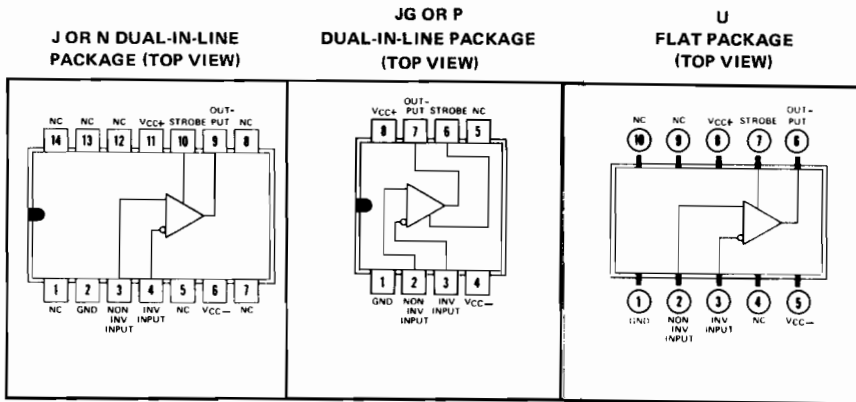
**description**

The TL510 monolithic high-speed voltage comparator is an improved version of the TL710 with an extra stage added to increase voltage amplification and accuracy, and a strobe input for greater flexibility. Typical voltage amplification is 33,000. Since the output cannot be more positive than the strobe, a low-level input at the strobe will cause the output to go low regardless of the differential input. Component matching, inherent in integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. These circuits are particularly useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector.

The TL510M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL510C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



**terminal assignments**



NC—No internal connection

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Note 1)	$\pm 7$ V
Strobe Voltage (see Note 1)	6 V
Peak output current ( $t_w \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 3)	300 mW
Operating free-air temperature range: TL510M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL510C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J, JG, or U package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N or P package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL510M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL510M chips are alloy-mounted; TL510C chips are glass-mounted.

# TYPES TL510M, TL510C

## DIFFERENTIAL COMPARATORS WITH STROBE

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL510M			TL510C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S < 200\ \Omega$ , See Note 4	25°C		0.6	2	1.6	3.5	mV
		Full range			3		4.5	
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C		3		3		$\mu\text{V}/^\circ\text{C}$
		25°C to MAX		3		20		
$I_{IO}$ Input offset current	See Note 4	25°C		0.75	3	1.8	5	$\mu\text{A}$
		MIN		1.8		7.5		
		MAX		0.25		3		
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C		15		24		nA/°C
		25°C to MAX		5		25		
$I_{IB}$ Input bias current	See Note 4	25°C		7		7		$\mu\text{A}$
		MIN		12		25		
$I_{IH(S)}$ High-level strobe current	$V_{(strobe)} = 5\text{ V}$ , $V_{ID} = -5\text{ mV}$	25°C					$\pm 100$	$\mu\text{A}$
$I_{IL(S)}$ Low-level strobe current	$V_{(strobe)} = -100\text{ mV}$ , $V_{ID} = 5\text{ mV}$	25°C		-1	-2.5	-1	-2.5	mA
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range		$\pm 5$		$\pm 5$		V
$V_{ID}$ Differential input voltage range		Full range		$\pm 5$		$\pm 5$		V
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to $2.5\text{ V}$	25°C		12.5	33	10	33	V/mV
		Full range		10		8		
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = 0$	Full range		4 <sup>§</sup>		5		V
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range		2.5	3.6 <sup>§</sup>	2.5	3.6 <sup>§</sup>	
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range		-1	-0.5 <sup>§</sup>	-1	-0.5 <sup>§</sup>	V
	$V_{(strobe)} = 0.3\text{ V}$ , $V_{ID} = 5\text{ mV}$ , $I_{OL} = 0$	Full range		-1	0 <sup>‡</sup>	-1	0 <sup>‡</sup>	
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C		2	2.4	1.6	2.4	mA
		MIN		1		2.3		
		MAX		0.5		2.3		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C		200			200	$\Omega$
CMRR Common-mode rejection ratio	$R_S < 200\ \Omega$	Full range		80	100 <sup>§</sup>	70	100 <sup>§</sup>	dB
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , No load	Full range		5.5 <sup>§</sup>		9		mA
$I_{CC-}$ Supply current from $V_{CC-}$		Full range		-3.5 <sup>§</sup>		-7		mA
$P_D$ Total power dissipation	No load	Full range		90 <sup>§</sup>	150	90 <sup>§</sup>	150	mW

† Unless otherwise noted, all characteristics are measured with the strobe open. Full range (MIN to MAX) for TL510M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL510C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

§ These typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL510M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL510C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ ,	$C_L = 5\text{ pF}$ ,	See Note 5		30	80	ns
Strobe release time	$R_L = \infty$ ,	$C_L = 5\text{ pF}$ ,	See Note 6		5	25	ns

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdriven output voltage crosses the 1.4-V level.

# TYPES TL510M, TL510C DIFFERENTIAL COMPARATORS WITH STROBE

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
J (Glass-Mounted Chip)	300 mW	8.2 mW/°C	113°C
JG (Alloy-Mounted Chip)	300 mW	8.4 mW/°C	114°C
JG (Glass-Mounted Chip)	300 mW	6.6 mW/°C	105°C
N	300 mW	9.2 mW/°C	117°C
P	300 mW	8.0 mW/°C	112°C
U	300 mW	5.4 mW/°C	94°C

Also see Dissipation Derating Curves, Section 2.

## TYPICAL CHARACTERISTICS

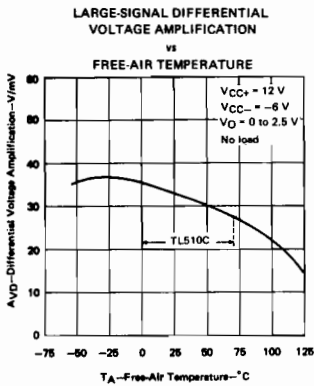


FIGURE 1

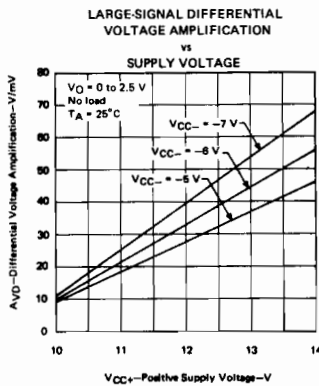


FIGURE 2

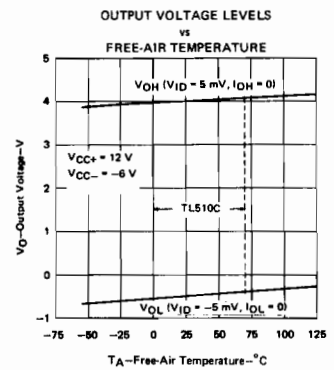


FIGURE 3

5

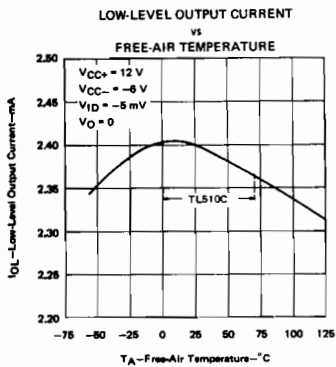


FIGURE 4

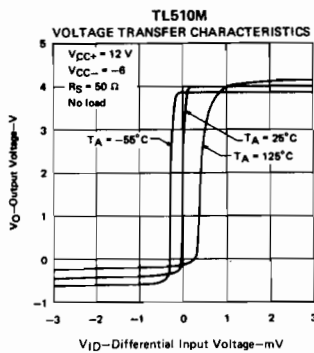


FIGURE 5

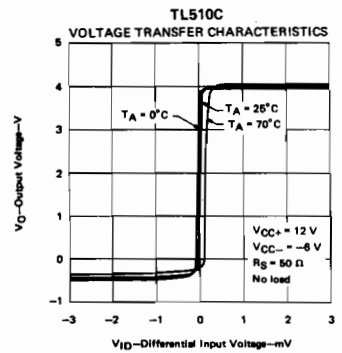


FIGURE 6

# TYPES TL510M, TL510C

## DIFFERENTIAL COMPARATORS WITH STROBE

### TYPICAL CHARACTERISTICS

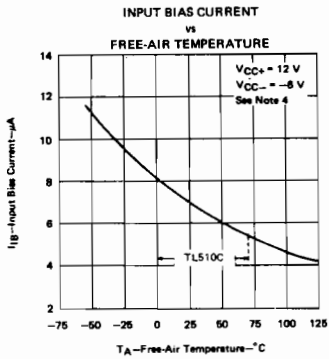


FIGURE 7

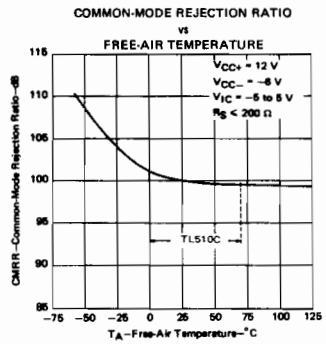


FIGURE 8

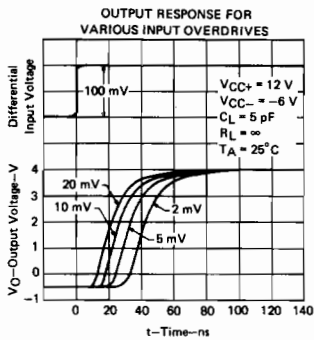


FIGURE 9

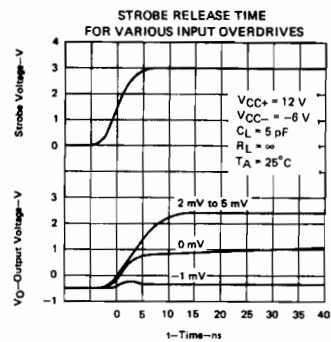


FIGURE 10.

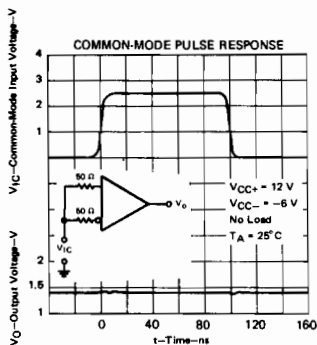


FIGURE 11

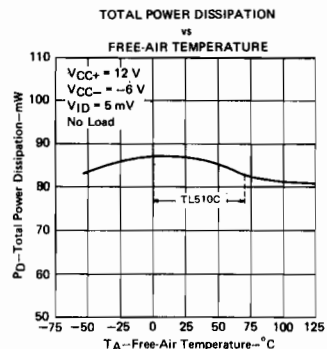


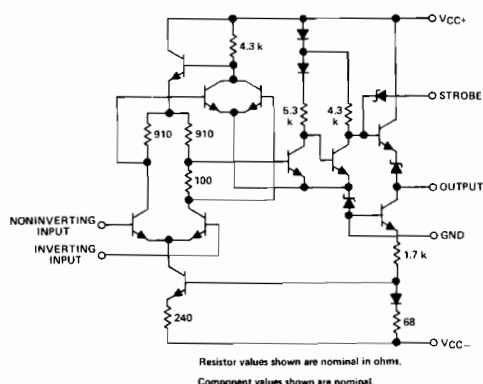
FIGURE 12

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL510M,  $V_O = 1.8 V$  at  $T_A = -55^\circ C$ ,  $V_O = 1.4 V$  at  $T_A = 25^\circ C$ , and  $V_O = 1 V$  at  $T_A = 125^\circ C$ ; for TL510C,  $V_O = 1.5 V$  at  $T_A = 0^\circ C$ ,  $V_O = 1.4 V$  at  $25^\circ C$ , and  $V_O = 1.2 V$  at  $T_A = 70^\circ C$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

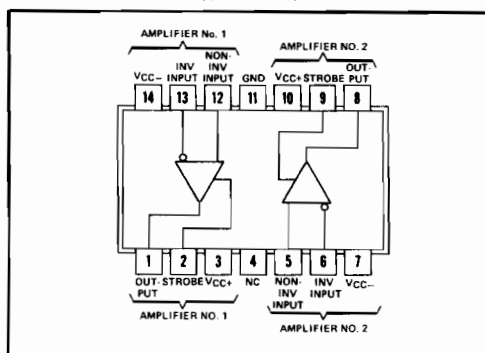
- Fast Response Times
- High Differential Voltage Amplification

- Low Offset Characteristics
- Outputs Compatible with Most TTL and DTL Circuits

schematic (each comparator)



J OR N DUAL-IN-LINE PACKAGE  
OR W FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

## description

The TL514 is an improved version of the TL720 dual high-speed voltage comparator. When compared with the TL720, these circuits feature higher amplification (typically 33,000) due to an extra amplification stage, increased accuracy because of lower offset characteristics, and greater flexibility with the addition of a strobe to each comparator. Since the output cannot be more positive than the strobe, a low-level input at the strobe will cause the output to go low regardless of the differential input.

These circuits are especially useful in applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector. The TL514M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL514C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Note 1)	$\pm 7$ V
Strobe voltage (see Note 1)	6 V
Peak output current ( $t_W \leq 1$ s)	10 mA
Continuous total dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (See Note 3):	
each comparator	300 mW
total package	600 mW
Operating free-air temperature range: TL514M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL514C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or W package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
3. For operation of the TL514M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TL514M chips are alloy-mounted; TL514C chips are glass-mounted.

# TYPES TL514M, TL514C

## DUAL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL514M			TL514C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	25°C	0.6	2	1.6	3.5		mV
		Full range		3		4.5		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C	3	10	3	20		$\mu\text{V}/^\circ\text{C}$
		25°C to MAX	3	10	3	20		
$I_{IO}$ Input offset current	See Note 4	25°C	0.75	3	1.8	5		$\mu\text{A}$
		MIN	1.8	7		7.5		
		MAX	0.25	3		7.5		
$\alpha I_{IO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C	15	75	24	100		$\text{nA}/^\circ\text{C}$
		25°C to MAX	5	25	15	50		
$I_{IB}$ Input bias current	See Note 4	25°C	7	15	7	20		$\mu\text{A}$
		MIN	12	25	9	30		
$I_{IL(S)}$ High-level strobe current	$V_{(\text{strobe})} = 5\text{ V}$ , $V_{ID} = -5\text{ mV}$	25°C		$\pm 100$		$\pm 100$		$\mu\text{A}$
$I_{IH(S)}$ Low-level strobe current	$V_{(\text{strobe})} = -100\text{ mV}$ , $V_{ID} = 5\text{ mV}$	25°C	-1	-2.5	-1	-2.5		$\text{mA}$
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	$\pm 5$		$\pm 5$			$\text{V}$
$V_{ID}$ Differential input voltage range		Full range	$\pm 5$		$\pm 5$			$\text{V}$
$AVD$ Large-signal differential voltage amplification	No load, $V_O = 0$ to $2.5\text{ V}$	25°C	12.5	33	10	33		$\text{V}/\text{mV}$
		Full range	10		8			
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = 0$	Full range		4 <sup>§</sup> 5		4 <sup>§</sup> 5		$\text{V}$
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6 <sup>§</sup>	2.5	3.6 <sup>§</sup>		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5 <sup>§</sup> 0 <sup>‡</sup>	-1	-0.5 <sup>§</sup> 0 <sup>‡</sup>		$\text{V}$
	$V_{(\text{strobe})} = 0.3\text{ V}$ , $V_{ID} = 5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	0 <sup>‡</sup>	-1	0 <sup>‡</sup>		$\text{V}$
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C	2	2.4	1.6	2.4		$\text{mA}$
		MIN	1	2.3	0.5	2.4		
		MAX	0.5	2.3	0.5	2.4		
$r_O$ Output resistance	$V_O = 1.4\text{ V}$	25°C		200		200		$\Omega$
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	Full range	80	100 <sup>§</sup>	70	100 <sup>§</sup>		$\text{dB}$
$I_{CC+}$ Supply current from $V_{CC+}$ †		Full range		5.5 <sup>§</sup> 9		5.5 <sup>§</sup> 9		$\text{mA}$
$I_{CC-}$ Supply current from $V_{CC-}$ †	$V_{ID} = -5\text{ mV}$ ,	Full range		-3.5 <sup>§</sup> -7		-3.5 <sup>§</sup> -7		$\text{mA}$
$P_D$ Total power dissipation †	No load	Full range		90 <sup>§</sup> 150		90 <sup>§</sup> 150		$\text{mW}$

<sup>†</sup> Unless otherwise noted, all characteristics are measured with the strobe open. Full range (MIN to MAX) for TL514M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL514C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

<sup>‡</sup> The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

<sup>§</sup> These typical values are at  $T_A = 25^\circ\text{C}$ .

<sup>†</sup> Supply current and power dissipation limits apply for each comparator.

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL514M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL514C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

### switching characteristics, $V_{CC+} = 12\text{ V}$ , $V_{CC-} = -6\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ ,	$C_L = 5\text{ pF}$ ,	See Note 5		30	80	ns
Strobe release time	$R_L = \infty$ ,	$C_L = 5\text{ pF}$ ,	See Note 6		5	25	ns

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdriven output voltage crosses the 1.4-V level.



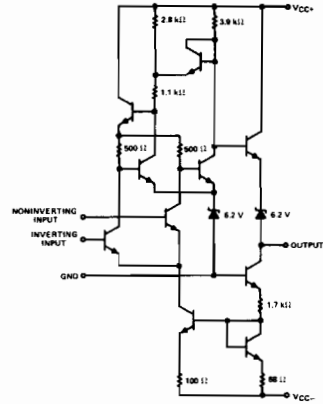
# LINEAR INTEGRATED CIRCUITS

# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

BULLETIN NO. DL-S 11441, FEBRUARY 1971—REVISED OCTOBER 1979

- Fast Response Times
- Low Offset Characteristics
- Output Compatible with Most TTL and DTL Circuits

schematic

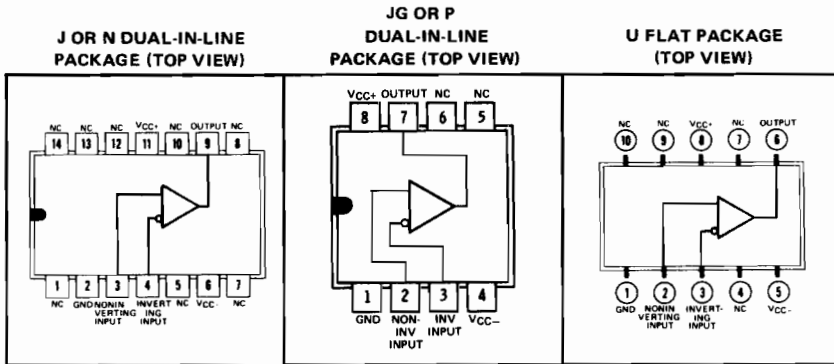


Component values shown are nominal.

## description

The TL710 is a monolithic high-speed comparator having differential inputs and a low-impedance output. Component matching, inherent in silicon integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. These circuits are especially useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed voltage comparator. The TL710M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL710C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## terminal assignments



NC—No internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL710M	TL710C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	14	14	V
Supply voltage $V_{CC-}$ (see Note 1)	-7	-7	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (either input, see Note 1)	$\pm 7$	$\pm 7$	V
Peak output current ( $t_W \leq 1$ s)	10	10	mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 3)	300	300	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	300	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds		260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL710M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL710M chips are alloy-mounted; TL710C chips are glass-mounted.

# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL710M			TL710C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	25°C	2	5	2	7.5		mV	
		Full range	6			10			
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	Full range	5		7.5			$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	See Note 4	25°C	1	10	1	15		$\mu\text{A}$	
		Full range	20			25			
$I_{IB}$ Input bias current	See Note 4	25°C	25	75	25	100		$\mu\text{A}$	
		Full range	150			150			
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	±5		±5			V	
$V_{ID}$ Differential input voltage range		25°C	±5		±5			V	
$A_{VD}$ Large-signal differential voltage amplification	No load, See Note 4	25°C	750	1500	700	1500		V/mV	
		Full range	500		500				
$V_{OH}$ High-level output voltage	$V_{ID} = 15\text{ mV}$ , $I_{OH} = -0.5\text{ mA}$	25°C	2.5	3.2	4	2.5	3.2	4	V
$V_{OL}$ Low-level output voltage	$V_{ID} = -15\text{ mV}$ , $I_{OL} = 0$	25°C	-1	-0.5	0‡	-1	-0.5	0‡	V
$I_{OL}$ Low-level output current	$V_{ID} = -15\text{ mV}$ , $V_O = 0$	25°C	1.6	2.5					mA
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200			$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	25°C	70	90	65	90		dB	
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ V to } 5\text{ V}$ (-10 mV for typ),	25°C	5.4	10.1	5.4			mA	
$I_{CC-}$ Supply current from $V_{CC-}$		25°C	-3.8	-8.9	-3.8			mA	
$P_D$ Total power dissipation	No load	25°C	88	175	88			mW	

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL710M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL710C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

† Full range for TL710M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for TL710C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL710M	TL710C	UNIT
		TYP	TYP	
Response time	No load, See Note 5	40	40	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
J (Glass-Mounted Chip)	300 mW	8.2 mW/°C	113°C
JG (Alloy-Mounted Chip)	300 mW	8.4 mW/°C	114°C
JG (Glass-Mounted Chip)	300 mW	6.6 mW/°C	105°C
N	300 mW	9.2 mW/°C	117°C
P	300 mW	8.0 mW/°C	112°C
U	300 mW	5.4 mW/°C	94°C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

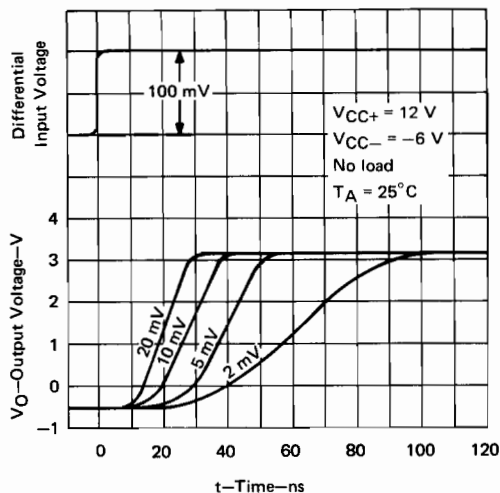


FIGURE 1

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

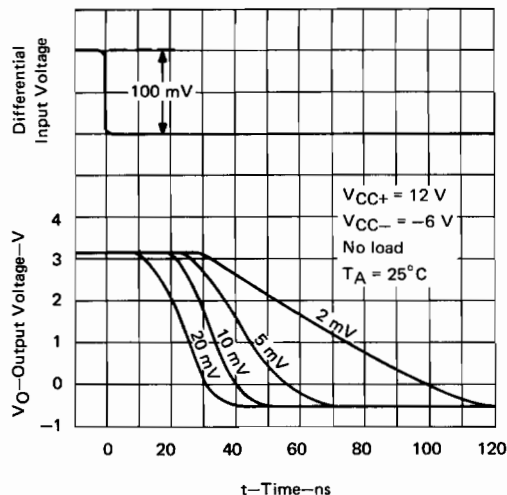


FIGURE 2

COMMON-MODE PULSE RESPONSE  
vs  
ELAPSED TIME

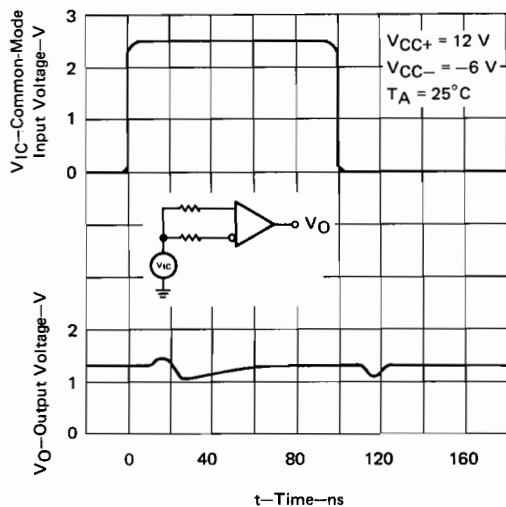


FIGURE 3

OUTPUT VOLTAGE  
vs  
FREE-AIR TEMPERATURE

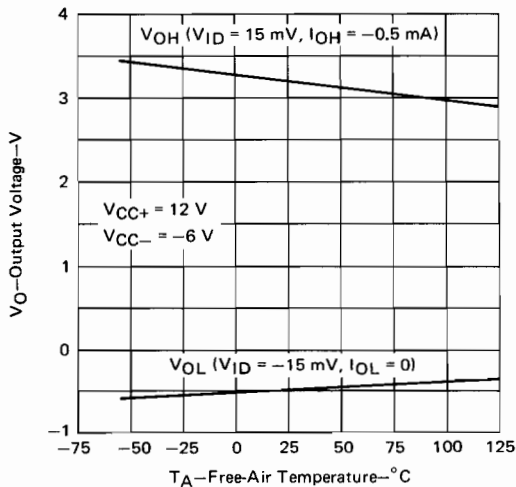


FIGURE 4

# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

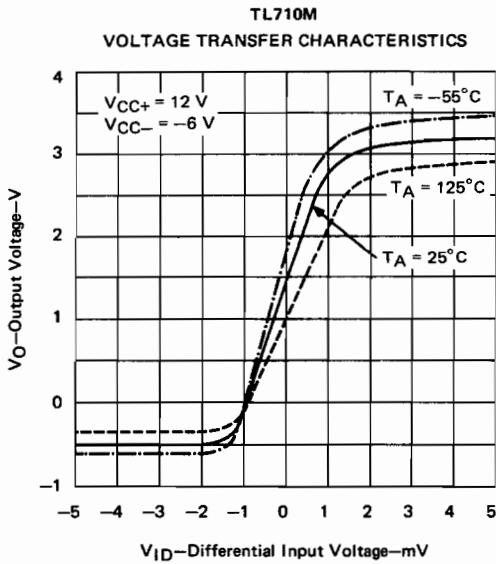


FIGURE 5

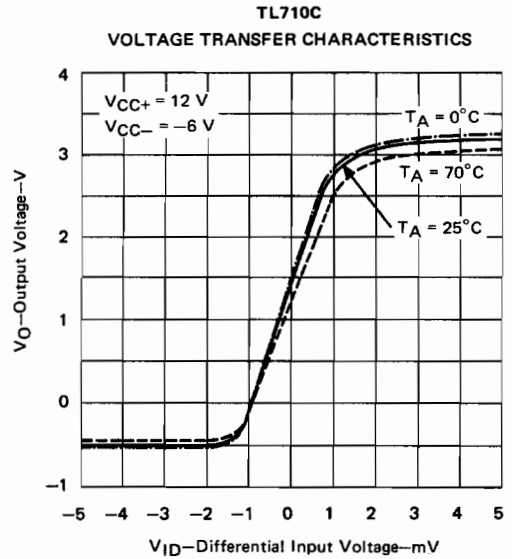


FIGURE 6

TOTAL POWER DISSIPATION  
vs  
FREE-AIR TEMPERATURE

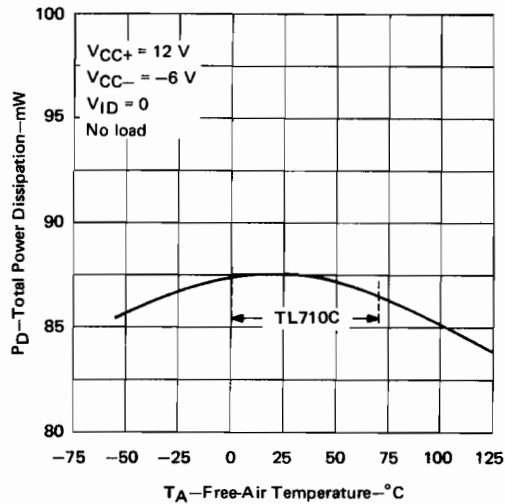
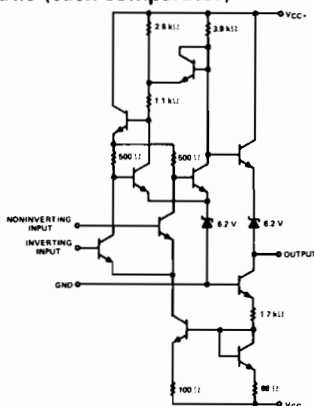


FIGURE 7

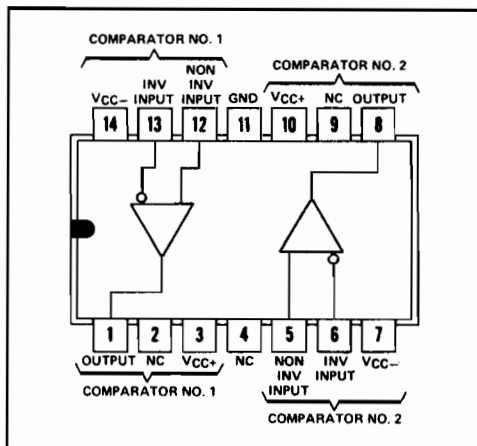
**NOT RECOMMENDED FOR NEW DESIGN**  
FOR NEW DESIGN, USE TL820C

schematic (each comparator)



Component values shown are nominal.

J OR N  
DUAL-IN-LINE PACKAGE (TOP VIEW)



NC—No internal connection

**description**

The TL720 is two high-speed comparators in a single package, each electrically identical to the TL710 and having differential inputs and a low-impedance output. Component matching, inherent in silicon monolithic circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. This circuit is especially useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed voltage comparator. The TL720C is characterized for operation from 0°C to 70°C.

**absolute maximum ratings over operating temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	±5 V
Input voltage (any input, see Note 1)	±7 V
Peak output current, each comparator ( $t_W \leq 1$ s)	10 mA
Continuous total power dissipation: each comparator	300 mW
total package	600 mW
Operating free-air temperature range	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.

# TYPE TL720C

## DUAL DIFFERENTIAL COMPARATOR

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 3	25°C	2	7.5		mV
			0°C to 70°C		10		
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	$R_S \leq 200\ \Omega$ , See Note 3	0°C to 70°C		7.5		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current	See Note 3	25°C	1	15		$\mu\text{A}$
			0°C to 70°C		25		
$I_{IB}$	Input bias current	See Note 3	25°C	25	100		$\mu\text{A}$
			0°C to 70°C		150		
$V_{ICR}$	Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	$\pm 5$			V
$V_{ID}$	Differential input voltage range		25°C	$\pm 5$			V
AVD	Large-signal differential voltage amplification	No load, See Note 3	25°C	700	1500		
			0°C to 70°C	500			
$V_{OH}$	High-level output voltage	$V_{ID} = 15\text{ mV}$ , $I_{OH} = -0.5\text{ mA}$	25°C	2.5	3.2	4	V
$V_{OL}$	Low-level output voltage	$V_{ID} = -15\text{ mV}$ , $I_{OL} = 0$	25°C	-1	-0.5	0 $\ddagger$	V
$r_o$	Output resistance	$V_O = 1.4\text{ V}$	25°C		200		$\Omega$
CMRR	Common-mode rejection ratio	$R_S \leq 200\ \Omega$	25°C	65	90		dB
$I_{CC+}$	Supply current from $V_{CC+}$ (each comparator)	$V_{ID} = -5\text{ V to } 5\text{ V}$ (-10 mV for typ).	25°C		5.4		mA
$I_{CC-}$	Supply current from $V_{CC-}$ (each comparator)		25°C		-3.8		mA
$P_D$	Total power dissipation (each comparator)	No load	25°C		88		mW

NOTE 3: These characteristics are verified by measurements at the following temperatures and output voltage levels:  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

$\ddagger$ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TYP	UNIT
Response time	No load, See Note 4	40	ns

NOTE 4: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

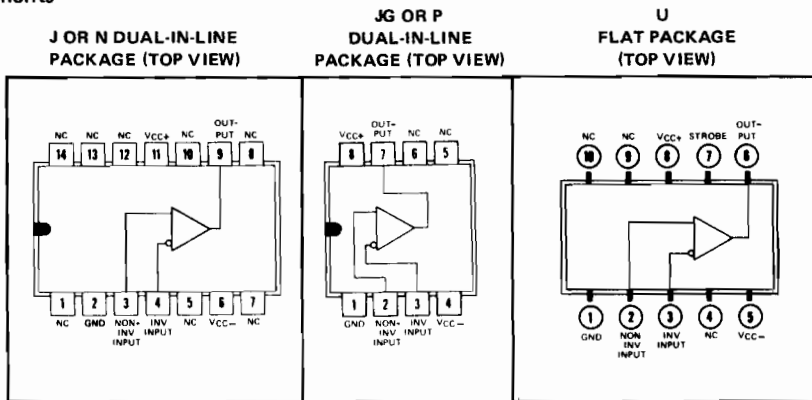
- Low Offset Characteristics
- High Differential Voltage Amplification
- Fast Response Times
- Output Compatible with Most TTL and DTL Circuits

### description

The TL810 is an improved version of the TL710 high-speed voltage comparator with an extra stage added to increase voltage amplification and accuracy. Typical amplification is 33,000. Component matching, inherent in monolithic integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. These circuits are particularly useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector.

The TL810M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL810C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

### terminal assignments



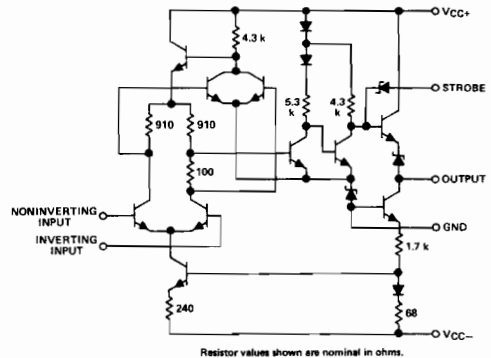
NC—No internal connection

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Note 1)	$\pm 7$ V
Peak output current ( $t_w \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 3)	300 mW
Operating free-air temperature range: TL810M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL810C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J, JG, or U package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N or P package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL810M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J and JG packages, TL810M chips are alloy-mounted; TL810C chips are glass-mounted.

### schematic



# TYPES TL810M, TL810C

## DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL810M			TL810C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S < 200\ \Omega$ , See Note 4	25°C	0.6		2	1.6		3.5	mV
		Full range			3			4.5	
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C	3		10	3		20	$\mu\text{V}/^\circ\text{C}$
		25°C to MAX	3		10	3		20	
$I_{IO}$ Input offset current	See Note 4	25°C	0.75		3	1.8		5	$\mu\text{A}$
		MIN	1.8		7	7.5			
		MAX	0.25		3	7.5			
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C	15		75	24		100	nA/°C
		25°C to MAX	5		25	15		50	
$I_{IB}$ Input bias current	See Note 4	25°C	7		15	7		20	$\mu\text{A}$
		MIN	12		25	9		30	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	±5			±5			V
$V_{ID}$ Differential input voltage range		Full range	±5			±5			V
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25°C	12.5	33		10	33		V/mV
		Full range	10			8			
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ $I_{OH} = 0$	Full range	4§		5	4§		5	V
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6§		2.5	3.6§		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5§		0‡	-1 -0.5§ 0‡		V
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C	2	2.4		1.6	2.4		mA
		MIN	1	2.3		0.5	2.4		
		MAX	0.5	2.3		0.5	2.4		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C			200			200	$\Omega$
CMRR Common-mode rejection ratio	$R_S < 200\ \Omega$	Full range	80	100§		70	100§		dB
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , No load	Full range	5.5§		9	5.5§		9	mA
$I_{CC-}$ Supply current from $V_{CC-}$		Full range	-3.5§		-7	-3.5§		-7	
$P_D$ Total power dissipation	No load	Full range	90§	150		90§	150		mW

† Full range (MIN to MAX) for TL810M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL810C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

§ These typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL810M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL810C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 5		30	80	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.



# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
J (Glass-Mounted Chip)	300 mW	8.2 mW/°C	113°C
JG (Alloy-Mounted Chip)	300 mW	8.4 mW/°C	114°C
JG (Glass-Mounted Chip)	300 mW	6.6 mW/°C	105°C
N	300 mW	9.2 mW/°C	117°C
P	300 mW	8.0 mW/°C	112°C
U	300 mW	5.4 mW/°C	94°C

Also see Dissipation Derating Curves, Section 2.

## TYPICAL CHARACTERISTICS

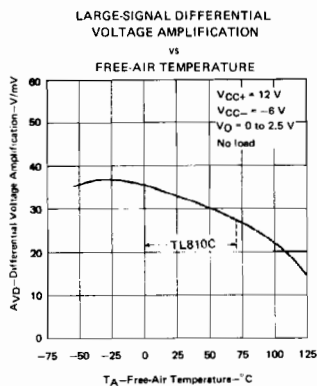


FIGURE 1

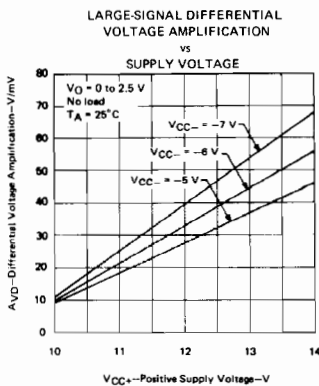


FIGURE 2

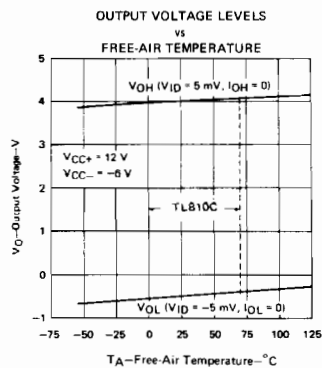


FIGURE 3

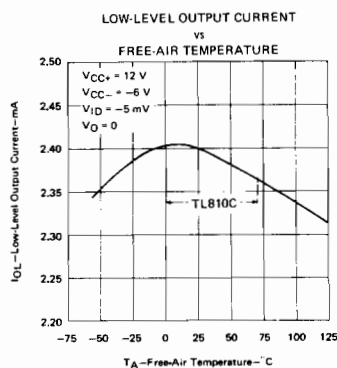


FIGURE 4

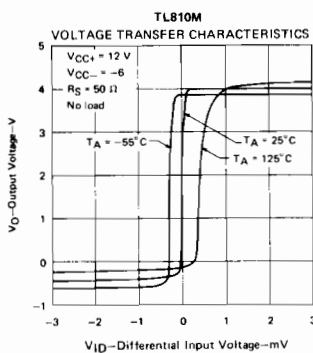


FIGURE 5

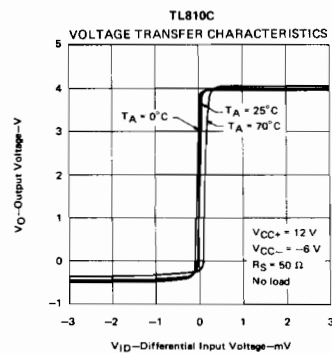


FIGURE 6

# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

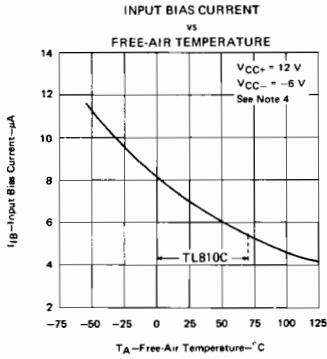


FIGURE 7

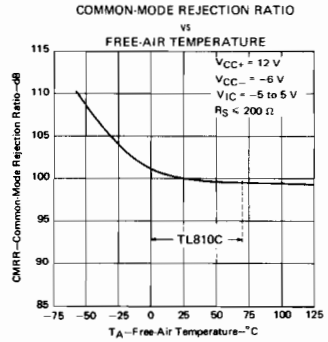


FIGURE 8

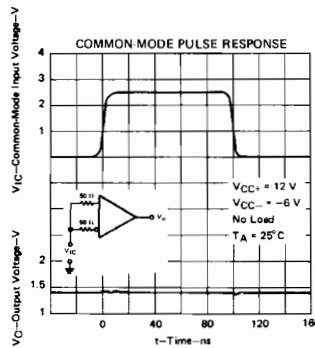


FIGURE 9

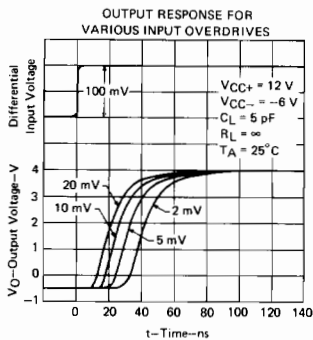


FIGURE 10

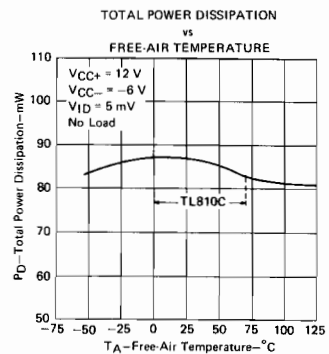


FIGURE 11

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL810M,  $V_O = 1.8 V$  at  $T_A = -55^{\circ}C$ ,  $V_O = 1.4 V$  at  $T_A = 25^{\circ}C$ , and  $V_O = 1 V$  at  $T_A = 125^{\circ}C$ ; for TL810C,  $V_O = 1.5 V$  at  $T_A = 0^{\circ}C$ ,  $V_O = 1.4 V$  at  $25^{\circ}C$ , and  $V_O = 1.2 V$  at  $T_A = 70^{\circ}C$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

- Fast Response Times
- Improved Voltage Amplification and Offset Characteristics
- Output Compatible with Most TTL and DTL Circuits

**description**

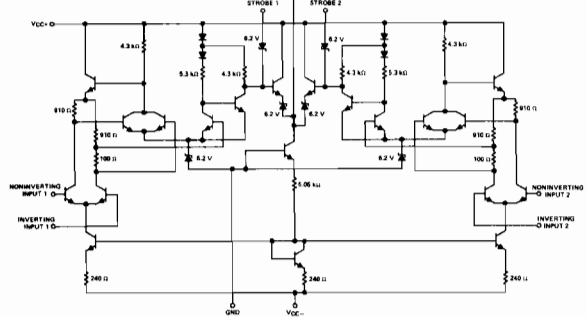
The TL811 is an improved version of the TL711 high-speed dual-channel voltage comparator. Voltage amplification is higher (typically 17,500) due to an extra stage, increasing the comparator accuracy. The output pulse width may be "stretched" by varying the capacitive loading.

Each channel has differential inputs, a strobe input, and an output in common with the other channel. When either strobe is taken low, it inhibits the associated channel. If both strobes are simultaneously low, the output will be low regardless of the conditions applied to the differential inputs.

These dual-channel voltage comparators are particularly attractive for applications requiring an amplitude-discriminating sense amplifier with an adjustable threshold voltage.

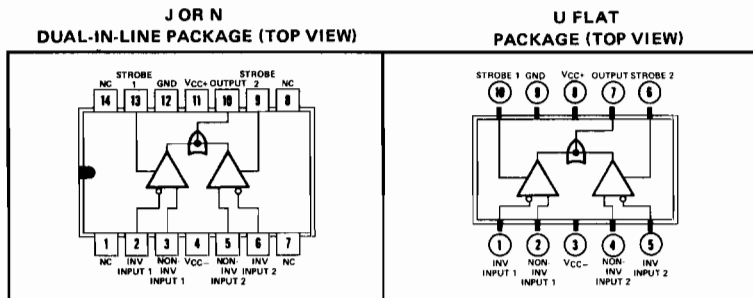
The TL811M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL811C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**



Component values shown are nominal.

**terminal assignments**



NC—No internal connection

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Note 1)	$\pm 7$ V
Strobe Voltage (see Note 1)	6 V
Peak output current ( $t_w \leq 1$ s)	50 mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 3)	300 mW
Operating free-air temperature range: TL811M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL811C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J or U package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL811M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, the TL811M chips are alloy-mounted; TL811C chips are glass-mounted.

# TYPES TL811M, TL811C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL811M			TL811C			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$ Input offset voltage	$R_S < 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	25°C	1	3.5		1	5	mV		
		Full range		4.5		6				
	$R_S < 200\ \Omega$ , See Note 4	25°C	1	5		1	7.5			
		Full range		6		10				
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S < 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	Full range	5		5		$\mu\text{V}/^\circ\text{C}$			
$I_{IO}$ Input offset current	See Note 4	25°C	0.5	3		0.5	5	$\mu\text{A}$		
		Full range		5		10				
$I_{IB}$ Input bias current	See Note 4	25°C	7	20		7	30	$\mu\text{A}$		
		Full range		30		50				
$I_{IL(S)}$ Low-level strobe current	$V(\text{strobe}) = -100\text{ mV}$	25°C	-1.2	-2.5		-1.2	-2.5	mA		
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	$\pm 5$		$\pm 5$		V			
$V_{ID}$ Differential input voltage range		25°C	$\pm 5$		$\pm 5$		V			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 0$ to 2.5 V, No load	25°C	12.5	17.5		10	17.5	V/mV		
		Full range	8			5				
$V_{OH}$ High-level output voltage	$V_{ID} = 10\text{ mV}$ , $I_{OH} = 0$	25°C	4	5		4	5	V		
		$V_{ID} = 10\text{ mV}$ , $I_{OH} = -5\text{ mA}$	25°C	2.5	3.6		2.5		3.6	
$V_{OL}$ Low-level output voltage	$V_{ID} = -10\text{ mV}$ , $I_{OL} = 0$	25°C	-1	-0.4	0‡	-1	-0.4	0‡	V	
		25°C	$V_{ID} = 10\text{ mV}$ , $V(\text{strobe}) = 0.3\text{ V}$ , $I_{OL} = 0$	-1		0‡	-1			0‡
			$V_{ID} = -10\text{ mV}$ , $V_O = 0$	0.5	0.8		0.5	0.8		
$I_{OL}$ Low-level output current	$V_{ID} = -10\text{ mV}$ , $V_O = 0$	25°C	0.5	0.8		0.5	0.8	mA		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200		$\Omega$			
CMRR Common-mode rejection ratio	$R_S < 200\ \Omega$	25°C	70	90		65	90	dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5$ to 5 V (-10 mV for typ)	25°C	6.5		6.5		mA			
$I_{CC-}$ Supply current from $V_{CC-}$		25°C	-2.7		-2.7		mA			
$P_D$ Total power dissipation	No load, See Note 5	25°C	94	150		94	200	mW		

† Unless otherwise noted, all characteristics are measured with the strobe of the channel under test open, the strobe of the other channel is grounded. Full range for TL811M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL811C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

NOTES: 4. These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL811M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL811C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

5. The strobes are alternately grounded.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL811M			TL811C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 6		33	80		33		ns
Strobe release time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 7		5	25		5		ns

NOTES: 6. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

7. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdriven output voltage crosses the 1.4-V level.

# TYPES TL811M, TL811C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

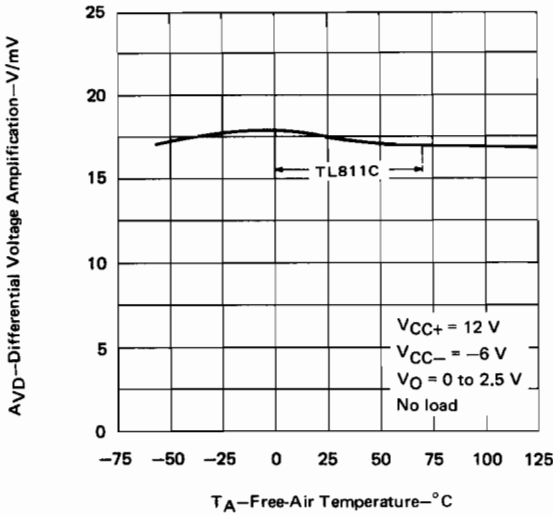


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

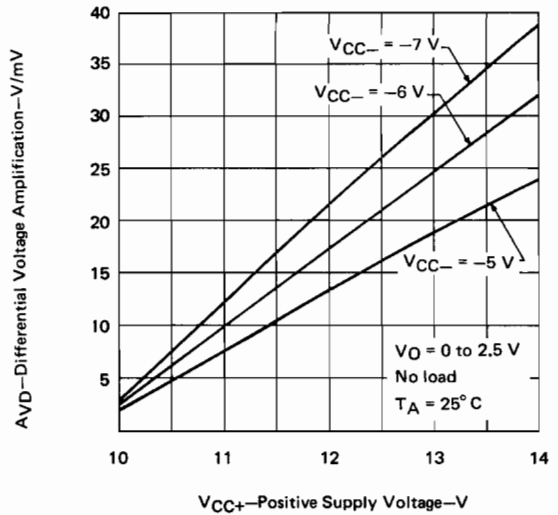


FIGURE 2

TL811M  
VOLTAGE TRANSFER CHARACTERISTICS

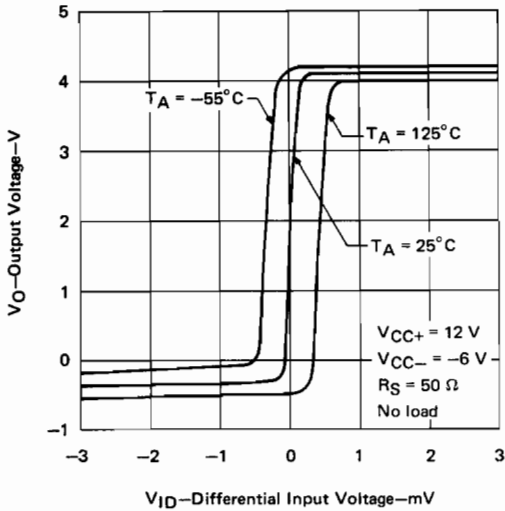


FIGURE 3

TL811C  
VOLTAGE TRANSFER CHARACTERISTICS

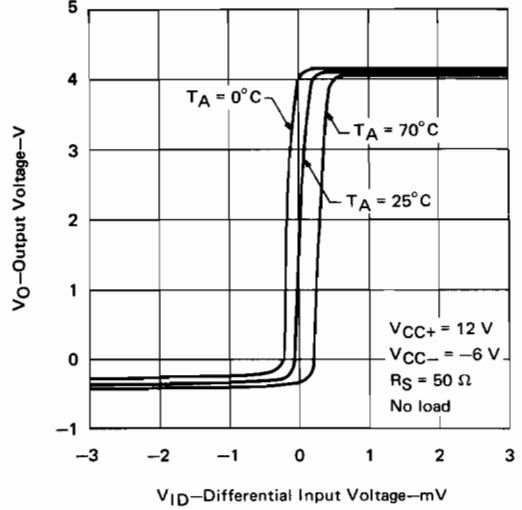


FIGURE 4

# TYPES TL811M, TL811C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

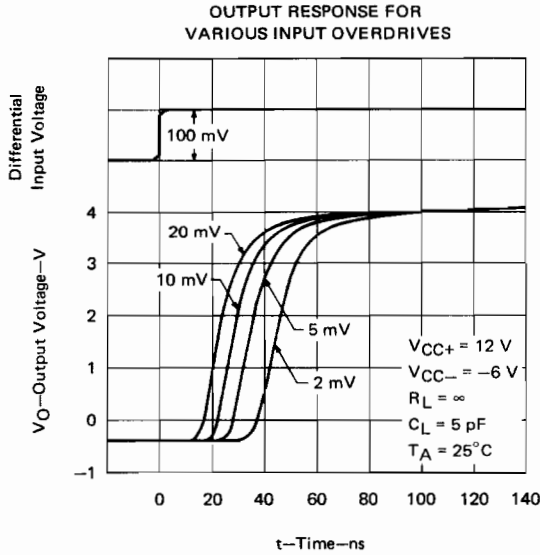


FIGURE 5

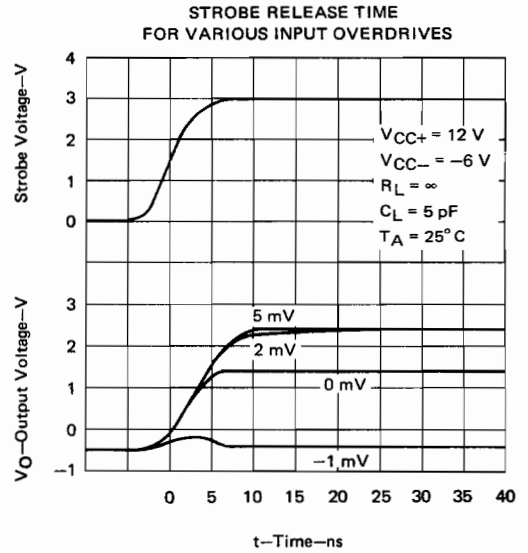


FIGURE 6

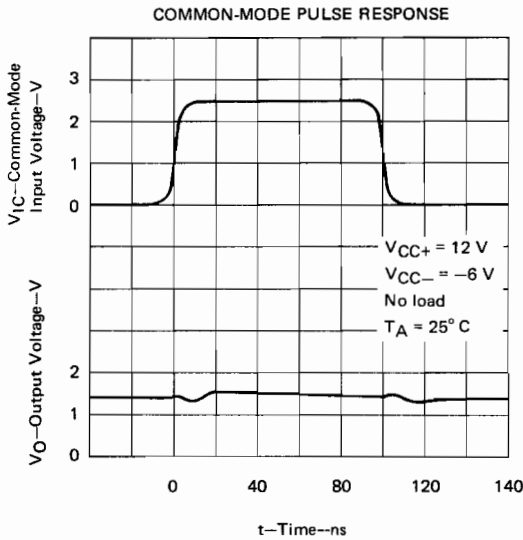
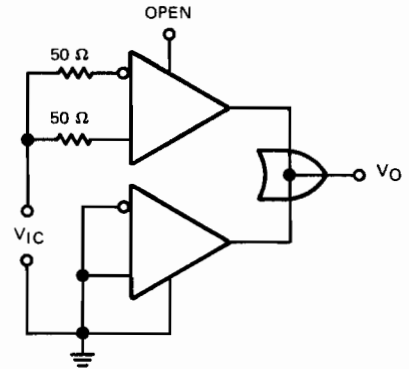


FIGURE 7



TEST CIRCUIT  
FOR FIGURE 7

# TYPES TL811M, TL811C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS

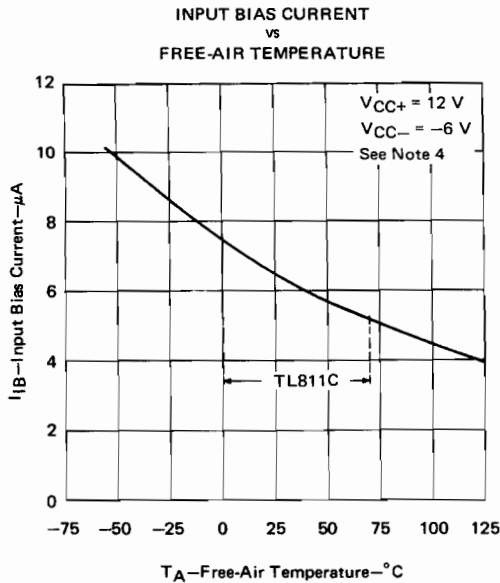


FIGURE 8

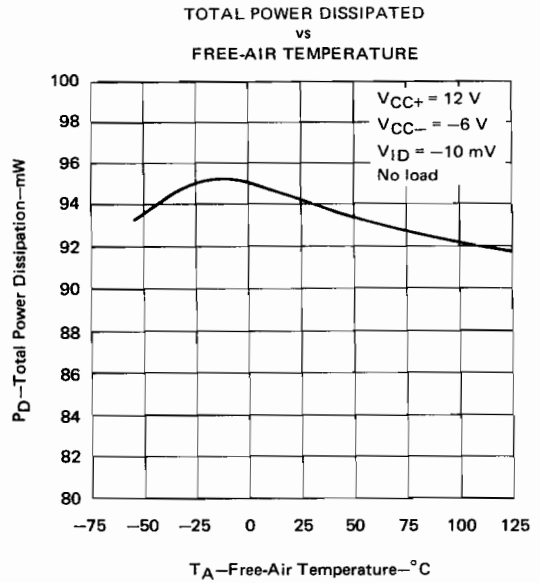


FIGURE 9

NOTE 4. These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL811M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^{\circ}\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^{\circ}\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^{\circ}\text{C}$ ; for TL811C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^{\circ}\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^{\circ}\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^{\circ}\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 $\text{mW}/^{\circ}\text{C}$	123 $^{\circ}\text{C}$
J (Glass-Mounted Chip)	300 mW	8.2 $\text{mW}/^{\circ}\text{C}$	113 $^{\circ}\text{C}$
N	300 mW	9.2 $\text{mW}/^{\circ}\text{C}$	117 $^{\circ}\text{C}$
U	300 mW	5.4 $\text{mW}/^{\circ}\text{C}$	94 $^{\circ}\text{C}$

Also see Dissipation Derating Curves, Section 2.

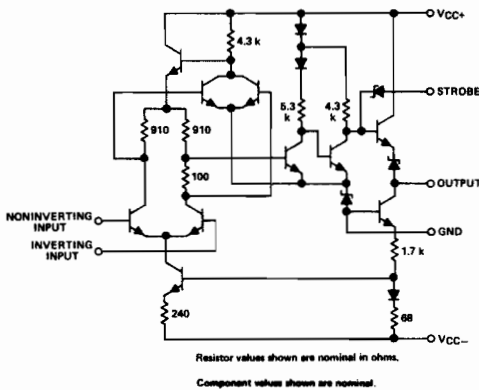




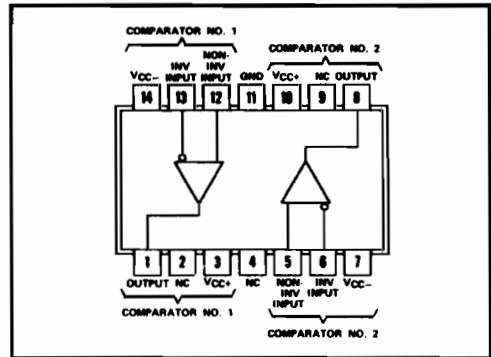
- Fast Response Times
- High Differential Voltage Amplification

- Low Offset Characteristics
- Outputs Compatible with Most TTL and DTL Circuits

schematic (each comparator)



J OR N DUAL-IN-LINE  
PACKAGE (TOP VIEW)



NC—No internal connection

**description**

The TL820 is an improved version of the TL720 dual high-speed voltage comparator. Each comparator has differential inputs and a low-impedance output. When compared with the TL720, these circuits feature high amplification (typically 33,000) due to an extra amplification stage and increased accuracy because of lower offset characteristics. They are particularly useful in applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector. The TL820M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL820C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**5**

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Note 1)	$\pm 7$ V
Peak output current ( $t_w \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature: each comparator	300 mW
total package, (see Note 3)	600 mW
Operating free-air temperature range: TL820M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL820C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL820M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package, TL820M chips are alloy-mounted; TL820C chips are glass-mounted.

# TYPES TL820M, TL820C

## DUAL DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL820M			TL820C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S < 200\ \Omega$ , See Note 4	25°C	0.6	2	1.6	3.5	mV	
		Full range		3		4.5		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C	3	10	3	20	$\mu\text{V}/^\circ\text{C}$	
		25°C to MAX	3	10	3	20		
$I_{IO}$ Input offset current	See Note 4	25°C	0.75	3	1.8	5	$\mu\text{A}$	
		MIN	1.8	7		7.5		
		MAX	0.25	3		7.5		
$\alpha I_{IO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C	15	75	24	100	$\text{nA}/^\circ\text{C}$	
		25°C to MAX	5	25	15	50		
$I_{IB}$ Input bias current	See Note 4	25°C	7	15	7	20	$\mu\text{A}$	
		MIN	12	25	9	30		
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	±5		±5		V	
$V_{ID}$ Differential input voltage range		Full range	±5		±5		V	
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25°C	12.5	33	10	33	V/mV	
		Full range	10		8			
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ $I_{OH} = 0$	Full range	4§		4§		V	
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6§	2.5	3.6§		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5§	-1	-0.5§	V	
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C	2	2.4	1.6	2.4	mA	
		MIN	1	2.3	0.5	2.4		
		MAX	0.5	2.3	0.5	2.4		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200		$\Omega$	
CMRR Common-mode rejection ratio	$R_S < 200\ \Omega$	Full range	80	100§	70	100§	dB	
$I_{CC+}$ Supply current from $V_{CC+}$ (each comparator)	$V_{ID} = -5\text{ mV}$ , No load	Full range	5.5§	9	5.5§	9	mA	
$I_{CC-}$ Supply current from $V_{CC-}$ (each comparator)		Full range	-3.5§	-7	-3.5§	-7	mA	
$P_D$ Total power dissipation (each comparator)		Full range	90§	150	90§	150	mW	

† Full range (MIN to MAX) for TL820M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL820C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

§ These typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL820M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL820C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 5		30	80	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

# TYPES TL820M, TL820C DUAL DIFFERENTIAL COMPARATORS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	600 mW	11.0 mW/°C	95°C
J (Glass-Mounted Chip)	600 mW	8.2 mW/°C	77°C
N	600 mW	9.2 mW/°C	85°C

Also see Dissipation Derating Curves, Section 2.

## TYPICAL CHARACTERISTICS

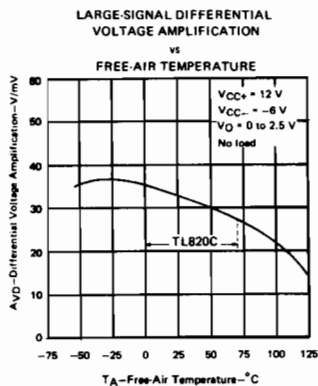


FIGURE 1

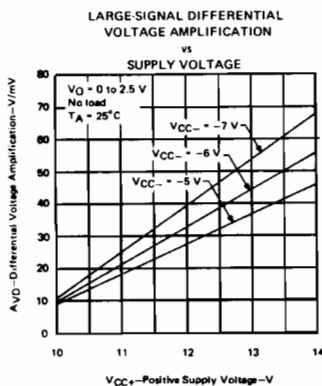


FIGURE 2

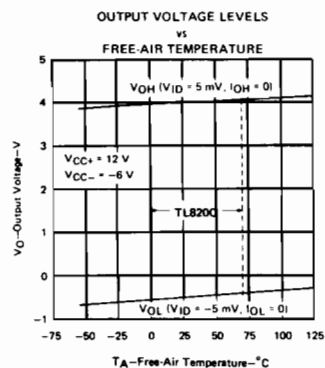


FIGURE 3

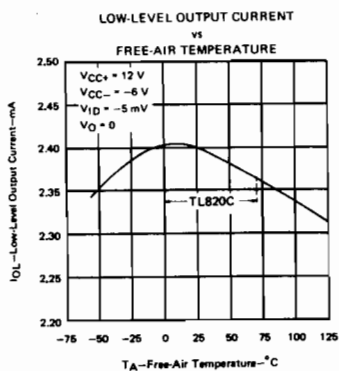


FIGURE 4

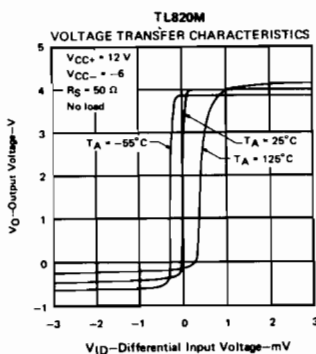


FIGURE 5

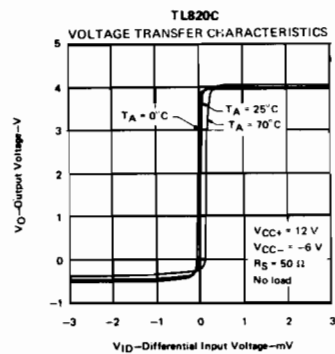


FIGURE 6

# TYPES TL820M, TL820C DUAL DIFFERENTIAL COMPARATOR

## TYPICAL CHARACTERISTICS

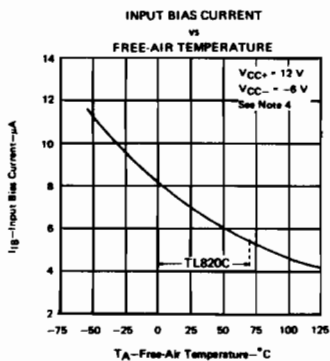


FIGURE 7

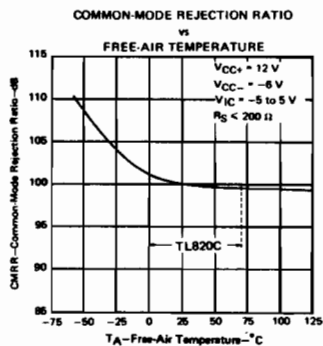


FIGURE 8

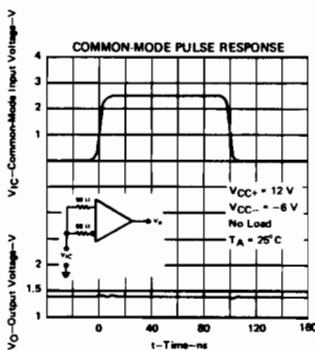


FIGURE 9

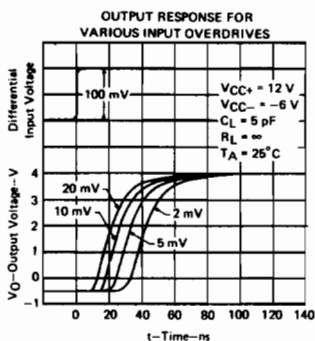


FIGURE 10

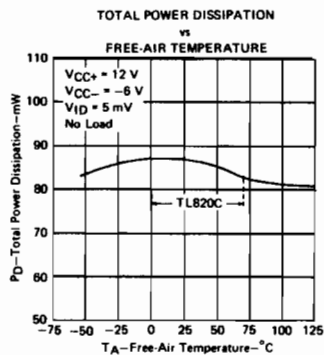


FIGURE 11

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL820M,  $V_O = 1.8 V$  at  $T_A = -55^{\circ}C$ ,  $V_O = 1.4 V$  at  $T_A = 25^{\circ}C$ , and  $V_O = 1 V$  at  $T_A = 125^{\circ}C$ ; for TL820C,  $V_O = 1.5 V$  at  $T_A = 0^{\circ}C$ ,  $V_O = 1.4 V$  at  $25^{\circ}C$ , and  $V_O = 1.2 V$  at  $T_A = 70^{\circ}C$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

# LINEAR INTEGRATED CIRCUITS

# TYPE $\mu$ A710M DIFFERENTIAL COMPARATOR

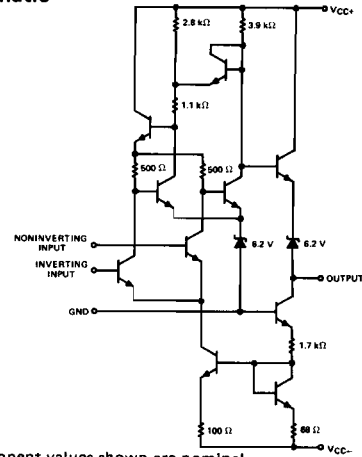
BULLETIN NO. DL-S 12415, JUNE 1976—REVISED OCTOBER 1979

- Fast Response Times
- Low Offset Characteristics
- Output Compatible with Most TTL and DTL Circuits
- Designed to be Interchangeable with Fairchild  $\mu$ A710

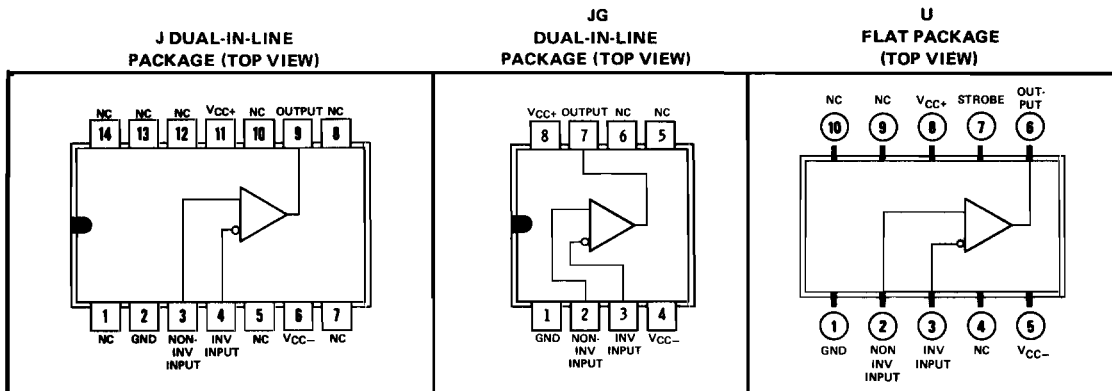
## description

The  $\mu$ A710 is a monolithic high-speed comparator having differential inputs and a low-impedance output. Component matching, inherent in silicon integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. This circuit is especially useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed voltage comparator. The  $\mu$ A710M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

schematic



## terminal assignments



NC—No Internal connection

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Note 1)	$\pm 7$ V
Peak output current ( $t_w \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature	300 mW
Operating free-air temperature range	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	$300^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to the Dissipation Derating Table. In the J and JG packages,  $\mu$ A710M chips are alloy-mounted.

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TEXAS INSTRUMENTS  
INCORPORATED

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# TYPE $\mu$ A710M

## DIFFERENTIAL COMPARATOR

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage	$R_S < 200\ \Omega$ ,	See Note 4	25°C	0.6	2	mV	
				Full range		3		
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	$R_S < 50\ \Omega$ ,	See Note 4	Full range	3	10	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	See Note 4	See Note 4	25°C	0.75	3	$\mu\text{A}$	
				Full range		7		
$\alpha I_{IO}$	Average temperature coefficient of input offset current	See Note 4	See Note 4	-55°C to 25°C	5	25	$\text{nA}/^\circ\text{C}$	
				25°C to 125°C	15	75		
$I_{IB}$	Input bias current	See Note 4	See Note 4	25°C	13	20	$\mu\text{A}$	
				Full range		45		
$V_{ICR}$	Common-mode input voltage range	$V_{CC-} = -7\text{ V}$		25°C	$\pm 5$		V	
$V_{ID}$	Differential input voltage range			25°C	$\pm 5$		V	
$A_{VD}$	Large-signal differential voltage amplification	No load,	See Note 4	25°C	1250	1700		
				Full range	1000			
$V_{OH}$	High-level output voltage	$V_{ID} = 5\text{ mV}$ ,	$I_{OH} = -5\text{ mA}$	25°C	2.5	3.2	4	V
$V_{OL}$	Low-level output voltage	$V_{ID} = -5\text{ mV}$ ,	$I_{OL} = 0$	25°C	-1	-0.5	6‡	V
$I_{OL}$	Low-level output current	$V_{ID} = -5\text{ mV}$ ,	$V_O = 0$	25°C	2	2.5	mA	
				-55°C	1	2.3		
				125°C	0.5	1.7		
$r_o$	Output resistance	$V_O = 1.4\text{ V}$		25°C	200		$\Omega$	
CMRR	Common-mode rejection ratio	$R_S < 200\ \Omega$		25°C	80	100	dB	
$I_{CC+}$	Supply current from $V_{CC+}$	$V_{ID} = -5\text{ V to } 5\text{ V}$ (-10 mV for typ),		25°C	5.2	9	mA	
$I_{CC-}$	Supply current from $V_{CC-}$			25°C	-4.6	-7	mA	
$P_D$	Total power dissipation	No load		25°C	90	150	mW	

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels:  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

† Full range for  $\mu\text{A}710\text{M}$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ .

‡ The algebraic convention where the more-positive (less-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		TYP	UNIT
Response time	No load,	See Note 5	40	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 $\text{mW}/^\circ\text{C}$	123°C
JG (Alloy-Mounted Chip)	300 mW	8.4 $\text{mW}/^\circ\text{C}$	114°C
U	300 mW	5.4 $\text{mW}/^\circ\text{C}$	94°C

Also see Dissipation Derating Curves, Section 2.

# TYPE $\mu$ A710M DIFFERENTIAL COMPARATOR

## TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

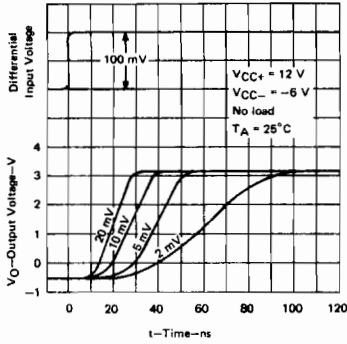


FIGURE 1

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

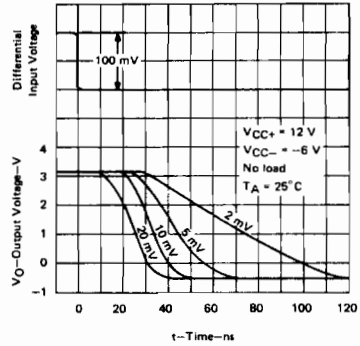


FIGURE 2

COMMON-MODE PULSE RESPONSE  
VS  
ELAPSED TIME

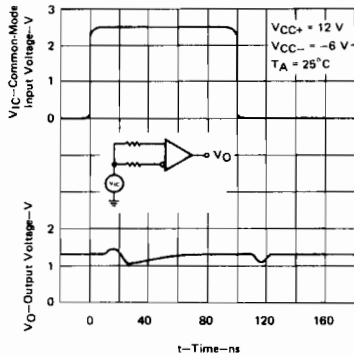


FIGURE 3

OUTPUT VOLTAGE  
VS  
FREE-AIR TEMPERATURE

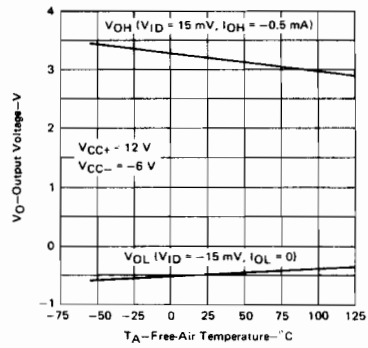


FIGURE 4

VOLTAGE TRANSFER CHARACTERISTICS

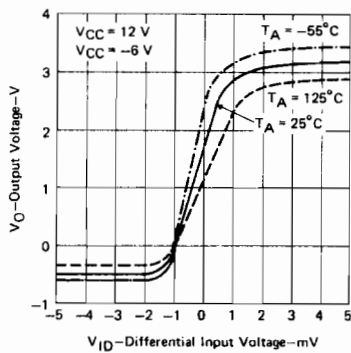


FIGURE 5

TOTAL POWER DISSIPATION  
VS  
FREE-AIR TEMPERATURE

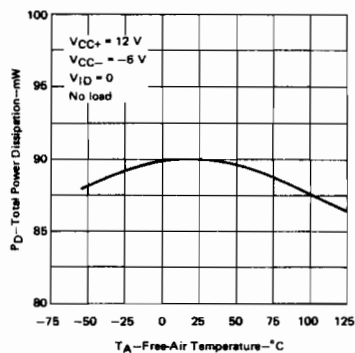


FIGURE 6



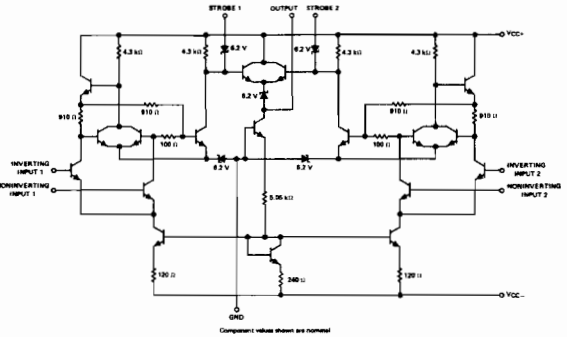


- Fast Response Times
- Output Compatible with Most TTL and DTL Circuits
- Low Offset Characteristics
- Designed to be Interchangeable with Fairchild  $\mu$ A711 and  $\mu$ A711C

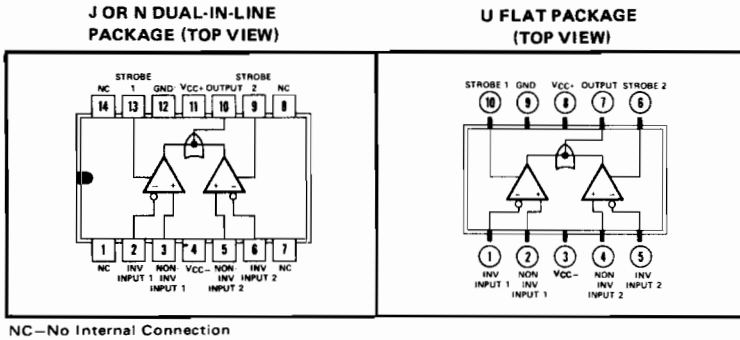
**description**

The  $\mu$ A711 is a high-speed dual-channel comparator with differential inputs and a low-impedance output. Component matching, inherent with silicon monolithic circuit fabrication techniques, produces a comparator circuit with low-drift and low-offset characteristics. An independent strobe input is provided for each of the two channels, which when taken low, inhibits the associated channel. If both strobes are simultaneously low, the output will be low regardless of the conditions applied to the differential inputs. The comparator output pulse width may be "stretched" by varying the capacitive loading. These dual comparators are particularly useful for applications requiring an amplitude-discriminating sense amplifier with an adjustable threshold voltage. The  $\mu$ A711M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A711C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**



**terminal assignments**



NC—No Internal Connection

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	$\mu$ A711M	$\mu$ A711C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	14	14	V
Supply voltage $V_{CC-}$ (see Note 1)	-7	-7	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (any input, see Note 1)	$\pm 7$	$\pm 7$	V
Strobe voltage (see Note 1)	6	6	V
Peak output current ( $t_w \leq 1$ s)	50	50	mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 3)	300	300	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature $1/16$ inch (1,6 mm) from case for 60 seconds	300	300	$^{\circ}\text{C}$
Lead temperature $1/16$ inch (1,6 mm) from case for 10 seconds		260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of  $\mu$ A711M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package,  $\mu$ A711M chips are alloy-mounted;  $\mu$ A711C chips are glass-mounted.

# TYPES $\mu$ A711M, $\mu$ A711C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	$\mu$ A711M			$\mu$ A711C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	25°C	1	3.5	1	5	mV		
		Full range	4.5		6				
	$R_S \leq 200\ \Omega$ , See Note 4	25°C	1	5	1	7.5			
		Full range	6		10				
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S \leq 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	Full range	5		5		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current	See Note 4	25°C	0.5	10	0.5	15	$\mu\text{A}$		
		Full range	20		25				
$I_{IB}$ Input bias current	See Note 4	25°C	25	75	25	100	$\mu\text{A}$		
		Full range	150		150				
$I_{IL(S)}$ Low-level strobe current	$V_{(\text{strobe})} = 0$ , $V_{ID} = 10\text{ mV}$	25°C	-1.2	-2.5	-1.2	-2.5	mA		
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	$\pm 5$		$\pm 5$		V		
$V_{ID}$ Differential input voltage range		25°C	$\pm 5$		$\pm 5$		V		
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25°C	750	1500	700	1500			
		Full range	500		500				
$V_{OH}$ High-level output voltage	$V_{ID} = 10\text{ mV}$ , $I_{OH} = 0$	25°C	4.5	5	4.5	5	V		
	$V_{ID} = 10\text{ mV}$ , $I_{OH} = -5\text{ mA}$	25°C	2.5	3.5	2.5	3.5			
$V_{OL}$ Low-level output voltage	$V_{ID} = -10\text{ mV}$ , $I_{OL} = 0$	25°C	-1	-0.5	0‡	-1	-0.5	0‡	V
	$V_{ID} = 10\text{ mV}$ , $V_{(\text{strobe})} = 0.3\text{ V}$ , $I_{OL} = 0$	25°C	-1	0‡	-1	0‡			
$I_{OL}$ Low-level output current	$V_{ID} = -10\text{ mV}$ , $V_O = 0$	25°C	0.5	0.8	0.5	0.8	mA		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200		$\Omega$		
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	25°C	70	90	65	90	dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ V}$ to 5 V (-10 mV for typ.)	25°C	9		9		mA		
$I_{CC-}$ Supply current from $V_{CC-}$	Strobes alternately grounded,	25°C	-4		-4		mA		
$P_D$ Total power dissipation	No load	25°C	130	200	130	230	mW		

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for  $\mu$ A711M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for  $\mu$ A711C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

† Unless otherwise noted, all characteristics are measured with the strobe of the channel under test open. The strobe of the other channel is grounded. Full range for  $\mu$ A711M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the  $\mu$ A711C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡ The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A711M			$\mu$ A711C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time	No load, See Note 5	40	80	40	40	40	ns	
Strobe release time	No load, See Note 6	7	25	7	7	7	ns	

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdriven output voltage crosses the 1.4-V level.

# TYPES $\mu$ A711M, $\mu$ A711C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	300 mW	11.0 mW/°C	123°C
J (Glass-Mounted Chip)	300 mW	8.2 mW/°C	113°C
N	300 mW	9.2 mW/°C	117°C
U	300 mW	5.4 mW/°C	94°C

Also see Dissipation Derating, Section 2.

### TYPICAL CHARACTERISTICS

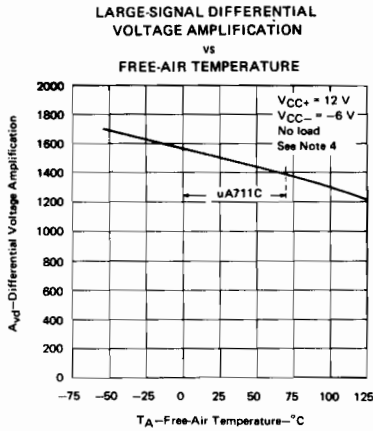


FIGURE 1

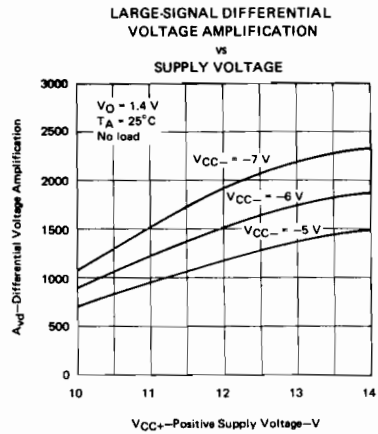


FIGURE 2

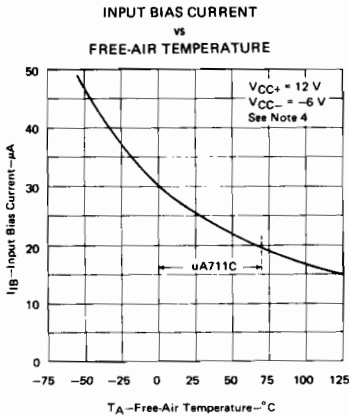


FIGURE 3

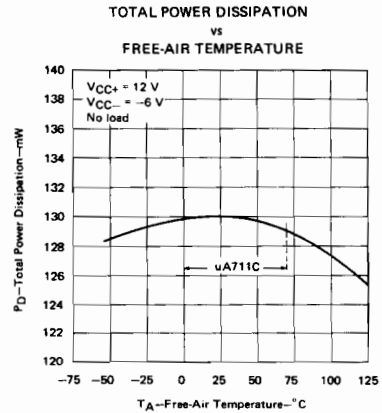


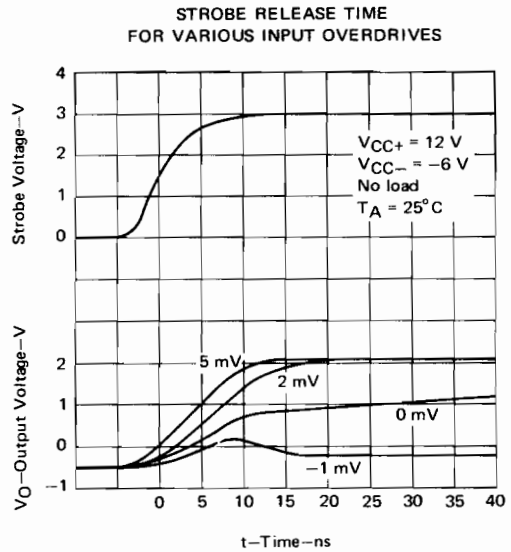
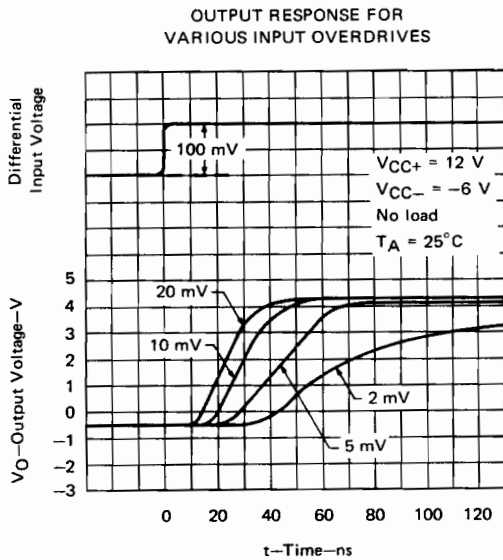
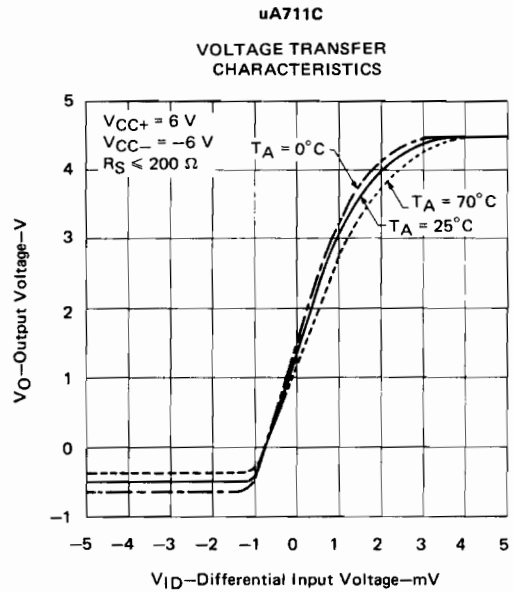
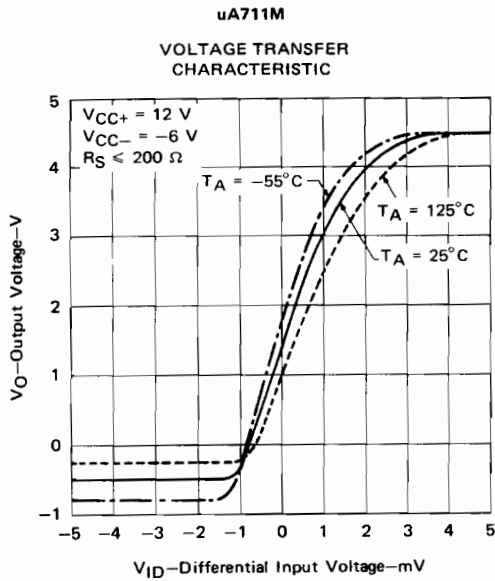
FIGURE 4

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for  $\mu$ A711M,  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ ; for  $\mu$ A711C,  $V_O = 1.5$  V at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2$  V at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

# TYPES $\mu$ A711M, $\mu$ A711C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

### TYPICAL CHARACTERISTICS



# Special Functions

# SELECTION GUIDE

## SPECIAL FUNCTIONS

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## SPECIAL FUNCTIONS

### Analog Switches With 30-mA Capability (Bi-MOS)

DEVICE	FUNCTION	$Z_{sw}$ (TYP)	ANALOG RANGE	SUPPLIES	PAGE
TL182	Twin SPST	100 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	303
TL185	Twin DPST	150 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	306
TL188	Dual Complementary SPST	100 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	309
TL191	Twin Dual Complementary SPST	150 $\Omega$	$\pm 10$ V	$\pm 15$ , +5	312

### Analog Switches With 10-mA Capability (P-MOS)

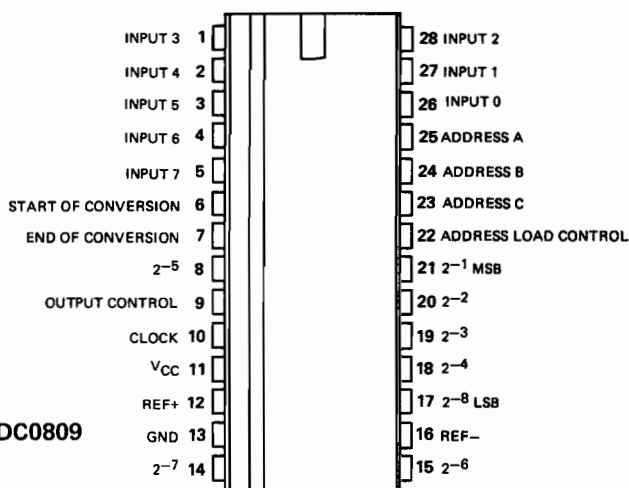
DEVICE	FUNCTION	$Z_{sw}$ (TYP)	ANALOG RANGE	SUPPLIES	PAGE
TL601	SPDT	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL604	Complementary SPST	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL607	SPDT	200 $\Omega$	$\pm 10$ V	+10, -20	387
TL610	SPST	100 $\Omega$	$\pm 10$ V	+10, -20	387

### Hall-Effect Devices

DEVICE	DESCRIPTION	ON	OFF	HYSTERESIS	PAGE
TL170	General purpose switch	$>+350$ G	$<-350$ G	200 G	293
TL172	Normally-off switch	$>+600$ G	$<+100$ G	230 G	295
TL175	Latch	$>+350$ G	$<-350$ G	400 G	299
TL176	Normally-off switch (Automotive Temp. Range)	$>+500$ G	$<+100$ G	75 G	301
TL173	Linear sensor	1.5 mV/G Sensitivity			297

- Total Unadjusted Error . . .  $\pm 1/2$  LSB Max for ADC0808 and  $\pm 1$  LSB Max for ADC0809
- Resolution of 8 Bits
- 100  $\mu$ s Conversion Time
- Ratiometric Conversion
- Guaranteed Monotonicity
- No Missing Codes
- Easy Interface with Microprocessors
- Latched 3-State Outputs
- Latched Address Inputs
- Single 5-Volt Supply
- Low Power Consumption
- Designed to be Interchangeable with National Semiconductor ADC0808, ADC0809

N  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The ADC0808 and ADC0809 are monolithic CMOS devices with an 8-channel multiplexer, an 8-bit analog-to-digital (A/D) converter, and microprocessor-compatible control logic. The 8-channel multiplexer can be controlled by a microprocessor through a 3-bit address decoder with address load to select any one of eight single-ended analog switches connected directly to the comparator. The 8-bit A/D converter uses the successive-approximation conversion technique featuring a high-impedance chopper-stabilized comparator, a 256R end-compensated voltage divider with analog switch tree, and a successive-approximation register (SAR).

Each device features an overall error of  $\pm 1$  LSB maximum at 25°C including resolution (quantization) error. The comparison and converting methods used eliminate the possibility of missing codes, nonmonotonicity, and the need for zero or full-scale adjustment. Also featured are latched 3-state outputs from the SAR and latched inputs to the multiplexer address decoder. The single 5-volt supply and low power requirements make the ADC0808 and ADC0809 especially useful for a wide variety of applications. Ratiometric conversion is made possible by access to the reference voltage input terminals.

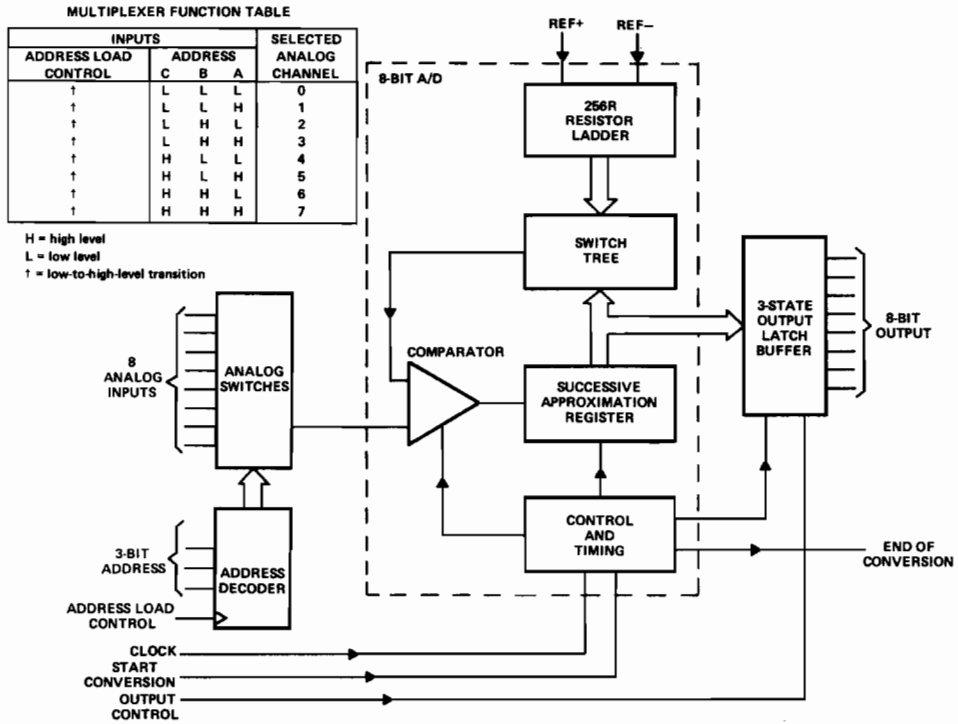
The ADC0808 and ADC0809 are characterized for operation from -40°C to 85°C.



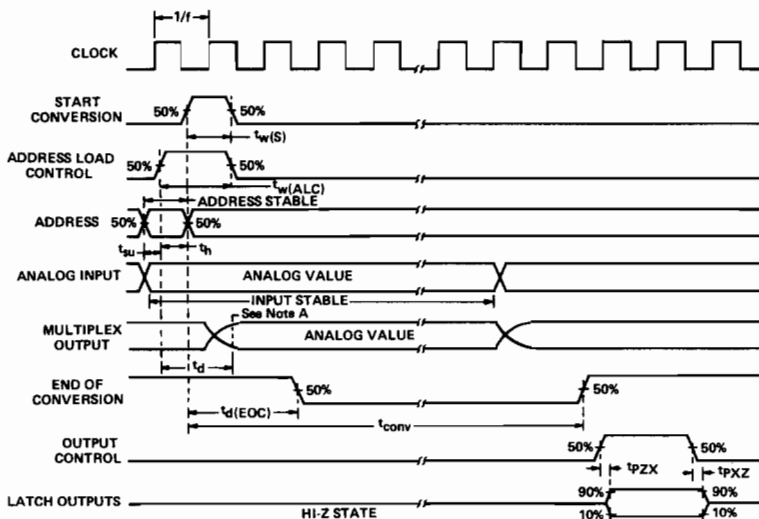
# TYPES ADC0808, ADC0809 DATA ACQUISITION SYSTEMS

## functional block diagram

functional block diagram

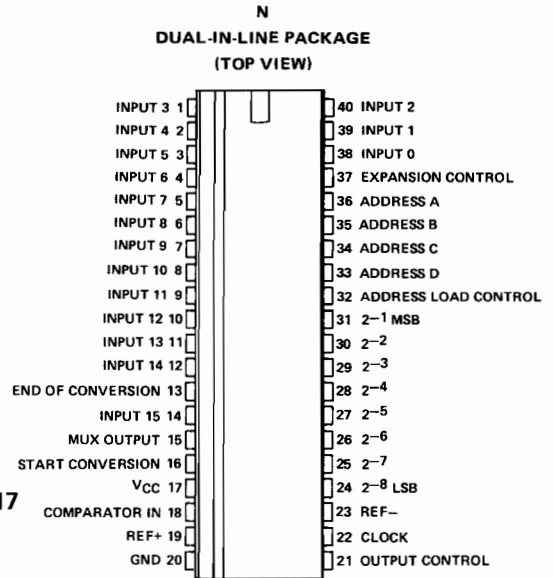


## operating sequence



NOTE A: Instant at which output is within 1/2 LSB of final value.

- Total Unadjusted Error . . .  $\pm\frac{1}{2}$  LSB Max for ADC0816 and  $\pm 1$  LSB Max for ADC0817
- Resolution of 8 Bits
- 100  $\mu$ s Conversion Time
- Ratiometric Conversion
- Guaranteed Monotonicity
- No Missing Codes
- Easy Interface with Microprocessors
- Latched 3-State Outputs
- Latched Address Inputs
- Single 5-Volt Supply
- Low Power Consumption
- Designed to be Interchangeable with National Semiconductor ADC0816, ADC0817



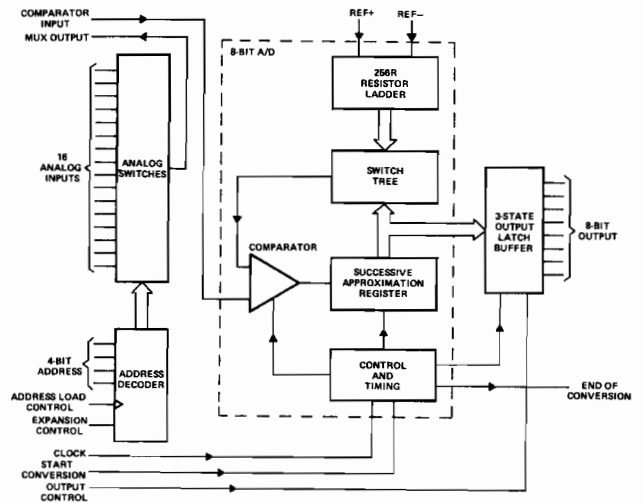
**description**

The ADC0816 and ADC0817 are monolithic CMOS devices with a 16-channel multiplexer, an 8-bit analog-to-digital (A/D) converter, and microprocessor-compatible control logic. The 16-channel multiplexer can be controlled by a microprocessor through a 4-bit address decoder with address load and expansion control logic, to select any one of 16 single-ended analog switches. The 8-bit A/D converter uses the successive-approximation conversion technique featuring a high-impedance chopper-stabilized comparator, a 256R end-compensated voltage divider with analog switch tree, and a successive-approximation register (SAR).

Each device features an overall error of  $\pm 1$  LSB maximum at 25°C including resolution (quantization) error. The comparison and converting methods used eliminate the possibility of missing codes, non-monotonicity, and the need for zero or full-scale adjustment. Also featured are latched 3-state outputs from the SAR and latched inputs to the multiplexer address decoder. The single 5-volt supply and low power requirements make the ADC0816 and ADC0817 especially useful for a wide variety of applications. Ratiometric conversion is made possible by access to the reference voltage input terminals.

The ADC0816 and ADC0817 are characterized for operation from -40°C to 85°C.

**functional block diagram**



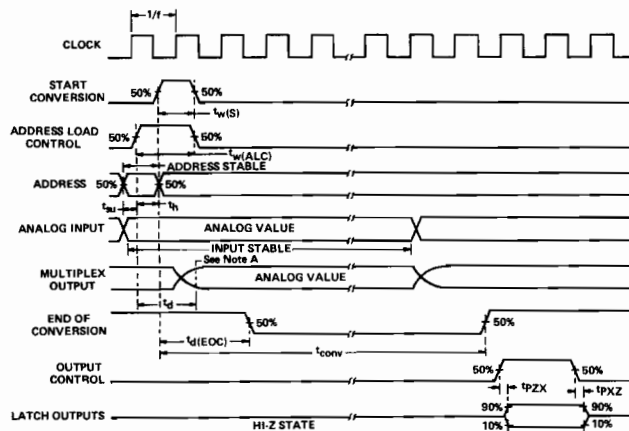
# TYPES ADC0816, ADC0817 DATA ACQUISITION SYSTEMS

MULTIPLEXER FUNCTION TABLE

ADDRESS LOAD CONTROL	INPUTS				SELECTED ANALOG CHANNEL	
	EXPANSION CONTROL	D	C	B		A
↑	H	L	L	L	L	0
↑	H	L	L	L	H	1
↑	H	L	L	H	L	2
↑	H	L	L	H	H	3
↑	H	L	H	L	L	4
↑	H	L	H	L	H	5
↑	H	L	H	H	L	6
↑	H	L	H	H	H	7
↑	H	H	L	L	L	8
↑	H	H	L	L	H	9
↑	H	H	L	H	L	10
↑	H	H	L	H	H	11
↑	H	H	H	L	L	12
↑	H	H	H	L	H	13
↑	H	H	H	H	L	14
↑	H	H	H	H	H	15
X	L	X	X	X	X	All channels OFF

H = high level, L = low level, X = irrelevant, ↑ = low-to-high-level transition

**operating sequence**



NOTE A: Instant at which output is within 1/2 LSB of final value.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage: control inputs	-0.3 V to 15 V
all other inputs	-0.3 V to $V_{CC} + 0.3$ V
Continuous total dissipation	500 mW
Operating free-air temperature	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

NOTE 1: All voltage values are with respect to network ground terminal.

# TYPES ADC0816, ADC0817

## DATA ACQUISITION SYSTEMS

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	5	6	V
Voltage at top of 256R ladder, $V_{ref+}$		$V_{CC}$	$V_{CC} + 0.1$	V
Voltage at bottom of 256R ladder, $V_{ref-}$		0	-0.1	V
Voltage across 256R ladder (see Note 2)	0.512	5.12	5.25	V
Start pulse width, $t_w(S)$	200			ns
Address load control pulse width, $t_w(ALC)$	200			ns
Address setup time, $t_{SU}$	50			ns
Address hold time, $t_H$	50			ns
Clock frequency, $f_{clock}$	10	640	1200	kHz
Operating free-air temperature, $T_A$	-40		85	$^{\circ}C$

NOTE 2: For proper operation, the voltage across the ladder must be centered on  $\frac{V_{CC}}{2} \pm 0.1$  V.

### electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 4.75$ V to 5.25 V (unless otherwise noted)

#### total device

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{IH}$	High-level input voltage	$V_{CC} = 5$ V	$V_{CC} - 1.5$			V
$V_{IL}$	Low-level input voltage	$V_{CC} = 5$ V		1.5		V
$V_{OH}$	High-level output voltage	$I_O = -360$ $\mu$ A	$V_{CC} - 0.4$			V
$V_{OL}$	Low-level output voltage	Data outputs $I_O = 1.6$ mA			0.45	V
		End of conversion $I_O = 1.2$ mA			0.45	
$I_{OZ}$	Off-state (high-impedance-state) output current	$V_O = 5$ V			3	$\mu$ A
		$V_O = 0$			-3	
$I_I$	Input current at maximum control input voltage	$V_I = 15$ V			1	$\mu$ A
$I_{IL}$	Low-level control input current	$V_I = 0$			-1	$\mu$ A
	Comparator input current	$V_{ref+} = V_{CC}$ , $V_{ref-} = 0$ , $f_{clock} = 640$ kHz, See Note 3		$\pm 0.5$	$\pm 2$	$\mu$ A
$I_{CC}$	Supply current	$f_{clock} = 500$ kHz		0.3	1	mA
$C_i$	Input capacitance	Analog inputs		5	7.5	pF
		Control inputs		10	15	
$C_o$	Output capacitance, data outputs			5	7.5	pF
	Ladder resistance from pin 19 to pin 23		1	4.5		k $\Omega$

#### analog multiplexer

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
$r_{on}$	Channel on-state resistance	$R_L = 10$ k $\Omega$	$T_A = 25^{\circ}C$		1.5	3	k $\Omega$
			$T_A = -40^{\circ}C$ to $85^{\circ}C$			6	
	Difference in on-state resistance between any two channels	$R_L = 10$ k $\Omega$			75		$\Omega$
$I_{off}$	Channel off-state current	$V_{CC} = 5$ V, $T_A = 25^{\circ}C$	$V_I = 5$ V		10	200	nA
			$V_I = 0$		-10	-200	

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V and  $T_A = 25^{\circ}C$ .

NOTE 3: Comparator Input current is the bias current into or out of the chopper stabilized comparator. The bias current varies directly with clock frequency and has little temperature dependence.

# TYPES ADC0816, ADC0817 DATA ACQUISITION SYSTEMS

operating characteristics over recommended operating free-air temperature range,  $V_{CC} = V_{REF+} = 5\text{ V}$ ,  $V_{REF-} = 0\text{ V}$ , analog input voltage = comparator input voltage (unless otherwise noted)

PARAMETER		TEST CONDITIONS	ADC0816			ADC0817			UNIT
			MIN	TYP†	MAX	MIN	TYP†	MAX	
kSVS	Supply voltage sensitivity	$V_{CC} = V_{REF+} = 4.75\text{ V to }5.25\text{ V}$ , $T_A = -40^\circ\text{C to }85^\circ\text{C}$ , See Note 4	0.05	0.15		0.05	0.15	%/V	
	Linearity error (see Note 5)		±0.25	±0.5		±0.5	±1	LSB	
	Zero error (see Note 6)		±0.25	±0.5		±0.25	±0.5	LSB	
	Full-scale error (see Note 7)		±0.25	±0.5		±0.25	±0.5	LSB	
Total unadjusted error (see Note 8)		$T_A = 25^\circ\text{C}$	±0.25	±0.5		±0.5	±1	LSB	
		$T_A = -40^\circ\text{C to }85^\circ\text{C}$		±0.75					
Resolution (quantization) error (see Note 9)				±0.5			±0.5	LSB	
Overall error (see Note 10)		$T_A = 25^\circ\text{C}$	±0.75	±1		±1	±1.5	LSB	
		$T_A = -40^\circ\text{C to }85^\circ\text{C}$		±1.25					
t <sub>d</sub>	Delay time, address load control to analog multiplexer output	$R_S + R_{On} \leq 5\text{ k}\Omega$ , $C_L = 10\text{ pF}$ , Pin 15 connected to pin 18		1	2.5		1	2.5	μs
tpZX	Output enable time	$C_L = 50\text{ pF}$ , See Note 11		125	250		125	250	ns
tpXZ	Output disable time	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$ , See Note 11		125	250		125	250	ns
t <sub>conv</sub>	Conversion time	f <sub>clock</sub> = 640 kHz, See Note 11	90	100	114	90	100	114	μs
t <sub>d</sub> (EOC)	Delay time, end of conversion output		1		8	1		8	Clock periods

† Typical values for all except supply voltage sensitivity at  $V_{CC} = 5\text{ V}$ , and all are at  $T_A = 25^\circ\text{C}$ .

NOTES: 4. Supply voltage sensitivity relates to the ability of an analog-to-digital converter to maintain accuracy as the supply voltage varies.

The supply and  $V_{REF+}$  are varied together and the change in accuracy is measured with respect to full-scale.

5. Linearity error is the maximum deviation from a straight line through the end points of the A/D transfer characteristic.

6. Zero error is the difference between the output of an ideal converter and the actual A/D converter for zero input voltage.

7. Full-scale error is the difference between the output of an ideal converter and the actual A/D converter for full-scale input voltage.

8. Total unadjusted error is the maximum sum of linearity error, zero error, and full-scale error.

9. Resolution error is the  $\pm\frac{1}{2}$  LSB uncertainty caused by the converter's finite resolution.

10. Overall error describes the difference between the actual input voltage and the full-scale weighted equivalent of the binary output code. Included are resolution and all other errors.

11. Refer to the operating sequence diagram.

# TYPES ADC0816, ADC0817

## DATA ACQUISITION SYSTEMS

### PRINCIPLES OF OPERATION

The ADC0816 and ADC0817 each consists of an analog-signal multiplexer, an 8-bit successive-approximation converter, and related control and output circuitry.

#### multiplexer

The analog multiplexer selects 1 of 16 single-ended input channels as determined by the address decoder. Address load control loads the address code into the decoder on a low-to-high transition, and expansion control enables the output of the analog multiplexer. The analog signal output and comparator input pins allow additional conditioning (prescaling, sample and hold, amplification, etc.) of the selected signal before conversion.

#### converter

The 8-bit analog-to-digital converter is the primary operating unit in the ADC0816 and ADC0817. It is partitioned into three major sections: the 256R resistor ladder and switch tree (see Figure 1), the successive approximation register (SAR), and the comparator. Output from the converter is parallel binary positive logic with three-state control. The 256R resistor ladder and switch tree exhibits inherent monotonicity with no missing digital codes. This is particularly important in closed-loop feedback control systems, as a nonmonotonic relationship can cause oscillations that could be catastrophic for the system. The bottom resistor and the top resistor of the ladder are not the same value as the other resistors in the circuit. The difference in these resistors causes the output characteristic to be symmetrical with respect to the zero and full-scale points of the transfer curve. The first output transition corresponds to an analog signal equal to  $\frac{1}{2}$  LSB and each succeeding output transition equals 1 LSB up to full-scale. The 256R resistor ladder does not cause load variations on the reference voltage. The SAR performs eight iterations to approximate the input voltage.

The comparator is chopper stabilized. It is this stabilization that reduces temperature sensitivity, input offset error, and long-term dc drift.

The SAR is reset on the low-to-high transition of the start conversion (SC) pulse. The conversion is begun on the high-to-low transition of the SC pulse. A conversion in process will be interrupted by receipt of a new SC pulse. Continuous conversion may be accomplished by connecting the end-of-conversion output to the SC input. If used in this mode, an external start pulse should be applied after power up. The end-of-conversion output will go low between one and eight clock pulses after the low-to-high transition of the SC pulse.

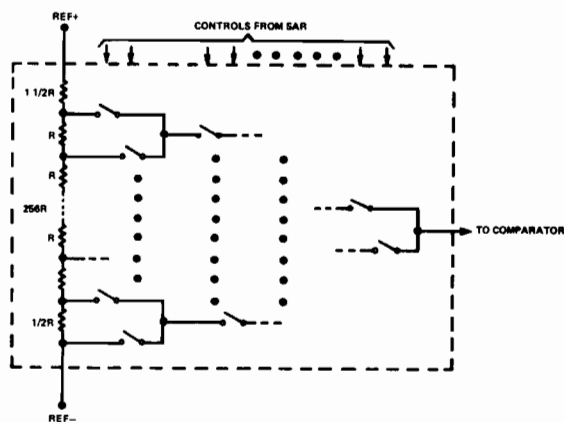


FIGURE 1-256R RESISTOR LADDER AND SWITCH TREE

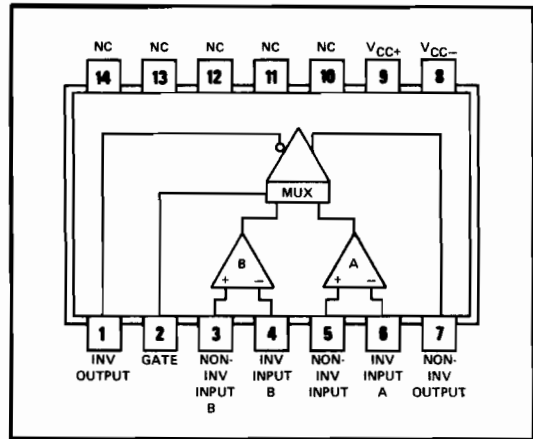
- Differential Inputs and Outputs
- Channel Select Time . . . 20 ns Typ
- Bandwidth Typically 50 MHz
- 16-dB Minimum Gain
- Common-Mode Rejection Typically 85 dB
- Broadband Noise Typically 25  $\mu$ V

**description**

The MC1545 and MC1445 are general-purpose, gated, dual-channel wideband amplifiers designed for use in video-signal mixing and switching. Channel selection is accomplished by control of the voltage level at the gate. A high logic level selects channel A; a low logic level selects channel B. The unselected channel will have a gain of one or less.

The MC1545 is characterized for operation over the full military operating temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The MC1445 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

MC1545 . . . J DUAL-IN-LINE OR  
W FLAT PACKAGE  
MC1445 . . . J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC — No internal connection

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	MC1545	MC1445	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	+12	+12	V
Supply voltage $V_{CC-}$ (see Note 1)	-12	-12	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Output current	$\pm 25$	$\pm 25$	mA
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 3)	675	675	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $75$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J or W package	300	$^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N package	260	$^{\circ}\text{C}$

- NOTES: 1. Voltage values, except differential input voltage, are with respect to the midpoint of  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential input voltages are measured at a noninverting input terminal with respect to the appropriate inverting input terminal.  
 3. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to the Dissipation Derating Table. In the J package, MC1545 chips are alloy-mounted; MC1445 chips are glass-mounted.

**6**

# TYPES MC1545, MC1445

## GATE-CONTROLLED 2-CHANNEL-INPUT VIDEO AMPLIFIER

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	675 mW	11.0 mW/°C	89° C
J (Glass-Mounted Chip)	675 mW	8.2 mW/°C	68° C
N	675 mW	9.2 mW/°C	77° C
W	675 mW	8.0 mW/°C	66° C

Also see Dissipation Derating Curves in Section 2.

electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = -5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MC1545			MC1445			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$A_{VS}$ Large-signal-single-ended voltage amplification	$f = 125\text{ kHz}$ , $V_i = 20\text{ mV}$	16	19	21	16	19.5	23	dB
BW Bandwidth	$V_i = 20\text{ mV}$	40	50		50			MHz
$V_{IO}$ Input offset voltage			1	5			7.5	mV
$I_{IO}$ Input offset current			2		2			$\mu\text{A}$
$I_{IB}$ Input bias current			15	25	15	30		$\mu\text{A}$
$V_{ICR}$ Common-mode voltage range			$\pm 2.5$		$\pm 2.5$			V
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$f = 50\text{ kHz}$ , $R_L = 1\text{ k}\Omega$	1.5	2.5		1.5	2.5		V
$Z_i$ Input impedance	$f = 50\text{ kHz}$	4	10		3	10		$\text{k}\Omega$
CMRR Common-mode rejection ratio	$f = 50\text{ kHz}$		85		85			dB
$V_n$ Broadband equivalent input noise voltage	$\text{BW} = 5\text{ Hz to } 10\text{ MHz}$ , $R_S = 50\ \Omega$		25		25			$\mu\text{V}$
$V_{TH}$ High-level gate threshold voltage	$A_{VS(A)} \geq 16\text{ dB}$ , $A_{VS(B)} \leq 0\text{ dB}$	1.5	2.2		1.3	3		V
$V_{TL}$ Low-level gate threshold voltage	$A_{VS(B)} \geq 16\text{ dB}$ , $A_{VS(A)} \leq 0\text{ dB}$	0.4	0.7		0.2	0.4		V
$I_{IH}$ High-level gate current	$V_i = 5\text{ V}$			2			4	$\mu\text{A}$
$I_{IL}$ Low-level gate current	$V_i = 0\text{ V}$			2.5			4	mA
$t_{PLH}$ Propagation delay time, low-to-high-level output	$\Delta V_i = 20\text{ mV}$ , 50% to 50%		6.5	10		6.5		ns
$t_{PHL}$ Propagation delay time, high-to-low-level output	$\Delta V_i = 20\text{ mV}$ , 50% to 50%		6.3	10		6.3		ns
$t_{TLH}$ Transition time, low-to-high-level	$\Delta V_i = 20\text{ mV}$ , 10% to 90%		6.5	15		6.5		ns
$t_{THL}$ Transition time, high-to-low-level	$\Delta V_i = 20\text{ mV}$ , 10% to 90%		7	15		7		ns
$I_{CC+}$ Supply current from $V_{CC+}$	No load, No signal		7	11		7	15	mA
$I_{CC-}$ Supply current from $V_{CC-}$	No load, No signal		-7	-11		-7	-15	mA
$P_D$ Power Dissipation	No load, No signal		70	110		70	150	mW



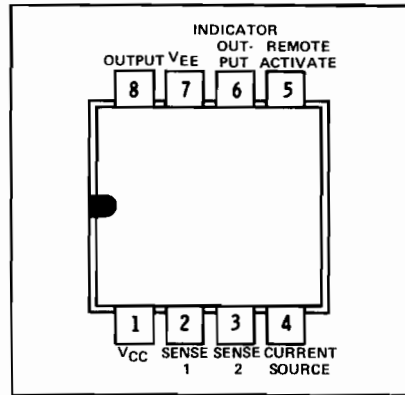
# LINEAR INTEGRATED CIRCUITS

# TYPES MC3523, MC3423 OVERVOLTAGE-SENSING CIRCUITS

BULLETIN NO. DL-S 12611, APRIL 1978

- Commercial and Military Temperature Ranges Available
- Separate Outputs for "Crowbar" and Logic Circuitry
- Programmable Time Delay to Eliminate Noise Triggering
- TTL-Level Activation Isolated from Voltage-Sensing Inputs
- 2.6-Volt Internal Voltage Reference with Temperature Coefficient Typically  $0.08\%/^{\circ}\text{C}$

MC3523 . . . . . JG  
MC3423 . . . . . JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)

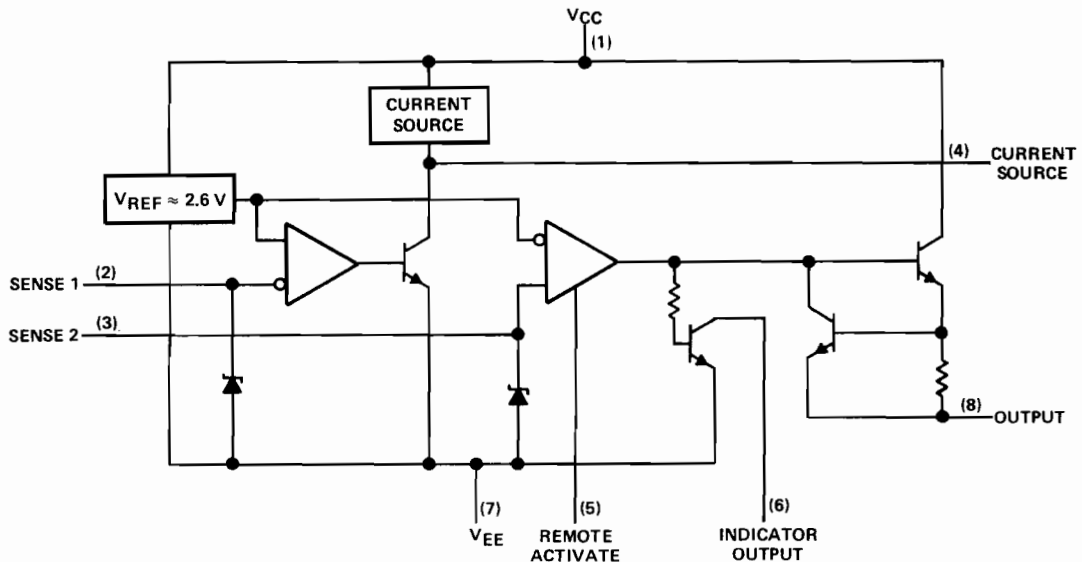


## description

These overvoltage-sensing circuits are designed to protect sensitive electronic circuitry by monitoring the supply rail and triggering an external "crowbar" SCR in the event of a voltage transient or loss of regulation. The protective mechanism may be activated by an overvoltage condition at the Sense 2 input or by application of a TTL high level to the remote activate terminal. Separate outputs are available to trigger the crowbar circuit and to provide a logic pulse to indicator or power supply control circuitry. The Sense 2 input provides a direct control of the output circuitry. The Sense 1 input controls an internal current source that may be utilized to implement a delayed trigger by connecting its output to an external capacitor and the Sense 2 input. This protects against false triggering due to noise at the Sense 1 input.

The MC3523 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The MC3423 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## functional block diagram



6

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# TYPES MC3523, MC3423

## OVERVOLTAGE-SENSING CIRCUITS

### absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	40 V
Sense 1 voltage	6.5 V
Sense 2 voltage	6.5 V
Remote activate input voltage	7 V
Output current, $I_O$	300 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2):	
MC3523JG	825 mW
MC3423JG	1000 mW
P package	1000 mW
Operating free-air temperature range:	
MC3423	0°C to 70°C
MC3523	-55°C to 125°C
Storage temperature range	-65°C to 150°C

- NOTES: 1. Voltage values are measured with respect to the  $V_{EE}$  terminal.  
 2. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table. In the JG package, MC3523 chips are alloy-mounted; MC3423 chips are glass-mounted.

### recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	40	V
High-level input voltage, remote activate input	2		V
Low-level input voltage, remote activate input		0.5	V

### electrical characteristics over operating free-air temperature range, $V_{CC} = 5\text{ V to }36\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage	Remote activate at 2 V, $I_O = 100\text{ mA}$	$V_{CC} - 2.2\text{ V}$	$V_{CC} - 1.8\text{ V}$		V
Indicator low-level output voltage	Remote activate 2 V, $I_O = 1.6\text{ mA}$		0.1	0.4	V
Threshold voltage at either sense input	$T_A = 25^\circ\text{C}$	2.45	2.6	2.75	V
Temperature coefficient at input threshold voltage			0.06		%/°C
Source current (pin 4)	Sense 1 at 3 V, Pin 4 at 1.3 V	0.1	0.22	0.3	mA
High-level input current, remote activate input	$V_{CC} = 5\text{ V}$ , $V_I = 2\text{ V}$		5	40	μA
Low-level input current, remote activate input	$V_{CC} = 5\text{ V}$ , $V_I = 0.8\text{ V}$		-120	-180	μA
Supply current	MC3423	Outputs open		6	10
	MC3523			5	7
Propagation delay time, remote activate input to output	$T_A = 25^\circ\text{C}$		0.5		μs
Output current rate of rise	$T_A = 25^\circ\text{C}$		400		mA/μs

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Alloy-Mounted Chip)	1050 mW	8.4 mW/°C	25°C
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	1000 mW	8 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

- Timing from Microseconds to Hours
- Astable or Monostable Operation
- Adjustable Duty Cycle
- TTL-Compatible Output Can Sink or Source up to 200 mA
- Designed to be Interchangeable with Signetics SE555/NE555

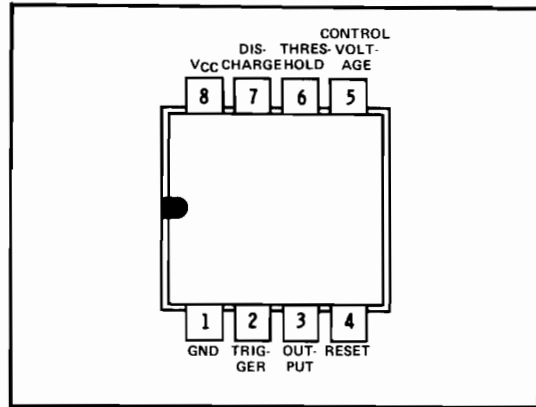
**description**

The SE555 and NE555 are monolithic timing circuits capable of producing accurate time delays or oscillation. In the time-delay or monostable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the astable mode of operation, the frequency and duty cycle may be independently controlled with two external resistors and a single external capacitor.

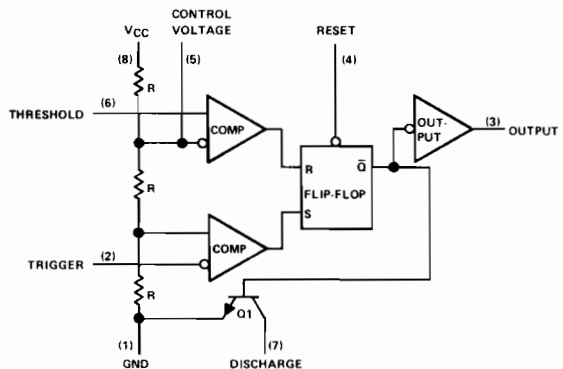
The threshold and trigger levels are normally two-thirds and one-third, respectively, of  $V_{CC}$ . These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. When the threshold input rises above the threshold level, the flip-flop is reset and the output goes low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. When the output is low, a low-impedance path is provided between the discharge terminal and ground.

The output circuit is capable of sinking or sourcing current up to 200 milliamperes. Operation is specified for supplies of 5 to 15 volts. With a 5-volt supply, output levels are compatible with TTL inputs.

**JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**functional block diagram**

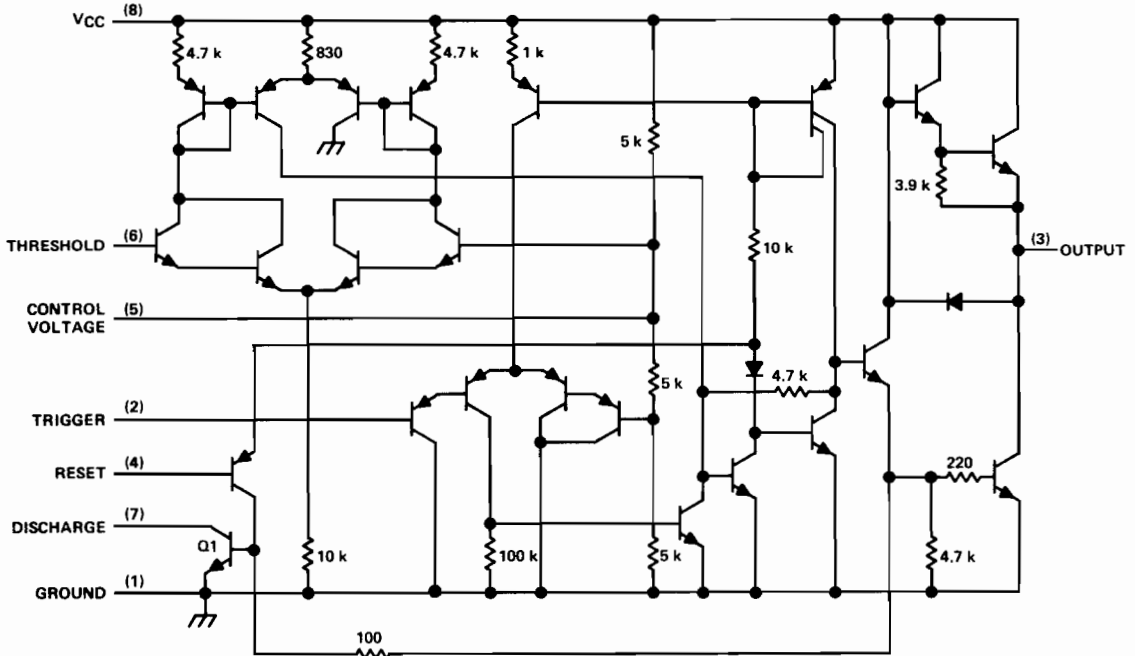


**6**

# TYPES SE555, NE555

## PRECISION TIMERS

### schematic



Resistor values shown are nominal and in ohms.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage (control voltage, reset, threshold, trigger)	$V_{CC}$
Output current	$\pm 225$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	600 mW
Operating free-air temperature range:	
SE555	-55°C to 125°C
NE555	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, SE555 chips are alloy-mounted, NE555 chips are glass-mounted.

### recommended operating conditions

	SE555			NE555			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.5		18	4.5		16	V
Input voltage, $V_I$ (control voltage, reset, threshold, trigger)			$V_{CC}$			$V_{CC}$	V
Output Current, $I_O$			$\pm 200$			$\pm 200$	mA
Operating free-air temperature, $T_A$	-55		125	0		70	°C

# TYPES SE555, NE555 PRECISION TIMERS

electrical characteristics at 25°C free-air temperature, V<sub>CC</sub> = 5 V to 15 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	SE555			NE555			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Threshold voltage level as a percentage of supply voltage		66.7			66.7			%
Threshold current (see Note 3)		0.1 0.25			0.1 0.25			μA
Trigger voltage level	V <sub>CC</sub> = 15 V	4.8	5	5.2	5			V
	V <sub>CC</sub> = 5 V	1.45	1.67	1.9	1.67			
Trigger current		0.5			0.5			μA
Reset voltage level		0.4	0.7	1	0.4	0.7	1	V
Reset current		0.1			0.1			mA
Control voltage (open-circuit)	V <sub>CC</sub> = 15 V	9.6	10	10.4	9	10	11	V
	V <sub>CC</sub> = 5 V	2.9	3.3	3.8	2.6	3.3	4	
Low-level output voltage	V <sub>CC</sub> = 15 V	I <sub>OL</sub> = 10 mA	0.1 0.15		0.1 0.25		V	
		I <sub>OL</sub> = 50 mA	0.4 0.5		0.4 0.75			
		I <sub>OL</sub> = 100 mA	2 2.2		2 2.5			
		I <sub>OL</sub> = 200 mA	2.5		2.5			
	V <sub>CC</sub> = 5 V	I <sub>OL</sub> = 5 mA			0.25 0.35			
		I <sub>OL</sub> = 8 mA	0.1 0.25					
High-level output voltage	V <sub>CC</sub> = 15 V	I <sub>OH</sub> = -100 mA	13	13.3	12.75	13.3	V	
		I <sub>OH</sub> = -200 mA	12.5		12.5			
	V <sub>CC</sub> = 5 V	I <sub>OH</sub> = -100 mA	3	3.3	2.75	3.3		
Supply current	Output low, No load	V <sub>CC</sub> = 15 V	10 12		10 15		mA	
		V <sub>CC</sub> = 5 V	3 5		3 6			
	Output high, No load	V <sub>CC</sub> = 15 V	9 11		9 14			
		V <sub>CC</sub> = 5 V	2 4		2 5			

NOTE 3: This parameter influences the maximum value of the timing resistors R<sub>A</sub> and R<sub>B</sub> in the circuit of Figure 13. For example when V<sub>CC</sub> = 5 V the maximum value is R = R<sub>A</sub>+R<sub>B</sub> ≈ 20 MΩ.

## operating characteristics, V<sub>CC</sub> = 5 V and 15 V

PARAMETER	TEST CONDITIONS†	SE555			NE555			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Initial error of timing interval	R <sub>A</sub> = 1 kΩ to 100 kΩ, T <sub>A</sub> = 25°C	0.5 2			1			%
Temperature coefficient of timing interval	R <sub>B</sub> = 0 to 100 kΩ, T <sub>A</sub> = MIN to MAX	30 100			50			ppm/°C
Supply voltage sensitivity of timing interval	C = 0.1 μF, T <sub>A</sub> = 25°C	0.05 0.2			0.1			%/V
Output pulse rise time	C <sub>L</sub> = 15 pF, T <sub>A</sub> = 25°C	100			100			ns
Output pulse fall time		100			100			ns

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE T <sub>A</sub>
JG (Alloy-Mounted Chip)	600 mW	8.4 mW/°C	79°C
JG (Glass-Mounted Chip)	600 mW	6.6 mW/°C	59°C
P	600 mW	8.0 mW/°C	75°C

Also see Dissipation Derating Curves, Section 2.

FIGURE 1

# TYPES SE555, NE555

## PRECISION TIMERS

### TYPICAL CHARACTERISTICS†

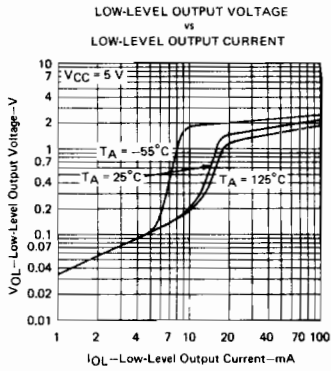


FIGURE 1

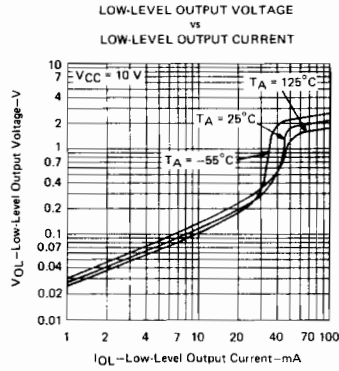


FIGURE 2

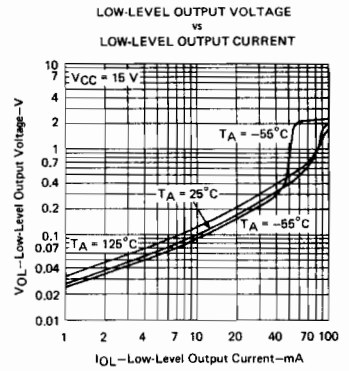


FIGURE 3

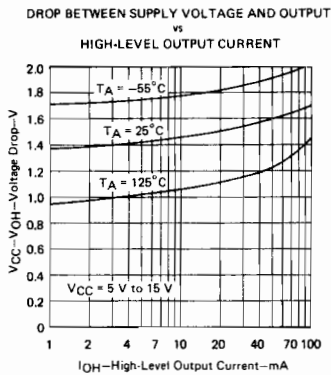


FIGURE 4

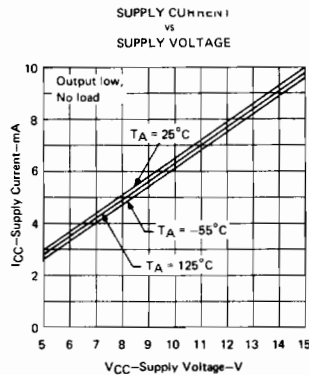


FIGURE 5

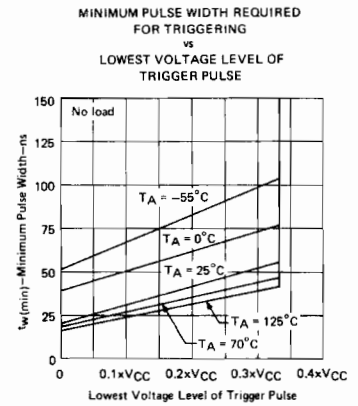


FIGURE 6

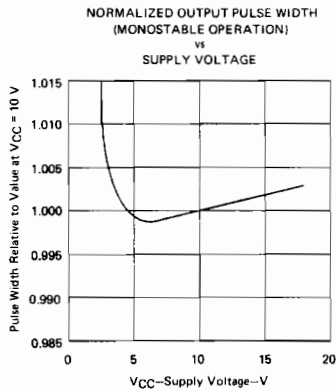


FIGURE 7

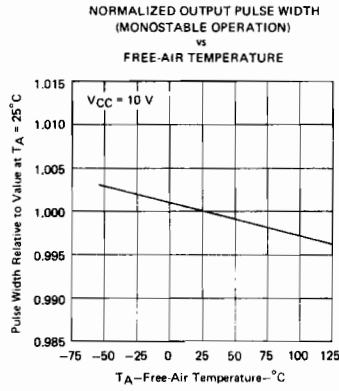


FIGURE 8

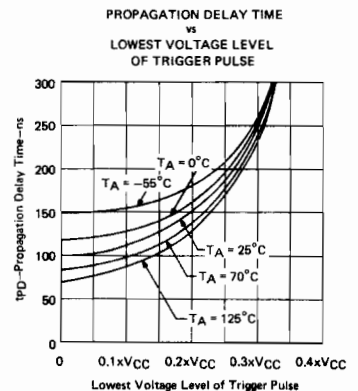


FIGURE 9

† Data for temperatures below 0°C and above 70°C are applicable for SE555 circuits only.

## TYPICAL APPLICATION DATA

### monostable operation

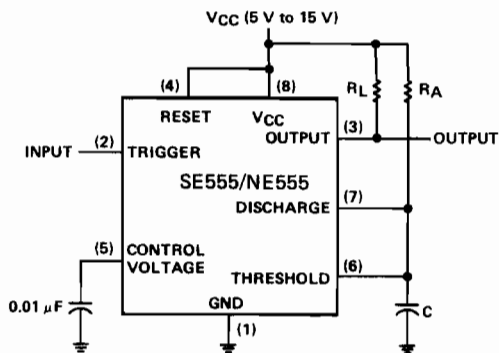


FIGURE 10—CIRCUIT FOR MONOSTABLE OPERATION

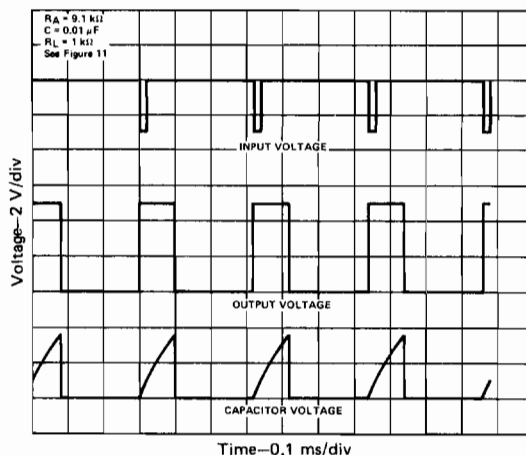


FIGURE 11—TYPICAL MONOSTABLE WAVEFORMS

For monostable operation, the SE555/NE555 may be connected as shown in Figure 10. If the output is low, application of a negative-going pulse to the trigger input sets the flip-flop ( $\bar{Q}$  goes low), drives the output high, and turns off Q1. Capacitor C is then charged through  $R_A$  until the voltage across the capacitor reaches the threshold voltage of the threshold input. If the trigger input has returned to a high level, the output of the threshold comparator will reset the flip-flop ( $\bar{Q}$  goes high), drive the output low, and discharge C through Q1.

Monostable operation is initiated when the trigger input voltage falls below the trigger threshold. Once initiated, the sequence will complete only if the trigger input is high at the end of the timing interval. Because of the threshold level and saturation voltage of Q1, the output pulse width is approximately  $t_w = 1.1 R_A C$ . Figure 12 is a plot of the time constant for various values of  $R_A$  and C. The threshold levels and charge rates are both directly proportional to the supply voltage,  $V_{CC}$ . The timing interval is therefore independent of the supply voltage, so long as the supply voltage is constant during the time interval.

Applying a negative-going trigger pulse simultaneously to the reset and trigger terminals during the timing interval will discharge C and re-initiate the cycle, commencing on the positive edge of the reset pulse. The output is held low as long as the reset pulse is low. When the reset input is not used, it should be connected to  $V_{CC}$  to prevent false triggering.

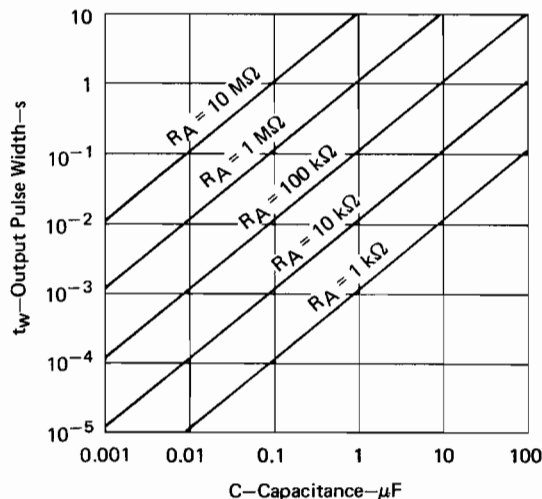


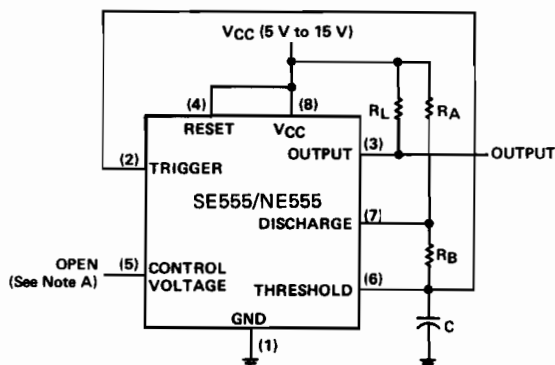
FIGURE 12—OUTPUT PULSE WIDTH vs CAPACITANCE

# TYPES SE555, NE555

## PRECISION TIMERS

### TYPICAL APPLICATION DATA

astable operation



NOTE A: Decoupling the control voltage input (pin 5) to ground with a capacitor may improve operation. This should be evaluated for individual applications.

FIGURE 13—CIRCUIT FOR ASTABLE OPERATION

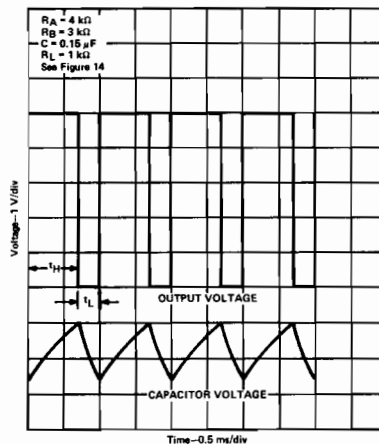


FIGURE 14—TYPICAL ASTABLE WAVEFORMS

Addition of a second resistor,  $R_B$ , to the circuit of Figure 10, as shown in Figure 13, and connection of the trigger input to the threshold input will cause the SE555/NE555 to self-trigger and run as a multivibrator. The capacitor  $C$  will charge through  $R_A$  and  $R_B$  then discharge through  $R_B$  only. The duty cycle may be controlled, therefore, by the values of  $R_A$  and  $R_B$ .

This astable connection results in capacitor  $C$  charging and discharging between the threshold-voltage level ( $\approx 0.67 \cdot V_{CC}$ ) and the trigger-voltage level ( $\approx 0.33 \cdot V_{CC}$ ). As in the monostable circuit, charge and discharge times (and therefore the frequency and duty cycle) are independent of the supply voltage.

Figure 14 shows typical waveforms generated during astable operation. The output high-level duration  $t_H$  and low-level duration  $t_L$  may be found by:

$$t_H = 0.693 (R_A + R_B) C$$

$$t_L = 0.693 (R_B) C$$

Other useful relationships are shown below.

$$\text{period} = t_H + t_L = 0.693 (R_A + 2R_B) C$$

$$\text{frequency} \approx \frac{1.44}{(R_A + 2R_B) C}$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} = \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} = 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Low-to-high ratio} = \frac{t_L}{t_H} = \frac{R_B}{R_A + R_B}$$

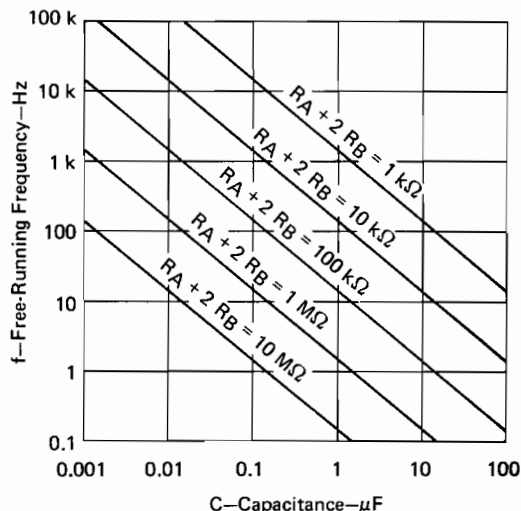


FIGURE 15—FREE-RUNNING FREQUENCY



## TYPICAL APPLICATION DATA

### missing-pulse detector

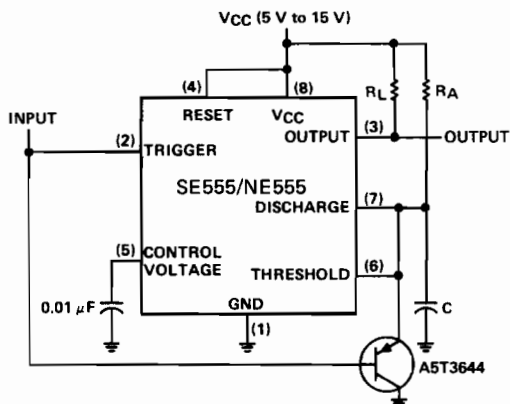


FIGURE 16—CIRCUIT FOR MISSING-PULSE DETECTOR

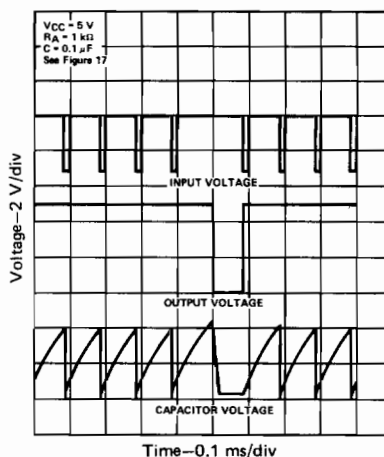


FIGURE 17—MISSING-PULSE DETECTOR WAVEFORMS

The circuit shown in Figure 16 may be utilized to detect a missing pulse or abnormally long spacing between consecutive pulses in a train of pulses. The timing interval of the monostable circuit is continuously retriggered by the input pulse train as long as the pulse spacing is less than the timing interval. A longer pulse spacing, missing pulse, or terminated pulse train will permit the timing interval to be completed, thereby generating an output pulse as illustrated in Figure 17.

### frequency divider

By adjusting the length of the timing cycle, the basic circuit of Figure 10 can be made to operate as a frequency divider. Figure 18 illustrates a divide-by-3 circuit that makes use of the fact that retriggering cannot occur during the timing cycle.

6

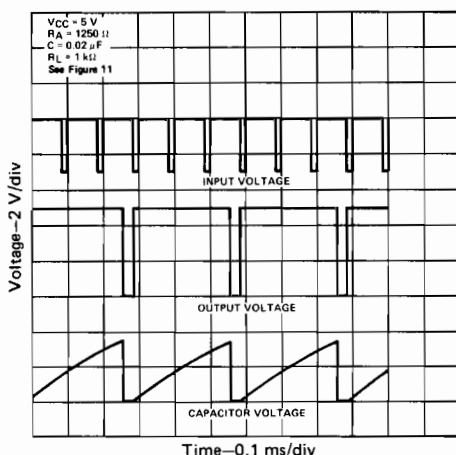
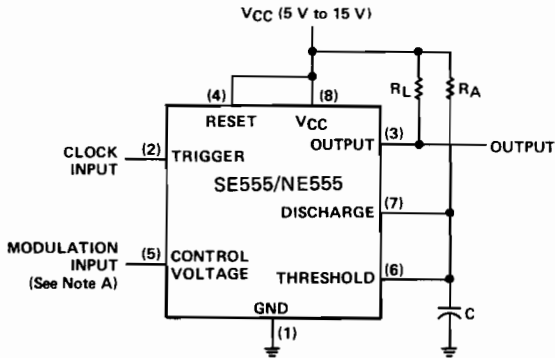


FIGURE 18—DIVIDE-BY-THREE CIRCUIT WAVEFORMS

# TYPES SE555, NE555 PRECISION TIMERS

## TYPICAL APPLICATION DATA

### pulse-width modulation



NOTE A: The modulating signal may be direct or capacitively coupled to the control voltage terminal. For direct coupling, the effects of modulation source voltage and impedance on the bias of the SE555/NE555 should be considered.

FIGURE 19—CIRCUIT FOR PULSE-WIDTH MODULATION

The operation of the timer may be modified by modulating the internal threshold and trigger voltages. This is accomplished by applying an external voltage (or current) to the control voltage pin. Figure 19 is a circuit for pulse-width modulation. The monostable circuit is triggered by a continuous input pulse train and the threshold voltage is modulated by a control signal. The resultant effect is a modulation of the output pulse width, as shown in Figure 20. A sine-wave modulation signal is illustrated, but any wave-shape could be used.

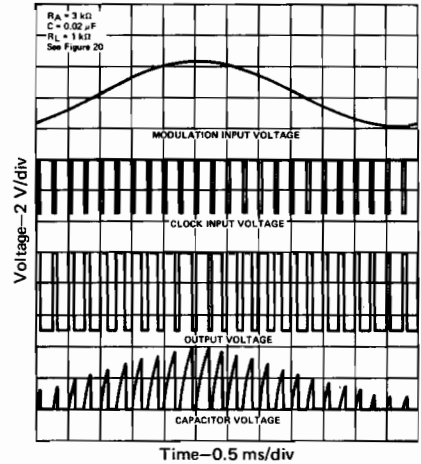
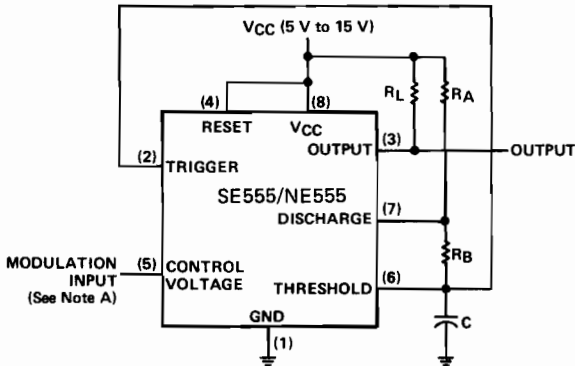


FIGURE 20—PULSE-WIDTH-MODULATION WAVEFORMS

### pulse-position modulation



NOTE A: The modulating signal may be direct or capacitively coupled to the control voltage terminal. For direct coupling, the effects of modulation source voltage and impedance on the bias of the SE555/NE555 should be considered.

FIGURE 21—CIRCUIT FOR PULSE-POSITION MODULATION

The SE555/NE555 may be used as a pulse-position modulator as shown in Figure 21. In this application, the threshold voltage, and thereby the time delay, of a free-running oscillator is modulated. Figure 22 shows such a circuit, with a triangular-wave modulation signal, however, any modulating wave-shape could be used.

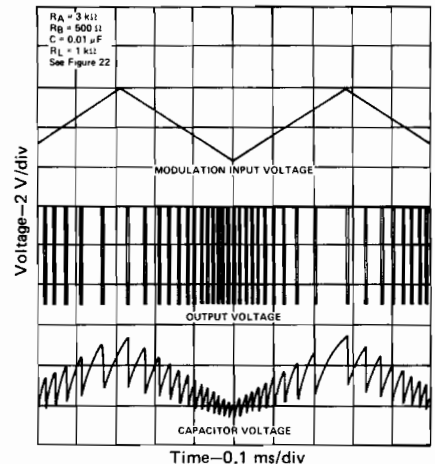


FIGURE 22—PULSE POSITION-MODULATION WAVEFORMS

## TYPICAL APPLICATION DATA

### sequential timer

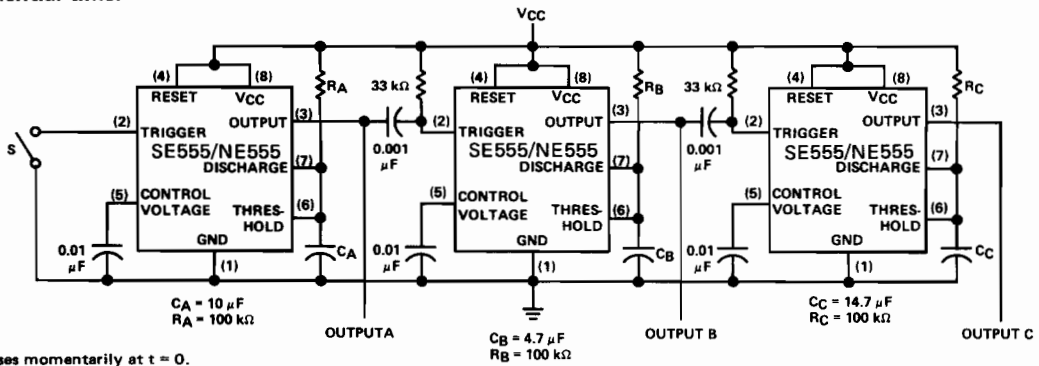


FIGURE 23—SEQUENTIAL TIMER CIRCUIT

Many applications, such as computers, require signals for initializing conditions during start-up. Other applications such as test equipment require activation of test signals in sequence. SE555/NE555 circuits may be connected to provide such sequential control. The timers may be used in various combinations of astable or monostable circuit connections, with or without modulation, for extremely flexible waveform control. Figure 23 illustrates a sequencer circuit with possible applications in many systems and Figure 24 shows the output waveforms.

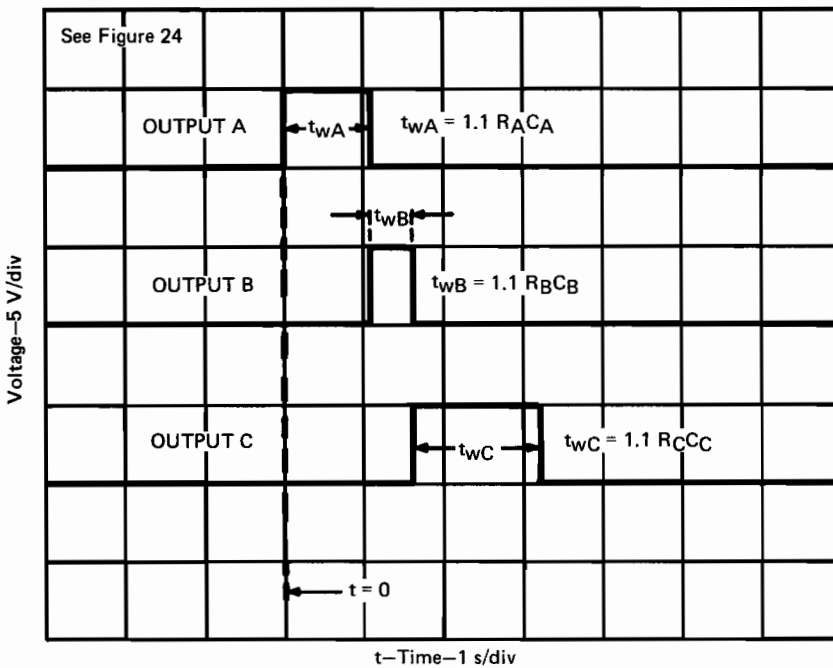


FIGURE 24—SEQUENTIAL TIMER WAVEFORMS

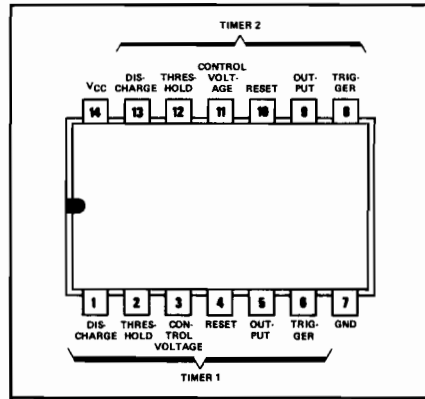


- Two Precision Timing Circuits per Package
- Astable or Monostable Operation
- TTL-Compatible Output Can Sink or Source up to 150 mA
- Active Pull-up and Pull-Down
- Designed to be Interchangeable with Signetics SE556/NE556

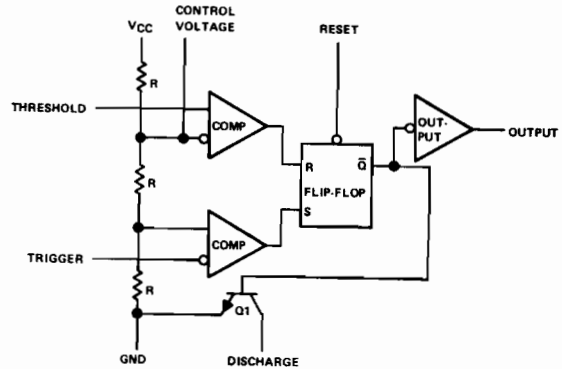
**APPLICATIONS**

- Precision Timer from Microseconds to Hours
- Sequential Timer
- Pulse-Shaping Circuit
- Pulse Generator
- Missing-Pulse Detector
- Tone-Burst Generator
- Pulse-Width Modulator
- Time-Delay Circuit
- Frequency Divider
- Pulse-Position Modulator
- Appliance Timer
- Touch-Tone Encoder
- Industrial Controls

SE556 . . . . J  
NE556 . . . . J OR N  
DUAL-IN-LINE PACKAGE (TOP VIEW)



functional block diagram of each timer



**description**

The SE556 and NE556 provide two monolithic, independent timing circuits of the SE555/NE555 type in each package. These circuits can be operated in the astable or the monostable mode with external resistor-capacitor timing control. The basic timing provided by the RC time constant may be actively controlled by modulating the bias of the control voltage input.

The SE556 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The NE556 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage (control voltage, reset, threshold, trigger)	$V_{CC}$
Output current	$\pm 225$ mA
Continuous total dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature (see Note 2)	600 mW
Operating free-air temperature range:	
SE556	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
NE556	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	$300^{\circ}\text{C}$
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	$260^{\circ}\text{C}$

NOTES: 1. All voltage values are with respect to network ground terminal.  
2. For operation of the SE556 above  $77^{\circ}\text{C}$  free-air temperature, derate linearly at the rate of  $8.2$  mW/ $^{\circ}\text{C}$ .

# TYPES SE556, NE556

## DUAL PRECISION TIMERS

### recommended operating conditions

	SE556			NE556			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.5		18	4.5		16	V
Input voltage, $V_I$ (control voltage, reset, threshold, trigger)	$V_{CC}$			$V_{CC}$			V
Output Current, $I_O$	$\pm 200$			$\pm 200$			mA
Operating free-air temperature, $T_A$	-55		125	0		70	$^{\circ}\text{C}$

### electrical characteristics at $25^{\circ}\text{C}$ free-air temperature, $V_{CC} = 5\text{ V to }15\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	SE556			NE556			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Threshold voltage level as a percentage of supply voltage		66.7			66.7			%
Threshold current (see Note 3)		30	100		30	100	nA	
Trigger voltage level	$V_{CC} = 15\text{ V}$	4.8	5	5.2	5			V
	$V_{CC} = 5\text{ V}$	1.45	1.67	1.9	1.67			
Trigger current		0.5			0.5			$\mu\text{A}$
Reset voltage level		0.4	0.7	1	0.4	0.7	1	V
Reset current		0.1			0.1			mA
Control voltage (open-circuit)	$V_{CC} = 15\text{ V}$	9.6	10	10.4	9	10	11	V
	$V_{CC} = 5\text{ V}$	2.9	3.3	3.8	2.6	3.3	4	
Low-level output voltage	$V_{CC} = 15\text{ V}$	$I_{OL} = 10\text{ mA}$	0.1	0.15	0.1	0.25	V	
		$I_{OL} = 50\text{ mA}$	0.4	0.5	0.4	0.75		
		$I_{OL} = 100\text{ mA}$	2	2.25	2	2.75		
		$I_{OL} = 200\text{ mA}$	2.5		2.5			
	$V_{CC} = 5\text{ V}$	$I_{OL} = 5\text{ mA}$			0.25	0.35		
		$I_{OL} = 8\text{ mA}$		0.1	0.25			
High-level output voltage	$V_{CC} = 15\text{ V}$	$I_{OH} = -100\text{ mA}$	13	13.3	12.75	13.3	V	
		$I_{OH} = -200\text{ mA}$		12.5		12.5		
	$V_{CC} = 5\text{ V}$	$I_{OH} = -100\text{ mA}$	3	3.3	2.75	3.3		
Supply current (average per timer)	Output low, No load	$V_{CC} = 15\text{ V}$	10	11	10	14	mA	
		$V_{CC} = 5\text{ V}$	3	5	3	6		
	Output high, No load	$V_{CC} = 15\text{ V}$	9	10	9	13		
		$V_{CC} = 5\text{ V}$	2	4	2	5		

NOTE 3: This parameter influences the maximum value of the timing resistors  $R_A$  and  $R_B$  in the circuit of Figure 13 on page 286. For example, when  $V_{CC} = 5\text{ V}$  the maximum value is  $R = R_A + R_B \approx 20\text{ M}\Omega$ .

### monostable<sup>†</sup> operating characteristics, $V_{CC} = 5\text{ V and }15\text{ V}$

PARAMETER	TEST CONDITIONS <sup>‡</sup>	SE556			NE556			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Initial error of timing interval <sup>§</sup>	Each timer	0.5			1			%
	Timer 1 – Timer 2	$\pm 0.05$			$\pm 0.1$			
Temperature coefficient of timing interval	Each timer	30			50			ppm/ $^{\circ}\text{C}$
	Timer 1 – Timer 2	$\pm 10$			$\pm 10$			
Supply voltage sensitivity of timing interval	Each timer	0.05			0.1			%/ $V$
	Timer 1 – Timer 2	$\pm 0.1$			$\pm 0.2$			
Output pulse rise time	$C_L = 15\text{ pF}$ , $T_A = 25^{\circ}\text{C}$	100			100			ns
Output pulse fall time	$T_A = 25^{\circ}\text{C}$	100			100			ns

<sup>†</sup> Values specified are for a device in a monostable circuit similar to Figure 10 on Page 285, with component values as follow:  $R_A = 2\text{ k}\Omega$ ,  $C = 0.1\text{ }\mu\text{F}$ .

<sup>‡</sup> For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>§</sup> Timing interval error is defined as the difference between the measured value and the nominal value computed by the formula:  $t_w = 1.1 R_A C$ .

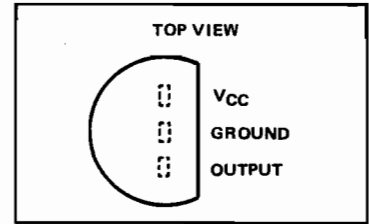
- Magnetic-Field-Sensing Hall-Effect Input
- On-Off Hysteresis
- Small Size
- Solid-State Technology
- Open-Collector Output

### description

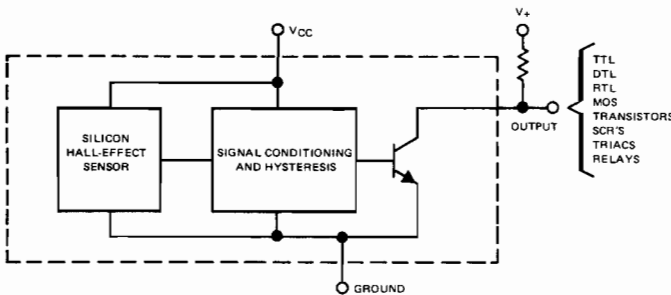
The TL170C is a low-cost magnetically-operated electronic switch that utilizes the Hall Effect to sense steady-state magnetic fields. Each circuit consists of a Hall-Effect sensor, signal conditioning and hysteresis functions, and an output transistor integrated into a monolithic chip. The outputs of these circuits can be directly connected to many different types of electronic components.

The TL170C is characterized for operation over the temperature range of 0°C to 70°C.

### LP SILECT† PACKAGE



### FUNCTIONAL BLOCK DIAGRAM

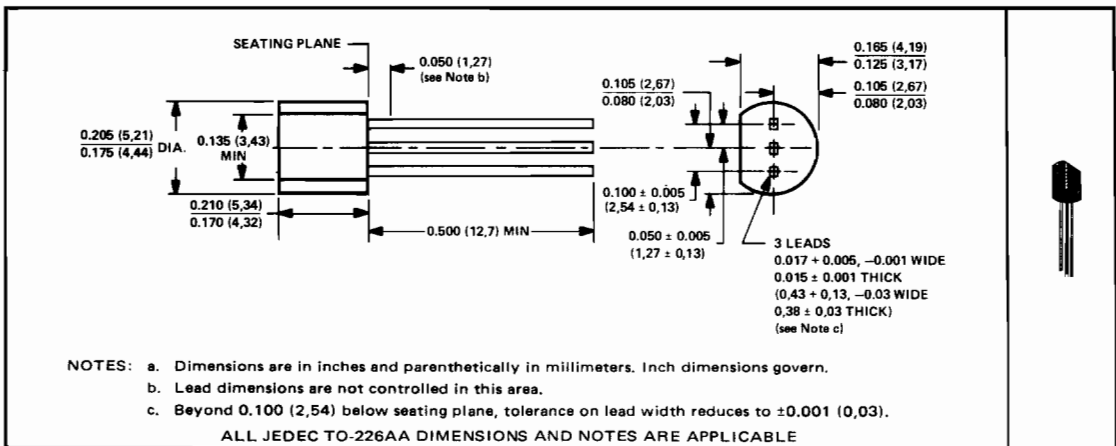


### FUNCTION TABLE (T<sub>A</sub> = 25°C)

FLUX DENSITY	OUTPUT
≤ -25 mT	Off
-25 mT < B < 25 mT	Undefined
≥ 25 mT	On

### mechanical data

The LP Silect package is an encapsulation in a plastic compound specifically designed for this purpose. The package will withstand soldering temperatures without deformation. The package exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C, Method 106B.



†Trademark of Texas Instruments Incorporated

# TYPE TL170C SILICON HALL-EFFECT SWITCH

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Output voltage	30 V
Output current	20 mA
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Magnetic flux density	unlimited

NOTE 1: Voltage values are with respect to network ground terminal.

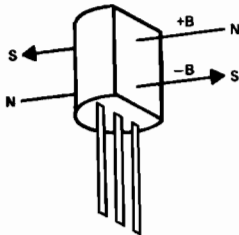
## electrical characteristics at specified free-air temperature, $V_{CC} = 5 V \pm 5\%$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$B_{T+}$	Threshold of positive-going magnetic flux density†	25°C				25	mT§
		0°C to 70°C				35	
$B_{T-}$	Threshold of negative-going magnetic flux density†	25°C		-25¶			mT§
		0°C to 70°C		-35¶			
$B_{T+} - B_{T-}$	Hysteresis	0°C to 70°C			20		mT§
$I_{OH}$	High-level output current	$V_{OH} = 20 V$		0°C to 70°C		100	$\mu A$
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.75 V$ , $I_{OL} = 16 mA$		0°C to 70°C		0.4	V
$I_{CC}$	Supply current	$V_{CC} = 5.25 V$		0°C to 70°C		6	mA
		Output low		Output high		4	

† Threshold values are those levels of magnetic flux density at which the output changes state. For the TL170C, a level more positive than  $B_{T+}$  causes the output to go to a low level and a level more negative than  $B_{T-}$  causes the output to go to a high level. See Figures 1 and 2.

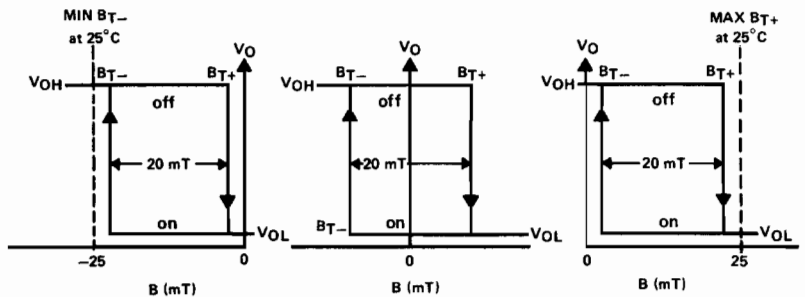
§ The unit of magnetic flux density in the International System of Units (SI) is the tesla (T). The tesla is equal to one weber per square meter. Values expressed in milliteslas may be converted to gauss by multiplying by ten.

¶ The algebraic convention, where the most negative limit is designated as minimum, is used in this data sheet for flux-density threshold levels only.



The north pole of a magnet is the pole that is attracted by the geographical north pole. The north pole of a magnet repels the north-seeking pole of a compass. By accepted magnetic convention, lines of flux emanate from the north pole of a magnet and enter the south pole.

FIGURE 1—DEFINITION OF MAGNETIC FLUX POLARITY



The positive-going threshold ( $B_{T+}$ ) may be a negative or positive B level at which a positive-going (decreasing negative or increasing positive) flux density results in the TL170 output turning on. The negative-going threshold is a positive or negative B level at which a negative-going (decreasing positive or increasing negative) flux density results in the TL170 turning off.

FIGURE 2—REPRESENTATIVE CURVES OF  $V_O$  vs B



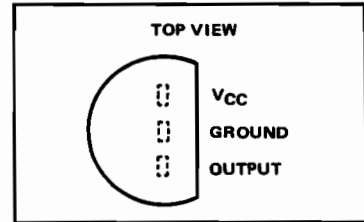
# LINEAR INTEGRATED CIRCUIT

# TYPE TL172C NORMALLY OFF SILICON HALL-EFFECT SWITCH

BULLETIN NO. DL-S 12643, AUGUST 1977—REVISED FEBRUARY 1979

- Magnetic-Field-Sensing Hall-Effect Input
- On-Off Hysteresis
- Small Size
- Solid-State Technology
- Open-Collector Output
- Normally Off Switch

LP SILECT<sup>†</sup> PACKAGE

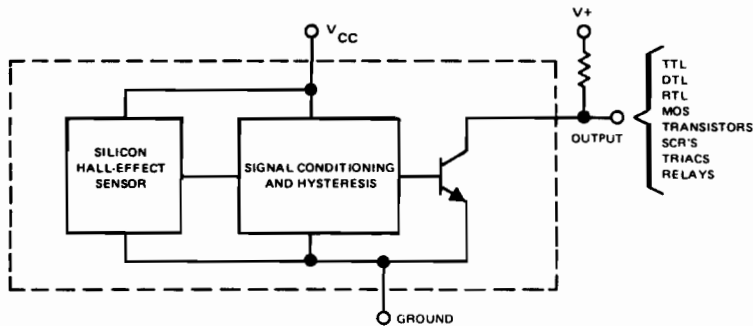


## description

The TL172C is a low-cost magnetically operated normally off electronic switch that utilizes the Hall Effect to sense the presence of a magnetic field. Each circuit consists of a Hall-Effect sensor, signal conditioning and hysteresis functions, and an output transistor integrated into a monolithic chip. A magnetic field of sufficient strength in the positive direction will cause the TL172C output to be in a low-impedance state. Otherwise the output will present a high impedance. The output of this circuitry can be directly connected to many different types of electronic components.

The TL172C is characterized for operation over the temperature range of 0°C to 70°C.

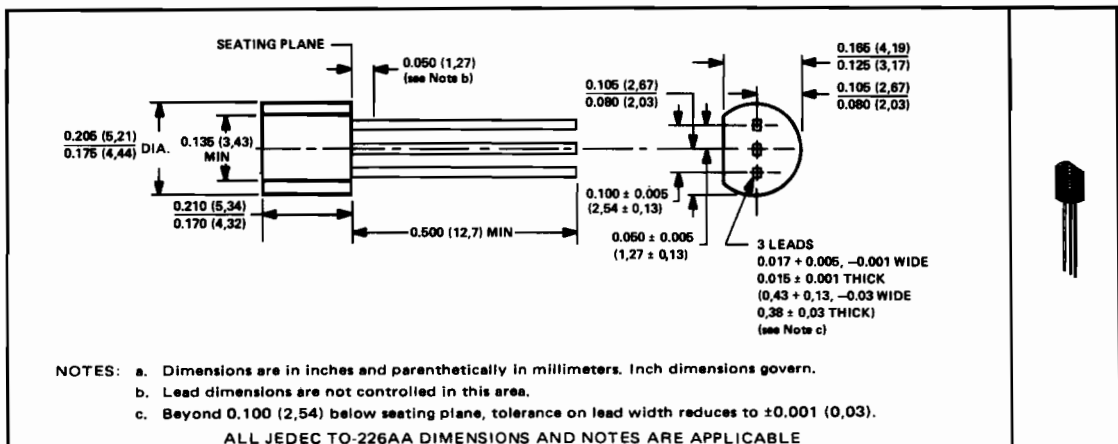
TL172C FUNCTIONAL BLOCK DIAGRAM



## mechanical data

The LP Silect package is an encapsulation in a plastic compound specifically designed for this purpose. The package will withstand soldering temperatures without deformation. The package exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C, Method 106B.

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<sup>†</sup>Trademark Registered U. S. Patent Office.

# TYPE TL172C

## NORMALLY OFF SILICON HALL-EFFECT SWITCH

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Output voltage	30 V
Output current	20 mA
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Magnetic flux density	unlimited

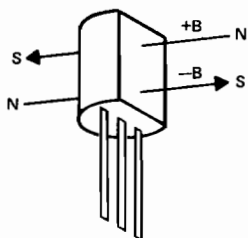
NOTE 1: Voltage values are with respect to network ground terminal.

electrical characteristics over rated operating free-air temperature range,  $V_{CC} = 5 V \pm 5\%$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$B_{T+}$	Threshold of positive-going Magnetic flux density <sup>†</sup>			60	mT <sup>§</sup>
$B_{T-}$	Threshold of negative-going magnetic flux density <sup>†</sup>	10			mT <sup>§</sup>
$B_{T+}-B_{T-}$	Hysteresis		23		mT <sup>§</sup>
$I_{OH}$	High-level output current	$V_{OH} = 20 V$		100	$\mu A$
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.75 V$ , $I_{OL} = 16 mA$		0.4	V
$I_{CC}$	Supply current	$V_{CC} = 5.25 V$		6	mA

<sup>†</sup>Threshold values are those levels of magnetic flux density at which the output changes state. For the TL172C, a level more positive than  $B_{T+}$  causes the output to go to a low level, and a level more negative than  $B_{T-}$  causes the output to go to a high level. See Figures 1 and 2.

<sup>§</sup>The unit of magnetic flux density in the International System of Units (SI) is the tesla (T). The tesla is equal to one weber per square meter. Values expressed in milliteslas may be converted to gauss by multiplying by ten.



The north pole of a magnet is the pole that is attracted by the geographical north pole. The north pole of a magnet repels the north-seeking pole of a compass. By accepted magnetic convention, lines of flux emanate from the north pole of a magnet and enter the south pole.

FIGURE 1—DEFINITION OF MAGNETIC FLUX POLARITY

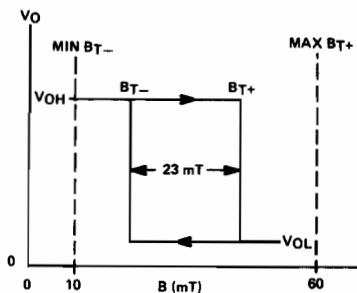


FIGURE 2—REPRESENTATIVE CURVE OF  $V_O$  vs  $B$

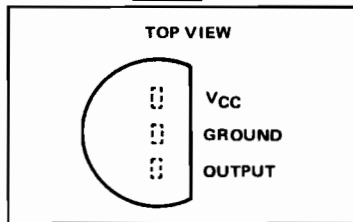
# LINEAR INTEGRATED CIRCUITS

# TYPES TL173I, TL173C LINEAR HALL-EFFECT SENSORS

BULLETIN NO. DLS 12678, MARCH 1979 — REVISED OCTOBER 1979

- Output Voltage Linear with Applied Magnetic Field
- Sensitivity Constant Over Wide Operating Temperature Range
- Solid-State Technology
- Three-Terminal Device
- Senses Static or Dynamic Magnetic Fields

LP SILECT<sup>†</sup> PACKAGE

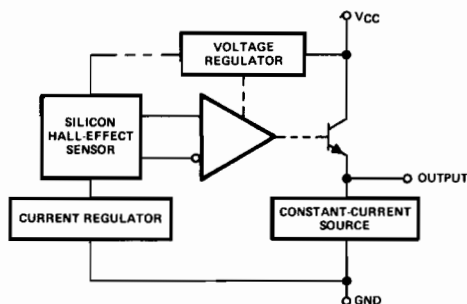


## description

The TL173I and TL173C are low-cost magnetic-field sensors designed to provide a linear output voltage proportional to the magnetic field they sense. These monolithic circuits incorporate a hall element as the primary sensor along with a voltage reference and a precision amplifier. Temperature stabilization and internal trimming circuitry yields a device that features high overall sensitivity accuracy with less than 5% error over its operating temperature range.

The TL173I is characterized for operation from  $-20^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL173C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## functional block diagram



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	25 V
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 2)	775 mW
Operating free-air temperature range: TL173I	$-20^{\circ}\text{C}$ to $85^{\circ}\text{C}$
TL173C	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Magnetic flux density	unlimited

- NOTES: 1. Voltage values are with respect to network ground terminal.  
2. For operation above  $25^{\circ}\text{C}$  free-air temperature, derate linearly at the rate of  $6.2\text{ mW}/^{\circ}\text{C}$ .

## recommended operating conditions

	TL173I			TL173C			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	10.8	12	13.2	10.8	12	13.2	V
Magnetic flux density, B	±50			±50			mT
Output current, $I_O$	Sink	0.5		0.5		mA	
	Source	-2		-2			
Operating free-air temperature, $T_A$	-20	85		0	70		$^{\circ}\text{C}$

<sup>†</sup>Trademark of Texas Instruments Incorporated.

# TYPES TL173I, TL173C LINEAR HALL-EFFECT SENSORS

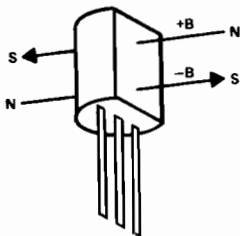
electrical characteristics over full range of recommended operating conditions (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
$V_O$ Output voltage	$I_O = -2 \text{ mA to } 0.5 \text{ mA}$ ,	5.8	6	6.2	V
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$B = 0 \text{ mT}^{\S}$ , $T_A = 25^\circ\text{C}$		18		mV/V
$S$ Magnetic sensitivity ( $\Delta V_O/\Delta B$ )	$B = -50 \text{ to } 50 \text{ mT}^{\S}$ , $T_A = 25^\circ\text{C}$	13.5	15	16.5	V/T <sup>§</sup>
$\Delta S$ Magnetic sensitivity change with temperature	$\Delta T_A = 25^\circ\text{C}$ to MIN or MAX			$\pm 5$	%
$I_{CC}$ Supply current	$B = 0 \text{ mT}^{\S}$ , $I_O = 0$		8	12	mA
$f_{max}$ Maximum operating frequency			100		kHz

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ Typical values are at  $V_{CC} = 12 \text{ V}$  and  $T_A = 25^\circ\text{C}$ .

§ The unit of magnetic flux density in the International System of Units (SI) is the tesla (T). The tesla is equal to one weber per square meter. Values expressed in milliteslas may be converted to gauss by multiplying by ten, e.g., 50 millitesla = 500 gauss.



The north pole of a magnet is the pole that is attracted by the geographical north pole. The north pole of a magnet repels the north-seeking pole of a compass. By accepted magnetic convention, lines of flux emanate from the north pole of a magnet and enter the south pole.

FIGURE 1—DEFINITION OF MAGNETIC FLUX POLARITY

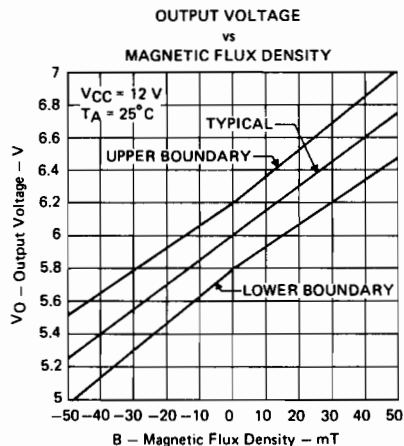


FIGURE 2

## TYPICAL APPLICATION DATA

The circuit in Figure 3 may be used to set the output voltage at zero field strength to exactly 6 V (using R1), and to set the sensitivity to exactly  $-15 \text{ V/T}$  (using R2), as depicted in Figure 4.

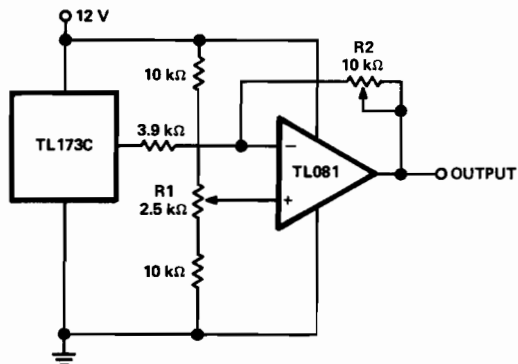


FIGURE 3—COMPENSATION CIRCUIT

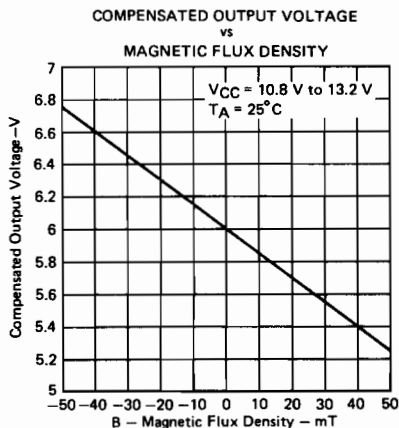


FIGURE 4

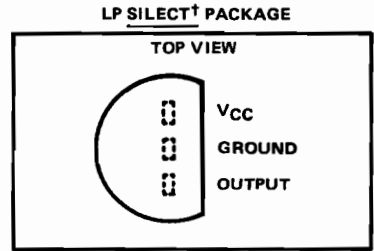
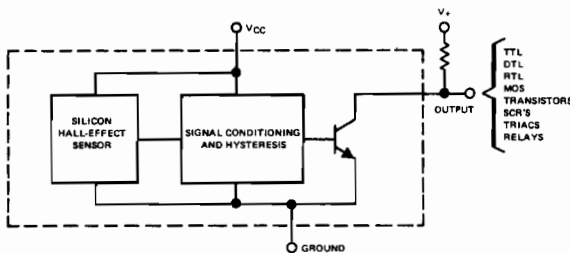
- Magnetic-Field-Sensing Hall-Effect Input
- On-Off Hysteresis Assures Latched Output
- Small Size
- Solid-state Technology
- Open-Collector Output

### description

The TL175C is a low-cost magnetically operated electronic switch that utilizes the Hall-Effect to sense the presence and the direction of a magnetic field. The built-in hysteresis of the switching thresholds is designed to provide a latched switch function. This means that the switch will retain its existing state when the magnetic field is removed and will change state only when the magnetic field is reversed and increased beyond the trigger threshold. This latching feature eliminates the need for external circuitry to record the occurrence of an intermittent fault condition. Additionally, the TL175C will always power-up in the latched-off state in the presence of zero magnetic field. Each circuit consists of a Hall-Effect sensor, signal conditioning and hysteresis functions, and an output transistor integrated into a monolithic chip. The outputs of these circuits can be directly connected to many different types of electronic components.

The TL175C is characterized for operation over the temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### FUNCTIONAL BLOCK DIAGRAM



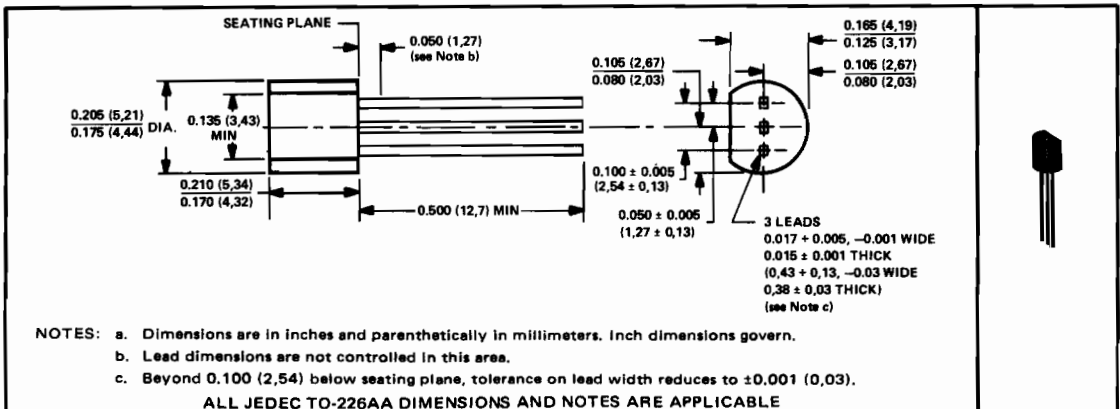
FUNCTION TABLE  
( $T_A = 25^{\circ}\text{C}$ , See Figure 2)

FLUX DENSITY	OUTPUT
$< -35 \text{ mT}$	High (off)
$-5 \text{ mT} < B < 5 \text{ mT}$	Latched in Previous State*
$> 35 \text{ mT}$	Low

\* During power-up the output will always assume the off state.

### mechanical data

The LP Silect package is an encapsulation in a plastic compound specifically designed for this purpose. The package will withstand soldering temperatures without deformation. The package exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C, Method 106B.



†Trademark of Texas Instruments Incorporated

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### ADVANCE INFORMATION

This document contains information on a new product. Specifications are subject to change without notice.

TEXAS INSTRUMENTS  
INCORPORATED

POST OFFICE BOX 225012 • DALLAS, TEXAS 75265

# TYPE TL175C SILICON HALL-EFFECT LATCH

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Output voltage	30 V
Output current	20 mA
Operating free-air temperature range	-40°C to 125°C
Storage temperature range	-65°C to 150°C
Magnetic flux density	unlimited

NOTE 1: Voltage values are with respect to network ground terminal.

## recommended operating conditions

		MIN	NOM	MAX	UNIT
$V_{CC}$	Supply voltage	$T_A = -40^\circ\text{C to } 125^\circ\text{C}$		10	16.5
		$T_A = 0^\circ\text{C to } 125^\circ\text{C}$		8.1	16.5

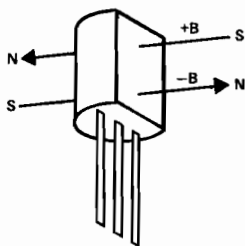
## electrical characteristics over rated operating free-air temperature range, $V_{CC} = 10.8\text{ V to } 13.2\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$B_{T+}$	Threshold of positive-going magnetic flux density †	5		35	mT §
$B_{T-}$	Threshold of negative-going magnetic flux density †	-35 ¶		-5 ¶	mT §
$B_{T+} - B_{T-}$	Hysteresis		40		mT §
$I_{OH}$	High-level output current	$V_{OH} = 20\text{ V}$		100	µA
$V_{OL}$	Low-level output voltage	$I_{OL} = 16\text{ mA}$		0.4	V
$I_{CC}$	Supply current	Output low		7	mA
		Output high		7	

† Threshold values are those levels of magnetic flux density at which the output changes state. For the TL175C, a level more positive than  $B_{T+}$  causes the output to go to a low level and a level more negative than  $B_{T-}$  causes the output to go to a high level. See Figures 1 and 2.

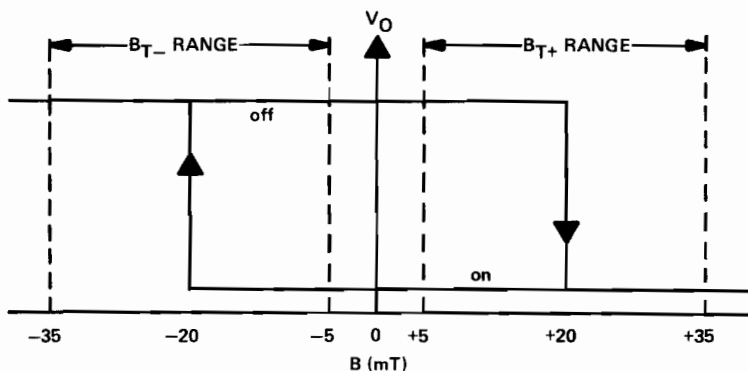
§ The unit of magnetic flux density in the International System of Units (SI) is the tesla (T). The tesla is equal to one weber per square meter. Values expressed in milliteslas may be converted to gauss by multiplying by ten.

¶ The algebraic convention, where the most negative limit is designated as minimum, is used in this data sheet for flux-density threshold levels only.



The north pole of a magnet is the pole that is attracted by the geographical north pole. The north pole of a magnet repels the north-seeking pole of a compass. By accepted magnetic convention, lines of flux emanate from the north pole of a magnet and enter the south pole.

FIGURE 1—DEFINITION OF MAGNETIC FLUX POLARITY



The positive-going threshold ( $B_{T+}$ ) is the positive B level at which a positive-going flux density results in the TL175 output going low. The negative-going threshold ( $B_{T-}$ ) is the negative B level at which a negative-going flux density results in the TL175 going high.

FIGURE 2—REPRESENTATIVE CURVES OF  $V_O$  vs B

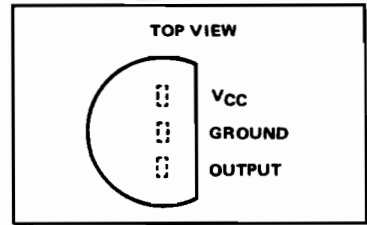
- Magnetic-Field-Sensing Hall-Effect Input
- On-Off Hysteresis
- Small Size
- Solid-State Technology
- Open-Collector Output
- Normally Off Switch

**description**

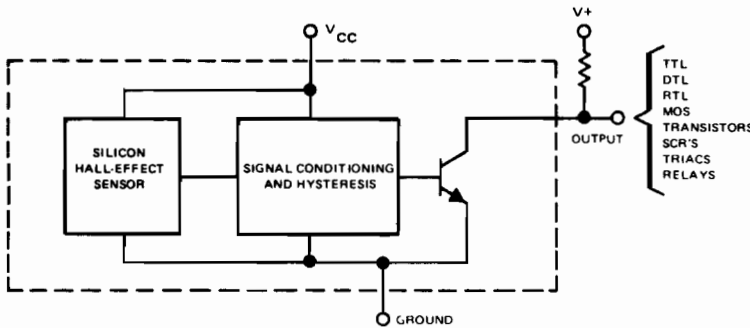
The TL176C is a low-cost magnetically operated normally off electronic switch that utilizes the Hall Effect to sense the presence of a magnetic field. Each circuit consists of a Hall-Effect sensor, signal conditioning and hysteresis functions, and an output transistor integrated into a monolithic chip. A magnetic field of sufficient strength in the positive direction will cause the TL176C output to be in a low-impedance state. Otherwise the output will present a high impedance. The output of this circuitry can be directly connected to many different types of electronic components.

The TL176C is characterized for operation over the temperature range of  $-40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ .

**LP SILECT<sup>†</sup> PACKAGE**



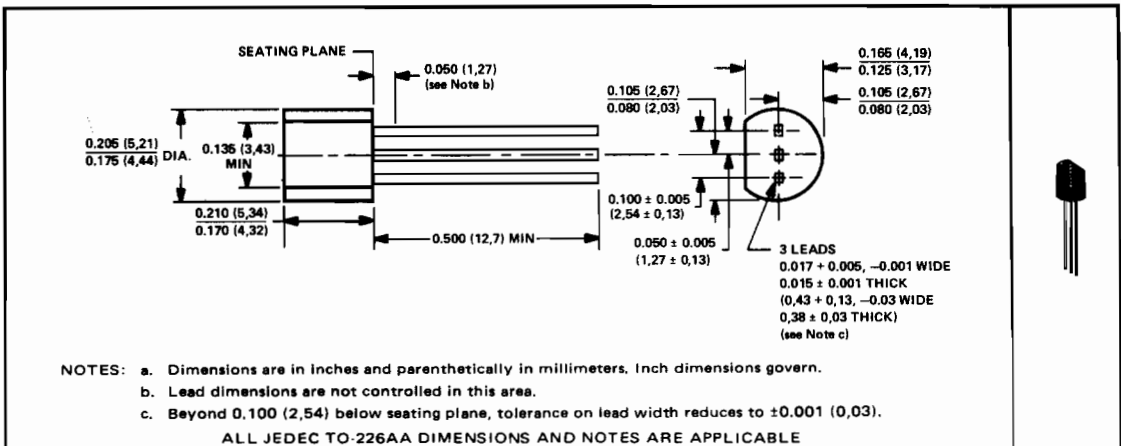
**FUNCTIONAL BLOCK DIAGRAM**



- TTL
- DTL
- RTL
- MOS
- TRANSISTORS
- SCR'S
- TRIACS
- RELAYS

**mechanical data**

The LP Silect package is an encapsulation in a plastic compound specifically designed for this purpose. The package will withstand soldering temperatures without deformation. The package exhibits stable characteristics under high-humidity conditions and is capable of meeting MIL-STD-202C, Method 106B.



<sup>†</sup>Trademark of Texas Instruments Incorporated

# TYPE TL176C

## NORMALLY OFF SILICON HALL-EFFECT SWITCH

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	30 V
Output voltage	30 V
Output current	20 mA
Operating free-air temperature range	-40°C to 150°C
Storage temperature range	-65°C to 150°C
Magnetic flux density	unlimited

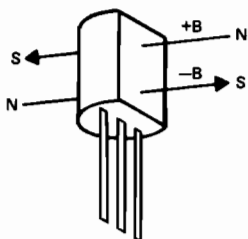
NOTE 1: Voltage values are with respect to network ground terminal.

electrical characteristics over rated operating free-air temperature range,  $V_{CC} = 4.5 \text{ V to } 24 \text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$B_{T+}$	Threshold of positive-going magnetic flux density†			50	mT§
$B_{T-}$	Threshold of negative-going magnetic flux density†	10			mT§
$B_{T+} - B_{T-}$	Hysteresis		7.5		mT§
$I_{OH}$	High-level output current	$V_{OH} = 20 \text{ V}$		100	$\mu\text{A}$
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.75 \text{ V}, I_{OL} = 16 \text{ mA}$		0.4	V
$I_{CC}$	Supply current	$V_{CC} = 24 \text{ V}$		10	mA

†Threshold values are those levels of magnetic flux density at which the output changes state. For the TL176C, a level more positive than  $B_{T+}$  causes the output to go to a low level, and a level more negative than  $B_{T-}$  causes the output to go to a high level. See Figures 1 and 2.

§The unit of magnetic flux density in the International System of Units (SI) is the tesla (T). The tesla is equal to one weber per square meter. Values expressed in milliteslas may be converted to gauss by multiplying by ten.



The north pole of a magnet is the pole that is attracted by the geographical north pole. The north pole of a magnet repels the north-seeking pole of a compass. By accepted magnetic convention, lines of flux emanate from the north pole of a magnet and enter the south pole.

FIGURE 1—DEFINITION OF MAGNETIC FLUX POLARITY

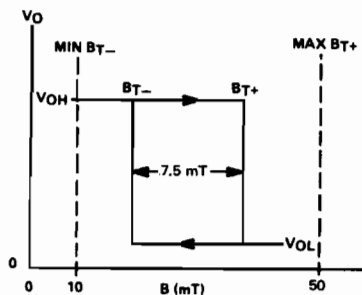


FIGURE 2—REPRESENTATIVE CURVE OF  $V_O$  vs  $B$



- Functionally Interchangeable with Siliconix DG182 with Same Terminal Assignments
- Monolithic Construction
- Adjustable Reference Voltage

- JFET Inputs
- Uniform On-State Resistance for Minimum Signal Distortion
- $\pm 10\text{-V}$  Analog Voltage Range
- TTL, MOS, and CMOS Logic Control Compatibility

**description**

The TL182 is a twin, monolithic, high-speed SPST analog switch constructed using BI-MOS technology. Each half consists of a JFET-input buffer, level translator, and output JFET switch.

The threshold of the input buffer is determined by the voltage applied to the reference input ( $V_{ref}$ ). The input threshold is related to the reference input by the equation  $V_{th} = V_{ref} + 1.4 \text{ V}$ . Thus, for TTL compatibility, the  $V_{ref}$  input is connected to ground. The JFET input makes the device compatible with bipolar, MOS, and CMOS logic families. Threshold compatibility may, again, be determined by  $V_{th} = V_{ref} + 1.4 \text{ V}$ .

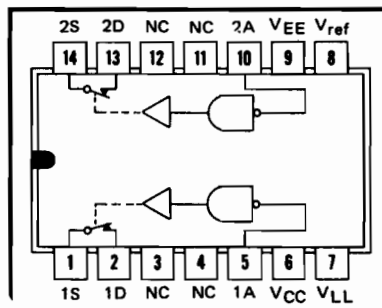
The output switches are junction field-effect transistors featuring low on-state resistance and high off-state resistance. The monolithic structure ensures uniform matching.

BI-MOS technology is a major breakthrough in linear integrated circuit processing. BI-MOS can have ion-implanted JFETs, p-channel MOS-FETs, plus the usual bipolar components all on the same chip. BI-MOS allows circuit designs that previously have been available only as expensive hybrids to be monolithic.

For the TL182, a low level at the input turns the switch on.

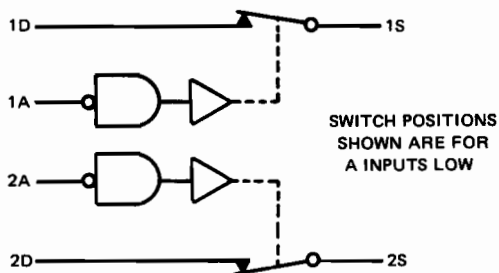
The TL182M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL182I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL182C from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**JORN  
DUAL-IN-LINE PACKAGE (TOP VIEW)**



NC—No internal connection  
Switch positions shown are A inputs low.

**functional diagram**



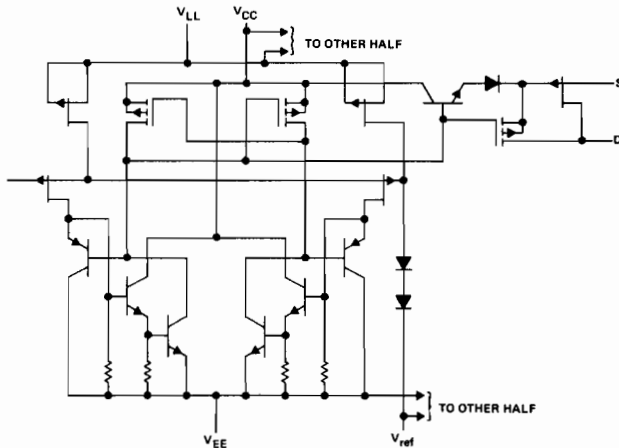
**FUNCTION TABLE  
(EACH HALF)**

INPUT A	SWITCH S
L	ON (CLOSED)
H	OFF (OPEN)

# TYPES TL182M, TL182I, TL182C

## TWIN SPST BI-MOS ANALOG SWITCHES

schematic (each channel)



### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Positive supply to negative supply voltage to either drain, $V_{CC} - V_{EE}$	36 V
Positive supply voltage to either drain, $V_{CC} - V_D$	33 V
Drain to negative supply voltage, $V_D - V_{EE}$	33 V
Drain to source voltage, $V_D - V_S$	$\pm 22$ V
Logic supply to negative supply voltage, $V_{LL} - V_{EE}$	36 V
Logic supply to logic input voltage, $V_{LL} - V_I$	33 V
Logic supply to reference voltage, $V_{LL} - V_{ref}$	33 V
Logic input to reference voltage, $V_I - V_{ref}$	33 V
Reference to negative supply voltage, $V_{ref} - V_{EE}$	27 V
Reference to logic input voltage, $V_{ref} - V_I$	2 V
Current (any terminal)	30 mA

Continuous dissipation at (or below) 25°C free-air temperature (see Note 1):	
TL182MJ	1375 mW
TL182IJ, TL182CJ	1025 mW
N package	1150 mW

Operating free-air temperature range:	TL182M	-55°C to 125°C
	TL182I	-25°C to 85°C
	TL182C	0°C to 70°C

Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

NOTE 1: For operation above 25°C free-air temperature, see Dissipation Derating Table. In the J package, TL182M chips are alloy-mounted; TL182I and TL182C chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25°C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL182M, TL182I, TL182C TWIN SPST BI-MOS ANALOG SWITCHES

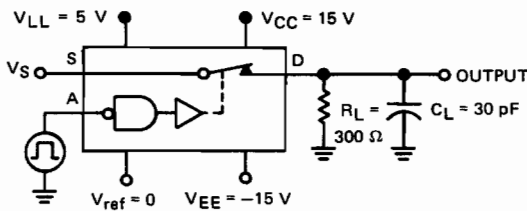
electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $V_{EE} = -15\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL182M	TL182I	TL182C	UNIT	
		MIN MAX	MIN MAX	MIN MAX		
$V_{IH}$ High-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+2$	$V_{ref}+2$	$V_{ref}+2$	V	
$V_{IL}$ Low-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+0.8$	$V_{ref}+0.8$	$V_{ref}+0.8$	V	
$I_{IH}$ High-level control input current	$V_I = 5\text{ V}$ $T_A = 25^\circ\text{C}$	10	10	20	$\mu\text{A}$	
$I_{IL}$ Low-level control input current	$V_I = 0\text{ V}$ $T_A = \text{MIN to MAX}$	-250	-250	-250	$\mu\text{A}$	
$I_{D(off)}$ Off-state drain current	$V_D = 10\text{ V}$ , $V_S = -10\text{ V}$ , $V_I = 2\text{ V}$	$V_{CC} = 15\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = \text{MAX}$	100	100	100	
$I_{S(off)}$ Off-state source current	$V_D = -10\text{ V}$ , $V_S = 10\text{ V}$ , $V_I = 2\text{ V}$	$V_{CC} = 15\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = \text{MAX}$	100	100	100	
$I_{D(on)}+I_{S(on)}$ On-state channel leakage current	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_I = 0.8\text{ V}$ $T_A = 25^\circ\text{C}$		-10	-10	nA	
$r_{DS(on)}$ Drain-to-source on-state resistance	$V_D = -10\text{ V}$ , $I_S = 1\text{ mA}$ , $V_I = 0.8\text{ V}$	$T_A = \text{MAX}$	-200	-200	-200	$\Omega$
		$T_A = \text{MIN to } 25^\circ\text{C}$	75	100	100	
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $0\text{ V}$ , $T_A = 25^\circ\text{C}$		1.5	1.5	1.5	mA
$I_{EE}$ Supply current from $V_{EE}$			-5	-5	-5	
$I_{LL}$ Supply current from $V_{LL}$			4.5	4.5	4.5	
$I_{ref}$ Reference current			-2	-2	-2	
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $5\text{ V}$ , $T_A = 25^\circ\text{C}$		1.5	1.5	1.5	mA
$I_{EE}$ Supply current from $V_{EE}$			-5	-5	-5	
$I_{LL}$ Supply current from $V_{LL}$			4.5	4.5	4.5	
$I_{ref}$ Reference current			-2	-2	-2	

switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{EE} = -20\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL182M	TL182I	TL182C	UNIT
		TYP	TYP	TYP	
$t_{on}$ Turn-on time	$R_L = 300\ \Omega$ , $C_L = 30\text{ pF}$ , See Figure 1	175	175	175	ns
$t_{off}$ Turn-off time		350	350	350	

### PARAMETER MEASUREMENT INFORMATION

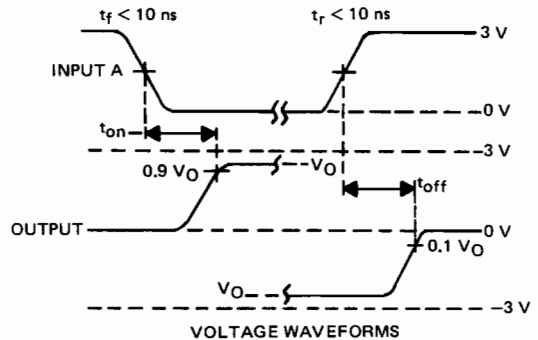


$C_L$  includes probe and jig capacitance.

#### TEST CIRCUIT

$V_S = 3\text{ V}$  for  $t_{on}$  and  $-3\text{ V}$  for  $t_{off}$ .

$$V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$



$V_O$  is the steady-state output with the switch on. Feed through via the gate capacitance may result in spikes (not shown) at the leading and trailing edges of the output waveform.

FIGURE 1

- Functionally Interchangeable with Silicon DG185 with Same Terminal Assignments
- Monolithic Construction
- Adjustable Reference Voltage

- JFET Inputs
- Uniform On-State Resistance for Minimum Signal Distortion
- $\pm 10\text{-V}$  Analog Voltage Range
- TTL, MOS, and CMOS Logic Control Compatibility

**description**

The TL185 is a twin, monolithic, high-speed DPST analog switch constructed using BI-MOS technology. Each half consists of a JFET-input buffer, level translator, and two output JFET switches.

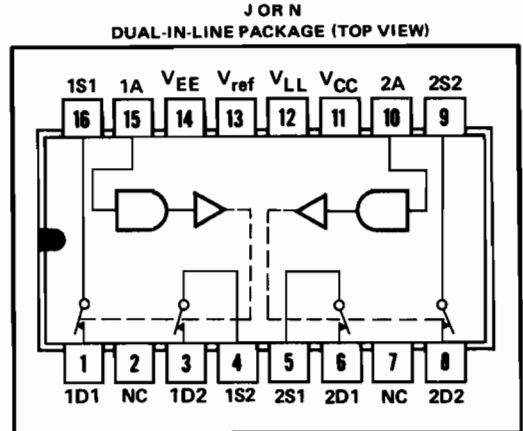
The threshold of the input buffer is determined by the voltage applied to the reference input ( $V_{ref}$ ). The input threshold is related to the reference input by the equation  $V_{th} = V_{ref} + 1.4\text{ V}$ . Thus, for TTL compatibility, the  $V_{ref}$  input is connected to ground. The JFET input makes the device compatible with bipolar, MOS, and CMOS logic families. Threshold compatibility may, again, be determined by  $V_{th} = V_{ref} + 1.4\text{ V}$ .

The output switches are junction field-effect transistors featuring low on-state resistance and high off-state resistance. The monolithic structure ensures uniform matching.

BI-MOS technology is a major breakthrough in linear integrated circuit processing. BI-MOS can have ion-implanted JFETs, p-channel MOS-FETs, plus the usual bipolar components all on the same chip. BI-MOS allows circuit designs that previously have been available only as expensive hybrids to be monolithic.

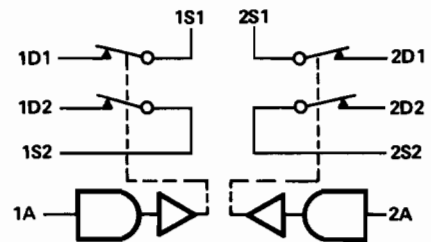
For the TL185, a high level at the input turns the switches on.

The TL185M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL185I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL185C from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



NC—No internal connection  
Switch positions shown are for A inputs high.

**functional diagram**



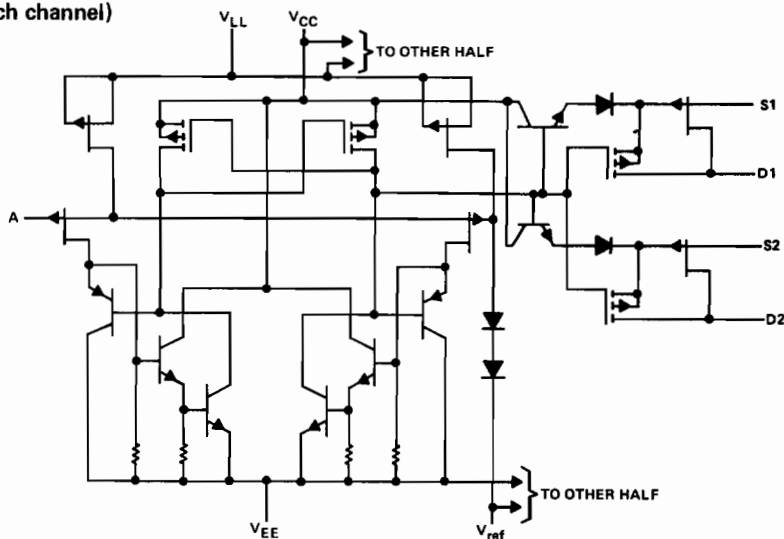
SWITCH POSITIONS SHOWN ARE FOR A INPUTS HIGH

**FUNCTION TABLE  
(EACH HALF)**

INPUT A	SWITCHES S1 AND S2
L	OFF (OPEN)
H	ON (CLOSED)

# TYPES TL185M, TL185I, TL185C TWIN DPST BI-MOS ANALOG SWITCHES

schematic (each channel)



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Positive supply to negative supply voltage, $V_{CC} - V_{EE}$	36 V
Positive supply voltage to either drain, $V_{CC} - V_D$	33 V
Drain to negative supply voltage, $V_D - V_{EE}$	33 V
Drain to source voltage, $V_D - V_S$	$\pm 22$ V
Logic supply to negative supply voltage, $V_{LL} - V_{EE}$	36 V
Logic supply to logic input voltage, $V_{LL} - V_I$	33 V
Logic supply to reference voltage, $V_{LL} - V_{ref}$	33 V
Logic input to reference voltage, $V_I - V_{ref}$	33 V
Reference to negative supply voltage, $V_{ref} - V_{EE}$	27 V
Reference to logic input voltage, $V_{ref} - V_I$	2 V
Current (any terminal)	30 mA

Continuous dissipation at (or below) 25°C free-air temperature (see Note 1):

TL185MJ	1375 mW
TL185IJ, TL185CJ	1025 mW
N package	1150 mW

Operating free-air temperature range: TL185M	-55°C to 125°C
TL185I	-25°C to 85°C
TL185C	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

NOTE 1: For operation above 25°C free-air temperature, see Dissipation Derating Table. In the J package, TL185M chips are alloy-mounted TL185I and TL185C chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25°C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

6

# TYPES TL185M, TL185I, TL185C

## TWIN DPST BI-MOS ANALOG SWITCHES

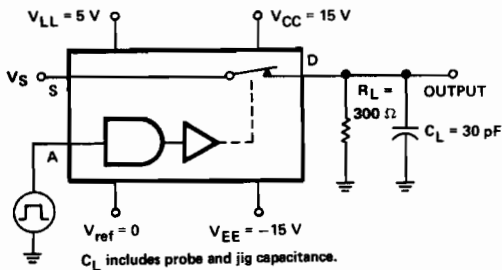
electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $V_{EE} = -15\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL185M	TL185I	TL185C	UNIT	
		MIN MAX	MIN MAX	MIN MAX		
$V_{IH}$ High-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+2$	$V_{ref}+2$	$V_{ref}+2$	V	
$V_{IL}$ Low-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+0.8$	$V_{ref}+0.8$	$V_{ref}+0.8$	V	
$I_{IH}$ High-level control input current	$V_I = 5\text{ V}$ $T_A = 25^\circ\text{C}$	10	10	20	$\mu\text{A}$	
$I_{IL}$ Low-level control input current	$V_I = 0\text{ V}$ $T_A = \text{MIN to MAX}$	-250	-250	-250	$\mu\text{A}$	
$I_{D(off)}$ Off-state drain current	$V_D = 10\text{ V}$ , $V_S = -10\text{ V}$ , $V_I = 0.8\text{ V}$	$V_{CC} = 15\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = \text{MAX}$	100	100	100	
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	
$I_{S(off)}$ Off-state source current	$V_D = -10\text{ V}$ , $V_S = 10\text{ V}$ , $V_I = 0.8\text{ V}$	$V_{CC} = 15\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = \text{MAX}$	100	100	100	
		$V_{CC} = 10\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	
$I_{D(on)}+I_{S(on)}$ On-state channel leakage current	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_A = 2\text{ V}$ $T_A = 25^\circ\text{C}$		-10	-10	nA	
$r_{DS(on)}$ Drain-to-source on-state resistance	$V_D = -10\text{ V}$ , $I_S = 1\text{ mA}$ , $V_I = 2\text{ V}$	$T_A = \text{MIN to } 25^\circ\text{C}$	125	150	150	$\Omega$
		$T_A = \text{MAX}$	250	300	300	
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $0\text{ V}$ , $T_A = 25^\circ\text{C}$		1.5	1.5	1.5	mA
$I_{EE}$ Supply current from $V_{EE}$			-5	-5	-5	
$I_{LL}$ Supply current from $V_{LL}$			4.5	4.5	4.5	
$I_{ref}$ Reference current			-2	-2	-2	
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $5\text{ V}$ , $T_A = 25^\circ\text{C}$		1.5	1.5	1.5	mA
$I_{EE}$ Supply current from $V_{EE}$			-5	-5	-5	
$I_{LL}$ Supply current from $V_{LL}$			4.5	4.5	4.5	
$I_{ref}$ Reference current			-2	-2	-2	

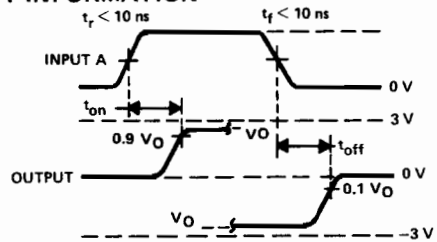
switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{EE} = -20\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL185M	TL185I	TL185C	UNIT
		TYP	TYP	TYP	
$t_{on}$ Turn-on time	$R_L = 300\ \Omega$ , $C_L = 30\text{ pF}$ , See Figure 1	175	175	175	ns
$t_{off}$ Turn-off time		350	350	350	

### PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

$$V_S = 3\text{ V for } t_{on} \text{ and } -3\text{ V for } t_{off}. \quad V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$

$V_O$  is the steady-state output with the switch on. Feed through via the gate capacitance may result in spikes (not shown) at the leading and trailing edges of the output waveform.

FIGURE 1

- Functionally Interchangeable with Siliconix DG188 with Same Terminal Assignments
- Monolithic Construction
- Adjustable Reference Voltage

- JFET Inputs
- Uniform On-State Resistance for Minimum Signal Distortion
- $\pm 10\text{-V}$  Analog Voltage Range
- TTL, MOS, and CMOS Logic Control Compatibility

## description

The TL188 is a monolithic, high-speed dual complementary SPST switch constructed using BI-MOS technology. It consists of a JFET-input buffer, level translator, and two output JFET switches that can easily be connected in SPDT configuration.

The threshold of the input buffer is determined by the voltage applied to the reference input ( $V_{ref}$ ). The input threshold is related to the reference input by the equation  $V_{th} = V_{ref} + 1.4\text{ V}$ . Thus, for TTL compatibility, the  $V_{ref}$  input is connected to ground. The JFET input makes the device compatible with bipolar, MOS, and CMOS logic families. Threshold compatibility may, again, be determined by  $V_{th} = V_{ref} + 1.4\text{ V}$ .

The output switches are junction field-effect transistors featuring low on-state resistance and high off-state resistance. The monolithic structure ensures uniform matching.

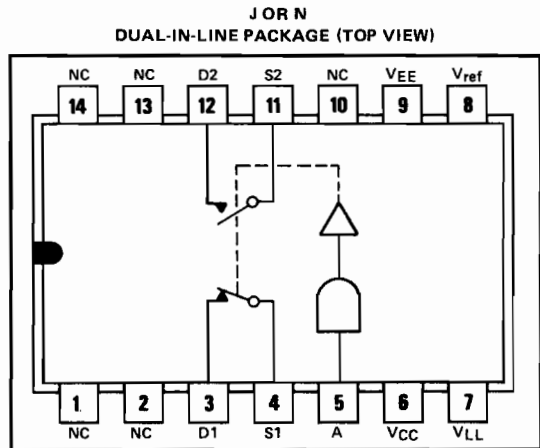
BI-MOS technology is a major breakthrough in linear integrated circuit processing. BI-MOS can have ion-implanted JFETs, p-channel MOS-FETs, plus the usual bipolar components all on the same chip. BI-MOS allows circuit designs that previously have been available only as expensive hybrids to be monolithic.

For the TL188, a high level at the input turns switch S1 on and S2 off.

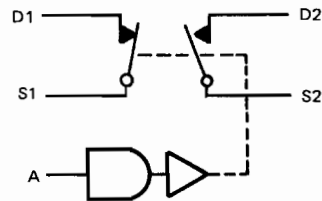
The TL188M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL188I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL188C from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

FUNCTION TABLE

INPUT A	SWITCHES	
	S1	S2
L	OFF (OPEN)	ON (CLOSED)
H	ON (CLOSED)	OFF (OPEN)



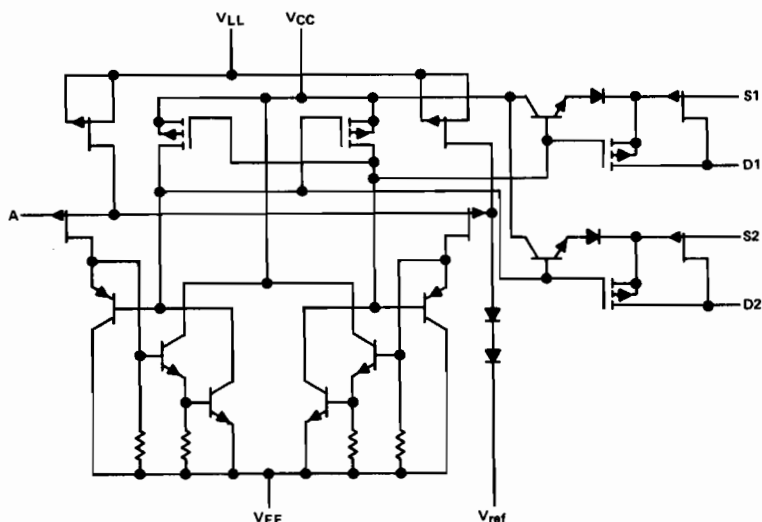
## functional diagram



SWITCH POSITIONS  
SHOWN ARE FOR  
INPUT A HIGH

# TYPES TL188M, TL188I, TL188C DUAL COMPLEMENTARY SPST BI-MOS ANALOG SWITCHES

schematic



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Positive supply to negative supply voltage, $V_{CC} - V_{EE}$	36 V
Positive supply voltage to either drain, $V_{CC} - V_D$	33 V
Drain to negative supply voltage, $V_D - V_{EE}$	33 V
Drain to source voltage, $V_D - V_S$	$\pm 22$ V
Logic supply to negative supply voltage, $V_{LL} - V_{EE}$	36 V
Logic supply to logic input voltage, $V_{LL} - V_I$	33 V
Logic supply to reference voltage, $V_{LL} - V_{ref}$	33 V
Logic input to reference voltage, $V_I - V_{ref}$	33 V
Reference to negative supply voltage, $V_{ref} - V_{EE}$	27 V
Reference to logic input voltage, $V_{ref} - V_I$	2 V
Current (any terminal)	30 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 1):	
TL188MJ	1375 mW
TL188IJ, TL188CJ	1025 mW
N package	1150 mW
Operating free-air temperature range: TL188M	-55°C to 125°C
TL188I	-25°C to 85°C
TL188C	-0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

NOTE 1: For operation above 25°C free-air temperature, see Dissipation Derating Table. In the J package, TL188M chips are alloy-mounted; TL188I and TL188C chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25°C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.



# TYPES TL188M, TL188I, TL188C DUAL COMPLEMENTARY SPST BI-MOS ANALOG SWITCHES

electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $V_{EE} = -15\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$  (unless otherwise noted)

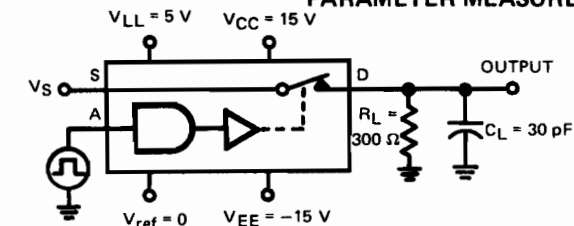
PARAMETER	TEST CONDITIONS	TL188M	TL188I	TL188C	UNIT
		MIN MAX	MIN MAX	MIN MAX	
$V_{IH}$ High-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+2$	$V_{ref}+2$	$V_{ref}+2$	V
$V_{IL}$ Low-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}-0.8$	$V_{ref}-0.8$	$V_{ref}-0.8$	V
$I_{IH}$ High-level control input current	$V_I = 5\text{ V}$ $T_A = 25^\circ\text{C}$	10	10	10	$\mu\text{A}$
$I_{IL}$ Low-level control input current	$V_I = 0\text{ V}$ $T_A = \text{MIN to MAX}$	-250	-250	-250	$\mu\text{A}$
$I_{D(\text{off})}$ Off-state drain current	$V_D = 10\text{ V}$ , $V_{CC} = 15\text{ V}$ , $V_S = -10\text{ V}$ , $V_{EE} = -15\text{ V}$ $T_A = \text{MAX}$		5	5	nA
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ $T_A = 25^\circ\text{C}$		5	5	
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ $T_A = \text{MAX}$	100	100	100	
	$V_D = -10\text{ V}$ , $V_{CC} = 15\text{ V}$ , $V_S = 10\text{ V}$ , $V_{EE} = -15\text{ V}$ $T_A = \text{MAX}$		5	5	
$I_{S(\text{off})}$ Off-state source current	$V_D = -10\text{ V}$ , $V_{CC} = 15\text{ V}$ , $V_S = 10\text{ V}$ , $V_{EE} = -15\text{ V}$ $T_A = \text{MAX}$		100	100	nA
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ $T_A = 25^\circ\text{C}$		5	5	
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ $T_A = \text{MAX}$	100	100	100	
	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ $T_A = 25^\circ\text{C}$		-10	-10	
$I_{D(\text{on})}+I_{S(\text{on})}$ On-state channel leakage current	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ $T_A = \text{MAX}$	-200	-200	-200	nA
	$V_D = -10\text{ V}$ , $V_S = 1\text{ mA}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ $T_A = \text{MIN to } 25^\circ\text{C}$	75	100	100	
$r_{DS(\text{on})}$ Drain-to-source on-state resistance	$V_D = -10\text{ V}$ , $V_S = 1\text{ mA}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ $T_A = \text{MAX}$	150	150	150	$\Omega$
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $0\text{ V}$ , $T_A = 25^\circ\text{C}$	1.5	1.5	1.5	mA
$I_{EE}$ Supply current from $V_{EE}$		-5	-5	-5	
$I_{LL}$ Supply current from $V_{LL}$		4.5	4.5	4.5	
$I_{ref}$ Reference current		-2	-2	-2	
$I_{CC}$ Supply current from $V_{CC}$		1.5	1.5	1.5	
$I_{EE}$ Supply current from $V_{EE}$	Both control inputs at $5\text{ V}$ , $T_A = 25^\circ\text{C}$	-5	-5	-5	mA
$I_{LL}$ Supply current from $V_{LL}$		4.5	4.5	4.5	
$I_{ref}$ Reference current		-2	-2	-2	

switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{EE} = -20\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$

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PARAMETER	TEST CONDITIONS	TL188M	TL188I	TL188C	UNIT
		TYP	TYP	TYP	
$t_{on}$ Turn-on time	$R_L = 300\ \Omega$ , $C_L = 30\text{ pF}$ , See Figure 1	175	175	175	ns
$t_{off}$ Turn-off time		350	350	350	

### PARAMETER MEASUREMENT INFORMATION



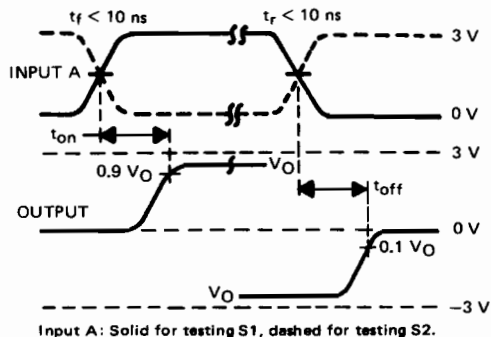
$C_L$  includes probe and jig capacitance.

#### TEST CIRCUIT

$V_S = 3\text{ V}$  for  $t_{on}$  and  $-3\text{ V}$  for  $t_{off}$ .

$$V_O = V_S \frac{R_L}{R_L + r_{DS(\text{on})}}$$

$V_O$  is the steady-state output with the switch on. Feed through via the gate capacitance may result in spikes (not shown) at the leading and trailing edges of the output waveform.



#### VOLTAGE WAVEFORMS

FIGURE 1

- Functionally Interchangeable with Siliconix DG191 with Same Terminal Assignments
- Monolithic Construction
- Adjustable Reference Voltage

- JFET Inputs
- Uniform On-State Resistance for Minimum Signal Distortion
- $\pm 10\text{-V}$  Analog Voltage Range
- TTL, MOS, and CMOS Logic Control Compatibility

**description**

Each TL191 consists of two monolithic, high-speed dual complementary SPST analog switches constructed using BI-MOS technology. Each half consists of a JFET-input buffer, level translator, and two output JFET switches that can easily be connected in SPDT configuration.

The threshold of the input buffer is determined by the voltage applied to the reference input ( $V_{ref}$ ). The input threshold is related to the reference input by the equation  $V_{th} = V_{ref} + 1.4 \text{ V}$ . Thus, for TTL compatibility, the  $V_{ref}$  input is connected to ground. The JFET input makes the device compatible with bipolar, MOS, and CMOS logic families. Threshold compatibility may, again, be determined by  $V_{th} = V_{ref} + 1.4 \text{ V}$ .

The output switches are junction field-effect transistors featuring low on-state resistance and high off-state resistance. The monolithic structure ensures uniform matching.

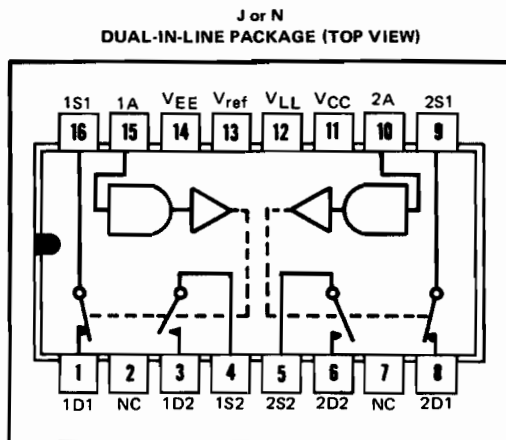
BI-MOS technology is a major breakthrough in linear integrated circuit processing. BI-MOS can have ion-implanted JFETs, p-channel MOS-FETs, plus the usual bipolar components all on the same chip. BI-MOS allows circuit designs that previously have been available only as expensive hybrids to be monolithic.

For the TL191, a high level at the input turns switches S1 on and S2 off.

The TL191 is characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , the TL191I is characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and the TL191 from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

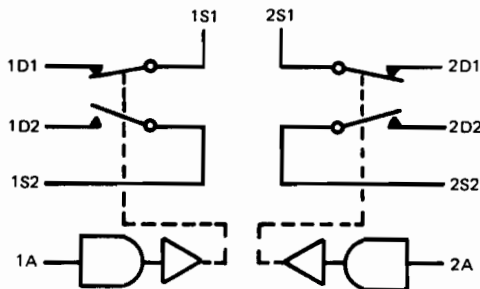
**FUNCTION TABLE  
(EACH HALF)**

INPUT A	SWITCHES	
	S1	S2
L	OFF (OPEN)	ON (CLOSED)
H	ON (CLOSED)	OFF (OPEN)



NC—No internal connection  
Switch positions shown are for A inputs high.

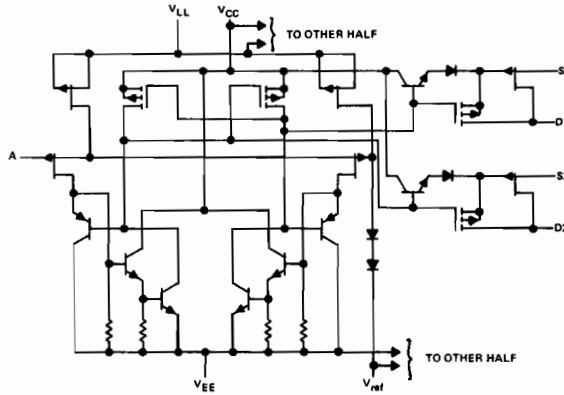
**functional diagram**



SWITCH POSITIONS  
SHOWN ARE FOR  
A INPUTS HIGH

# TYPES TL191M, TL191I, TL191C TWIN DUAL COMPLEMENTARY SPST BI-MOS ANALOG SWITCHES

schematic



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Positive supply to negative supply voltage, $V_{CC} - V_{EE}$	36 V
Positive supply voltage to either drain, $V_{CC} - V_D$	33 V
Drain to negative supply voltage, $V_D - V_{EE}$	33 V
Drain to source voltage, $V_D - V_S$	$\pm 22$ V
Logic supply to negative supply voltage, $V_{LL} - V_{EE}$	36 V
Logic supply to logic input voltage, $V_{LL} - V_I$	33 V
Logic supply to reference voltage, $V_{LL} - V_{ref}$	33 V
Logic input to reference voltage, $V_I - V_{ref}$	33 V
Reference to negative supply voltage, $V_{ref} - V_{EE}$	27 V
Reference to logic input voltage, $V_{ref} - V_I$	2 V
Current (any terminal)	30 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 1):	
TL191MJ	1375 mW
TL191IJ, TL191CJ	1025 mW
N package	1150 mW
Operating free-air temperature range:	
TL191M	-55°C to 125°C
TL191I	-25°C to 85°C
TL191C	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

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NOTE 1: For operation above 25°C free-air temperature, see Dissipation Derating Table. In the J package, TL191M chips are alloy-mounted; TL191I and TL191C chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1375 mW	11.0 mW/°C	25°C
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

# TYPES TL191M, TL191I, TL191C

## TWIN DUAL COMPLEMENTARY SPST BI-MOS ANALOG SWITCHES

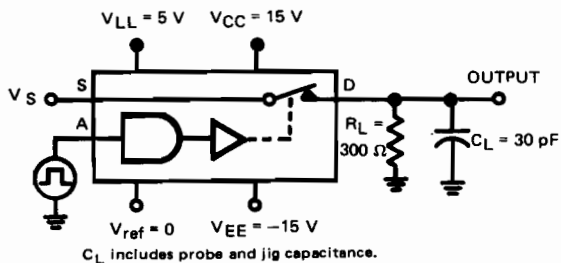
electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $V_{EE} = -15\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL191M	TL191I	TL191C	UNIT	
		MIN MAX	MIN MAX	MIN MAX		
$V_{IH}$ High-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+2$	$V_{ref}+2$	$V_{ref}+2$	V	
$V_{IL}$ Low-level control input voltage	$T_A = \text{MIN to MAX}$	$V_{ref}+0.8$	$V_{ref}+0.8$	$V_{ref}+0.8$	V	
$I_{IH}$ High-level control input current	$V_I = 5\text{ V}$ $T_A = 25^\circ\text{C}$	10	10	20	$\mu\text{A}$	
$I_{IL}$ Low-level control input current	$V_I = 0\text{ V}$ $T_A = \text{MIN to MAX}$	-250	-250	-250	$\mu\text{A}$	
$I_{D(off)}$ Off-state drain current	$V_D = 10\text{ V}$ , $V_{CC} = 15\text{ V}$ , $V_S = -10\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA	
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$	100	100	100		
	$T_A = \text{MAX}$	100	100	100		
$I_{S(off)}$ Off-state source current	$V_D = -10\text{ V}$ , $V_{CC} = 15\text{ V}$ , $V_S = 10\text{ V}$ , $V_{EE} = -15\text{ V}$ , $T_A = 25^\circ\text{C}$		5	5	nA	
	$V_{IH} = 2\text{ V}$ , $V_{CC} = 10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $V_{EE} = -20\text{ V}$ , $T_A = 25^\circ\text{C}$	100	100	100		
	$T_A = \text{MAX}$	100	100	100		
$I_{D(on)}+I_{S(on)}$ On-state channel leakage current	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $T_A = 25^\circ\text{C}$		-10	-10	nA	
$r_{DS(on)}$ Drain-to-source on-state resistance	$V_D = -10\text{ V}$ , $I_S = 1\text{ mA}$ , $T_A = \text{MIN to } 25^\circ\text{C}$	125	150	150	$\Omega$	
	$V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $T_A = \text{MAX}$	250	300	300		
$I_{CC}$ Supply current from $V_{CC}$	Both control inputs at $0\text{ V}$ , $T_A = 25^\circ\text{C}$	1.5	1.5	1.5	mA	
$I_{EE}$ Supply current from $V_{EE}$		-5	-5	-5		
$I_{LL}$ Supply current from $V_{LL}$		4.5	4.5	4.5		
$I_{ref}$ Reference current		-2	-2	-2		
$I_{CC}$ Supply current from $V_{CC}$		1.5	1.5	1.5		
$I_{EE}$ Supply current from $V_{EE}$		-5	-5	-5		
$I_{LL}$ Supply current from $V_{LL}$	Both control inputs at $5\text{ V}$ , $T_A = 25^\circ\text{C}$	4.5	4.5	4.5	mA	
		$I_{ref}$ Reference current	-2	-2		-2
		$I_{CC}$ Supply current from $V_{CC}$	1.5	1.5		1.5
$I_{EE}$ Supply current from $V_{EE}$		-5	-5	-5		
$I_{LL}$ Supply current from $V_{LL}$		4.5	4.5	4.5		
$I_{ref}$ Reference current		-2	-2	-2		

switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{EE} = -20\text{ V}$ ,  $V_{LL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL191M	TL191I	TL191C	UNIT
		TYP	TYP	TYP	
$t_{on}$ Turn-on time	$R_L = 300\ \Omega$ , $C_L = 30\text{ pF}$ , See Figure 1	175	175	175	ns
$t_{off}$ Turn-off time		350	350	350	

### PARAMETER MEASUREMENT INFORMATION



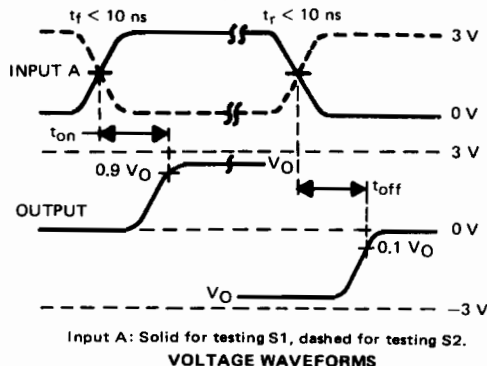
#### TEST CIRCUIT

$V_S = 3\text{ V}$  for  $t_{on}$  and  $-3\text{ V}$  for  $t_{off}$ .

$R_L$

$$V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$

$V_O$  is the steady-state output with the switch on. Feed through via the gate capacitance may result in spikes (not shown) at the leading and trailing edges of the output waveform.



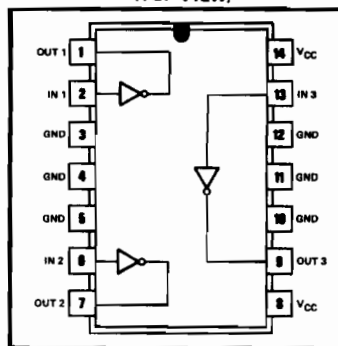
Input A: Solid for testing S1, dashed for testing S2.

#### VOLTAGE WAVEFORMS

FIGURE 1

- Three Independent Inverting Stepper-Motor Control Circuits
- High Output Source Current . . . 500 mA Typ
- High Output Sink Current . . . 500 mA Typ
- Inputs Are Compatible With Bipolar and MOS
- Large Supply Voltage Range . . . 4 V to 18 V
- Threshold Voltage Range is Approximately One-Half  $V_{CC}$
- Active Pull-Down on Each Input
- Low Standby Power Dissipation
- 14-Pin NE Power Package

NE DUAL-IN-LINE  
PACKAGE  
(TOP VIEW)

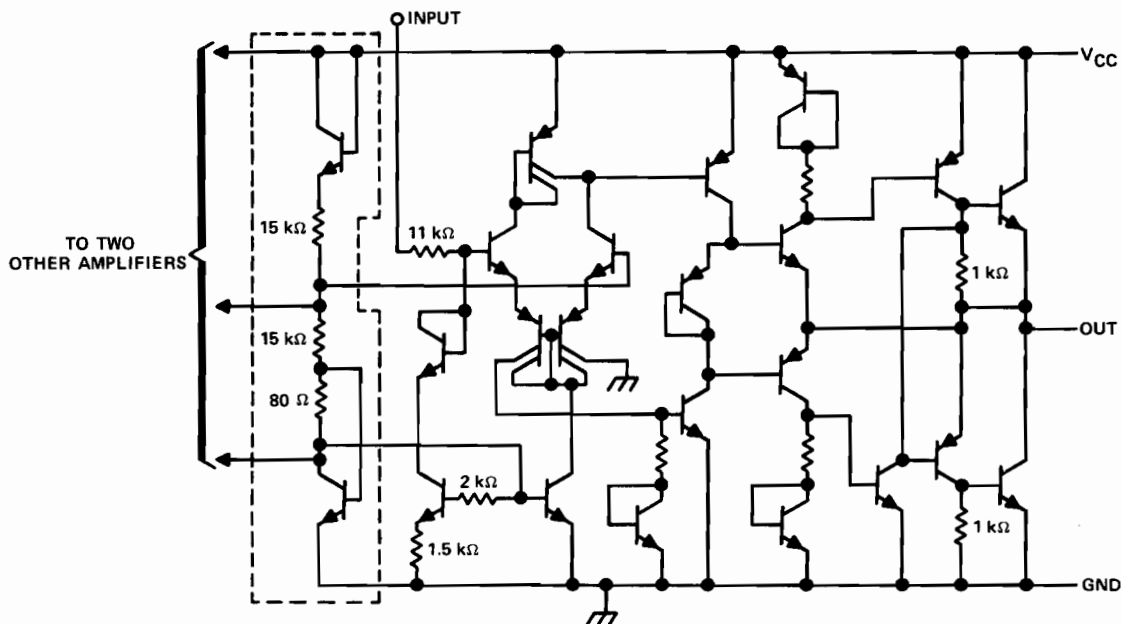


### description

The TL376C is a monolithic bipolar three-channel stepper-motor controller. The input signal is inverted through the device and drives a totem-pole output section. Each output can source or sink up to 500 milliamperes. The wide supply-voltage range coupled with a threshold voltage level of approximately one-half  $V_{CC}$  allows this device to interface with MOS as well as bipolar outputs. An active-pull-down circuit is included on each input. In typical operation, a microprocessor supplies a three-phase signal to the device, which then drives a two-winding stepper-motor.

The TL376C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

### schematic



Resistor values shown are nominal.

### ADVANCE INFORMATION

This document contains information on a new product. Specifications are subject to change without notice.

# TYPE TL376C

## THREE-CHANNEL STEPPER-MOTOR CONTROL

absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	22 V
Input voltage, $V_I$	$V_{CC}$
Output voltage range	-0.9 V to $V_{CC} + 1$ V
Output current, each amplifier	550 mA
Total power dissipation at (or below) 25°C free-air temperature (see Note 2)	2075 mW
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

- Notes: 1. Voltage values are with respect to the network ground terminal.  
 2. For operation above 25°C free-air temperature, derate linearly at the rate of 16.6 mW/°C.

recommended operating conditions

	MIN	NOM	MAX	UNIT
High-level input voltage, $V_{IH}$	$\frac{V_{CC}}{2} + 0.8$		$V_{CC}$	V
Low-level input voltage, $V_{IL}$			$\frac{V_{CC}}{2} - 0.2$	V
Supply voltage range, $V_{CC}$	4	11	18	V
Operating free-air temperature, $T_A$	0		70	C

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
$V_{OL}$ Low-level output voltage	$I_{OL} = 500$ mA, $V_I = V_{IH}$ min			1.5	V
$V_{OH}$ High-level output voltage	$I_{OH} = -500$ mA, $V_I = V_{IL}$ max	$V_{CC} - 1.5$			V
$I_I$ Input current	$V_I = V_{CC}$			100	µA
	$V_I = 1.8$ V	5			µA
$I_{CC}$ Supply current	Inputs open, Outputs open, $V_{CC} = 18$ V		0.7	2	mA

† Typical values are measured at  $V_{CC} = 15$  V,  $T_A = 25^\circ\text{C}$ .

### TYPICAL CHARACTERISTICS

INPUT CURRENT  
vs  
INPUT VOLTAGE

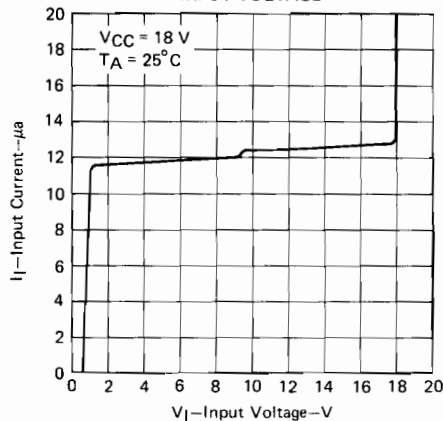


FIGURE 1

# TYPE TL376C

## THREE-CHANNEL STEPPER-MOTOR CONTROL

### TYPICAL CHARACTERISTICS

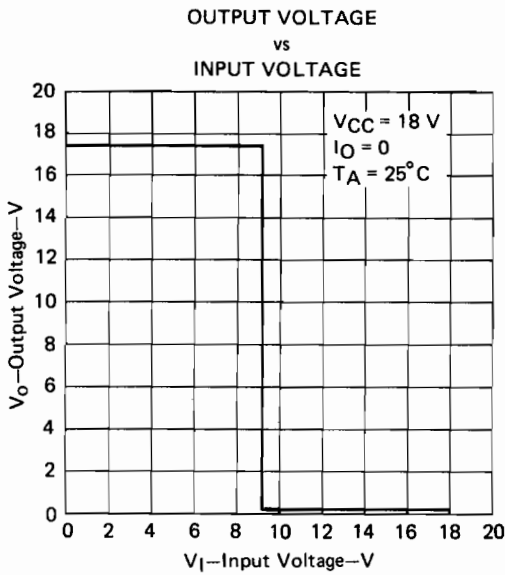


FIGURE 2

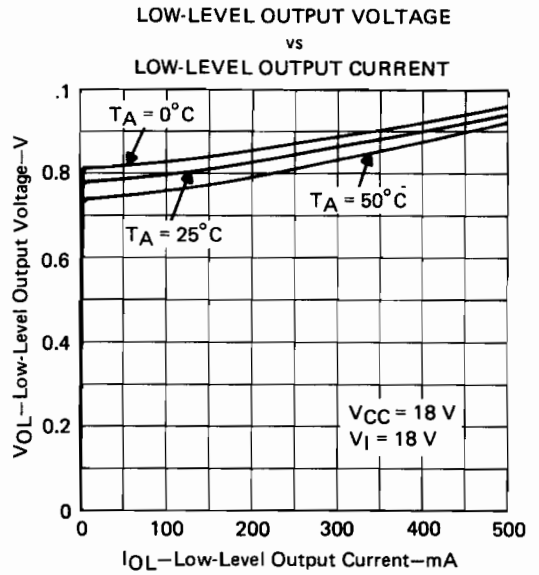


FIGURE 3

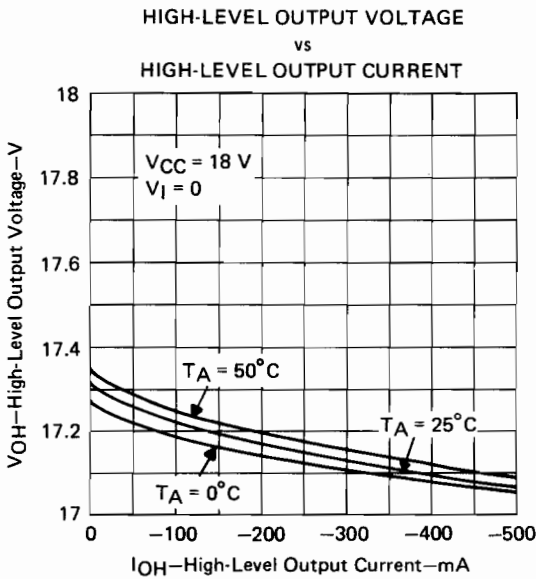


FIGURE 4

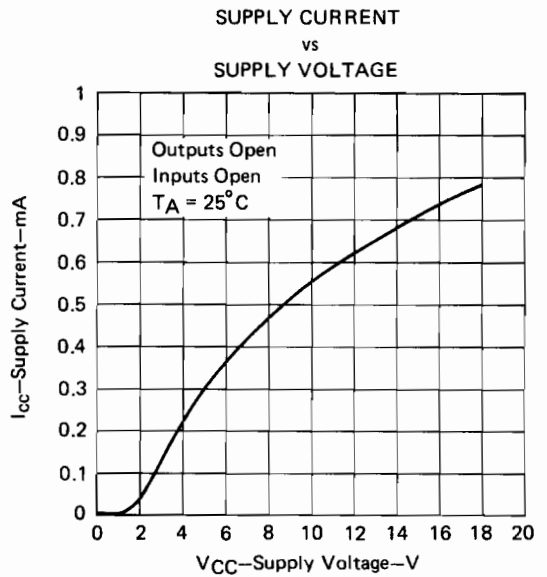


FIGURE 5





- Differential Amplifier Inputs
- A-C Line Operation
- Capable of Triggering Several Types of Triacs
- Internal Active Elements of Saw-Tooth Generator for Proportional Control
- Wide Variety of Possible Connections of Input Section and of Output Section

**description**

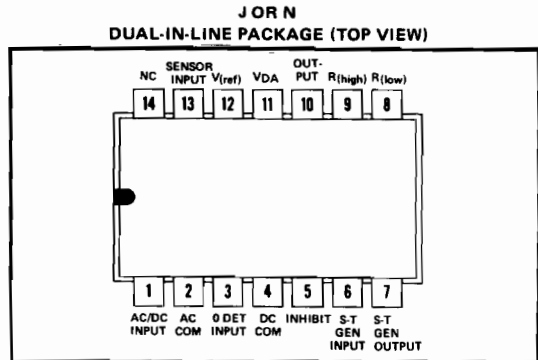
The TL440 is a combination threshold detector and zero-crossing trigger, intended primarily for a-c power-control circuits. It allows a triac or SCR to be fired when the a-c input signal crosses through zero volts, thereby minimizing undesirable electromagnetic interference. In this manner, the load utilizes full cycles of line voltage as opposed to partial cycles typical with SCR phase-control power circuits.

The circuit includes a zero-voltage detector, a differential amplifier that may be used in conjunction with a resistance bridge to sense the parameter being controlled, the active elements of a saw-tooth generator, and an output section. Also included are resistors which may be used as a voltage divider for the reference side of the resistance bridge. An external sensor suitable for the application and an external potentiometer form the input side of the resistance bridge.

The TL440 can be used either as an on-off control with or without hysteresis, or as a proportional control with the use of the internal saw-tooth generator. Although the principal application of this device is in temperature control, it can be used for many power control applications such as a photosensitive control, voltage level sensor, a-c lamp flasher, small relay driver, or a miniature lamp driver.

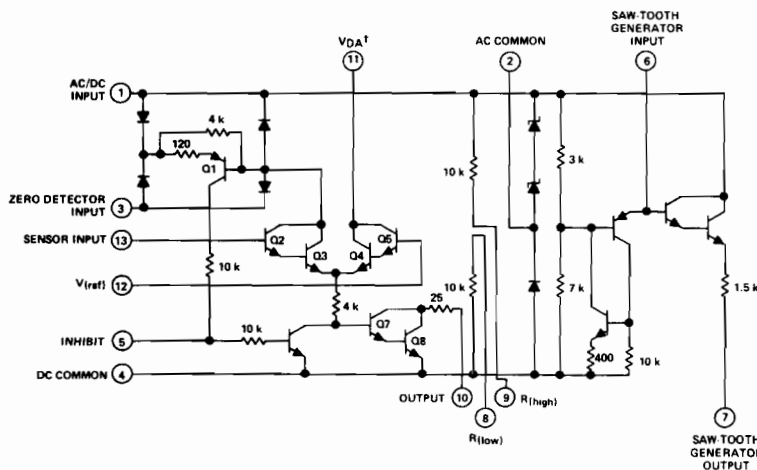
The inhibit function prevents any output pulses from occurring when the applied voltage at the inhibit input is typically 1 volt or greater. Conversely, if the inhibit input is shorted to dc common, an output pulse will be obtained for each zero-crossing of the a-c power input waveform regardless of the sensor input conditions.

The TL440C is characterized for operation from 0°C to 70°C.



NC—No internal connection.

**schematic**



Resistor values shown are nominal and in ohms.

†Pin 11 is usually connected to the AC/DC input, pin 1, unless a control circuit requiring hysteresis is desired. See Figure 4.

# TYPE TL440C

## ZERO-VOLTAGE SWITCH

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Voltage applied to AC/DC input (See Note 1)	15 V
Peak current into AC/DC input	40 mA
Peak current into zero-detector input	30 mA
Peak output sink current (See Note 2)	250 mA
Continuous total power dissipation at (or below) 70°C free-air temperature range	500 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. Voltage values are with respect to the dc common terminal unless otherwise specified.  
 2. This value applies for a maximum pulse width of 400  $\mu$ s and for a maximum duty cycle of 2%.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
D-c voltage applied to AC/DC input (See Note 3)		12		V
Differential input voltage, $V_{13} - V_{12}$		$\pm 2$		V
Voltage at sensor or $V_{(ref)}$ input, $V_{13}$ or $V_{12}$		6		V
Peak output current (See Note 4)			200	mA
Output pulse width	100		400	$\mu$ s
Operating free-air temperature, $T_A$	0		70	°C

- NOTES: 3. This is the recommended d-c supply voltage when the voltage across pins 1 and 4 is not being maintained by charging an electrolytic capacitor from the line voltage. See typical application data.  
 4. This value applies for  $t_w < 400 \mu$ s, duty cycle  $\leq 2\%$ .

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Sensor input voltage hysteresis	Pin 11 connected to Pin 1		30		mV
Voltage required at inhibit input to inhibit output		1	3		V
Current into sensor input	$V_{13} = 6$ V, $V_{12} = 4$ V		5		$\mu$ A
Current into $V_{(ref)}$ input	$V_{12} = 6$ V, $V_{13} = 4$ V		5		$\mu$ A
Current into inhibit terminal required to inhibit output			20		$\mu$ A
Peak output current (pulsing)	$V_5 = 0$	75	100		mA
Output current (inhibited)	$V_{10} = 13.5$ V		1		$\mu$ A
Output pulse width into resistive load	25 k $\Omega$ connected to zero-detector input, 60-Hz power source		150		$\mu$ s
Average temperature coefficient of output pulse width (0°C to 70°C)			0.7		$\mu$ s/°C
Peak output voltage of saw-tooth generator	$V_1 = 12$ V		9		V
Voltage at AC/DC input(See Note 5)		9	11.5		V

- NOTE 5: This is the voltage across an electrolytic capacitor connected between pins 1 and 4 whose charge is maintained by the a-c line voltage. See Figures 1 and 3.



# TYPE TL440C ZERO-VOLTAGE SWITCH

## TYPICAL APPLICATION DATA

The circuit shown in Figure 3 provides proportional control of a heating system. With the exception of the saw-tooth generator, the circuit of Figure 3 functions the same as that of Figure 1. The sensor of Figure 3 has a negative temperature coefficient.

Transistors Q9 and Q10 are connected to function as an SCR in order to discharge external capacitor C2 very quickly. The time constant of the saw-tooth generator can be varied by changing either the external capacitor or the external resistor. However it is suggested that the capacitor be varied and not the resistor since too low a value of resistance would allow Q9 and Q10 to stay on continuously. The period of the saw-tooth generator is usually 10 to 100 times the period of the line voltage.

At the start of the saw-tooth waveform the base of Q1 is high and output pulses occur at pin 10. At the desired temperature a certain number of output pulses occur during each saw-tooth cycle as shown in Figure 2(a). At a slightly decreased temperature the resistance of the sensor increases, lowering the d-c potential of pin 13. This lowers the potential of the entire saw-tooth waveform as shown in Figure 2(b) which causes a few more output pulses to occur. At greatly decreased temperatures many more pulses occur each saw-tooth cycle as shown in Figure 2(c).

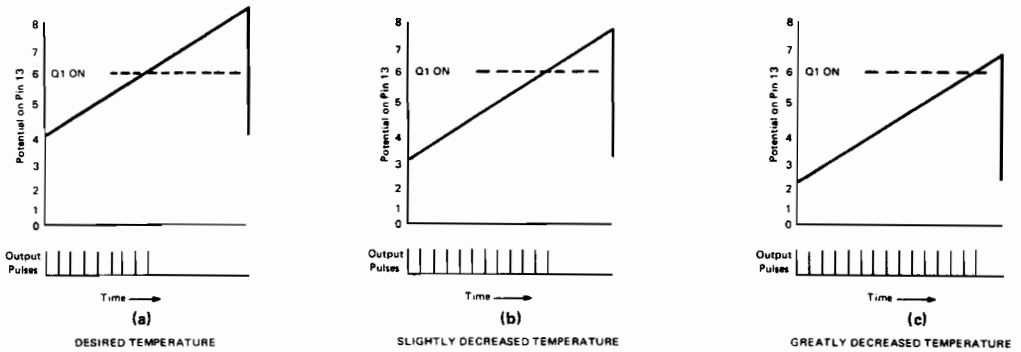


FIGURE 2

Similarly, increases in temperature cause proportionately fewer output pulses than the normal number of Figure 2(a). Thus the proportional control feature allows a smoother control of temperature in this application by always providing output pulses during some portion of the saw-tooth generator cycle as opposed to the "full on/full off" circuit of Figure 1.

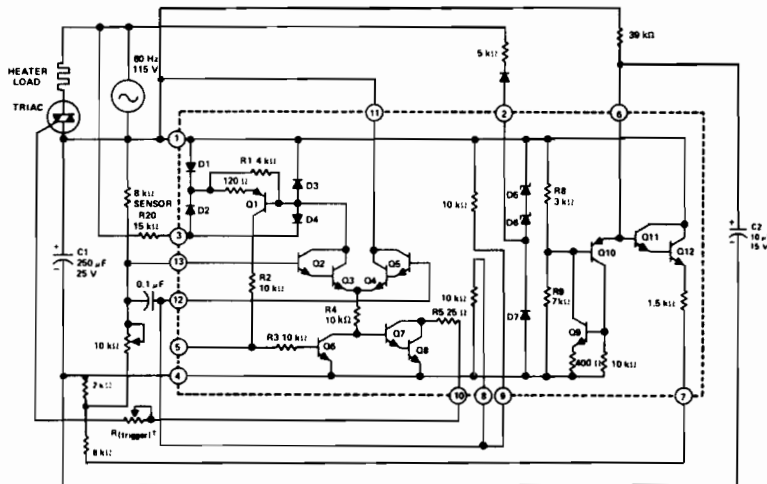


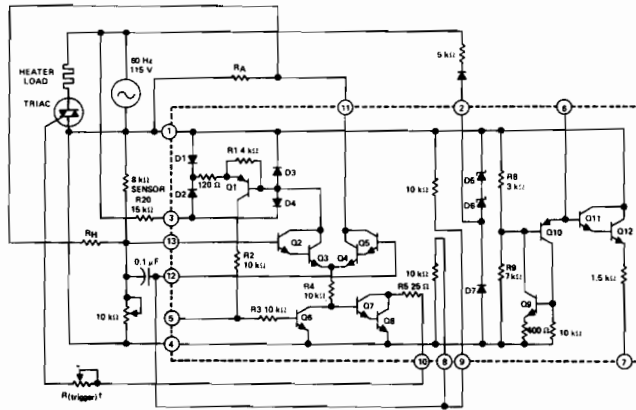
FIGURE 3—PROPORTIONAL HEATER CONTROL

<sup>†</sup>R<sub>(trigger)</sub> is adjusted so that the peak output is less than 200 mA.

# TYPE TL440C ZERO-VOLTAGE SWITCH

## TYPICAL APPLICATION DATA

Hysteresis may be added to the TL440 by externally making the differential amplifier appear in Schmitt-trigger configuration. This is done by applying positive feedback from pin 11 to pin 13 through hysteresis resistors  $R_A$  and  $R_H$ . When the output is enabled, the voltage drop developed across resistor  $R_A$  is fed through  $R_H$  to the sensor input of the differential amplifier. This lowers the voltage at this point from the voltage level present when the output is inhibited. The resistance of the sensor must now decrease enough to overcome this additional ("hysteresis") voltage in order to inhibit the output.  $R_H$  should have a typical value close to the value of the sensor used. The value of  $R_A$ , which determines the amount of hysteresis, should be approximately one tenth the value of  $R_H$ . In Figure 4 the  $10\text{ k}\Omega$  potentiometer is adjusted to set the voltage at pin 13 to the level at which the output is enabled. When precise control is not needed, such a circuit eliminates the small "uncertainty range" observed in time-proportioning systems.



<sup>†</sup> $R_{(trigger)}$  is adjusted so that the peak output is less than 200 mA.

FIGURE 4—ON-OFF HEATER CONTROL WITH HYSTERESIS ADDED

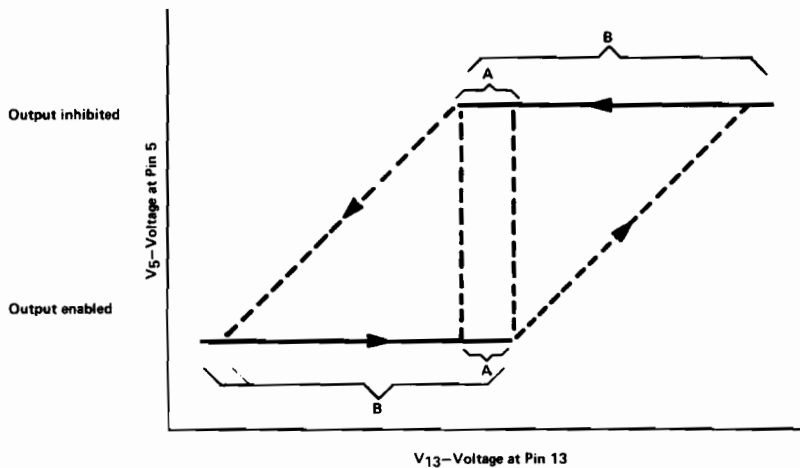


FIGURE 5—HYSTERESIS CURVE FOR FIGURE 4

A—Circuit without added hysteresis ( $\Delta V_{13} \approx 15$  to  $20\text{ mV}$  residual hysteresis)

B—Circuit with added hysteresis ( $\Delta V_{13} \approx 200$  to  $300\text{ mV}$  added hysteresis)

NOTE 1: Dotted lines represent discontinuous changes where the differential amplifier changes from inhibit to enable or vice-versa. Solid lines represent stable states (inhibit or enable) of the differential amplifier.



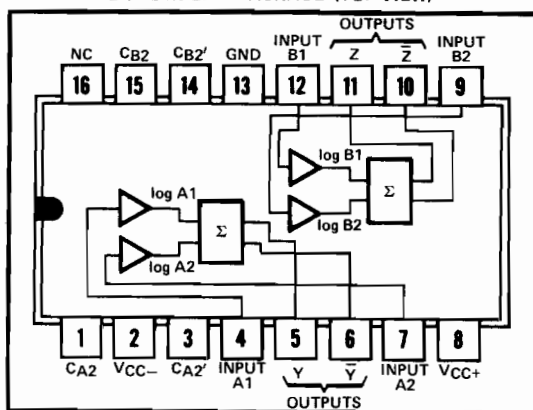
# LINEAR INTEGRATED CIRCUITS

# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

BULLETIN NO. DL-S 11427, JANUARY 1971—REVISED JUNE 1976

- Excellent Dynamic Range
- Wide Bandwidth
- Built-In Temperature Compensation
- Log Linearity (30 dBV Sections) . . . 1 dBV
- Wide Input Voltage Range

J OR N  
DUAL-IN-LINE PACKAGE (TOP VIEW)



$Y \propto \log A1 + \log A2$ ;  $Z \propto \log B1 + B2$   
 where: A1, A2, B1, and B2 are in dBV, 0 dBV = 1 V.  
 CA2, CA2', CB2, and CB2' are detector compensation inputs.  
 NC—No internal connection

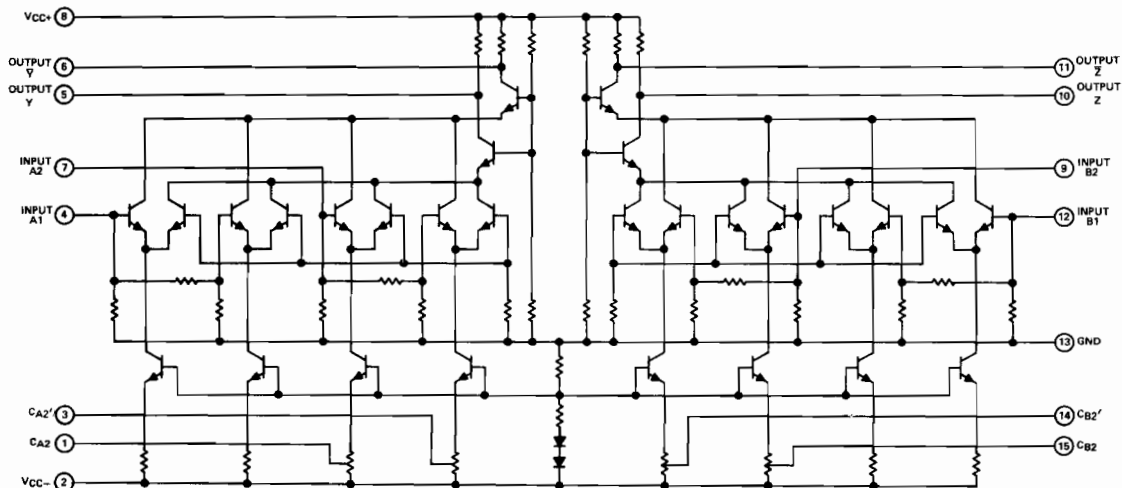
## description

This monolithic logarithmic amplifier circuit contains four 30-dBV log stages. Gain in each stage is such that the output of each stage is proportional to the logarithm of the input voltage over the 30-dBV input voltage range. Each half of the circuit contains two of these 30-dBV stages summed together in one differential output which is proportional to the sum of the logs of the input voltages of the two stages. The four stages may be interconnected to obtain a theoretical input voltage range of 120 dBV. In practice, this permits the input voltage range to be typically greater than 80 dBV with log linearity of  $\pm 0.5$  dBV (see application data). Bandwidth is from dc to 40 megahertz.

These circuits are useful in military weapons systems, broadband radar, and infrared reconnaissance systems. They serve for data compression and analog compensation. The logarithmic amplifiers are used in log IF circuitry as well as video and log amplifiers. The TL441M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL441C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

6

## schematic



# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltages (see Note 1):

V <sub>CC+</sub> . . . . .	8V
V <sub>CC-</sub> . . . . .	-8V
Input voltage (see Note 1) . . . . .	6V
Output sink current (any one output) . . . . .	30 mA
Continuous total dissipation at (or below) 70°C free-air temperature (see Note 2) . . . . .	500 mW
Operating free-air temperature range: TL441M Circuits . . . . .	-55°C to 125°C
TL441C Circuits . . . . .	0°C to 70°C
Storage temperature range . . . . .	-65°C to 150°C

- NOTES: 1. All voltages, except differential output voltages, are with respect to network ground terminal.  
 2. For operation of the TL441M above 70°C free-air temperature, refer to the Dissipation Derating Curves, Section 2. In the J package, TL441M chips are alloy-mounted; TL441C chips are glass-mounted.

### recommended operating conditions

	TL441M			TL441C			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Input voltage for each 30-dBV stage	0.01	1		0.01	1		V <sub>p-p</sub>
Operating free-air temperature, T <sub>A</sub>	-55	125		0	70		°C

electrical characteristics, V<sub>CC+</sub> = 6 V, V<sub>CC-</sub> = -6 V, T<sub>A</sub> = 25°C

PARAMETER	TEST FIGURE	TL441M			TL441C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Differential output offset voltage	1		±25	±60		±40		mV
Quiescent output voltage	2	5.45	5.6	5.85	5.45	5.6	5.85	V
D-c scale factor (differential output), each 30-dBV stage, -35 dBV to -5 dBV	3	7	8	10	6	8	12	mV/dBV
A-c scale factor (differential output)			8			8		mV/dBV
D-c error at -20 dBV (midpoint of -35 dBV to -5 dBV range)	3		1	2		1		dBV
Input impedance			500			500		Ω
Output impedance			200			200		Ω
Rise time, 10% to 90% points, C <sub>L</sub> = 24 pF	4		20	30		20	30	ns
Supply current from V <sub>CC+</sub>	2	14.5	18.5	23	14.5	18.5	23	mA
Supply current from V <sub>CC-</sub>	2	-6	-8.5	-10.5	-6	-8.5	-10.5	mA
Power dissipation	2	123	162	201	123	162	201	mW

### PARAMETER MEASUREMENT INFORMATION

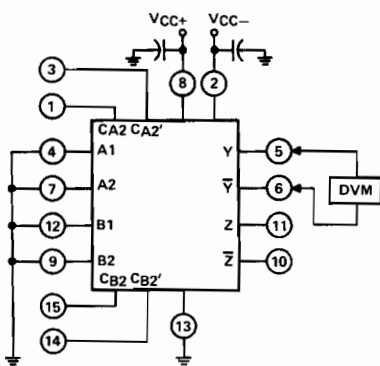


FIGURE 1

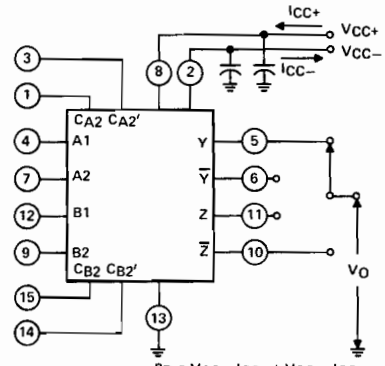


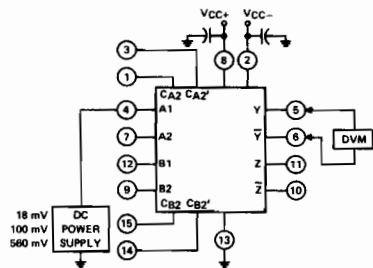
FIGURE 2

$$P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$$



# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

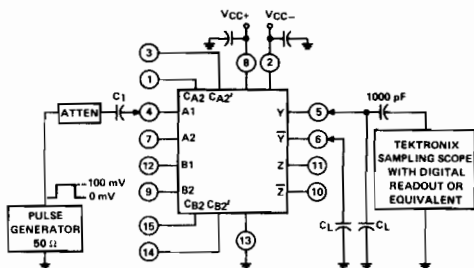
## PARAMETER MEASUREMENT INFORMATION



$$\text{Scale Factor} = \frac{[V_{\text{out}}(560 \text{ mV}) - V_{\text{out}}(18 \text{ mV})] \text{ mV}}{30 \text{ dBV}}$$

$$\text{Error} = \frac{V_{\text{out}}(100 \text{ mV}) - 0.5 V_{\text{out}}(560 \text{ mV}) - 0.5 V_{\text{out}}(18 \text{ mV})}{\text{Scale Factor}}$$

FIGURE 3



- NOTES: A. The input pulse has the following characteristics:  $t_W = 50 \text{ ns}$ ,  $t_r \leq 2 \text{ ns}$ ,  $t_f \leq 2 \text{ ns}$ ,  $\text{PRR} = 10 \text{ MHz}$ .
- B. Capacitor  $C_1$  consists of three capacitors in parallel:  $1 \mu\text{F}$ ,  $0.1 \mu\text{F}$ , and  $0.01 \mu\text{F}$ .
- C.  $C_L$  includes probe and jig capacitance.

FIGURE 4

## TYPICAL CHARACTERISTICS

TL441M  
DIFFERENTIAL OUTPUT OFFSET VOLTAGE  
VS  
FREE-AIR TEMPERATURE

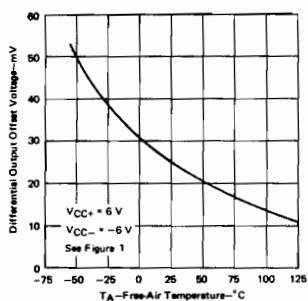


FIGURE 5

TL441M  
QUIESCENT OUTPUT VOLTAGE  
VS  
FREE-AIR TEMPERATURE

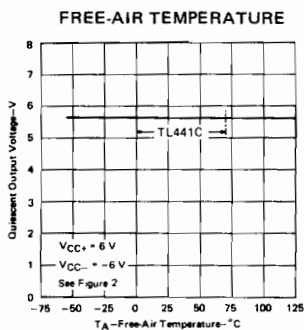


FIGURE 6

TL441M  
D-C SCALE FACTOR  
VS  
FREE-AIR TEMPERATURE

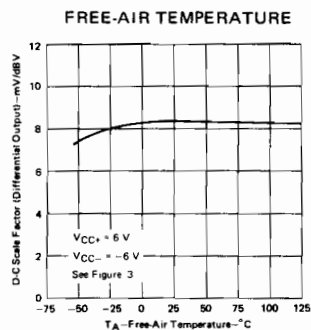


FIGURE 7

TL441M  
D-C ERROR  
VS  
FREE-AIR TEMPERATURE

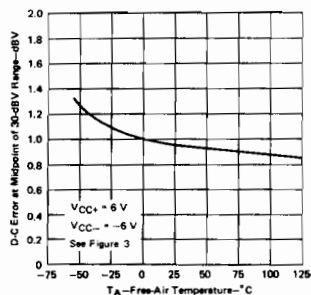


FIGURE 8

TL441M  
OUTPUT RISE TIME  
VS  
LOAD CAPACITANCE

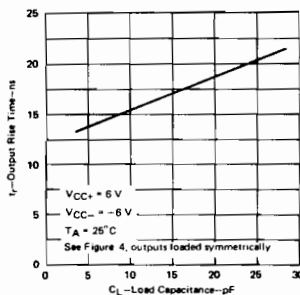


FIGURE 9

TL441M  
POWER DISSIPATION  
VS  
FREE-AIR TEMPERATURE

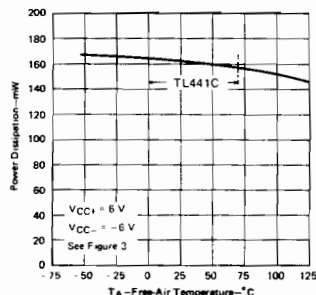


FIGURE 10

# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

## TYPICAL APPLICATION DATA

Although designed for high-performance applications such as broadband radar infrared detection, and weapons systems, this device has a wide range of applications in data compression and analog computation.

### basic log function

The basic log response is derived from the exponential current-voltage relationship of collector current and base-emitter voltage. This relationship is given in the equation:

$$m \cdot V_{BE} = \ln [(I_C + I_{CES})/I_{CES}]$$

where:  $I_C$  = collector current

$I_{CES}$  = collector current at  $V_{BE} = 0$

$m = q/kT$  (in  $V^{-1}$ )

$V_{BE}$  = base-emitter voltage

The differential input amplifier allows dual-polarity inputs, is self-compensating for temperature variations, and is relatively insensitive to noise.

### functional block diagram

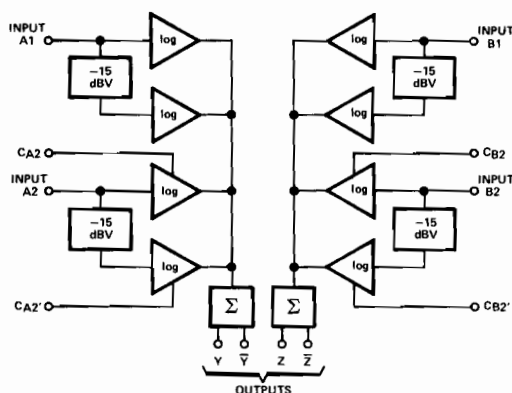


FIGURE 11

### log sections

As can be seen from the schematic, there are eight differential pairs. Each pair is a 15-dBV log subsection, and each input feeds two pairs for a range of 30 dBV per stage.

Four compensation points are made available to allow slight variations in the gain (slope) of the two individual 15-dBV stages of input A2 and B2. By slightly changing the voltage on any of the compensation pins from its quiescent value, the gain of that particular 15-dBV stage can be adjusted to match the other 15-dBV stage in the pair. The compensation pins may also be used to match the transfer characteristics of input A2 to A1 or B2 to B1.

The log stages in each half of the circuit are summed by directly connecting their collectors together and summing through a common-base output stage. The two sets of output collectors are used to give two log outputs, Y and  $\bar{Y}$  (or Z and  $\bar{Z}$ ) which are equal in amplitude but opposite in polarity. This increases the versatility of the device.

By proper choice of external connections, linear amplification, linear attenuation, and many different applications requiring logarithmic signal processing are possible.

### input levels

The recommended input voltage range of any one stage is given as 0.01 volt to one volt. Input levels in excess of one volt may result in a distorted output. When several log sections are summed together, the distorted area of one section overlaps with the next section and the resulting distortion is insignificant. However, there is a limit to the amount of overdrive that may be applied. As the input drive reaches  $\pm 3.5$  volts, saturation occurs, clamping the collector-summing line and severely distorting the output. Therefore, the signal to any input must be limited to approximately  $\pm 3$  volts to ensure a clean output.

### output levels

Differential-output-voltage levels are low, generally less than 0.6 volt. As demonstrated in Figure 12, the output swing and the slope of the output response can be adjusted by varying the gain by means of the slope control. The coordinate origin may also be adjusted by positioning the offset of the output buffer.

# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

## TYPICAL APPLICATION DATA

### circuits

Figures 12 through 19 show typical circuits using these logarithmic amplifiers. Operational amplifiers not otherwise designated are uA741. For operation at higher frequency, use of uA733 is recommended instead of uA741, with the differential outputs connected as in Figure 14.

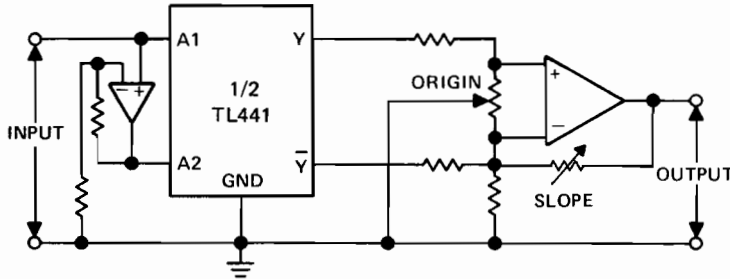


FIGURE 12—OUTPUT SLOPE AND ORIGIN ADJUSTMENT

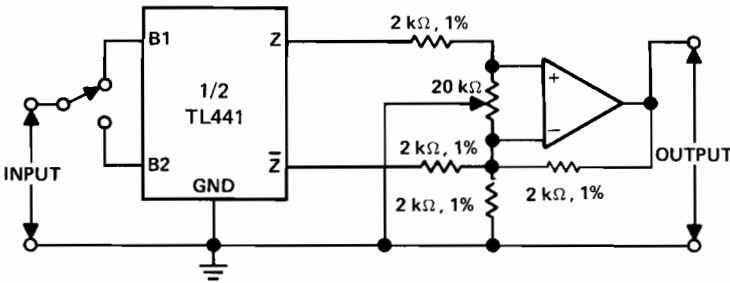
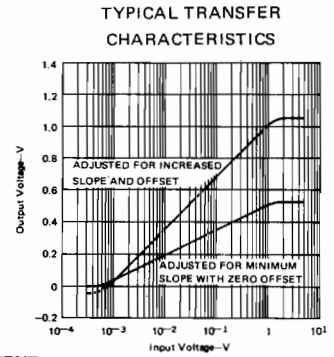


FIGURE 13—UTILIZATION OF SEPARATE STAGES

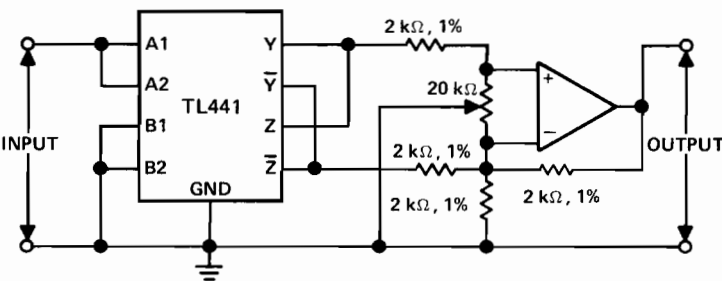
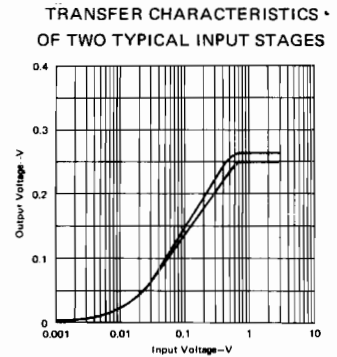
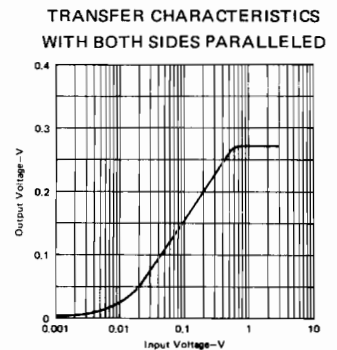


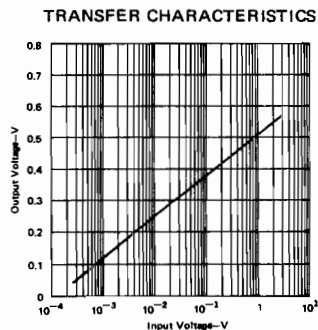
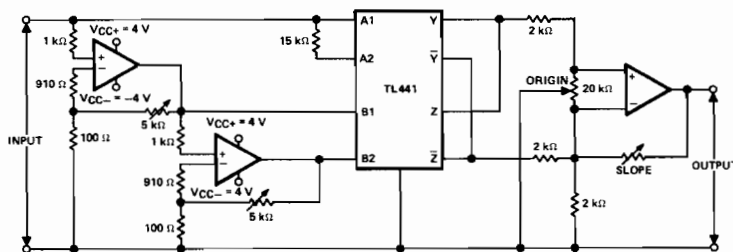
FIGURE 14—UTILIZATION OF PARALLELED INPUTS



6

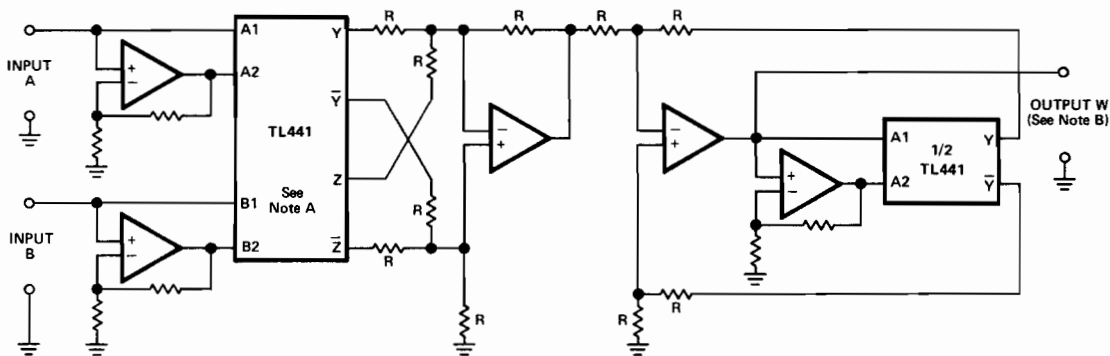
# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

## TYPICAL APPLICATION DATA



- NOTES: A. Inputs are limited by reducing the supply voltages for the input amplifiers to  $\pm 4$  V.  
B. The gains of the input amplifiers are adjusted to achieve smooth transitions.

FIGURE 15—LOGARITHMIC AMPLIFIER WITH INPUT VOLTAGE RANGE GREATER THAN 80 dBV



- NOTES: A. Connections shown are for multiplication. For division, Z and  $\bar{Z}$  connections are reversed.  
B. Output W may need to be amplified to give actual product or quotient of A and B.  
C. R designates resistors of equal value, typically 2 k $\Omega$  to 10 k $\Omega$ .

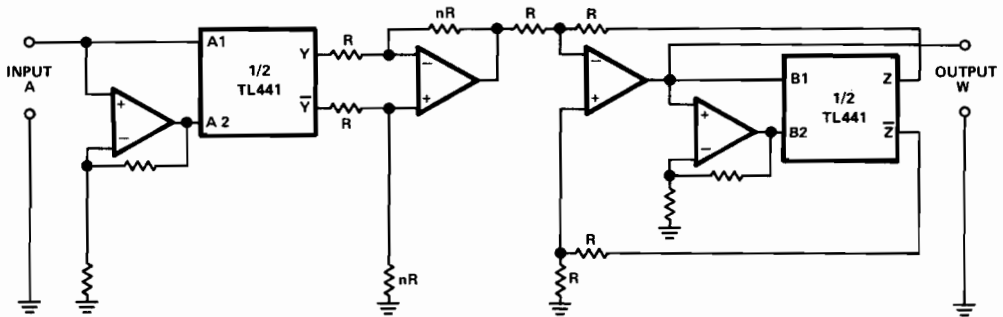
Multiplication:  $W = A \cdot B \Rightarrow \log W = \log A + \log B$ , or  $W = a^{(\log_a A + \log_a B)}$

Division:  $W = A/B \Rightarrow \log W = \log A - \log B$ , or  $W = a^{(\log_a A - \log_a B)}$

FIGURE 16—MULTIPLICATION OR DIVISION

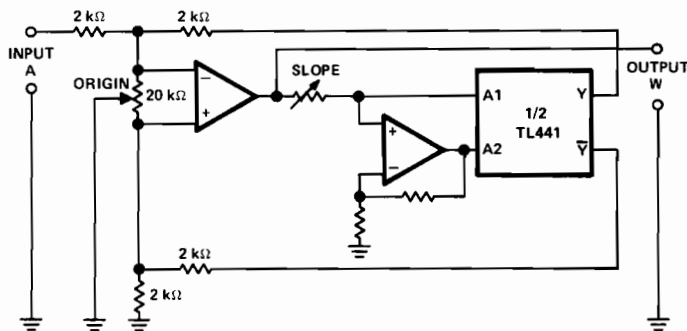
# TYPES TL441M, TL441C LOGARITHMIC AMPLIFIERS

## TYPICAL APPLICATION DATA



NOTE: R designates resistors of equal value, typically 2 kΩ to 10 kΩ. The power to which the input variable is raised is fixed by setting nR.  
Output W may need to be amplified to give the correct value.  
Exponential:  $W = A^n \Rightarrow \log W = n \log A$ , or  $W = a^{(n \log_b A)}$

FIGURE 17—RAISING A VARIABLE TO A FIXED POWER



NOTE: Adjust the slope to correspond to the base "a".  
Exponential to any base:  $W = a^x$

FIGURE 18—RAISING A FIXED NUMBER TO A VARIABLE POWER

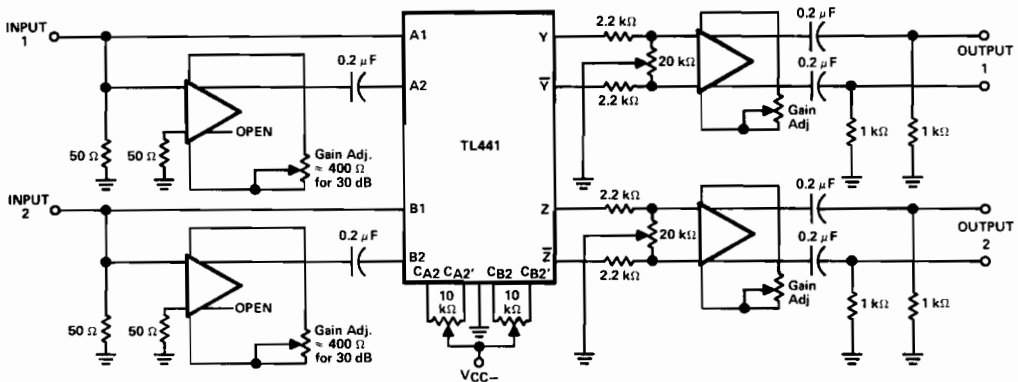


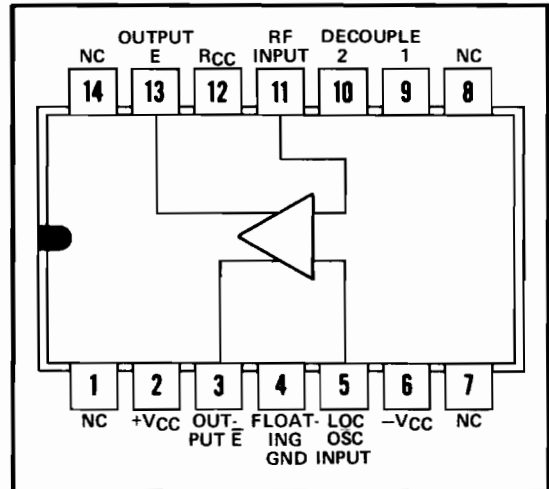
FIGURE 19—DUAL-CHANNEL RF LOGARITHMIC AMPLIFIER WITH 50-dB INPUT RANGE PER CHANNEL AT 10 MHz



FORMERLY SN56514, SN76514

- Flat Response to 100 MHz
- Local Oscillator IF Isolation . . . 30 dB Typ
- Local Oscillator RF Isolation . . . 60 dB Typ
- RF-IF Isolation . . . 30 dB Typ
- Conversion Gain . . . 14 dB Typ
- Use with 12-V or  $\pm 6$ -V Power Supplies

J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



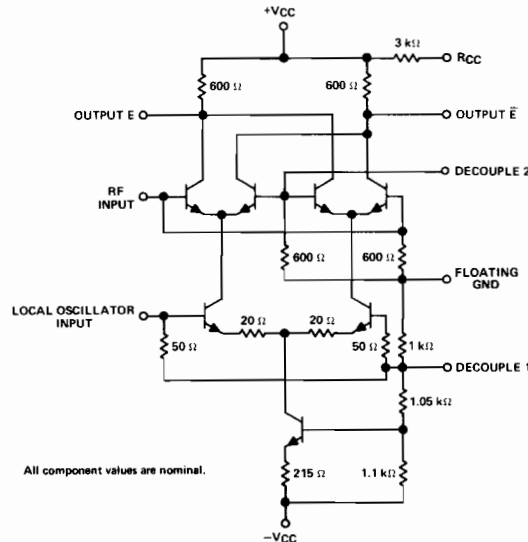
NC—No internal connection

**description**

The TL442M and TL442C are doubly balanced mixers that utilize two cross-coupled, differential transistor pairs driven by a third balanced pair. The circuit features a flat response over a wide band of frequencies. Operation from single or split power supplies is possible. Refer to typical application data.

The TL442M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL442C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**



# TYPES TL442M, TL442C

## BALANCED MIXERS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage (see Notes 1 and 2)	7 V
Continuous output current (see Note 3)	10 mA
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 4)	500 mW
Operating free-air temperature range: TL442M Circuits	-55°C to 125°C
TL442C Circuits	0°C to 70°C
Storage temperature range	-65°C to 150°C

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$		12		V
Local oscillator input voltage (see Note 5)		250	300	mV rms
RF input voltage (see Note 5)		10	30	mV rms
Operating free-air temperature range: TL442M Circuits	-55		125	°C
TL442C Circuits	0		70	°C

### electrical characteristics at 25°C free-air temperature, $V_{CC} = 12$ V

PARAMETER	TEST FIGURE	TEST CONDITIONS	TL442M			TL442C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_O$ Quiescent output voltage	1		9.6	10.5	11.3	9.6	10.5	11.3	V
$I_{CC}$ Supply current	1		5.5	7.4	10.9	5.5	7.4	10.9	mA
$G_C$ Conversion gain (single-ended output)	2	$f_{RF}$ and $f_{LO} = 100$ kHz thru 40 MHz	11	14	17	11	14	17	dB
LOIFI Local oscillator to IF isolation	3	$f_{LO} = 100$ kHz thru 40 MHz	15	29†			29†		dB
LORFI Local oscillator to RF isolation	3	$f_{LO} = 100$ kHz thru 40 MHz	40	52†			52†		dB
RFIFI RF to IF isolation	4	$f_{RF} = 100$ kHz thru 40 MHz	15	28†			28†		dB

†The typical values are at 40 MHz.

- NOTES: 1. All d-c voltage values are with respect to  $-V_{CC}$  terminal.  
 2. This rating applies to the local-oscillator input, RF input, and Decouple 2.  
 3. This value applies for both outputs simultaneously.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, TL442M chips are alloy-mounted; TL442C chips are glass-mounted.  
 5. All signal voltages are with respect to the floating-ground terminal. Alternatively, the RF input may be applied differentially between the RF input terminal and Decouple 2.

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J(Alloy-Mounted Chip)	500 mW	11.0 mW/°C	105°C
J(Glass-Mounted Chip)	500 mW	8.2 mW/°C	89°C
N	500 mW	9.2 mW/°C	96°C

Also see Dissipation Derating Curves, Section 2.



# TYPES TL442M, TL442C BALANCED MIXERS

## PARAMETER MEASUREMENT INFORMATION

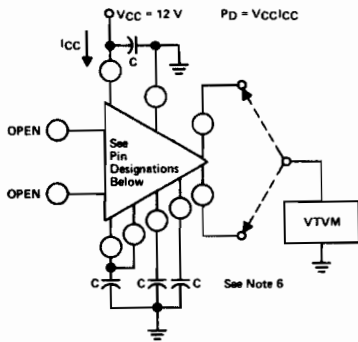


FIGURE 1— $V_O$ ,  $I_{C_c}$ , and  $P_d$

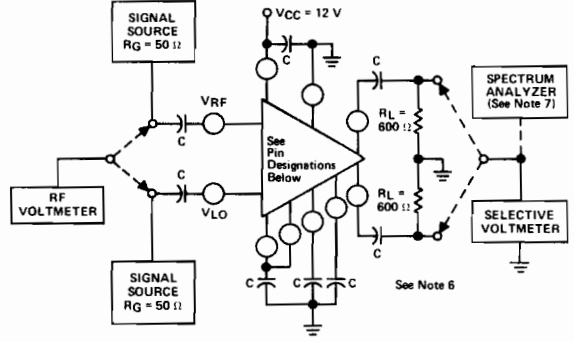


FIGURE 2— $G_c$

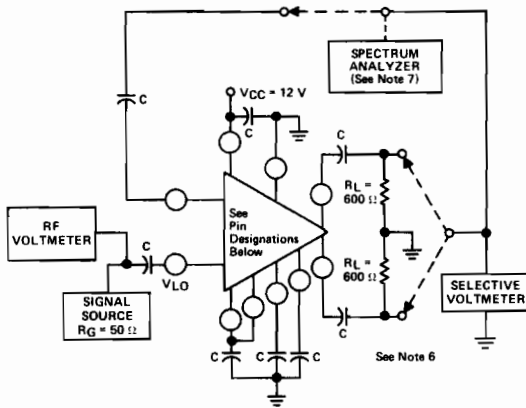


FIGURE 3—LOIFI and LORFI

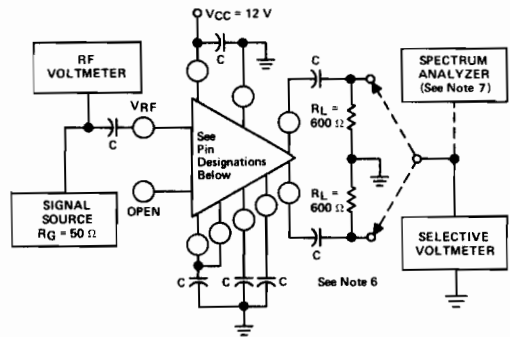
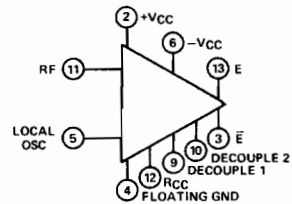


FIGURE 4—RFIF1

**Pin Designations:** For all test circuits appearing in this data sheet, terminal functions are defined by their relative positions as shown in the drawings in this block.



NOTES: 6. Capacitor C comprises the following capacitors in parallel:  $1 \mu\text{F}$ ,  $0.1 \mu\text{F}$ , and  $0.0015 \mu\text{F}$ .

7. The spectrum analyzer is used for frequencies above the normal range of the selective voltmeter.

# TYPES TL442M, TL442C BALANCED MIXERS

## TYPICAL CHARACTERISTICS

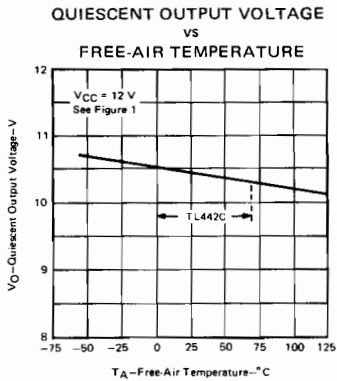


FIGURE 5

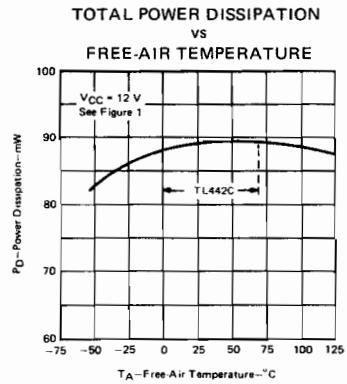


FIGURE 6

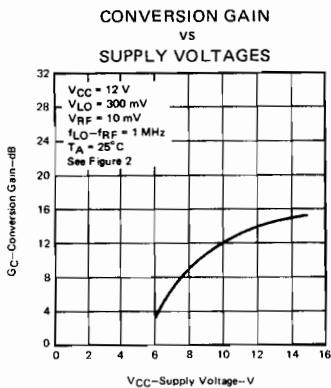


FIGURE 7

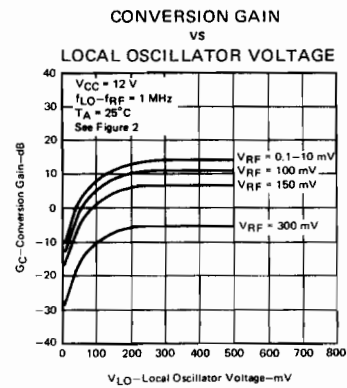


FIGURE 8

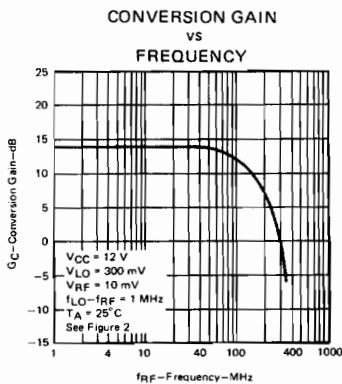


FIGURE 9

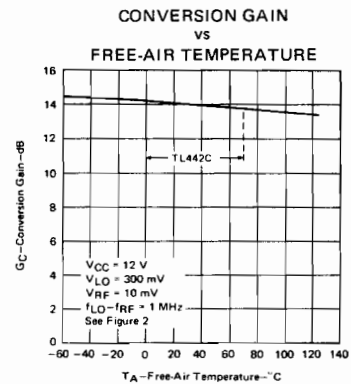


FIGURE 10

# TYPES TL442M, TL442C BALANCED MIXERS

## TYPICAL CHARACTERISTICS

LOCAL OSCILLATOR TO IF ISOLATION  
VS  
FREQUENCY

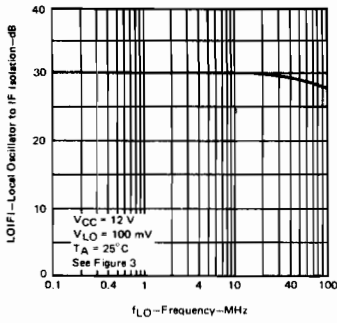


FIGURE 11

LOCAL OSCILLATOR TO IF ISOLATION  
VS  
FREE-AIR TEMPERATURE

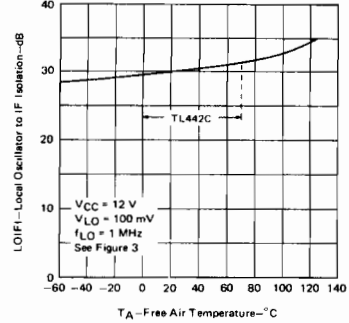


FIGURE 12

LOCAL OSCILLATOR TO RF ISOLATION  
VS  
FREQUENCY

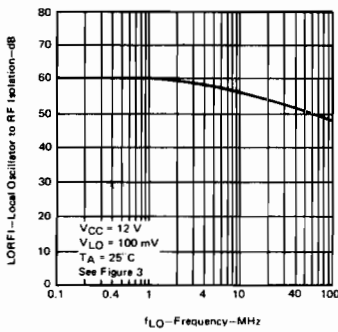


FIGURE 13

LOCAL OSCILLATOR TO RF ISOLATION  
VS  
FREE-AIR TEMPERATURE

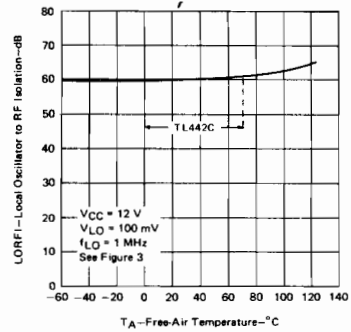


FIGURE 14

RF TO IF ISOLATION  
VS  
FREQUENCY

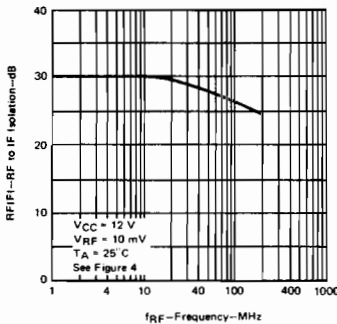


FIGURE 15

RF TO IF ISOLATION  
VS  
FREE-AIR TEMPERATURE

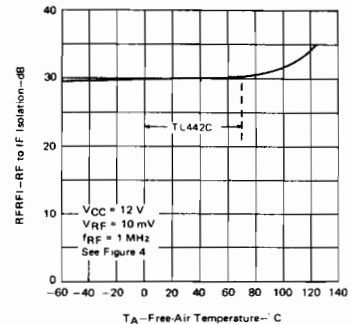


FIGURE 16

# TYPES TL442M, TL442C

## BALANCED MIXERS

### TYPICAL CHARACTERISTICS

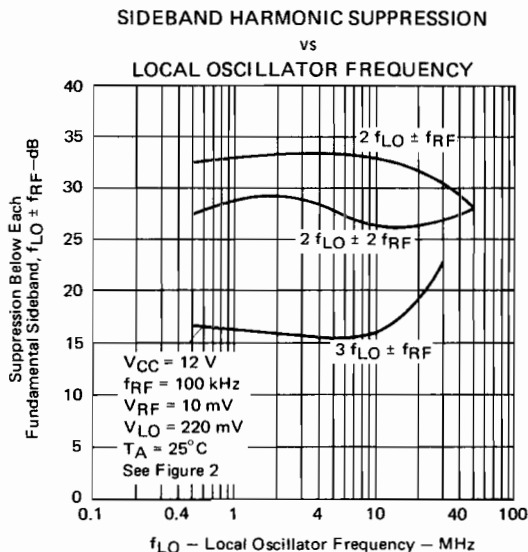


FIGURE 17

### TYPICAL APPLICATION DATA

The TL442M and TL442C balanced mixers are designed to have considerable circuit flexibility, which results in a wide range of applications. Typical applications include use as balanced modulators for sideband-suppressed-carrier generation, product detectors for demodulation, frequency converters, and frequency or phase modulators. In addition, the TL442M and TL442C may be used in control systems and analog computers as low-level multipliers or squaring circuits.

For operation from a single 12-V supply, connect the positive terminal of the supply to  $+V_{CC}$ , the negative terminal to  $-V_{CC}$ , and the floating-ground terminal to  $R_{CC}$ . For operation from two 6-V supplies, leave  $R_{CC}$  open and connect the positive terminal of one supply to  $+V_{CC}$ , the negative terminal of the other supply to  $-V_{CC}$ , and the remaining terminals of the two supplies to the floating-ground terminal. Electrical characteristics will be unchanged with the use of either power supply option. External bypass capacitors, as shown in Figure 18, should be used for optimum performance.

The mixer's electrical performance and the inherent IC advantages of size, reliability, and component matching make it very desirable for use in communication and control systems.

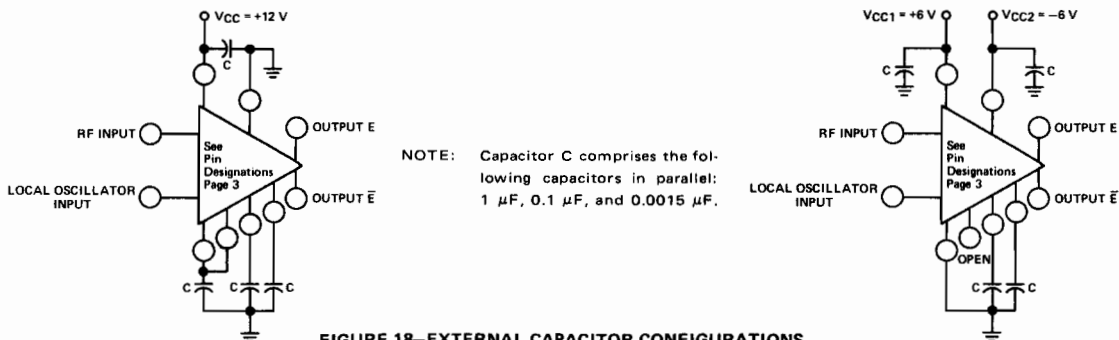


FIGURE 18—EXTERNAL CAPACITOR CONFIGURATIONS

- 10 Comparators Logrithmically Digitize Analog Input Signals
- High Input Impedance . . . 100 k $\Omega$  Typical
- Open-Collector Outputs Capable of Sinking up to 40 mA and Withstanding up to 32 V
- Economical 14-Pin Dual-In-Line Plastic Package
- 2-dB Intervals

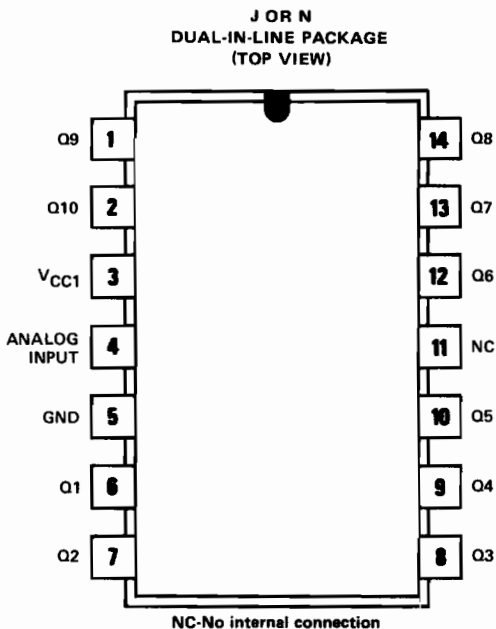
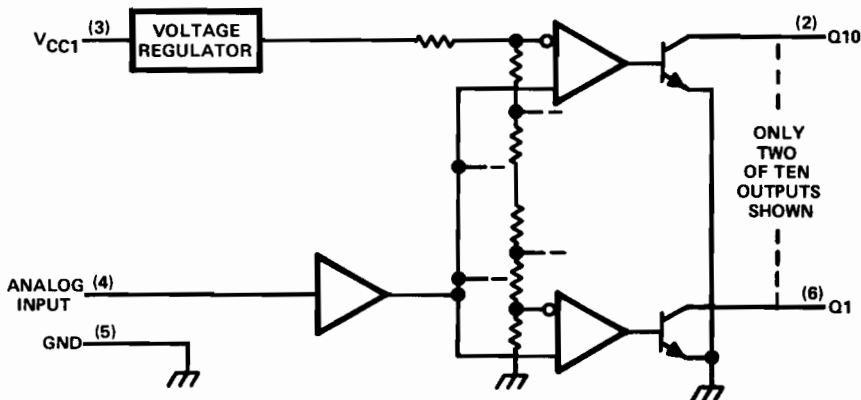
**description**

The TL480C consists of ten comparators and a reference voltage network to detect the level of a signal at the analog input. Output Q1 is switched to a low logic level at a typical input voltage of 218 millivolts. After each 2-dB increment, the next output is switched to a low logic level. All outputs are at low logic levels at a typical input voltage of 1732 millivolts. The hysteresis of all trigger points is typically 10 millivolts.

The TL480C is especially designed to detect logarithmic analog-signal levels and may be used in various industrial, consumer, or automotive applications such as low-precision meters, warning-signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and for automatic range switching. The open-collector outputs are capable of sinking currents up to 40 milliamperes and may be operated at voltages up to 32 volts. The power outputs are suitable for driving a variety of display elements such as LED's or filament lamps. The outputs may also drive digital integrated logic such as TTL, CMOS, or other high-level logic.

The TL480C is characterized for operation from 0°C to 70°C.

**functional block diagram**



# TYPE TL480C

## 10-STEP LOGARITHMIC ANALOG LEVEL DETECTOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	20 V
Input voltage	8 V
Off-state output voltage	40 V
On-state output current (each output)	60 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2): J package	1025 mW
N package	1150 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

NOTES: 1. Voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	10.8	12	13.2	V
Output voltage, $V_O$			32	V
Output current, $I_O$			40	mA
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics over recommended operating free-air temperature, $V_{CC} = 12$ V, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{T+}$	Positive-going threshold voltage at input A	Switching Q1	197	218	242	mV
		Switching Q2	247	275	304	
		Switching Q3	311	346	383	
		Switching Q4	392	435	483	
		Switching Q5	494	548	607	
		Switching Q6	621	690	765	
		Switching Q7	782	868	963	
		Switching Q8	985	1093	1212	
		Switching Q9	1240	1376	1526	
		Switching Q10	1561	1732	1921	
$V_{T+} - V_{T-}$	Input hysteresis		10		mV	
$I_{OH}$	High-level (off-state) output current	$V_{OH} = 32$ V	0.5	200	μA	
$V_{OL}$	Low-level (on-state) output voltage	$I_{OL} = 10$ mA	0.12	0.3	V	
		$I_{OL} = 40$ mA	0.3	0.6		
$I_I$	Input current	$V_I = 2$ V		10	20	μA
$I_{CC}$	Supply current	All outputs high	$V_{CC} = 12$ V, No load	7.5	12	mA
		All outputs low		24	38	

<sup>†</sup>All typical values are at  $V_{CC} = 12$  V and  $T_A = 25$ °C.

- 10 Comparators Logarithmically Digitize Analog Input Signals
- High Input Impedance . . . 100 k $\Omega$  Typical
- Open-Emitter Outputs Capable of Sourcing Up to 25 mA and Withstanding Up to 35 V
- Supply Voltage Range of 10 to 35 V (V<sub>CC2</sub>)
- Economical 14-Pin Dual-In-Line Plastic Package
- 2-dB Intervals

**description**

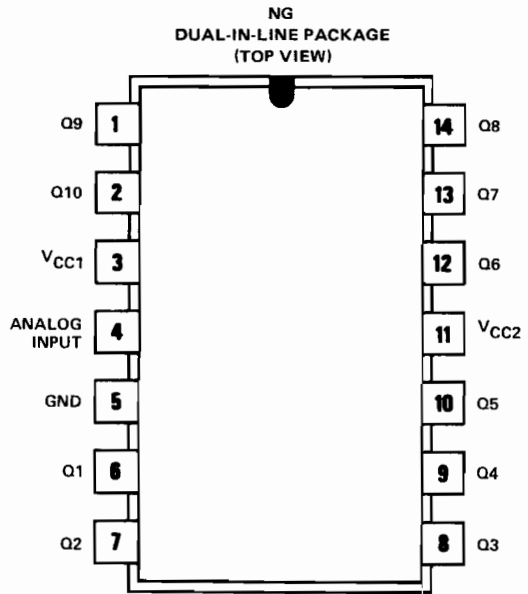
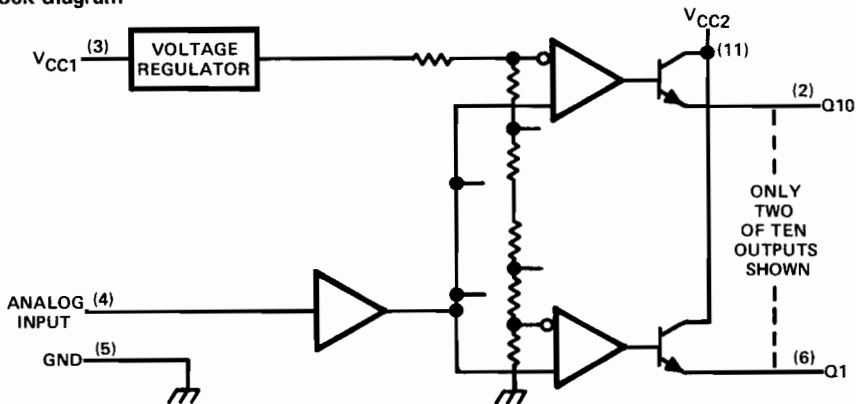
The TL481C features open-emitter outputs capable of operating to 35 volts and sourcing 25 milliamperes for driving vacuum fluorescent displays. The TL481C uses ten comparators and a reference voltage network to detect the level of a signal at the analog input. Output Q1 is switched to a high logic level at a typical input voltage of 218 millivolts. As the input signal is increased, subsequent outputs are switched to a high logic level at 2-dB intervals. All outputs are at high logic levels at a typical input voltage of 1732 millivolts. The hysteresis of all trigger points is typically 10 millivolts.

The analog input has an impedance of 100 kilohms. This high input impedance can be driven directly from a high-impedance source; however, the addition of a capacitor may be required to reduce noise.

The TL481C is designed for logarithmic detection of analog signals and may be used in applications such as low-precision meters, warning signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and automatic range switching.

The TL481C is characterized for operation from 0°C to 70°C.

**functional block diagram**



**6**

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

**TEXAS INSTRUMENTS  
INCORPORATED**

POST OFFICE BOX 225012 • DALLAS, TEXAS 75265

# TYPE TL481C

## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC1}$ (see Note 1)	20 V
$V_{CC2}$	40 V
Input voltage	8 V
Output voltage range	0 V to $V_{CC2}$
On-state output current (each output)	-30 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	2075 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

NOTES: 1. Voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, derate linearly to 1328 mW at 70°C at the rate of 16.6 mW/°C.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply Voltage, $V_{CC1}$	10.8	12	13.2	V
$V_{CC2}$	10	25	35	V
Output current, $I_O$			25	mA
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics over recommended operating free-air temperature and supply voltage ranges (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT				
$V_{T+}$	Positive-going threshold voltage at Analog input	$T_A = 25^\circ\text{C}$				mV				
							Switching Q1	197	218	242
							Switching Q2	247	275	304
							Switching Q3	311	346	383
							Switching Q4	392	435	483
							Switching Q5	494	548	607
							Switching Q6	621	690	765
							Switching Q7	782	868	963
							Switching Q8	985	1093	1212
							Switching Q9	1240	1376	1526
Switching Q10	1561	1732	1921							
$V_{T+} - V_{T-}$	Input hysteresis			10		mV				
$V_{OH}$	High-level (on-state) output voltage	$I_{OH} = -10\text{ mA}$	$V_{CC2}-1.3$	$V_{CC2}-0.8$		V				
		$I_{OH} = -25\text{ mA}$	$V_{CC2}-1.5$	$V_{CC2}-0.9$						
$I_{OL}$	Low-level (off-state) output current	$V_{CC2} = 35\text{ V}$		0.5	200	$\mu\text{A}$				
$I_I$	Input current	Analog input	$V_I = 2\text{ V}$	10	20	$\mu\text{A}$				
$I_{CC1}$	Supply current from $V_{CC1}$	All outputs high	$V_{CC1} = 12\text{ V},$	No load	15	25	mA			
		All outputs low			9	15				
$I_{CC2}$	Supply current from $V_{CC2}$	All outputs high	$V_{CC1} = 12\text{ V},$	$V_{CC2} = 35\text{ V},$	15	27	mA			
		All outputs low						No load	1	200

† All typical values are at  $V_{CC1} = 12\text{ V}, V_{CC2} = 25\text{ V},$  and  $T_A = 25^\circ\text{C}.$



- 5 Comparators to Digitize Logarithmic Analog Input Signals in 3-dB Step Increments
- High Input Impedance . . . 100 k $\Omega$  Typ
- Open-Collector Outputs Capable of Sinking up to 40 mA and Withstanding up to 18 V
- Supply Voltage Range of 10 to 18 V
- Economical 8-Pin Dual-in-Line Plastic Package and Ceramic Package

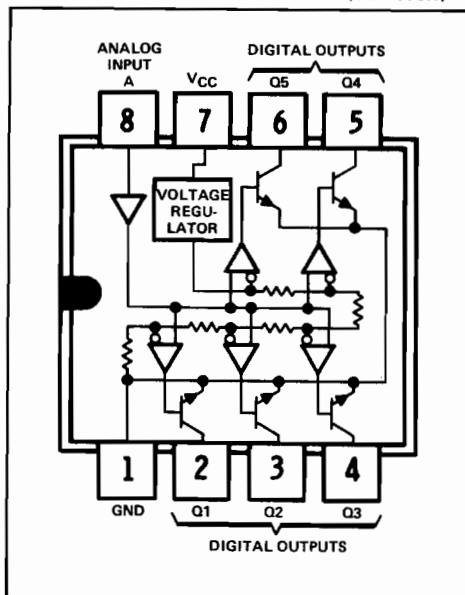
FUNCTION TABLE

INPUT A (NOM)	OUTPUTS				
	Q1	Q2	Q3	Q4	Q5
0 $\approx$ 266 mV	H	H	H	H	H
$\approx$ 266 $\approx$ 375 mV	L	H	H	H	H
$\approx$ 375 $\approx$ 530 mV	L	L	H	H	H
$\approx$ 530 $\approx$ 749 mV	L	L	L	H	H
$\approx$ 749 $\approx$ 1058 mV	L	L	L	L	H
$>$ $\approx$ 1058 mV	L	L	L	L	L

H = high level, L = low level

The nominal input voltage ranges shown are for rising input voltage. Negative-going thresholds are typically 10 mV lower.

JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW)



**description**

The TL487C is especially designed to detect and indicate analog signal levels. The device may be used in various industrial, consumer, or automotive applications such as low-precision meters, warning signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and automatic range switching. The power outputs are suitable for driving a variety of display elements such as LED's or filament lamps. The outputs may also drive digital integrated logic such as TTL, CMOS, or other high-level logic.

The TL487C consists of five comparators and a reference voltage network to detect the level of an analog input signal at the A input. Output Q1 is switched to a low logic level at a typical input voltage of 266 millivolts. After each 3-dB increase, the next output is switched to a low logic level. All outputs are at low logic levels at a typical input voltage of 1058 millivolts. The open-collector outputs are capable of sinking currents up to 40 milliamperes and may be operated at voltages up to 18 volts. The analog input has a high impedance of typically 200 kilohms.

Since all five trigger points have a switching hysteresis of typically 10 millivolts, the circuit may be operated with slow input signals without the danger of oscillation at the outputs. To prevent pickup of noise, a capacitor should be connected between the high-impedance input and ground, especially when the input is driven from a high-impedance source.

The TL487C is characterized for operation from 0°C to 70°C.

# TYPE TL487C

## 5-STEP LOGARITHMIC ANALOG LEVEL DETECTOR

### absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	20 V
Voltage at analog input A	8 V
Off-state output voltage	20 V
Current through analog input A	-10 mA
Low-level output current (each output)	80 mA
Total low-level output current	200 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2): JG package	825 mW
P package	1000 mW
Operating free-air temperature range	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

- NOTES: 1. Voltage values are with respect to network ground terminal.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the JG package, TL487C chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	1000 mW	8.0 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	10	12	18	V
Output voltage, $V_O$			18	V
Low-level output current			40	mA
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics over recommended operating ranges of $V_{CC}$ and $T_A$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT	
$V_{T+}$	Positive-going threshold voltage at input A‡	$T_A = 25^\circ\text{C}$	Switching Q1	237	266	298	mV
			Switching Q2	335	375	421	
			Switching Q3	473	530	595	
			Switching Q4	668	749	840	
			Switching Q5	943	1058	1187	
Switching interval§				3		dB	
$V_{T+} - V_{T-}$	Input hysteresis			10		mV	
$I_{OH}$	High-level output current	$V_{OH} = 18\text{ V}$		0.5	20	µA	
$V_{OL}$	Low-level output voltage	$I_{OL} = 16\text{ mA}$		0.15	0.3	V	
		$I_{OL} = 40\text{ mA}$		0.25	0.5		
$I_I$	Input current	$V_I = 1\text{ V}$		5	10	µA	
$I_{CC}$	Supply current	All outputs high	All outputs open,		8	12	mA
		All outputs low	$V_{CC} = 12\text{ V}$		18	27	

† All typical values are at  $V_{CC} = 12\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

‡ These thresholds increase with temperature at the approximate rate of 1 mV/°C.

§ Switching interval is the ratio of (1)  $V_{T+}$  for switching output  $Q_{n+1}$  to (2)  $V_{T+}$  for switching output  $Q_n$ .

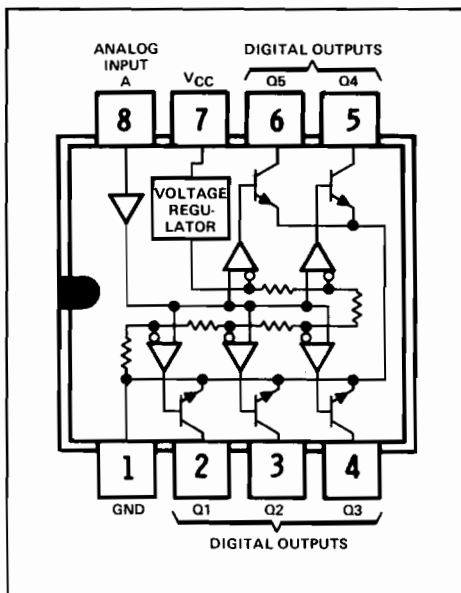
- 5 Comparators to Digitize Analog Input Signals in 200 mV Increments
- High Input Impedance . . . 100 kΩ Typ
- Open-Collector Outputs Capable of Sinking up to 40 mA and Withstanding up to 18 V
- Supply Voltage Range of 10 to 18 V
- Economical 8-Pin Dual-in-Line Plastic Package

FUNCTION TABLE

INPUT A (NOM)	OUTPUTS				
	Q1	Q2	Q3	Q4	Q5
0—≈200 mV	H	H	H	H	H
≈200—≈400 mV	L	H	H	H	H
≈400—≈600 mV	L	L	H	H	H
≈600—≈800 mV	L	L	L	H	H
≈800—≈1000 mV	L	L	L	L	H
>≈1000 mV	L	L	L	L	L

H = high level, L = low level

P DUAL-IN-LINE PACKAGE (TOP VIEW)



**description**

The TL489C consists of five comparators and a reference voltage network to detect the level of an analog input signal at the A input. Output Q1 is switched to a low logic level at a typical input voltage of 200 millivolts. After each 200-millivolt step, the next output is switched to low logic levels. All outputs are at low logic levels at a typical input voltage of 1000 millivolts. The open-collector outputs are capable of sinking currents up to 40 milliamperes and may be operated at voltages up to 18 volts. The analog input has a high impedance of typically 100 kilohms.

Since all five trigger points have a switching hysteresis of typically 10 millivolts, the circuit may be operated with slow input signals without the danger of oscillation at the outputs. To prevent pickup of noise, a capacitor should be connected between the high-impedance input and ground, especially when the input is driven from a high-impedance source.

The TL489C is especially designed to detect and indicate analog signal levels. The device may be used in various industrial, consumer, or automotive applications such as low-precision meters, warning signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and automatic range switching. The power outputs are suitable for driving a variety of display elements such as LED's or filament lamps. The outputs may also drive digital integrated logic such as TTL, CMOS, or other high-level logic.

The TL489C is characterized for operation from 0°C to 70°C.

# TYPE TL489C

## 5-STEP ANALOG LEVEL DETECTOR

### absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	20 V
Voltage at analog input A	8 V
Off-state output voltage	20 V
Current through analog input A	-10 mA
Low-level output current (each output)	80 mA
Total low-level output current	200 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000 mW
Operating free-air temperature range	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

NOTES: 1. Voltage values are with respect to network ground terminal.  
2. Derate linearly to 640 mW at 70°C free-air temperature at the rate of 8.0 mW/°C.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	10	12	18	V
Output voltage, $V_O$			18	V
Low-level output current			40	mA
Operating free-air temperature, $T_A$	0		70	°C

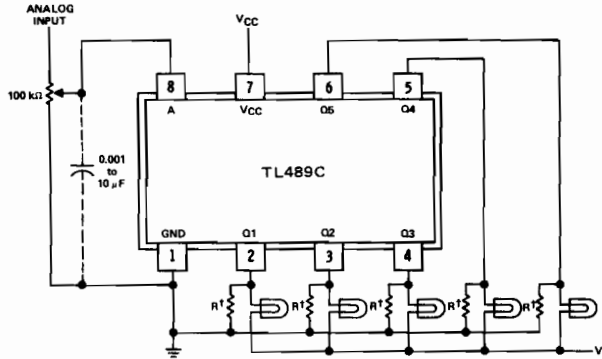
### electrical characteristics over recommended range of $V_{CC}$ and operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
$V_{T+}$	Positive-going threshold voltage at input A	Switching Q1	160	200	240	mV
		Switching Q2	350	400	450	
		Switching Q3	540	600	660	
		Switching Q4	730	800	870	
		Switching Q5	920	1000	1080	
$V_{T+} - V_{T-}$	Input hysteresis		10		mV	
$I_{OH}$	High-level output current	$V_{OH} = 18$ V	0.5	20	$\mu$ A	
$V_{OL}$	Low-level output voltage	$I_{OL} = 16$ mA	0.15		V	
		$I_{OL} = 40$ mA	0.25	0.5		
$I_I$	Input current	$V_I = 1$ V	0.5		$\mu$ A	
$I_{CC}$	Supply current	All outputs high	8	12	mA	
		All outputs low	15	25		

† All typical values are at  $V_{CC} = 12$  V,  $T_A = 25^\circ$ C.

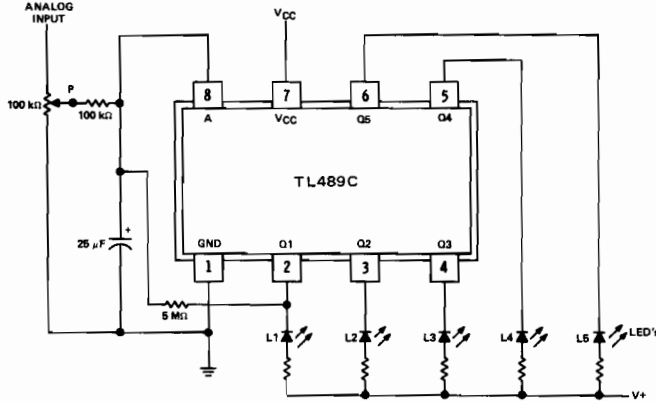
# TYPE TL489C 5-STEP ANALOG LEVEL DETECTOR

## TYPICAL APPLICATIONS DATA



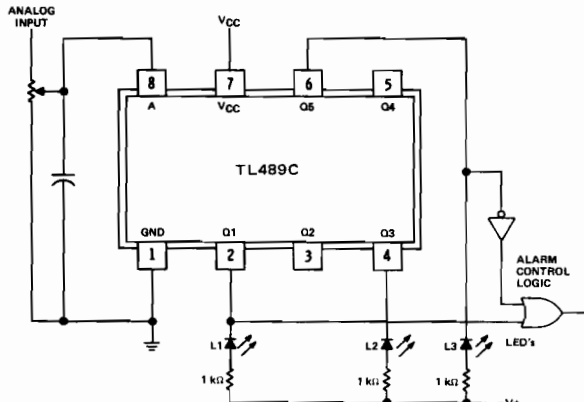
† Keep-alive resistors to avoid high switching current.

FIGURE 1—INTERFACING WITH INCANDESCENT LAMPS



Lamps L1 through L5 illuminate as the input voltage increases in nominally 200-mV steps. Additionally, lamp L1 will flash periodically when the input voltage at point P is below 200 mV.

FIGURE 2—LEVEL INDICATION WITH FLASHING FEATURE



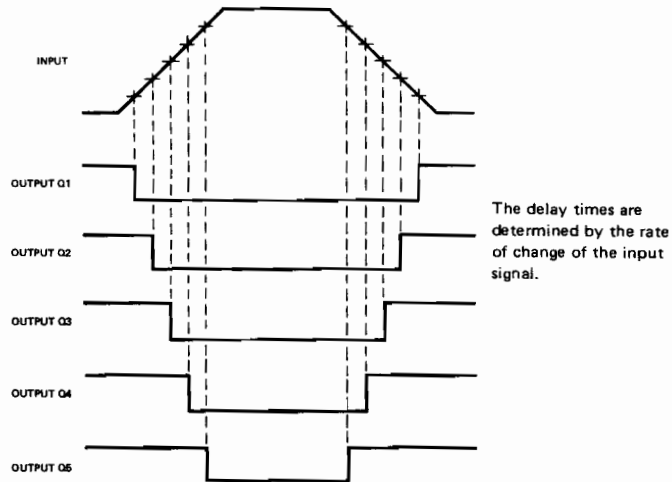
Lamp L1 is turned on at input voltages (pin 8)  $\geq$  200 mV and the alarm turns off. Lamp L2 is turned on at input voltages  $\geq$  600 mV to indicate correct operation. Lamp L3 is turned on at input voltages  $\geq$  1000 mV and the over-range alarm turns on.

FIGURE 3—THREE-STAGE LEVEL INDICATION AND CONTROL

# TYPE TL489C

## 5-STEP ANALOG LEVEL DETECTOR

### TYPICAL APPLICATION DATA



The delay times are determined by the rate of change of the input signal.

FIGURE 4—WAVEFORMS FOR FIVE DELAYED OUTPUTS

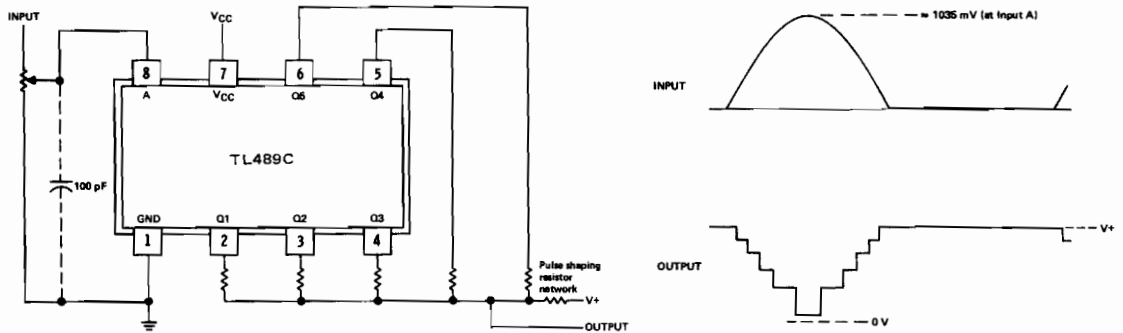
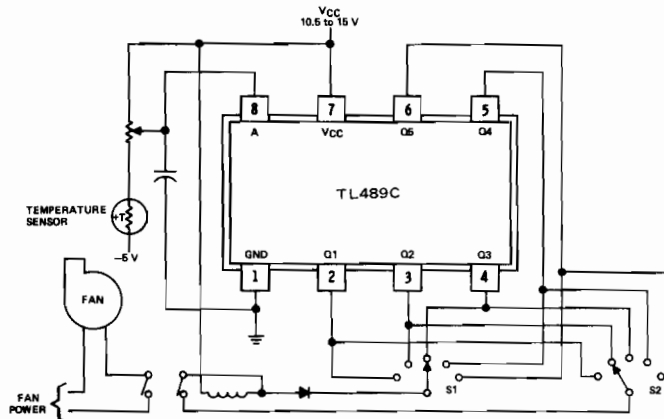


FIGURE 5—PULSE-SHAPE CONVERTER



Switch S1 selects the temperature at which the fan starts operating, and S2 selects the temperature at which the fan stops operating.

FIGURE 6—TEMPERATURE FEEDBACK REGULATION WITH SELECTABLE SYSTEM HYSTERESIS

- 10 Comparators to Digitize Analog Input Signals
- Cascade Feature Allows Stacking Output Display Strings
- Threshold Intervals Adjustable from 200 mV to 100 mV
- Open-Collector Outputs Capable of Sinking up to 40 mA and Withstanding up to 32 V
- Supply Voltage Range of 10 to 18 V

**description**

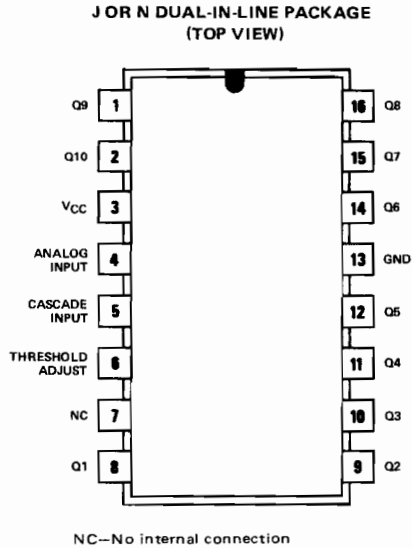
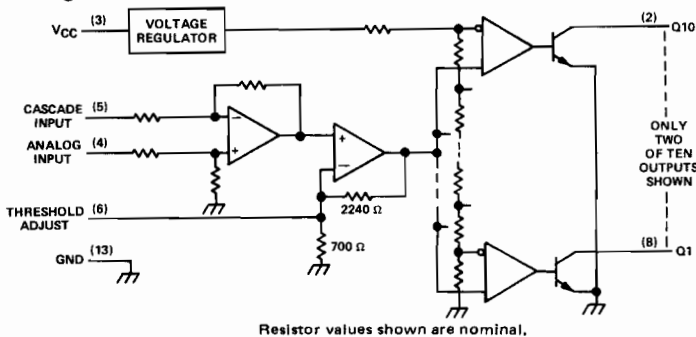
The TL490C consists of ten comparators and a reference voltage network to detect the level of a signal at the analog input. Output Q1 is switched to a low logic level at a typical input voltage of 200 millivolts with Threshold-Adjust open and the cascade input grounded. After each 200-millivolt increment, the next output is switched to a low logic level. All outputs are at low logic levels at a typical input voltage of 2000 millivolts. The threshold-adjust terminal allows the user to decrease the input voltage steps from 200-millivolt to 100-millivolt increments by connecting an external resistor from Threshold Input to ground.

This level detector is directly cascadable requiring only two external resistors. The maximum number of devices that can be cascaded is determined by the threshold level and the maximum input voltage. See Figure 4 in Typical Application Data. If the cascade feature is not utilized, the cascade input must be grounded for proper operation.

The TL490C is especially designed to detect and indicate analog signal levels and may be used in various industrial, consumer, or automotive applications such as low-precision meters, warning-signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and for automatic range switching. The open-collector outputs are capable of sinking currents up to 40 milliamperes and may be operated at voltages up to 32 volts. The power outputs are suitable for driving a variety of display elements such as LED's or filament lamps. The outputs may also drive digital integrated logic such as TTL, CMOS, or other high-level logic.

The TL490C is characterized for operation from 0°C to 70°C.

**functional block diagram**



# TYPE TL490C

## 10-STEP LOGARITHMIC ANALOG LEVEL DETECTOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	20 V
Input voltage: Analog input	8 V
Cascade input	8 V
Off-state output voltage	40 V
On-state output current (each output)	60 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2): J package	1025 mW
N package	1150 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N package	260°C

- NOTES: 1. Voltage values are with respect to network ground terminal.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chip)	1025 mW	8.2 mW/°C	25°C
N	1150 mW	9.2 mW/°C	25°C

Also see Dissipation Derating Curves, Section 2.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	10	12	18	V
Output voltage, $V_O$			32	V
Cascade input voltage (Pin 5) (when not grounded)	1		8	V
Output current, $I_O$			40	mA
Operating free-air temperature, $T_A$	0		70	°C

electrical characteristics over recommended operating free-air temperature and supply voltage ranges, pin 5 at gnd, pin 6 open (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT	
$V_{T+}$	Positive-going threshold voltage at input A	$T_A = 25^\circ\text{C}$	Switching Q1	125	200	275	mV
			Switching Q2	325	400	475	
			Switching Q3	525	600	675	
			Switching Q4	725	800	875	
			Switching Q5	925	1000	1075	
			Switching Q6	1125	1200	1275	
			Switching Q7	1325	1400	1475	
			Switching Q8	1525	1600	1675	
			Switching Q9	1725	1800	1875	
			Switching Q10	1925	2000	2075	
$V_{T+} - V_{T-}$	Input hysteresis			10		mV	
$I_{OH}$	High-level output current	$V_{OH} = 32\text{ V}$		0.5	200	$\mu\text{A}$	
$V_{OL}$	Low-level output voltage	$I_{OL} = 10\text{ mA}$		0.12	0.3	V	
		$I_{OL} = 40\text{ mA}$		0.3	0.6		
$I_I$	Input current	Analog input	$V_I = 2\text{ V}$		260	400	$\mu\text{A}$
		Cascade input			1000	1700	
$I_{CC}$	Supply current	All outputs high	$V_{CC} = 12\text{ V}$ , All outputs open		10	15	mA
		All outputs low			30	45	

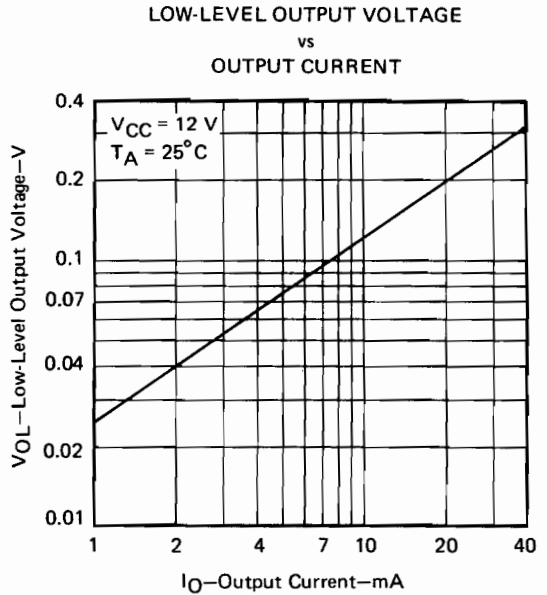
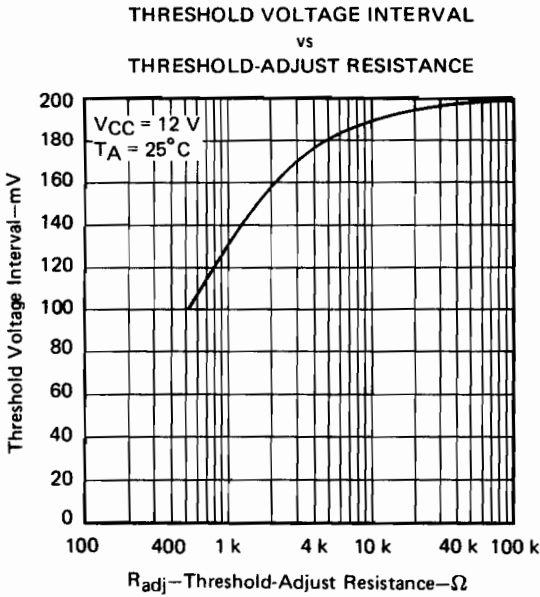
†All typical values are at  $V_{CC} = 12\text{ V}$  and  $T_A = 25^\circ\text{C}$



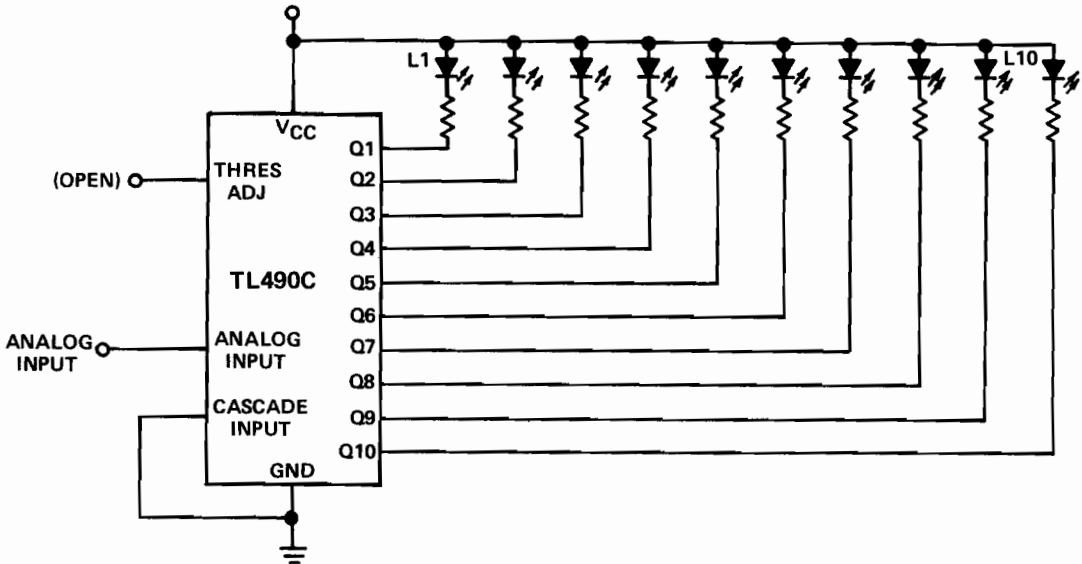
# TYPE TL490C

## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### TYPICAL CHARACTERISTICS



### TYPICAL APPLICATION DATA



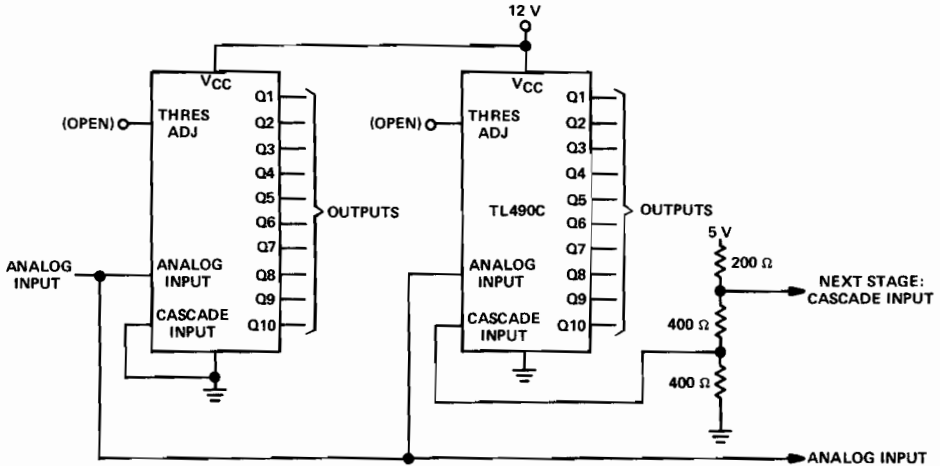
Lamps L1 through L10 sequentially illuminate as the input voltage increases in nominally 200-millivolt steps.

FIGURE 3—LEVEL INDICATION WITH LIGHT-EMITTING DIODES

# TYPE TL490C

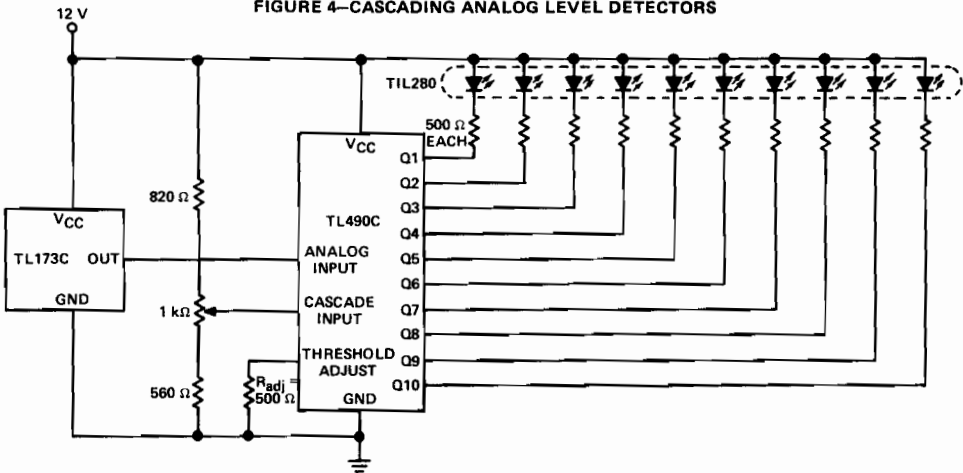
## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### TYPICAL APPLICATION DATA



To cascade three TL490C detectors, parallel all analog inputs, connect cascade input 1 to ground, bias cascade input 2 to 2 volts (or 10 times the threshold interval), and bias cascade input 3 to 4 volts (or 20 times the threshold interval). This provides drive for 30 output steps with one continuous 0- to 6-volt input. The maximum number of devices that can be cascaded is determined by the threshold level and the maximum input voltage rating.

FIGURE 4—CASCADED ANALOG LEVEL DETECTORS



The appropriate value of  $R_{adj}$ , the external resistance between the threshold-adjust terminal and ground, may be calculated from:

$$\frac{0.84}{V_T} \approx \frac{(R_{adj} + 700 \Omega) \cdot 2240 \Omega}{700 \Omega \cdot R_{adj}} + 1; \text{ or } R_{adj} \approx \frac{533 V_T}{0.2 - V_T}$$

where:  $V_T$  = threshold voltage interval, V

Alternatively,  $R_{adj}$  can be estimated using Figure 1.

In the circuit shown with  $R_{adj} = 500 \Omega$ ,  $V_T \approx 100 \text{ mV}$ .

FIGURE 5—LINEAR HALL-EFFECT SENSOR WITH 10-STEP ANALOG LEVEL INDICATOR

- 10 Comparators to Digitize Analog Input Signals
- Cascade Feature Allows Stacking Output Display Strings
- Threshold Intervals Adjustable from 200 mV to 100 mV
- Open-Emitter Outputs Capable of Sourcing up to 25 mA and Withstanding up to 35 V
- Supply Voltage Range of 10 to 35 V (V<sub>CC2</sub>)

**description**

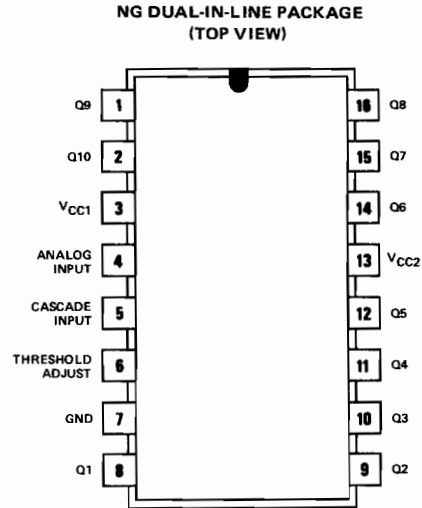
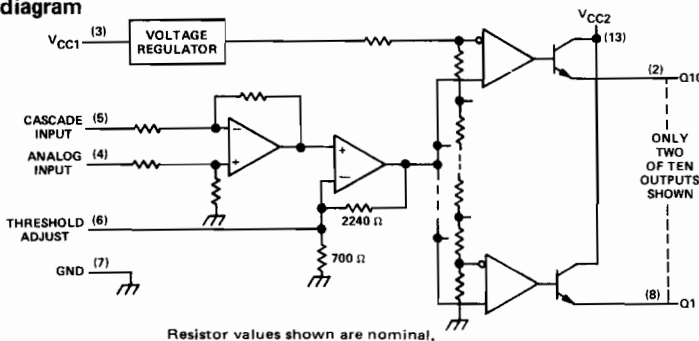
The TL491C consists of ten comparators and a reference voltage network to detect the level of a signal at the analog input. Output Q1 is switched to a low logic level at a typical input voltage of 200 millivolts with Threshold Adjust open and the cascade input grounded. After each 200-millivolt increment, the next output is switched to a low logic level. All outputs are at low logic levels at a typical input voltage of 2000 millivolts. The threshold-adjust terminal allows the user to decrease the input voltage steps from 200-millivolt to 100-millivolt increments by connecting an external resistor from Threshold Adjust to ground.

This level detector is directly cascadable requiring only two external resistors to establish a zero-reference level voltage for the cascade input. The maximum number of devices that can be cascaded is determined by the threshold level and the maximum input voltage. See Figure 4 in Typical Application Data. If the cascade feature is not utilized, the cascade input must be grounded for proper operation.

The TL491C is especially designed to detect and indicate analog signal levels and may be used in various industrial, consumer, or automotive applications such as low-precision meters, warning-signal indicators, A/D converters, feedback regulators, pulse shapers, delay elements, and for automatic range switching. The open-emitter outputs are capable of sourcing currents up to 25 milliamperes and may be operated at voltages up to 35 volts. The power outputs are suitable for driving a variety of display elements such as vacuum fluorescent displays, LED's, or filament lamps. The outputs may also drive digital integrated logic such as CMOS or other high-level logic.

The TL491C is characterized for operation from 0°C to 70°C.

**functional block diagram**



# TYPE TL491C

## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage: $V_{CC1}$ (see Note 1)	20 V
$V_{CC2}$	40 V
Input voltage: Analog input	8 V
Cascade input	8 V
Output voltage range	0 V to $V_{CC2}$
On-state output current (each output)	-30 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	2075 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

- NOTES: 1. Voltage values are with respect to network ground terminal.  
 2. For operation above 25°C free-air temperature, derate linearly to 1328 mW at 70°C at the rate of 16.6 mW/°C.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage: $V_{CC1}$	10.8	12	13.2	V
$V_{CC2}$	10	25	35	V
Cascade input voltage (When not at ground)	1		8	V
Output current, $I_O$			25	mA
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics over recommended operating free-air temperature and supply voltage ranges, pin 5 at gnd, pin 6 open (unless otherwise noted)

PARAMETERS		TEST CONDITIONS	MIN	TYP†	MAX	UNIT	
$V_{T+}$	Positive-going threshold voltage at input A	Switching Q1	125	200	275	mV	
		Switching Q2	325	400	475		
		Switching Q3	525	600	675		
		Switching Q4	725	800	875		
		Switching Q5	925	1000	1075		
		Switching Q6	1125	1200	1275		
		Switching Q7	1325	1400	1475		
		Switching Q8	1525	1600	1675		
		Switching Q9	1725	1800	1875		
		Switching Q10	1925	2000	2075		
$V_{T+} - V_{T-}$	Input hysteresis		10		mV		
$V_{OH}$	High-level (on-state) output voltage	$I_{OH} = -10$ mA	$V_{CC2} - 1.3$	$V_{CC2} - 0.8$		V	
		$I_{OH} = -25$ mA	$V_{CC2} - 1.5$	$V_{CC2} - 0.9$			
$I_{OL}$	Low-level (off-state) output current	$V_{CC2} = 35$ V		0.5	200	$\mu$ A	
$I_I$	Input current	Analog input	$V_I = 2$ V		260	400	$\mu$ A
		Cascade input			1000	1700	
$I_{CC}$	Supply current from $V_{CC1}$	All outputs high	$V_{CC1} = 12$ V,		15	25	mA
		All outputs low		No load		9	
$I_{CC}$	Supply current from $V_{CC2}$	All outputs high	$V_{CC1} = 12$ V, $V_{CC2} = 35$ V,		15	27	mA
		All outputs low		No load		1	

† All typical values are at  $V_{CC1} = 12$  V,  $V_{CC2} = 25$  V, and  $T_A = 25^\circ$  C.

# TYPE TL491C

## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### TYPICAL CHARACTERISTICS

#### THRESHOLD VOLTAGE INTERVAL vs THRESHOLD-ADJUST RESISTANCE

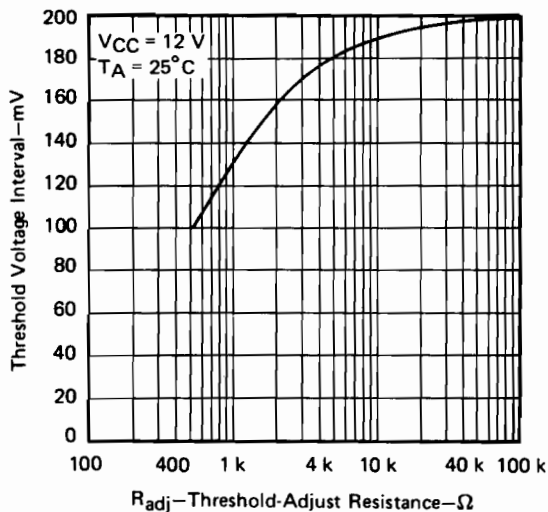
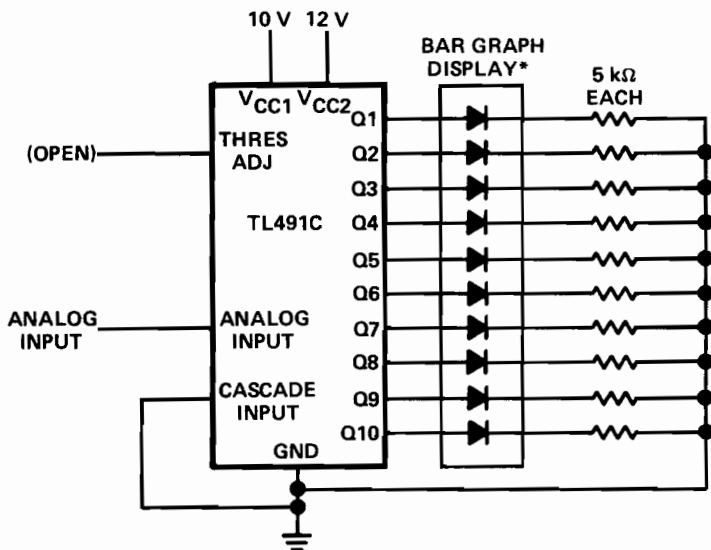


FIGURE 1

### TYPICAL APPLICATION DATA



Outputs Q1 through Q10 turn on LED's to represent the input voltage level in multiples of the 200-millivolt threshold voltage. The threshold interval can be reduced for greater accuracy by adding a shunt resistor between Threshold Adjust and ground. The appropriate value of shunt resistance,  $R_{adj}$ , can be approximated from

$$\frac{0.84}{V_T} \approx \frac{(R_{adj} + 700 \Omega) \cdot 2240 \Omega}{700 \Omega \cdot R_{adj}} + 1 \text{ or}$$

$$R_{adj} \approx \frac{533 V_T}{0.2 - V_T}$$

where:  $V_T$  = threshold voltage interval. Alternatively  $R_{adj}$  can be estimated using Figure 1.

Lamps L1 through L10 sequentially illuminate as the input voltage increases in nominally 200-millivolt steps.

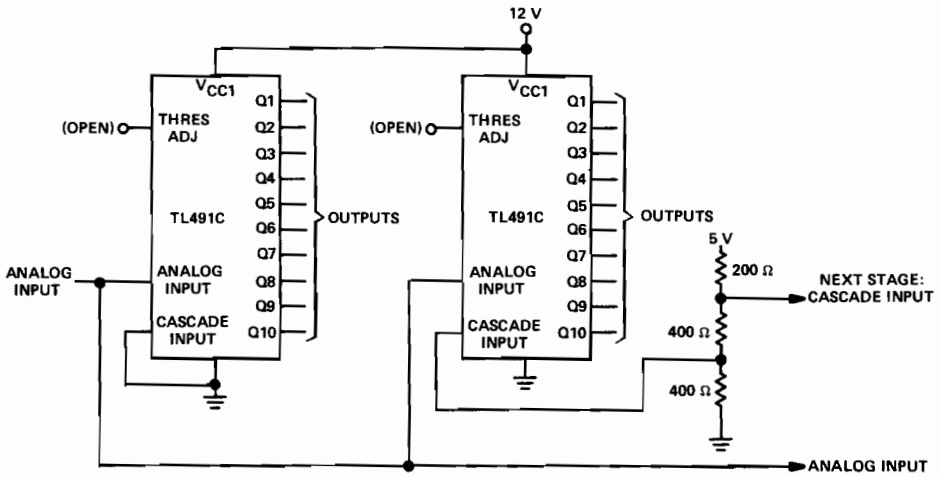
\*General Instruments MV57164 or equivalent.

FIGURE 2—LEVEL INDICATION WITH LIGHT-EMITTING DIODES

# TYPE TL491C

## 10-STEP ADJUSTABLE ANALOG LEVEL DETECTOR

### TYPICAL APPLICATION DATA



To cascade three TL491C detectors, parallel all analog inputs, connect cascade input 1 to ground, bias cascade input 2 to 2 volts (or 10 times the threshold interval), and bias cascade input 3 to 4 volts (or 20 times the threshold interval). This provides drive for 30 output steps with one continuous 0- to 6-volt input. The maximum number of devices that can be cascaded is determined by the threshold level and the maximum input voltage rating.

FIGURE 3—CASCADING ANALOG LEVEL DETECTORS

**TL500C/TL501C  
ANALOG PROCESSORS**

- True Differential Inputs
- Automatic Zero
- Automatic Polarity
- High Input Impedance . . . 10<sup>9</sup> Ohms Typically

**TL500C CAPABILITIES**

- Resolution . . . 14 Bits (with TL502C)
- Linearity Error . . . 0.001%
- 4 1/2-Digit Readout Accuracy with External Precision Reference

**TL501C CAPABILITIES**

- Resolution . . . 10-13 Bits (with TL502C)
- Linearity Error . . . 0.01%
- 3 1/2-Digit Readout Accuracy

**TL502C/TL503C  
DIGITAL PROCESSORS**

- Fast Display Scan Rates
- Internal Oscillator May Be Driven or Free-Running
- Interdigit Blanking
- Over-Range Blanking
- Display Test
- 4 1/2-Digit Display Circuitry
- High-Sink-Current Digit Driver for Large Displays

**TL502C CAPABILITIES**

- Compatible with Popular Seven-Segment Common-Anode Displays
- High-Sink-Current Segment Driver For Large Displays

**TL503C CAPABILITIES**

- Multiplexed BCD Outputs
- High-Sink-Current BCD Outputs

**description of converter system**

The TL500C and TL501C analog processors and TL502C and TL503C digital processors provide the basic functions for a dual-slope-integrating analog-to-digital converter.

The TL500C and TL501C contain the necessary analog switches and decoding circuits, reference voltage generator, buffer, integrator, and comparator. These devices may be controlled by the TL502C, TL503C, by discrete logic, or by a software routine in a microprocessor.

The TL502C and TL503C each includes oscillator, counter, control logic, and digit enable circuits. The TL502C provides multiplexed outputs for seven-segment displays, while the TL503C has multiplexed BCD outputs.

When used in complementary fashion, these devices form a system that features automatic zero-offset compensation, true differential inputs, high input impedance, and capability for 4 1/2-digit accuracy. Applications include the conversion of analog data from high-impedance sensors of pressure, temperature, light, moisture, and position. Analog-to-digital-logic conversion provides display and control signals for weight scales, industrial controllers, thermometers, light-level indicators, and many other applications.

# TYPES TL500C THRU TL503C

## ANALOG-TO-DIGITAL-CONVERTER BUILDING BLOCKS

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### principles of operation

The basic principle of dual-slope-integrating converters is relatively simple. A capacitor,  $C_X$ , is charged through the integrator from  $V_{CT}$  for a fixed period of time at a rate determined by the value of the unknown voltage input. Then the capacitor is discharged at a fixed rate (determined by the reference voltage) back to  $V_{CT}$  where the discharge time is measured precisely. The relationship of the charge and discharge values are shown below (see Figure 1).

$$V_{CX} = V_{CT} - \frac{V_I t_1}{R_X C_X} \quad \text{Charge} \quad (1)$$

$$V_{CT} = V_{CX} - \frac{V_{ref} t_2}{R_X C_X} \quad \text{Discharge} \quad (2)$$

Combining equations 1 and 2 results in:

$$\frac{V_I}{V_{ref}} = - \frac{t_2}{t_1} \quad (3)$$

where:

$V_{CT}$  = Comparator (offset) threshold voltage

$V_{CX}$  = Voltage change across  $C_X$  during  $t_1$  and during  $t_2$  (equal in magnitude)

$V_I$  = Average value of input voltage during  $t_1$

$t_1$  = Time period over which unknown voltage is integrated

$t_2$  = Unknown time period over which a known reference voltage is integrated.

Equation 3 illustrates the major advantages of a dual-slope converter:

- a. Accuracy is not dependent on absolute values of  $t_1$  and  $t_2$ , but is dependent on their ratios. Long-term clock frequency variations will not affect the accuracy.
- b. Offset values,  $V_{CT}$ , are not important.

The BCD counter in the digital processor (see Figure 2) and the control logic divide each measurement cycle into three phases. The BCD counter changes at a rate equal to one-half the oscillator frequency.

### auto-zero phase

The cycle begins at the end of the integrate-reference phase when the digital processor applies low levels to inputs A and B of the analog processor. If the trigger input is at a high level, a free-running condition exists and continuous conversions are made. However, if the trigger input is low, the digital processor stops the counter at 20,000, entering a hold mode. In this mode, the processor samples the trigger input every 4000 oscillator pulses until a high level is detected. When this occurs, the counter is started again and is carried to completion at 30,000. The reference voltage is stored on reference capacitor  $C_{ref}$ , comparator offset voltage is stored on integration capacitor  $C_X$ , and the sum of the buffer and integrator offset voltages is stored on zero capacitor  $C_Z$ . During the auto-zero phase, the comparator output is characterized by an oscillation (limit cycle) of indeterminate waveform and frequency that is filtered and d-c shifted by the level shifter.

### integrate-input phase

The auto-zero phase is completed at a BCD count of 30,000, and high levels are applied to both control inputs to initiate the integrate-input phase. The integrator charges  $C_X$  for a fixed time of 10,000 BCD counts at a rate determined by the input voltage. Note that during this phase, the analog inputs see only the high impedance of the noninverting operational amplifier input. Therefore, the integrator responds only to the difference between the analog input terminals, thus providing true differential inputs.

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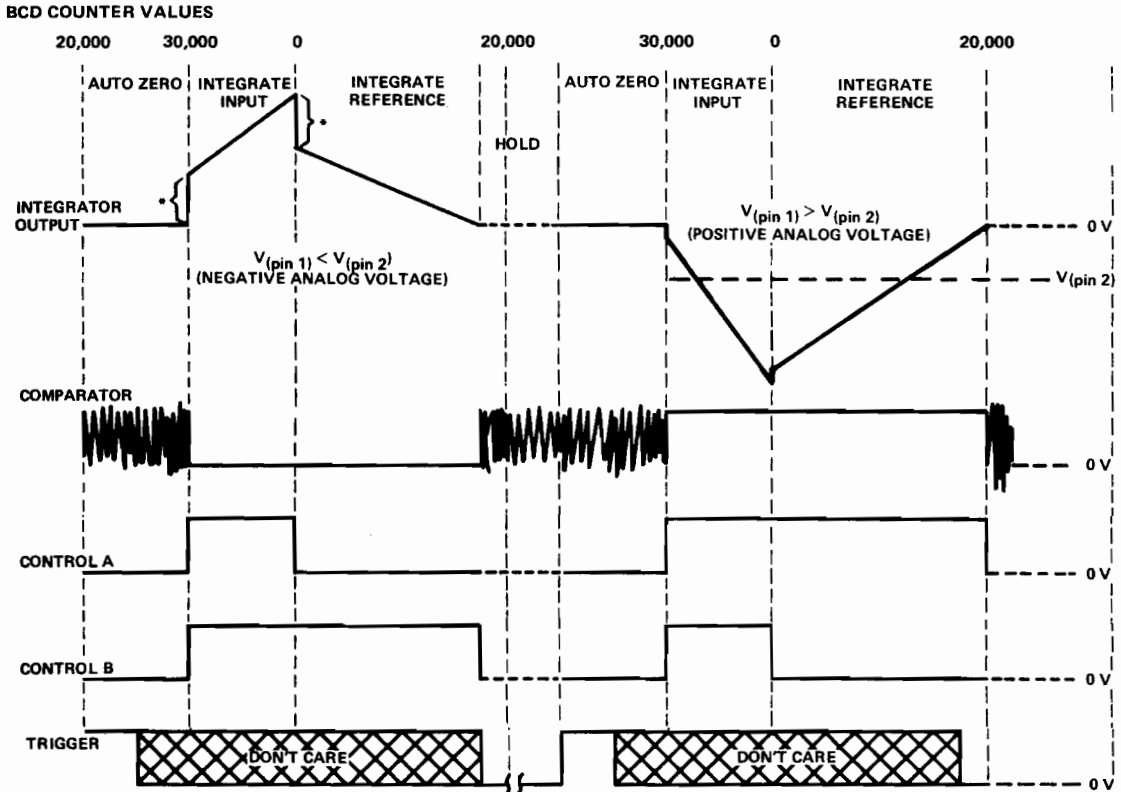


# TYPES TL500C THRU TL503C ANALOG-TO-DIGITAL-CONVERTER BUILDING BLOCKS

## integrate-reference phase

At a BCD count of  $39,999 + 1 = 40,000$  or 0, the integrate-input phase is terminated and the integrate-reference phase is begun by sampling the comparator output. If the comparator output is low corresponding to a negative average analog input voltage, the digital processor applies a low and a high to inputs A and B, respectively, to apply the reference voltage stored on  $C_{ref}$  to the buffer. If the comparator output is high corresponding to a positive input, inputs A and B are made high and low, respectively, and the negative of the stored reference voltage is applied to the buffer. In either case, the processor automatically selects the proper logic state to cause the integrator to ramp back toward zero at a rate proportional to the reference voltage. The time required to return to zero is measured by the counter in the digital processor. The phase is terminated when the integrator output crosses zero and the counter contents are transferred to the register, or when the BCD counter reaches 20,000 and the over-range indication is activated. When activated, the over-range indication blands all but the most significant digit and sign.

Seventeen parallel bits (4 1/2 digits) of information are strobed into the buffer register at the end of the integrate-input phase. Information for each digit is multiplexed out to the BCD outputs (TL503C) or the seven-segment drivers (TL502C) at a rate equal to the oscillator frequency divided by 400.

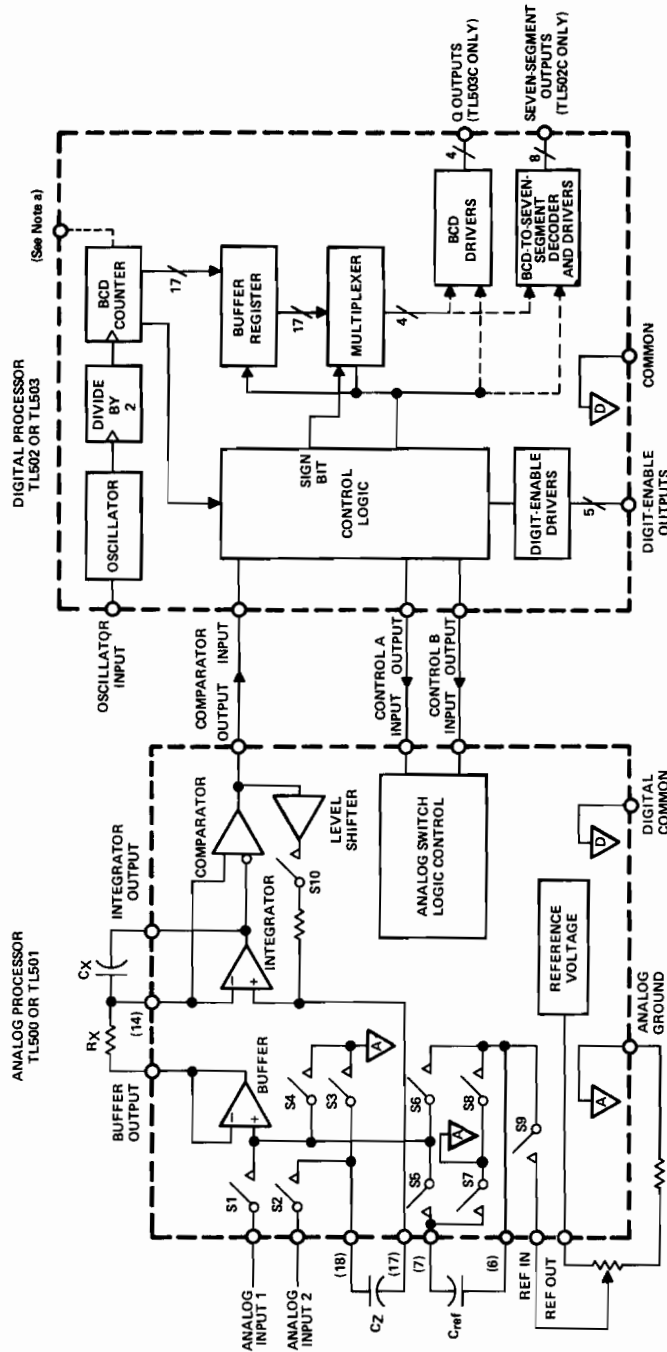


\* This step is the voltage at pin 2 with respect to analog ground.

FIGURE 1—VOLTAGE WAVEFORMS AND TIMING DIAGRAM

6

# TYPES TL500C THRU TL503C ANALOG-TO-DIGITAL-CONVERTER BUILDING BLOCKS



NOTE a. Pin 18 of the TL502 provides an output of  $f_{osc}$  (oscillator frequency)  $\div$  20,000.

FIGURE 2—BLOCK DIAGRAM OF BASIC ANALOG-TO-DIGITAL CONVERTER  
USING TL500C OR TL501C AND TL502C OR TL503C

MODE	ANALOG INPUT	COMPARATOR	CONTROLS A AND B	ANALOG SWITCHES CLOSED
Auto Zero	X	Oscillation	L L	S3, S4, S7, S9, S10
Hold*				
Integrate Input	Positive	H	H H	S1, S2
	Negative	L		
Integrate Reference	X	H†	L H	S3, S6, S7
		L†	H L	S3, S5, S8

H  $\equiv$  High, L  $\equiv$  Low, X  $\equiv$  Irrelevant

\* If the trigger input is low at the beginning of the auto-zero cycle, the system will enter the hold mode. A high level (or open circuit) will signal the digital processor to continue or resume normal operation.

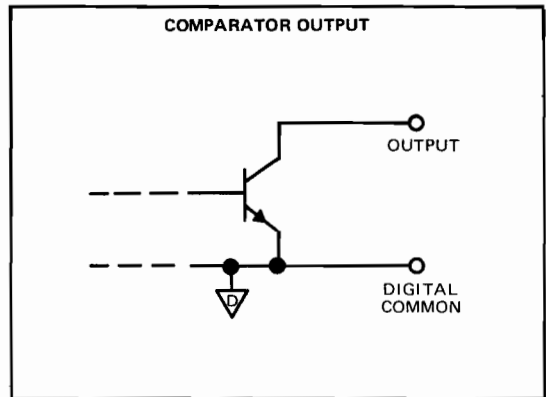
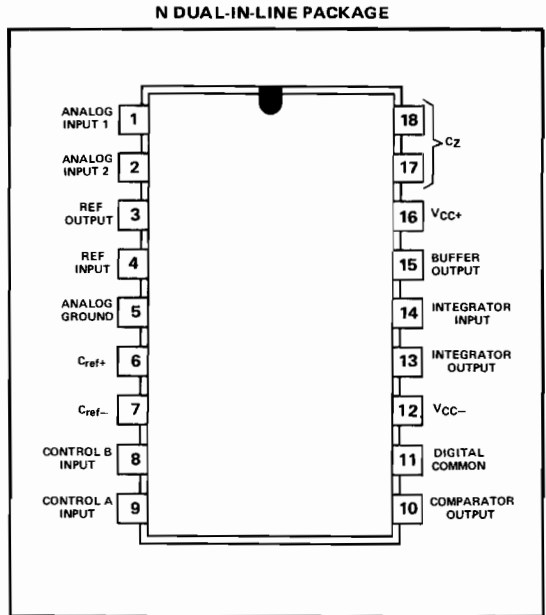
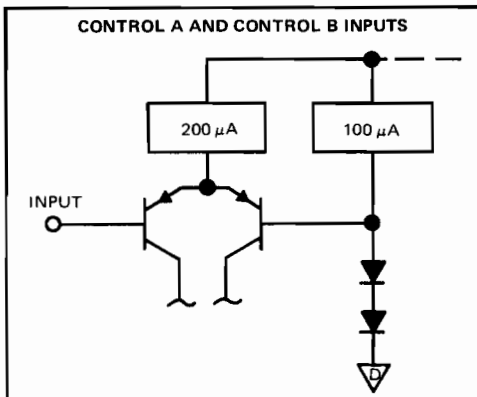
† This is the state of the comparator output as determined by the polarity of the analog input during the integrate input phase.

# TYPES TL500C, TL501C ANALOG PROCESSORS

## description of analog processors

The TL500C and TL501C analog processors are designed to automatically compensate for internal zero offsets, integrate a differential voltage at the analog inputs, integrate a voltage at the reference input in the opposite direction, and provide an indication of zero-voltage crossing. The external control mechanism may be a microcomputer and software routine, discrete logic, or a TL502C or TL503C controller. The TL500C and TL501C are designed primarily for simple, cost-effective, dual-slope analog-to-digital converters. Both devices feature true differential analog inputs, high input impedance, and an internal reference-voltage source. The TL500C provides 4 1/2-digit readout accuracy when used with a precision external reference voltage. The TL501C provides 100-ppm linearity error and 3 1/2-digit accuracy capability. These devices are manufactured using TI's advanced technology to produce JFET, MOSFET, and bipolar devices on the same chip. The TL500C and TL501C are intended for operation over the temperature range of 0°C to 70°C.

## schematics of inputs and outputs



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Positive supply voltage, $V_{CC+}$ (see Note 1)	+18 V
Negative supply voltage, $V_{CC-}$	-18 V
Input voltage, $V_I$	$\pm V_{CC}$
Comparator output voltage range (see Note 2)	0 V to $V_{CC+}$
Comparator output sink current (see Note 2)	20 mA
Buffer, reference, or integrator output source current (see Note 2)	10 mA
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 125°C

NOTES: 1. Voltage values, except differential voltages, are with respect to the analog ground and digital common pins tied together.  
2. Buffer, integrator, and comparator outputs are not short-circuit protected.

# TYPES TL500C, TL501C

## ANALOG PROCESSORS

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Positive supply voltage, $V_{CC+}$	7	12	15	V
Negative supply voltage, $V_{CC-}$	-9	-12	-15	V
Reference input voltage, $V_{reg(I)}$	0.1		5	V
Analog input voltage, $V_I$			5	V
Differential analog input voltage, $V_{ID}$			10	V
Peak positive integrator output voltage, $V_{OM+}$			+9	V
Peak negative integrator output voltage, $V_{OM-}$			-5	V
Full scale input voltage			$2 V_{ref}$	
Autozero and reference capacitors, $C_Z$ and $C_{ref}$	0.2			$\mu F$
Integrator capacitor, $C_X$	0.2			$\mu F$
Integrator resistor, $R_X$	15		100	$k\Omega$
Integrator time constant, $R_X C_X$	See Note 3			
Free-air operating temperature, $T_A$	0		70	$^{\circ}C$
Maximum conversion rate (see Figure 2)	4 1/2 Digits		15	conv/sec
	3 1/2 Digits		150	

system electrical characteristics at  $V_{CC} = \pm 12 V$ ,  $T_A = 25^{\circ}C$  (unless otherwise noted) see Figure 3

PARAMETER	TEST CONDITIONS	TL501C			TL500C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Zero error			50	300		10	30	$\mu V$
Linearity error relative to full scale			0.005	0.05		0.001	0.005	%
Full scale temperature coefficient	$T_A = 0^{\circ}C$ to $70^{\circ}C$		6			6		$ppm/^{\circ}C$
Temperature coefficient of zero error	$T_A = 0^{\circ}C$ to $70^{\circ}C$		4			1		$\mu V/^{\circ}C$
Rollover error			200	500		30	100	$\mu V$
Equivalent peak-to-peak input noise voltage			20			20		$\mu V$
Analog input resistance	Pin 1 or 2		$10^9$			$10^9$		$\Omega$
Common-mode rejection ratio	$V_{IC} = -1 V$ to $+1 V$		86			90		dB
Current into analog input	$V_I = \pm 5 V$		50			50		pA
Supply voltage rejection ratio			90			90		dB

NOTE 3. The minimum integrator time constant may be found by use of the following formula:

$$\text{Minimum } R_X C_X = \frac{V_{ID}(\text{full scale}) t_1}{V_{OM-} - V_I(\text{pin 2})}$$

where

$V_{ID}$  = voltage at pin 1 with respect to pin 2

$V_I(\text{pin 2})$  = voltage at pin 2 with respect to analog ground

$t_1$  = input integration time seconds

# TYPES TL500C, TL501C ANALOG PROCESSORS

electrical characteristics at  $V_{CC} = \pm 12\text{ V}$ ,  $V_{ref} = 1\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , see Figure 3

integrator and buffer operational amplifiers

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IO}$	Input offset voltage		15		mV
$I_{IB}$	Input bias current		50		pA
$V_{OM+}$	Positive output voltage swing	9	11		V
$V_{OM-}$	Negative output voltage swing	-5	-7		V
AVD	Voltage amplification		110		dB
$B_1$	Unity-gain bandwidth		3		MHZ
CMRR	Common mode rejection	$V_{IC} = -1\text{ V to }+1\text{ V}$		100	dB
SR	Output slew rate		5		V/ $\mu$ s

comparator

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
$V_{IO}$	Input offset voltage		15		mV	
$I_{IB}$	Input bias current		50		pA	
AVD	Voltage amplification		100		dB	
$V_{OL}$	Low-level output voltage	$I_{OL} = 1.6\text{ mA}$		200	400	mV
$I_{OH}$	High-level output current	$V_{OH} = 3\text{ V}$		5	20	nA

voltage reference output

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{ref(0)}$	Reference voltage	1.12	1.22	1.32	V
	Reference-voltage temperature coefficient	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		80	ppm/ $^\circ\text{C}$
$r_o$	Reference output resistance		3		$\Omega$

logic control section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
$V_{IH}$	High-level input voltage	2			V	
$V_{IL}$	Low-level input voltage			0.8	V	
$I_{IH}$	High-level input current	$V_{IH} = 2\text{ V}$		1	$\mu$ A	
$I_{IL}$	Low-level input current	$V_{IL} = 0.8\text{ V}$		-40	-300	$\mu$ A

total device

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$I_{CC+}$	Positive supply current		15	20	mA
$I_{CC-}$	Negative supply current		12	18	mA

# TYPES TL500C, TL501C ANALOG PROCESSORS

## PARAMETER MEASUREMENT INFORMATION

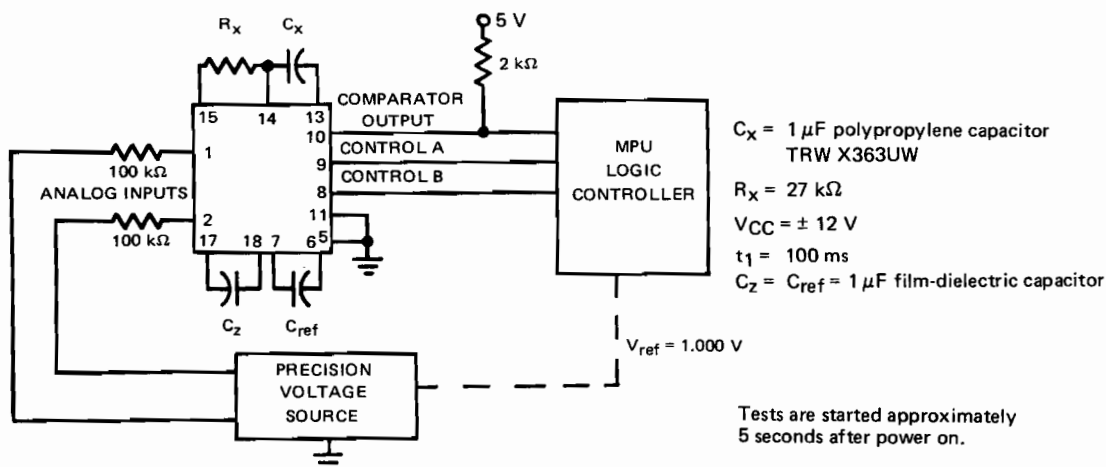


FIGURE 3—TEST CIRCUIT CONFIGURATION

### external-component selection guide

The autozero capacitor  $C_z$  and reference capacitor  $C_{ref}$  should be within the recommended range of operating conditions and should have low leakage characteristics. Most film-dielectric capacitors and some tantalum capacitors provide acceptable results. Ceramic and aluminum capacitors are not recommended because of their relatively high leakage characteristics.

The integrator capacitor  $C_x$  should also be within the recommended range and must have good voltage linearity and low dielectric absorption. A polypropylene-dielectric capacitor similar to TRW's X363UW is recommended for 4 1/2-digit accuracy. For 3 1/2-digit applications, polyester, polycarbonate, and other film dielectrics are usually suitable. Ceramic and electrolytic capacitors are not recommended.

Stray coupling from the comparator output to any analog pin (in order of importance 17, 18, 14, 7, 6, 13, 1, 2, 15) must be minimized to avoid oscillations. In addition, all power supply pins should be bypassed at the package.

Analog and digital common are internally isolated and may be at different potentials. Digital common can be within 4 volts of positive or negative supply with the logic decode still functioning properly.

The time constant  $R_x C_x$  should be kept as near the minimum value as possible and is given by the formula:

$$\text{Minimum } R_x C_x = \frac{V_{ID}(\text{full scale}) t_1}{V_{OM-} - V_I(\text{pin 2})}$$

where:

$V_{ID}(\text{full scale})$  = Voltage on pin 1 with respect to pin 2

$t_1$  = Input integration time in seconds

$V_I(\text{pin 2})$  = Voltage on pin 2 with respect to analog ground

# TYPES TL502C, TL503C DIGITAL PROCESSORS

## description of digital processors

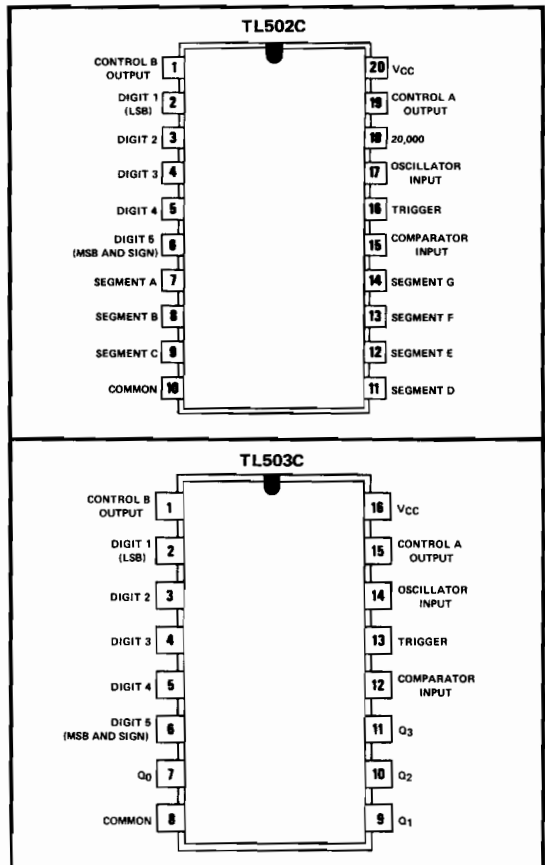
The TL502C and TL503C are control logic devices designed to complement the TL500C and TL501C analog processors. They feature interdigit blanking, over-range blanking, an internal oscillator, and a fast display scan rate. The internal-oscillator input is a Schmitt trigger circuit that can be driven by an external clock pulse or provide its own time base with the addition of a capacitor. The typical oscillator frequency is 240 kHz with a 470-picofarad capacitor connected between the oscillator input and ground.

The TL502C provides seven-segment-display output drivers capable of sinking 100 milliamperes and compatible with popular common-anode displays. The TL503C has four BCD output drivers capable of 100-milliampere sink currents. The code (see next page and Figure 4) for each digit is multiplexed to the output drivers in phase with a pulse on the appropriate digit-enable line at a digit rate equal to  $f_{osc}$ , divided by 400. Each digit-enable output is capable of sinking 20 milliamperes.

The comparator input of each device, in addition to monitoring the output of the zero-crossing detector in the analog processor, may be used in the display test mode to check for wiring and display faults. A high logic level at the trigger input starts the integrate-input phase and, in combination with the comparator input, can provide a system clear function to reset the display output to zero and restart the conversion cycle at the auto-zero phase.

These devices are manufactured using  $I^2L$  and bipolar techniques. The TL502C and TL503C are intended for operation from 0°C to 70°C.

N DUAL-IN-LINE PACKAGE



6

TABLE OF SPECIAL FUNCTIONS

$V_{CC} = 5V \pm 10\%$

TRIGGER INPUT	COMPARATOR INPUT	FUNCTION
$V_I < 0.8V$	$V_I < 6.5V$	Hold at auto-zero cycle after completion of conversion
$2V < V_I < 6.5V$	$V_I < 6.5V$	Normal operation (continuous conversion)
$V_I < 6.5V$	$V_I \geq 7.9V$	Display Test: All segment or BCD outputs high
$V_I \geq 7.9V$	$V_I < 6.5V$	Internal Test
Both inputs go high ( $V_I \geq 2V$ ) simultaneously		System clear: Sets outputs to zero and BCD counter to 20,000. When normal operation is resumed, cycle begins with Auto Zero.

# TYPES TL502C, TL503C DIGITAL PROCESSORS

DIGIT 5 (MOST SIGNIFICANT DIGIT) CHARACTER CODES

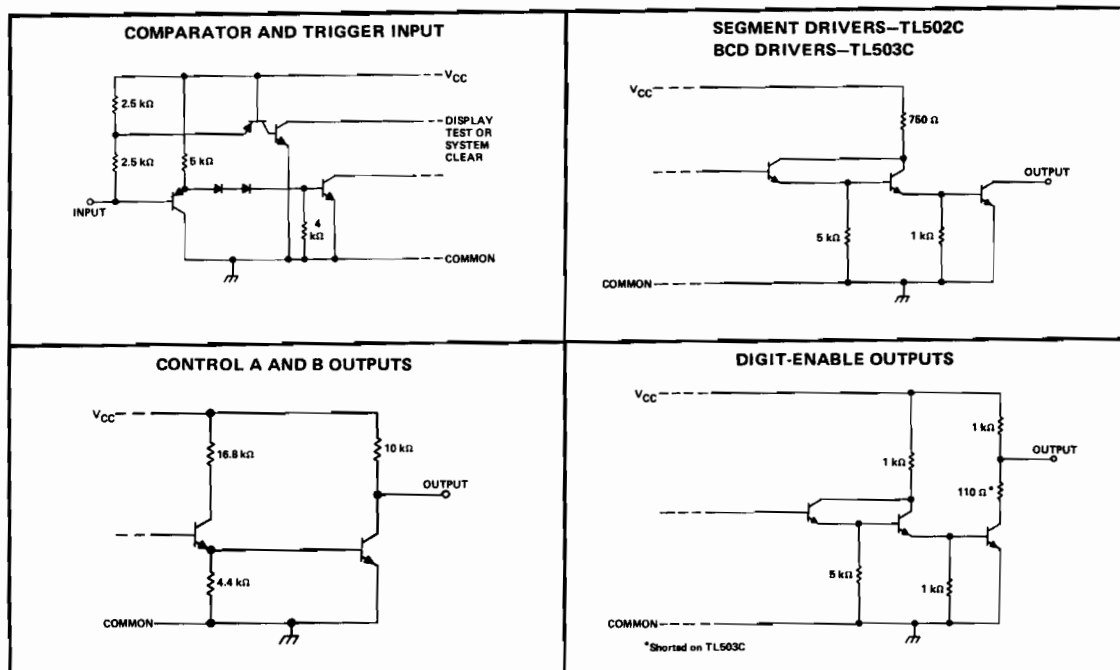
CHARACTER	TL502C SEVEN-SEGMENT LINES							TL503C BCD OUTPUT LINES			
	A	B	C	D	E	F	G	Q3	Q2	Q1	Q0
+	H	H	H	H	L	L	L	8	4	2	1
+1	H	L	L	H	L	L	L	H	H	H	L
-	L	H	H	L	H	H	L	H	L	H	H
-1	L	L	L	L	H	H	L	H	H	H	H

DIGITS 1 THRU 4 NUMERIC CODE (See Figure 4)

NUMBER	TL502C SEVEN-SEGMENT LINES							TL503C BCD OUTPUT LINES			
	A	B	C	D	E	F	G	Q3	Q2	Q1	Q0
0	L	L	L	L	L	L	H	L	L	L	L
1	H	L	L	H	H	H	H	L	L	L	H
2	L	L	H	L	L	H	L	L	L	H	L
3	L	L	L	L	H	H	L	L	L	H	H
4	H	L	L	H	H	L	L	L	H	L	L
5	L	H	L	L	H	L	L	L	H	L	H
6	L	H	L	L	L	L	L	L	H	H	L
7	L	L	L	H	H	H	H	L	H	H	H
8	L	L	L	L	L	L	L	H	L	L	L
9	L	L	L	L	H	L	L	H	L	L	H

H = high level, L = low level

## schematics of inputs and outputs





# TYPES TL502C, TL503C DIGITAL PROCESSORS

## absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 4)		7	V
Input voltage, $V_I$	Oscillator	5.5	V
	Comparator or Trigger	9	
Output current	BCD or Segment drivers	120	mA
	Digit-enable outputs	40	
	Pin 18 (TL502C only)	20	
Total power dissipation at (or below) 30°C free-air temperature (see Note 5)		1100	mW
Operating free-air temperature range		0 to 70	°C
Storage temperature range		-65 to 150	°C

NOTES: 4. Voltage values are with respect to the network ground terminal.

5. For operation above 30°C free-air temperature, derate linearly at the rate of 9.2 mW/°C.

## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	5	5.5	V
High-level input voltage, $V_{IH}$	Comparator and trigger inputs			V
Low-level input voltage, $V_{IL}$	Comparator and trigger inputs			0.8 V
Operating free-air temperature	0	70		°C

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

PARAMETER	TERMINAL	TEST CONDITIONS	TL502C			TL503C			UNIT			
			MIN	TYP	MAX	MIN	NOM	MAX				
$V_{IK}$	Input clamp voltage	All inputs	$V_{CC} = 4.5\text{ V}$ , $I_I = -12\text{ mA}$			-0.8	-1.5	-0.8	-1.5	V		
$V_{T+}$	Positive-going input threshold voltage	Oscillator	$V_{CC} = 5\text{ V}$			1.5			V			
$V_{T-}$	Negative-going input threshold voltage	Oscillator	$V_{CC} = 5\text{ V}$			0.9			V			
$V_{T+} - V_{T-}$	Hysteresis	Oscillator	$V_{CC} = 5\text{ V}$			0.4	0.6	0.8	0.4	0.6	0.8	V
$I_{T+}$	Input current at positive-going input threshold voltage	Oscillator	$V_{CC} = 5\text{ V}$			-40	-94	-100	-40	-94	-100	μA
$I_{T-}$	Input current at negative-going input threshold voltage	Oscillator	$V_{CC} = 5\text{ V}$			-40	117	170	-40	117	170	μA
$V_{OH}$	High-level output voltage	Digit enable	$V_{CC} = 4.5\text{ V}$ , $I_{OH} = 0$			4.15	4.4	4.15	4.4	V		
		Pin 18 (TL502C only)				4.25	4.4	4.25	4.4			
		Control A and B				4.25	4.4					
$V_{OL}$	Low-level output voltage	Digit enable	$V_{CC} = 4.5\text{ V}$	$I_{OL} = 20\text{ mA}$			0.2		0.5	V		
		Pin 18 (TL502C only)		$I_{OL} = 10\text{ mA}$	0.15	0.4						
		Control A and B		$I_{OL} = 2\text{ mA}$	0.088	0.4	0.088		0.4			
		Segment drivers		$I_{OL} = 100\text{ mA}$	0.17		0.3					
		BCD drivers		$I_{OL} = 100\text{ mA}$			0.17		0.3			
$I_I$	Input current	All inputs	$V_{CC} = 5.5\text{ V}$ , $V_I = 5.5\text{ V}$			65	100	65	100	μA		
$I_{IH}$	High-level input current	Oscillator, Comparator, Trigger	$V_{CC} = 5.5\text{ V}$ , $V_I = 2.4\text{ V}$			-0.6	-1	-0.6	-1	mA		
$I_{IL}$	Low-level input current	Oscillator	$V_{CC} = 5.5\text{ V}$ , $V_I = 0.4\text{ V}$			-0.1	-0.17	-0.1	-0.17	mA		
		Comparator, Trigger				-1	-1.6	-1	-1.6			
$I_{OH}$	High-level output current (Output transistor off)	Digit enable	$V_{CC} = 4.5\text{ V}$	$V_O = 0.5\text{ V}$	-2.5	-4	-2.5	-4	mA			
		Pin 18 (TL502C only)		$V_O = 0.5\text{ V}$	-0.5	-0.9						
		Control A and B		$V_O = 0.5\text{ V}$	-0.25	-0.4	-0.25			-0.4		
		Segment drivers		$V_O = 5.5\text{ V}$	0.25							
		BCD drivers		$V_O = 5.5\text{ V}$			0.25					
$I_{OL}$	Low-level output current (Output transistor on)	Digit enable	$V_{CC} = 4.5\text{ V}$ , $V_O = 3.55\text{ V}$			18	23			mA		
$I_{CC}$	Supply current	$V_{CC}$	$V_{CC} = 5.5\text{ V}$			73	110	73	110	mA		

## special functions<sup>§</sup> operating characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_I$	Input current into comparator or trigger inputs	$V_{CC} = 5.5\text{ V}$ , $V_I = 8.55\text{ V}$	1.2	1.8	mA
		$V_{CC} = 5.5\text{ V}$ , $V_I = 6.25\text{ V}$	0.5		mA

<sup>§</sup>The comparator and trigger inputs may be used in the normal mode or to perform special functions. See the Table of Special Functions.

# TYPES TL502C, TL503C DIGITAL PROCESSORS

## TYPICAL APPLICATION DATA

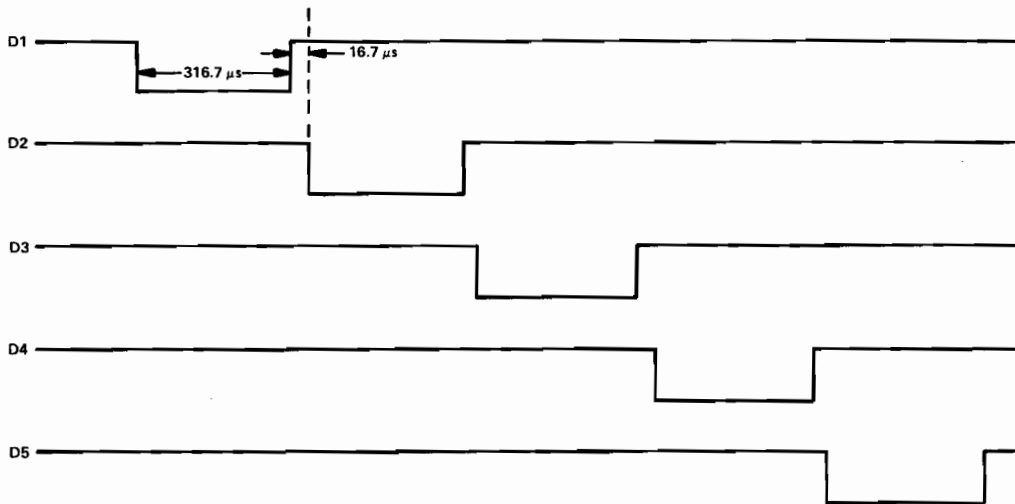


FIGURE 4—TL502C, TL503C DIGIT TIMING WITH 240-kHz CLOCK SIGNAL AT OSCILLATOR INPUT

This 4½-digit thermistor thermometer application will indicate the temperature inside a deep freeze, solution temperature in a darkroom, or any other temperature measurable with a thermistor. However, to ensure accuracy to 4¼ digits, an external precision reference and a very stable external oscillator should be used. The external oscillator could be crystal-controlled or stabilized with a phase-locked loop. For 3½-digit accuracy, the TL500C internal reference and the TL502C internal oscillator are sufficient.

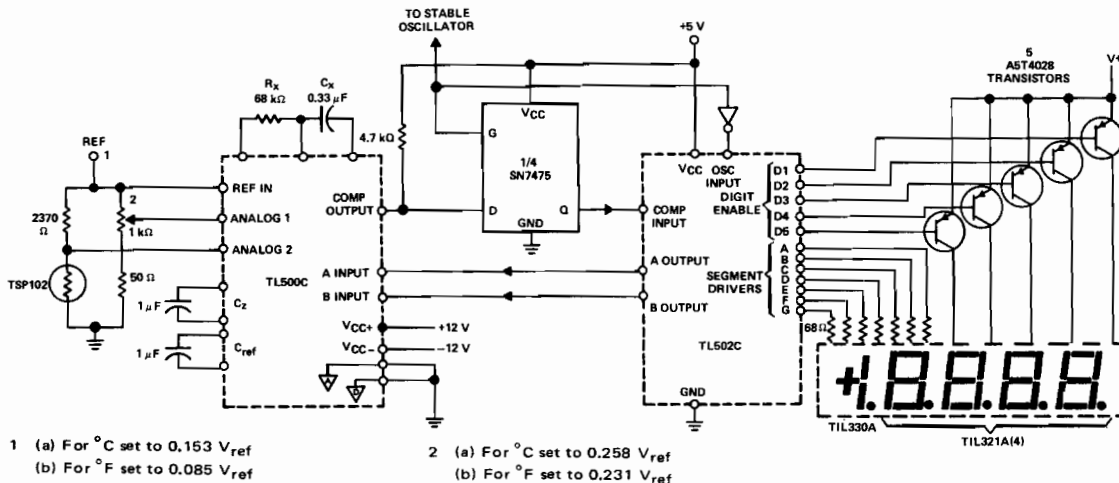
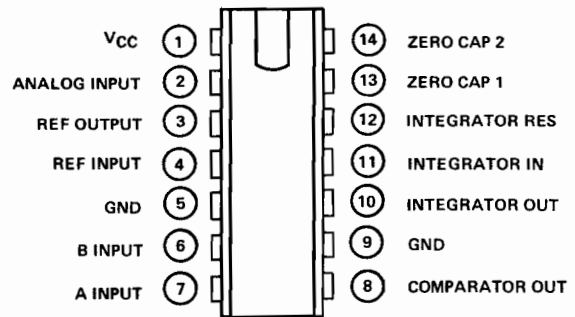


FIGURE 5-4 1/2-DIGIT THERMISTOR THERMOMETER

- 3-Digit Accuracy (0.1%)
- Automatic Zero
- Internal Reference Voltage
- Single-Supply Operation
- High-Impedance MOS Input
- Designed for use with TMS 1000 Type Microprocessors for Cost-Effective High-Volume Applications
- BI-MOS Technology
- Only 40 mW Typical Power Consumption

N DUAL-IN-LINE  
(TOP VIEW)



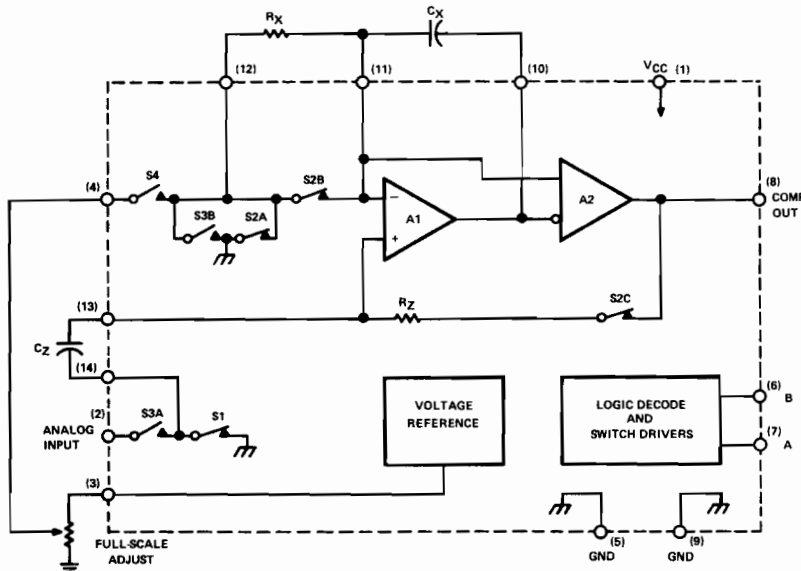
**description**

The TL505C is an analog-to-digital converter building block designed for use with TMS 1000 type microprocessors. It contains the analog elements (operational amplifier, comparator, voltage reference, analog switches, and switch drivers) necessary for a unipolar automatic-zeroing dual-slope converter. The logic for the dual-slope conversion can be performed by the associated MPU as a software routine or it can be implemented with other components such as the TL502 logic-control device.

The high-impedance MOS inputs permit the use of less expensive, lower value capacitors for the integration and offset capacitors and permit conversion speeds from 20 per second to 0.05 per second.

The TL505C is a product of TI's BI-MOS process, which incorporates bipolar and MOSFET transistors on the same monolithic integrated circuit. The TL505C is characterized for operation from 0°C to 70°C.

**functional block diagram**



# TYPE TL505C

## ANALOG-TO-DIGITAL CONVERTER

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage, pins 2, 4, 6, and 7	$V_{CC}$
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	900 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C

NOTES: 1. Voltage values are with respect to the two ground terminals connected together.

2. For operation above 25°C free-air temperature, derate linearly from 900 mW at 52°C to 736 mW at 70°C at the rate of 9.2 mW/°C.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	7	9	15	V
Analog input voltage, $V_I$	0		4	V
Reference input voltage, $V_{ref(I)}$	0.5		3	V
Integrator capacitor, $C_X$	See "component selection"			
Integrator resistor, $R_X$	0.5		2	MΩ
Integration time, $t_I$	16.6		500	ms
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics, $V_{CC} = 9\text{ V}$ , $V_{ref(I)} = 1\text{ V}$ , $T_A = 25^\circ\text{C}$ , connected as shown in figure 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$	High-level input voltage at A or B	3.6		$V_{CC}+1$	V
$V_{IL}$	Low-level input voltage at A or B	0.2		1.8	V
$V_{OH}$	High-level output voltage at pin 8	$I_{OH} = 0$	7.5	8.5	V
$I_{OH}$	High-level output current at pin 8	$V_{OH} = 7.5\text{ V}$	-100		μA
$V_{OL}$	Low-level output voltage at pin 8	$I_{OL} = -100\text{ μA}$		120	mV
$V_{OM}$	Maximum peak output voltage swing at integrator output	$R_X \geq 500\text{ k}\Omega$	$V_{CC}-2$	$V_{CC}-1$	V
$V_{ref(0)}$	Reference output voltage	1.15	1.22	1.35	V
	Temperature coefficient of reference output voltage	$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	±100		ppm/°C
$I_{IH}$	High-level input current into A or B	$V_I = 9\text{ V}$	1	10	μA
$I_{IL}$	Low-level input current into A or B	$V_I = 1\text{ V}$	10	200	μA
$I_I$	Current into analog input	$V_I = 0\text{ to } 4\text{ V}$ , A input at 0 V	±10	±200	pA
	Total integrator input bias current		±10		pA
$I_{CC}$	Supply current	No load	4.5	8	mA

### system electrical characteristics, $V_{CC} = 9\text{ V}$ , $V_{ref(I)} = 1\text{ V}$ , $T_A = 25^\circ\text{C}$ , connected as shown in figure 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Zero error	$V_I = 0$		0.1	0.4	mV
Linearity error	$V_I = 0\text{ to } 4\text{ V}$		0.02	0.1	%
Ratiometric reading	$V_I = V_{ref(I)} \approx 1\text{ V}$	0.998	1.000	1.002	
Temperature coefficient of ratiometric reading	$V_{ref(I)}$ constant and $\approx 1\text{ V}$ , $T_A = 0^\circ\text{C to } 70^\circ\text{C}$		±10		ppm/°C

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## DEFINITION OF TERMS

### Zero Error

The intercept (b) of the analog-to-digital converter-system transfer function  $y = mx + b$ , where y is the digital output, x is the analog input, and m is the slope of the transfer function, which is approximated by the ratiometric reading.

### Linearity Error

The maximum magnitude of the deviation from a straight line between the end points of the transfer function.

### Ratiometric Reading

The ratio of negative integration time (t<sub>2</sub>) to positive integration time (t<sub>1</sub>).

## PRINCIPLES OF OPERATION

A block diagram of an MPU system utilizing the TL505C is shown in Figure 1. The TL505C operates in a modified positive-integration three-step dual-slope conversion mode. The A/D converter waveforms during the conversion process are illustrated in Figure 2.

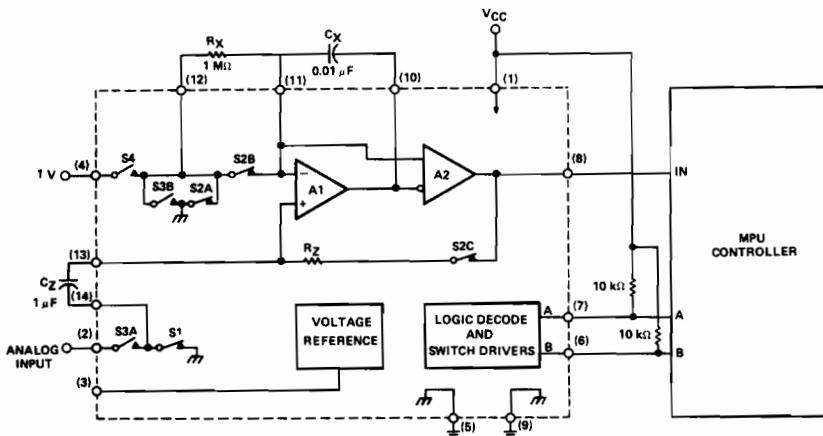


FIGURE 1—FUNCTIONAL BLOCK DIAGRAM OF TL505C INTERFACE WITH A MICROPROCESSOR SYSTEM

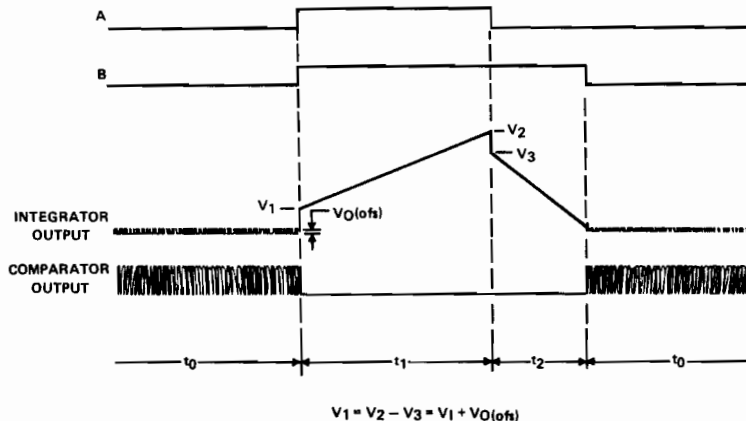


FIGURE 2—CONVERSION PROCESS TIMING DIAGRAMS

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## PRINCIPLES OF OPERATION

The first step of the conversion cycle is the auto-zero period  $t_0$  during which the integrator offset is stored in the auto-zero capacitor and the offset of the comparator is stored in the integrator capacitor. To accomplish this, the MPU takes the A and B inputs both low. This is decoded by the switch drivers, which close  $S_1$  and  $S_2$ . The output of the comparator is connected to the input of the integrator through the low-pass filter consisting of  $R_Z$  and  $C_Z$ . The closed loop of A1 and A2 will seek a null condition where the offsets of the integrator and comparator are stored in  $C_Z$  and  $C_X$ , respectively. This null condition is characterized by a high-frequency oscillation at the output of the comparator. The purpose of  $S_{2B}$  is to shorten the amount of time required to reach the null condition.

At the conclusion of  $t_0$ , the MPU takes the A and B inputs both high. This closes  $S_3$  and turns all other switches off. The input signal  $V_I$  is applied to the noninverting input of A1 through  $C_Z$ .  $V_I$  is then positively integrated by A1. Since the offset of A1 is stored in  $C_Z$ , the change in voltage across  $C_X$  will be due to only the input voltage. It should be noted that since the input is integrated in a positive integration during  $t_1$ , the output of A1 will be the sum of the input voltage, the integral of the input voltage, and the comparator offset, as shown in Figure 2. The change in voltage across capacitor  $C_X$  ( $V_{CX}$ ) during  $t_1$  is given by

$$\Delta V_{CX(1)} = \frac{V_I t_1}{R_1 C_X} \quad (1)$$

where  $R_1 = R_X + R_{S3B}$  and

$R_{S3B}$  is the resistance of switch  $S_{3B}$ .

At the end of  $t_1$  the MPU takes the A input low and the B input high. This turns on  $S_1$  and  $S_4$ ; all other switches are turned off. In this state the reference is integrated by A1 in a negative sense until the integrator output reaches the comparator threshold. At this point the comparator output goes high. This change in state is sensed by the MPU, which terminates  $t_2$  by again taking the A and B inputs both low. During  $t_2$  the change in voltage across  $C_X$  is given by

$$\Delta V_{CX(2)} = \frac{V_{ref} t_2}{R_2 C_X} \quad (2)$$

where  $R_2 = R_X + R_{S6} + R_{ref}$  and

$R_{ref}$  is the equivalent resistance of the reference divider.

Since  $\Delta V_{CX1} = -\Delta V_{CX2}$ , equations (1) and (2) can be combined to give

$$V_I = V_{ref} \frac{R_1 \cdot t_2}{R_2 \cdot t_1} \quad (3)$$

This equation is a variation on the ideal dual-slope equation, which is

$$V_I = V_{ref} \frac{t_2}{t_1} \quad (4)$$

Ideally then, the ratio of  $R_1/R_2$  would be exactly equal to one. In a typical TL505C system where  $R_X = 1 \text{ M}\Omega$ , the scaling error introduced by the difference in  $R_1$  and  $R_2$  is so small that it can be neglected, and equation (3) reduces to (4).

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## TYPICAL APPLICATION DATA

There are a wide variety of applications for the TL505C to convert signals to a more useful form from high-impedance sources; appliance controls; weight-scales; and temperature-, light-, or moisture-sensitive transducers.

The TL505C can be used with the TL502, discrete logic, or with an MPU controller that has the control algorithm implemented in software. Figure 3 is a generalized flow chart for any type of TL505C logic controller. The TL505C will directly interface with the TL502 as shown in Figure 4. The sign output of the TL502 will be negative and should be ignored.

When used with the TMS 1000 microprocessor as illustrated in Figure 5, a 3-digit BCD conversion can be accomplished in about 500 ms. This combination is especially useful in applications that do not require fast updates such as temperature controllers or weight scales. The computing power of the TMS 1000 can be used to linearize responses from nonlinear transducers such as thermistors and to make control decisions. Both the TMS 1000 and TL505C can operate from a single 7- to 15-V supply making them ideally suited for battery operation.

The TL505C can be used with the TMS 8080 microprocessor for either binary or BCD conversion. Figure 7 shows a generalized system using the TL505C and TMS 8080.

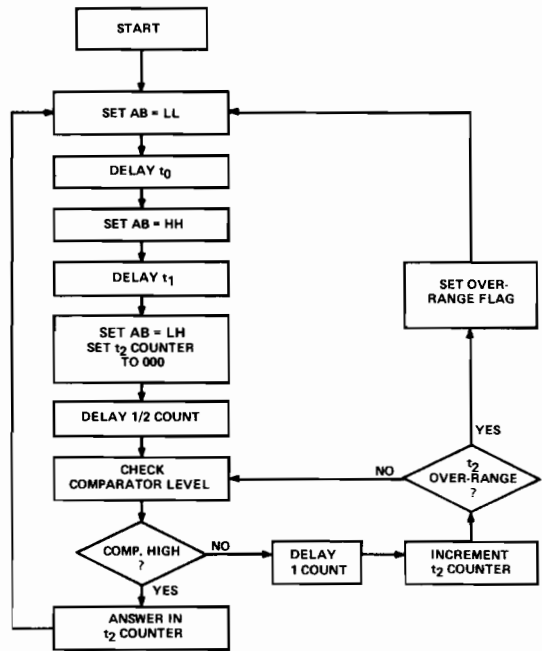


FIGURE 3—TL505C LOGIC CONTROL FLOW CHART

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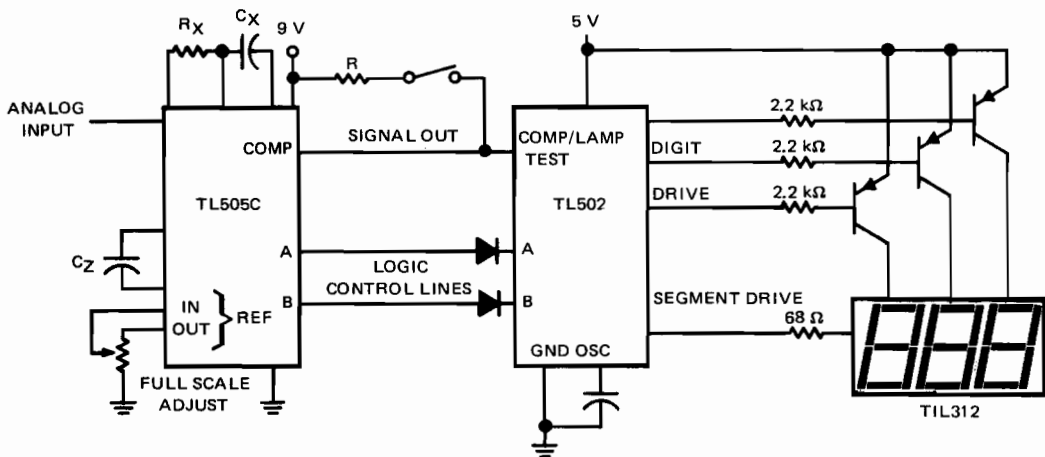
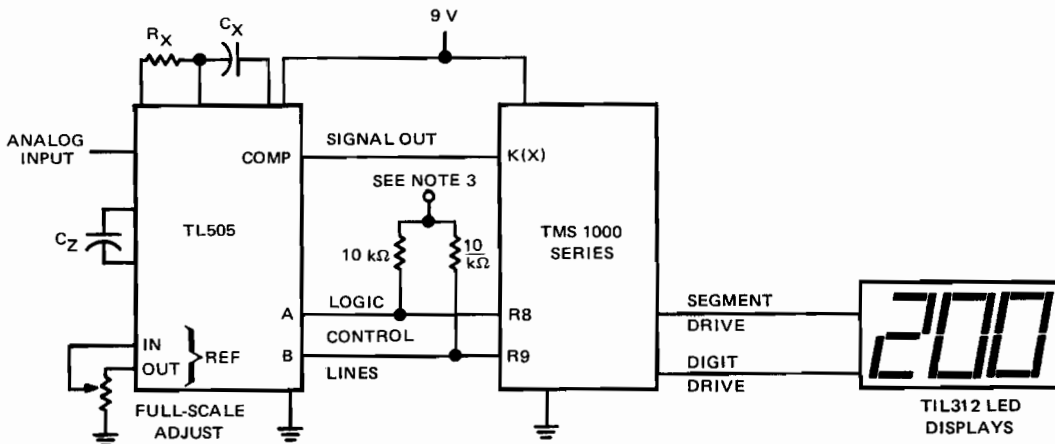


FIGURE 4—TL505C AND TL502 INPUT TO A 3-DIGIT DISPLAY APPLICATION

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## TYPICAL APPLICATION DATA



NOTE 3: Connect to either +9 V or 0 V depending on which device in the TMS 1000 series is used and how it is programmed.

FIGURE 5—TL505C IN CONJUNCTION WITH A TMS 1000 SERIES MICROPROCESSOR FOR A 3-DIGIT DIGITAL PANEL METER APPLICATION

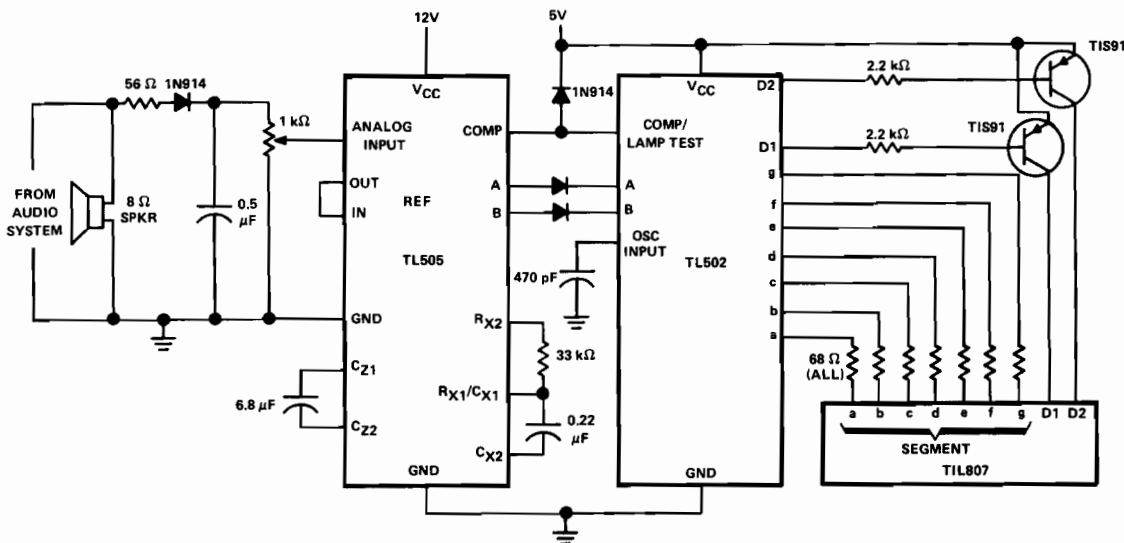


FIGURE 6—AUDIO POWER METER



# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## TYPICAL APPLICATION DATA

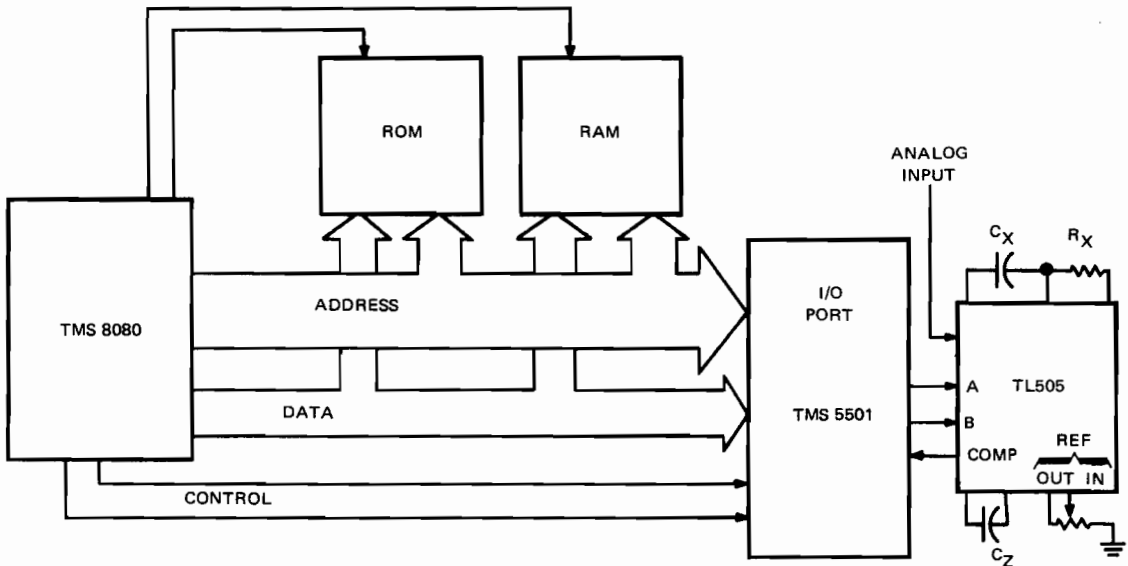


FIGURE 7—TL505C WITH INTERFACE AND CONTROL OF A TMS 8080 MICROPROCESSOR

### component selection

When the desired conversion speed and conversion control method have been selected, the passive components can be selected. The capacitor for the auto zero,  $C_Z$ , is not critical and can be any value greater than  $0.15 \mu\text{F}$ . The only restriction on this part is that it should not have high leakage. Almost any film capacitor and most tantalum electrolytics are suitable. Ceramic and aluminum capacitors are not recommended.

The integrator capacitor should be a film capacitor. Good results have been obtained at the specified system accuracy for all film capacitors tried, including polycarbonate, polyester, and polypropylene capacitors. Electrolytic and ceramic capacitors are not suitable because of their high dielectric absorption characteristics. The absolute value of  $C_X$  should be consistent with the equation

$$C_X = \frac{V_{I\text{max}} \cdot t_1}{(V_{CC} - V_{I\text{max}} - 2V) R_X}$$

where  $V_{I\text{max}}$  is the most positive analog signal to be encountered in the specific application.

This equation gives the maximum integrator output swing without saturating the integrator. A large integrator output swing is desired for best system performance.

The resistor used for  $R_X$  is not critical in either absolute value or tolerance. The value should be selected per the guidelines given under "Recommended Operating Conditions" and the equation above.

The input source resistance to pin 4 should be 2 kilohms or less. This ensures good operation with equation (4) as discussed on page 4.

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## TYPICAL APPLICATION DATA

### design example

Figure 8 is a schematic of a position indication and control system that uses a precision potentiometer to convert a mechanical displacement to an electrical signal. Note the following features of this system:

- The output of the potentiometer is connected directly to the input of the TL505C. Since the TL505C input impedance is so high ( $10^{11} \Omega$  typically) the TL505C does not load the potentiometer.
- The reference output of the TL505C is connected directly to the reference input of the TL505C and also to the position potentiometer. In this application, the variable being measured is the voltage at the wiper of  $R_1$ , which is a fraction  $N$  (directly related to the potentiometer position) of the reference voltage. Recalling equation (4) from the "Principles of Operation" and plugging in  $N \cdot V_{ref}$  for  $V_1$ , we have

$$N \cdot V_{ref} = V_{ref} \frac{t_2}{t_1} \quad \text{or} \quad N = \frac{t_2}{t_1}$$

Thus the absolute value of  $V_{ref}$  is not critical as long as it is stable during a conversion cycle. Long-term changes in  $V_{ref}$  due to time and temperature will have no effect on the accuracy of the system.

- The TL505C communicates with the TMS 1000 via the R8 and R9 digit outputs and the K8 input. The R outputs are latched outputs from the TMS 1000. Since the R outputs are open sources, pullups for the A and B inputs provided by R2 and R3 are required.
- A 4-digit LED display is driven directly by the TMS 1000. The information displayed by the system is program dependent and can be either the value  $N$  or some arbitrary function of  $N$ , such as the arcsin ( $N$ ).
- The TMS 1000 has three K inputs and three R outputs available for control purposes such as monitoring limit switches or controlling valve positions.

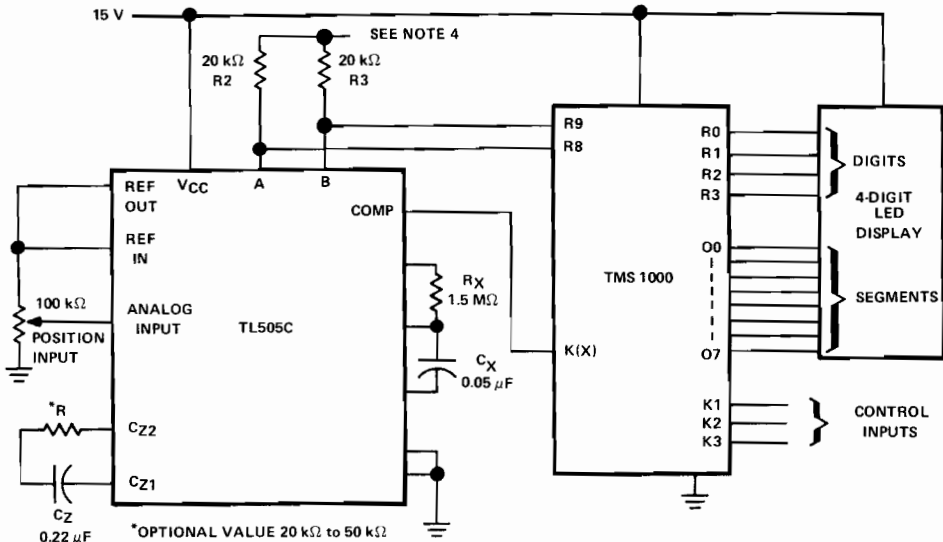
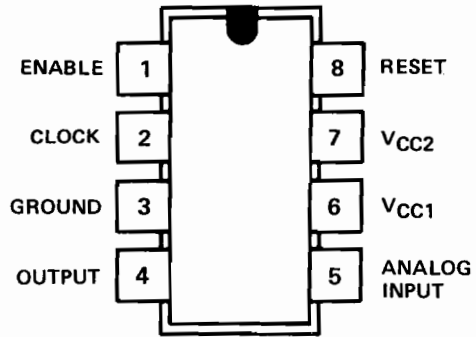


FIGURE 8—TL505C SYSTEM FOR POSITION INDICATION AND CONTROL

- Low Cost
- 7-Bit Resolution
- Guaranteed Monotonicity
- Ratiometric Conversion
- Conversion Speed . . . approximately 1 ms
- Single-Supply Operation . . . Either Unregulated 8-V to 18-V  $V_{CC2}$  Input, or Regulated 3.5-V to 6-V  $V_{CC1}$  Input
- I<sup>2</sup>L Technology
- Power Consumption at 5 V . . . 25 mW Typ

P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



FUNCTION TABLE

ANALOG INPUT CONDITION	ENABLE	OUTPUT
X	L <sup>†</sup>	H
$V_I < 200 \text{ mV}$	H	L
$V_{\text{ramp}} > V_I > 200 \text{ mV}$	H	H
$V_I > V_{\text{ramp}}$	H	L

<sup>†</sup>Low level on enable also inhibits the reset function.  
H = high level, L = low level, X = irrelevant

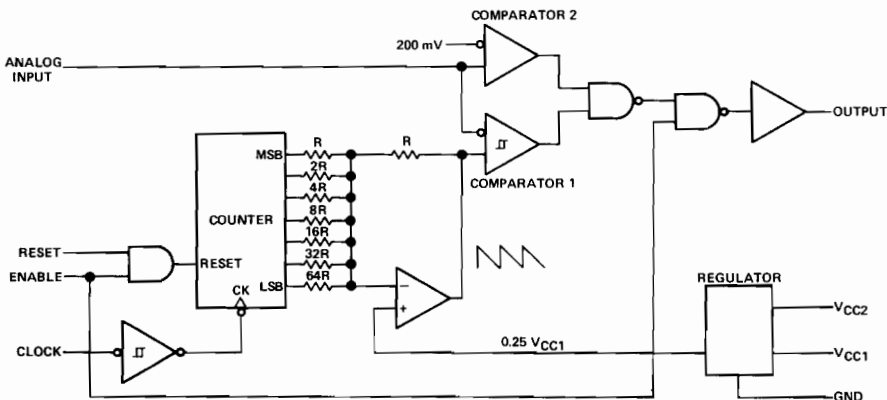
**description**

The TL507C is a single-slope analog-to-digital converter designed for use with TMS 1000 type microprocessors. It contains a 7-bit synchronous counter, a binary weighted resistor ladder network, an operational amplifier, two comparators, a buffer amplifier, an internal regulator, and necessary logic circuitry. Integrated-injection logic (I<sup>2</sup>L) technology makes it possible to offer this complex circuit at low cost in a small dual-in-line 8-pin package.

In continuous operation, it is possible to obtain conversion speeds up to 1000 per second. The TL507 requires external signals for clock, reset, and enable. Versatility and simplicity of operation coupled with low cost, makes this converter especially useful for a wide variety of applications.

The TL507C is characterized for operation from 0°C to 70°C.

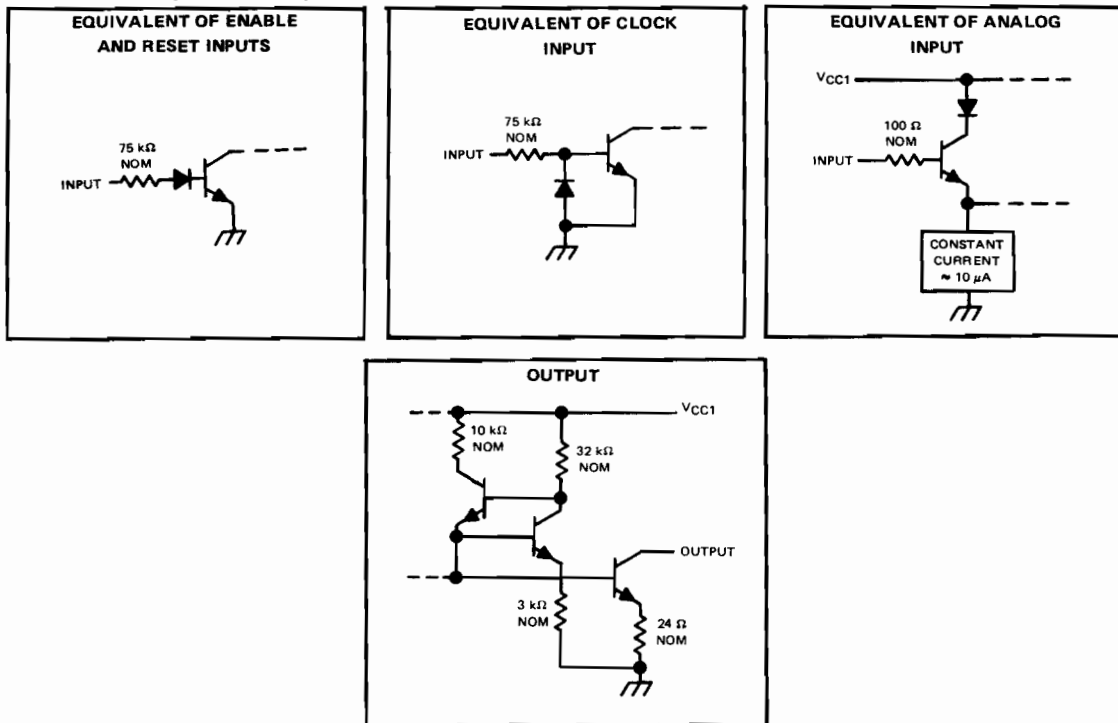
**functional block diagram**



# TYPE TL507C

## ANALOG-TO-DIGITAL CONVERTER

### schematics of inputs and outputs



### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>CC1</sub> (see Note 1)	6.5 V
Supply voltage, V <sub>CC2</sub>	20 V
Input voltage at analog input	6.5 V
Input voltage at enable, clock, and reset inputs	±20 V
On-state output voltage	6 V
Off-state output voltage	20 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

NOTES: 1. Voltage values are with respect to network ground terminal unless otherwise noted.  
 2. For operation above 25°C free-air temperature, derate linearly at 8 mW/°C.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V <sub>CC1</sub>	3.5	5	6	V
Supply voltage, V <sub>CC2</sub>	8	15	18	V
Input voltage at analog input	0		5.5	V
Input voltage at chip enable, clock, and reset inputs			±18	V
On-state output voltage			5.5	V
Off-state output voltage			18	V
Clock frequency, f <sub>clock</sub>		125	150	kHz

# TYPE TL507C

## ANALOG-TO-DIGITAL CONVERTER

electrical characteristics over recommended operating free-air temperature range,  $V_{CC1} = V_{CC2} = 5\text{ V}$   
(unless otherwise noted)

### regulator section

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
$V_{CC1}$	Supply voltage (output)	$V_{CC2} = 12\text{ V to }18\text{ V}$ , $I_{CC1} = 0\text{ to }-1\text{ mA}$	5	5.6	6	V
$I_{CC1}$	Supply current	$V_{CC1} = 5\text{ V}$ , $V_{CC2}$ open		5	8	mA
$I_{CC2}$	Supply current	$V_{CC2} = 15\text{ V}$ , $V_{CC1}$ open		7	10	mA

### inputs

PARAMETER			TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
$V_{IH}$	High-level input voltage	Reset and Enable		2			V
$V_{IL}$	Low-level input voltage	Enable				0.8	V
$V_{T+}$	Positive-going threshold voltage	Clock Input		2.5	3.5	4.5	V
$V_{T-}$	Negative-going threshold voltage			0.4	0.9	1.2	V
$V_{T+} - V_{T-}$	Hysteresis			2	2.6	4	V
$I_{IH}$	High-level input current	Reset, Enable, and Clock	$V_I = 2.4\text{ V}$		17	35	$\mu\text{A}$
			$V_I = 18\text{ V}$	130	220	320	
$I_{IL}$	Low-level input current	Clock	$V_I = 0$			$\pm 10$	$\mu\text{A}$
$I_I$	Analog input current		$V_I = 4\text{ V}$		10	300	nA

### output section

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
$I_{OH}$	High-level output current	$V_{OH} = 18\text{ V}$		0.1	100	$\mu\text{A}$
$I_{OL}$	Low-level output current	$V_{OL} = 5.5\text{ V}$	5	10	15	mA
$V_{OL}$	Low-level output voltage	$I_{OL} = 1.6\text{ mA}$		80	400	mV

operating characteristics over recommended operating free-air temperature range,  $V_{CC1} = V_{CC2} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Resolution		7			Bits
Overall error				$\pm 80$	mV
Differential nonlinearity	See Figure 1			$\pm 1$	LSB
Zero error	Binary count = 0			$\pm 80$	mV
Scale error	Binary count = 127			$\pm 80$	mV
Propagation delay time from reset or enable			2		$\mu\text{s}$

<sup>‡</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

# TYPE TL507C ANALOG-TO-DIGITAL CONVERTER

## PARAMETER MEASUREMENT INFORMATION

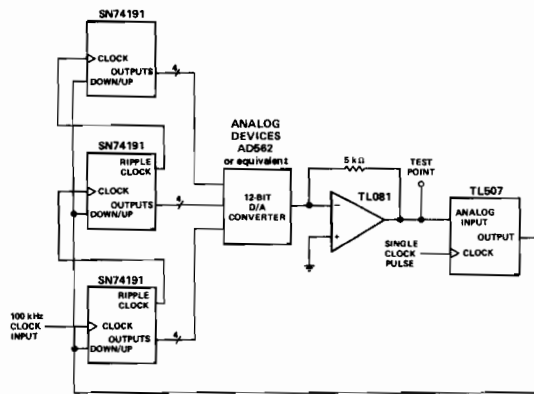


FIGURE 1—MONOTONICITY AND NONLINEARITY TEST CIRCUIT

## PRINCIPLES OF OPERATION

The TL507 is a single-slope analog-to-digital converter. All single-slope converters are basically voltage-to-time or current-to-time converters. A study of the functional block diagram shows the versatility of the TL507.

An external clock signal is applied through a buffer to a negative-edge-triggered synchronous counter. Binary-weighted resistors from the counter are connected to an operational amplifier used as an adder. The operational amplifier generates a signal that ramps from  $0.75 \cdot V_{CC1}$  down to  $0.25 \cdot V_{CC1}$ . Comparator 1 compares the ramp signal to the analog input signal. Comparator 2 functions as a fault detector. With the analog input voltage in the range  $0.25 \cdot V_{CC1}$  to  $0.75 \cdot V_{CC1}$ , the duty cycle of the output signal is determined by the unknown analog input as shown in Figure 2 and the Function Table.

For illustration assume  $V_{CC1} = 5.12 \text{ V}$ ,

$$0.25 \cdot V_{CC1} = 1.28 \text{ V}$$

$$1 \text{ binary count} = \frac{(0.75 - 0.25) V_{CC1}}{128} = 20 \text{ mV}$$

$$0.75 \cdot V_{CC1} - 1 \text{ count} = 3.82 \text{ V}$$

The output is an open-collector n-p-n transistor capable of withstanding up to 18 volts in the off state. The output is current limited to the 8- to 12-milliampere range; however, care must be taken to ensure that the output does not exceed 5.5 volts in the on state.

The voltage regulator section allows operation from either an unregulated 8- to 18-volt  $V_{CC2}$  source or a regulated 3.5- to 6-volt  $V_{CC1}$  source. Regardless of which external power source is used, the internal circuitry operates at  $V_{CC1}$ . When operating from a  $V_{CC1}$  source,  $V_{CC2}$  may be connected to  $V_{CC1}$  or left open. When operating from a  $V_{CC2}$  source,  $V_{CC1}$  can be used as a reference voltage output.

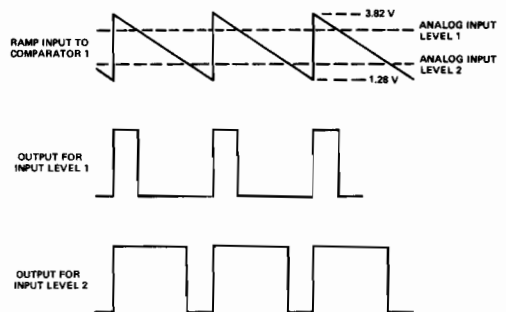


FIGURE 2

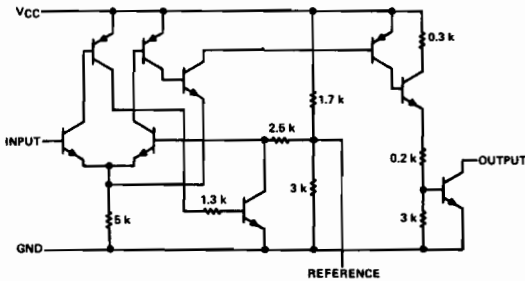
- Stable Threshold Level
- Low Input Current
- High Output Sink Current Capability
- Threshold Hysteresis
- Wide Supply Voltage Range

**description**

The TL560C is a precision level detector intended for applications that require a Schmitt-trigger function. The detector has excellent voltage and temperature stability and an internal voltage reference for the input threshold level. The reference-voltage pin is available for external adjustment of the positive-going threshold voltage level.

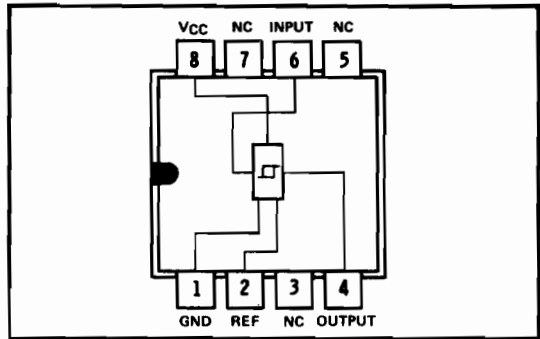
The TL560C is characterized for operation from 0°C to 70°C.

**schematic**



Resistor values shown are nominal and in ohms.

**JG OR P DUAL-IN-LINE  
PACKAGE (TOP VIEW)**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage (see Note 1)	$V_{CC}$
Output voltage (see Note 1)	25 V
Output sink current	160 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	800 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

**6**

- NOTES: 1. All voltage values are with respect to the network ground terminal.  
 2. For operation above 25°C free-air temperature refer to the Dissipation Derating Table. In the JG package, TL560C chips are glass-mounted.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	800 mW	6,6 mW/°C	29°C
P	800 mW	8,0 mW/°C	50°C

Also see Dissipation Derating Curves, Section 2.

# TYPE TL560C

## PRECISION LEVEL DETECTOR

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	2.5	5	7	V
Low-level output current, $I_{OL}$			48	mA
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 5V$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$V_{T+}$	Positive-going threshold voltage†	2.8	3	3.2	V	
$V_{T+}/V_{CC}$	Ratio of positive-going threshold voltage to supply voltage	0.6				
$V_{T-}$	Negative-going threshold voltage‡	0.4	0.6	0.8	V	
$I_{T+}$	Input current below positive-going threshold voltage	$V_I = 2.75 V$ ,	Output on	2	30	nA
$I_{T-}$	Input current above negative-going threshold voltage	$V_I = 1 V$ ,	Output off	1.2		μA
$I_{O(off)}$	Off-state output current	$V_I = 4 V$ ,	$V_O = 25 V$	10		μA
$V_{O(on)}$	On-state output voltage	$V_I = 0$ ,	$I_O = 48 mA$	0.2	0.4	V
$I_{CC(off)}$	Supply current, output off (each detector)	$V_I = 4 V$		4.8	6.5	mA
$I_{CC(on)}$	Supply current, output on (each detector)	$V_I = 0$		10	15	mA

†Positive-going threshold voltage,  $V_{T+}$ , is the input voltage level at which the output changes state as the input voltage is increased.  
‡Negative-going threshold voltage,  $V_{T-}$ , is the input voltage level at which the output changes state as the input voltage is decreased.

### TYPICAL CHARACTERISTICS

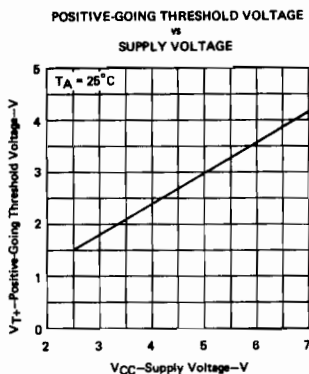


FIGURE 1

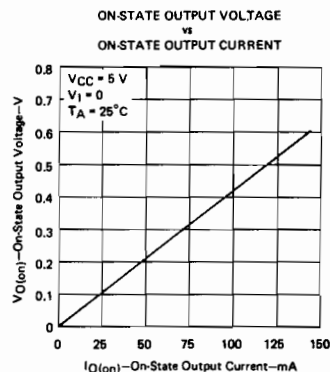


FIGURE 2

### TYPICAL APPLICATION DATA

The TL560C performs the function of a Schmitt-trigger circuit. The logic function is noninverting and has a wide hysteresis between the positive-going and negative-going threshold voltage levels (see Figure 3).

Operation of the TL560C is specified at a  $V_{CC}$  of 5 V, although 2.5-V to 7-V supply operation is possible. The device can be used with popular logic systems (such as Series 54/74 TTL) and standard battery voltages.

Figure 4 is used to illustrate operation of the TL560C circuit. The input stage is a differential amplifier composed of Q1, Q2, Q3, and Q4. The input signal is applied at the base of Q1 while the base of Q2 is connected to an internal reference voltage determined by resistors R4 and R5 and  $V_{CC}$ ;  $V_{ref} = V_{CC} \cdot R5 / (R4 + R5)$ .



# TYPE TL560C PRECISION LEVEL DETECTOR

## TYPICAL APPLICATION DATA

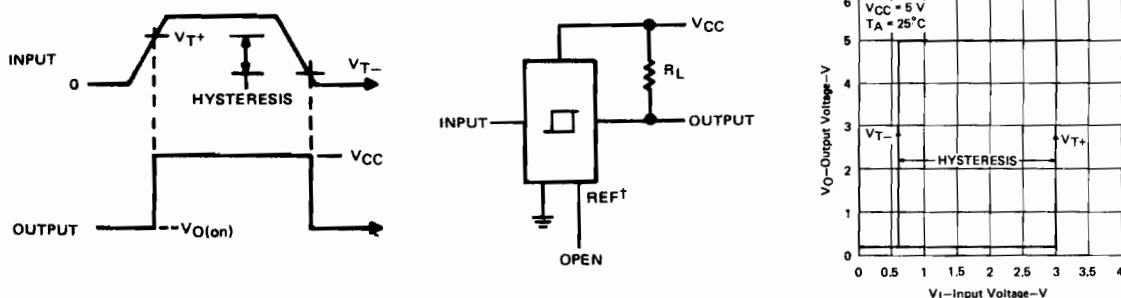


FIGURE 3—INPUT-OUTPUT TRANSFER FUNCTION

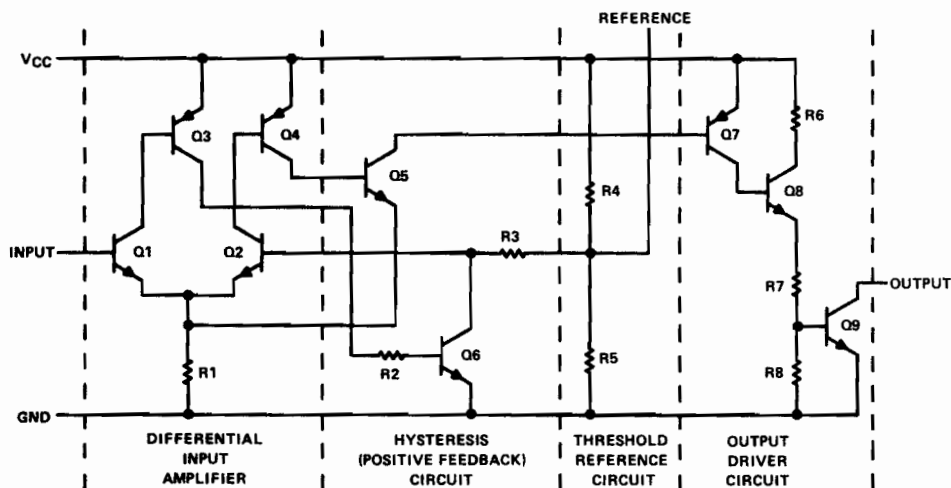


FIGURE 4—FUNCTIONAL CIRCUIT DIAGRAM

If the base of Q1 is less positive than the base of Q2, Q2 conducts and causes Q4, Q5, Q7, Q8, and the output transistor, Q9, to conduct. Transistors Q2 and Q5 share the current in emitter resistor R1. Since Q1 does not conduct, Q3 and Q6 do not conduct. There is no base current in Q1, and therefore no current required from the input source. A very high input impedance therefore exists. Since Q2 is conducting, a small voltage drop exists across R3 due to Q2 base current.

If the input voltage is increased, Q1 does not conduct until the input voltage (base voltage of Q1) approaches the base voltage of Q2. Current is then switched from the emitters of Q2 and Q5 to the emitter of Q1. Conduction in Q1 causes current to flow in Q3 and Q6 which results in additional voltage drop in R3 and therefore a reduction in the base voltage of Q2. This positive feedback accelerates switching action and causes conduction to rapidly cease in Q2, Q4, Q5, Q7, Q8, and the output transistor, Q9. Conduction in Q6 causes the base of Q2 to assume a voltage (approximately 0.6 V) much lower than the original reference voltage (approximately 3 V). This results in hysteresis between the positive-going and negative-going threshold levels.

6

# TYPE TL560C

## PRECISION LEVEL DETECTOR

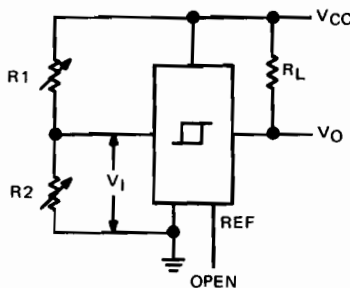
### TYPICAL APPLICATION DATA

After switching occurs, the base current of Q1 increases to a somewhat higher value than just below threshold because of higher Q1 operating currents. Once the positive-going threshold level ( $\approx 3$  V) has been reached, the input voltage must be reduced to the negative-going threshold level ( $\approx 0.6$  V) before switching back to the original state will occur. Figure 3 illustrates the threshold levels of the TL560C. Because the input current increases after the positive-going threshold voltage level has been exceeded, the input voltage will be reduced by an amount dependent on the source resistance. If the reduced input voltage is not below the negative-going threshold voltage level, a stable state will exist. If the source resistance is too high, oscillation or periodic switching may occur.

The positive-going threshold voltage level ( $V_{T+}$ ) is guaranteed to be  $3.00 \pm 0.20$  volts at a  $V_{CC}$  of 5 V. It is also approximately 60% of the supply voltage over the supply voltage range of 2.5 V to 7 V. With a resistor-capacitor network as illustrated in Figure 6, a  $V_{T+}/V_{CC}$  ratio of 60% results in a timed interval of approximately RC seconds, independent of the  $V_{CC}$  level. Since the input current is nominally 2 nA just below the  $V_{T+}$  level, very large values of R and/or large values of C may be used to achieve long-timed intervals. The duration of the timed interval may be greatly increased (at the expense of accuracy) by using a P-N-P transistor as shown in Figure 10 in a capacitance-multiplication technique. The timed interval is, however, sensitive to variations in the  $h_{FE}$  of the P-N-P transistor. Also for any of the timing applications, very-low-leakage capacitors are necessary for accurate operation.

The low input current (30 nA maximum for  $I_{T+}$ ) and high output sink current (160 mA maximum) make the TL560C excellent in applications of interfacing between low-level systems and TTL systems where precision level detection is required. The output is capable of sinking up to a maximum of 160 mA with a TTL-compatible on-state voltage of 0.4 V maximum guaranteed at a sink current of 48 mA. With an appropriate output pull-up resistor ( $R_L \approx 2$  k $\Omega$  to 5 V), a fan-out of approximately 30 Series 74 TTL loads can be accommodated.

In addition to applications interfacing with TTL systems, the TL560C finds application in driving relays, lamps, solenoids, thyristors (SCRs and triacs), and other peripheral devices.



Output turns off when  $V_I \geq V_{T+}$   
Output turns on when  $V_I < V_{T-}$

$$\text{where } V_I = V_{CC} \frac{R_2}{R_1 + R_2}$$

FIGURE 5—BASIC SENSOR CIRCUIT

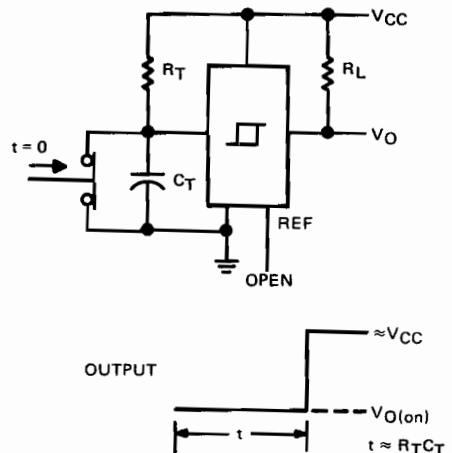


FIGURE 6—BASIC TIMED-INTERVAL CIRCUIT

# TYPE TL560C PRECISION LEVEL DETECTOR

## TYPICAL APPLICATION DATA

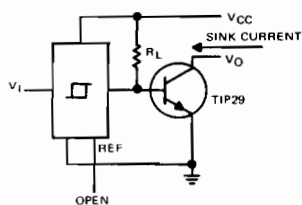


FIGURE 7—EXTERNAL N-P-N TRANSISTOR FOR INCREASING SINK CURRENT

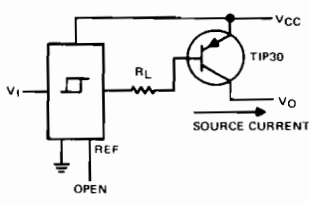


FIGURE 8—EXTERNAL P-N-P TRANSISTOR FOR INCREASING SOURCE CURRENT

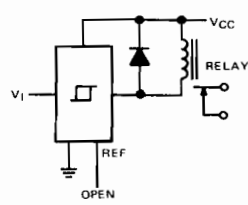


FIGURE 9—RELAY DRIVER

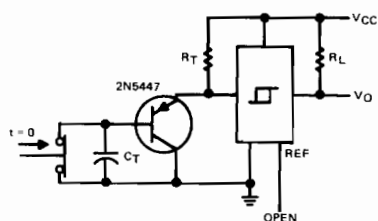


FIGURE 10—LONG-TIMED-INTERVAL CIRCUIT

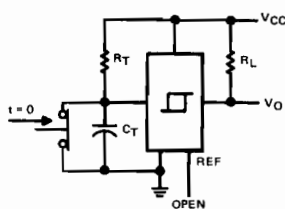
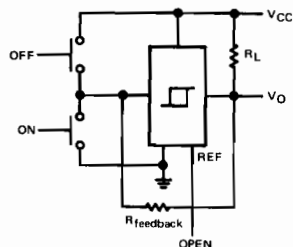


FIGURE 11—BOUNCELESS SWITCH



NOTE A: This circuit can be used as a touch-control switch with  $R_{feedback} \approx 10 \text{ M}\Omega$ .

FIGURE 12—SWITCH WITH TWO STABLE STATES

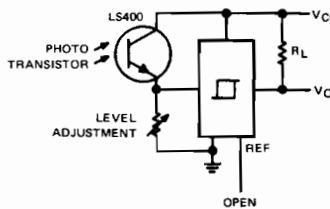


FIGURE 13—LIGHT-LEVEL SENSOR

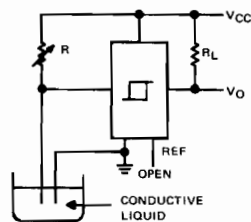


FIGURE 14—LIQUID-LEVEL SENSOR

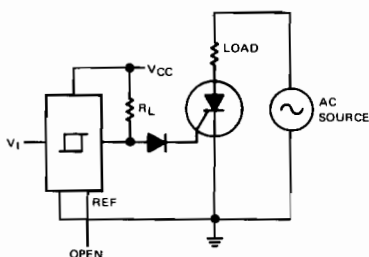


FIGURE 15—THYRISTOR DRIVER CIRCUIT

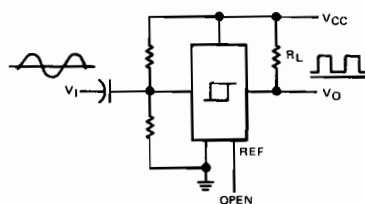


FIGURE 16—SINE-WAVE-TO-SQUARE-WAVE CONVERTER



- Switches  $\pm 10$ -V Analog Signals
- TTL/DTL Logic Capability
- 5- to 30-V Supply Ranges
- Low ( $100 \Omega$ ) On-State Resistance
- High ( $10^{11} \Omega$ ) Off-State Resistance
- 8-Pin Functions

**description**

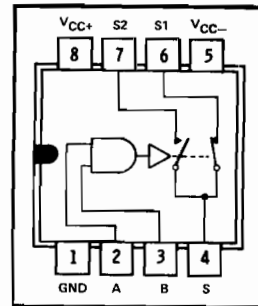
The TL601, TL604, TL607, and TL610 are a family of monolithic P-MOS analog switches that provide fast switching speeds with high  $r_{off}/r_{on}$  ratio and no offset voltage. The p-channel enhancement-type MOS switches will accept analog signals up to  $\pm 10$  volts and are controlled by TTL-compatible logic inputs. The monolithic structure is made possible by BI-MOS technology, which combines p-channel MOS with standard bipolar transistors.

These switches are particularly suited for use in military, industrial, and commercial applications such as data acquisition, multiplexers, A/D and D/A converters, MODEMS, sample-and-hold systems, signal multiplexing, integrators, programmable operational amplifiers, programmable voltage regulators, crosspoint switching networks, logic interface, and many other analog systems.

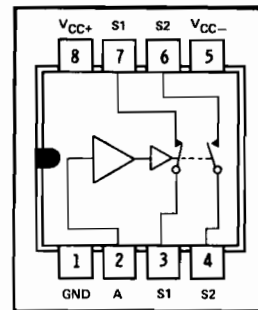
The TL601 is an SPDT switch with two logic control inputs. The TL604 is a dual complementary SPST switch with a single control input. The TL607 is an SPDT switch with one logic control input and one enable input. The TL610 is an SPST switch with three logic control inputs. The TL610 features a higher  $r_{off}/r_{on}$  ratio than the other members of the family.

The TL601M, TL604M, TL607M, and TL610M are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL601I, TL604I, TL607I, and TL610I are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL601C, TL604C, TL607C, and TL610C are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

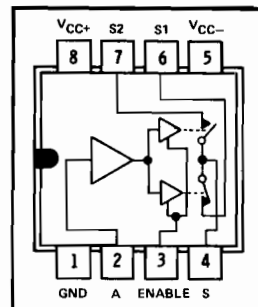
JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW)  
TL601



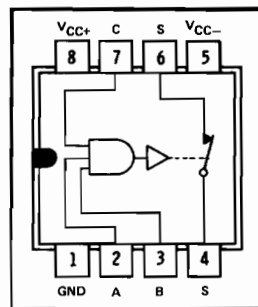
TL604



TL607

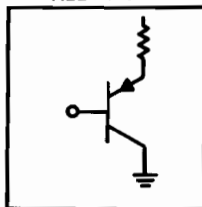


TL610

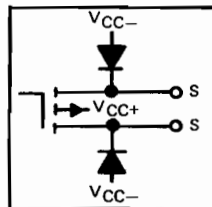


Switch positions shown are for all inputs high.

TYPICAL OF  
ALL INPUTS

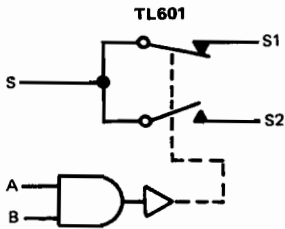


TYPICAL OF  
ALL SWITCHES



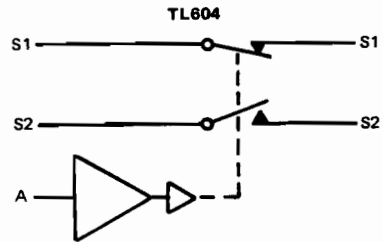
# TYPES TL601, TL604, TL607, TL610

## P-MOS ANALOG SWITCHES



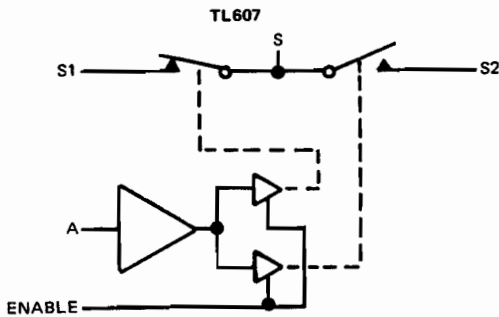
FUNCTION TABLE

LOGIC INPUTS		ANALOG SWITCH	
A	B	S1	S2
L	X	OFF (OPEN)	ON (CLOSED)
X	L	OFF (OPEN)	ON (CLOSED)
H	H	ON (CLOSED)	OFF (OPEN)



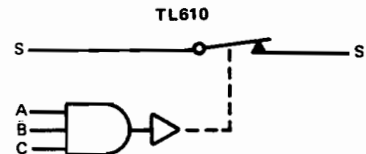
FUNCTION TABLE

LOGIC INPUT	ANALOG SWITCH	
A	S1	S2
H	ON (CLOSED)	OFF (OPEN)
L	OFF (OPEN)	ON (CLOSED)



FUNCTION TABLE

INPUTS		ANALOG SWITCH	
A	ENABLE	S1	S2
X	L	OFF (OPEN)	OFF (OPEN)
L	H	OFF (OPEN)	ON (CLOSED)
H	H	ON (CLOSED)	OFF (OPEN)



FUNCTION TABLE

INPUTS			ANALOG SWITCH
A	B	C	S
L	X	X	OFF (OPEN)
X	L	X	OFF (OPEN)
X	X	L	OFF (OPEN)
H	H	H	ON (CLOSED)

H = high logic level

L = low logic level

X = irrelevant

Switch positions shown are for all inputs high.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	30 V
Supply voltage, $V_{CC-}$	-30 V
$V_{CC+}$ to $V_{CC-}$ supply voltage differential	35 V
Control input voltage	$V_{CC+}$
Switch off-state voltage	30 V
Switch on-state current	10 mA
Operating free-air temperature range: TL601M, TL604M, TL607M, TL610M	-55°C to 125°C
TL601I, TL604I, TL607I, TL610I	-25°C to 85°C
TL601C, TL604C, TL607C, TL610C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

NOTE 1: All voltage values are with respect to network ground terminal.

# TYPES TL601, TL604, TL607, TL610 P-MOS ANALOG SWITCHES

## recommended operating conditions

	TL601M, TL604M TL607M, TL610M			TL601I, TL604I TL607I, TL610I			TL601C, TL604C TL607C, TL610C			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
	Supply voltage, $V_{CC+}$ (see Figure 1)	5	10	25	5	10	25	5	10	
Supply voltage, $V_{CC-}$ (see Figure 1)	-5	-20	-25	-5	-20	-25	-5	-20	-25	V
$V_{CC+}$ to $V_{CC-}$ supply voltage differential (see Figure 1)	15		30	15		30	15		30	V
Control input voltage	0		5.5	0		5.5	0		5.5	V
Switch on-state current			10			10			10	mA
Operating free-air temperature, $T_A$	-55		125	-25		85	0		70	°C

Figure 1 shows power supply boundary conditions for proper operation of the TL601 Series. The range of operation for supply  $V_{CC+}$  from +5 V to +25 V is shown on the vertical axis. The range of supply  $V_{CC-}$  from -5 V to -25 V is shown on the horizontal axis. A recommended 30-volt maximum voltage differential from  $V_{CC+}$  to  $V_{CC-}$  governs the maximum  $V_{CC+}$  for a chosen  $V_{CC-}$  (or vice versa). A minimum recommended difference of 15 volts from  $V_{CC+}$  to  $V_{CC-}$  and the boundaries shown in Figure 1 allow the designer to select the proper combinations of the two supplies.

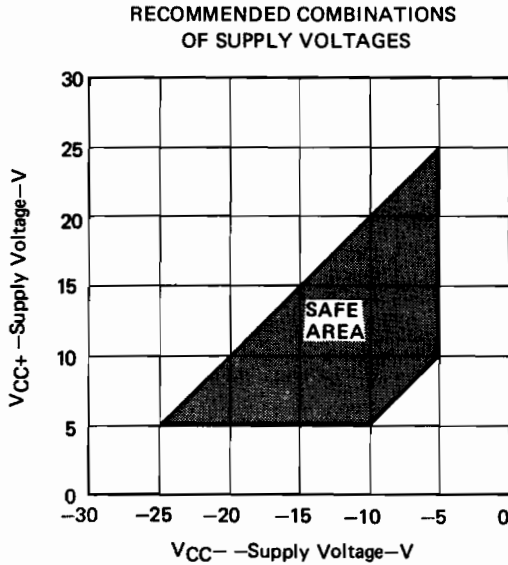


FIGURE 1

# TYPES TL601, TL604, TL607, TL610

## P-MOS ANALOG SWITCHES

electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC+} = 10\text{ V}$ ,  $V_{CC-} = -20\text{ V}$ , analog switch test current = 1 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL6--M TL6--I			TL6--C			UNIT	
		MIN	TYP‡	MAX	MIN	TYP‡	MAX		
$V_{IH}$ High-level input voltage		2			2			V	
$V_{IL}$ Low-level input current	Enable input of TL607M	0.6						V	
	All other inputs	0.8			0.8				
$I_{IH}$ High-level input current	$V_I = 5.5\text{ V}$	0.5 10			0.5 10			$\mu\text{A}$	
$I_{IL}$ Low-level input current	$V_I = 0.4\text{ V}$	-50 -250			-50 -250			$\mu\text{A}$	
$I_{off}$ Switch off-state current	$V_{I(sw)} = -10\text{ V}$ , See Note 2	$T_A = 25^\circ\text{C}$	-400 -800			-500 -1000			$\mu\text{A}$
		$T_A = \text{MAX}$	-50 -100			-10 -20			nA
$r_{on}$ Switch on-state resistance	$V_{I(sw)} = 10\text{ V}$ , $I_{O(sw)} = -1\text{ mA}$	TL601							$\Omega$
		TL604	55 100			75 200			
	TL607								
	TL610	40 80			40 100				
	$V_{I(sw)} = -10\text{ V}$ , $I_{O(sw)} = -1\text{ mA}$	TL601							
		TL604	220 400			220 600			
		TL607							
		TL610	120 300			120 400			
$r_{off}$ Switch off-state resistance		$1 \times 10^{11}$			$5 \times 10^{10}$			$\Omega$	
$C_{on}$ Switch on-state input capacitance	$V_{I(sw)} = 0\text{ V}$ , $f = 1\text{ MHz}$	16			16			pF	
$C_{off}$ Switch off-state input capacitance	$V_{I(sw)} = 0\text{ V}$ , $f = 1\text{ MHz}$	8			8			pF	
$I_{CC+}$ Supply current from $V_{CC+}$	Logic input(s) at 5.5 V, All switch terminals open	TL601	5 10			5 10			mA
		TL604							
		Enable input high	5 10			5 10			
		Enable input low	3 5			3 5			
		TL610	5 10			5 10			
$I_{CC-}$ Supply current from $V_{CC-}$	Logic input(s) at 5.5 V, All switch terminals open	TL601	-1.2 -2.5			-1.2 -2.5			mA
		TL604							
		Enable input high	-2.5 -5			-2.5 -5			
		Enable input low	-0.05 -0.5			-0.05 -0.5			
		TL610	-1.2 -2.5			-1.2 -2.5			

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡All typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 2: The other terminal of the switch under test is at  $V_{CC+} = 10\text{ V}$ .

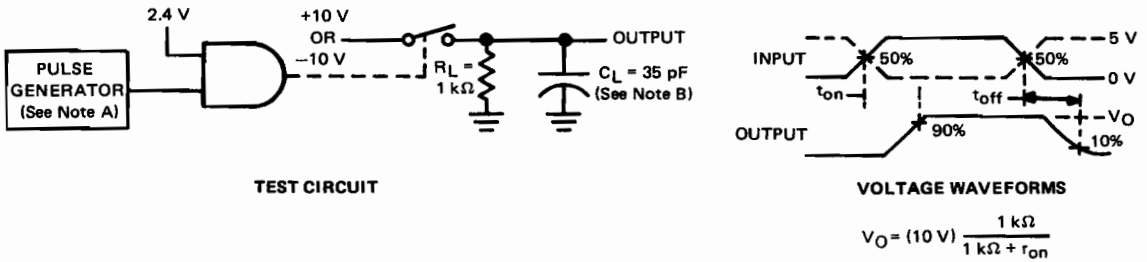
switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{CC-} = -20\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{off}$ Switch turn-off time	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ , See Figure 2	400 500			ns
$t_{on}$ Switch turn-on time		100 150			



# TYPES TL601, TL604, TL607, TL610 P-MOS ANALOG SWITCHES

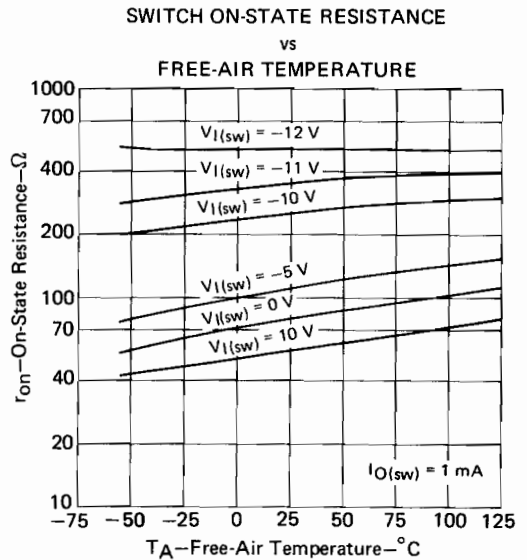
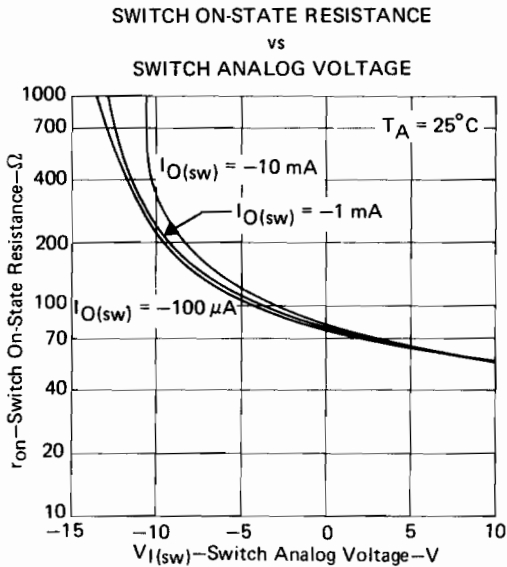
## PARAMETER MEASUREMENT INFORMATION



NOTES: A. The pulse generator has the following characteristics:  $Z_{out} = 50 \Omega$ ,  $t_r = 15 \text{ ns}$ ,  $t_f = 15 \text{ ns}$ ,  $t_w = 500 \text{ ns}$ .  
B.  $C_L$  includes probe and jig capacitance.

FIGURE 2

## TYPICAL CHARACTERISTICS





# LINEAR INTEGRATED CIRCUITS

# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

BULLETIN NO. DL-S 11415, NOVEMBER 1970—REVISED OCTOBER 1979

- 200 MHz Bandwidth
- 250 k $\Omega$  Input Resistance
- Selectable Nominal Amplification of 10, 100, or 400
- No Frequency Compensation Required
- Designed to be Interchangeable with Fairchild  $\mu$ A733M and  $\mu$ A733C

## description

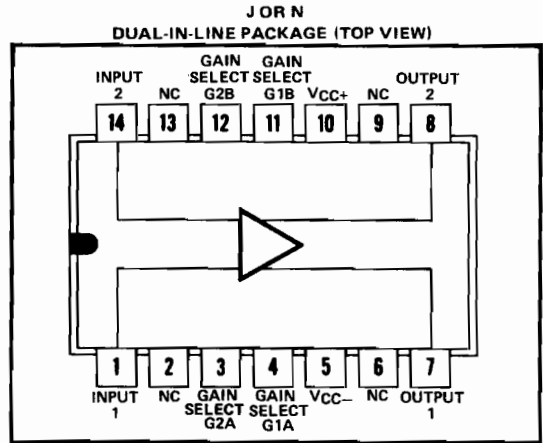
The  $\mu$ A733 is a monolithic two-stage video amplifier with differential inputs and differential outputs.

Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

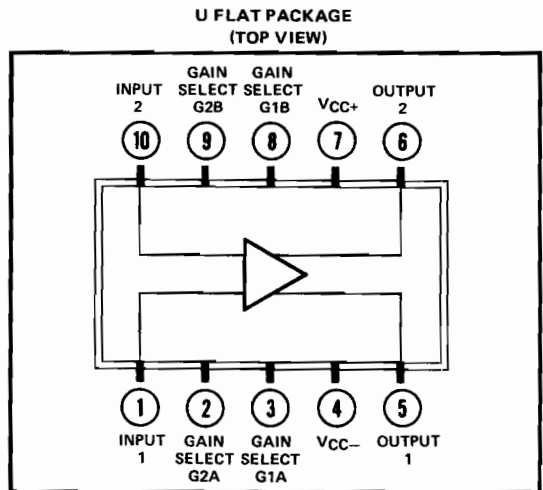
Fixed differential amplification of 10, 100, or 400 may be selected without external components, or amplification may be adjusted from 10 to 400 by the use of a single external resistor connected between G1A and G1B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disc-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

The  $\mu$ A733M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A733C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



NC—No internal connection



6

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A733M	$\mu$ A733C	UNIT
Supply voltage $V_{CC+}$ (See Note 1)	8	8	V
Supply voltage $V_{CC-}$ (See Note 1)	-8	-8	V
Differential input voltage	$\pm 5$	$\pm 5$	V
Common-mode input voltage	$\pm 6$	$\pm 6$	V
Output current	10	10	mA
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 2)	500	500	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature $1/16$ inch (1,6 mm) from case for 60 seconds	J or U package		$300$
Lead temperature $1/16$ inch (1,6 mm) from case for 10 seconds	N package		$260$

- NOTES: 1. All voltage values, except differential input voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
2. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Table. In the J package,  $\mu$ A733M chips are alloy-mounted;  $\mu$ A733C chips are glass-mounted.

# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	500 mW	11.0 mW/°C	105°C
J (Glass-Mounted Chip)	500 mW	8.2 mW/°C	89°C
N	500 mW	9.2 mW/°C	96°C
U	500 mW	5.4 mW/°C	57°C

Also see Dissipation Derating Curves, Section 2.

electrical characteristics,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN† SELECT	$\mu$ A733M			$\mu$ A733C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$A_{VD}$ Large-signal differential voltage amplification	1	$V_{OD} = 1\text{ V}$	1	300	400	500	250	400	600	
			2	90	100	110	80	100	120	
			3	9	10	11	8	10	12	
BW Bandwidth	2	$R_S = 50\ \Omega$	1	50			50			MHz
			2	90			90			
			3	200			200			
$I_{IO}$ Input offset current			Any	0.4		3	0.4		5	$\mu\text{A}$
$I_{IB}$ Input bias current			Any	9		20	9		30	$\mu\text{A}$
$V_{ICR}$ Common-mode input voltage range	1		Any	$\pm 1$			$\pm 1$			V
$V_{OC}$ Common-mode output voltage	1		Any	2.4	2.9	3.4	2.4	2.9	3.4	V
$V_{OO}$ Output offset voltage	1		1	0.6		1.5	0.6		1.5	V
			2 & 3	0.35		1	0.35		1.5	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	1		Any	3	4.7		3	4.7		V
$r_i$ Input resistance	3	$V_{OD} < 1\text{ V}$	1	4			4			k $\Omega$
			2	20	24		10	24		
			3	250			250			
$r_o$ Output resistance				20			20			$\Omega$
$C_i$ Input capacitance	3	$V_{OD} < 1\text{ V}$	2	2			2			pF
CMRR Common-mode rejection ratio	4	$V_{IC} = \pm 1\text{ V}$ , $V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$ $f = 5\text{ MHz}$	2	60	86		60	86		dB
			2	70			70			
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	1	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50	70		50	70		dB
$V_n$ Broadband equivalent input noise voltage	5	BW = 1 kHz to 10 MHz	Any	12			12			$\mu\text{V}$
$t_{pd}$ Propagation delay time	2	$R_S = 50\ \Omega$ , Output voltage step = 1 V	1	7.5			7.5			ns
			2	6.0	10		6.0	10		
			3	3.6			3.6			
$t_r$ Rise time	2	$R_S = 50\ \Omega$ , Output voltage step = 1 V	1	10.5			10.5			ns
			2	4.5	10		4.5	12		
			3	2.5			2.5			
$I_{sink(max)}$ Maximum output sink current			Any	2.5	3.6		2.5	3.6		mA
$I_{CC}$ Supply current		No load, no signal	Any	16	24		16	24		mA

† The gain selection is made as follows:

Gain 1 . . . Gain Select pin G1A is connected to pin G1B, and pins G2A and G2B are open.

Gain 2 . . . Gain Select pin G1A and pin G1B are open, pin G2A is connected to pin G2B.

Gain 3 . . . All four gain-select pins are open.

# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

electrical characteristics (continued),  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
 $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$  for  $\mu$ A733M,  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for  $\mu$ A733C

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN <sup>†</sup> SELECT	$\mu$ A733M		$\mu$ A733C		UNIT
				MIN	MAX	MIN	MAX	
$A_{VD}$ Large-signal differential voltage amplification	1	$V_{OD} = 1\text{ V}$	1	200	600	250	600	
			2	80	120	80	120	
			3	8	12	8	12	
$I_{IO}$ Input offset current			Any		5		6	$\mu\text{A}$
$I_{IB}$ Input bias current			Any		40		40	$\mu\text{A}$
$V_{ICR}$ Common-mode input voltage range	1		Any	$\pm 1$		$\pm 1$		V
$V_{OO}$ Output offset voltage	1		1		1.5		1.5	V
			2 & 3		1.2		1.5	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	1		Any	2.5		2.8		V
$r_i$ Input resistance	3	$V_{OD} < 1\text{ V}$	2	8		8		$\text{k}\Omega$
CMRR Common-mode rejection ratio	4	$V_{IC} = \pm 1\text{ V}$ , $f < 100\text{ kHz}$	2	50		50		dB
		$V_{IC} = \pm 1\text{ V}$ , $f = 5\text{ MHz}$	2					
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	1	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50		50		dB
$I_{\text{sink(max)}}$ Maximum output sink current			Any	2.2		2.5		mA
$I_{CC}$ Supply current		No load, No signal	Any		27		27	mA

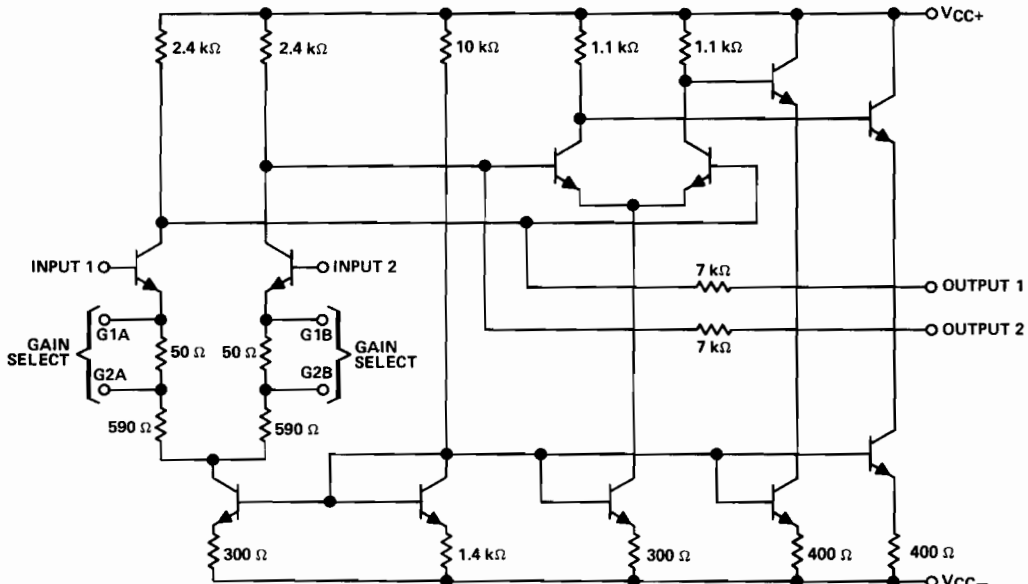
<sup>†</sup>The gain selection is made as follows:

Gain 1 ... Gain Select pin G1A is connected to pin G1B, and pins G2A and G2B are open.

Gain 2 ... Gain Select pin G1A and pin G1B are open, pin G2A is connected to pin G2B.

Gain 3 ... All four gain-select pins are open.

## schematic



Component values shown are nominal.

# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

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### DEFINITION OF TERMS

**Large-Signal Differential Voltage Amplification ( $A_{VD}$ )** The ratio of the change in voltage between the output terminals to the change in voltage between the input terminals producing it.

**Bandwidth (BW)** The range of frequencies within which the differential gain of the amplifier is not more than 3 dB below its low-frequency value.

**Input Offset Current ( $I_{IO}$ )** The difference between the currents into the two input terminals with the inputs grounded.

**Input Bias Current ( $I_{IB}$ )** The average of the currents into the two input terminals with the inputs grounded.

**Input Voltage Range ( $V_I$ )** The range of voltage that if exceeded at either input terminal will cause the amplifier to cease functioning properly.

**Common-Mode Output Voltage ( $V_{OC}$ )** The average of the d-c voltages at the two output terminals.

**Output Offset Voltage ( $V_{OO}$ )** The difference between the d-c voltages at the two output terminals when the input terminals are grounded.

**Maximum Peak-to-Peak Output Voltage Swing ( $V_{OPP}$ )** The maximum peak-to-peak output voltage swing that can be obtained without clipping. This includes the unbalance caused by output offset voltage.

**Input Resistance ( $r_i$ )** The resistance between the input terminals with either input grounded.

**Output Resistance ( $r_o$ )** The resistance between either output terminal and ground.

**Input Capacitance ( $C_i$ )** The capacitance between the input terminals with either input grounded.

**Common-Mode Rejection Ratio (CMRR)** The ratio of differential voltage amplification to common-mode voltage amplification. This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

**Supply Voltage Rejection Ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )** The absolute value of the ratio of the change in power supply voltages to the change in input offset voltage. For these devices, both supply voltages are varied symmetrically.

**Equivalent Input Noise Voltage ( $V_n$ )** The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

**Propagation Delay Time ( $t_{pd}$ )** The interval between the application of an input voltage step and its arrival at either output, measured at 50% of the final value.

**Rise Time ( $t_r$ )** The time required for an output voltage step to change from 10% to 90% of its final value.

**Maximum Output Sink Current ( $I_{sink(max)}$ )** The maximum available current into either output terminal when that output is at its most negative potential.

**Supply Current ( $I_{CC}$ )** The average of the magnitudes of the two supply currents  $I_{CC1}$  and  $I_{CC2}$ .

# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

## PARAMETER MEASUREMENT INFORMATION

test circuits

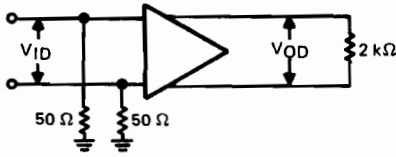


FIGURE 1

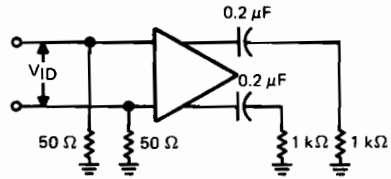


FIGURE 2

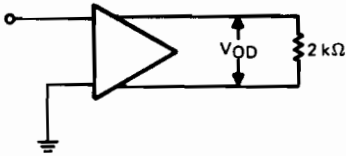


FIGURE 3

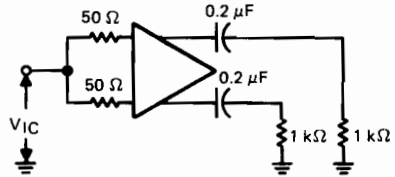


FIGURE 4

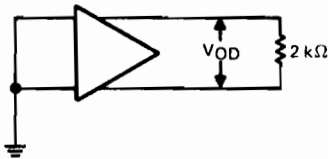
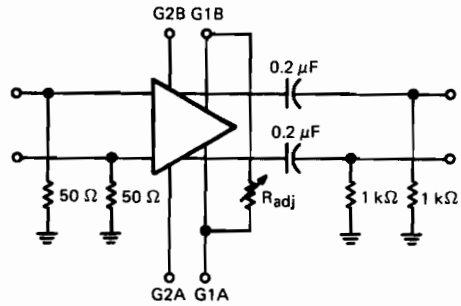


FIGURE 5



VOLTAGE AMPLIFICATION ADJUSTMENT

FIGURE 6

## TYPICAL CHARACTERISTICS

PHASE SHIFT  
vs  
FREQUENCY

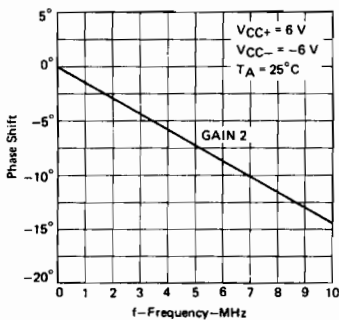


FIGURE 7

PHASE SHIFT  
vs  
FREQUENCY

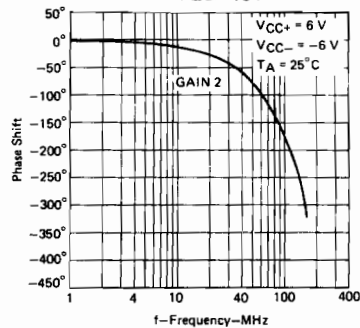


FIGURE 8

# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

### TYPICAL CHARACTERISTICS

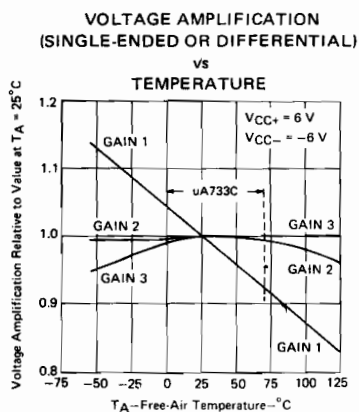


FIGURE 9

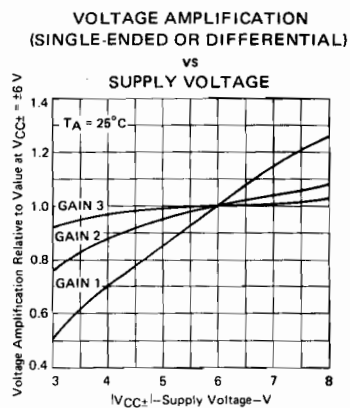


FIGURE 10

DIFFERENTIAL VOLTAGE AMPLIFICATION  
VS  
RESISTANCE BETWEEN G1A AND G1B

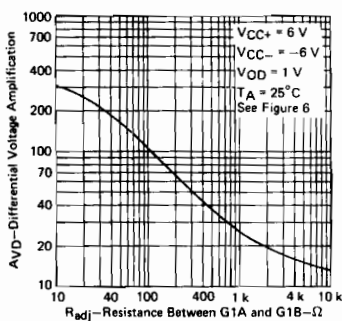


FIGURE 11

SINGLE-ENDED VOLTAGE AMPLIFICATION  
VS  
FREQUENCY

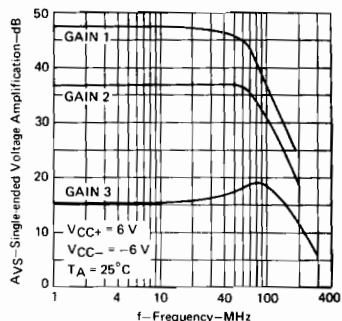


FIGURE 12

SUPPLY CURRENT  
VS  
FREE-AIR TEMPERATURE

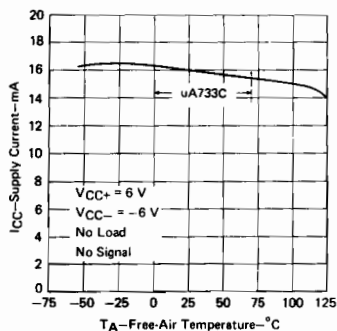


FIGURE 13

SUPPLY CURRENT  
VS  
SUPPLY VOLTAGE

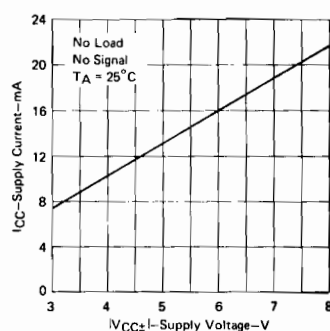


FIGURE 14



# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

## TYPICAL CHARACTERISTICS

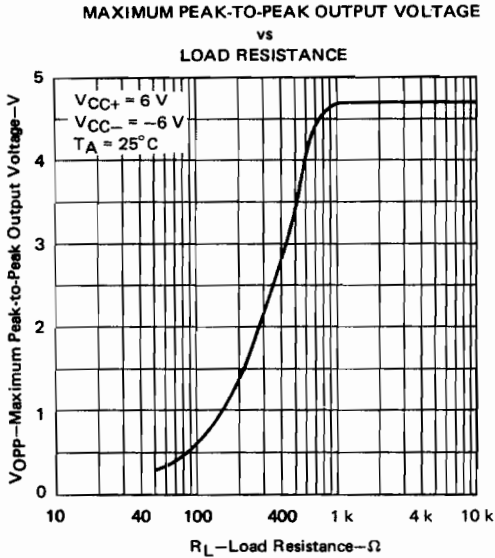


FIGURE 15

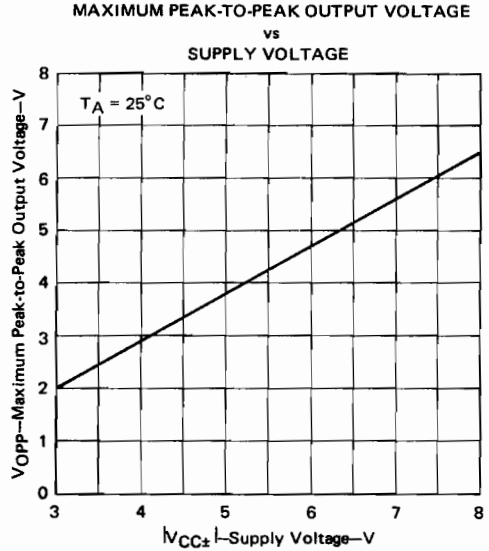


FIGURE 16

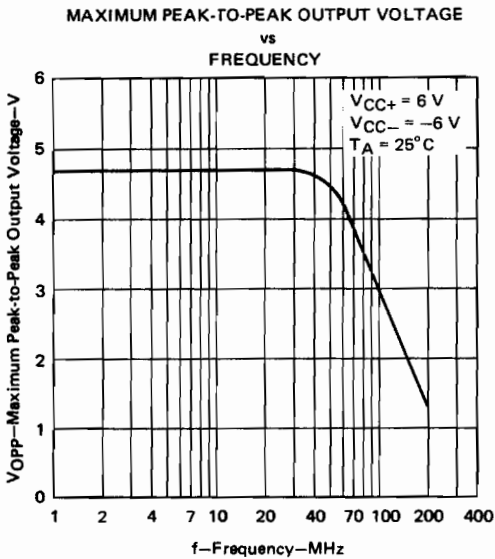


FIGURE 17

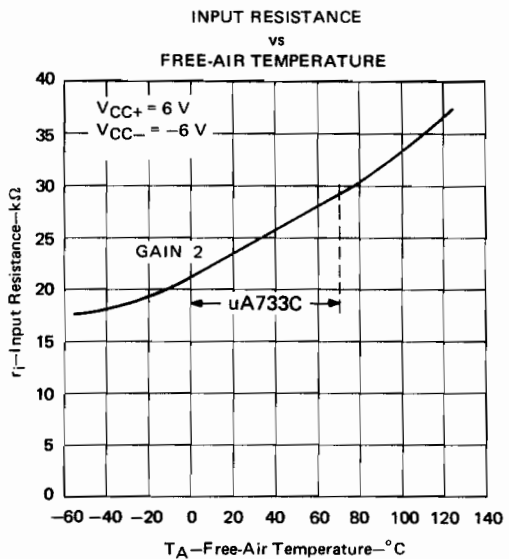


FIGURE 18

# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

### TYPICAL CHARACTERISTICS

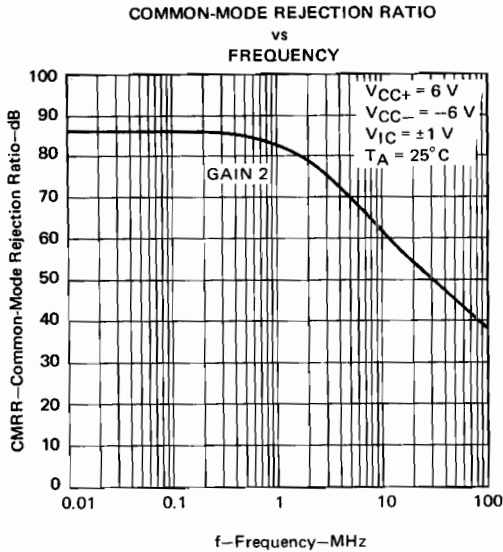


FIGURE 19

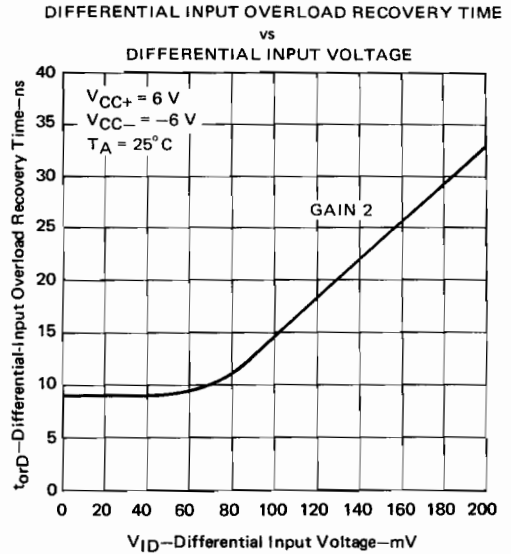


FIGURE 20

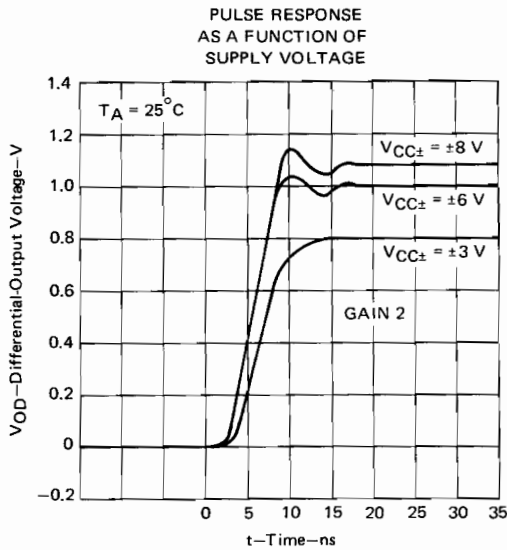


FIGURE 21

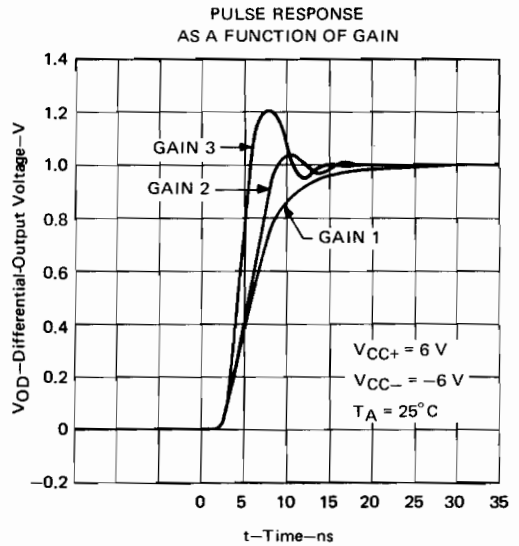
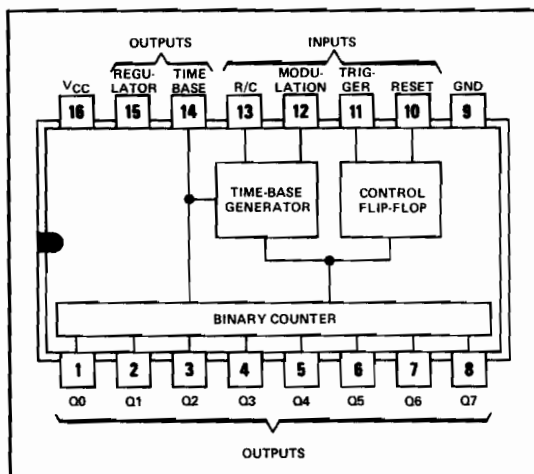


FIGURE 22

- Accurate Timing from Microseconds to Days
- Programmable Delays from 1 Time Constant to 255 Time Constants
- Outputs Compatible with TTL, DTL, CMOS
- Wide Supply-Voltage Range
- External Sync and Modulation Capability

$\mu$ A2240C . . . J OR N  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

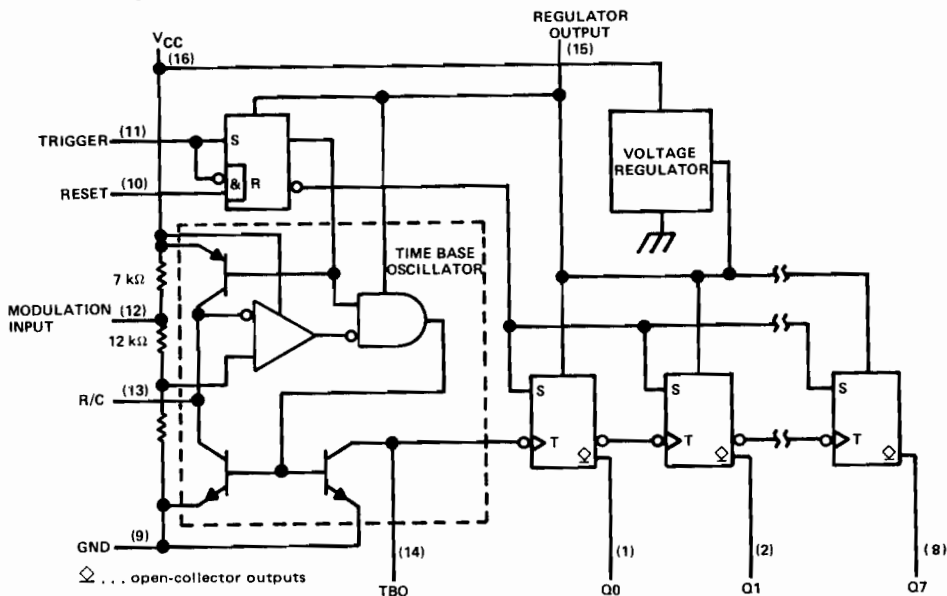
These circuits consist of a time-base oscillator, an eight-bit counter, a control flip-flop, and a voltage regulator. The frequency of the time-base oscillator is set by the time constant of an external resistor and capacitor at pin 13 and can be synchronized or modulated by signals applied to the modulation input. The output of the time-base section is applied directly to the input of the counter section and also appears at pin 14 (time base). The time-base pin may be used to monitor the frequency of the oscillator, to provide an output pulse to other circuitry, or (with the time-base section disabled) to drive the counter input from an external source. The counter input is activated on a negative-going transition. The reset input stops the time-base oscillator and sets each binary output, Q0 through Q7, and the time-base output to a TTL high level. After resetting, the trigger input starts the oscillator and all Q outputs go low. Once triggered, the  $\mu$ A2240 will ignore any signals at the trigger input until it is reset.

The  $\mu$ A2240C timer/counter may be operated in the free-running mode or with output-signal feedback to the reset input for automatic reset. Two or more binary outputs may be connected together to generate complex pulse patterns, or each output may be used separately to provide eight output frequencies. Using two circuits in cascade can provide precise time delays of up to three years.

The  $\mu$ A2240C is intended for operation from 0°C to 70°C.

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

functional block diagram



## absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Output voltage: Q0 thru Q7	18 V
Output current: Q0 thru Q7	10 mA
Regulator output current	-5 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2): J package	750 mW
N package	650 mW
Operating free-air temperature range	0°C to 70°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: J Package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: N Package	260°C

- NOTES: 1. Voltage values are with respect to the network ground terminal.  
2. For operation above 25°C, see the Dissipation Derating Table. In the J package  $\mu$ A2240C chips are glass-mounted.

## recommended operating conditions

	$\mu$ A2240C			UNIT
	MIN	NOM	MAX	
Supply voltage, $V_{CC}$ (see Note 3)	4		15	V
Timing resistor	0.001		10	M $\Omega$
Timing capacitor	0.01		1000	$\mu$ F
Counter input frequency (Pin 14)		1.5		MHz
Pull-up resistor, time-base output		20		k $\Omega$
Trigger and reset input pulse voltage	2	3		V
Trigger and reset input pulse width	2			$\mu$ s
External clock input pulse voltage	3			V
External clock input pulse width	1			$\mu$ s

NOTE 3: For operation with  $V_{CC} < 4.5$  V, short regulator output to  $V_{CC}$ .

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

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

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	$\mu$ A2240C			UNIT
			MIN	TYP	MAX	
Regulator output voltage	1	$V_{CC} = 5V$ , Trigger and reset open or grounded	3.9	4.4		V
	2	$V_{CC} = 15V$ , Trigger and reset open or grounded	5.8	6.3	6.8	
Modulation input open-circuit voltage	1	$V_{CC} = 5V$ , Trigger and reset open or grounded	2.8	3.5	4.2	V
	1	$V_{CC} = 15V$ , Trigger and reset open or grounded		10.5		
Trigger threshold voltage	1	$V_{CC} = 5V$ , Reset at 0 V		1.4	2	V
High-level trigger current	1	$V_{CC} = 5V$ , Trigger at 2 V, Reset at 0 V		10		$\mu$ A
Reset threshold voltage	1	$V_{CC} = 5V$ , Trigger at 0 V		1.4	2	V
High-level reset current	1	$V_{CC} = 5V$ , Trigger at 0 V		10		$\mu$ A
Counter input (time base) threshold voltage	2	$V_{CC} = 5V$ , Trigger and reset open or grounded	1	1.4		V
Low-level output current, Q0 thru Q7	2	$V_{CC} = 5V$ , $V_{OL} < 0.4V$ , Trigger at 2 V, Reset at 0 V,	2	4		mA
	2	$V_{OH} = 15V$ , Reset at 2 V, Trigger at 0 V		0.01	15	
Supply current	1	$V_{CC} = 5V$ , Trigger at 0 V, Reset at 5 V		4	7	mA
	1	$V_{CC} = 15V$ , Trigger at 0 V, Reset at 5 V		13	18	
	3	$V_{+} = 4V$		1.5		

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

PARAMETER	TEST CIRCUIT	TEST CONDITIONS†	$\mu$ A2240C			UNIT
			MIN	TYP	MAX	
Initial error of time base‡	1	$V_{CC} = 5V$ , Trigger at 5 V, Reset at 0 V		$\pm 0.5$	$\pm 5$	%
Temperature coefficient of time-base period	1	$T_A = 0^{\circ}C$ to $70^{\circ}C$ $V_{CC} = 5V$ $V_{CC} = 15V$		-200		ppm/°C
Supply voltage sensitivity of time-base period	1	$V_{CC} > 8V$		-0.08	-0.3	%/V
Time-base output frequency	1	$V_{CC} = 5V$ , R = MIN, C = MIN		130		kHz
Propagation delay time		From trigger input		1		
Output rise time		From reset input		0.8		$\mu$ s
	Output fall time	Q0 thru Q7		180		
	2	$R_L = 3k\Omega$ , $C_L = 10pF$		180		ns

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ This is the time-base period error due only to the  $\mu$ A2240 and expressed as a percentage of nominal (1.00 RC).

NOTE 4: Propagation delay time is measured from the 50% point on the leading edge of an input pulse to the 50% point on the leading edge of the resulting change of state at Q0.

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

## PARAMETER MEASUREMENT INFORMATION

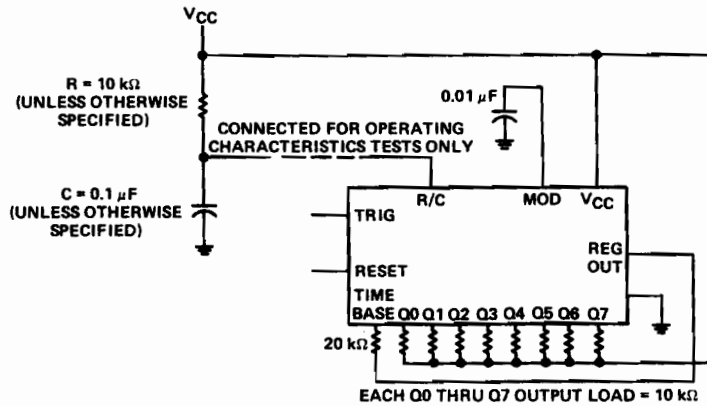


FIGURE 1—GENERAL TEST CIRCUIT

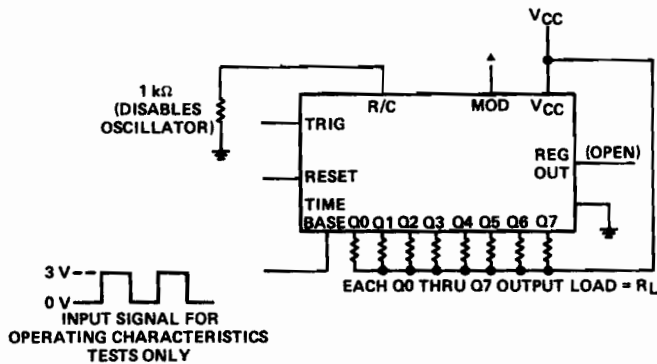


FIGURE 2—COUNTER TEST CIRCUIT

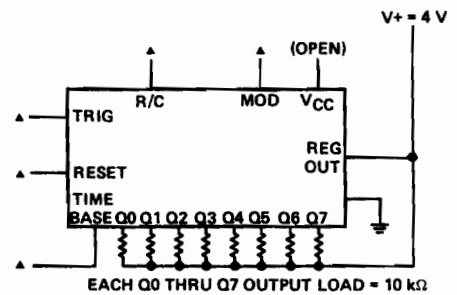


FIGURE 3—REDUCED-POWER TEST CIRCUIT  
(TIME BASE DISABLED)

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Glass-Mounted Chips)	750 mW	8.2 mW/°C	58°C
N	650 mW	9.2 mW/°C	79°C

Also see Dissipation Derating Curves, Section 2.

^These connections maybe open or grounded for this test.

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

## TYPICAL CHARACTERISTICS

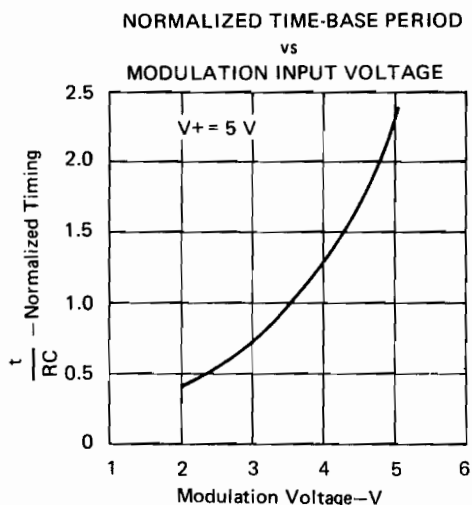


FIGURE 4

## TYPICAL APPLICATION INFORMATION

Figure 5 shows voltage waveforms for typical operation of the  $\mu$ A2240. If both reset and trigger inputs are low during power-up, the timer/counter will be in a reset state with all binary (Q) outputs high and the oscillator stopped. In this state, a high level on the trigger input starts the time-base oscillator. The initial negative-going pulse from the oscillator sets the Q outputs to low logic levels at the beginning of the first time-base period. The  $\mu$ A2240 will ignore any further signals at the trigger input until after a reset signal is applied to the reset input. With the trigger input low, a high level at the reset input will set Q outputs high and stop the time-base oscillator. If the reset signal occurs while the trigger input is high, the reset is ignored. If the reset input remains high when the trigger input goes low, the  $\mu$ A2240 will reset.

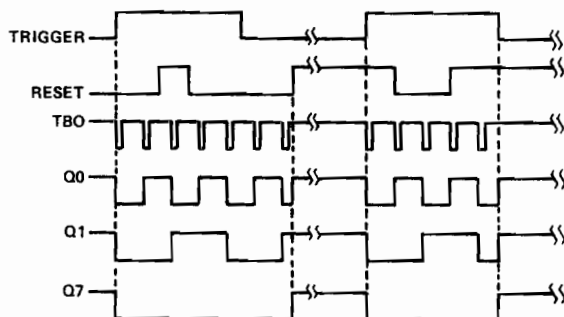


FIGURE 5—TIMING DIAGRAM OF  
OUTPUT WAVEFORMS

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

## TYPICAL APPLICATION INFORMATION

In monostable applications of the  $\mu$ A2240 one or more of the binary outputs will be connected to the reset terminal as shown in Figure 6. The binary outputs are open-collector stages that can be connected together to a common pull-up resistor to provide a "wired-OR" function. The combined output will be low as long as any one of the outputs is low. This type of arrangement can be used for time delays that are integer multiples of the time-base period. For example, if Q5 ( $2^5 = 32$ ) only is connected to the reset input, every trigger pulse will generate a 32-period active-low output. Similarly, if Q0, Q4, and Q5 are connected to reset, each trigger pulse creates a 49-period delay.

In astable operation, the  $\mu$ A2240 will free-run from the time it is triggered until it receives an external reset signal.

The period of the time-base oscillator is equal to the RC time constant of an external resistor and capacitor connected as shown in Figure 6 when the modulation input is open (approximately 3.5 volts internal, see Figure 4). Under conditions of high supply voltage ( $V_{CC} > 7$  V) and low value of timing capacitor ( $C < 0.1 \mu\text{F}$ ), the pulse width of the time-base oscillator may be too short to properly trigger the counters. This situation can be corrected by adding a 300-picofarad capacitor between the time-base output and ground. The time-base output (TBO) is an open-collector output that requires a 20-k $\Omega$  pull-up resistor to Pin 15 for proper operation. The time-base pin may also be used as an input to the counters for an external time-base or as an active-low inhibit input to interrupt counting without resetting.

The modulation input varies the ratio of the time-base period to the RC time constant as a function of the dc bias voltage (see Figure 4). It can also be used to synchronize the timer/counter to an external clock or sync signal.

The regulator output is used internally to drive the binary counters and the control logic. This terminal can also be used to supply voltage to additional  $\mu$ A2240 devices to minimize power dissipation when several timer circuits are cascaded. For circuit operation with an external clock, the regulator output can be used as the  $V_{CC}$  input terminal to power down the internal time base and reduce power dissipation. When supply voltages less than 4.5 volts are used with the internal time base, Pin 15 should be shorted to Pin 16.

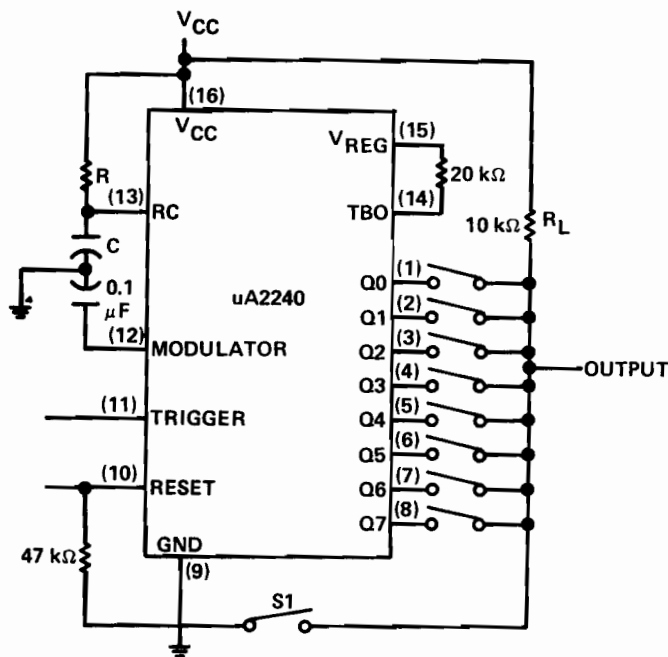


FIGURE 6—BASIC CONNECTIONS FOR  
TIMING APPLICATIONS



# **Military Products**



## MIL-M 38510 AND MIL-STD-883 MILITARY HIGH-RELIABILITY INTEGRATED CIRCUITS

The Texas Instruments MIL-M-38510 and MIL-STD-883 programs offer a variety of options designed to meet contractual, reliability, and cost goals. MIL-M-38510 and MIL-STD-883 have been fully implemented to provide a broad product line of control circuits for both military original equipment and logistic requirements. Included in this section is a complete cross reference from the JAN part number to the corresponding standard catalog part number for ease in locating the commercial equivalent. A cross reference from the catalog number to the JAN slash sheet number is also included.

When system designs require military-class circuits and no slash-sheet specification exists, the T1/883 or MIL-M-38510 JAN-processed program is recommended as a cost-effective substitute for nonstandard program drawings or specifications.

As an aid to predicting system reliability performance, the following is the estimated quality factor,  $\pi_Q$ , for Texas Instruments Linear Circuits processed to the options outlined in Table IV.

TABLE I  
STANDARD-PROCESS PROGRAM QUALITY LEVELS

OPTION		$\pi_Q$
JAN MIL-M-38510	CLASS B	2
JAN-PROCESSED (SNJ)	CLASS B	3
JAN-PROCESSED (/883)	CLASS B	3
STANDARD HERMETIC		10

The documents listed below (see Note 1) establish the processing for quality and reliability assurance requirements for JAN integrated circuits. The detail requirements of each individual JAN device are specified in the slash sheets.

MIL-M-38510/XXX, Microcircuits, Digital, Linear  
Monolithic Silicon (Slash Sheets)

MIL-M-38510, Microcircuits, General Specification for  
MIL-STD-883, Test Methods and Procedure for Microelectronics  
QPL-38510, Qualified Products List for MIL-M-38510

NOTE 1: Copies of these documents may be requested from the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120.

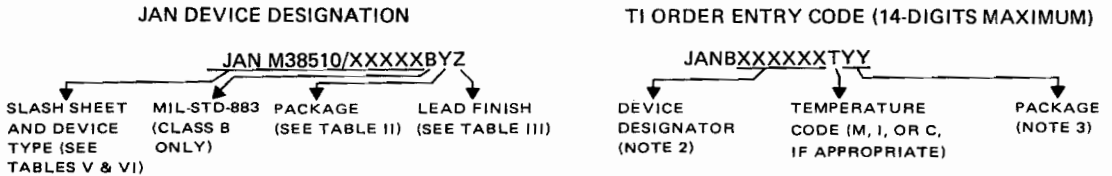
# MILITARY PRODUCTS

## MILITARY HIGH-REL PRODUCTS

### 1. JAN MIL-M-38510 CLASS B PRODUCT

These devices will be manufactured to the full requirements of the appropriate MIL-M-38510 slash sheet in DESC-approved domestic production facilities. The TI Linear Department is supplying only Class B product (see Table V).

#### A. Ordering Information:



Examples: JAN M38510/10101BHB ..... JANBUA741MU  
 JAN M38510/10303BPB ..... JANBLM106JG  
 JAN M38510/10401BCB ..... JANB55107J  
 JAN M38510/11004BFB ..... JANBRM4136W

#### B. Symbolization:

JM38510/XXXXXY  
 TI Symbol (Trade Mark)  
 4-Digit Date Code

**TABLE II**  
**JAN AND TI PACKAGE CODE DESIGNATIONS AND LEAD-FINISH AVAILABILITY**

JAN PACKAGE CODE	TI PACKAGE CODE	DESCRIPTION	JAN CODE AVAILABLE LEAD FINISH	38510 APP. C
A	NOT AVAIL.	14-PIN F/P 1/4" X 1/4"		F-1
B/T†	T	14-PIN F/P 3/16" X 1/4"	C/D†	F-3
C	J	14-PIN C DIP	B	D-1
D	W	14-PIN F/P 1/4" X 3/8"	B	F-2
E	J	16-PIN C DIP	B	D-2
F	W	16-PIN F/P 1/4" X 3/8"	B	F-5
G	NOT AVAIL.	8-PIN CAN (TO-99)		A-1
H	U	10-PIN F/P 1/4" X 1/4"	B	F-4
I	NOT AVAIL.	10-PIN CAN (TO-100)		A-2
J	J	24-PIN C DIP	B	D-3
K	W	24-PIN F/P 3/8" X 5/8"	B	F-6
M	NOT AVAIL.	12-PIN CAN (TO-101)		A-3
P	JG	8-PIN C DIP	B	D-4
Q	NOT AVAIL.	40-PIN C DIP		D-5
R	J	20-PIN C DIP	B	D-8
V	JR	18-PIN C DIP	C	D-6
W	JR	22-PIN C DIP	C	D-7

†Per MIL-M-0038510B, Class S.

‡"X" denotes lead finish A, B, or C at option of manufacturer. Devices will be marked A, B, or C as applicable.

- NOTES: 2. The device designator may include a letter A, B, or C as a last character.  
 3. The package code may include one or two characters.

**TABLE III**  
**LEAD-FINISH CODE DESIGNATIONS**

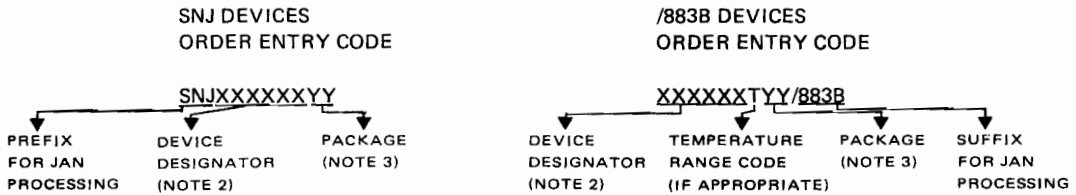
JAN	DESCRIPTION
A	SOLDER DIP
B	TIN-PLATE
C/D†	GOLD-PLATE
X	OPTIONAL‡

# MILITARY PRODUCTS

## II. JAN-PROCESSED (SNJ OR /883B) PRODUCTS PROCESSED PER MIL-STD-883 METHOD 5004

These devices will be tested to the electrical characteristics specified on the Texas Instruments Data Sheet and 100% processed in accordance with MIL-STD-883 Class B requirements of method 5004 as defined in Table IV.

### A. Ordering Information:



Examples: SNJ55107AJ  
SNJ55107BJ  
SNJ55325W

TL022MJG/883B  
TL497AMJ/883B  
RM4558JG/883B

### B. Symbolization:

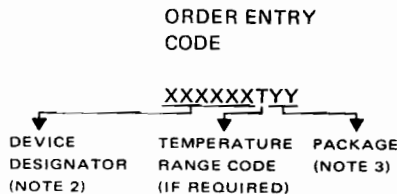
SNJXXXXXXXXY  
TI Symbol (Trade Mark)  
4-Digit Date Code

XXXXXXTY/883B  
TI Symbol (Trade Mark)  
4-Digit Date Code

## III. STANDARD PRODUCTS

These devices will be tested to data sheet electrical requirements and processed in accordance with Table IV. For detailed ordering information see ordering instructions on page 37.

### A. Ordering Information:



Example: TL494MJ  
SN55325J  
SN55107AJ

### B. Symbolization-

XXXXXXTY  
TI Symbol (Trade Mark)  
4-Digit Date Code

NOTES: 2. The device designator may include a letter A, B, or C as a last character.  
3. The package code may include one or two characters.

# MILITARY PRODUCTS

TABLE IV  
SCREENING AND LOT CONFORMANCE—CLASS B

SCREEN	JAN QUALIFIED		SNJ AND /883B		STANDARD HERMETIC	
	METHOD	RQMT	METHOD	RQMT	METHOD	RQMT
Internal Visual (Precap)	2010 Condition B and 38510	100%	2010 Condition B and 38510	100%	Commercial Standard 40X	100%
Stabilization Bake	1008 24 hours minimum test Condition C	100%	1008 24 hours minimum test Condition C	100%	1008 24 hours minimum test Condition C	100%
Temperature Cycling	1010 Condition C	100%	1010 Condition C	100%		
Constant Acceleration	2001 Condition E (min) in Y <sub>1</sub> plane	100%	2001 Condition E (min) in Y <sub>1</sub> plane	100%		
Seal Fine & Gross	1014	100%	1014	100%	1 × 10 <sup>-7</sup> atm cc/sec	100%
Interim Electrical	JAN slash-sheet electrical specifications	As applicable	TI data sheet electrical specifications	As applicable		
Burn-In Test	1015 125° C minimum <sup>§</sup>	100%	1015 (Note 4) 125° C minimum <sup>§</sup>	100%		
Final Electrical Tests	JAN slash-sheet electrical specifications		TI data sheet electrical specifications		TI data sheet electrical specifications	
(a) Static tests		100%		100%		100%
(1) 25° C (Subgroup 1, table 1, 5005)						
(2) Temperature (Subgroups 2 and 3, table 1, 5005)		100%		100%		100% (Note 5)
(b) Dynamic tests and switching tests 25° C (Subgroup 4 and 9, table 1, 5005)		100%		100%		
(c) Functional test (Note 6) (Subgroup 7.8, table 1, 5005)		100%		100%		100%
Quality Conformance Inspection				(Note 7)		(Note 7)
Group A	5005 Class B	LTPD	5005 Class B (Note 4)	LTPD		LTPD
(a) Static						
(1) 25° C (Subgroup 1)		5%		5%		5%
(2) Temperature (Subgroups 2 & 3)		7%		7%		
(b) Switching						
(1) 25° C (Subgroup 9)		7%		7%		
(2) Temperature (Subgroups 10 & 11)		10%		10%		
(c) Functional test (Note 6)						
(1) 25° C (Subgroup 7)		5%		5%		
(2) Temperature (Subgroup 8)		10%		10%		
Group B	5005 Class B	Insp. Lot	5005 Class B	6 weeks package prod.		
Group C	5005 Class B	13 weeks prod.	5005 Class B	13 weeks prod.		
Group D	5005 Class B	6 months package prod.	5005 Class B	6 months package prod.		
External Visual	2009	100%	2009	100%	2009	100%

<sup>§</sup> Lower temperatures if required to limit T<sub>J</sub> to 150° C.

- NOTES: 4. Includes group A and burn-in attributes data reports.  
 5. Temperature guardband test may be used in lieu of 100% test.  
 6. When specified on data sheets.  
 7. Group A per 5005. Generic data available for groups B, C, and D.

# MILITARY PRODUCTS

TABLE V  
JAN DEVICE TO CIRCUIT TYPE CROSS REFERENCE

JAN TYPE	CIRCUIT TYPE
10101	uA741
10102	uA747
10103	LM101A
10201	uA723
10202*	LM104
10203*	LM105
10301	uA710
10302	uA711
10303	LM106
10304	LM111
10501*	uA733
10701	LM109
10702*	LM140-12
10703*	LM140-15
10704*	LM140-24
10901*	SE555
10902*	SE556
11004	RM4156

TABLE VI  
CIRCUIT TYPE TO JAN DEVICE CROSS REFERENCE

CIRCUIT TYPE	JAN TYPE
LM101A	10103
LM104	10202*
LM105	10203*
LM106	10303
LM109	10701
LM111	10304
LM140-12	10702*
LM140-15	10703*
LM140-24	10704*
RM4156	11004
SE555	10901*
SE556	10902*
uA710	10301
uA711	10302
uA723	10201
uA733	10501*
uA741	10101
uA747	10102

\*Slash sheets not released as of date of this publication.

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