3Hz TO 5MHz

DIGITAL PHASEMETER

MODEL 6500A SERIAL NO.______

OPERATING AND MAINTENANCE MANUAL

KROHN-HITE CORPORATION

AVON INDUSTRIAL PARK/BODWELL STREET/AVON, MASS. 02322 USA

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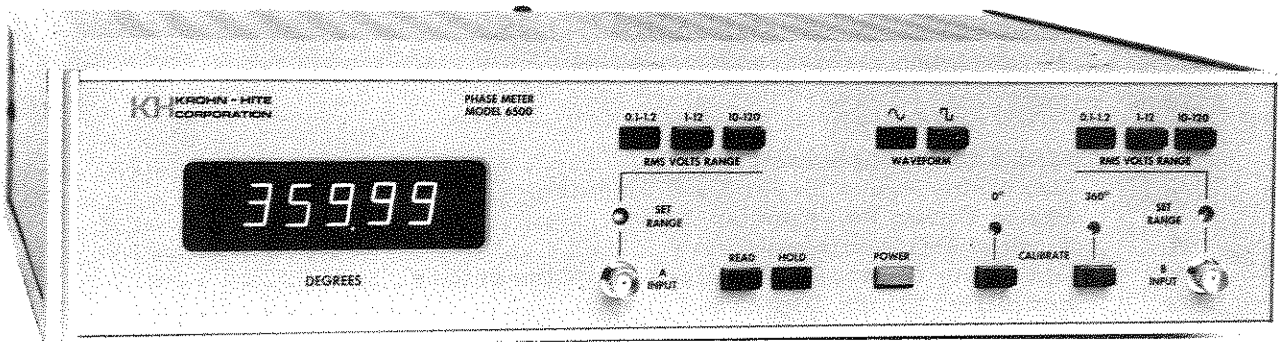


Figure 1. Model 6500 Phasemeter

SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

The Krohn-Hite Model 6500 Phasemeter measures the phase angle between two waveforms of coincident frequency, over a range of 3 Hz to 5 MHz, and provides a typical accuracy of 0.02°, with 0.01° resolution. A 5 digit planar gas discharge display provides direct readout of the phase angle from 000.00° to 360.00°. The 6500 accepts input voltages from 0.01 volts RMS to 120 volts RMS. The fluctuations or inconsistencies normally encountered in phase angle readings near zero and 360° (sometimes referred to as ambiguity) are eliminated by a unique network in the 6500 that permits readings as small as 0.01° to be observed, without the need of changing ranges or 180° shifting. In addition, the circuitry of the 6500 significantly reduces the effects of distortion and noise on phase accuracy. An analog output on the rear panel provides a DC voltage equal to -10 mv/degree phase, for use with an external meter or recorder. An optional BCD output is also available. A read/hold switch also provides continuous display of the phase angle reading, or holding of the reading for an indefinite period.

An optional rack-mounting kit (Part No. RK-319) is available from Krohn-Hite, for installing the Model 6500 in a standard 19" rack-spacing.

The phasemeter is carefully inspected, aged, and adjusted before shipment, and should be ready for operation when it is unpacked. If it appears to have been damaged in shipment, make a claim with the carrier, and notify Krohn-Hite immediately.

1.2 SPECIFICATIONS

Frequency Range

3 Hz to 5 MHz

Accuracy

(For typical performance, refer to Figure 4)

Sinewave: ±0.1°±1 digit from 20Hz to 50kHz, rising to ±0.7° at 100kHz; ±0.2° at 10Hz; for any amplitude within the selected voltage range. Above 100kHz, ±0.7° per 100kHz, with equal amplitude and the same voltage range on each input.

Squarewave: ±0.1°±1 digit from 10Hz to 20Hz, rising to ±0.7° at 100kHz; for any amplitude within the selected voltage range. Above 100kHz, ±0.7° per 100kHz, with equal amplitude and the same voltage range on each input.

Input Signal Amplitude

0.01 volts RMS to 120 volts RMS in three ranges: 0.1-1.2, 1-12 and 10-120. For higher input voltages, the use of matched attenuator probes, such as Tektronix types P6006, P6007, P6013A, P6049A, or P6060 is recommended.

(For input levels between 0.01 volts and 0.1 volts RMS, the 0.1-1.2 volt range is used; refer to Figure 4 for typical performance).

Input Waveforms

Sine, triangle, square and positive pulse waveforms.

(The phasemeter is triggered on the negative-going transition of the input waveform in both sine and square wave positions of the WAVEFORM switch.)

Input Impedance

1 Megohm in parallel with 50 pf.

Maximum DC Component

±200 volts (for higher voltages, the use of matched, attenuator probes, such as Tektronix types P6006, P6007, P6013A, P6049A, or P6060 is recommended).

Response

Time constant: Less than 500 msec.

Settling Time: To within specified accuracy, within one to eight seconds, dependent upon input signal amplitude.

Display

0.55 inch, 7-segment, planar gas discharge

Display Range

Continuous, 000.00° to 360.00°

Resolution

0.01°

Repeatability

Better than ±1 digit

Drift

None

VS TIME (30 days without CAL reset):

Sine Wave: $\pm 0.025^{\circ}$ from 20 Hz to 100 kHz; $\pm 0.1^{\circ}$ at 10 Hz; $\pm 0.35^{\circ}$ per 100 kHz above 100 kHz.

Square Wave: $\pm 0.025^{\circ}$ from 10 Hz to 5 kHz; $\pm 0.05^{\circ}$ to 100 kHz; $\pm 0.35^{\circ}$ per 100 kHz above 100 kHz.

Analog Output: ±0.1 mv (±0.01°)

VS TEMPERATURE (without CAL reset):

±0.01°/°C, 10 Hz to 100 kHz; ±0.05°/°C to 1 MHz; ±0.05°/°C per MHz about 1 MHz.

Ambient Temperature Range

0°C to 45°C

Analog Output

(For use with an external meter or recorder): 0 to -3.6 volts DC, -10 mv DC/degree phase, impedance 250 ohms.

BCD Output (Optional)

Provides 18 lines of phase angle equivalent BCD output, plus polarity, data ready, read/hold and read rate control lines. Compatible with DTL, TTL logic.

Programming connector AMP type 200277-2 rear panel mounted; mating connector (AMP type 200276-2), is provided.

Panel Controls and Adjustments

Front Panel: 3 decade push-button RMS VOLTS RANGE control (each channel), plus push-button READ/HOLD, WAVEFORM, POWER, 0° CAL and 360° CAL.

Rear Panel: 115/230V LINE, CHASSIS/FLOATING.

Terminals

Front Panel: BNC for A input, B input.

Rear Panel: BNC for A input, B input, analog output, AMP type 200277-2 for BCD output (optional).

Power Requirements

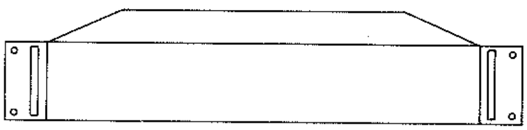
105-125 volts, or 210-250 volts, single phase, 50-60 Hz, 40 watts.

Dimensions and Weights

Model 6500: 16-1/2" wide, 3-1/2" high, 16" deep, 15 lbs/6.8 Kgs net, 18 lbs/8 Kgs shipping.

Optional Rack Mounting Kit

Part No. RK-319, permits installation of the 6500 into a standard 19" rack spacing.



1.3 FACTORS AFFECTING PHASEMETER ACCURACY

1.3.1 Inconsistencies in Meter Readings Near 0° and 360°

A problem affecting a phasemeter's accuracy is the inability of the phasemeter circuit to detect relatively small phase angles, resulting in meter fluctuations or inconsistencies in readings. The 6500 overcomes this inconsistency (or ambiguity as it is sometime referred to) by using a specially designed network that permits measurements as small as 0.01° to be made without meter fluctuations or repeatability errors, and eliminates the need for multiple meter ranges, or shifting of the meter scale.

1.3.2 Distortion Present on the Input Signal

If there is distortion present on one of the signals, a phase error may be introduced, depending on the relationship between the fundamental and its harmonics. If the amplitudes of all odd or even harmonics add up to zero at the negative zero crossing of the fundamental, then the harmonics will produce no phase error. If the resultant of the amplitudes is not zero, however, it will cause a shift in the zero crossing of the input waveform. (Worst case would occur when the maximum of the harmonic coincides with the negative zero crossing of the fundamental.) The effect of an even harmonic will not only shift the zero crossing of the waveform, but also alter the symmetry of the comparator or detector output. If a symmetry control loop is added to the phasemeter circuit, the effect of the even harmonic on accuracy can be minimized. The 6500 uses the type of symmetry loop mentioned above.

The effect of an odd order harmonic, however, is not as easily corrected. An odd order harmonic simply shifts the phase of the output of the comparator or detector loop. Since the symmetry is not affected there is no way to detect any phase error.

Figure 2 shows the maximum phase error introduced versus the percentage of harmonic distortion present on each input channel.

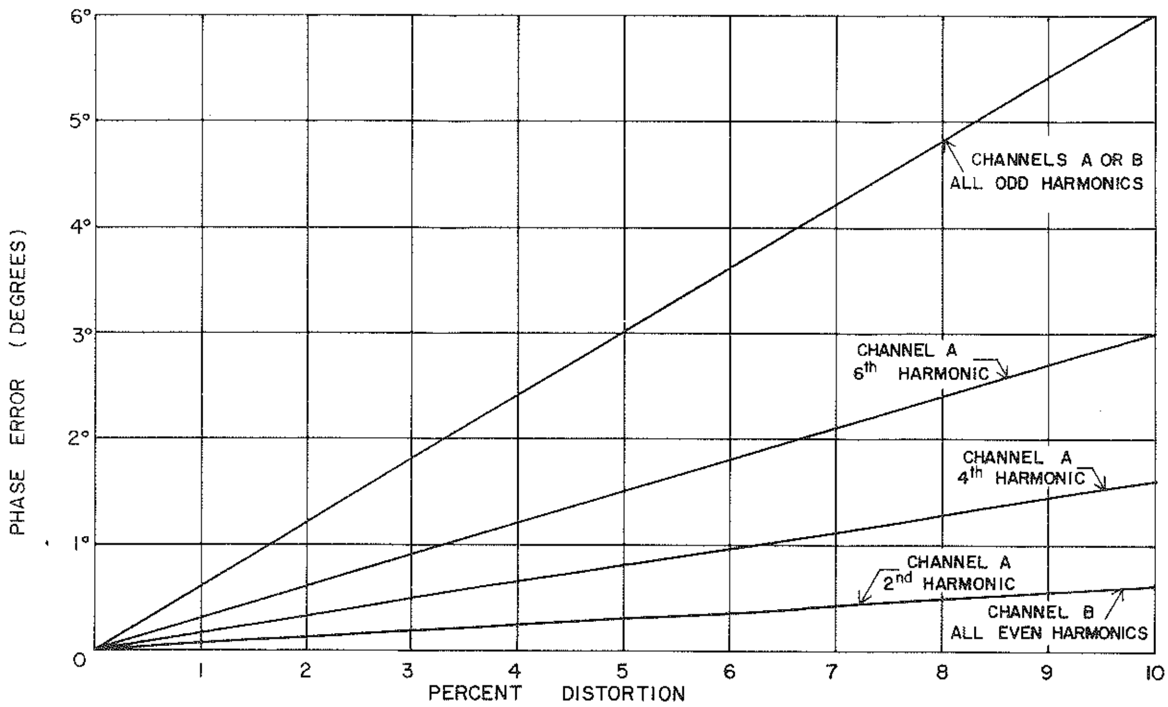


Figure 2. Maximum Phase Error vs % Harmonic Distortion (Worst case would occur when the maximum of the harmonic coincides with the negative zero crossing of the fundamental.)

1.3.3 Noise Present on the Input Signals

Another problem affecting phase accuracy is random noise. If there is a sufficient noise level on either input (or both), false triggering will occur and a phase error is introduced. The 6500 uses special circuits plus filtering to minimize the effects of noise on the phase accuracy. Typically, any broadband noise present on both inputs 40 db down from the input signals will produce only a 0.05° error. Figure 3 gives a typical curve for phase error versus input frequency, for a signal to noise ratio of 10:1 on both inputs.

1.3.4 Typical Performance

The typical performance of the Model 6500 is illustrated in Figure 4.

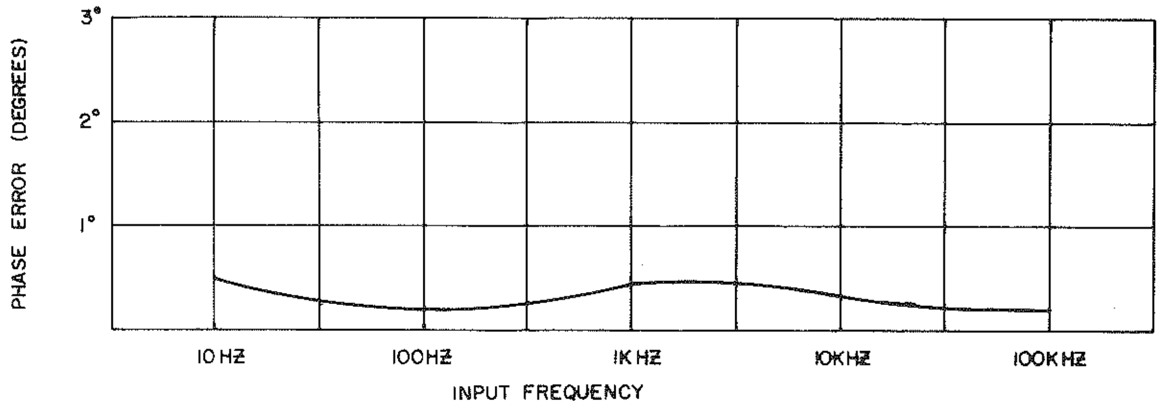


Figure 3. Phase Error vs. Random Noise

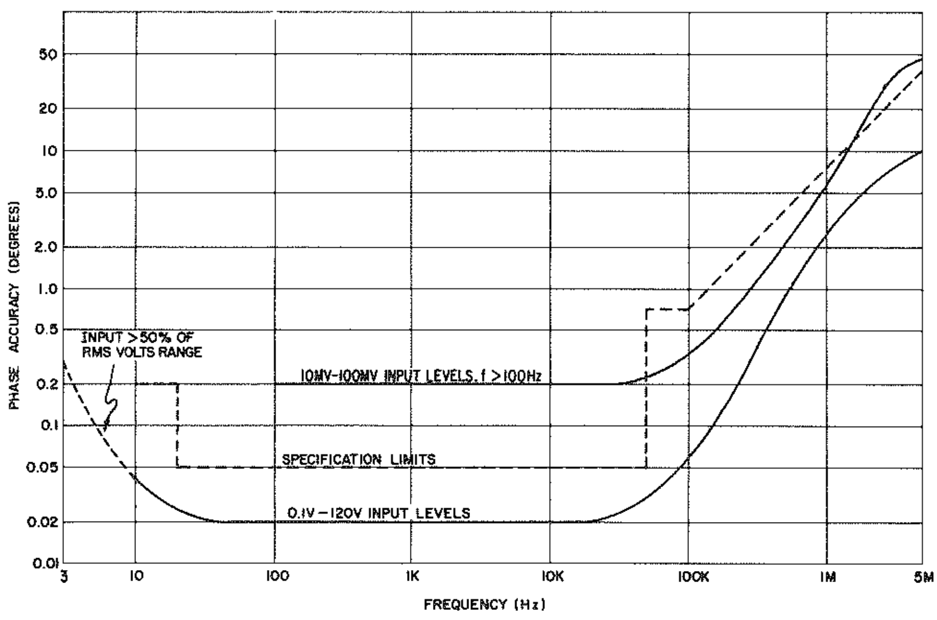
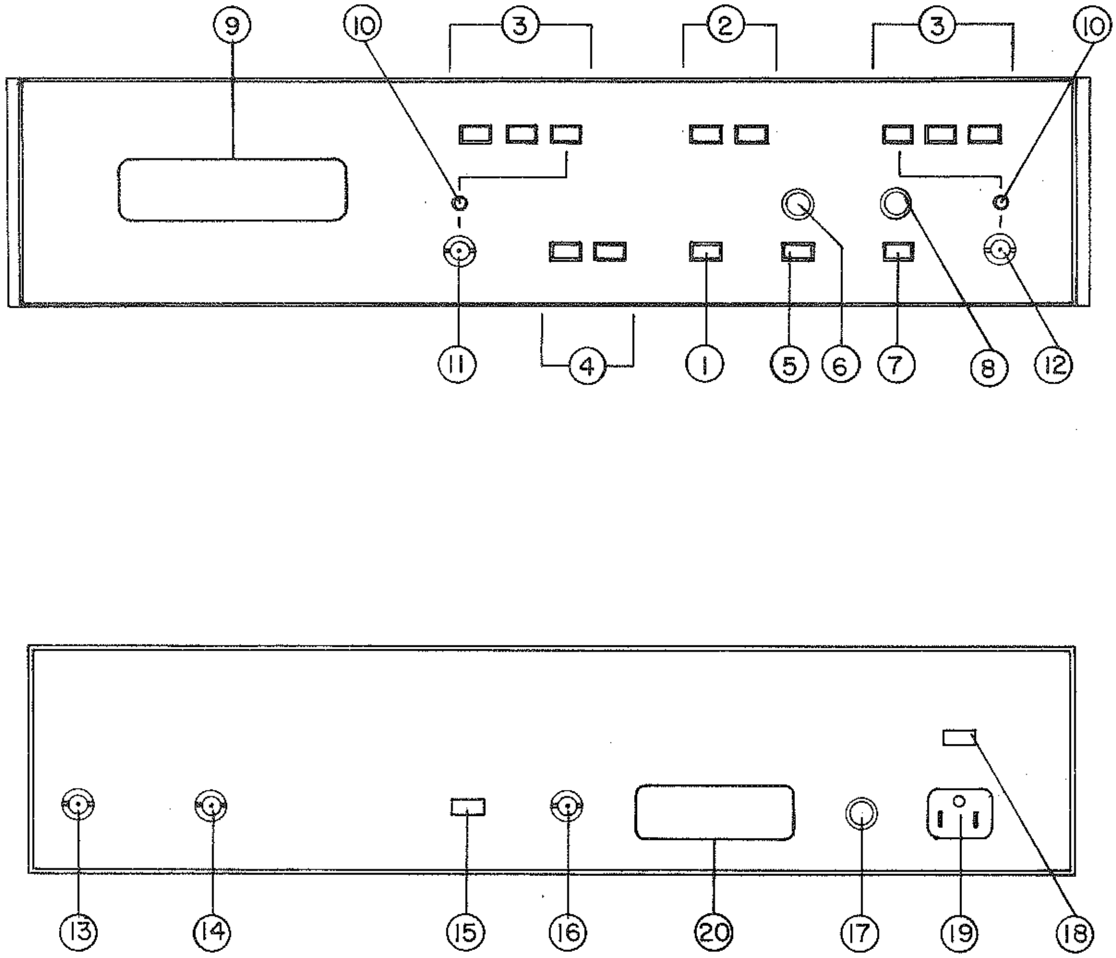


Figure 4. Typical Performance



- (1) POWER SWITCH
- (2) WAVEFORM SWITCHES
- (3) RMS VOLTS RANGE SWITCHES
- (4) READ/HOLD SWITCHES
- (5) 0° CAL SWITCH
- (6) 0° CAL SCREWDRIVER ADJUST
- (7) 360° CAL SWITCH
- (8) 360° CAL SCREWDRIVER ADJUST
- (9) DIGITAL PANEL METER
- (10) SET RANGE INDICATORS
- (11) CHANNEL A INPUT (BNC)
- (12) CHANNEL B INPUT (BNC)
- (13) CHANNEL B REAR INPUT (BNC)
- (14) ANALOG DC OUTPUT
- (15) GROUND SWITCH (CHASSIS/FLOATING)
- (16) CHANNEL A REAR INPUT (BNC)
- (17) FUSE
- (18) LINE SWITCH
- (19) POWER RECEPTACLE
- (20) BCD OUTPUT (OPTIONAL; AMP TYPE 200277-2)

Figure 5. Operating Controls, Displays and Connectors

SECTION 2
OPERATION

2.1 POWER REQUIREMENTS

The Model 6500 Phasemeter may be used with either a 105 - 125 volt, 50 - 400 Hz line or a 210-250 volt 50 - 400 Hz line. The line voltage can be selected by operation of the LINE switch on the rear panel. When the line voltage is 115 volts, a 0.5 ampere fuse is required; when the line voltage is 220 volts, a 0.25 ampere fuse should be used.

2.2 OPERATING CONTROLS, DISPLAYS AND CONNECTORS (See figure 5)

2.2.1 Front Panel Controls

POWER: On-off pushbutton switch.

WAVEFORM: Two-position push button switch selects sine wave or square wave mode of operation. When sine or triangle waveforms are used as input signals, the WAVEFORM switch should be set for ∿; when square waves or positive pulses are used, the WAVEFORM switch is set to the ⊓⊔ mode.

RMS VOLTS RANGE: Three position push button switch (each channel) for selecting input voltage ranges from 0.01 volts RMS to 120 volts RMS. For input levels between 0.01 volts and 0.1 volts RMS, the 0.1-1.2 volt range is used. (Refer to Figure 4, Page 5 for typical performance.) The voltage ranges are 0.1-1.2, 1-12 and 10-120. The voltage range may be extended using Tektronix matched probes. (Types P6006, P6007, P6013A, P6049A, or P6060.)

READ/HOLD: Two - position push button switch. In the READ mode, the phase angle being measured is continuously displayed on the readout. In the HOLD mode, the last reading is held for an indefinite period.

0° CAL: Push-button hold-release switch for checking 0° calibration. A front panel screwdriver control is also provided for adjustment of zero scale.

360° CAL: Push-button hold-release switch for checking 360° (full scale) calibration. A front panel screwdriver control is also provided for adjustment of full scale.

2.2.2 Rear Panel Controls

LINE: Two-position slide switch for selecting 115 or 230 volt operation.

CHASSIS/FLOATING: Two-position slide switch for selecting chassis or floating ground. In the FLOATING mode, signal ground is isolated from chassis ground.

2.2.3 Displays

5 digit planar gas discharge displays the phase angle being measured, in degrees, from 000.00° to 360.00°.

SET RANGE: Front panel LED indicator, (one for each channel) illuminates when the input voltage for that particular channel is either above or below the selected range.

2.2.4 Connectors

Front panel: BNC connector for each channel input.

Rear panel: BNC connector for each channel input. ANALOG OUTPUT, BNC, equal to -10 mv/degree phase, for use with external meter or recorder. BCD OUTPUT (optional), AMP type 200277-2 connector. Power Receptacle for line cord.

2.3 OPERATION

To operate the 6500 phasemeter proceed as follows:

1. Make appropriate power connections (see Section 2.1).
2. Push the POWER switch to the ON (recessed) position, and allow the unit to warm up for at least 30 minutes to achieve rated accuracy.
3. Set the READ/HOLD switch to the READ position.
4. Push the 0° CAL button. Adjust the 0° screwdriver control (if necessary) so that the meter reads 000.00°.
5. Push the 360° CAL button. Adjust the 360° screwdriver control (if necessary) so that the meter reads 360.00°.

After the unit has been allowed to warm up, connect the reference signal to the A input and the signal to be measured to the B input.

(It is recommended that matched, equal length, coaxial input cables be used, as a difference in length or cable capacitance may affect the phasemeter accuracy, particularly at high frequencies. As an example, consider two cables that are the same type (approximately 30 pf/foot) but of different length. A difference of one foot between the two cables will create an error at 100 KHz of about 0.06°.)

After connecting the cables to the two input channels, set the WAVEFORM switch to the desired mode. In the ∿ mode, the phasemeter will measure phase angles between sine waves, a sine and triangle wave, or triangular waves. In the ⊓⊔ mode, square waves, a square wave and positive pulse, or positive pulses should be used. If a sine wave is used in the ⊓⊔ mode or vice-versa, an error of several degrees can be expected.

After selecting the proper WAVEFORM mode, set the VOLTS RMS RANGE buttons to a position where the LED indicator is extinguished. This will indicate that the input signal level is within the proper range. The 6500 will now display the phase angle, in degrees, between the two input signals. Refer to Section 1 for the appropriate accuracy specifications.

For phase angle readings passing through 360.00°, the meter reading will remain at the 360.00° end until the reading is approximately 364.00°. At this point the meter reading will shift itself 360° to its corresponding low end, or 004.00°.

Conversely, if the meter reading passes through 000.00°, the meter reading will remain at the low end until about -004.00°, where it will then shift itself 360° to a new reading of 356.00°.

This feature allows readings to be taken at or near 0° or 360° without meter fluctuations.

It is also possible to shift the phase reading as follows (applicable to sine wave position of WAVEFORM switch, only):

If the meter is reading near 0°, and a reading near 360° is desired, simply depress the 360° CAL button for about 3 seconds, then release. If the meter reading is near 360°, and a reading near 0° is desired, simply depress the 0° CAL button for about 3 seconds, and then release.

When the input voltage level exceeds 120 volts RMS, or the DC component of the signal exceeds ±200 volts, the input range of the 6500 can be extended with Tektronix or similar type matched probes. (Tektronix types P6006, P6007, P6013A, P6049A or P6060, or equivalent).

The probe should match an input resistance of 1 megohm and should be adjustable to match an input capacitance up to 50 pf. The broadbanding screw should be adjusted for 0° (or 360°) reading with a signal directly on one of the phasemeter inputs and the probe (on the other phase meter input) connected to the same signal. Reverse the procedure for a probe on the other phase meter input. For optimum accuracy, the probe(s) should be adjusted at each frequency used before making phase measurements. For less stringent accuracy requirements, the probe(s) need not be adjusted carefully.

If a 10 Megohm probe (or 10 Megohm source impedance) is used on one channel only, below 200 Hz, or a 1 Megohm source impedance below 20 Hz on one channel only, an appreciable error is introduced, because of the phasemeter input coupling capacitors. (10 Megohms will produce approximately 0.8° at 10 Hz). This error can be cancelled by adding an equivalent source impedance in series with the input to the other channel at these low frequencies. (If left in at higher frequencies, it must be accurately broadbanded with a shunt capacitance).

2.4 BCD OUTPUT (OPTIONAL)

A digital programming connector (AMP type 200277-2), is mounted on the rear panel, and provides an equivalent BCD output of the front-panel display, plus four additional data control lines. A total of 22 programming lines plus 3 lines of the programming ground return are provided.

A total of 18 lines are used to provide the BCD equivalent output of the 5 digit, front panel display. Each digit, with the exception of the 100's digit, is represented by four output lines, and is binary-coded in a 1-2-4-8 format. The 100's digit is represented by two lines, coded in a 1-2 format.

The four additional data control lines provide the following functions:

1. POLARITY (OUTPUT): The output logic level of this line remains in a "High" state when the displayed phase angle is positive; output level will convert to a "Low" state if the phase angle display goes negative.

(Con't on Page 11)

Table 1.
OPTIONAL BCD OUTPUT PIN CONNECTIONS
(Using AMP type 200277-2 Connector)

Pin Letter	Function	Description
A	000.01	↑
B	000.02	
C	000.04	
D	000.08	
E	DIG. GND.	
F	000.10	
H	000.20	
J	000.40	
K	000.80	
L	DIG. GND.	
M	001.00	Phase Angle BCD OUTPUTS
N	002.00	
P	004.00	
R	008.00	
S	DIG. GND.	
T	010.00	
U	020.00	
V	040.00	
W	080.00	
X	100.00	
Y	200.00	↓
Z	Polarity (Output)	"High" for pos. angle "Low" for neg. angle
a	Conversion Complete (Output)	"High" for data ready "Low" for conversion
b	Transfer Inhibit (Input)	"Low" for data read "High" or open for data hold
c	Read Rate (Input)	"High" for 4 cts/sec "Low" for 20 cts/sec

2. CONVERSION COMPLETE (OUTPUT): The output logic level of this line will remain "Low" during the Digital Panel Meter's measurement or conversion cycle; the output will convert to a "High" state when conversion of data is completed.

3. TRANSFER INHIBIT (INPUT): This input is used in conjunction with the front panel READ/HOLD switch, and provides remote control of the READ/HOLD function. When the front panel READ/HOLD switch is in the READ mode, the TRANSFER INHIBIT control line is inoperative; when the switch is in the HOLD mode, a "Low" level applied to the TRANSFER INHIBIT input line will allow both the front panel display and the BCD outputs to be continuously updated by new data. A "High" level applied to the TRANSFER INHIBIT line will hold or maintain the last data displayed, plus the equivalent data on the BCD outputs.

4. READ RATE (INPUT): This input is provided for selection of the DPM's read/rate. A "High" level applied to the READ/RATE input will effect a DPM read/rate of 4 counts/second; a "Low" level will convert the read/rate to 20 counts/second.

The logic levels for all OUTPUT lines are as follows:

$0V \leq Low \leq 0.5V$; $I_{sink} = 10mA$

$2.4V \leq High \leq 5.5V$; $R_{source} = 6K\ Ohm$

The logic levels for all INPUT lines are as follows:

$0V \leq Low \leq 0.8V$; $I_{sink} = 1.6mA$

$2.0V \leq High \leq 5.0V$; $I_{source} = 0.1mA$

A mating connector for the AMP type 200277-2 (Part No. AMP type 200276-2) is provided.

SECTION 3

INCOMING INSPECTION AND CHECKOUT

3.1 INTRODUCTION

The following procedure is used to verify that the phasemeter is operating within specifications, both for incoming inspection and for routine servicing. Tests should be made with all covers in place, and the procedure given below should be followed in sequence.

SPECIAL NOTE

As an alternate to the following procedure, a Primary Phase Angle Standard such as the Dytronics Model 311/RT-1/717S may be used for accuracy measurements between 30 Hz and 10 KHz. A second alternative is the use of a Computing Counter System such as the Hewlett Packard Model 5360A when used with a suitable phase shifting circuit).

3.2 EQUIPMENT REQUIRED

(a) 10 Hz to 100 KHz low distortion* oscillator, with output adjustable from 0.1 volts RMS to 10 volts RMS, Krohn-Hite Model 4000A or equivalent.

(b) 10 Hz to 10 MHz sine wave oscillator, with two outputs, 180° apart, and output voltage adjustable from zero to 1.5 volts RMS, Hewlett Packard Model 654A or equivalent.

(c) Variable phase generator, capable of providing two sine wave and/or square wave outputs, with adjustable phase angle from 0° to 360° Hewlett Packard Model 203A or equivalent.

(d) 10 Hz to 5 MHz square wave signal source, with two outputs, not in phase, and output voltage at least 1 volt peak to peak. (If a signal source with two outputs is not available, a single source may be used with a suitable balanced transformer such as the North Hills Electronics Model 50-201RA, to produce two outputs approximately 180° apart.)

(e) 50 ohm terminators, (2 required), Tektronix type 011-0055-00 or equal. (For use with above transformer only).

(f) Calibrated DPM, zero to -3.6 volts DC, with 0.1 millivolt resolution, Newport Model 2000AS or equal.

(g) Matched set of coaxial cables (BNC) for connections to inputs. (Same length and impedance).

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* Less than 0.01% from 10 Hz to 20 KHz, rising to 0.1% at 100 KHz.

3.3 PROCEDURE

After allowing the instrument to warm up for at least 30 minutes, set the controls to the following positions:

WAVEFORM	∿
RMS VOLTS RANGE (input A)	0.1-1.2
RMS VOLTS RANGE (input B)	0.1-1.2
READ/HOLD	READ
GROUND SWITCH	CHASSIS

3.3.1 Meter Calibration

Press the 0° CAL button. Adjust the screwdriver control on the front panel until the meter reads 000.00°. Press the 360° CAL button. Adjust the screwdriver control on the front panel until the meter reads 360.00°.

3.3.2 100 Hz Sine Wave Check

Connect the output of the low distortion oscillator to both inputs of the phasemeter, using the set of matched cables. Set the oscillator frequency to 100 Hz, output amplitude to 0.1 volts RMS. Depress the 0° CAL button momentarily, then release; meter should read $000.00^{\circ} \pm 0.05^{\circ}$. Depress the 360° CAL button, then release; meter should read $360.00^{\circ} \pm 0.05^{\circ}$. Repeat procedure at 20 Hz, 1 KHz and 10 KHz.

3.3.3 10 Hz Sine Wave Check

Repeat procedure of 3.3.2 at 10 Hz; meter tolerance is $\pm 0.2^{\circ}$.

3.3.4 100 KHz Sine Wave Check

Repeat procedure of 3.3.2 at 100 KHz; meter tolerance is $\pm 0.7^{\circ}$.

3.3.5 High Frequency Sine Wave Check

Connect the outputs of the 10 MHz oscillator to the phasemeter inputs, using the matched cables. Set the oscillator frequency to 200 KHz and both output voltages to 0.1 volts RMS. Observe the phase reading.

Reverse the two inputs. Observe the phase reading. The Total* of both readings should equal $360.00^{\circ} \pm 2.8^{\circ}$ at 200 KHz. Repeat this procedure at 500 KHz, 1 MHz, 2 MHz and 5 MHz. Tolerance of the total reading is $\pm 7^{\circ}$ at 500 KHz, $\pm 14^{\circ}$ at 1 MHz, $\pm 28^{\circ}$ at 2 MHz and $\pm 70^{\circ}$ at 5 MHz. Disconnect the oscillator.

3.3.6 100 Hz Square Wave Check

Set the phasemeter WAVEFORM switch to ⊓⊔ . Connect the outputs of the square wave signal source to the phasemeter inputs. (If a signal source with two outputs is not available, proceed as follows: Connect a single square wave source to the input of a suitable balancing transformer, as described in 3.2.c. The output impedance (Z) of the signal source should approximately equal the input Z of the transformer. Some transformers require a load on their outputs equal to their output Z. Check manufacturer's specifications). Set the signal source output voltage for 1 volt peak to peak at the phasemeter inputs. Observe the phase reading. Reverse the inputs and observe the reading. The Total* of both readings

* If both readings are in error by E degrees, the total will be off by (2xE) degrees. Therefore the tolerance of the total is twice the specified accuracy. (See Section 1.2)

should equal $360^\circ \pm 0.1^\circ$. Repeat this procedure at 10 Hz, 1 KHz and 5 KHz. Total of the two readings should be $360^\circ \pm 0.1^\circ$.

3.3.7 20 KHz Square Wave Check

Repeat the procedure of 3.3.6 at 20 KHz; total of the two readings should be $360^\circ \pm 0.2^\circ$.

3.3.8 High Frequency Square Wave Check

Repeat the procedure of 3.3.6 at 200 KHz, 500 KHz, 1 MHz, 2 MHz, and 5 MHz. Tolerance of the total reading from 360° should be $\pm 2.8^\circ$ at 200 KHz, $\pm 7^\circ$ at 500 KHz, $\pm 14^\circ$ at 1 MHz, $\pm 28^\circ$ at 2 MHz and $\pm 70^\circ$ at 5 MHz. Disconnect square wave source (and transformer if applicable).

3.3.9 Analog Output Check

Set the phasemeter WAVEFORM switch to ∿ . Connect the sine wave outputs of the variable phase generator to the phasemeter inputs. Set the generator frequency to 1 KHz, output voltage to 1 volt RMS. Connect the DVM to the analog output. Check to see that the analog output is approximately-10 mv/degree for any phase angle between 0° and 360°.

3.3.10 Read/Hold Control Check

Set the output angle of the variable phase generator to some angle between 0° and 360°. Press the front panel HOLD button. Remove the phasemeter inputs. The last meter reading should remain stored until the READ button is pressed.

<u>NOTE</u>

The analog output voltage will still vary with a change in the input phase angle, even though the meter display is in the HOLD mode.

3.3.11 Optional BCD Output Check

The operation of the phasemeter's optional BCD output can be checked by connecting the variable phase generator to the phasemeter inputs, and measuring the logic levels on the respective pins for the meter readings listed in Table 1, Page 10. It may be necessary to use a large angle to measure the BCD outputs of phase angles less than 1.0°, for example, 200.01, 200.02, etc. Be sure to connect the common or ground lead of the DVM to the BCD output Digital Ground (pins E, L or S).

To check the "Conversion Complete" output (pin a), the logic level should remain "high" when the meter reading is stable. To check the "low" condition, depress either the 0° CAL or 360° CAL button; the level at pin a should go "low" while the meter reading is converting.

To check the "Transfer Inhibit" input, place the READ/HOLD switch in the HOLD mode. Vary the phase angle of the generator. The meter reading should not change. Connect a jumper from pin b to pin E, L or S and vary the phase angle of the generator; the reading should vary as the phase angle is varied.

SECTION 4
CIRCUIT DESCRIPTION

4.1 SYSTEM OPERATION

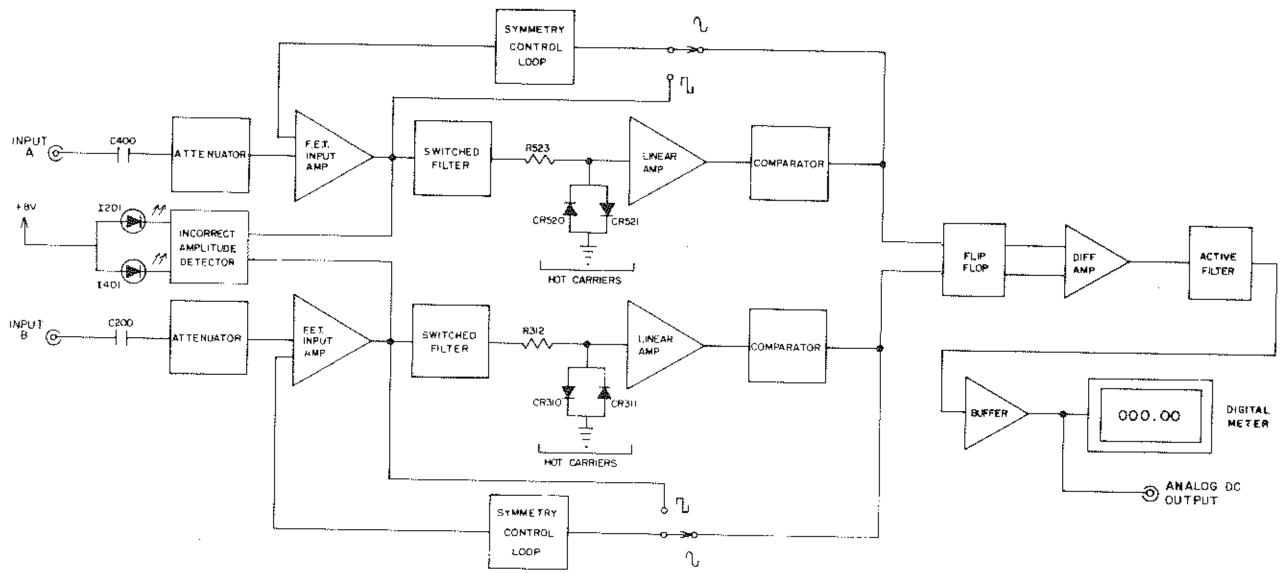


Figure 6. Simplified Block Diagram

A simplified block diagram of the phasemeter circuit is shown in Figure 6. A reference signal is applied to the A input and the signal to be measured is applied to the B input. Each input signal goes through a coupling capacitor, an attenuator, a high impedance (FET) amplifier for isolation and a switched filter that reduces any high frequency signals or noise. Each signal is then fed to a high speed comparator. The comparator detects the point where the input signal crosses the zero axis, and produces a square wave. The output of each comparator is then used to trigger a bi-stable flip flop. The output of the flip flop is a square wave, with a duty cycle that is proportional to the time between the two trigger inputs. The DC average of the accurately clamped flip-flop output is displayed by a digital meter, and corresponds to the phase angle, in degrees, between the two input signals.

4.2 ATTENUATOR AND FET INPUT AMPLIFIER (see figure 6)

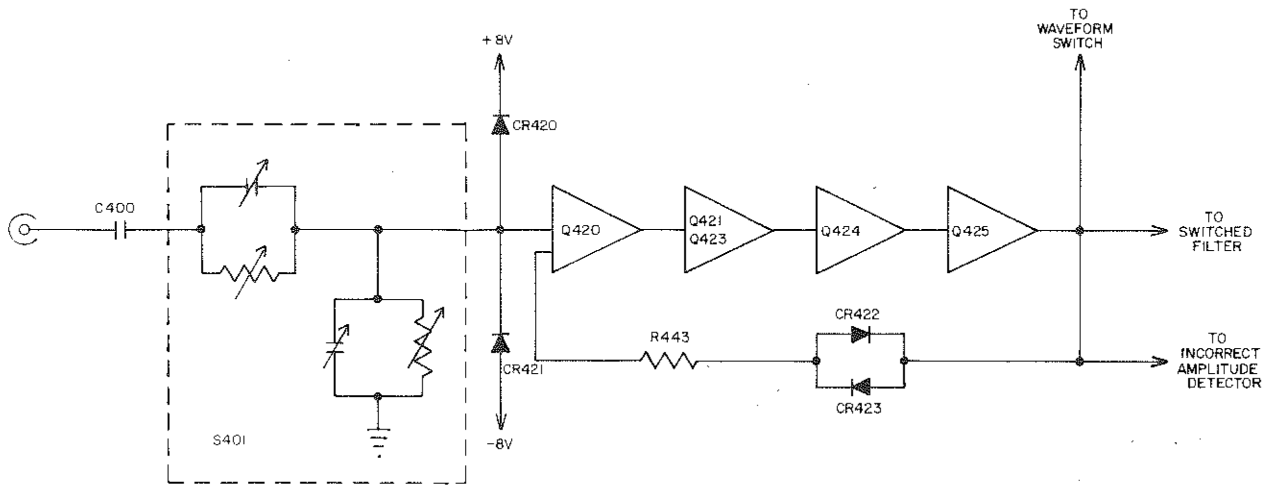


Figure 7. Attenuator and Fet Input Amplifier

(NOTE: since both channels are similar up to their comparator outputs, we shall limit part of the circuit description to channel A.)

The input signal first goes through an AC coupling capacitor, C400, that is matched with C200 for equal low frequency phase shift. The signal is then fed to an attenuator that provides a constant input impedance on all three ranges. Capacitors C401 through C411 are used for broadbanding and to keep the impedance the same on all three ranges at high frequencies. Diodes CR420 and CR421 on the attenuator output prevent damage of the FET amplifier by excessive input signal levels.

The FET amplifier is a high impedance non-inverting amplifier with gain, and consists of an input stage Q420, a balanced differential stage Q421 and Q423, a driver stage Q424, and an emitter follower Q425. The amplifier provides both isolation and gain between the attenuator and the switched filter (section 4. 4.) A degenerative path from the amplifier output through CR422, CR423 and R443 limits the amplifier gain and output swing.

4.3 INCORRECT AMPLITUDE DETECTOR (see figure 8)

The incorrect amplitude detector monitors the output of the Fet amplifier. When the input signal voltage falls within the attenuator voltage range selected, the positive DC voltage developed on C464 opens diodes CR 464 and CR465, so that the current in R475 turns Q461 on, turning off Q460, and turning off the LED Set Range Indicator. When the input signal exceeds the upper limit of the attenuator range, the negative DC voltage developed across C463 is sufficient to turn on CR466, turning off Q461 and turning on the LED. When the input signal falls below the selected range Q461 is shut off by the current from the -8v supply through R478, CR464 and CR465. Diode CR465 is in series with CR464 for temperature compensation.

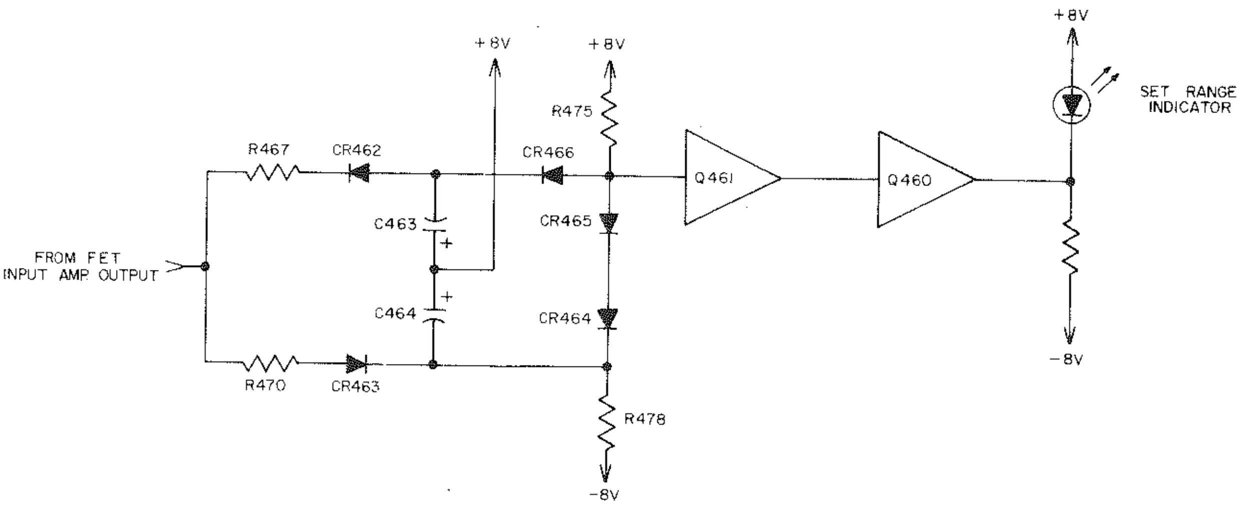


Figure 8. Incorrect Amplitude Detector

4.4 SWITCHED FILTER AND HOT CARRIER LIMITER (see figure 9)

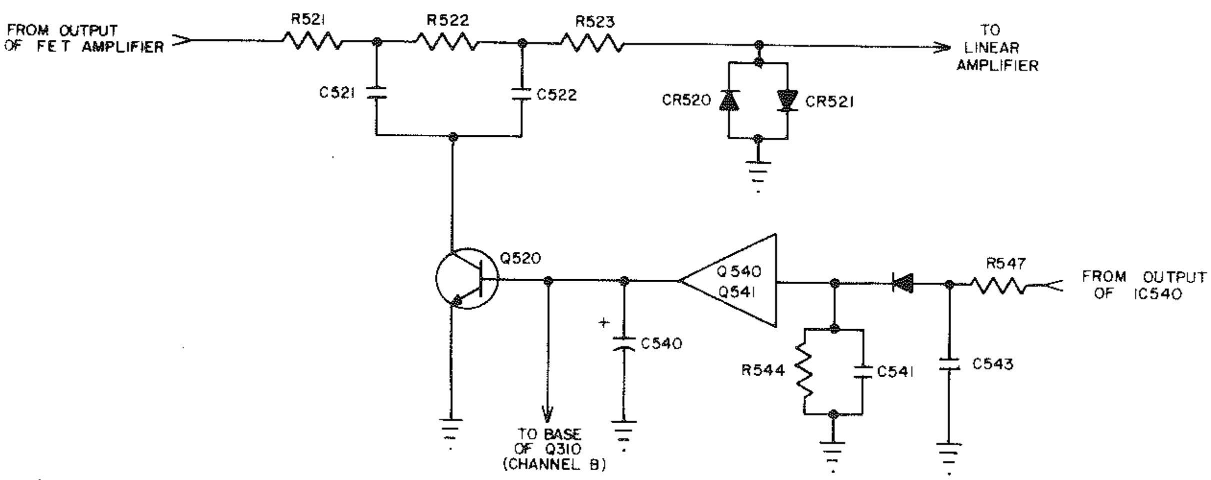


Figure 9. Switched Filter and Hot Carrier Limiter

The switched filter is a low pass filter that is used to reduce excessive high frequency noise at input frequencies below 200 Hz. The control signal is taken from the output of IC540. At low frequencies, the control signal charges C541, turning on Q541 and Q540. This drives the base of Q520 plus, providing a path to ground for C521 and C522.

At frequencies above 200 Hz, the control signal is removed by a bypass capacitor C543, discharging C541, and turning off Q541 and Q540. This drives the base of Q520 negative and opens the path to ground.

The hot carrier limiter consists of two diodes CR520 and CR521. These diodes clamp the input signal at a level of approximately + 0. 3 volts and - 0. 3 volts.

4.5 LINEAR AMPLIFIER (see figure 10)

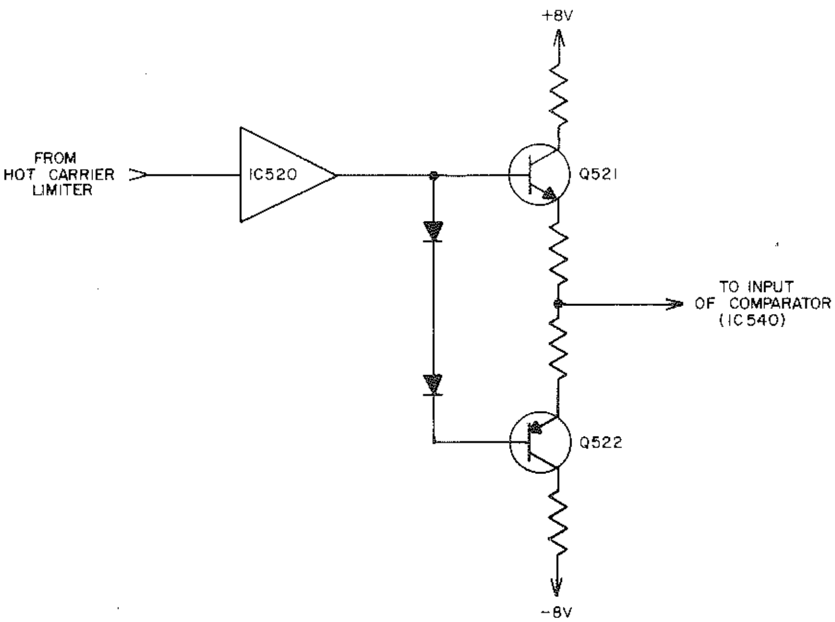


Figure 10. Linear Amplifier

The linear amplifier is an inverting amplifier with gain and consists of an integrated circuit IC520 and a push-pull emitter follower Q521 and Q522. The amplifier serves two purposes: (1) although the hot carrier limiter clamps its input signal at 0. 3 volts, the slope of the clamped signal will vary with the amplitude of the input signal, which in turn will affect the point where the comparator is triggered. The linear amplifier provides sufficient gain so that the difference in the slope is negligible; (2) since the output of the limiter is not sufficient to drive the low impedance of the comparator, the linear amplifier provides the current needed.

4.6 COMPARATOR (see figure 11)

The comparator consisting of IC540 converts the output of the linear amplifier to a fast square wave that is clamped at + 10 volts by CR545. The negative excursion of each comparator is capacitively coupled to the flip flop.

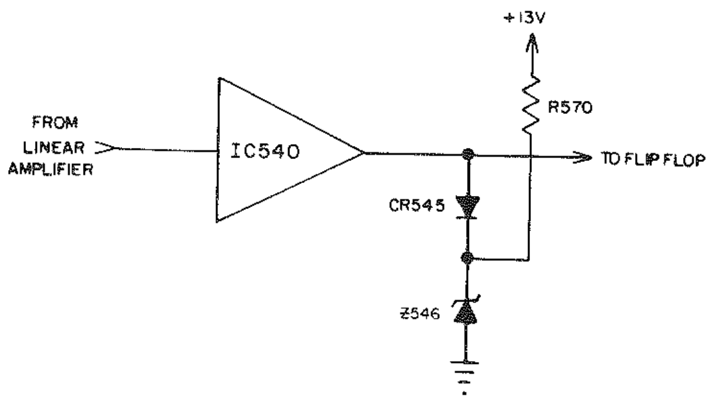


Figure 11. Comparator

4.7 SYMMETRY CORRECTION LOOP (see figure 12)

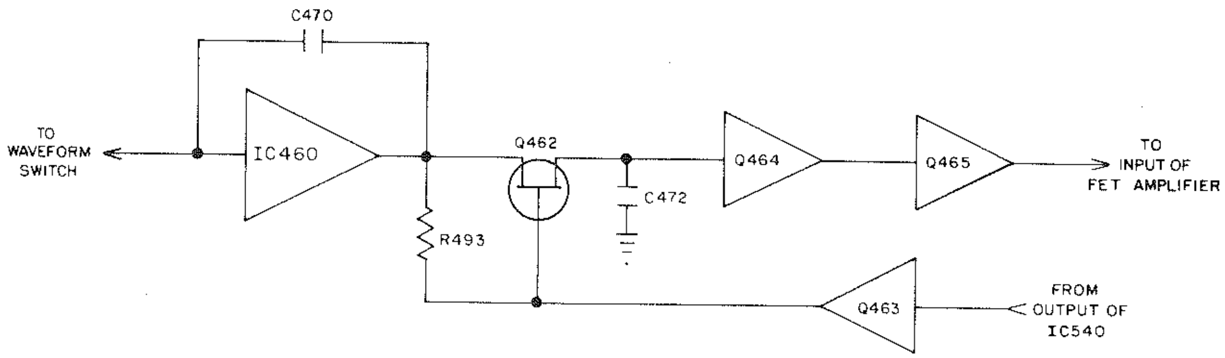


Figure 12. Symmetry Correction Loop

The symmetry correction loop is switched in when the Waveform switch is set to the ∿ mode, and consists of an integrator IC460 and C470, a gated filter Q462 and Q463 and buffers Q464 and Q465. The purpose of this loop is to compensate for phase errors caused by a shift in the DC level of the input signal, which shifts the zero crossover point. The symmetry loop averages the output of the comparator signal from Q466 and Q467 and the resultant DC voltage is fed back to the complementary input of the FET amplifier. If there is no shift in the DC level of the input signal, the signal from Q466 and Q467 will be symmetrical about zero volts, and the DC average will be zero. If a level shift occurs, the square wave signal from Q466 and Q467 will no longer by symmetrical about zero volts, and the average DC voltage from Q466 and Q467 will be fed back to the FET amplifier input and cancel the error.

4.8 FLIP FLOP (see figure 13)

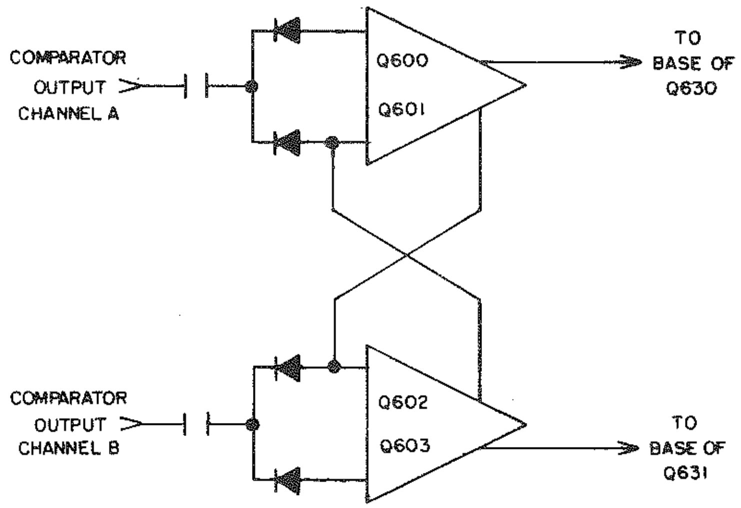


Figure 13. Flip Flop

The Flip Flop consisting of Q600, Q601, Q602 and Q603 operates in a bi-stable non-saturating mode, and is triggered on the negative excursion of each comparator output. The outputs are taken from the collectors of Q601 and Q602.

4.9 DIFFERENTIAL AMPLIFIER AND METER NETWORK (see figure 14)

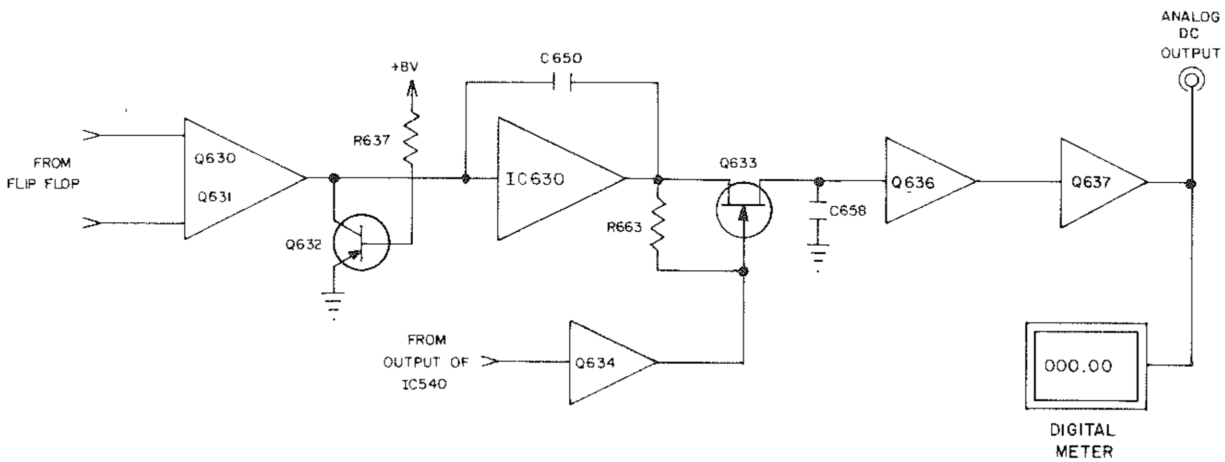


Figure 14. Differential Amplifier and Meter Network

The push-pull output of the flip flop is fed to a differential amplifier Q630 and Q631, which cancels any drift and increases the amplitude of the flip flop output. The base to emitter junction of Q632 functions as a zener, and the base to collector junction clamps the output of the Differential Amplifier at approximately + 6 volts.

The output of the Differential Amplifier is converted to a DC voltage by an active filter, IC 630 and a gated filter Q633 and Q634, providing additional smoothing of the active filter output.

A buffer stage, Q636 and Q637 provides isolation between the gated filter and the digital meter.

The digital meter displays the resultant DC voltage, which corresponds to the phase angle in degrees, between the two input signals.

4.10 POWER SUPPLIES (see figure 15)

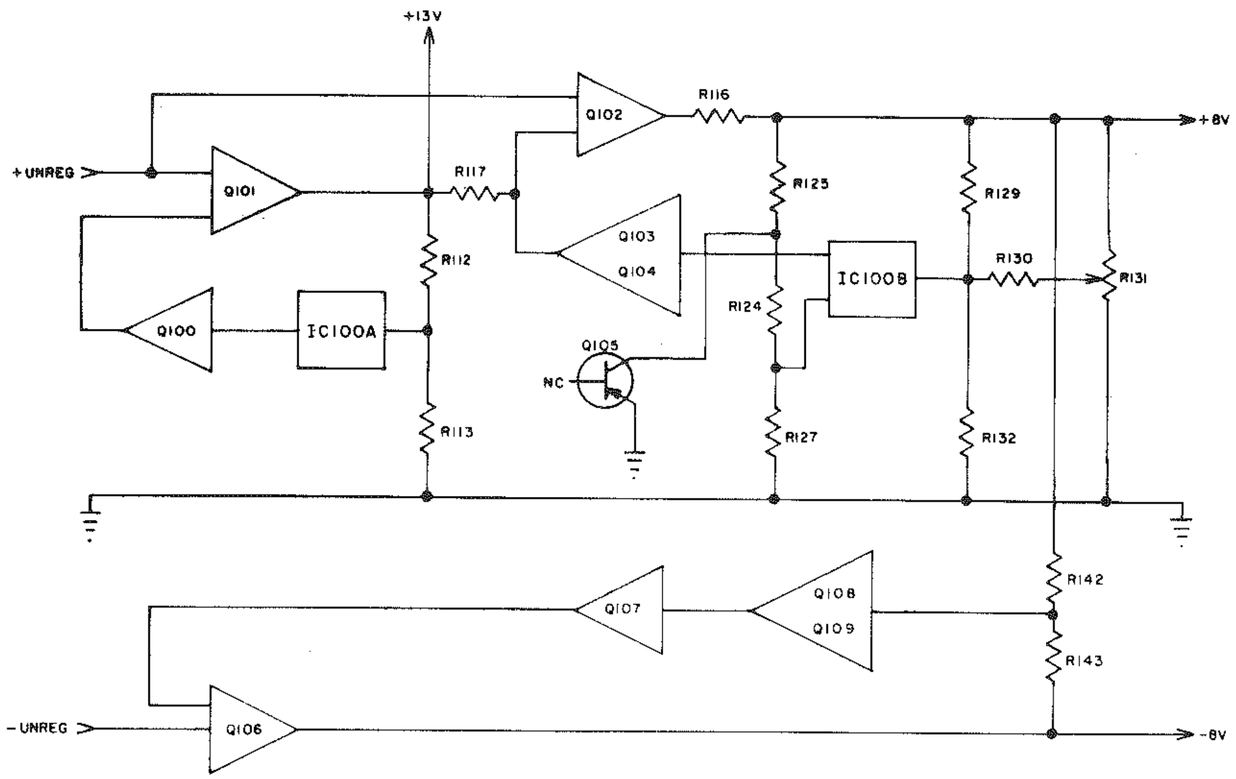


Figure 15. Power Supplies

There are three supply voltages used in the Phasemeter. The ±8 volt supply is used to power the IC' s, and wherever a large signal swing is not needed. The + 13 volt supply is used to provide the additional voltage swing needed on the outputs of the comparator and differential amplifier. Q105 is used as a zener reference for the +8 volt master supply. IC100 is used for improved temperature compensation.

SECTION 5
MAINTENANCE

5.1 INTRODUCTION

If the Phasemeter does not appear to be working properly, the following procedure may facilitate locating the source of trouble. First, check to see if all controls are properly set, and all external connections have been made. Next, make a visual inspection of the unit to locate any broken wires or burnt or broken components. If a visual inspection does not locate the source of trouble, the troubleshooting procedure given in this section should help to localize the problem. Before attempting any detailed troubleshooting however, reference should be made to Section 4, Circuit Description.

5.2 TEST EQUIPMENT REQUIRED

(a) 10 Hz to 100 kHz low distortion* oscillator, with two outputs 180° apart, adjustable from 0.1 volts RMS to 10 volts RMS.

(b) Oscilloscope, with 1 mv/cm sensitivity and bandwidth of at least 45 MHz, Tektronix type 7403N or equal, with 7B50 Time Base and 7A13 Differential Comparator Amplifier.

(c) Digital voltmeter, zero to 15 volts DC, with 1 mv resolution.

(d) Matched set of coaxial cables (BNC) for connections to inputs. (Same length and impedance).

5.3 POWER SUPPLY

If the phase meter does not seem to be working properly, the power supply circuit should be checked first. The three regulated outputs should measure + 8V ±0.2V, - 8V ± 0.2V, and + 13V ±0.3V. Normal 60 Hz ripple should be less than 2 mv peak to peak. If the preceding three voltages appear to be correct, go to Section 5.4.

The regulated voltages are provided with current limiting circuits that will shut down the supply when excessive current is being drawn from it. Because of this, an apparent power supply malfunction may be the result of an overload in the phase meter circuits. This may be determined by measuring the voltage drop across R104, R116 and R134. These voltages should be no greater than 0.7V. If the voltage across R104, R116, or R134 is considerably greater than 0.7V, measure the voltage across the three power supply PC busses which feed the left channel, the right channel and the rear card circuits. A drop of over 10 millivolts on any of these will indicate that the overload is in that section.

* Less than 0.01% from 10 Hz to 20 kHz, rising to 0.1% at 100 kHz.

Check the unregulated voltages on the + end of C103 and the - end of C104. If these voltages are correct and if there is no indication of overload, but the +8V regulated output is not correct, check the +8V supply first, because it is the reference for the other supplies. If the +13V (as well as the +8V) is low, connect a 4.7K resistor from the collector of Q103 to the + end of C103. If this corrects the +8V, but not the +13V, the trouble is in the +13V supply.

Normal voltages for various points are given on the schematic diagram in the appendix. A good way to find the source of trouble in any of the three supplies is to trace the error signal developed. For example, if the -8V supply were to become less negative than normal, the base of Q109 would tend to become more positive, allowing less current to flow through it and R140, making both the collector of Q109 and the base of Q107 more negative. This would allow more current to flow through Q107 and make its collector more positive, thus turning on the series transistor Q106 and restoring the -8V supply to its normal level.

NOTE: Most of the circuitry discussed in the following sections is of high impedance making it necessary to use high impedance, low capacitance equipment when making AC or DC measurements.

5.4 SIGNAL TRACING ANALYSIS

If the power supply seems to be functioning properly then the following procedure should localize the malfunction. Set both attenuator switches to the 0.1V-1.2V position. Apply two 1 kHz, 0.1V rms sine waves, 180° apart, to the inputs of the phasemeter. Set the MODE switch to the ∿ position. The schematic shows various test points with their correct signal levels. The test points basically trace the signal through the entire system. A quick look at either the Block Diagram (Figure 5, Section 4) or the detailed schematic (appendix) will show that before the two input signals reach the flip-flop, they are processed independently by identical circuitry. Therefore the notation Q222 (Q423) implies that Q222 and Q423 have identical functions in their respective channels.

5.5 FET AMPLIFIER

If test point TP1(6) appears incorrect check Q220 (Q420), CR220 (CR420) and CR221(CR421). If test point TP1 (6) is normal but test point 2(7) is in error first check the output from the symmetry correction loop on TP11 (TP12). If this value is greater than 0.35 volts DC, switch the sine-square switch to square wave. If the output of the symmetry loop is then less than ±0.35 volts DC, the trouble is probably in the limiter (section 5.10), the Linear Amplifier (Section 5.6) or the Comparator (Section 5.7). If there is still more than ±0.35 volts DC, the malfunction is likely to be in the symmetry loop or its associated gated filter or buffer.

If the preceding voltage check shows no malfunction in these circuits, then the malfunction is somewhere between Q221 (Q421) and Q225 (Q425). The signal error can be traced back from test point 2 in the direction of Q221 until the faulty component(s) is (are) located.

5.6 LINEAR AMPLIFIER

If the DC voltage on TP3 (8) is incorrect tie pin 5 to pin 10 of IC310 (IC520). Pin 5 should be zero volts, and TP3 (8) should be approximately -0.6V. If TP3(8) is not -0.6V, check the two diode drop from pin 5 of IC310 (IC520) to the base of Q312 (Q522). This shoud be around 1.2V. If this checks out and pin 5 of IC310 (IC520) is at 0.0V then the malfunction is associated with either Q311 (Q521) or

Q312 (Q522). If pin 5 of IC310 (IC520) is not zero, check to see that the plus and minus supplies reach their respective pins on IC310 (IC520). If they do, then IC310 (IC520) is the source of the problem. If TP3(8) does go to -0.6V check the negative feedback loop from TP3 to pin 10 to see if there is an open circuit. If not, the malfunction is probably between TP2 and the inputs of IC310 (IC520). The problem can be further localized by tracing the signal from TP2 towards IC310 (IC520).

5.7 COMPARATOR

First check pin 3 of IC330 (IC540) to see that the signal, normally around 8V p-p, reaches it from TP3(8). If not, check the components between the two above mentioned points. There is a small amount of regenerative feedback from the output (pin 7 of IC330 (IC540)) to the + input (pin 2), but the DC signal level at pin 2 should not be much greater than 100 mv p-p. If it is, check the feedback circuitry. If both inputs appear normal but the output, pin 7, refuses to change state (OV or + 10V) in response to pin 3, the problem is probably with IC330 (IC540) but it could also be accounted for if CR331 (CR546) has gone bad or CR330 (CR545) is shorted.

5.8 FLIP FLOP AND DIFFERENTIAL AMPLIFIER

Depress the 0° CAL button and then the 360° CAL button while monitoring the DC level at TP 4. The voltages should be approximately OV and 6.6V for 0° and 360° respectively. Correct values here indicate that the source of the problem is after the Differential Amplifier. If these voltages are incorrect, monitor the collector of Q630 in the 0° and 360° cal modes. Correct levels here are -0.5V and 8.5V for 0° and 360° respectively. Repeat for Q631. Correct levels here are 8.5V and -0.5V for 0° and 360° respectively. Correct levels here indicate the malfunction is between the two above mentioned collectors and TP4. If these voltages are incorrect check the DC levels at the collector of Q602 in the 0° and 360° cal. modes. Correct values are 9.5V and 8V respectively. Using this same procedure check the 0° and 360° CAL levels at the collector of Q601. Correct levels are 8V and 9.5V respectively. Proper levels at the collectors of Q601 and Q602 indicate that Q630 or Q631 or their associated circuitry is the source of the malfunction. Incorrect voltages at the collectors of Q601 and Q602 indicate a malfunction in the flip-flop or the calibration switch. Check the switch for faulty contacts. If the switch seems in order, then the malfunction is most likely associated with the four transistors that make up the flip-flop. Measure the emitter to base voltage drop in each of the four transistors while in the 360° and 0° CAL modes. In at least one of the two CAL positions the transistor in question should show a minimum voltage drop of -0.6V. (On 0° CAL, Q600 and Q602 are "on" and Q601 and Q603 are biased off. On 360° CAL, Q600 and Q602 are biased off and Q601 and Q603 are "on").

5.9 ACTIVE FILTER LOOP, GATED FILTER AND BUFFER

For this section it will be necessary to short pin 5 to pin 10 of IC630. This can be most easily done by putting a jumper wire across C650. The DC level at pin 5 should now be OV plus a small offset (a max. of ±15 mv). If not, check the DC level of pin 9 of IC630. If this does not produce results IC630 is probably the source of trouble. If pin 5 showed only the acceptable offset check the DC level at the drain of Q633. It should have essentially the same value as pin 5 of IC630. Monitor the signal level at the collector of Q634. There should be a base line DC level of -7V with pulses to +7V. (DC average approx. -4.6V). If not check Q634 and CR637. Monitor the signal level at the base of Q634. There should be a base line DC level of -7V with pulses to -12V. If not check CR548, C547, and R574. Check the DC level at the source of Q636 (R679). This should be ±0.3V, ±0.2V. If not check the voltage drop across CR640. If it is normal (between 0.5V and 0.8V), Q636 is probably bad. If the drop across CR640 is not within these normal limits set, check the diode itself. Monitor the DC level at the base of Q637. It should be around -0.65V. If not check R679. Check the DC level at the emitter of Q637. This voltage should be around -1.3V. If not, Q637 is probably the source of trouble.

5.10 LIMITER

If the limiter output at the junction of R294 (R505) and R295 (R506) is not swinging sufficiently positive, the trouble may be Q266 (Q466). If this output is not negative enough, the trouble may be Q267 (Q467) or the driver Q268 (Q468) or the associated circuitry.

5.11 SYMMETRY CORRECTION, GATED FILTER, BUFFER

In this section it will be necessary to short pin 5 to pin 10 of IC260 (IC460). This can be most easily done by placing a jumper wire across C270 (C470). The DC level at pin 5 should now be OV except for a small offset (a max. of ±15 mv). If not check R283 (R487). If this does not produce results IC260 (IC460) is probably the source of trouble. If pin 5 showed only the acceptable offset check the DC level at the drain of Q262 (Q462). It should have essentially the same value as pin 5 of IC260 (IC460). Monitor the signal level at the base of Q263 (Q463) to see that the comparator output reaches it. The signal should be around -7 VDC base line with pulses to -12V. Check the signal level at the gate of Q262 (Q462). This point should be around -8V DC base line with pulses to +2.5 V. If not, check Q262 (Q462) and Q263 (Q463). Monitor the DC level at the source of Q264(Q464). The correct value here is about +2 VDC. If this disagrees with the measured value check R287 (R497), R289(R498) and Q264 (Q464). In narrowing down the malfunction to the faulty component, it will be helpful to note that the base of Q265 (Q465) should be around + 0.5 VDC. Check the DC level at TP11 (TP12) [emitter of Q265 (Q465)] for a value of 0 ±0.6V. If the measured value is very different, Q265 (Q465) is probably defective.

5.12 SET RANGE INDICATORS

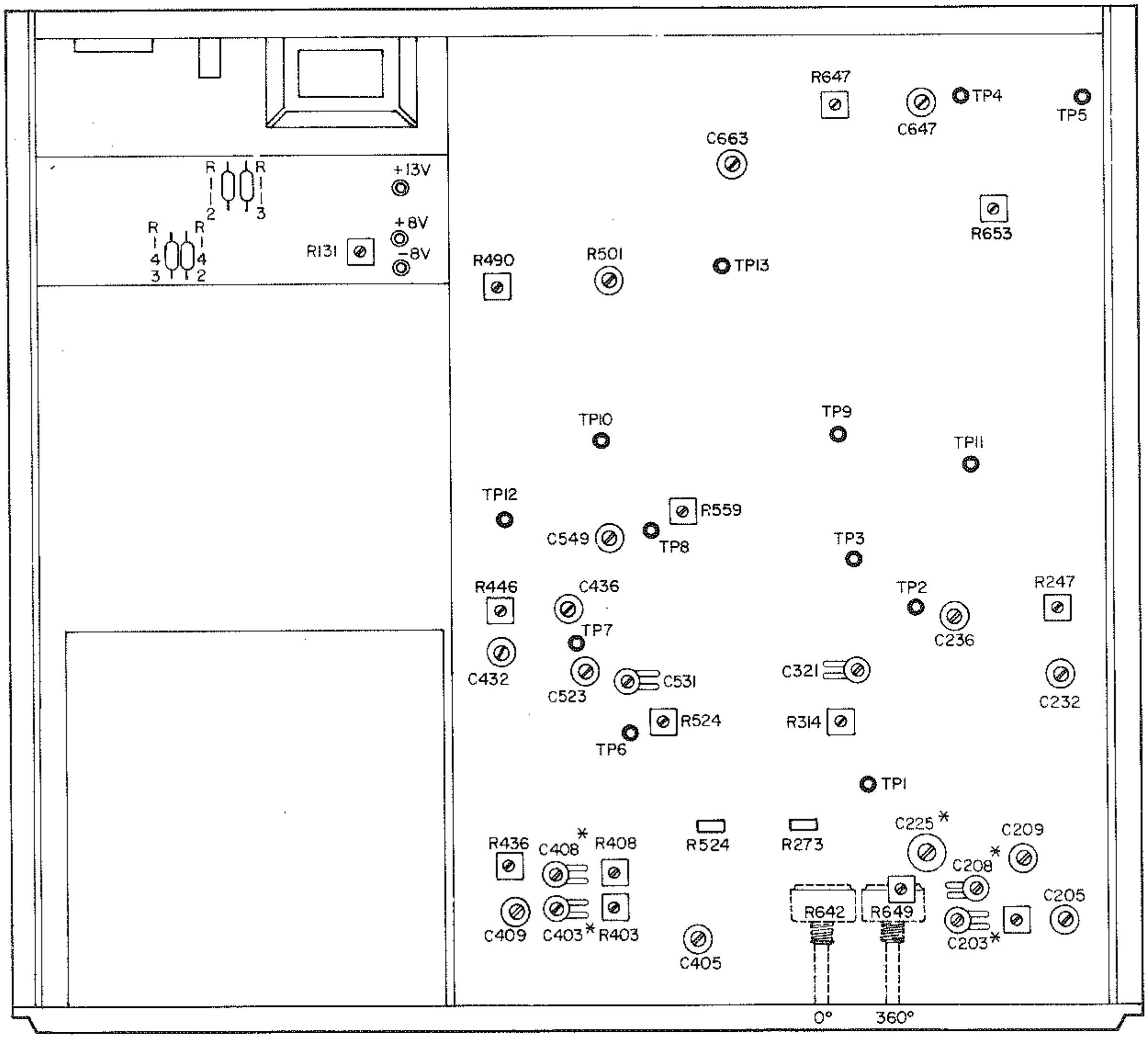
If the LED Set Range Indicators are not working properly, proceed as follows:

Apply a .08 volt RMS, 100 Hz sine wave to both inputs of the phasemeter. Set the VOLTS RANGE switches to 0.1-1.2, WAVEFORM switch to ∿. Adjust R273(R477) until the LED flickers or just goes out. If R273(R477) cannot be adjusted properly then Q260(Q460) or Q261(Q461) or their associated components are defective. (Refer to Section 4.3.)

SECTION 6
CALIBRATION

6.1 INTRODUCTION

The following procedure is provided for periodic calibration and adjustment of the phasemeter in the field, and adherence to this procedure should restore the phasemeter to its performance specifications. All tests should be made with covers in place. If the phasemeter cannot be calibrated by the procedure given, refer to Maintenance, Section 5, or consult our factory service department. The location of test points and adjustable components are shown in Figure 16.



*(These trims may be adjusted through slots provided in the top cover of the instrument.)

Figure 16. Test Points and Adjustable Components

SPECIAL NOTE

As an alternate to the following procedure, a Primary Phase Angle Standard such as the Dytronics Model 311/RT-1/717S may be used for accuracy measurements between 30 Hz and 10 KHz. A second alternative is the use of a Computing Counter System such as the Hewlett Packard Model 5360A when used with a suitable phase shifting circuit).

6.2 TEST EQUIPMENT REQUIRED

(a) Oscilloscope, with 1 mv/cm sensitivity and bandwidth of at least 45 MHz, Tektronix type 7403N or equal, with 7B50 Time Base, 7A13 Differential Comparator Amplifier and calibrated X1 probe.

(b) 10 Hz to 100 KHz low distortion* oscillator, with 200 ohm main and quadrature outputs adjustable from 0.1 volts RMS to 10 volts RMS, Krohn-Hite Model 4024A or equivalent.

(c) 10 Hz to 10 MHz sine wave oscillator, with 135 ohm balanced outputs (67.5 ohms each output), adjustable from zero to 1.5 volts RMS, Hewlett Packard Model 654A or equivalent.

(d) 10 Hz to 10 MHz sine/square generator, output adjustable from zero to 10 volts RMS, Krohn-Hite Model 4300A or equivalent.

(e) Digital voltmeter, zero to 15 volts DC, with 1 mv resolution, Fluke Model 8000A or equivalent.

(f) AC differential voltmeter, 10 mv to 10 volts RMS, Fluke Model 931A or equivalent.

(g) Wideband attenuator, 50 ohm input and output impedance, Texscan Model LA-51 or equivalent.

(h) X10 oscilloscope probes (2 required), Tektronix type P6006, P6049A or P6060.

(i) 75 ohm terminator (2 required), Tektronix type 011-0055-00 or equal.

(j) 50 ohm terminator, Tektronix type 011-0049-01 or equal.

(k) Matched set of coaxial cables (BNC) for connections to inputs. (Same length and impedance).

6.3 TEST PROCEDURE

After allowing the unit to warm up for at least 30 minutes, set the controls to the following positions:

WAVEFORM	∿
RMS VOLTS RANGE (input A)	0.1-1.2

* Less than 0.01% from 10 Hz to 20 KHz, rising to 0.1% at 100 KHz.

RMS VOLTS RANGE (input B)	0.1-1.2
READ/HOLD	READ
GROUND SWITCH	CHASSIS

6.3.1 Power Supplies

Check the voltages at the following test points, and adjust if necessary.

Test Point	Value	Adjustment
TP + 8	+8V ± 0.2V	R131
TP + 13	+13V ± 0.3V	R112, R113
TP - 8	-8V ± 0.2V	R142, R143

6.3.2 0° and 360° CAL Adjust

Set the front panel 0° ADJ pot (R642) for 0 ± 0.1 volts DC on its center arm. Adjust R647 for 0 ± 1 mv at TP4. Depress the 0° CAL button. Adjust R642 for a meter reading of 000.00°.

Set the front panel 360° ADJ pot (R649) for the center of its range. Depress the 360° CAL button and adjust R653 for a meter reading of 360.00°.

6.3.3 Symmetry Correction Loop Adjust

Connect one of the outputs of the balanced oscillator to channel A; connect the other output to channel B. Set the oscillator frequency to 1 KHz, output to 1V RMS at each phasemeter input. Adjust R247 for 0 ± 0.1 volts DC at TP11. Adjust R446 for 0 ± 0.1 volts DC at TP 12. Disconnect the balanced oscillator.

6.3.4 0° and 360° Calibration (100 Hz)

Depress the phasemeter 0° CAL button. Adjust the 0° ADJ pot for a reading of 000.00°. Depress the 360° CAL button. Adjust the 360° ADJ pot for a reading of 360.00°.

Connect the output of the low distortion oscillator to both inputs of the phasemeter, using a matched set of coaxial cables. Set oscillator frequency to 100 Hz, output to 0.1 volts RMS. Depress the 0° CAL button momentarily, then release. Meter should read 000.00.° If off, adjust R501.

Depress the 360° CAL button momentarily, then release. Meter should read 360.00°. If off, adjust R490. Recheck 0° CAL and readjust, if necessary. Disconnect the oscillator.

6.3.5 Phase Vs. Amplitude, Input A

Connect the low distortion oscillator and wideband attenuator to the phasemeter as shown in Figure 17. Set the oscillator frequency to 10 KHz, and adjust the main and quadrature outputs for 1 Volt RMS at each phasemeter input. Adjust R524 for a minimum change in meter reading when switching the wideband attenuator from 0 db to 20 db. Tolerance: ±0.01°.

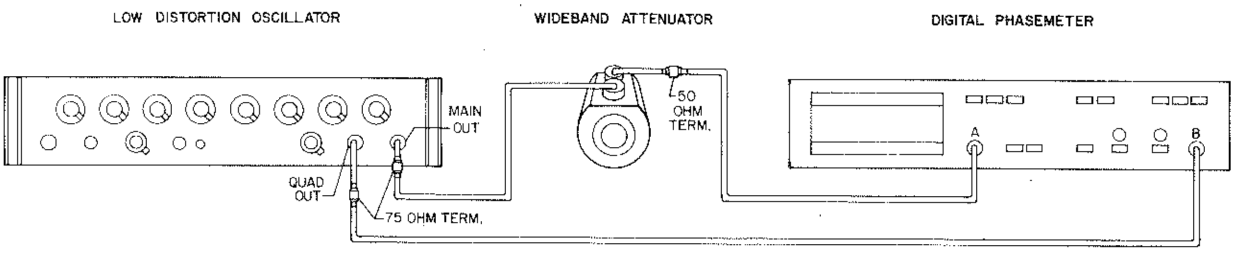


Figure 17. Phase Vs. Amplitude, Input A, Test Set-up

Set oscillator to 50 KHz. Maintain 1 volt RMS on phasemeter inputs. Adjust C531 for a minimum change in meter reading when switching the wideband attenuator from 0 db to 20 db. Tolerance: ± 0.01°.

Switch wideband attenuator from 0 db to 10 db. Adjust C436 for a minimum change in meter reading. Tolerance: ±0.01.°

6.3.6 Phase Vs. Amplitude, Input B

Connect the low distortion oscillator and wideband attenuator as shown in Figure 18. Set the oscillator frequency to 10 KHz, and adjust the main and quadrature outputs for 1 volt RMS at each phasemeter input. Adjust R314 for a minimum change in meter reading when switching the wideband attenuator from 0 db to 20 db. Tolerance: ±0.01.°

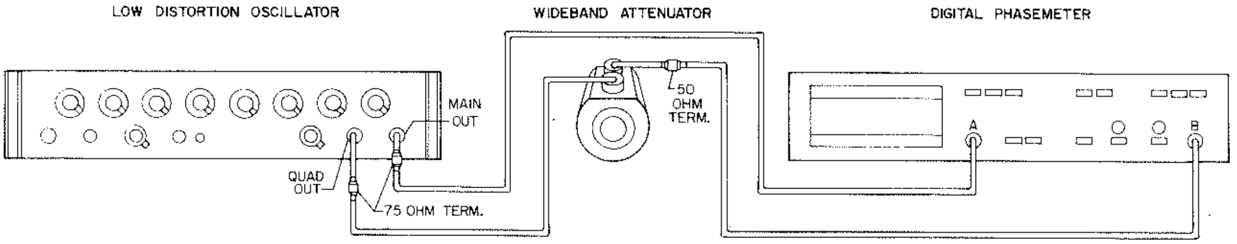


Figure 18. Phase Vs. Amplitude, Input B, Test Set-up

Set oscillator to 50 KHz. Maintain 1 volt RMS on phasemeter inputs. Adjust C321 for minimum change when switching wideband attenuator from 0 db to 20 db. Tolerance: ±0.01.°

Switch wideband attenuator from 0 db to 10 db. Adjust C236 for a minimum change in meter reading. Tolerance: ± 0.01.° Remove terminators, attenuator and quadrature output from phasemeter.

6.3.7 Phase Vs. Frequency Adjust

Reset 0° CAL and 360° CAL adjust (if necessary). Connect the main output of the low distortion oscillator to both inputs of the phasemeter, using matched cables. Set oscillator frequency to 100 Hz, output to 0.1 volts RMS. Depress 0° CAL button momentarily, then release. Meter should read 000.00.° If off, readjust R501.

Set oscillator frequency to 50 KHz. Maintain 0.1 volts RMS on oscillator output. Depress 360° CAL button momentarily, then release. Adjust C225 for a meter reading of 360.00°, $\pm 0.03^{\circ}$.

Set oscillator frequency to 100 KHz output at 0.1 volts RMS. Depress the 360° CAL button momentarily, then release. Adjust R436 for a reading of $360.00^{\circ} \pm 0.07.^{\circ}$ Recheck 50 KHz.

6.3.8 Phase Vs. Attenuator Setting, Input A

Change oscillator frequency to 10 KHz, output to 1 volt RMS. Depress 360° CAL button momentarily, then release. Meter should read 360.00°. Switch input A attenuator to 1-12V position. Adjust C403 for minimum change when switching from 0.1-1.2 V to 1-12 V position. Tolerance: $\pm 0.02.^{\circ}$

Switch input A attenuator to 0.1-1.2V position. Change oscillator frequency to 40 KHz. Depress 360° CAL button momentarily, then release. Switch input A attenuator to 1-12V position. Adjust R403 for minimum change. Tolerance $\pm 0.02^{\circ}$.

Set both input attenuators to the 1-12V position. Change the oscillator frequency to 10 KHz, output to 10 volts RMS. Depress 360° CAL button momentarily, then release. Meter should read $360.00.^{\circ}$ Switch input A attenuator to 10-120 V position. Adjust C408 for minimum change. Tolerance: $\pm 0.02^{\circ}$.

Switch input A attenuator to 1-12V position. Change oscillator frequency to 40 KHz, output at 10 volts RMS. Depress 360° CAL button momentarily, then release. Meter should read $360.00.^{\circ}$ Switch input A attenuator to 10-120V position, Adjust R408 for minimum change. Tolerance: $\pm 0.02^{\circ}$.

6.3.9 Phase Vs. Attenuator Setting, Input B

Set both input attenuators to 0.1-1.2V position. Set oscillator frequency to 10 KHz, output to 1 volt RMS. Depress 0° CAL button momentarily, then release. Meter should read 000.00°. Switch input B attenuator to 1-12V position. Adjust C203 for minimum change. Tolerance: $\pm 0.02^{\circ}$.

Reset input B attenuator to 0.1-1.2V position. Set oscillator frequency to 40 KHz, output to 1 volt RMS. Depress 0° CAL button momentarily, then release. Meter should read 000.00°. Switch input B attenuator to 1-12V position. Adjust R203 for minimum change. Tolerance: $\pm 0.02^{\circ}$.

Set both input attenuators to 1-12V position. Change oscillator frequency to 10 KHz, output to 10 volts RMS. Depress 0°CAL button momentarily, then release. Meter should read 000.00°. Switch input B attenuator to 10-120V position. Adjust C208 for minimum change. Tolerance: $\pm 0.02^{\circ}$.

Switch input B attenuator to 1-12V position. Change oscillator frequency to 40 KHz, output to 10 volts RMS. Depress 0° CAL button momentarily, then release. Meter should read 000.00°. Switch input B attenuator to 10-120V position. Adjust R208 for minimum change. Tolerance: $\pm 0.02^{\circ}$. Disconnect phasemeter inputs.

6.3.10 Attenuator Impedance Adjust (Inputs A and B)

Connect a square wave generator to the phasemeter inputs, using two (2) x 10 probes as shown in Figure 19. Set input attenuators to 0.1-1.2V, phasemeter waveform switch to ⊓⊔. Set the generator frequency to 1 KHz, output to .3V p-p. Connect the oscilloscope, using a calibrated X10 probe to phasemeter TP7. Set the oscilloscope for 10 mv/cm, Cal., AC coupled, horizontal to .2 ms/cm Cal. Adjust the probe connected to input A for a good square wave on the scope. (A slight ringing is normal).

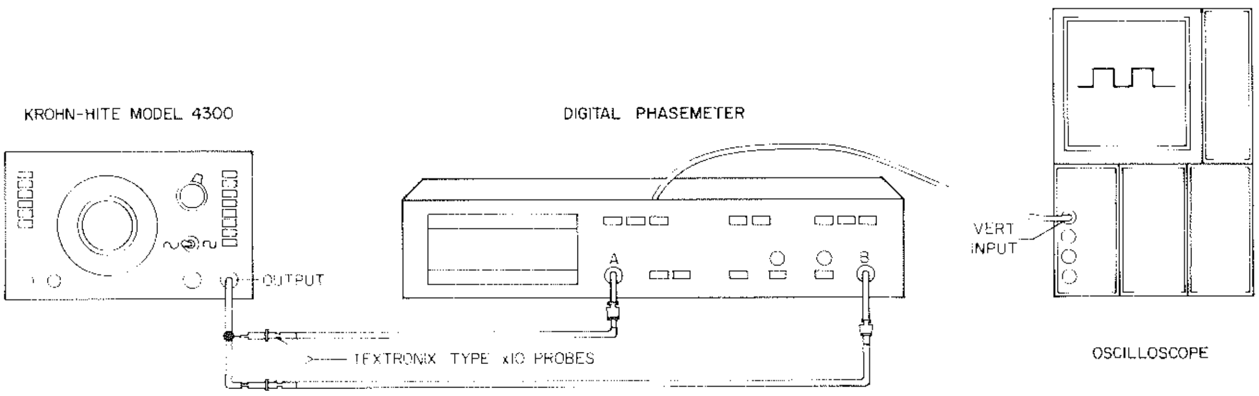


Figure 19. Attenuator Impedance Adjustment Test Set-up

Connect the oscilloscope probe to TP2. Adjust the probe connected to input B for a good square wave on the scope. (A slight ringing is normal).

Switch both input attenuators to 1-12V position. Set generator output to 3V p-p on each phasemeter input. Change the scope vertical to .1 volt/cm, Cal. Connect scope probe to TP7. Adjust C405 for a good square wave. Connect scope probe to TP2. Adjust C205 for a good square wave.

Switch both attenuators to 10-120V position. Set the generator output for 30V p-p. Change the scope vertical to 1 volt/cm Cal. Connect the oscilloscope probe to TP7. Adjust C409 for a good square wave.

Connect the oscilloscope probe to TP2. Adjust C209 for a good square wave. Remove generator, oscilloscope, and X10 probes.

6.3.11 Incorrect Amplitude Indicator Adjust

Connect the main output of the low distortion oscillator to both phasemeter inputs, using matched cables. Set the oscillator frequency to 100 Hz, output amplitude to exactly 0.09 volts RMS. Set both phasemeter input attenuators to 0.1-1.2V positions, waveform switch to ∿. Adjust R477 so that the input A indicator light just goes out. Adjust R273 so that the input B indicator light just goes out.

6.3.12 Phase Vs. Frequency Calibration Check (50 kHz)

Leave the output of the low distortion oscillator connected to both phasemeter inputs. Change the oscillator output to 0.1 volts RMS. Depress the 0° CAL button and readjust the 0° CAL ADJ pot for a meter reading of 000.00°. Depress the 360° CAL button and readjust the 360° CAL ADJ pot for a reading of 360.00°. Depress the 0° CAL button momentarily, then release. Readjust R501 for a reading of 000.00°. Depress the 360° CAL button momentarily, then release. Readjust R490 for a reading of 360.00°.

Change oscillator frequency to 50 kHz, output to 0.3 volts RMS. Depress the 360° CAL button momentarily, then release. Readjust C225 for a reading of 360.00°. Depress the 0° CAL button momentarily, then release. Adjust C647 for a reading of 000.00°. Recheck 360.00° at 50 kHz (C225). Disconnect the low distortion oscillator.

ITORS

Symbol	Description			Mfr.	Mfr. Part No.
C432	22pF	10%	500V	KGN	DM15C220K
C433	50uf		25V	SP	30D506G025CC4
C434	TRIM			ELM	TYPE DM15
C436	3.5-13pF			STT	7S-TRIKO-02
C437	6.8uf	20%	35V	SP	196D685X0035FB
C438	6.8uf	20%	35V	SP	196D685X0035FB
C439	1000pf	20%	500V	SP	C023B501E102M
C440	2pF	10%	500V	ASP	9208-20910
C460	1uf	20%	35V	SP	196D105X0035HA1
C461	22pf	10%	500V	ELM	DM15C220K
C462	36pf	10%	500V	SP	DM15C360K
C463	6.8uf	20%	35V	SP	196D685X0035FB
C464	6.8uf	20	35V	SP	196D685X0035SB
C465	0.47uf	20%	100V	ERT	8131-100-651-474M
C466	1uf	20%	35V	SP	196D105X0035HA1
C469	1uf	20%	35V	SP	196D105X0035HA1
C470	10uf	10%	100V	TRW	X663F-17
C471	0.1uf	20%	100V	ERT	8131-100-651-104M
C472	0.047uf	20%	50V	ERT	8131-050-651-473M
C473	1uf	20%	35V	SP	196D105X0035HA1
C474	0.01uf	20%	500V	SP	C023B501G103M
C475	100uf		25V	SP	30D107G025DD4
C476	1uf	20%	35V	SP	196D105X0035HA1
C477	22pf	10%	500V	ELM	DM15C220K
C520	0.001uf	20%	500V	SP	C023B501E102M
C521	0.01uf	20%	500V	SP	C023B501G103M
C522	3300pf	20	500V	SP	C023B501F332M
C523	4.5-20pf TRIMMER			STT	7S-TRIKO-02-N750
C524	33pf	5%	500V	ELM	DM15C330J
C525	22pf	10%	500V	ELM	DM15C220K
C527	1000pf	20%	500V	SP	C023B501E102M
C531	0.8-4.5pf TRIMMER			ERT	561-013
C532	3.3pF	10%	500V	ASP	9209-33910
C533	1uf	20%	35V	SP	196D105X0035HA1
C534	1uf	20%	35V	SP	196D105X0035HA1
C535		TRIM		ELM	TYPE DM15
C536	1uF	20%	35V	SP	196D105X0035HA1
C537	1uF	20%	100V	ITT	SR401E105MAA
C540	6.8uf	20%	35V	SP	196D685X0035FB
C541	1uf	20%	35V	SP	196D105X0035HA1
C542	50uf		25V	SP	30D506G025CC4
C543	0.1uf	20%	100V	ERT	8131-100-651-104M
C544	50uf		25V	SP	30D506G025CC4
C545	39pf	10%	500V	ELM	DM15C390K
C546	12pf	10%	500V	ASP	9213-12110
C547	4700pf	20%	500V	SP	C023B501F472M
C548	36pF	5%	500V	ELM	DM15C360K
C550	100pF	10%	500V	ELM	DM15C101K
C551	6.8uf	20%	35V	SP	196D685X0035FB
C552	1pf	10%	500V	ASP	9206-10910
C553	1uf	20%	35V	SP	196D105X0035HA1
C554	1uf	20%	35V	SP	196D105X0035HA1
C555	1000pf	20%	500V	SP	C023B501E102M
C556	6.8uf	20%	35V	SP	196D685X0035FB
C557	50uf		25V	SP	30D506G025CC4
C558	15uf		50V	SP	30D156G050CB4
C600	1000pf	20%	500V	SP	C023B501E102M
C601	12pf	10%	500V	ASP	9213-12110
C602	1000pf	20%	500V	SP	C023B501E102M
C603	1000pf	20%	500V	SP	C023B501E102M
C604	39pf	10%	500V	ELM	DM15C390K
C630	4.7pf	10%	500V	ASP	9210-47910
C632	1uf	20%	35V	SP	196D105X0035HA1
C633	7-35pf TRIMMER			STT	7S-TRIKO-02-N1500
C634	1uf	20%	35V	SP	196D105X0035HA1
C635	36pf	10%	500V	ELM	DM15C360K
C636	1uf	20%	35V	SP	196D105X0035HA1
C637	10pf	10%	500V	ELM	DM15C100J
C638		TRIM			
C639		TRIM			
C640	0.0033uf	20%	500V	SP	C023B501F332M
C641	4.7pf	10%	500V	ASP	9210-47910
C642	0.001uf	20%	500V	SP	C023B501E102M
C643	1uf	20%	35V	SP	196D105X0035HA1
C644	0.001uf	20%	500V	SP	C023B501E102M
C645	0.02uf	20%	500V	SP	C023A501J203M
C646	0.02uf	20%	500V	SP	C023A501J203M
C647	4.5-20pf TRIMMER			STT	7S-TRIKO-02-N750
C648	1pf	10%	500V	ASP	9206-10910
C649	0.001uf	20%	500V	SP	C023B501E102M
C650	10uf	10%	100V	TRW	X663F-17
C651	1uf	20%	35V	SP	196D105X0035HA1
C652	100pF	10%	500V	ELM	DM15C101K
C654	1uf	20%	35V	SP	196D105X0035HA1
C655	0.22uf	20%	50V	ERT	8131-100-651-224M
C656	22pf	10%	500V	ELM	DM15C220K
C657	0.01uf	20%	500V	SP	C023B501G103M
C658	0.047uf	20%	100V	ERT	8131-100-651-473M
C659	1uf	20%	35V	SP	196D105X0035HA1
C660	1uf	20%	35V	SP	196D105X0035HA1
C661	1uf	20%	35V	SP	196D105X0035HA1
C662	0.001uf	20%	500V	SP	C023B501E102M
C663	0.01uf	20%	500V	SP	C023B501G103M
C664	6.8uf	20%	35V	SP	196D685X0035FB
C665	6pf	5%	500V	ELM	DM15C6095
C700	25uf		16V	SP	30D256G016BB4
C701	25uf		16V	SP	30D256G016BB4

*C200, C400 matched within 1%.

RESISTORS

Symbol	Description			Mfr.	Mfr. Part No.
R200	1M	1%	1/4W	CGW	RN60D-NA60
R201	22M	10%	1/4W	AB	CB2261
R202	2.7	10%	1/4W	AB	CB27G1
R203	5K POT			BKM	72PM
R204	10M	10%	1/4W	AB	CB1061
R205	124K	1%	1/4W	CGW	RN60D-NA60
R206	180	10%	1/4W	AB	CB1811
R208	5K POT			BKM	72PM
R209	39M	10%	1/4W	AB	CB3961
R210	10K	1%	1/2W	CGW	RN60D-NA60
R211	1.2M	10%	1/4W	AB	CB1251
R212	22	10%	1/4W	AB	CB2201
R220	470	10%	1/4W	AB	CB4711
R221	22K	10%	1/2W	AB	EB2231
R222	1M	1%	1/4W	AB	CC1004F
R223	820	10%	1/4W	AB	CB8211
R224	2K	5%	1/4W	AB	CB2025
R225		TRIM		AB	TYPE CB
R226		TRIM		AB	TYPE CB
R227		TRIM		AB	TYPE CB
R228	1K	10%	1/4W	AB	CB1021
R229	2K	5%	1/4W	AB	CB2025
R230	5.1K	5%	1/4W	AB	CB5125
R231	100	10	1/4W	AB	CB1011
R232	10K	10%	1/4W	AB	CB1031
R233	820	10%	1/4W	AB	CB8211
R234	10K	10%	1/4W	AB	CB1031
R235	820	10%	1/4W	AB	CB8211
R236	22K	10%	1/4W	AB	CB2231
R237	1.5K	10%	1/4W	AB	CB1521
R238	100	10%	1/4W	AB	CB1011
R239	100	10	1/4W	AB	CB1011
R240	4.7K	10%	1/4W	AB	CB4721
R241	6.8K	10%	1/4W	AB	CB6821
R242	2.7K	10%	1/4W	AB	CB2721
R243	1.2K	5%	1/4W	AB	CB1225
R244	3.6K	5%	1/4W	AB	CB3625
R245		TRIM		AB	TYPE CB
R246	2.2K	10%	1/4W	AB	CB2221
R247	1K POT			BKM	72PM
R248	100	10%	1/4W	AB	CB1011
R249	100	10%	1/4W	AB	CB1011
R250	100	10%	1/4W	AB	CB1011
R251	1.8K	10%	1/4W	AB	CB1821
R252	680	10%	1/2W	AB	EB6811
R254	8.2K	10%	1/4W	AB	CB8221
R255	2.7	10%	1/4W	AB	CB27G1
R260	330	10%	1/4W	AB	CB3311
R261	3.3K	10%	1/4W	AB	CB3321
R262	470	10%	1/4W	AB	CB4711
R263	1K	10%	1/4W	AB	CB1021
R264	47K	10%	1/4W	AB	CB4731
R265	2.7	10%	1/4W	AB	CB2731
R266	27K	10%	1/4W	AB	CB2731
R267	22K	10%	1/4W	AB	CB2231
R268	1K	10	1/4W	AB	CB1021
R269	120K	10%	1/4W	AB	CB1241
R270	120K	10%	1/4W	AB	CB1241
R271	680K	5%	1/4W	AB	CB6845
R272	560K	10%	1/4W	AB	CB5641
R273	100K POT			BKM	72XW
R274	330K	10%	1/4W	AB	CB3341
R275	1.5M	10%	1/4W	AB	CB1551
R276	1M	10%	1/4W	AB	CB1051
R277		TRIM		AB	TYPE CB
R278	15K	10%	1/4W	AB	CB1531
R279	100K	10%	1/4W	AB	CB1041
R280	24K	5%	1/4W	AB	CB2435
R281	30K	5%	1/4W	AB	CB3035
R282	8.2K	10%	1/4W	AB	CB8221
R284	10	10%	1/4W	AB	CB1001
R285	3.3K	10%	1/4W	AB	CB3321
R286	220	10%	1/4W	AB	CB2211
R287	6.8K	10%	1/4W	AB	CB6821
R288	3K	5%	1/4W	AB	CB3025
R289	18K	10%	1/4W	AB	CB1831
R290	1K	10%	1/4W	AB	CB1021
R291	33K	10%	1/4W	AB	CB3331
R292	11.3K	1	1/4W	AB	CC1132F
R293	23.2K	1%	1/4W	AB	CC2322F
R294	220	10	1/4W	AB	CB2211
R295	220	10%	1/4W	AB	CB2211
R296	18K	10	1/4W	AB	CB1831
R297	3.3K	10%	1/4W	AB	CB3321
R298	1K	10%	1/4W	AB	CB1021
R299	6.2K	5%	1/4W	AB	CB6225
R300	5.1K	5%	1/4W	AB	CB5125
R301	10K	10%	1/4W	AB	CB1031
R302	1K	10%	1/4W	AB	CB1021
R303	8.2K	10	1/4W	AB	CB8221
R310	39	10%	1/4W	AB	CB3901
R311	100	10%	1/4W	AB	CB1011
R312	1K	10%	1/4W	AB	CB1021
R313	2.2K	10%	1/4W	AB	CB2221
R314	1M POT			BKM	72PM
R315	100K	10%	1/4W	AB	CB1041
R316	2K	5%	1/4W	AB	CB2025
R317	680	10%	1/4W	AB	CB6811
R320	10K	10%	1/4W	AB	CB1031
R321	24K	5%	1/4W	AB	CB2435
R322	13K	5%	1/4W	AB	CB1335
R323	3.6M	5%	1/4W	AB	CB3655
R324	47	10%	1/4W	AB	CB4701
R325	47	10%	1/4W	AB	CB4701
R326	1.5K	10%	1/4W	AB	CB1521
R327	220	10%	1/4W	AB	CB2211
R329	3K	5%	1/4W	AB	CB3025
R330	27	10%	1/4W	AB	CB2701
R331	100	10%	1/4W	AB	CB1011
R332	220	10%	1/4W	AB	CB2211
R333	470	10%	1/4W	AB	CB4711
R334	220	10%	1/4W	AB	CB2211
R335	27	10%	1/4W	AB	CB2701
R336	36K	5%	1/4W	AB	CB3635
R337	39	10%	1/4W	AB	CB3901
R338	10K	10%	1/4W	AB	CB1031
R339	390	5%	1W	AB	CB3915
R340	2.7	10%	1/4W	AB	CB27G1
R341	1K	10%	1/4W	AB	CB1021
R342	10K	10%	1/4W	AB	CB1031
R343	240	5%	1/4W	AB	CB2415
R344	2.7K	10%	1/4W	AB	CB2721
R345	10K	10%	1/4W	AB	CB1031
R346	3.3K	10%	1/4W	AB	CB3321
R347	22K	10%	1/4W	AB	CB2231
R348	56K	10%	1/4W	AB	CB5631
R349	560	10%	1/4W	AB	CB5611
R400	1M	1%	1/2W	CGW	RN60D-NA60
R401	22M	10%	1/4W	AB	CB2261
R402	2.7	10%	1/4W	AB	CB27G1
R403	5K POT			BKM	72PM
R404	10M	10%	1/4W	AB	CB1061
R405	124K	1%	1/4W	CGW	RN60D-NA60
R406	180	10%	1/4W	AB	CB1811
R408	5K POT			BKM	72PM
R409	39M	10%	1/4W	AB	CB3961
R410	10K	1%	1/4W	CGW	RN60D-NA60
R411	1.2M	10	1/4W	AB	CB1251
R412	22	10%	1/4W	AB	CB2201
R420	470	10%	1/4W	AB	CB4711
R421	22K	10%	1/4W	AB	CB2231
R422	1M	1%	1/4W	AB	CB1004F
R423	820	10%	1/4W	AB	CB8211
R424	2K	5%	1/4W	AB	CB2025
R425		TRIM		AB	TYPE CB
R426		TRIM		AB	TYPE CB
R427	3.3K	10%	1/4W	AB	CB3321
R428	1K	10%	1/4W	AB	CB1021
R429	2K	5%	1/4W	AB	CB2025
R430	5.1K	5%	1/4W	AB	CB5125
R431	100	10	1/4W	AB	CB1011
R432	10K	10%	1/4W	AB	CB1031
R433	820	10%	1/4W	AB	CB8211
R434	10K	10%	1/4W	AB	CB1031
R435	820	10%	1/4W	AB	CB8211
R436	22K	10%	1/4W	AB	CB2231
R437	1.5K	10%	1/4W	AB	CB1521
R438	100	10%	1/4W	AB	CB1011
R439	100	10%	1/4W	AB	CB1011
R440	4.7K	10%	1/4W	AB	CB4721
R441	6.8K	10%	1/4W	AB	CB6821
R442	2.7K	10	1/4W	AB	CB2721
R443	1.2K	5%	1/4W	AB	CB1225
R444	3.6K	5%	1/4W	AB	CB3625
R445		TRIM		AB	TYPE CB
R446	2.2K	10%	1/4W	AB	CB2221
R447	1K POT			BKM	72PM
R448	100	10%	1/4W	AB	CB1011
R449	100	10%	1/4W	AB	CB1011
R450	100	10%	1/4W	AB	CB1011
R451	1.8K	10%	1/4W	AB	CB1821
R452	680	10%	1/2W	AB	CB6811
R453	47	10%	1/4W	AB	CB4701
R454	8.2K	10%	1/4W	AB	CB8221
R455	2.7	10%	1/4W	AB	CB27G1
R456	25K POT			BKM	72PM
R460	330	10%	1/4W	AB	CB3311
R461	3.3K	10%	1/4W	AB	CB3321
R462	470	10%	1/4W	AB	CB4711
R463	1K	10	1/4W	AB	CB1021
R464	100	10%	1/4W	AB	CB1011
R465	2.7	10%	1/4W	AB	CB27G1
R466	5.1K	5%	1/4W	AB	CB5125
R467	15K	10%	1/4W	AB	CB1531
R468	47K	10%	1/4W	AB	CB4731
R469	91K	5%	1/4W	AB	CB9135
R470	22K	10%	1/4W	AB	CB2231
R471	1K	10%	1/4W	AB	CB1021
R472	120K	10%	1/4W	AB	CB1241
R473	680K	5%	1/4W	AB	CB6845
R474	120K	10%	1/4W	AB	CB1241
R475	560K	10%	1/4W	AB	CB5641
R477	100K POT			BKM	72XW
R478	330K	10%	1/4W	AB	CB3341
R479	1.5M	10%	1/4W	AB	CB1551
R480	100K	10%	1/4W	AB	CB1041
R481	5.6K	10%	1/4W	AB	CB5621
R482	15K	10%	1/4W	AB	CB1531
R483	1M	10%	1/4W	AB	CB1051
R484		TRIM		AB	TYPE CB
R485	24K	5%	1/4W	AB	CB2435
R486	30K	5%	1/4W	AB	CB3035
R488	187K	1%	1/8W	KID	M3-T1-187
R489		TRIM	1/8W	AB	TYPE CC
R490	5K POT			BKM	72PM
R491	180K	10%	1/4W	AB	CB1841
R492	8.2K	10%	1/4W	AB	CB8221
R493	3.3K	10%	1/4W	AB	CB3321
R494	10K	10%	1/4W	AB	CB1031
R495	220	10%	1/4W	AB	CB2211
R496	3K	5%	1/4W	AB	CB3025
R497	6.8K	10%	1/4W	AB	CB6821
R498	18K	10%	1/4W	AB	CB1831
R499	1K	10%	1/4W	AB	CB1021
R500A	318.4K	1%	1/8W	KID	M3-T1-31
R500B		TRIM		AB	TYPE CC
R501	20K POT, 18 TURN			BKM	6BWR20K
R502	33K	10%	1/4W	AB	CB3331

SISTORS

Symbol	Description			Mfr.	Mfr. Part No.
R602	390	10%	1/4W	AB	CB3911
R603	510	5%	1/4W	AB	CB5115
R604	330	10%	1/4W	AB	CB3311
R605	220	10%	1/4W	AB	CB2211
R606	1.1K	5%	1/4W	AB	CB1125
R607	240	5%	1/4W	AB	CB2415
R608	3.3K	10%	1/4W	AB	CB3321
R609	1.2K	10%	1/4W	AB	CB1221
R610	1.2K	10%	1/4W	AB	CB1221
R611	1.1K	5%	1/4W	AB	CB1125
R612	240	5%	1/4W	AB	CB2415
R613	3.3K	10%	1/4W	AB	CB3321
R614	220	10%	1/4W	AB	CB2211
R615	390	10%	1/4W	AB	CB3911
R616	1.8K	10%	1/4W	AB	CB1821
R617	1.8K	10%	1/4W	AB	CB1821
R618	510	5%	1/4W	AB	CB5115
R619	1K	10	1/4W	AB	CB1021
R630	680	10%	1/4W	AB	CB6811
R631	220	10%	1/4W	AB	CB2211
R632	1K	10	1/4W	AB	CB1021
R633	562	1%	1/4W	AB	EC5620F
R634	562	1%	1/4W	AB	EC5620F
R635	49.9	1%	1/4W	AB	CC49R9F
R636	680	10%	1/4W	AB	CB6811
R637	2K	5%	1/4W	AB	CB2025
R638	12K	10%	1/4W	AB	CB1231
R639	49.9	1%	1/4W	AB	CC49R9F
R640A	220	10%	1/4W	AB	CB2211
R640B	TRIM			AB	TYPE CB
R641	18K	10%	1/4W	AB	CB1831
R642	10K, POT, 0° ADJ			KH	B3304-C
R643	1.33K	1%	1/4W	AB	CC1331F
R644	TRIM			AB	TYPE CB
R645	15.8K	1%	1/8W	TRW	TYPE RN55E*
R646	200K	1%	1/8W	AB	CC2003F
R647	500 POT			BKM	72PM
R648	1K	1%	1/4W	AB	CC1001F
R649	10K POT, 360° ADJ			KH	B3304-C
R650	100	10%	1/4W	AB	CB1011
R651	17.8K	1%	1/8W	TRW	TYPE RN55E*
R652	19.6K	1%	1/8W	TRW	TYPE RN55E*
R653	200 POT			BKM	72PM
R654	61.9K	1%	1/8W	AB	CC6192F
R655	3.3K	10%	1/4W	AB	CB3321
R656	TRIM			AB	TYPE CB
R657A	TRIM			AB	TYPE CB
R657B	TRIM			AB	TYPE CB
R658	180K	10%	1/4W	AB	CB1841
R659	15K	10%	1/4W	AB	CB1531
R660	TRIM			AB	TYPE CB
R662	27	10%	1/4W	AB	CB2701
R663	100K	10%	1/4W	AB	CB1041
R665	82	10%	1/4W	AB	CB8201
R666	27K	10%	1/4W	AB	CB2731
R671	1K	10%	1/4W	AB	CB1021
R672	432	1%	1/8W	AB	CC4321F
R673	220	10%	1/4W	AB	CB2211
R674	3.3K	10%	1/4W	AB	CB3321
R677	5.6K	10%	1/4W	AB	CB5621
R678	1K	10%	1/4W	AB	CB1021
R679	1K	10%	1/4W	AB	CB1021
R680	220K	5%	1/4W	AB	CB2245
R681	3.3K	10%	1/4W	AB	CB3321

*T.C.: 25 ppm/°C

TRANSISTORS, DIODES & MISC.

Symbol	Description	Mfr.	Mfr. Part No.
Q220	FET, N-CHANNEL	GE	2N4340*
Q221	TRANSISTOR, NPN	MOT	MPS6566
Q222	TRANSISTOR, PNP	MOT	MPS6566
Q223	TRANSISTOR, NPN	MOT	MPS3640
Q224	TRANSISTOR, PNP	MOT	MPS6518
Q225	TRANSISTOR, PNP	MOT	MPS6518
Q260	TRANSISTOR, NPN	TI	TIS97
Q261	TRANSISTOR, NPN	TI	TIS97
Q262	FET, N-CHANNEL	MOT	MPF4392
Q263	TRANSISTOR, NPN	MOT	MPS2369
Q264	FET, N-CHANNEL	GE	2N4340
Q265	TRANSISTOR, NPN	TI	TIS97
Q266	TRANSISTOR, NPN	MOT	MPS3640
Q267	TRANSISTOR, PNP	MOT	MPS3640
Q268	TRANSISTOR, NPN	MOT	MPS3646
Q310	TRANSISTOR, NPN	TI	TIS97
Q311	TRANSISTOR, NPN	MOT	MPS6515
Q312	TRANSISTOR, PNP	MOT	MPS6518
Q420	FET, N-CHANNEL	GE	2N4340*
Q421	TRANSISTOR, NPN	MOT	MPS6566
Q422	TRANSISTOR, PNP	MOT	MPS3640
Q423	TRANSISTOR, NPN	MOT	MPS6566
Q424	TRANSISTOR, PNP	MOT	MPS6518
Q425	TRANSISTOR, PNP	MOT	MPS6518
Q460	TRANSISTOR, NPN	TI	TIS97
Q461	TRANSISTOR, NPN	TI	TIS97
Q462	FET, N-CHANNEL	MOT	MPF4392
Q463	TRANSISTOR, NPN	MOT	MPS2369
Q464	FET, N-CHANNEL	GE	2N4340
Q465	TRANSISTOR, NPN	TI	TIS97
Q466	TRANSISTOR, PNP	MOT	MPS3640
Q467	TRANSISTOR, PNP	MOT	MPS3640
Q468	TRANSISTOR, NPN	MOT	MPS3646
Q520	TRANSISTOR, NPN	TI	TIS97
Q521	TRANSISTOR, NPN	MOT	MPS6515
Q522	TRANSISTOR, PNP	MOT	MPS6518
Q540	TRANSISTOR, NPN	MOT	2N5087
Q541	TRANSISTOR, NPN	MOT	MPS6515
Q542	TRANSISTOR, PNP	MOT	MPS~~6518~~ 3640
Q543	FET, N-CHANNEL	MOT	MPF4392
Q544	TRANSISTOR, PNP	MOT	MPS~~6518~~ 3640
Q545	FET, N-CHANNEL	MOT	MPF4392
Q600	TRANSISTOR, PNP	MOT	MPS3640
Q601	TRANSISTOR, PNP	MOT	MPS3640
Q602	TRANSISTOR, PNP	MOT	MPS3640
Q603	TRANSISTOR, PNP	MOT	MPS3640
Q630	TRANSISTOR, PNP	MOT	MPS3640
Q631	TRANSISTOR, PNP	MOT	MPS3640
Q632	TRANSISTOR, PNP	MOT	MPS3640‡
Q633	FET, N-CHANNEL	MOT	MPF4392
Q634	TRANSISTOR, NPN	MOT	MPS2369
Q636	FET, DUAL N-CHANNEL	SIL	SU2366
Q637	TRANSISTOR, NPN	TI	TIS97
U260	OP AMP	NAT	LM318N
U310	OP AMP	NAT	LM318N**
U330	VOLTAGE COMPARATOR	NS	LM306H
U460	OP AMP	NAT	LM318N
U520	OP AMP	NAT	LM318N**
U540	VOLTAGE COMPARATOR	NS	LM306H
U630	OP AMP	MOT	LM308AN
CR220		MOT	MPS6515
CR221		MOT	MPS6515
CR222	DIODE, SWITCHING	APD	1N4149
CR223	DIODE, SWITCHING	APD	1N4149
CR260	DIODE, SWITCHING	APD	1N4149
CR261	DIODE, SWITCHING	APD	1N4149
CR262	DIODE, SWITCHING	APD	1N4149
CR263	DIODE, SWITCHING	APD	1N4149
CR264	DIODE, SWITCHING	APD	1N4149
CR265	DIODE, SWITCHING	APD	1N4149
CR266	DIODE, SWITCHING	APD	1N4149
CR310	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR311	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR312	DIODE, SWITCHING	APD	1N4149
CR313	DIODE, SWITCHING	APD	1N4149

Symbol	Description	Mfr.	Mfr. Par
CR330	DIODE, SWITCHING	APD	1N4149
CR331	DIODE, SWITCHING	APD	1N4149
CR332	DIODE, SWITCHING	APD	1N4149
CR333	DIODE, SWITCHING	APD	1N4149
CR334	DIODE, SWITCHING	APD	1N4149
CR420	TRANSISTOR, NPN	MOT	MPS6515
CR421	TRANSISTOR, NPN	MOT	MPS6515
CR422	DIODE, SWITCHING	APD	1N4149
CR423	DIODE, SWITCHING	APD	1N4149
CR460	DIODE, SWITCHING	APD	1N4149
CR461	DIODE, SWITCHING	APD	1N4149
CR462	DIODE, SWITCHING	APD	1N4149
CR463	DIODE, SWITCHING	APD	1N4149
CR464	DIODE, SWITCHING	APD	1N4149
CR465	DIODE, SWITCHING	APD	1N4149
CR466	DIODE, SWITCHING	FR	FD-300‖
CR520	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR521	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR522	DIODE, SWITCHING	APD	1N4149
CR523	DIODE, SWITCHING	APD	1N4149
CR540	DIODE, SWITCHING	APD	1N4149
CR541	DIODE, SWITCHING	APD	1N4149
CR542	DIODE, SWITCHING	APD	1N4149
CR543	DIODE, SWITCHING	APD	1N4149
CR544	DIODE, SWITCHING	APD	1N4149
CR545	DIODE, SWITCHING	APD	1N4149
CR546	DIODE, SWITCHING	APD	LN4149
CR547	DIODE, SWITCHING	APD	1N4149
CR548	DIODE, SWITCHING	APD	1N4149
CR600	DIODE, SWITCHING	APD	1N4149
CR601	DIODE, SWITCHING	APD	1N4149
CR602	DIODE, SWITCHING	APD	1N4149
CR603	DIODE, SWITCHING	APD	1N4149
CR630	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR631	DIODE, SWITCHING, H.C.§	MOT	MBD501
CR632	DIODE, SWITCHING	APD	1N4149
CR633	DIODE, SWITCHING	APD	1N4149
CR634	DIODE, SWITCHING	APD	1N4149
CR635	DIODE, SWITCHING, H.C.	MOT	MDB501¶
CR636	DIODE, SWITCHING, H.C.	MOT	MBD501¶
CR637	DIODE, SWITCHING	APD	1N4149
CR639	DIODE, SWITCHING	APD	1N4149
CR640	DIODE, SWITCHING	APD	1N4149
VR331	DIODE, ZENER, 9V	APD	LN937
VR546	DIODE, ZENER, 9V	APD	LN937
L220	5.6uH 10% 1/4W	DLV	1537-30
L221	5.6uH 10% 1/4W	DLV	1537-30
L222	5.6uH 10% 1/4W	DLV	1537-30
L224	5.6uH 10% 1/4W	DLV	1537-30
L225	1uH 10% 1/4W	DLV	1537-12
L330	5.6uH 10% 1/4W	DLV	1537-3
L331	47uH 10 1/4W	DLV	1537-6
L420	5.6uH 10% 1/4W	DLV	1537-3
L421	5.6uH 10% 1/4W	DLV	1537-3
L422	5.6uH 10% 1/4W	DLV	1537-3
L424	5.6uH 10% 1/4W	DLV	1537-3
L425	1uH 10% 1/4W	DLV	1537-1
L540	5.6uH 10 1/4W	DLV	1537-3
L541	47uH 10 1/4W	DLV	1537-6
L630	5.6uH 10% 1/4W	DLV	1537-3
L631	100uH 10% 1/4W	DLV	3500-0
L632	22uH 10% 1/4W	DLV	1537-4
DS201	LIGHT, INDICATOR, SET RANGE	DIA	2-559-
DS401	LIGHT, INDICATOR, SET RANGE	DIA	2-559-
S201	SWITCH, PUSHBUTTON, RMS VOLTS	KH	Part of #B3298
S401	SWITCH, PUSHBUTTON, RMS VOLTS	KH	
S601	SWITCH, PUSHBUTTON, 0° CAL	KH	Part of #B330
S602	SWITCH, PUSHBUTTON, 360° CAL	KH	
S701	SWITCH, PUSHBUTTON, WAVEFORM	KH	Part of #B329

NOTES:

*Q220, Q240 selected for $0.7V \le V_{gs} \le 1.1V$ @ $I_d = 400uA$, and for Vgs matching $\le$ 200 uV.

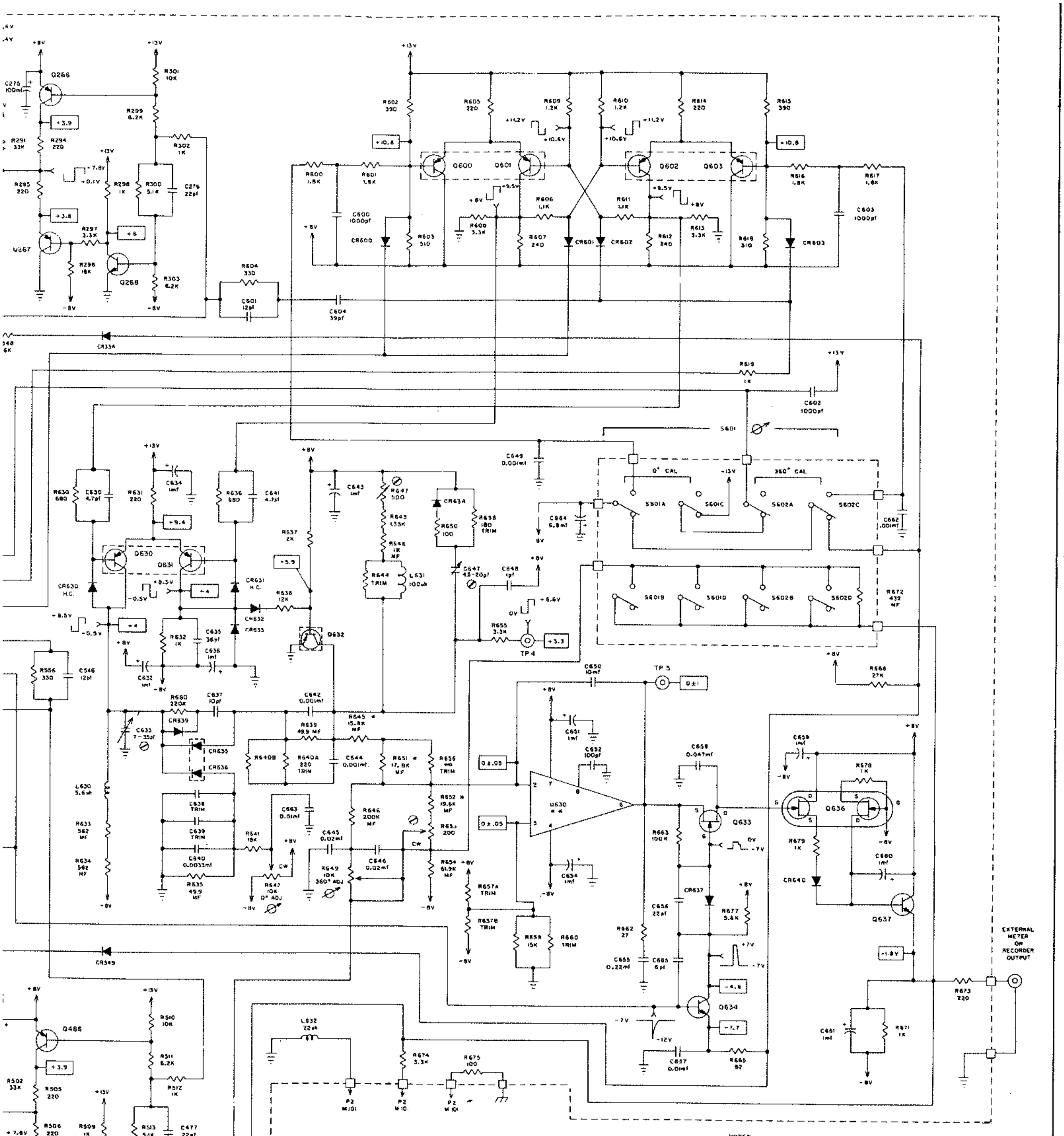
‡ Q632 selected for $\Delta V_f \le 3mV$ @ $\begin{cases} 10uA \le I_f \le 10mA \\ -55^oC \le T_A \le 100^oC \end{cases}$

§HC = HOT CARRIER.

‖VR466 selected for $I_R \le 1mA$ @ $V_R = 125V$.

¶CR635, CR636 T.C. matched within $5uV/^oC$, plus thermal clamping.

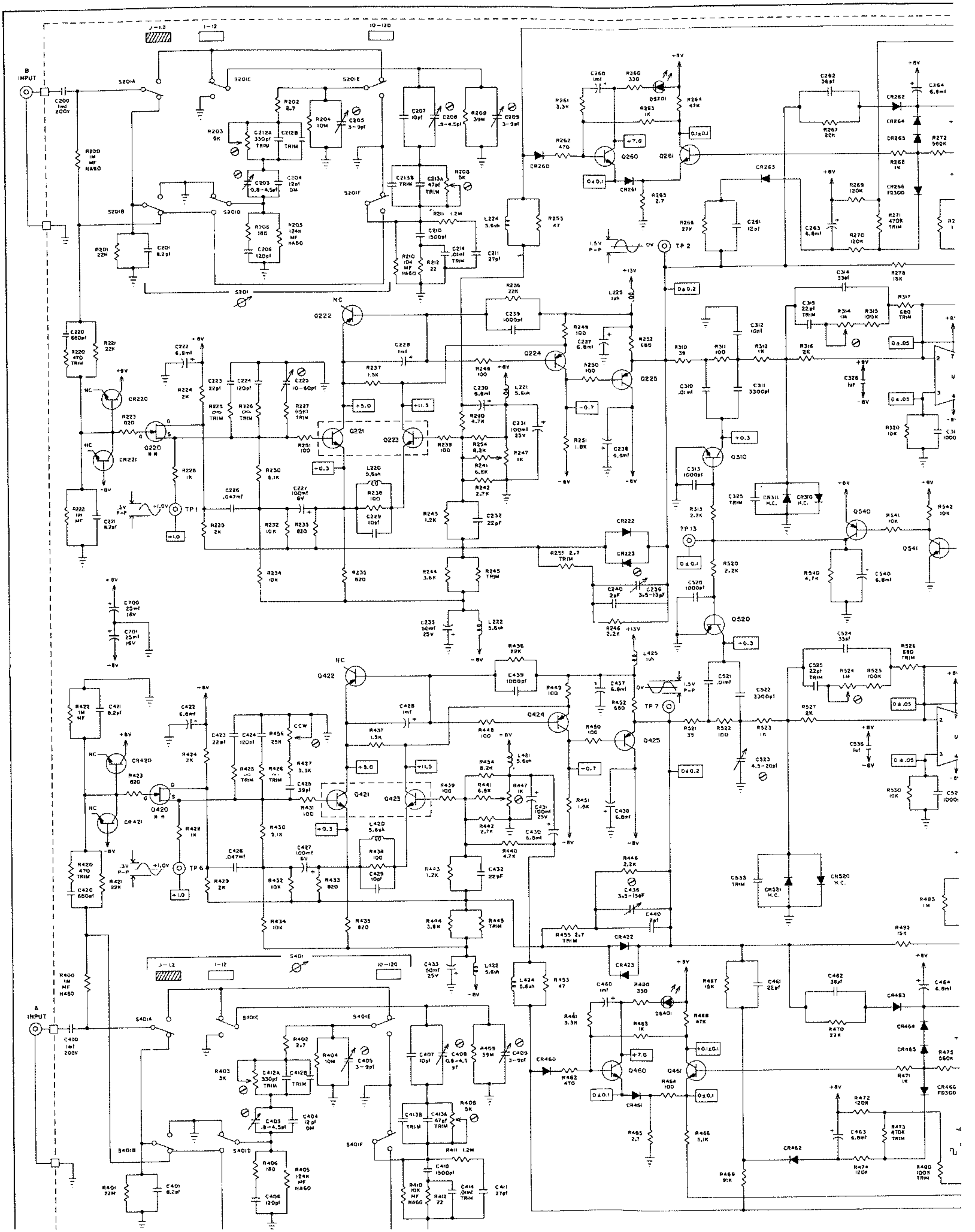
** SELECTED FOR LOW NOISE



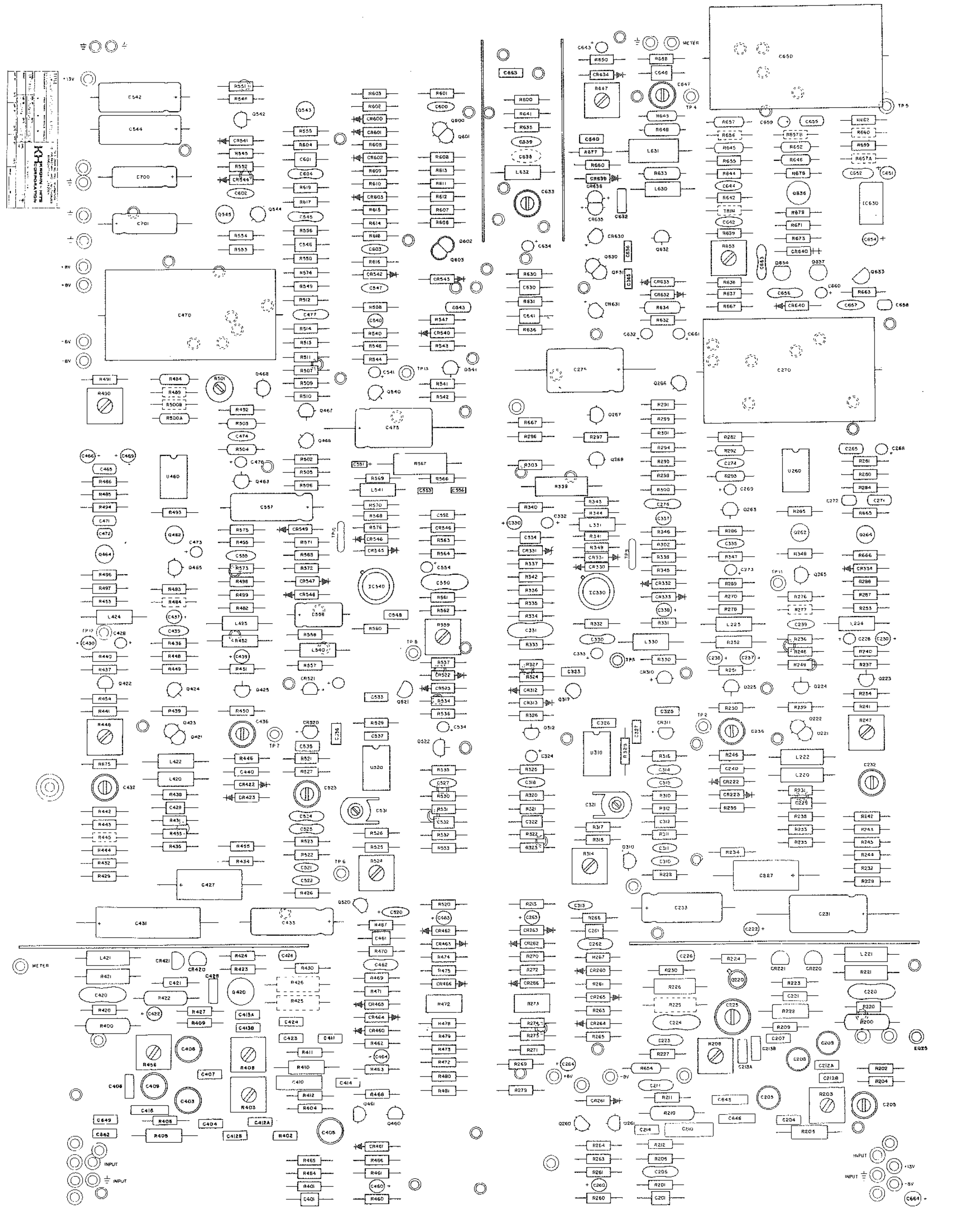
NOTES:

1. ALL RESISTORS IN OHMS UNLESS OTHERWISE SPECIFIED.
2. * TC 25 ppm/°C
3. VOLTAGES MEASURED UNDER THE FOLLOWING CONDITIONS: 1KHZ, 0.1V RMS SINE WAVES, 180° APART, APPLIED TO BOTH INPUTS
4. S201, S401 SHOWN IN .1–1.2V POSITION.
5. S701 SHOWN IN ∿ POSITION.
6. S603 SHOWN IN READ POSITION.
7. HOT CARRIER HC
8. FRONT PANEL CONTROL
9. P.C. CARD CONTROL
10. SIGNAL GROUND
11. CHASIS GROUND
12. TEST POINT
13. * * : SELECTED

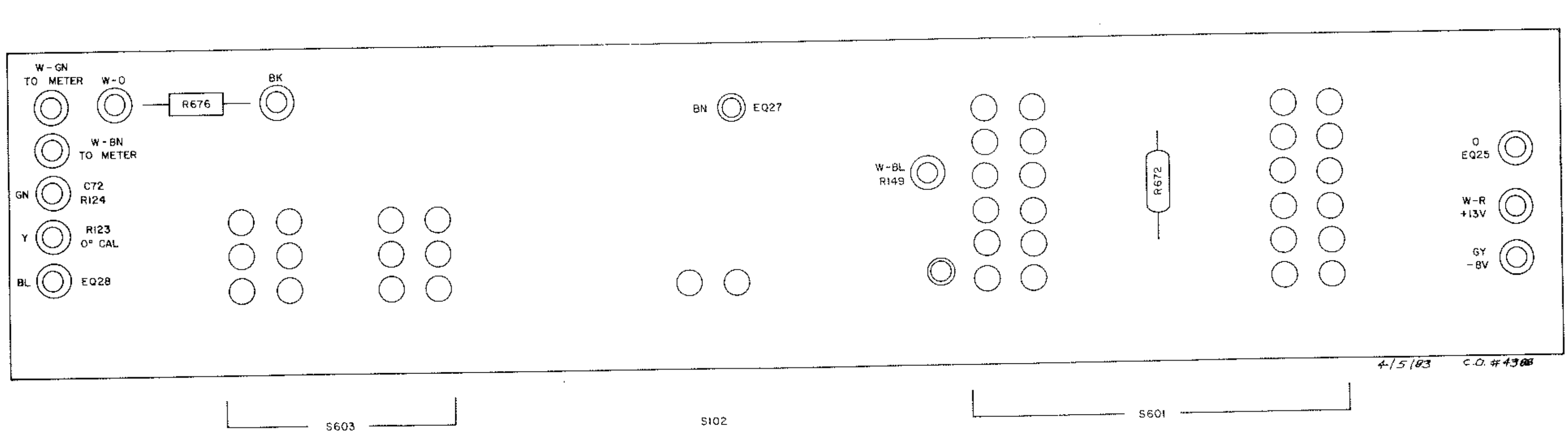
TITLE PHASEMETER	KROHN-HITE CORPORATION, CAMBRIDGE, MASS. U.S.A.
DRN BY R. Astbury, DATE 11-18-74	
CHK BY S.L.S., DATE 2-12-75	S-3452 E
4/5/83	CO# 4388, SHEET 1 OF 1



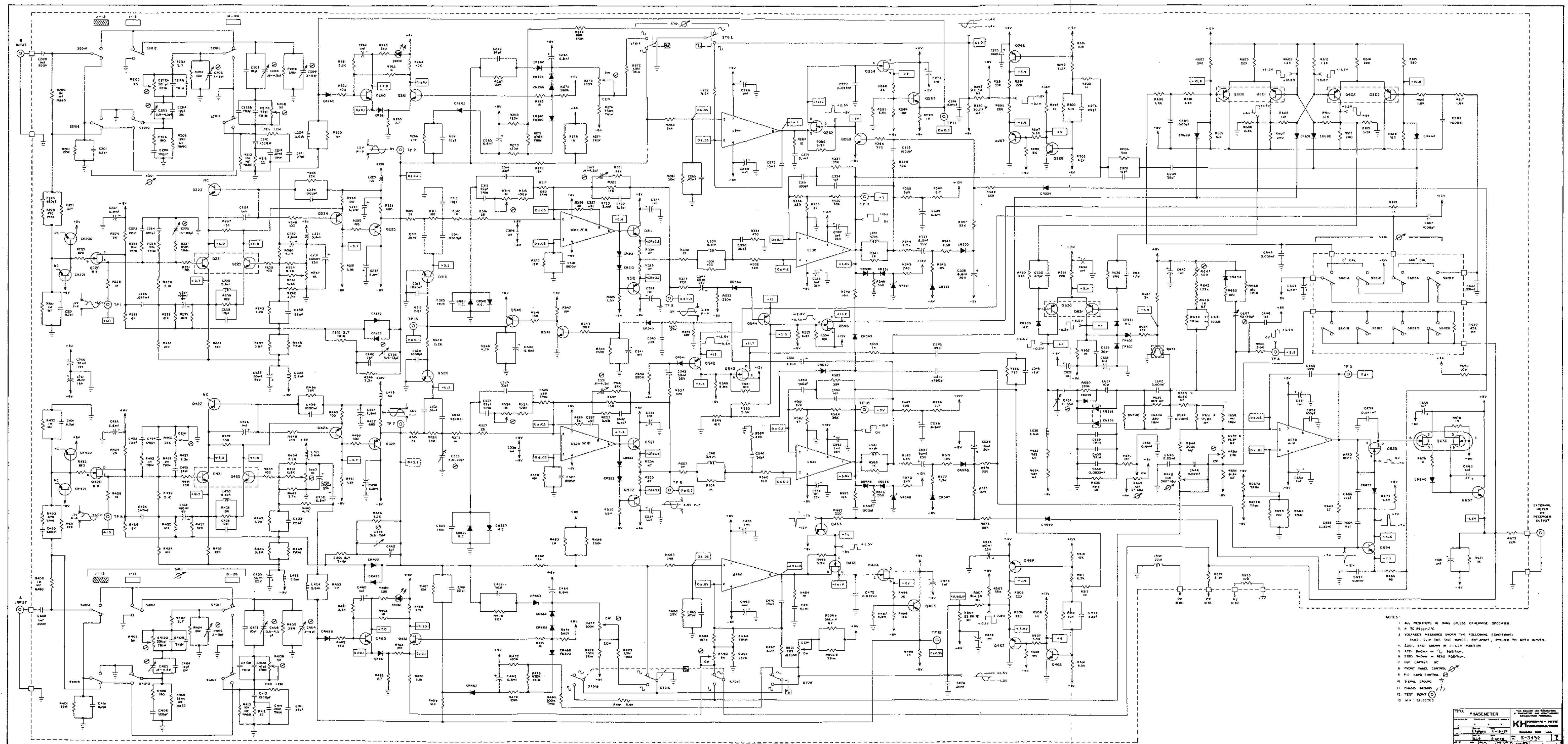
B INPUT
A INPUT
C200 1mf 200V
C400 1mf 200V
S201A
S201B
S201C
S201D
S201E
S201F
S201
S401A
S401B
S401C
S401D
S401E
S401F
S401
.1-1.2
1-12
10-120
R200 1M MF NA60
R400 1M MF NA60
R201 22M
C201 8.2pf
R401 22M
C401 8.2pf
R202 2.7
R203 5K
R204 10M
C205 3-9pf
C212A 330pf TRIM
C212B TRIM
C203 0.8-4.5pf
C204 12pf DM
R206 180
R205 124K MF NA60
C206 120pf
C207 10pf
C208 .8-4.5pf
R209 39M
C209 3-9pf
C213B TRIM
C213A 47pf TRIM
R208 5K
R211 1.2M
C210 1500pf
R210 10K MF NA60
R212 22
C214 .01mf TRIM
C211 27pf
L224 5.6uh
R253 47
CR260
R262 470
Q260
Q261
CR261
R265 2.7
DS201
R260 330
C260 1mf
R261 3.3K
R263 1K
R264 47K
+7.0
0±0.1
TP 2
1.5V P-P
0V
Q222
Q224
Q225
Q221
Q223
Q220
CR220
CR221
TP 1
+1.0V
+5.0
+11.5
-0.3
-0.7
Q310
Q520
Q540
Q541
TP 13
TP 7
TP 6
CR222
CR223
C235 50mf 25V
L222 5.6uh
C700 25mf 15V
C701 25mf 15V
Q422
Q424
Q425
Q421
Q423
Q420
CR420
CR421
Q460
Q461
DS401
CR460
CR461
CR462
CR422
CR423
L424 5.6uh
R453 47
C433 50mf 25V
L422 5.6uh
CR262
CR263
CR264
CR265
CR266 FD300
CR463
CR464
CR465
CR466 FD300
CR311 H.C.
CR310 H.C.
CR521 H.C.
CR520 H.C.
+8V
-8V
+13V


4/5/83
C.O #4388

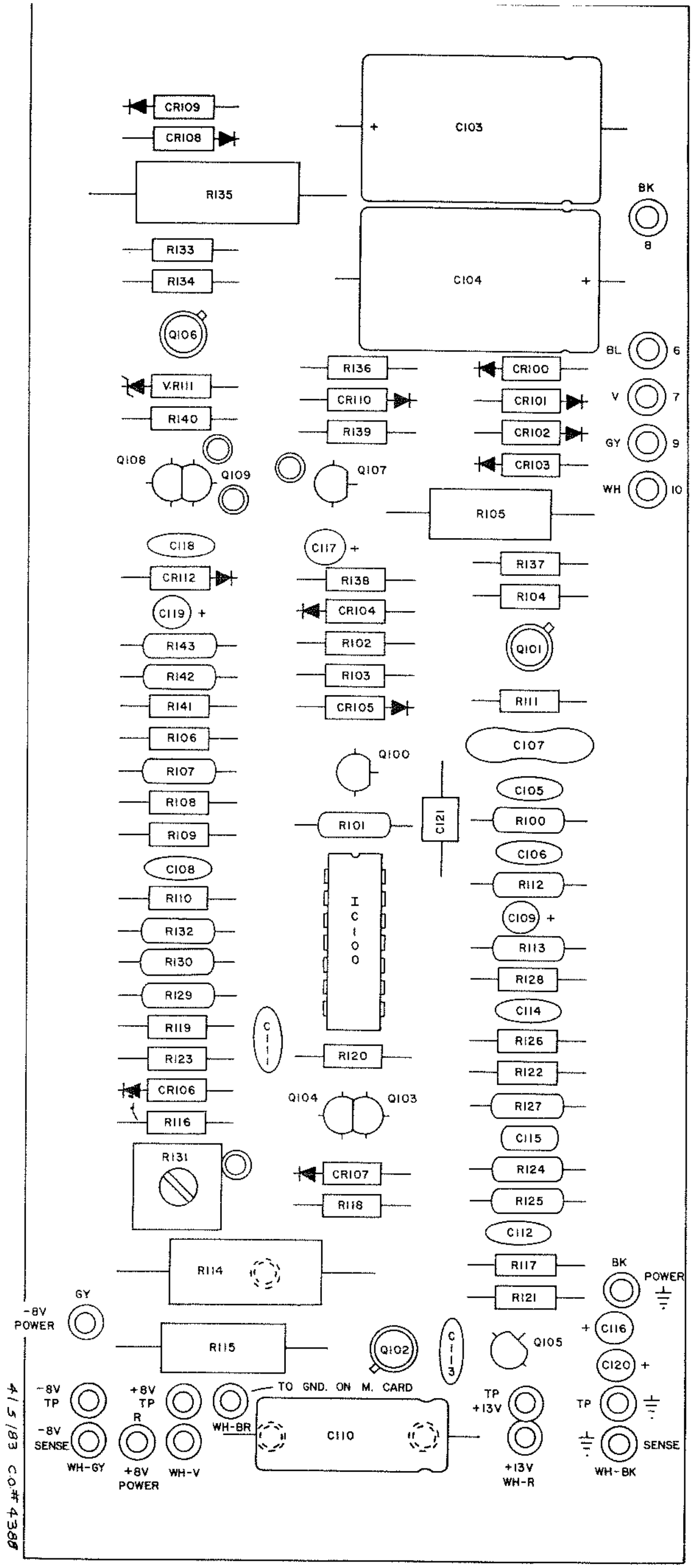
PC 601

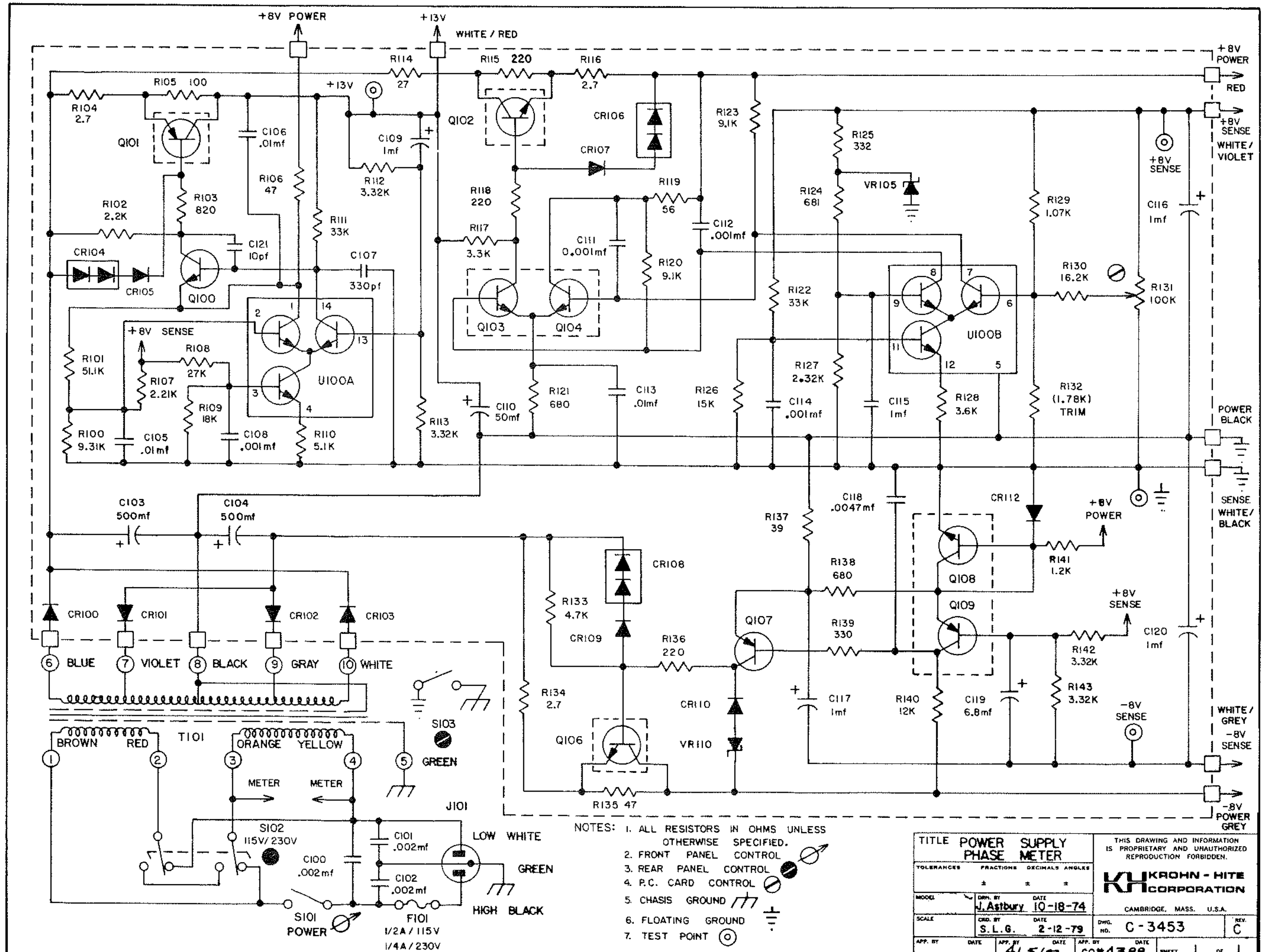

W-GN
TO METER
W-O
R676
BK
W-BN
TO METER
GN
C72
R124
Y
R123
0° CAL
BL
EQ28
BN
EQ27
W-BL
R149
R672
O
EQ25
W-R
+13V
GY
-8V
4/5/83
C.O. #4388
S603
S102
S601

PC 602



INPUT
EXTERNAL METER OR RECORDER OUTPUT
NOTES:
1. ALL RESISTORS IN OHMS UNLESS OTHERWISE SPECIFIED.
2. * TC 25ppm/°C
3. VOLTAGES MEASURED UNDER THE FOLLOWING CONDITIONS:
1KHZ, 0.1V RMS SINE WAVES, 180° APART, APPLIED TO BOTH INPUTS.
4. S201, S401 SHOWN IN .1-1.2V POSITION
5. S701 SHOWN IN POSITION.
6. S603 SHOWN IN READ POSITION.
7. HOT CARRIER HC
8. FRONT PANEL CONTROL
9. P.C. CARD CONTROL
10. SIGNAL GROUND
11. CHASIS GROUND
12. TEST POINT
13. * * : SELECTED
TITLE PHASEMETER
KH KROHN-HITE CORPORATION
S-3452
4/5/83
CO#4388





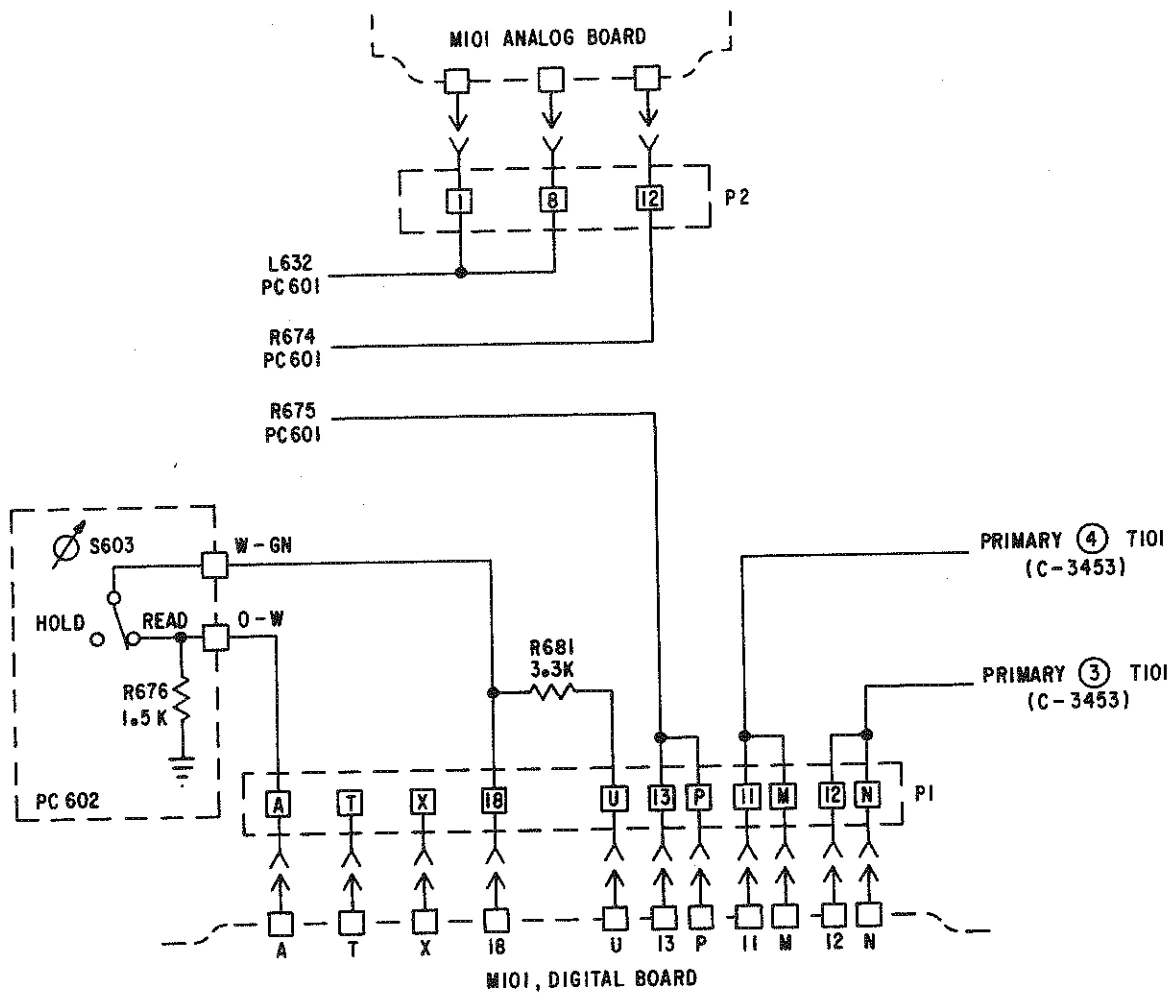
NOTES:
1. ALL RESISTORS IN OHMS UNLESS OTHERWISE SPECIFIED.
2. FRONT PANEL CONTROL
3. REAR PANEL CONTROL
4. P.C. CARD CONTROL
5. CHASIS GROUND
6. FLOATING GROUND
7. TEST POINT

TITLE POWER SUPPLY PHASE METER

THIS DRAWING AND INFORMATION IS PROPRIETARY AND UNAUTHORIZED REPRODUCTION FORBIDDEN.

KH KROHN-HITE CORPORATION
CAMBRIDGE, MASS. U.S.A.

DRN. BY J. Astbury DATE 10-18-74
CKD. BY S.L.G. DATE 2-12-79
DWG. NO. C-3453 REV. C
APP. BY 4/5/83 CO#4388
SHEET 1 OF 1



RESISTORS

Symbol	Description			Mfr.	Mfr. Part No.
R100	9.31K	1%	1/4W	AB	CC9311F
R101	51.1K	1%	1/4W	AB	CC5112F
R102	2.2K	10%	1/4W	AB	CB2221
R103	820	10%	1/4W	AB	CB8211
R104	2.7	10%	1/4W	AB	CB27G1
R105	100	10%	1W	AB	GB1011
R106	47	10%	1/4W	AB	CB4701
R107	2.21K	1%	1/4W	AB	CC2211F
R108	27K	10%	1/4W	AB	CB2731
R109	18K	10%	1/4W	AB	CB1831
R110	5.1K	5%	1/4W	AB	CB5125
R111	33K	10%	1/4W	AB	CB3331
R112	3.32K	1%	1/4W	AB	CC3321F
R113	3.32K	1%	1/4W	AB	CC3321F
R114	27	10%	2W	AB	HB2701
R115	220	10%	1W	AB	GB2211
R116	2.7	10%	1/4W	AB	CB27G1
R117	3.3K	10%	1/4W	AB	CB3321
R118	220	10%	1/4W	AB	CB2211
R119	56	10%	1/4W	AB	CB5601
R120	9.1K	5%	1/4W	AB	CB9125
R121	680	10%	1/4W	AB	CB6811
R122	33K	10%	1/4W	AB	CB3331
R123	9.1K	5%	1/4W	AB	CB9125
R124	681	1%	1/4W	AB	CC6815F
R125	332	1%	1/4W	AB	CC3320F
R126	15K	10%	1/4W	AB	CB1531
R127	2.32K	1%	1/4W	AB	CC2321F
R128	3.6K	5%	1/4W	AB	CB3625
R129	1.07K	1%	1/4W	AB	CC1071F
R130	16.2K	1%	1/4W	AB	CC1622F
R131	100K POT			BKM	72PM
R132	1.78K	1%	1/4W	AB	CC1781F
R133	4.7K	10%	1/4W	AB	CB4721
R134	2.7	10%	1/4W	AB	CB27G1
R135	39	10%	2W	AB	HB3901
R136	220	10%	1/4W	AB	CB2211
R137	39	10%	1/4W	AB	CB3901
R138	680	10%	1/4W	AB	CB6811
R139	330	10%	1/4W	AB	CB3311
R140	12K	10%	1/4W	AB	CB1231
R141	1.2K	10%	1/4W	AB	CB1221
R142	3.32K	1%	1/4W	AB	CC3321F
R143	3.32K	1%	1/4W	AB	CC3321F
R676	1.5K	10%	1/4W	AB	CB1521
R681	3.3K	10%	1/4W	AB	CB3321

CAPACITORS

Symbol	Description			Mfr.	Mfr. Part No.
C100	0.002uf	20%	1000V	SP	C023B102F202M
C101	0.002uf	20%	1000V	SP	C023B102F202M
C102	0.002uf	20%	1000V	SP	C023B102F202M
C103	500uf	+75%-10%	25V	MAL	TT501N025G1A1P
C104	500uf	+75%-10%	25V	MAL	TT501N025G1A1P
C105	0.01uf	20%	100V	SP	C023B501G103M
C106	0.01uf	20%	100V	SP	C023B501G103M
C107	330pf	5%	500V	ELM	DM15C331J
C108	0.001uf	20%	500V	SP	C023B501E102M
C109	1uf	20%	35V	SP	196D105X0035HA1
C110	50uf	+75%-10%	25V	SP	30D506G025CC4
C111	0.001uf	20%	500V	SP	C023B501E102M
C112	0.001uf	20%	500V	SP	C023B501E102M
C113	0.01uf	20%	100V	SP	C023B501G103M
C114	0.001uf	20%	500V	SP	C023B501E102M
C115	1uf	+80%-20%	25V	SP	50C023105D8250B3
C116	1uf	20%	35V	SP	196D105X0035HA1
C117	1uf	20%	35V	SP	196D105X0035HA1
C118	0.0047uf	20%	500V	SP	C023B501F472M
C119	6.8uf	20%	35V	SP	196D685X0035FB
C120	1uf	20%	35V	SP	196D105X0035HA1
C121	10pf	10%	500V	ASP	9213-10110

SEMICONDUCTORS & MISC.

Symbol	Description	Mfr.	Mfr. Part No.
Q100	TRANSISTOR, NPN	MOT	MPS6515
Q101	TRANSISTOR, PNP	MOT	2N2905A
Q102	TRANSISTOR, NPN	MOT	2N2219A
Q103	TRANSISTOR, NPN	MOT	MPS6515
Q104	TRANSISTOR, NPN	MOT	MPS6515
Q106	TRANSISTOR, NPN	MOT	2N2219A
Q107	TRANSISTOR, PNP	MOT	2N5087
Q108	TRANSISTOR, NPN	MOT	2N5225*
Q109	TRANSISTOR, PNP	MOT	2N5087*
CR100	DIODE, RECTIFIER, 100PIV	ITT	1N4002
CR101	DIODE, RECTIFIER, 100PIV	ITT	1N4002
CR102	DIODE, RECTIFIER, 100PIV	ITT	1N4002
CR103	DIODE, RECTIFIER, 100PIV	ITT	1N4002
CR104	DIODE, DUAL	MOT	MZ2361
CR105	DIODE, SWITCHING	APD	1N4149
CR106	DIODE, DUAL	MOT	MZ2361
CR107	DIODE, SWITCHING	APD	1N4149
CR108	DIODE, DUAL	MOT	MZ2361
CR109	DIODE, SWITCHING	APD	1N4149
CR110	DIODE, SWITCHING	APD	1N4149
CR112	DIODE, SWITCHING	APD	1N4149
U100	TRANSISTOR ARRAY	RCA	CA3054
VR105	DIODE, ZENER, 6.4V	NS	1N4577A
VR110	DIODE, ZENER, 6.8V	APD	1N957B
F101	FUSE, SLOW BLOW, 115VAC FUSE, SLOW BLOW, 230VAC	BUS BUS	MDL-.5A MDL-.25A
J101	RECEPTACLE, AC POWER	SWC	EAC-301
M101	METER, DIGITAL	NP	2000AS-2
P1	CONNECTOR, MALE, DPM DIGITAL BOARD	TRW	250-22-30-270
P2	CONNECTOR, MALE, DPM ANALOG BOARD	TRW	250-15-30-170
[S101] [S603]	[SWITCH, PUSHBUTTON, POWER] [SWITCH, PUSHBUTTON, READ/HOLD]	[KH]	[Part of Assy. B3301-B]
S102	SWITCH, SLIDE, LINE	SWC	46256LFR
S103	SWITCH, SLIDE, GROUND	CW	GF-123
T101	TRANSFORMER, POWER	KH	82975-E

*Q108, Q109 physically clamped to cancel thermal drift.

MANUFACTURERS CODE

Code		Name	Location
AB	(01121)	Allen Bradley Company	Milwaukee, WI
APD	(50273)	American Power Devices	Andover, MA
ASP	(82142)	Airco Speer	Dubois, PA
BKM	(30646)	Beckman Instrument Co.	Cedar Grove, NJ
BRN	( )	Bourns, Inc.	Riverside, CA
BUS	(71400)	Bussman Mfg. Co.	St. Louis, MO
CD	(88419)	Cornell-Dubilier	Newark, NJ
CGW	(14674)	Corning Glass Works	Corning, NY
COD	(16352)	Computer Diode Corp.	Fairlawn, NJ
CW	(79727)	C.W. Industries	Warminster, PA
DIA	( )	Dialight Corp.	Brooklyn, NY
DLV	(99800)	Delevan Electronics	East Aurora, NY
ELM	(72136)	Electro-Motive Mfg. Co.	Willimantic, CN
ERT	(72982)	Erie Technological Prod.	Erie, PA
FR	(07263)	Fairchild Semiconductor	San Rafael, CA
GE	(03508)	General Electric	Syracuse, NY
ITT	( )	ITT Semiconductor	Woburn, MA
MAL	(37942)	P. R. Mallory & Co.	Indianapolis, IN
MOT	(04713)	Motorola Semiconductor	Phoenix, AZ
NP	(32873)	Newport Labs., Inc.	Santa Anna, CA
NS	(36462)	National Semiconductor	Plattsburgh, NY
RCA	(49671)	Radio Corporation of America	Harrison, NJ
SIL	(17856)	Siliconix	Sunnyvale, CA
SP	(56289)	Sprague Electric	North Adams, MA
STT		Stettner-Trush, Inc.	Cazenovia, NY
SWC	(82389)	Switchcraft, Inc.	Chicago, IL
TI	(02195)	Texas Instruments, Inc.	Dallas, TX
TR	(03877)	Transitron Electric Co.	Wakefield, MA
TRW	(84411)	TRW Capacitor Div.	Ogallala, NB

TITLE DIGITAL PANEL METER		THIS DRAWING AND INFORMATION IS PROPRIETARY AND UNAUTHORIZED REPRODUCTION FORBIDDEN.	
TOLERANCES	FRACTIONS ± DECIMALS ± ANGLES ±	KROHN - HITE CORPORATION AVON, MASS. U.S.A	
MODEL	DRN. BY J. Asterbury DATE 3-7-79		
SCALE	CKD. BY S. Guinta DATE 3-7-79	DWG. NO. M101	REV.
APP. BY DATE	APP. BY DATE	APP. BY DATE	SHEET ____ OF ____