

**Instruction Manual
Model 640
Electrometer**

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SPECIFICATIONS

AS A MICROVOLTMETER:

RANGE: 30 microvolts full scale to 30 volts in thirteen 1x and 3x ranges.

ACCURACY: $\pm 1\%$ of full scale on 30-volt to 300-microvolt ranges, decreasing to $\pm 5\%$ on 30-microvolt range.

ZERO DRIFT: Less than $35 \mu\text{V}$ in the first hour and in each succeeding 24-hour period after 1-hour warm-up. Less than $35 \mu\text{V}/^\circ\text{C}$.

METER NOISE: Less than 0.4 microvolt rms (2 microvolts p-p) with 1 megohm or less input resistance on most sensitive range.

INPUT IMPEDANCE: Greater than 10^{16} ohms shunted by less than 2 picofarads. Input resistance may also be selected in four steps from 10^6 to 10^{12} ohms.

RISE TIME (10%-90%, with up to 100 megohms source resistance and no external capacitance): Less than 10 milliseconds on 1-mv and higher ranges, increasing to 6 seconds on the 30- μV range.

AS AN AMMETER:

RANGE: 10^{-15} ampere full scale to 3×10^{-5} ampere in twenty-two 1x and 3x ranges using built-in high-megohm resistors and range switch.

ACCURACY: $\pm 3\%$ of full scale on 3×10^{-5} to 10^{-11} ampere ranges using the smallest recommended multiplier setting; $\pm 4\%$ of full scale on 3×10^{-12} to 10^{-15} ampere ranges. Instrument can be calibrated to $\pm 2\%$ accuracy below 10^{-9} ampere with external voltage supply and built-in calibrating circuits.

METER NOISE: Less than 2×10^{-17} ampere rms (10-16 ampere p-p) on 10^{-15} ampere range when overdamped on 10-16 ampere rms (5×10^{-16} ampere p-p) when critically damped. Less than 24 alpha pulses per hour as observed on the 30-millivolt range.

DAMPING: Variable from critical damping to overdamping with 20 picofarads shunting the high-megohm resistor.

CURRENT STABILITY: Better than 5×10^{-17} ampere/day after stabilization. Long-term drift is non-cumulative.

MAX. EXTERNAL CAPACITANCE (Feedback current ranges): 500 pf.

RISE TIME: Seconds, from 10% to 90%.

Recommended Full-Scale Ranges	Resistor Value, ohms	Critically Damped; no external capacitance	Overdamped; up to maximum capacitance
10-15 to 3×10^{-11}	10^{12}	1.5	44
10-12 to 3×10^{-9}	10^{10}	0.2	0.5
10-11 to 3×10^{-7}	10^8	0.05	0.05
10-9 to 3×10^{-5}	10^6	0.01	0.01

AS A COULOMB METER/CURRENT INTEGRATOR:

RANGE (recommended): 2×10^{-14} coulombs full scale to 6×10^{-10} coulombs in ten 2x and 6x ranges.

ACCURACY: Integrating capacitance is 20 picofarads $\pm 0.25\%$.

METER NOISE: Less than 3×10^{-16} coulomb rms (1.5×10^{-15} coulomb p-p) on lowest recommended range. Less than 24 alpha pulses per hour as observed on 30-millivolt range.

AS AN AMPLIFIER:

RECORDER OUTPUT: ± 1 volt at up to 1 ma for full-scale input. Output polarity is opposite input polarity.

Gain: 0.033 to 3.3×10^4 .

Frequency Response (Within 3db): dc to 0.07 cps at a gain of 3.3×10^4 , rising to 35 cps at a gain of 10^3 or below.

Noise: Below 1 cps: same as meter noise for specified function. Above 1 cps: less than 2% of full output p-p on the 30-v to 10-mv ranges, increasing to 10% on the 1-mv and lower ranges.

UNITY GAIN OUTPUT: At dc, output is equal to input within $.01\%$ or $10 \mu\text{V}$, exclusive of zero drift, for output currents of 100 μA or less.

GENERAL:

ZERO CHECK: Remote "zero" solenoid shorts input to low through 1 kilohm in volts position, to feedback in current or integrate position.

ISOLATION: Circuit ground to chassis ground: Greater than $10^9 \Omega$ shunted by 0.05 μf . Circuit ground may be floated up to $\pm 100\text{V}$ with respect to main case. Head case is circuit ground. On battery operation, instrument may be completely isolated from power line and ground.

POLARITY: Meter switch selects left-zero (positive or negative) or center-zero scales. Meter switch does not reverse polarity of output.

CONNECTORS: Input: Special type, mates with many commercially available ion chambers and other accessories (adapter to UHF included). Low: Binding post. Recorder output: Amphenol 80-PC2F. Unity-Gain Output and Case Ground: Binding posts.

POWER:

Line Operation: 105-125 or 210-250 volts (switch selected), 50 or 60 cps, 20 watts.

Battery Operation: Rechargeable nickel-cadmium 6-volt battery pack, 8 hours full charge to complete discharge. For maximum battery life, battery operation recommended for no more than 6 consecutive hours before recharge.

DIMENSIONS, WEIGHT:

Power Chassis: 7" high x $8\frac{3}{4}$ " wide x 10" deep; net weight, 14 lbs.

Amplifier Head: 6" high x 5" wide x 6" deep; net weight, 6 lbs.

ACCESSORIES SUPPLIED: Connecting Cable: 5' long, connects head to main chassis. UHF Adapter: adapts input to UHF connector. Shield Cap. Mating output connector. Internally mounted nickel-cadmium battery pack and charging circuit.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL. The Model 640 Vibrating Capacitor Electrometer is an ultra-stable, solid-state microvolt electrometer.

a. As a Microvoltmeter. When used as a microvoltmeter, the Model 640 has an input resistance greater than 10^{16} ohms with thirteen ranges from 30 microvolts full scale to 30 volts.

b. As a Picoammeter. When used with the built-in, high-megohm SHUNT RESISTORS, the instrument has twenty two ranges from 10^{-15} ampere full scale to 3×10^{-5} ampere.

c. As a Coulombmeter. By switching an accurate guarded capacitor in the feedback loop the instrument is useful as a coulombmeter or current integrating amplifier. In the CURRENT INTEGRATE mode the instrument has ten ranges from 2×10^{-14} coulomb full scale to 6×10^{-10} coulomb.

d. As an Amplifier. The analog OUTPUT permits use of the instrument as a very stable, variable gain amplifier.

1-2. FEATURES.

a. Excellent Stability. A stability specified at better than 5×10^{-17} ampere/day is useful for mass spectrometer, resistivity, and ion chamber measurements.

b. Remote Input Head. A compact Remote Input pre-amplifier permits convenient set up of an experiment.

c. High Input Impedance. Guarding plus the use of sapphire insulation provides an input resistance greater than 10^{16} ohms shunted by less than 2 picofarads.

d. Battery or Line Operation. A choice of battery or line operation permits complete isolation (in battery mode) from power line when required.

e. Built-In Shunt Resistors. Four high-megohm shunt resistors can be switch selected (Input Head) for shunt or feedback current measurements.

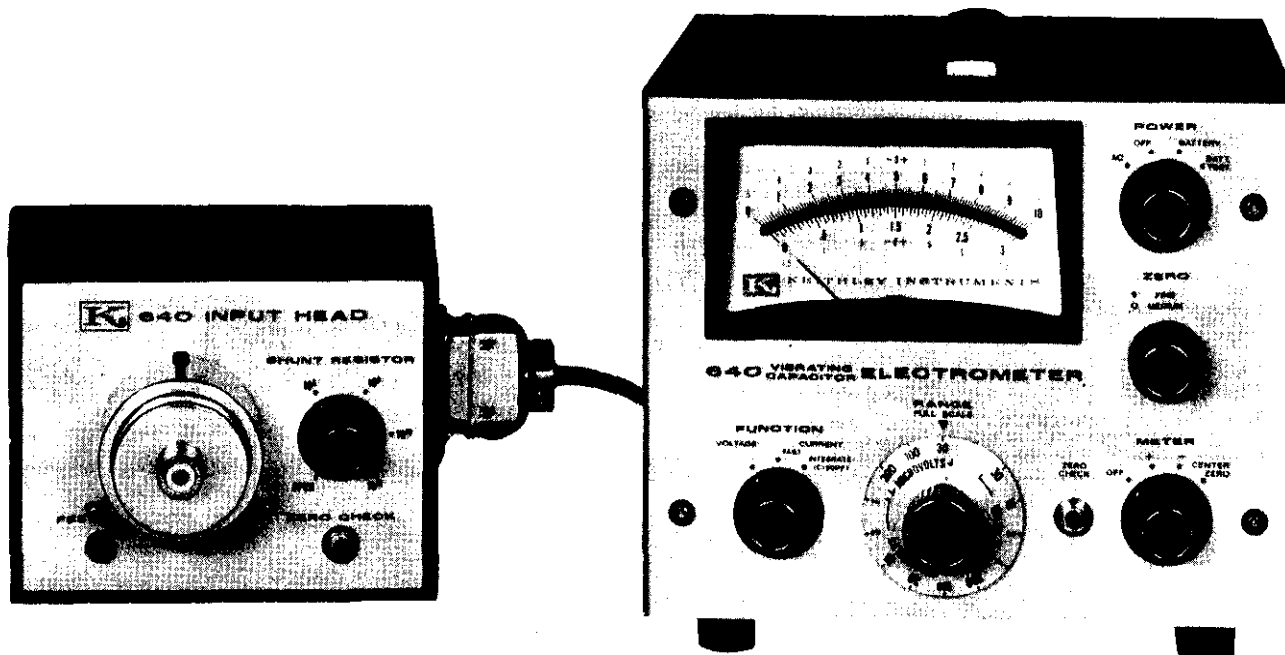


TABLE 1-1.
Front Panel Controls.

Control	Functional Description	Paragraph
<u>POWER Switch</u> (S301)	Controls the power to the instrument.	2-3, a
<u>FUNCTION Switch</u> (S402)	Selects the mode of operation.	2-3, b
<u>RANGE Switch</u> (S403)	Selects the meter sensitivity.	2-3, c
<u>METER Switch</u> (S404)	Selects meter polarity, center scale, and meter off.	2-3, d
<u>ZERO Controls</u>		
MEDIUM (S407)	Adjusts meter zero.	2-3, e
FINE (R431)	Adjusts meter zero (fine control).	2-3, e
<u>ZERO CHECK Switch</u> (S401)	Permits a meter zero check.	2-3, f

TABLE 1-2.
Input Head Controls and Terminals.

Control	Functional Description	Paragraph
<u>SHUNT RESISTOR Switch</u> (S102)	Selects a shunt or feedback resistor from 10^6 to 10^{12} ohms.	2-2, a
<u>ZERO CHECK Switch</u> (S101)	Permits a meter zero check.	2-2, b
<u>FEEDBACK Terminal</u> (J103)	Useful for unity gain or guarded measurements.	2-2, d
<u>Input Receptacle</u> (J105)	Provides connection to Input High	2-2, c
<u>DAMPING Control</u> (R108)	Adjusts damping for CURRENT INTEGRATE function.	2-2, e

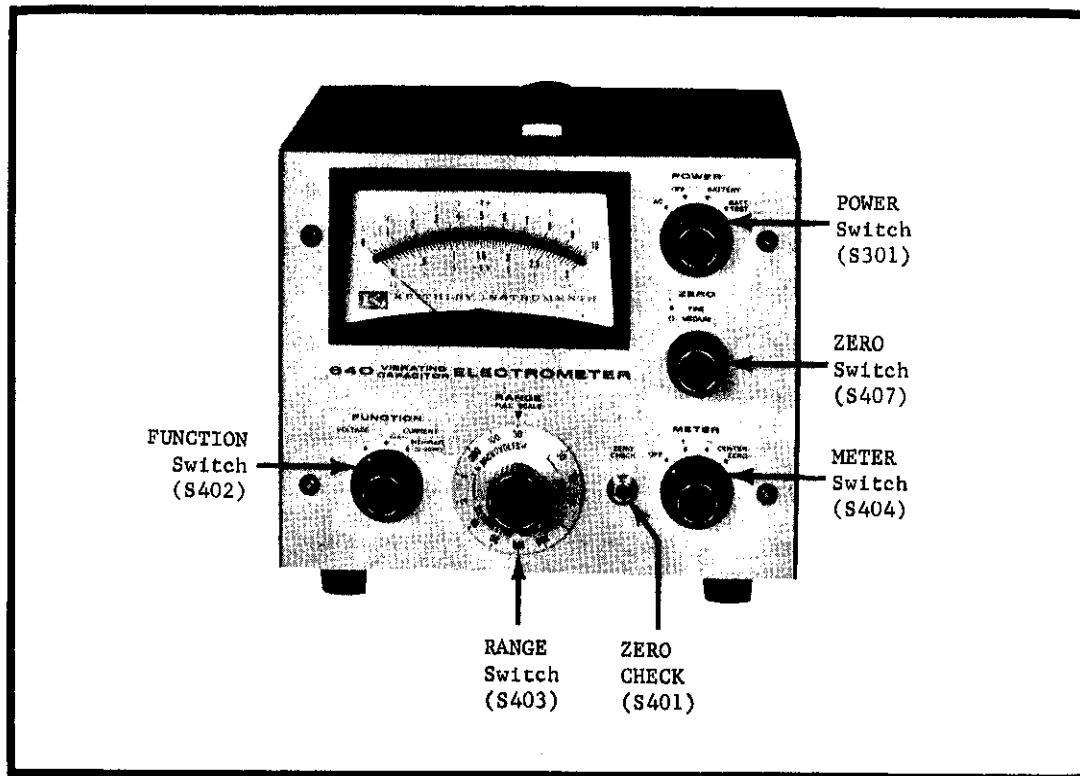


FIGURE 2. Front Panel Controls.

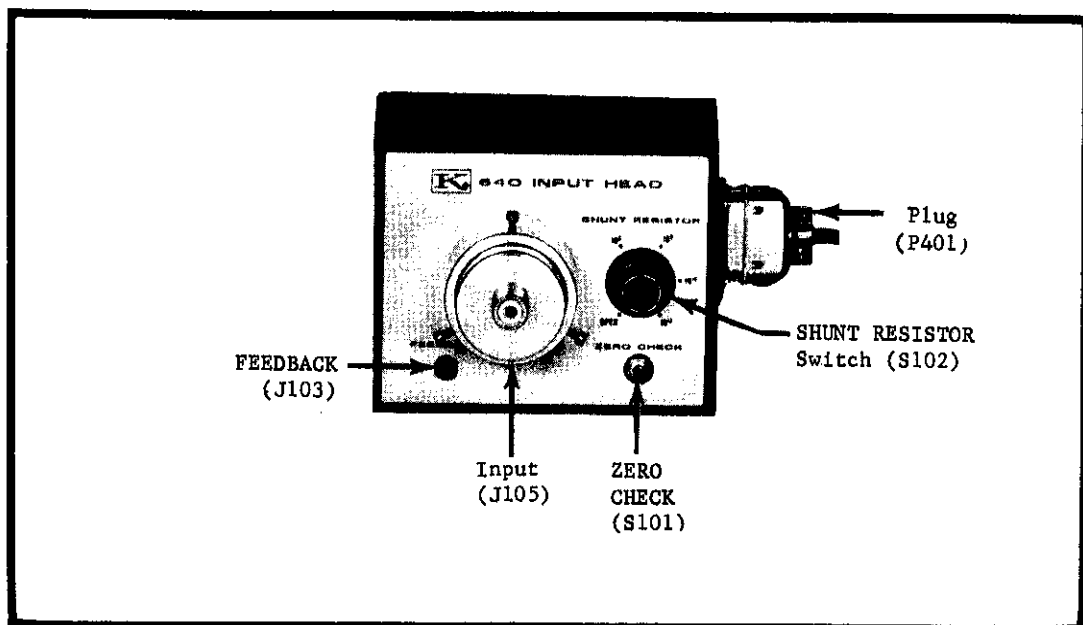


FIGURE 3. Input Head Controls.

TABLE 1-3.
Rear Panel Controls and Terminals.

Control	Functional Description	Paragraph
REMOTE HEAD Receptacle (J405)	Provides connection to Input Head.	2-4, a
OUTPUT Receptacle (J404)	Provides an analog output.	2-4, b
GND Terminal (J406)	Connection to Main Chassis ground.	2-4, c
LO Terminal (J402)	Provides connection to Input LO.	2-4, d
FEEDBACK Terminal (J403)	Useful for unity gain or guarded measurements.	2-4, e
COARSE ZERO Switch (S405)	Adjusts meter zero (coarse control).	2-4, f
LINE VOLTAGE Switch (S302)	Sets instrument for either 117 or 234 V power.	2-4, g
Line Power Fuse (F301)	Protects line power circuit.	2-4, h
Battery Power Fuse (F302)	Protects battery power circuit.	2-4, i
1V-1MA Switch (S406)	Sets OUTPUT for either 1V or 1MA.	2-4, j
1MA CAL Control (R423)	Adjusts OUTPUT current for .95-1.05 MA.	2-4, k

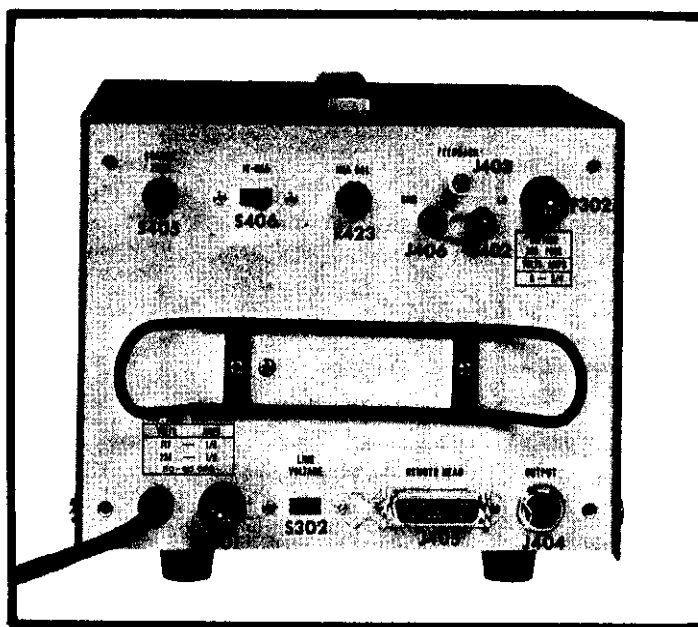


FIGURE 4. Rear Panel Controls and Terminals.

SECTION 2. OPERATION

2-1. INPUT CONSIDERATIONS.

a. Input Head Connections.

1. Remote Cable. A shielded coaxial cable (5 feet long) is supplied to permit remote location of the Input Head from the Main Chassis. An accessory Model 6401 Cable (25 feet long) also can be used without degradation of specifications.

2. Mounting. The Input Head Chassis can be custom mounted as described in paragraph 2-12.

3. Input Assembly. This assembly (J105) consists of an insulated input High terminal (center post) and a machined housing which is input Low. High input resistance (over 10^{16} ohms shunted by less than 2 picofarads) is maintained by use of sapphire insulation.

a.) Custom Connections. The input housing has been designed to easily adapt for use with ion chambers and other applications where high input impedance and low capacitance is required. Dimensions of the input housing are given in Figure 5.

b.) UHF Adapter. The adapter supplied with the Model 640 is useful when quick connections must be made using standard UHF cables. However, this adapter is limited to measurements above 10^{-13} ampere or source resistances below 10^{14} ohms.

c.) GR874 (General Radio) Adapter. This accessory adapter is available for use with GR874 Series coaxial accessories. The limitations of this adapter are similar to those for the UHF adapter.

b. Insulation. Use high resistance, low-loss materials such as sapphire, teflon, polyethylene or polystyrene for insulation of the input circuit.

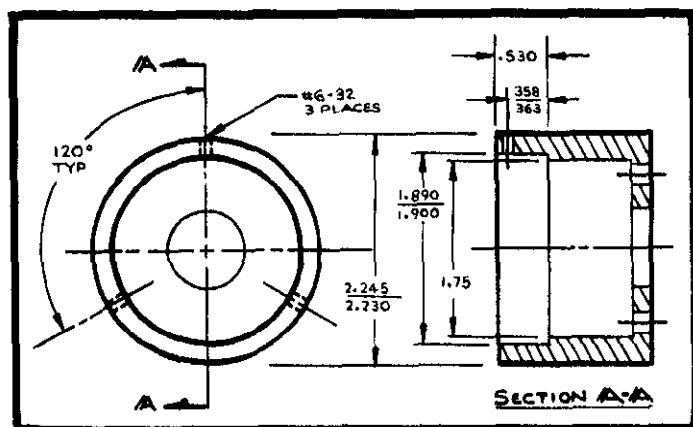


FIGURE 5. Dimensions of Input Housing.

NOTE

The input terminal and sapphire insulator should be protected from contamination so that the insulation will not be degraded. Clean, dry connections and cables are very important to maintain the value of all insulation materials. Even the best insulation can be compromised by dust, dirt, solder, flux, films of oil or water vapor. A good cleaning agent is methyl alcohol, which dissolves most common dirt without chemically attacking the insulation.

c. Noise Consideration. The limit of resolution in voltage and current measurements is determined largely by the noise generated in the source. Stray low-level noise is present in some form in nearly all electrical circuits. The instrument does not distinguish between stray and signal voltages since it measures the net voltage. When using the microvolt ranges consider the presence of low-level electrical phenomena such as thermocouples (thermoelectric effect), flexing of coaxial cables (triboelectric effect), apparent residual charges on capacitors (dielectric absorption), and battery action of two terminals (galvanic action).

1. Thermal EMFS. Thermoelectric potentials (thermal emfs) are generated by thermal gradients between two junctions of dissimilar metals. These can often be large compared to the signal to be measured. To minimize the drift caused by thermal emfs, use pure copper leads wherever possible in the source circuit. Drift can also be minimized by maintaining constant junction temperatures especially by using a large heat sink near the connections. The Keithley accessory Model 1483 Low Thermal Connection Kit contains all necessary materials for making very low thermal copper crimp connections for minimizing thermal effects.

2. AC Electric Fields. The presence of electric fields generated by power lines or other sources can have an effect on instrument operation. AC voltages which are very large with respect to the full-scale range sensitivity could drive the ac amplifier into saturation, thus producing an erroneous dc output. Proper shielding as described in paragraph 2-1, d can minimize noise pick-up when the instrument is in the presence of large ac fields or when very sensitive measurements are being made.

3. Magnetic Fields. The presence of strong magnetic fields can be a potential source of ac noise. Magnetic flux lines which cut a conductor can produce large ac noise especially at power line frequencies. The voltage induced due to magnetic flux is proportional to the area enclosed by the circuit as well as the rate of change of magnetic flux. For

example, the motion of a 3-inch diameter loop in the earth's magnetic field will induce a signal of several tenths of a microvolt. One way to minimize magnetic pickup is to arrange all wiring so that the loop area enclosed is as small as possible (such as twisting input leads). A second way to minimize magnetic pickup is to use shielding as described in paragraph 2-1, d.

d. Shielding.

1. Electric Fields. Shielding is usually necessary when the instrument is in the presence of very large ac fields or when very sensitive measurements are being made. The shields of the measurement circuit and leads should be connected together to ground at only one point. This provides a "tree" configuration, which minimizes ground loops.

2. Magnetic Fields. Magnetic shielding is useful where very large magnetic fields are present. Shielding, which is available in the form of plates, foil or cables, can be used to shield the measuring circuit, the lead wires, or the instrument itself.

e. Moisture. The Model 640 Input Head is shipped with a dessicant bag sealed inside. This bag soaks up the moisture inside the Input Head to insure optimum operation. The dessicant bag, however, will eventually become saturated. At this point the Model 640 offset will increase beyond the specified amount. When this happens take off the bottom cover of the Input Head to remove the dessicant bag. Reactivate it according to the instructions on the bag.

f. Guarding. Use of a "driven guard" or "guard ring" is important when making measurements from source resistances greater than 10^{12} ohms. The guard minimizes the effects of leakage currents from input High to input Low.

2-2. INPUT HEAD CONTROLS AND TERMINALS. The Input Head is shown in Figures 1 and 3. The operation of each control or terminal is described as follows:

a. SHUNT RESISTOR Switch (S102). This switch selects 5 positions corresponding to the shunt resistor (across input of feedback) required by the measurement. The switch positions are 10^6 , 10^8 , 10^{10} , 10^{12} and "OPEN". The "OPEN" position has no resistor connected.

b. ZERO CHECK Switch (S101). This switch is a normally-open contact type switch permitting a check of meter zero. (The ZERO CHECK Switch (S401) on the Main Chassis has the same function). The ZERO CHECK switch shunts the input HI to LO (in VOLTAGE function) by 1000 ohms.

c. Input Receptacle (J105). This receptacle provides input connection to the Model 640 Input High and Input Low.

d. FEEDBACK Terminal (J103). This terminal is used for unity gain or guarded measurements.

e. DAMPING Control (R108). (Not Shown). This control permits adjustment of the damping for CURRENT INTEGRATE operation. When the control is set fully clockwise to "MAX" damping, the rise time is approximately 44 seconds with a 10^{12} shunt resistor. When the control is set fully counter-clockwise to "MIN" damping, the rise time corresponds to the critically damped or CURRENT FAST condition as given in the specifications.

2-3. FRONT PANEL CONTROLS. The front panel controls are shown in Figures 1 and 2. The operation of each control is described as follows:

a. POWER Switch (S301). This switch has four positions designated AC, OFF, BATTERY, and BATT TEST.

1. AC Position. This position permits normal operation of the instrument when the power cord is connected to line power. (The battery charging circuit operates in this position.)

2. OFF Position. This position disables both AC and BATTERY power to the electrometer circuits except for the battery charging circuit which operates in this position.

3. BATTERY Position. This position permits normal operation of the instrument when the internal battery pack is satisfactorily charged.

4. BATT TEST Position. This position permits a check of the battery voltage as indicated by the meter.

b. FUNCTION Switch (S402). This switch has three positions designated VOLTAGE, CURRENT FAST, and CURRENT INTEGRATE.

1. VOLTAGE Position. This position connects the electrometer as a very sensitive, high impedance voltmeter with the SHUNT RESISTORS connected in shunt across the input.

2. CURRENT FAST. This position connects the electrometer as a feedback picoammeter which neutralizes the effect of input capacitance and increase response speed. The SHUNT RESISTORS are connected in the feedback loop of the amplifier.

3. CURRENT INTEGRATE. This position connects the 20 picofarad guarded capacitor in the feedback loop of the amplifier.

c. RANGE Switch (S403). This switch has thirteen positions corresponding to full scale voltage sensitivity from 30 microvolts to 30 volts.

d. METER Switch (S404). This switch has 4 positions designated OFF, +, -, and CENTER ZERO.

1. OFF Position. This position disables the meter movement to protect against overloads. This position has no effect on the OUTPUT voltage when using a recorder or other instrument.

2. "+" and "-" Positions. These positions select the polarity of the meter only. The OUTPUT voltage is not affected by these positions.

3. CENTER ZERO. This position sets the meter circuit so that zero is indicated at center scale (mid-scale). The deflection of the meter corresponds to one-half RANGE setting. The OUTPUT voltage is not affected by this position.

e. ZERO Switch. This switch is a dual-concentric control.

1. MEDIUM Control (S407). This control is the outer knob with eleven positions which adjust the meter-zero.

2. FINE Control (R431). This control is the inner knob which permits fine meter-zero adjustment.

f. ZERO CHECK (S401). This switch is a normally-open contact-type switch permitting meter-zero check. The ZERO CHECK switch shunts the input HI to input LO (in voltage function) by 1000 ohms.

2-4. REAR PANEL CONTROLS AND TERMINALS. The rear panel controls and terminals are shown in Figure 4. The operation of each control or terminal is described as follows.

a. REMOTE HEAD Receptacle (J405). This receptacle is a 24-pin connector (Amphenol 57-40240) which mates with the interconnecting cable between the Main Chassis and Input Head (Remote Head). Two mechanical retaining clips are provided on the receptacle to secure the mating plug (P405).

b. OUTPUT Receptacle (J404). This connector provides an analog output for recording or monitoring purposes. The output is -1 volt at up to 1 mA for full scale input. The output polarity is opposite the input polarity. The front panel METER switch has no effect on the polarity of the analog output.

c. GND Terminal (J406). This terminal is connected to Main Chassis ground and the outside shell of connector J405. With no connection between GND and LO (shorting link removed), the INPUT LO to Main Chassis ground isolation is greater than $10^9 \Omega$ shunted by .05 microfarad.

d. LO Terminal (J402). This terminal is connected to INPUT LO on INPUT HEAD.

e. FEEDBACK Terminal (J403). This terminal is used for unity gain or guarded measurements. The terminal (J403) on the Main Chassis is connected to J103 on the INPUT HEAD by way of the remote cable.

f. COARSE ZERO Switch (S405). This switch has ten positions for adjusting the meter-zero circuit. This switch should only be used when the FINE and MEDIUM

ZERO Controls do not provide sufficient range of control.

g. LINE VOLTAGE Switch (S302). This switch sets the instrument for either 117 or 234 volt rms line-power. The line-power fuse (F301) should be checked for proper line voltage rating.

h. Line Power Fuse (F301). This fuse protects the power supply circuits when 117-234V line power is used.

<u>Line Voltage</u>	<u>Fuse Rating</u>
117 V	1/4 amp, 3AG
234 V	1/8 amp, 3AG

i. Battery Power Fuse (F302). This fuse protects the power supply circuits when battery power is used. Fuse rating: 3/4 amp, 3AG.

j. 1V-1MA Switch (S406). This switch sets the OUTPUT for either 1 volt or 1 mA.

k. 1MA CAL Control (R423). This control permits adjustment of the OUTPUT (with 1V-1MA Switch set to 1MA) over the range 0.95 to 1.05 mA.

2-5. OPERATING CONSIDERATIONS.

a. Mode of Operation.

1. AC Line-Power. The Model 640 can be operated using ac line-power at 117V or 234V, 50 or 60 Hz. To operate, set LINE VOLTAGE Switch (S302) to 117 or 234, check for proper rated fuse (F301), and connect the line cord. Set the POWER Switch (S301) to "AC" operation.

2. Battery Power. The Model 640 can be operated using battery power supplied by a rechargeable 6-volt nickel-cadmium battery pack.

a.) To check the battery charge, set the POWER Switch to "BATT TEST" position. The meter should indicate +6V or greater if charge is satisfactory.

b.) To recharge the battery pack, connect the power cord to ac power. Set the POWER Switch to "OFF". (The battery will automatically recharge when the POWER Switch is in either "AC" or "OFF" positions). Battery charging-time is approximately 16 hours for full charge after 8 hours of continuous use.

3. AC to Battery Switching. The Model 640 can be modified so that it will automatically switch from "AC" operation to "BATTERY" operation if the line power fails. An explanation of this modification is given in paragraph 3-4 in the Circuit Description section.

b. Warm-up. If the instrument is to be used for very sensitive measurements, allow the instrument to stabilize for an hour or more. The POWER Switch can be set at either "AC" or "BATTERY".

c. Meter Zero. The meter zero circuit utilizes three controls FINE, MEDIUM, and COARSE.

1. After warm-up, set the METER Switch to CENTER ZERO.

2. Adjust the MEDIUM ZERO Control for center-zero meter position. (The rear panel COARSE ZERO Switch can be used if meter reads off scale).

3. Increase sensitivity using the RANGE Switch and adjust the FINE ZERO Control for center-zero meter indication.

2-6. VOLTAGE FUNCTION.

a. General. When the FUNCTION Switch is set to the VOLTAGE position, the Model 640 operates as a high input-impedance electrometer.

b. Input Impedance. The input resistance (HI to LO) is greater than 10^{10} ohms shunted by less than 2 picofarads. This specification is valid only for the SHUNT RESISTOR Switch set to "OPEN" with no degradation of the input HI to input LO insulation. The input resistance can be lowered by selecting SHUNT RESISTOR values in four steps from 10^6 to 10^{12} ohms.

c. Microvoltmeter Measurements.

1. Theory. The electrometer, when used as a microvoltmeter, can be illustrated as shown in Figure 6. In this configuration the instrument is useful for making sensitive measurements from 30 microvolts full scale to 30 volts. The sensitivity is adjusted by the RANGE Switch (S403) represented by R_A . The input voltage is represented by e_i . The voltage e_A is defined by the following expression,

$$e_A = e_i \left(\frac{K}{K + 1} \right)$$

where K is the amplifier loop gain.

Therefore $i_A = \frac{e_A}{R_A} \approx \frac{e_i}{R_A}$ where R_A is selected by the RANGE Switch (S403).

2. Voltage Measurement.

a.) High Impedance. Although the electrometer has a very high input impedance, the useability of the Model 640 as a microvoltmeter is limited by the thermal (Johnson) noise generated in the source impedance. Refer to paragraph 2-10 for a complete discussion of thermal noise.

b.) Low Impedance. The Model 640 can be used on the more sensitive ranges by setting the SHUNT RESISTOR Switch to 10^{12} ohms or lower. The loading effects should be considered when measuring high source-impedance.

3. Current Measurement. The Model 640 can be used for current measurements since the microvoltmeter measures the voltage across a known shunt resistor selected for 10^6 , 10^8 , 10^{10} , or 10^{12} ohms. Current can be calculated by the ratio of voltage reading to shunt resistance. Use this technique where low noise is important, although faster response is provided by setting the FUNCTION Switch to CURRENT FAST as described in paragraph 2-7.

4. Unity Gain Measurements. The Model 640 can be used for measuring a potential from a very high impedance source with .025% accuracy. Connect a digital voltmeter (or differential) to FEEDBACK and LO terminals as shown in Figure 7.

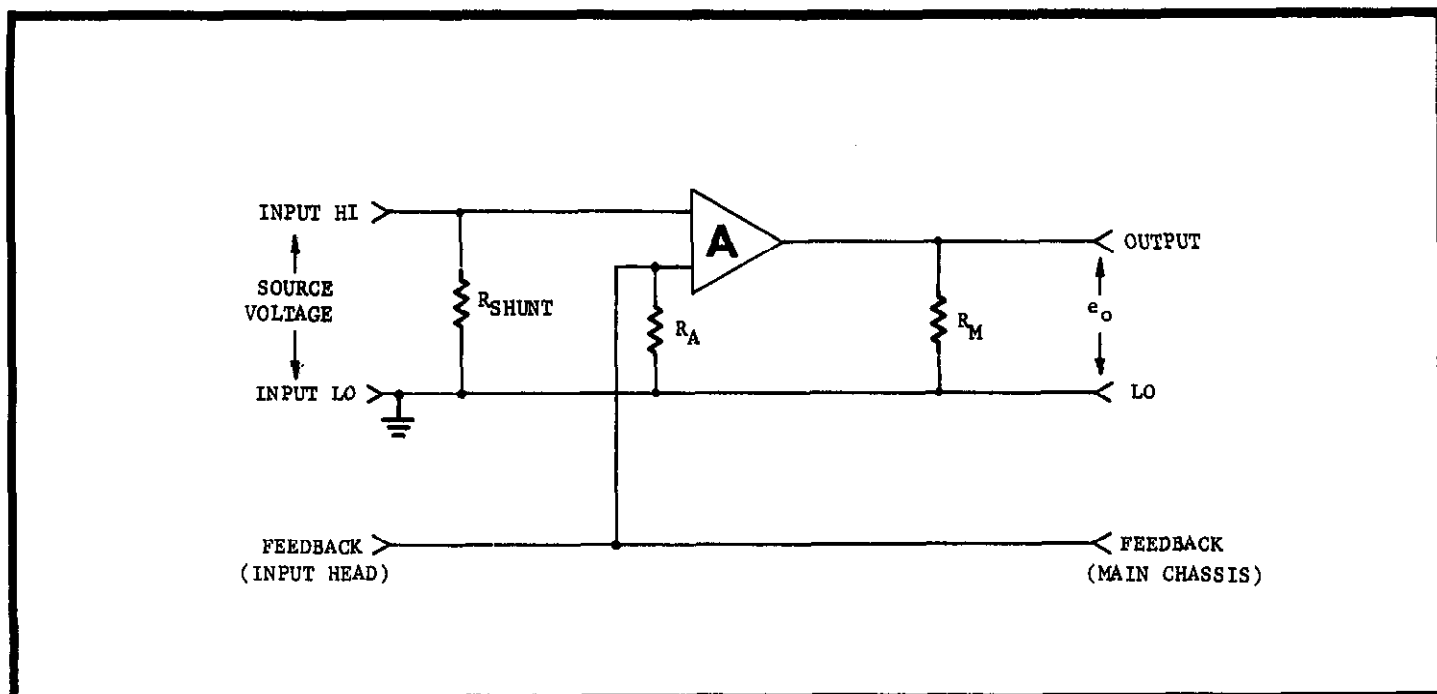


FIGURE 6. Voltage Function With Shunt Resistor R_S

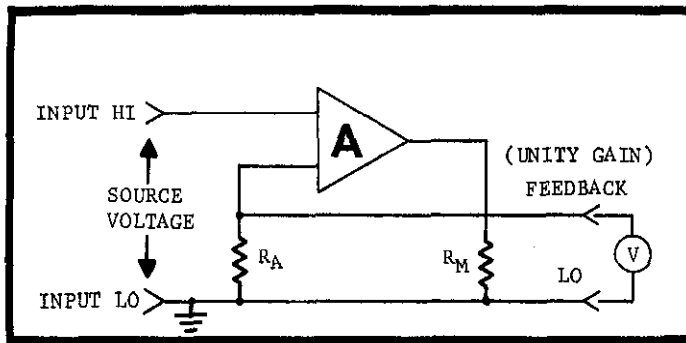


FIGURE 7. Use of FEEDBACK Connection.

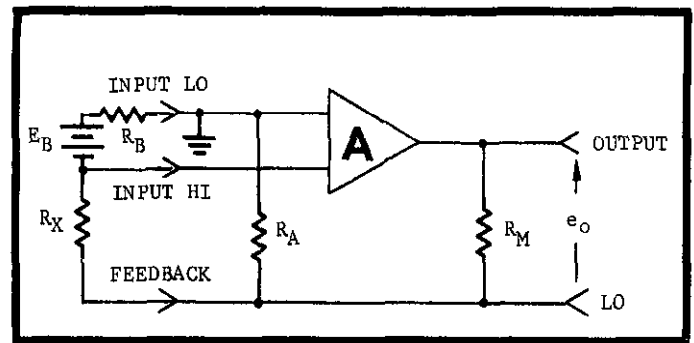


FIGURE 9. Guarded Measurement.

2-7. CURRENT FAST FUNCTION.

a. General. When the FUNCTION Switch is set to the CURRENT FAST position, the Model 640 operates as a feedback ammeter with feedback resistors selected by the SHUNT RESISTOR Switch in four steps from 10^6 to 10^{12} ohms.

b. Feedback Ammeter Measurements.

1. Theory. The Model 640, when used as a feedback ammeter, can be illustrated as shown in Figure 8. In this configuration the instrument is useful for making sensitive measurements from 10^{-15} ampere full scale. Response speed is greatly improved compared to the VOLTAGE FUNCTION configuration since the effect of input capacitance is largely neutralized. The input voltage drop and effective ammeter input resistance is given for each RANGE setting as in Table 2-1.

TABLE 2-1.
Input Resistance in CURRENT FAST Function.

RANGE	Current	Input Resistance	Input Voltage
10V	1×10^{-11}	10^8	1mV
1V	1×10^{-12}	10^8	$100 \mu\text{V}$
100mV	1×10^{-13}	10^8	$10 \mu\text{V}$
10mV	1×10^{-14}	10^8	$1 \mu\text{V}$
1mV	1×10^{-15}	10^8	$0.1 \mu\text{V}$

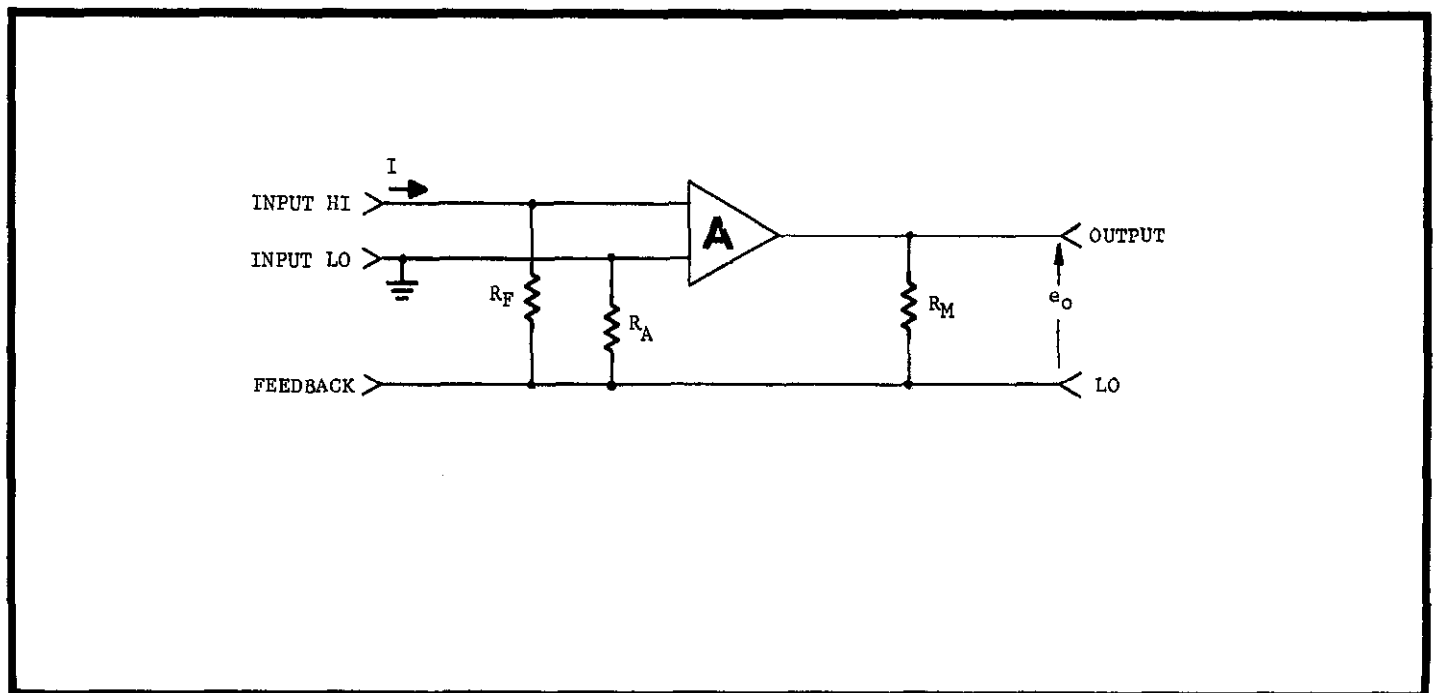


FIGURE 8. Current Fast Function.

2. Current Measurement.

a.) Rise Time. The actual rise time for a particular measurement depends on the shunt resistor and residual capacitance across the feedback loop. The specified rise time (10 to 90%) is given in the specifications for each resistor value. These rise times are for a critically damped condition where no external capacitance is present. Additional external capacitance can be connected between the FEEDBACK terminal and input HI.

b.) Guarded Measurements. The Model 640 can be used for guarded resistance measurements using the FEEDBACK Terminal and Input HI connections as shown in Figure 9. Since E_B and R_B develop a known current I_B , then the electrometer will indicate the voltage developed across R_x (unknown resistance).

$$R_x = \frac{E_o}{I_B} = \frac{E_o}{E_B} \times R_B$$

2-8. CURRENT INTEGRATE FUNCTION.

a. General. When the FUNCTION Switch is set to the CURRENT INTEGRATE position the Model 640 operates as a feedback ammeter with damping.

b. Feedback Ammeter Measurements.

1. Theory. The Model 640 operation can be illustrated as shown in Figure 10. In this configuration the DAMPING Control is set to "MAX" position so that a 20 pf capacitance is connected in the feedback loop (SHUNT RESISTOR Switch set to "OPEN"). The current measured is determined by the following equation,

$$I = C \int_{t_o}^{t_f} \frac{dE}{dt} = C \left(\frac{\Delta E}{\Delta t} \right) = \frac{dQ}{dt}$$

where I = current in amperes.

C = feedback capacitance (2×10^{-11}).

ΔE = change in the meter reading during time interval Δt .

Δt = time interval of measurement.

2. Variable Damping. When the DAMPING Control (R108) is adjusted counter-clockwise, the Model 640 can be used for current measurements with variable damping.

2-9. SHUNT RESISTOR CALIBRATION.

a. General. The Model 640 can be calibrated for use as an ammeter accurate to $\pm 0.25\%$.

b. Theory. Calibration of the high value (10^{10} , 10^{12}) shunt resistors can be accomplished using a current integrating technique. An accurately known voltage source can be connected in series with the shunt resistor forming a current source where $I = V/R$. With FUNCTION Switch set to CURRENT INTEGRATE the meter reading E_M is a function of capacitance C and the integral of the current.

$$E_M = \frac{1}{C} \int i dt \quad \text{or} \\ \text{or } \Delta E_M = \frac{I}{C} \Delta T = \left(\frac{V}{RC} \right) \Delta T$$

Solving for R ,

$$R = \frac{V}{C} \left(\frac{T - T_o}{E - E_o} \right)$$

Where R = shunt resistance, ohms.
 V = source voltage.
 C = integrating capacitor (20 pf).
 $E - E_o$ = change in voltage indication.
 $T - T_o$ = time interval for voltage change.

Since the accuracy of C is $\pm 0.25\%$ the overall accuracy of the calibration will depend on the accuracies of the voltage source V , the meter accuracy E_M , and the time accuracy T . (To obtain the best possible accuracy, measure the analog OUTPUT using a 0.01% digital voltmeter.) Refer to Figure 11 for circuit connections.

c. Calibration Procedure.

1. Set the FUNCTION Switch to CURRENT INTEGRATE.
2. Set the DAMPING to "MAX".
3. Apply the voltage source between P106 and input LO. (Remove the Input Head bottom cover for access).
4. Zero meter.
5. Select 10^{10} or 10^{12} SHUNT RESISTOR.
6. Measure time interval from zero to full scale on the meter. Record time interval $T - T_o$.
7. Calculate the value of R using equation.

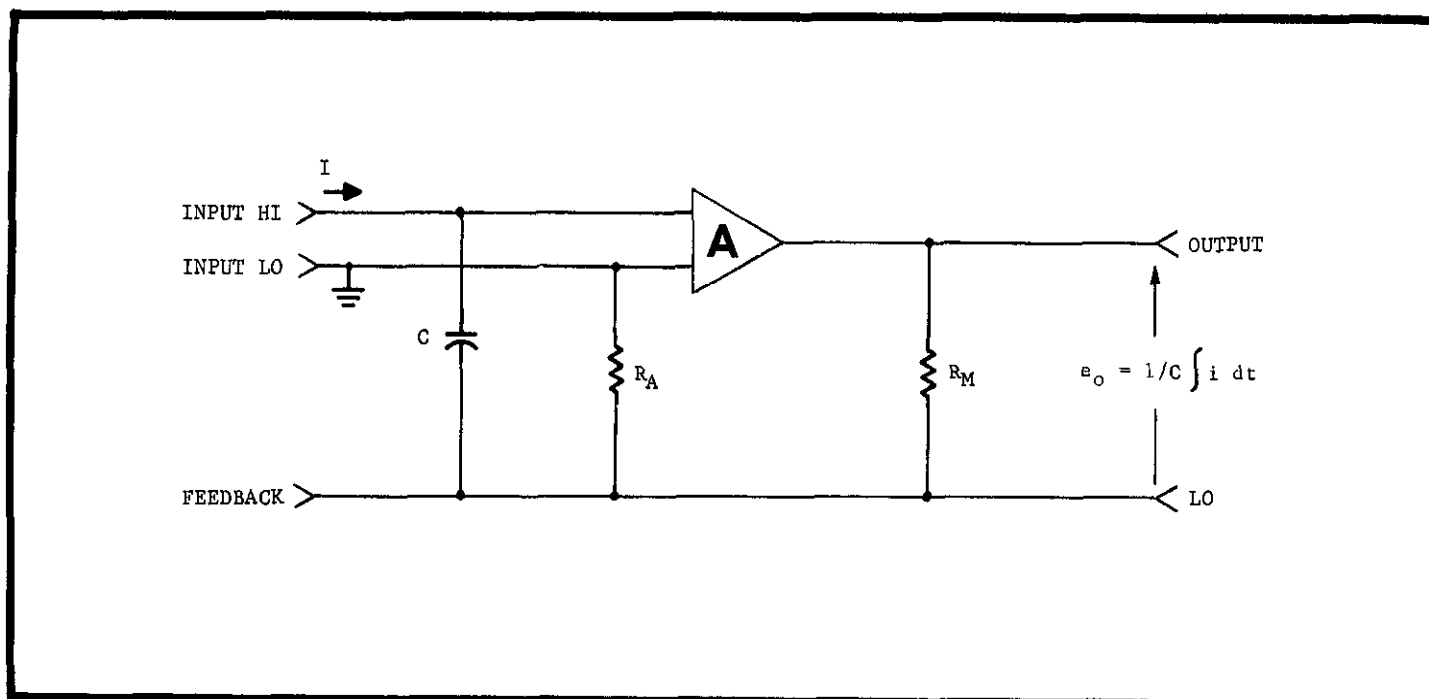


FIGURE 10. Equivalent Current Integrator.

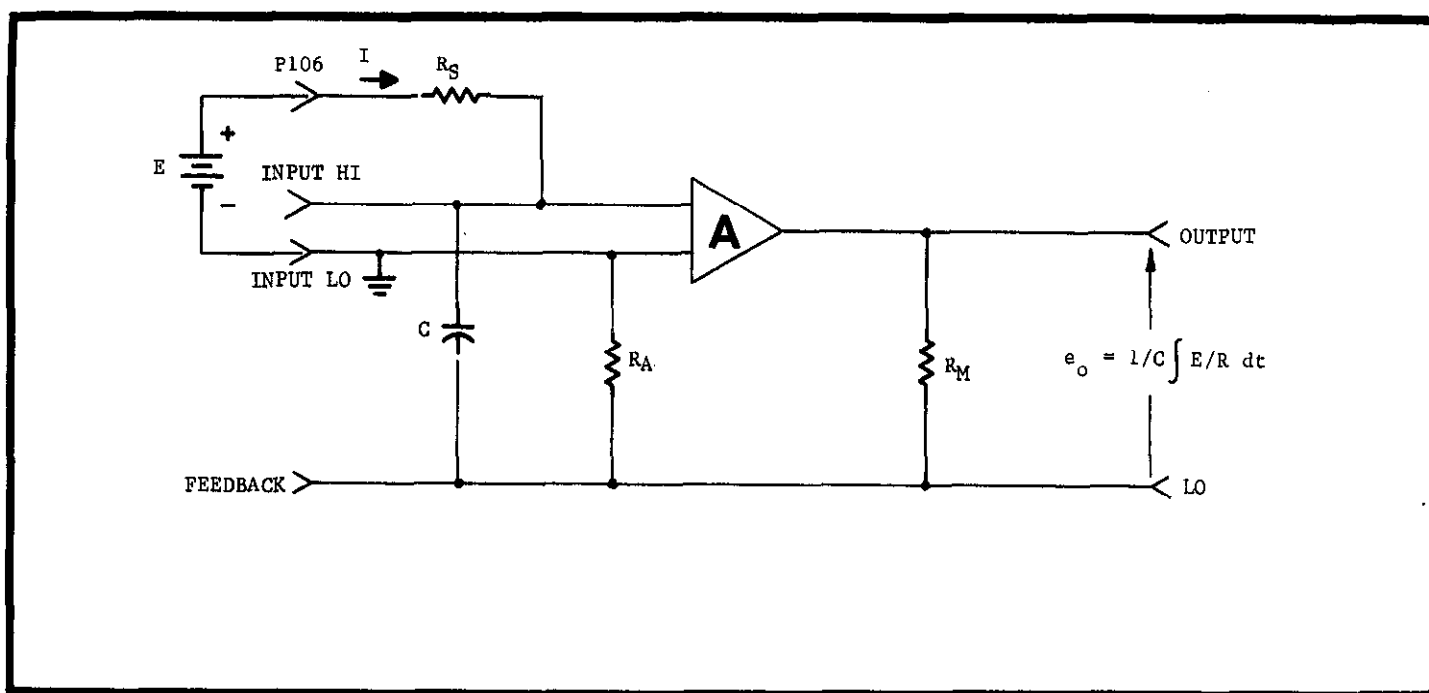


FIGURE 11. Current Integrate - Shunt Resistor Calibration.

2-10. ANALOG OUTPUTS.

a. OUTPUT Terminal (J404). This terminal provides an analog output for recording or monitoring purposes.

1. 1V Output. With the 1V-1MA Switch (S406) set to "1V" the output is +1 volt corresponding to a full scale input. The polarity of the output is opposite the input signal.

Gain: 0.033 to 3.3×10^4

Frequency Response (Within 3 db): dc to 0.07 cps at a gain of 3.3×10^4 , rising to 35 cps at a gain of 10^3 or below.

Noise: Below 1 cps: same as meter noise for specified function. Above 1 cps: less than 2% of full output p-p on the 30-v to 10-mv ranges, increasing to 10% on the 1-mv and lower ranges.

2. 1MA Output. With the 1V-1MA Switch set to "1MA" the output is approximately 1MA for a full scale input.

b. Unity Gain Output. When the FUNCTION Switch is set to VOLTAGE the FEEDBACK terminal can be used for measuring a potential from a very high impedance source. At dc, the output is equal to the input within .01% or 10 μ V, exclusive of zero drift, for output current of 100 pA or less.

2-11. THERMAL NOISE.

a. General. A common limitation of microvoltmeter measurements from high source impedances is the thermal noise (Johnson noise) generated in the source.

b. Theory. Thermal noise in an ideal resistance can be theoretically determined from the Johnson noise equation as follows.

$$E_{rms} = \sqrt{4K \cdot T \cdot R \cdot F}$$

Where

E_{rms} = rms voltage noise generated in the resistance.

T = temperature, $^{\circ}$ K.

R = ideal resistance, ohms.

F = amplifier bandwidth, Hz.

K = Boltzmann constant (1.38×10^{-10} joules/ $^{\circ}$ K)

The peak-to-peak noise is approximately five times the rms value (from experimental measurements), therefore the equation can be expressed as follows.

$$E_{pp} = 5 \times E_{rms}$$

If the ambient temperature is 300 $^{\circ}$ K (room ambient) then the peak-peak noise can be expressed as follows.

$$E_{pp} = 6.45 \times 10^{-10} \sqrt{RF}$$

c. Typical Example. The peak-peak thermal noise generated in an ideal source resistance can be illustrated as follows.

Given: Amplifier Bandwidth $\Delta F = 0.08$ *

R = 10^{12} ohms.

RANGE set to 1 MV.

$$E_{pp} \text{ (typically) } = 6.45 \times 10^{-10} \sqrt{10^{12} \times .08}$$

$$E_{pp} \approx 180 \mu\text{V Peak-Peak}$$

$$* \Delta F = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot 10^{12} \times 2 \times 10^{-12}} \approx .08$$

2-12. MOUNTING DIMENSIONS.

a. Casting Dimensions. The overall dimensions of the Input Head Casting are shown in Figures 12 and 13.

b. Input Contact. The input contact is spring loaded with the dimensions from the base as shown in Figure 12.

c. Mounting the Base Plate. The Base Plate can be mounted on a machined surface for custom installation of the Input Head. The Base Plate is fastened to the Input Head casting using four type 6-32 x 1/4 screws. The rubber feet are attached to the base plate using type 6-32 x 1/2 Phillips Head screws and mating #6 kep nuts. (The dessicant bag is also attached using this hardware). In order to mount the Input Head Casting to a surface plate, clearance holes must be drilled in the surface plate as shown in Figure 14. The Casting can be fastened to the surface using type 6-32 screws. The rubber feet should be removed and the four screws replaced. (Note that the holes drilled should provide sufficient clearance for the 6-32 Phillips screw heads.)

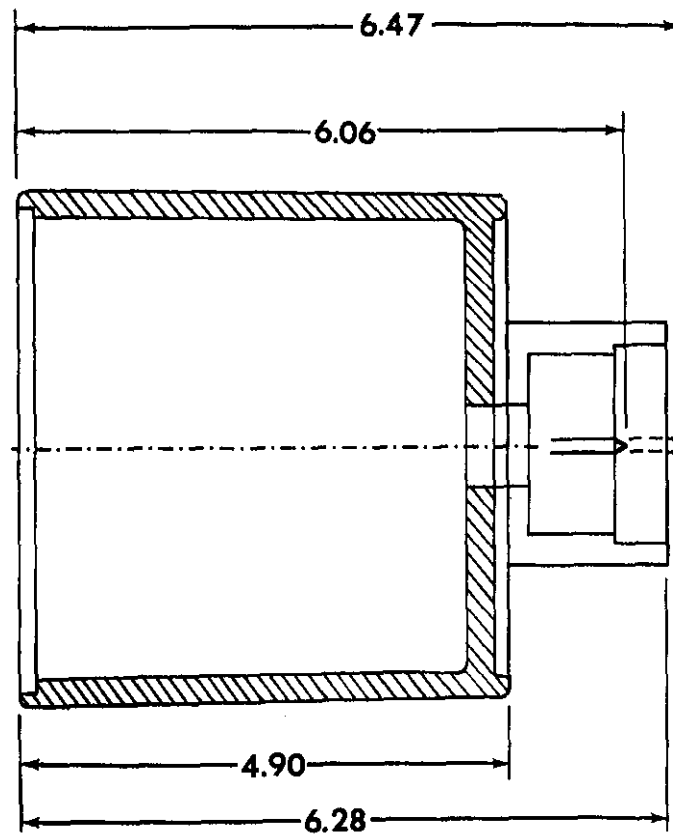


FIGURE 12. Input Head Casting.

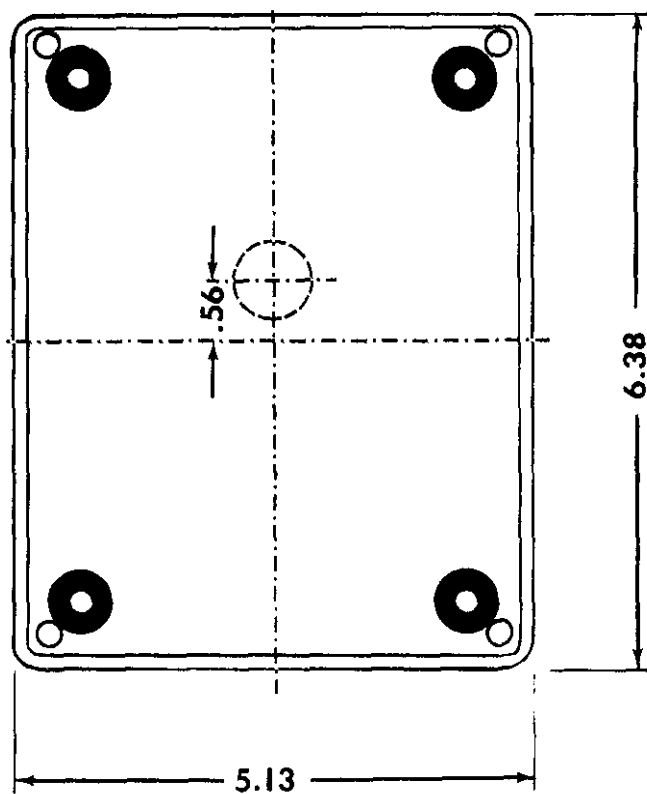


FIGURE 13. Base Plate Dimensions.

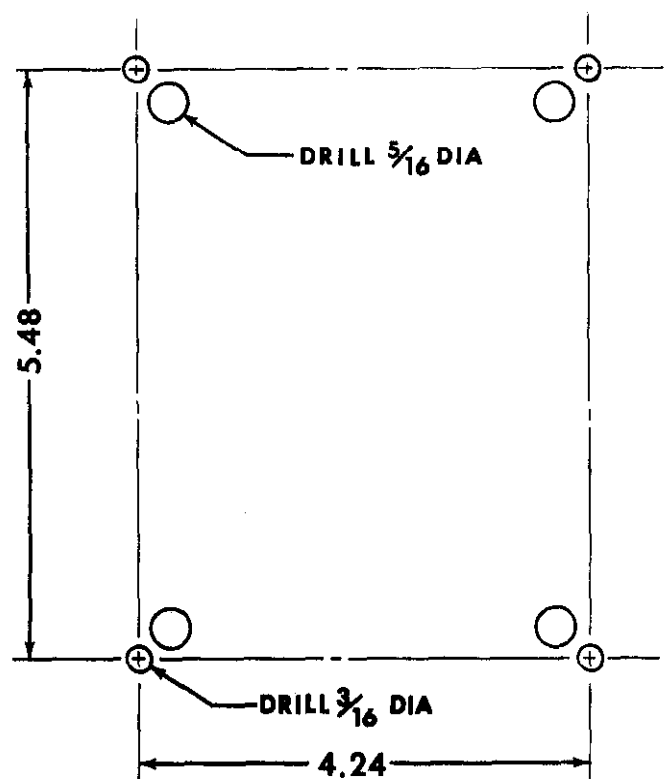


FIGURE 14. Mounting Hole Locations

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Model 640 is composed of an Input Head (Remote Preamplifier) and a Main Chassis (Amplifier and Power Supply).

a. High Impedance Microvoltmeter. When the FUNCTION Switch is set to VOLTAGE, the Model 640 operates as a very sensitive, stable voltmeter with very high input impedance.

b. Vibrating Capacitor Electrometer. When the FUNCTION Switch is set to either CURRENT position, the Model 640 operates as a stable current and charge measuring instrument.

3-2. ELECTROMETER AMPLIFIER. The basic electrometer amplifier utilizes a vibrating-capacitor input pre-amplifier and variable-sensitivity amplifier. The overall amplifier operates as a very sensitive dc amplifier using a vibrating capacitor as an input signal modulator. The input signal is modulated, amplified and demodulated in the preamplifier circuit. The dc signal is filtered and amplified further by the main dc amplifier. Feedback is used extensively to provide gain accuracy and stability. A block diagram of the overall amplifier is shown in Figure 15.

3-3. INPUT HEAD. (Remote Preamplifier). The Input Head contains the input modulator, high-gain ac amplifier, oscillator and demodulator. The Shunt Resistors are connected across the overall amplifier-feedback using Switch S102.

a. Vibrating Capacitor. A special capacitor is used consisting of two stationary plates and a vibrating membrane which is excited at a carrier frequency of approximately 400 kHz. The glass membrane has deposited metal surfaces and is sealed in an evacuated glass "bottle". This unique capacitor provides very high input-impedance and low drift. When driven at the carrier frequency (under proper conditions), the membrane resonates at approximately 6000 Hertz. Since the carrier (drive) frequency is much higher than the resonant frequency, the carrier frequency and harmonics does not appreciably affect the amplifier circuit.

b. Input Circuit. The input High signal is applied to receptacle J105 on the Input Head. The input LO is isolated from Main Chassis ground. A 10 megohm resistor (R105) prevents a rapid discharge of the vibrating capacitor back into the source circuit. The modulated signal is applied to the first stage ac amplifier through a guarded, three-terminal air capacitor. (C105 which is $20 \text{ pF} \pm 0.25\%$).

c. Zero Check Circuit. The ZERO CHECK control is a normally-open control which energizes solenoid K101. When K101 is energized, a contact connects input High to FEEDBACK through a 1000 ohm resistor. The input source and vibrating capacitor remain connected in the circuit during zero check. A loading error will result in the meter zero reading if the source resistance (R_S) is less than 100 K in accordance with the following equation.

$$\% \text{ Error} = \frac{100}{R_S + 1}, \text{ where } R_S \text{ is expressed in kilohms.}$$

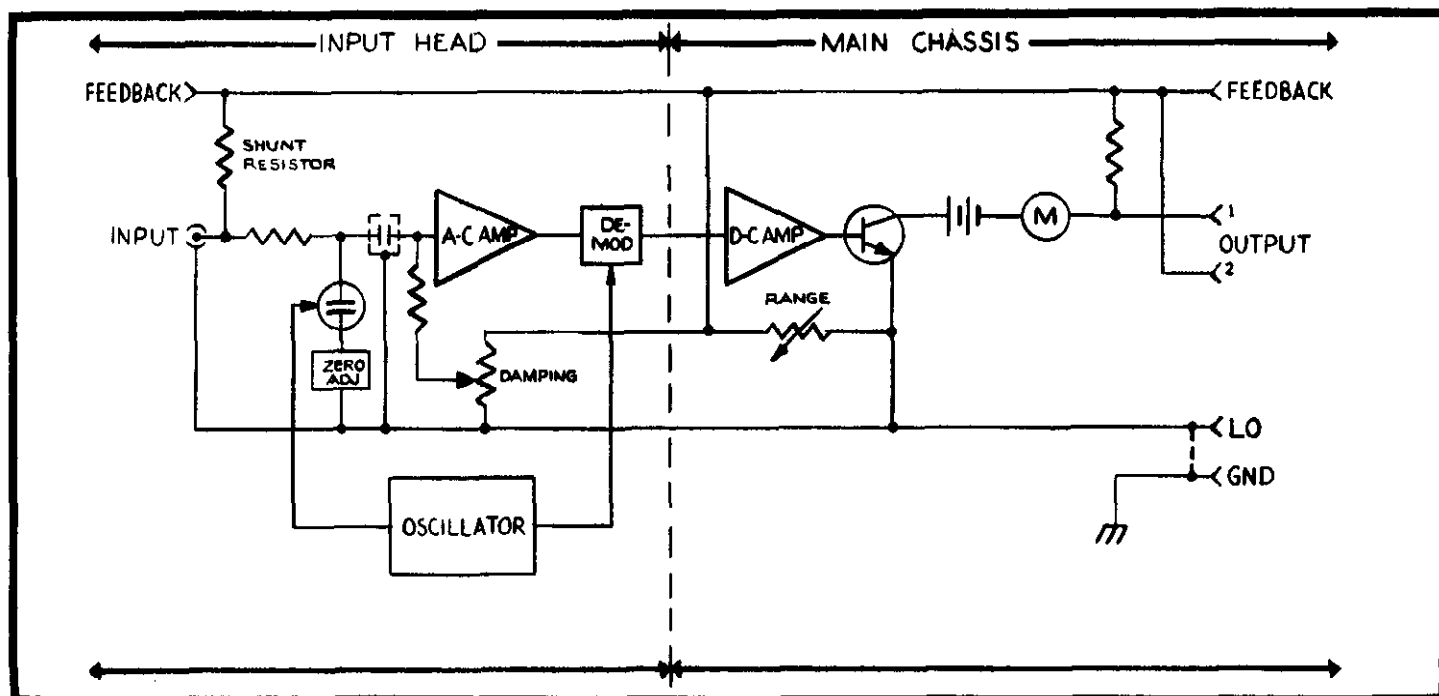


FIGURE 15. Block Diagram of Model 640.

d. AC Amplifier. The ac amplifier provides very high gain through the use of a two-stage amplifier and a phase splitter amplifier. An FET (Q101) provides a high input impedance. An emitter-follower stage (transistor Q102) provides impedance matching between Q101 and transistor Q106. Transistors Q103, Q104, Q105 and Q108 are switches providing gain adjustment to prevent oscillation on the higher ranges. Transistors Q107, Q109 and Q110 form a second stage ac amplifier. A phase splitter circuit is formed by transistors Q111 and Q112. A tuned circuit composed of integ. ckt. QA101, inductor L101 and trimmer capacitor C124 provide attenuation of carrier frequency (6000 Hz) second harmonic noise. The ac signal is synchronously demodulated by transistors Q506 and Q507 (located in the oscillator circuit).

e. Oscillator Circuit. The high frequency drive (400 kHz) signal is generated by a tuned circuit consisting of transformer T501, capacitors C502, C503 and C504 and transistor Q501. Capacitor C502 adjusts the 400 kHz carrier frequency. Potentiometer R506 adjusts the gain of the drive circuit. The drive output is developed across transformer T502 and capacitor C509 to excite vibrating capacitor plates (pins 1 and 4). The actual signal is a modulated "envelope" as shown in Figure 28 in Section 6. FET Q503 and integrated circuit QA501 form a wave-shaping circuit for phase and symmetry control. Integrated circuit QA502 is part of a phase control circuit for the demodulator output. Potentiometer R517 adjusts the phase of the demodulator drive. Integrated circuit QA503 is part of a symmetry control circuit. Potentiometer R521 adjusts the demodulator on and off times (symmetry). Transistor Q505 controls the switching of demodulating transistors Q506 and Q507.

3-4. MAIN CHASSIS. The Main Chassis contains a dc amplifier circuit, meter circuit, sensitivity switching circuit, power supply circuit, and battery charging circuit as shown on Schematic 21383E.

a. DC Amplifier. A differential input stage is formed by FET's Q401 and Q402 and transistors Q403 and Q404. Potentiometer R404 provides dc amplifier balance. Capacitors C401, C402, and C403 provide filtering of the demodulator ripple. FET Q405 and transistors Q406 and Q409 (Darlington amplifier) provide additional gain for driving the meter circuit and analog OUTPUT. Transistor Q408 provides current limiting when the output is overloaded. Transistor Q407 provides a constant current for biasing purposes.

b. Meter Circuit. The meter circuit consists of a meter switch S404, a 1-MA meter movement (M401), and various meter circuit adjustments. The Meter switch has an OFF position (which shorts out the meter movement), "+" and "-" polarity positions (which connect the meter for either positive or negative deflection), and a ZERO CENTER position (which biases the meter such that center scale represents zero). Potentiometer R421 is an internal adjustment of the ZERO CENTER meter bias current. Potentiometer R455 is an internal adjustment of the meter calibration.

c. Zero Controls. Switch S405 is a COARSE ZERO adjustment which can select up to 11 positions on a divider string (resistors R432 through R442). Switch S407 is a MEDIUM ZERO adjustment which can select up to 11 positions on a divider string (resistors R443 through R452). Potentiometer R431 is a FINE ZERO adjustment.

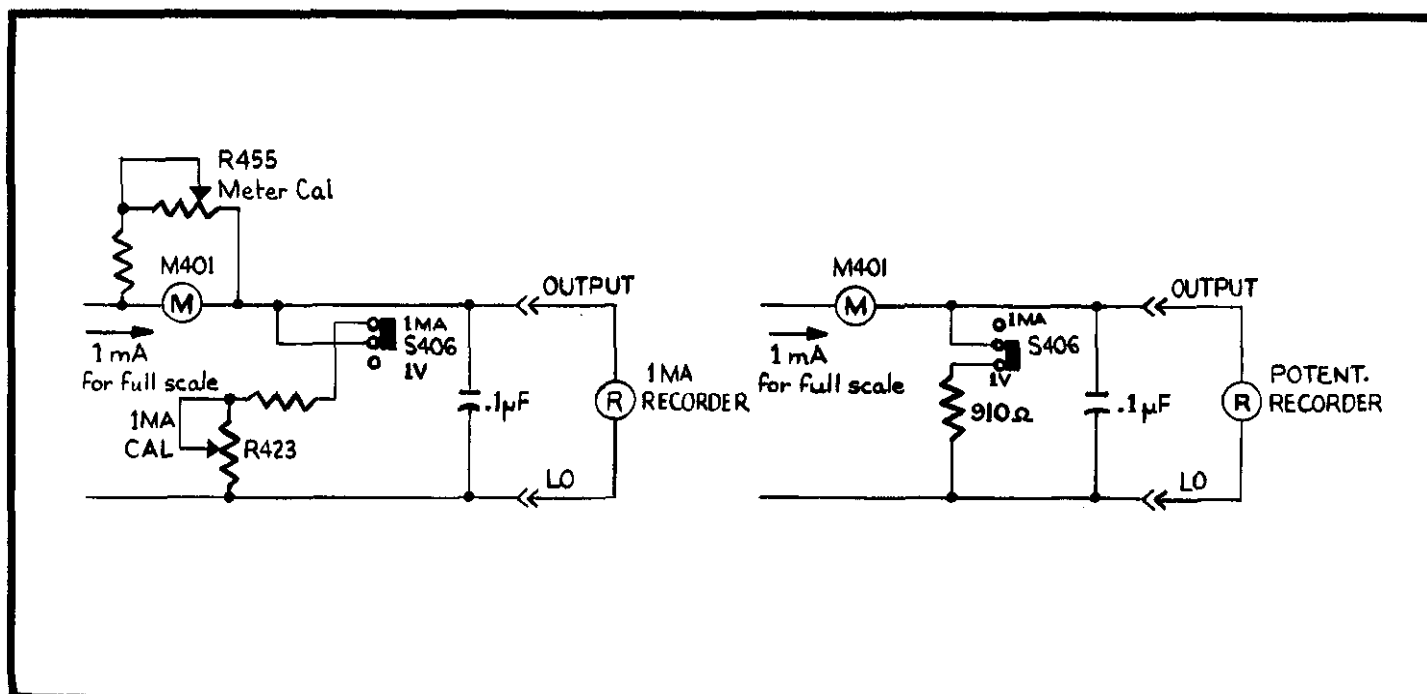


FIGURE 16. Meter and Analog Output Circuits.

d. Sensitivity Switching. RANGE Switch S403 has 13 positions which connect resistors R457 through R469. The range resistors determine the voltmeter gain or sensitivity from 30 microvolts to 30 volts full scale.

e. Power Supply. (As shown on Schematic 21382E). The power for the Model 640 is provided by either a rechargeable 6-volt battery pack or a rectifier circuit operated by 50-60 Hz line power. Power Switch S301 selects four positions: "AC" (line power), "OFF", "BATT" (battery power) and "BATT TEST" (battery voltage check). The power supply utilizes a -6 volt unregulated voltage from the battery pack or a rectifier circuit composed of transformer T303 secondary (yellow and green taps) and diodes D317-D318. A 5-volt regulator is composed of capacitor C321, transistors Q317-Q319 (Darlington series regulator), and reference diode D319. Transistors Q321 and Q322 compose an output sensing amplifier to regulate the series transistor stage. Potentiometer R338 is an internal adjustment of the regulated output (approximately -5 volts). The regulated voltage is applied to an inverter circuit consisting of transistors Q301-Q302 and saturable core transformer T301.

1. + 40V Supply. Power is tapped from a secondary winding on transformer T302 (brown/yellow, brown/white, brown). Diodes D301-D304 and capacitors C302-C303 provide + 40 volts for the dc amplifier output stage.

2. - 20V Supply. This voltage is not used in the Model 640.

3. + 12V Supply. Power is tapped from a secondary winding on transformer T302 (red/yellow, yellow/white, yellow). Diodes D307-D310, resistor R304, and capacitor C307 form a rectifier circuit. A voltage doubling circuit consisting of capacitors C305-C306, and diodes D308-D309 forms a bootstrap voltage). Transistors Q303-Q304 form a Darlington series regulator circuit. Feedback is obtained by sampling the + and - 12 volt outputs at the junction of resistors R316 and R317. Transistors Q308 and Q309 form a differential amplifier which senses a change in either the + or - outputs. Another differential pair (transistors Q306-Q307) drives the base of transistor Q304 to complete the feedback loop. Transistor Q305 provides overload-current protection by sensing the current through resistor R305.

4. -12V Supply. Power is tapped from a secondary winding on transformer T302 (red, blue/white, blue). Diodes D311-D312, resistor R318, and capacitor form a rectifier circuit. Transistors Q310-Q311 form a Darlington series regulator circuit. Feedback is obtained by sampling the -12 volt output at the wiper arm of potentiometer R327. This potentiometer adjusts the output voltage. Transistors Q114-Q115 form a differential amplifier with the base of Q314 referenced to diode D314. Transistor Q313 drives the base of Q310 to series regulate the output. Transistor Q312 provides overload current protection by sensing the current through resistor R345.

5. Line Power to Battery Switching. The Model 640 can be modified so that a failure of line power (with POWER Switch set to "AC") will cause an automatic switching to battery operation to occur. A diode (0.75A, 50V, Keithley Part No. RF-17) can be connected at the POWER Switch as shown in Figure 17. When line power is present the diode is turned off and the battery is not used.

f. Battery Charging Circuit. The charging circuit functions whenever the POWER switch is set to "AC" or "OFF". Charging current is provided by a rectifier circuit consisting of diodes D315-D316 and resistor R329. Fuse F302 is rated for 3/4 ampere and used to protect the battery and circuitry during charging or discharging.

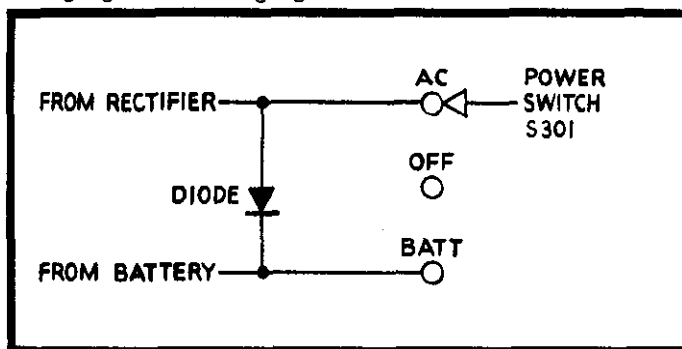


FIGURE 17. Line to Battery Switching.

3-5. VOLTAGE FUNCTION. With the FUNCTION Switch set to "VOLTAGE", the Model 640 operates as a sensitive voltmeter with input "OPEN" or shunted by any one of four resistors, R101 through R104.

3-6. CURRENT FAST FUNCTION. With the FUNCTION Switch set to "CURRENT FAST", the Model 640 operates as a feedback ammeter with a Shunt Resistor connected across the amplifier (from High to Feedback). An external resistance can be connected in place of the four Shunt Resistors when switch S102 is set to "OPEN". This method minimizes the slowing effect of capacitance across the input.

3-7. CURRENT INTEGRATE FUNCTION. With the FUNCTION Switch set to "CURRENT INTEGRATE", the Model 640 operates as a feedback ammeter or coulomb-meter. With a Shunt Resistor connected, (R101 through R104) a 20 pF capacitor (C105) shunts the amplifier to therefore slow the response and filter noisy signals. With switch S102 set to "OPEN", capacitor C105 acts as an integrating capacitor for charge or current integration measurements. A simplified diagram of the current integration amplifier is shown in Figure 11. When the FUNCTION Switch is set to "CURRENT INTEGRATE", switch S402 connects -5 volts to solenoid K102 which in turn closes a contact. The contact connects the Damping Control (R108) such that Capacitor C105 is connected in the feedback loop. The Damping Control adjusts the effective capacitance connected in the feedback loop and thus controls the amount of damping. When the Damping Control is adjusted fully clockwise the maximum damping (20 pF \pm .25%) is provided.

SECTION 4. ACCESSORIES

4-1. GENERAL. The following Keithley accessories can be used with the Model 640 to provide additional convenience and versatility.

4-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 6401 Remote Cable

Description:

The Model 6401 is a shielded coaxial cable with a Keithley CS-195 (male) connector on each end. The cable is 25 feet long.

Application:

The Model 6401 permits remote location of the Input Head up to 25 feet from the Main Chassis with no degradation to the specifications.

Model 6402 Adapter

Description:

The Model 6402 is special adapter which replaces the UHF adapter supplied with the instrument.

Application:

The Model 6402 adapts the Input Receptacle for GR874 series of coaxial accessories. (General Radio Co.). This adapter is limited to measurements above 10^{-13} amperes or source resistances below 10^{14} ohms. The adapter can be connected to the Input Head as shown in the illustration.



Model 399 Isolating Amplifier

Description:

The Model 399 is a unity-gain amplifier which permits operation with the instrument output floated at up to 1500 volts off ground while the Model 399 output is grounded or floated up to 100 volts off ground.

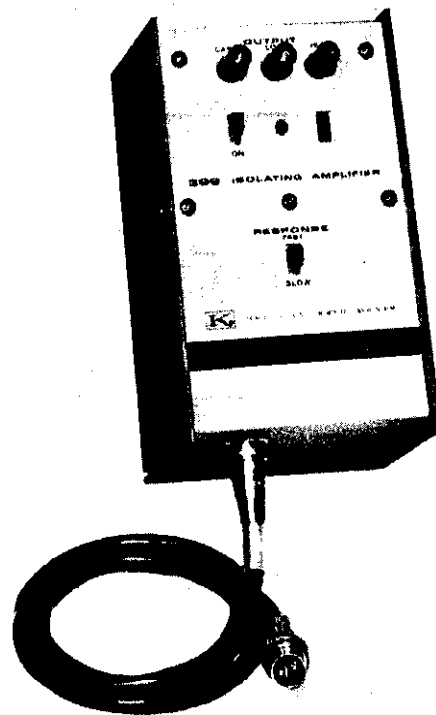
Application:

The Model 399 can be used for "TIFO" operation (floating input, floating output) or when it is necessary to break ground loops within a system. The 1 volt at up to 1 mA output enables use of the Model 399 as a preamp for driving most analog recorders.

Model 399 Isolating Amplifier (Cont'd.)

Specifications:

GAIN: $\times 1$, adjustable $\pm 3\%$.
 GAIN ACCURACY: $\pm 0.2\%$ (as set at factory).
 GAIN LINEARITY: Within 3 millivolts for signal levels below 1 volt.
 FREQUENCY RESPONSE (minimum): Fast: dc to 100 Hz (-3 dB); Slow: dc to 0.3 Hz (-3 dB).
 NOISE: Less than 5 millivolts p-p, .01 Hz to 1 kHz; * less than 0.5 millivolt p-p, .01 Hz to 0.35 Hz.*
 ZERO STABILITY: Better than 3 millivolts/24 hours at reasonably constant ambient temperature.
 INPUT RESISTANCE: 10^6 ohms.
 INPUT OFFSET CURRENT: Less than 10^{-6} ampere.
 FULL-SCALE INPUT: ± 1 volt with 100% overrange.
 MAXIMUM INPUT OVERLOAD: 100 volts.
 INPUT ISOLATION: Greater than 10^{12} ohms at 50% relative humidity and 25°C shunted by less than 100 picofarads.
 MAXIMUM COMMON MODE VOLTAGE: 1500 volts peak, dc or ac.
 CMRR: Greater than 120 dB at dc, greater than 100 dB up to 1 kHz.
 OUTPUT: ± 1 volt at up to 1 milliamperes, 100% overrange.
 OUTPUT ISOLATION: Greater than 10^8 ohms shunted by less than 0.001 microfarad.
 POWER: 105-125 or 210-250 volts (switch selected), 50-60 Hz, 5 watts.
 DIMENSIONS, WEIGHT: 4-1/2" high x 4-1/2" wide x 7" deep (11 cm x 11 cm x 18 cm); net weight, 3 pounds (1.3 kg).
 ACCESSORIES FURNISHED:
 Model 3991 Input Cable (to safely mate Model 399 to most Keithley instruments).
 *Modulation spikes a few hundredths of a volt p-p at a 10-kHz rep-rate may be observed with wideband systems.



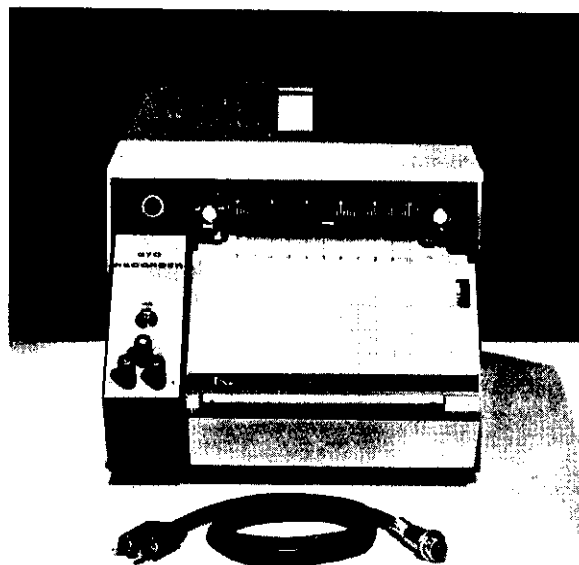
Model 370 Recorder

Description:

The Model 370 is a compact, paper chart recorder which is compatible with most Keithley instruments having a 1 volt, 1 milliamperes output.

Application:

The Model 370 can be used for analog recording applications with inputs floated at up to 500 volts off ground. The Model 3701 Input Cable supplied permits convenient connections to the instrument.



Model 4006 Rack Mounting Kit

Description:

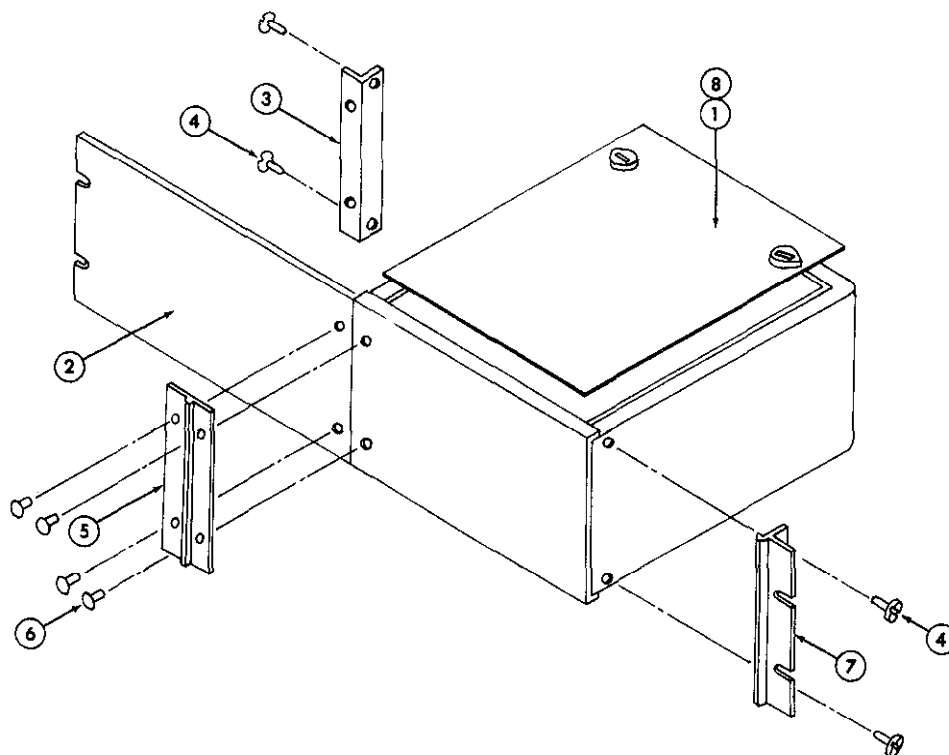
The Model 4006 is a rack mounting kit with overall dimensions, 7 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4006 converts the instrument from bench mounting to rack mounting. It is suitable for mounting one instrument in one-half of a standard 19-inch rack.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Top Cover, 10"	1	20016B
2	Panel Adapter Plate	1	19158A
3	Angle Support	1	19157A
4	Screw, #10 x 3/8"	4	---
5	Connecting Plate	1	19154A
6	Screw, #10 x 1/2"	4	---
7	Angle	1	19147B
8	Top Cover, 13"	1	20015B



Model 4007 Rack Mounting Kit

Description:

The Model 4007 is a rack mounting kit with overall dimensions, 7 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4007 converts the instrument from bench mounting to rack mounting. It is suitable for mounting two instruments in a standard 19-inch rack.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Top Cover, 10"	2	20016B
4	Screw, #10 x 1/2"	8	---
5	Connecting Plate	1	19154A
6	Screw, #10 x 1/2"	4	---
7	Angle	2	14147B
8	Top Cover, 13"	2	20015B
9	Zee Bracket	1	19167A
10	Plate	1	19700A

SECTION 5. SERVICING

5-1. GENERAL. This section contains procedures for checkout and servicing the instrument. Follow the step-by-step procedures for complete servicing.

5-2. SERVICING SCHEDULE. This instrument requires no periodic maintenance beyond the normal care required for high-quality electronic equipment.

5-3. PARTS REPLACEMENT. Refer to the Replaceable Parts List, Section 7, for information regarding component specifications and part numbers. Replace components as indicated using replacement parts which meet the listed specifications.

5-4. TROUBLESHOOTING.

a. Test Equipment. Refer to Table 5-1 for recommended test equipment for servicing and calibrating this instrument.

b. Troubleshooting Guide. Refer to Table 5-2 for a brief outline of troubleshooting hints. The Table identifies the Symptoms or Trouble, the Probable Cause, and the suggested Solution.

NOTE

If the instrument problem cannot be readily located or repaired, contact a Keithley representative or the Sales Service Department, Cleveland, Ohio.

TABLE 5-1.
Test Equipment.

Code Letter	Instrument Type	Specification	Manufacturer and Model No.	Use
A	High Voltage Supply	0-1000V, .01-V steps, .05% accuracy.	Keithley, Model 241	Accuracy checks.
B	Nanovolt Source	10 ⁻¹⁰ to 1V, .25 to .75% accuracy.	Keithley, Model 260	Accuracy checks.
C	Picoampere Source	10 ⁻⁴ to 10 ⁻¹⁴ A, .25 to .7% accuracy.	Keithley, Model 261	Accuracy checks.
D	Megohmmeter	10 ⁷ to 10 ¹³ ohms \pm 20% accuracy.	Keithley, Model 500	Isolation Resistance Check.
E	Differential Voltmeter	100mV - 500V, .01%	Keithley, Model 662	Accuracy checks.
F	Digital Voltmeter	1 μ V to 1000V, 0.1%	Keithley, Model 163	Trouble-shooting.
G	Function Generator	-	Wavetek, Type 110	Frequency Response Check.
H	Oscilloscope	-	Tektronix 503/561A	Trouble-shooting Calibration.
I	Probes; 10:1 & 1:1	-	Tektronix	Use with Oscilloscope.
J	Capacitance Bridge	-	General Radio 1616A	Capacitor checks.
K	Variable Transformer & Power Line Meter	-	Variac/RCA	Power Supply Calibration.
L	Recorder	1mA sensitivity; .05 s Rise Time 10-90%	Keithley, Model 370	Drift and Noise Checks.

TABLE 5-2.
Troubleshooting Guide.

Symptom or Trouble	Probable Cause	Solution	Sub-Assembly	Figure
Excessive Voltage Drift	Vibrating Capacitor	Replace V.C. (C121).	INPUT HEAD	-
	Meter Zero Circuit	Check diodes D405-6 and potentiometer R431.	PC-149	23
	DC Amplifier	Check bias voltages.	PC-150	25
Excessive Noise at OUTPUT or Meter	Vibrating Capacitor	Replace V.C. (C121).	INPUT HEAD	-
	Input FET (Q101)	Replace FET (Q101).	PC-151	24
Excessive Current - Offset or drift	Vibrating Capacitor	Replace V.C. (C121).	INPUT HEAD	-
	Defective Insulation	Check sapphire insulation.	INPUT HEAD	-
	Excessive Humidity	Allow instrument to warm-up. Re-activate the dessicant in the INPUT HEAD.	INPUT HEAD	-
Response Time Slow	Vibrating Capacitor	Calibrate drive circuit as in para. 6-3.	-	-
	Power Supplies	Check voltages in the INPUT HEAD.	INPUT HEAD	-
	AC Amplifier	Check for proper gain.	PC-151	24
	Oscillator Circuit	Check drive voltages. Calibrate as in para. 6-3.	PC-247	27
Meter Pegs Off-Scale (all ranges)	Power Supplies	Check voltages on the Main Chassis.	PC-148, PC-149	18 19
	DC Amplifier	Check meter circuit.	PC-150	25
	Vibrating Capacitor	Replace V.C. (C121).	INPUT HEAD	-
	(one range only) RANGE Resistor	Check RANGE switch. Replace RANGE resistors.	S403	-

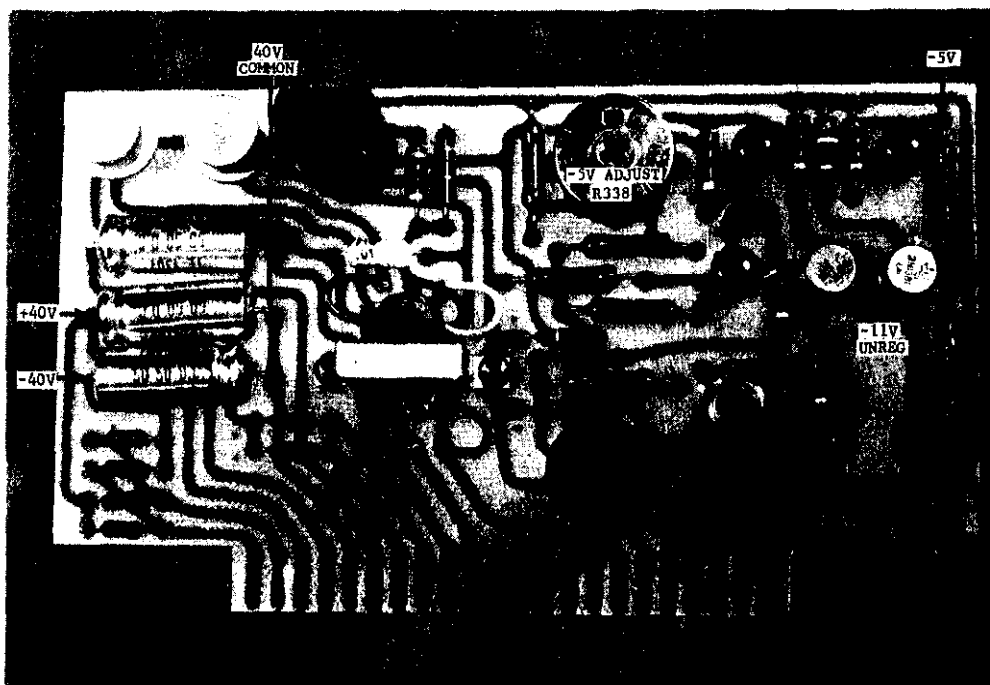


FIGURE 18. Test Points, PC-148.

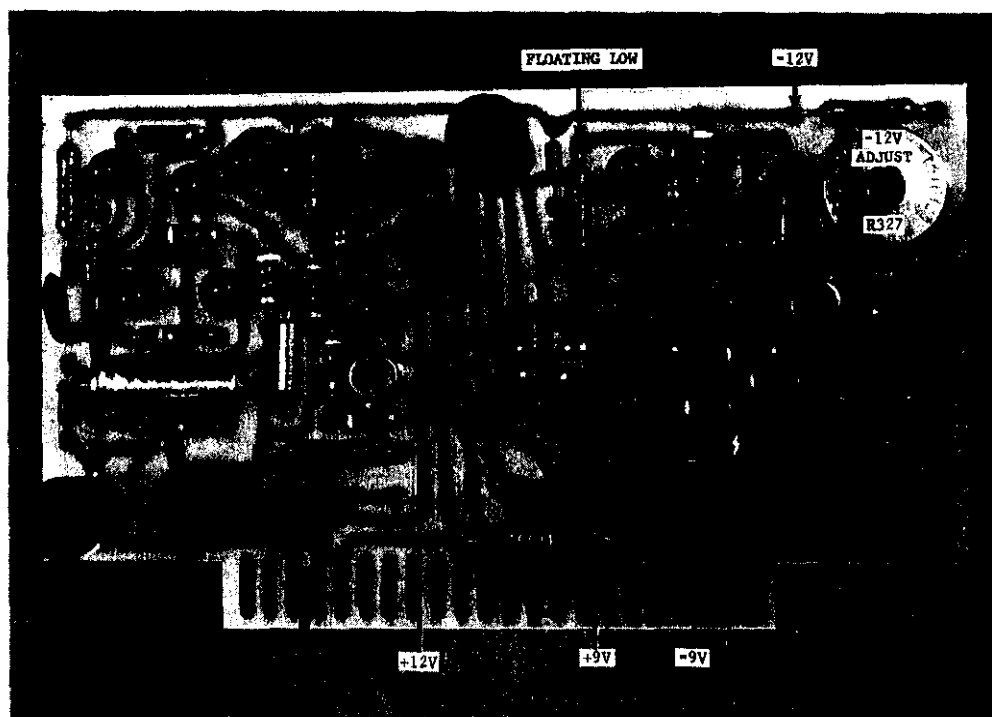


FIGURE 19. Test Points, PC-149.

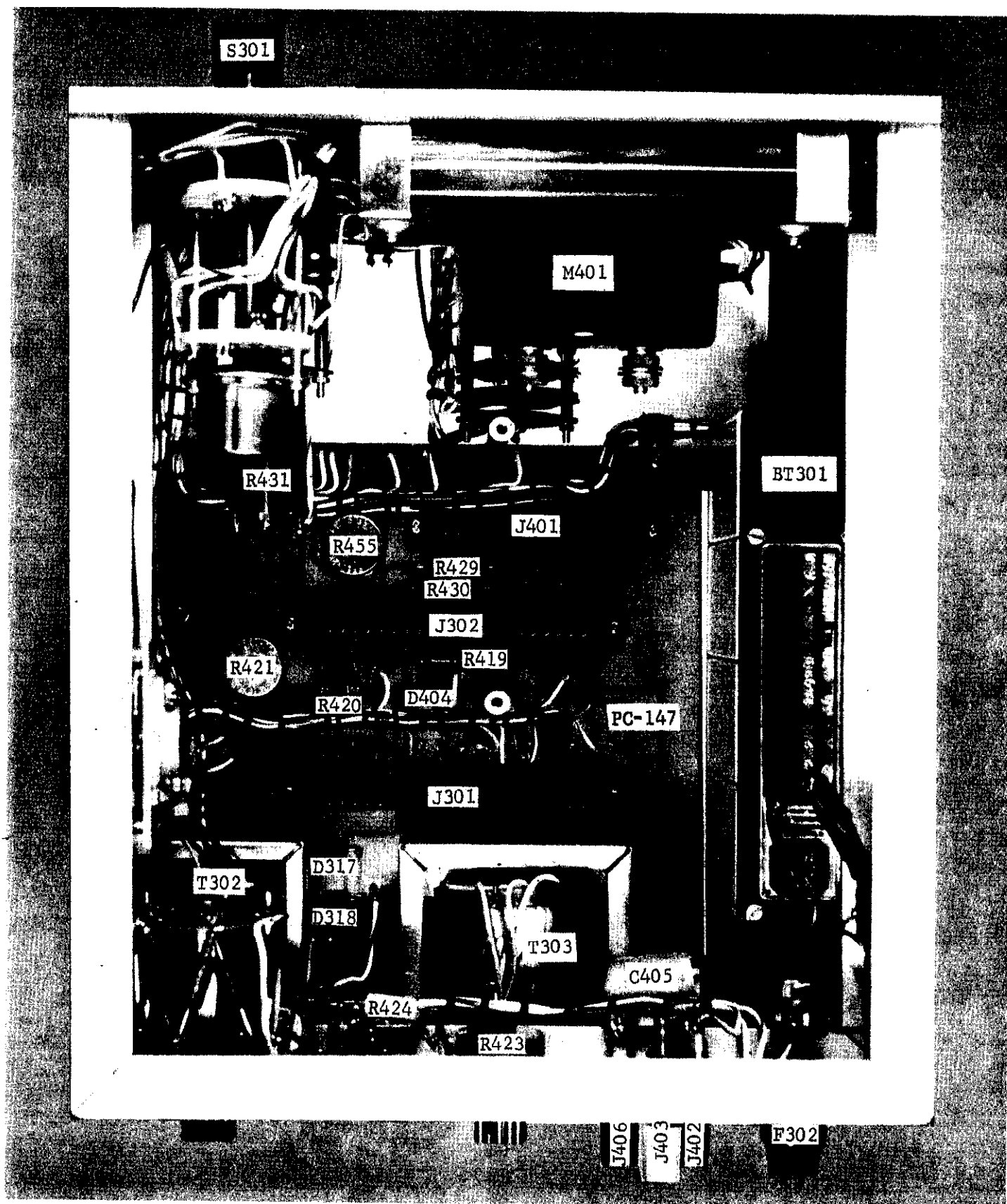


FIGURE 20. Chassis, Top View.

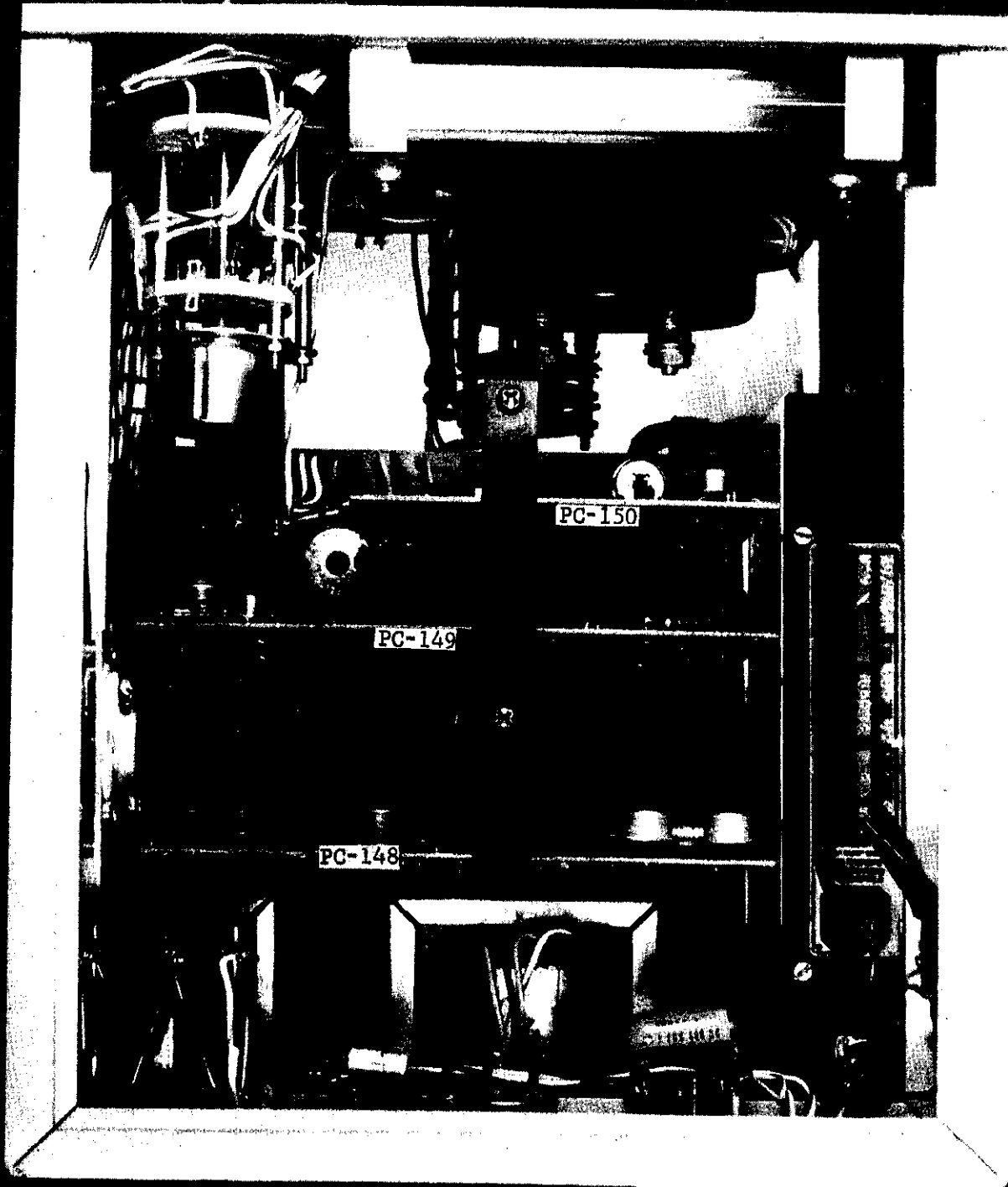


FIGURE 21. Chassis, Top View.

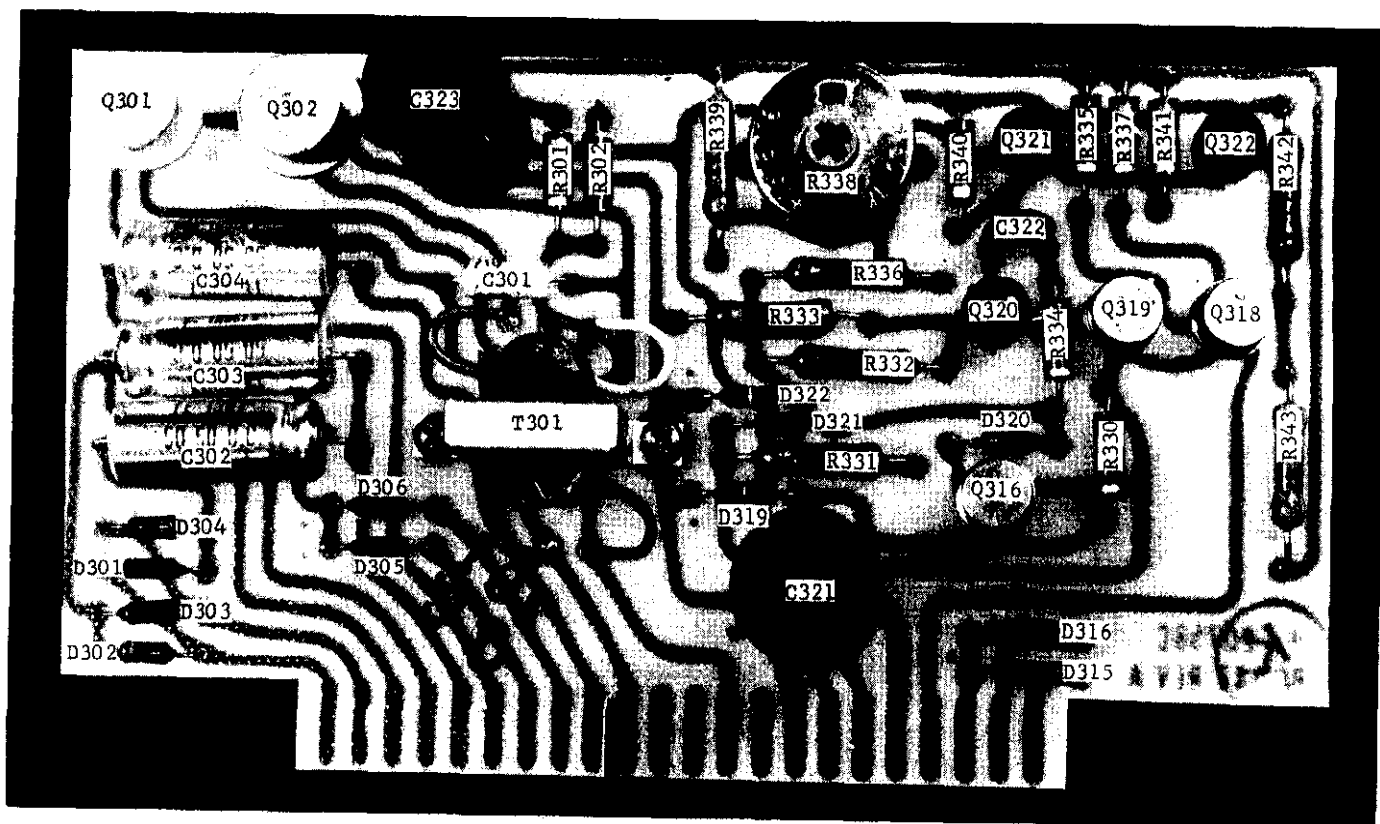


FIGURE 22. Component Layout, PC-148.

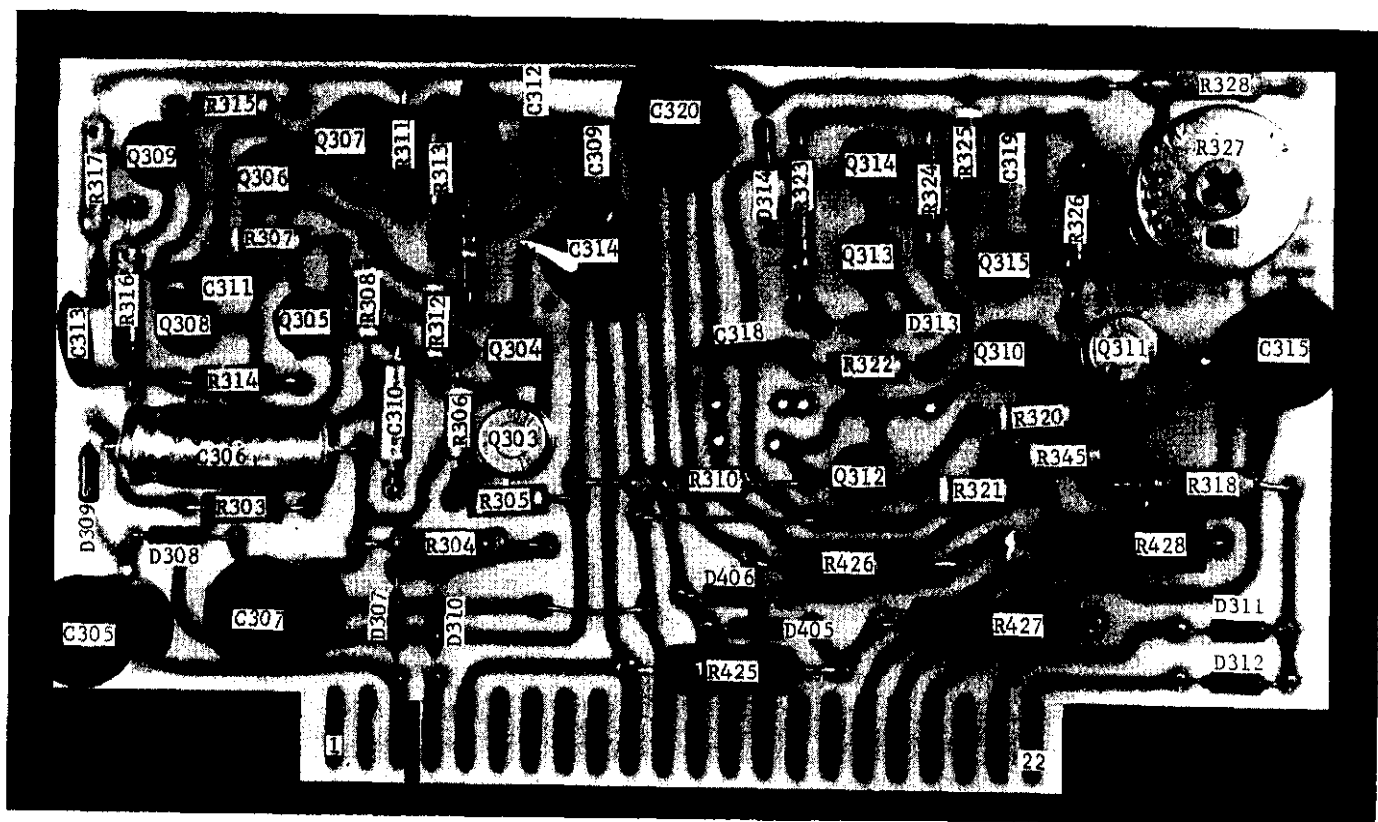


FIGURE 23. Component Layout, PC-149.

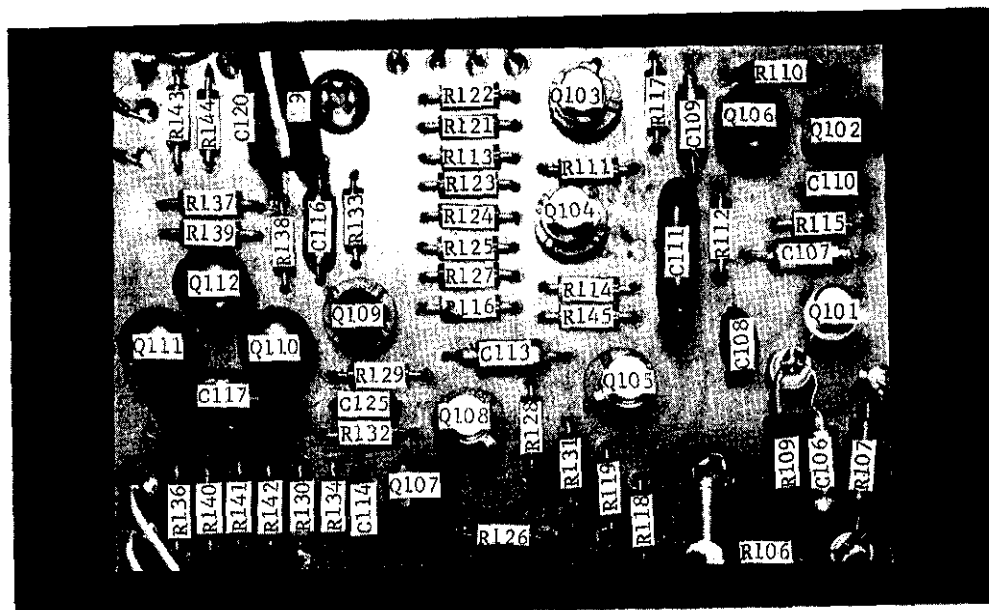


FIGURE 24. Component Layout, PC-151.

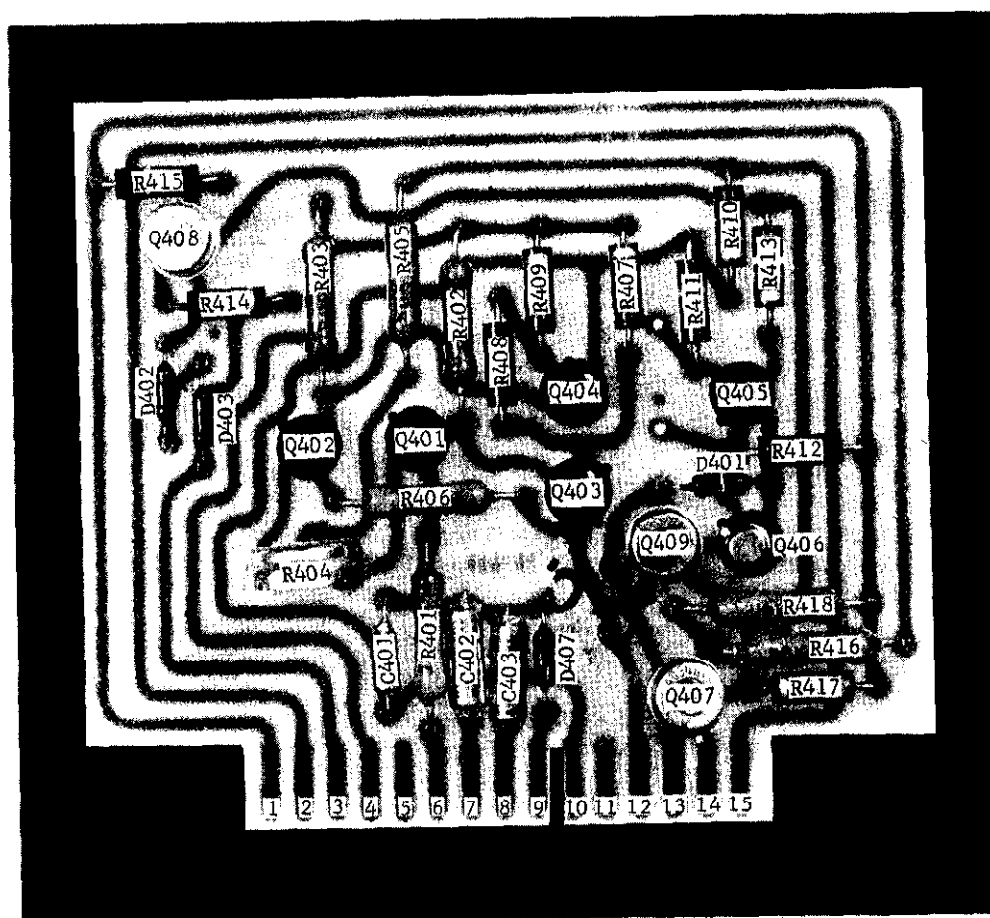


FIGURE 25. Component Layout, PC-150.

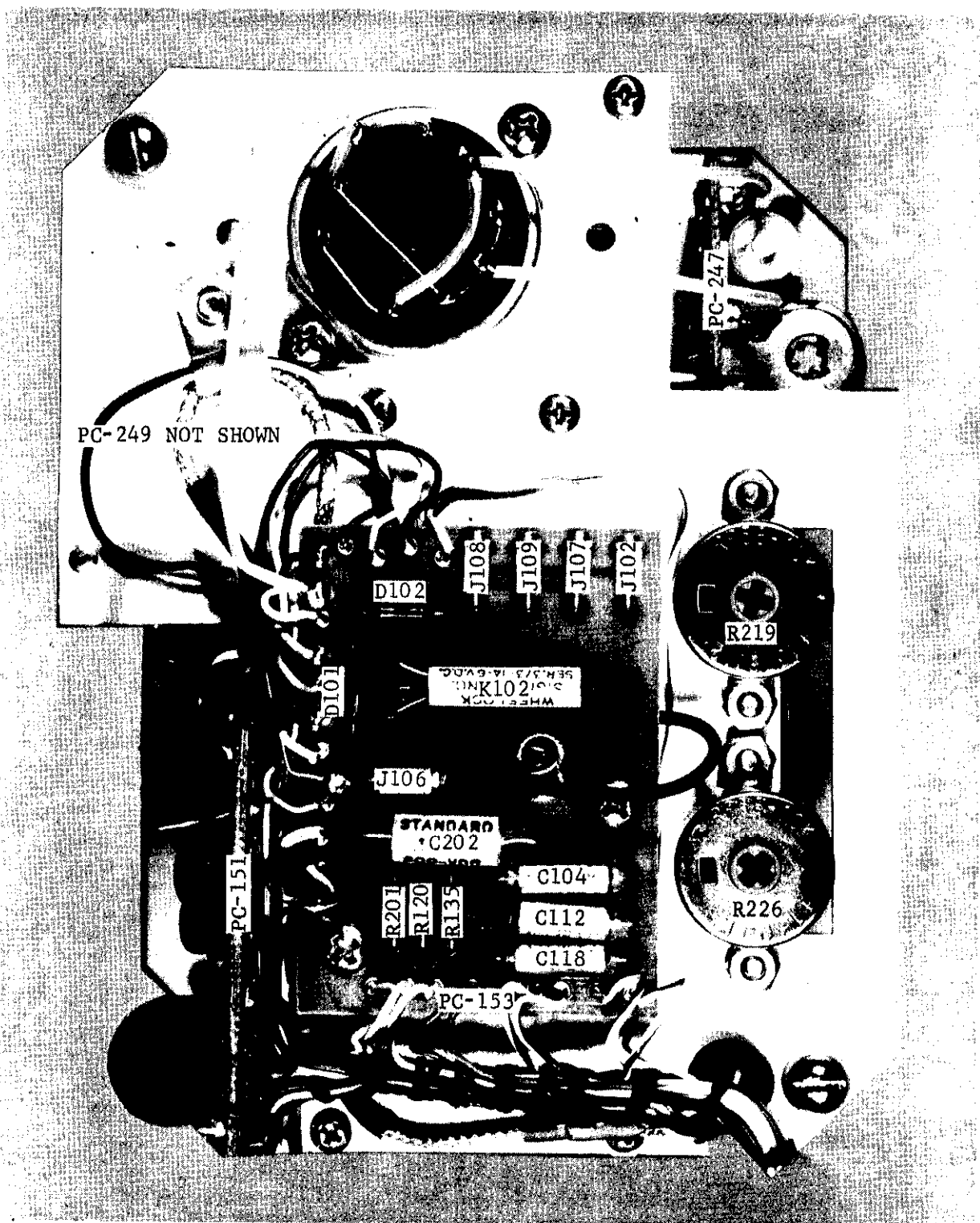


FIGURE 26. Component Layout, PC-153.

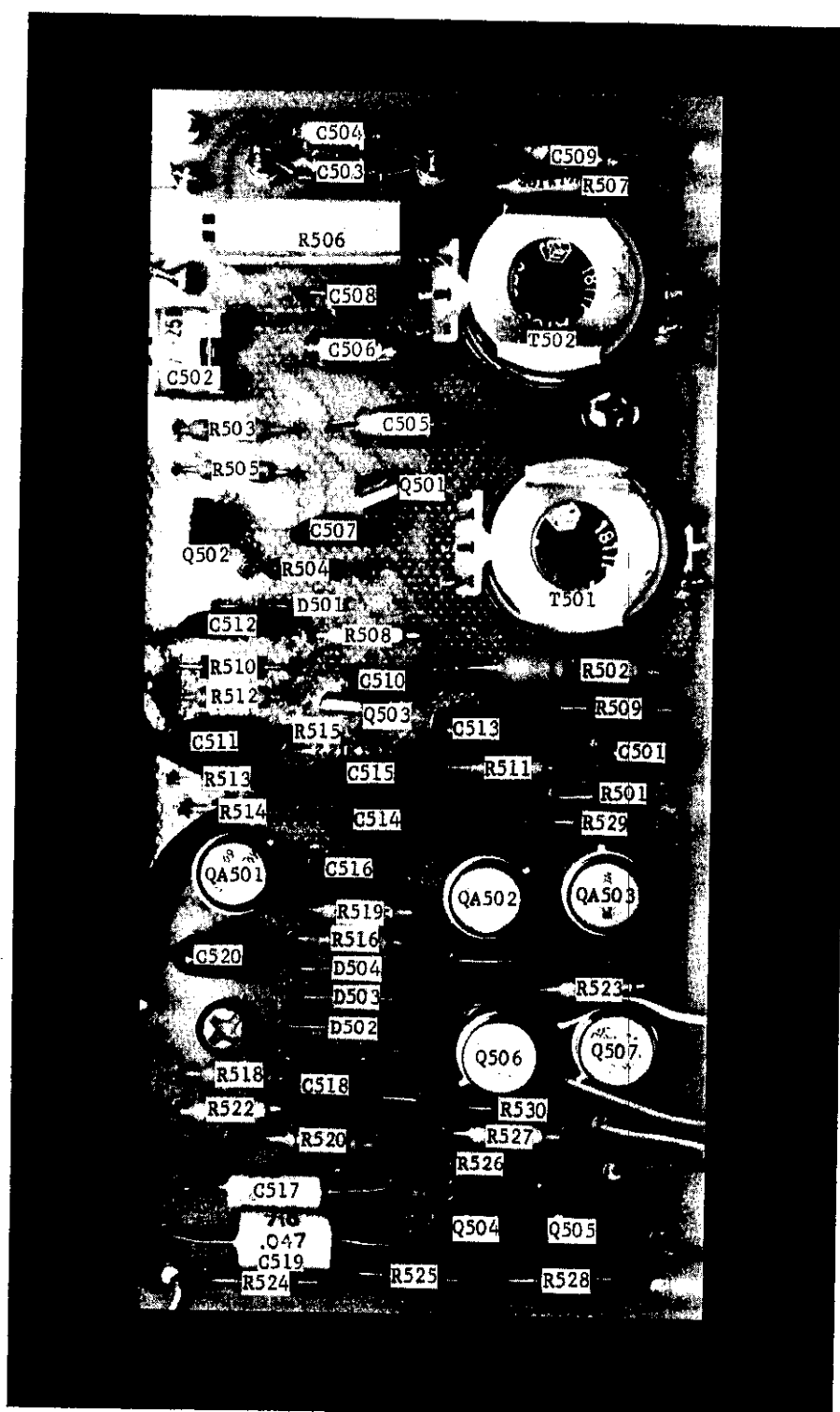


FIGURE 27. Component Layout, PC-247.

5-5. CHECKOUT PROCEDURE. Refer to Table 5-3 for step-by-step procedures for instrument checkout.

NOTE

Before a step-by-step checkout is started, inspect the circuits visually to detect problems such as broken wire, loose parts, dirty or oily switch contacts, etc.

WARNING

Use care when troubleshooting an instrument connected to line power and/or with Power switch on. Whenever resistance checks are made, remove all power to instrument and discharge power supply capacitors through a low value resistor (100 Ω).

TABLE 5-3.
Checkout Procedure.

Para. 5-5	Description	Sub- Assembly	Figure	Test Point	Circuit Description
a.	Connect the shorting link between GND and LO on rear panel of Model 640.	Main Chassis	4	Rear Panel	-
b.	Place Dust Cover (20911A) over Input receptacle (To prevent contamination and stray noise pickup)	INPUT HEAD	-	-	-
c.	Check retaining screws on all PC boards in the INPUT HEAD. (The LO to case connection is made through these screws).	INPUT HEAD	-	-	-
d.	Check the unregulated voltage on PC-148. Voltage should be nominal -11 volts dc with 3 volts p-p ripple. Use Oscilloscope (H).	PC-148	18	-11V Unreg.	Para. 3-4e
e.	Check the regulated voltage on PC-148. Voltage should be nominal -5 volts.	PC-148	18	-5V	Para. 3-4e
f.	Check inverter voltage on PC-148. Voltage should be 5V p-p square wave at 1100 Hz.	PC-148	18	Inverter	Para. 3-4e
g.	Check the $\pm 40V$ unregulated voltages on PC-149.	PC-149	19	$\pm 40V$	Para. 3-4e
h.	Check the unregulated voltage at collector of Q303. Voltage should be nominal 15 volts dc.	PC-149	19	+15V Unreg.	Para. 3-4e
i.	Check regulated +12V on PC-149.	PC-149	19	+12V	Para. 3-4e
j.	Check regulated -12V on PC-149.	PC-149	19	-12V	Para. 3-4e
k.	If all power supply voltages are nominal proceed to oscillator check.	-	-	-	-
l.	Check Vibrating Capacitor drive signal on PC-247.	PC-247	27	-	Para. 3-3e
m.	Check demodulator drive signal on PC-247.	PC-247	27	-	Para. 3-3e
n.	Check the dc amplifier circuit on PC-150.	PC-150	25	-	Para. 3-4a
p.	Check meter circuit on PC-149, PC-150.	PC-149, PC-150	23 25	- -	Para. 3-4b

SECTION 6. CALIBRATION

6-1. GENERAL. This section contains procedures for checking the instrument in order to verify operation within specifications.

6-2. TEST EQUIPMENT. Refer to Table 5-1 for recommended test equipment for servicing and calibrating this instrument.

6-3. CALIBRATION PROCEDURE. Refer to Table 6-1 for step-by-step procedures for calibrating this instrument.

NOTE

If proper facilities and equipment are not available, contact a Keithley representative or the Sales Service Department, Cleveland, Ohio. Keithley Instruments, Inc. maintains a complete repair and calibration facility with equipment traceable to the National Bureau of Standards.

TABLE 6-1.
Calibration Procedures.

Para. 6-3	Specification or Adjustment	Description	Measurement	Sub- Assembly	Figure	Test Point
a.	LO to GND Isolation	Set Power to "OFF". Remove shorting link between GND and LO on rear panel. Measure LO to GND resistance using Megohmmeter (D).	LO to GND should be greater than $10^9\Omega$.	Main Chassis	4	LO to GND
b.	Mechanical Zero Adjust	Set meter zero.	-	Main Chassis	2	Meter
c.	Line Voltage Setting	Connect Variac and set line voltage for 115V.	115V nominal.			
d.	-5V Reg. Voltage	Set Power to "AC" Measure -5V Supply on PC-148 using Diff. Voltmeter (F).	Adjust potentiometer R338 for -5V $\pm 5\text{mV}$.	PC-148	22	-
e.	Ripple Voltage	Measure ripple on -5V supply using Oscilloscope (H).	Ripple to be less than 500mV p-p.	PC-148	18, 22	-
f.	Voltage Checks	Check remaining voltages. -12V Supply. (Ripple should not exceed 5mV p-p).	Adjust potentiometer R327 for -12V $\pm 5\text{mV}$.			
		+12V Supply. (Ripple should not exceed 15mV p-p).	+12V $\pm 500\text{mV}$	PC-149	19, 23	-
		-40V Supply. (Ripple should not exceed 50mV p-p).	-40V $\pm 2\text{V}$	PC-148	18, 22	-
		+40V Supply. (Ripple should not exceed 50mV p-p).	+40V $\pm 2\text{V}$	PC-148	18, 22	-
g.	Zero Circuit	Check zener voltage on PC-149 using Diff. Voltmeter (E).	D405 voltage should be +9V $\pm 5\%$, Noise less than 0.3mV.	PC-149	23	-
		Check zener voltage on PC-149 using Diff. Voltmeter (E).	D406 voltage should be -9V $\pm 5\%$, Noise less than 0.3mV.	PC-149	23	-

TABLE 6-1. (cont'd)
Calibration Procedures.

Para. 6-3	Specification or Adjustment	Description	Measurement	Sub- Assembly	Figure	Test Point
h.	Battery Charging Circuit	Set Power to "OFF". With line cord connected measure the charging voltage at R329.	Voltage should be -22V with less than 27V p-p ripple.	Main Chassis	-	R329
i.	Battery Check	Set POWER Switch to "BATT TEST".	Meter should indicate greater than 6V.	Main Chassis	-	Meter
j.	Oscillator Check	Check waveform on PC-247 using Oscilloscope (H). NOTE: Use a 10:1 Probe for the Oscilloscope input. Use 1:1 Probe for EXT TRIGGER and connect to R521 (wiper).	See Figure 28 for desired waveform.	PC-247	27, 28	Oscillator Waveform J104 R521
k.	Oscillator Recovery	Set Power to "OFF" for 10 seconds. When Power is set to "AC" the Oscillator signal should recover.	-	-	-	-
l.	Oscillator Adjustment	Adjust variable capacitor C502 to "start" oscillator if necessary. Set the Gain Adjust potentiometer R506 to obtain a stable waveform.	-	PC-247	27	C502
m.	Symmetry Adjustment	Set the Sym. Adjust potentiometer R521 for equal demodulator "ON" and "OFF" times.	See Figure 29.	PC-247	27, 28	R521
n.	Phase Adjustment	Set Phase Adjust potentiometer R517 for proper phasing as shown in Fig. 30. Note: The amplifier must be driven into saturation to obtain a phase pattern.	See Figure 30 for phasing.	PC-247	27, 29	R517
p.	Unity Gain Check	Set FUNCTION to VOLTAGE RANGE to 1VOLT Meter to "+" POWER to AC SHUNT RESISTOR to 10^6 Connect the Nanovolt Source (B) to the Model 640 Input using UHF adapter. Connect the Differential Voltmeter to read the difference potential between the Input high and FEEDBACK terminals of the Model 640. With the Nanovolt Source set to 0-0-0, adjust the Model 640 zero controls for null on the Diff. Voltmeter ($\pm 10\mu\text{V}$). Apply +1.000V to Model 640 and check the Diff. Voltmeter null. The Diff. Voltmeter should indicate within ± 100 microvolts.	-	INPUT HEAD	-	FEEDBACK Terminal on INPUT HEAD

TABLE 6-1. (cont'd)
Calibration Procedures.

Para. 6-3	Specification or Adjustment	Description	Measurement	Sub- Assembly	Figure	Test Point
q.	Meter Cal. for Full Scale	Set front panel controls as in 6-3p. Apply +1 volt using Nanovolt Source (B). Observe the Model 640 OUTPUT using Diff. Voltmeter. Adjust Meter Cal potentiometer R455 for full scale deflection.	Input +1.000V OUTPUT should be +1.000V \pm 10mV.	- - PC-147	- - 20	- - R455
r.	Meter Cal. for Center Scale	Without readjusting the Zero controls set the Meter for Center Scale. Adjust the Center Zero potentiometer R421 for zero while in ZERO CHECK mode.	-	PC-147	20	R421
s.	Voltage Range Accuracy Check	Set front panel controls as in 6-3 p. Check all voltage ranges for full scale accuracy. Use the Nanovolt Source as input reference.	Accuracy to be $\pm 1\%$ of full scale on 30V-300 μ V ranges. $\pm 5\%$ on the 30 μ V range.	-	-	-
t.	Meter Noise	Set front panel controls as in 6-3 p. Place Dust Cap over the Input. Observe Meter Noise on the 30 μ V Range.	- Meter Noise to be less than 2 μ V p-p.	- -	- -	- -
u.	OUTPUT Noise	Observe OUTPUT Noise using Oscilloscope (H).	OUTPUT noise to be less than 100mV p-p, however occasional spikes may exceed 100mV.	-	-	-
v.	Current Range Accuracy ($10^6\Omega$ Shunt)	Set RANGE to 10V FUNCTION to CURRENT FAST METER to "+" POWER to "AC" SHUNT RESISTOR to 10^6 Check the OUTPUT accuracy with the Picoampere Source (C) used as Input current reference. <div style="display: flex; justify-content: space-around;"> <div> <u>RANGE</u> 10V 1V 100mV 10mV 1mV </div> <div> <u>CURRENT</u> 10^{-5}A 10^{-6}A 10^{-7}A 10^{-8}A 10^{-9}A </div> </div>	Accuracy should be $\pm 3\%$ of full scale.	-	-	-
w.	Current Range Accuracy ($10^8\Omega$ Shunt)	Verify OUTPUT accuracy as in 6-3 v. with SHUNT RESISTOR set to 10^8 and RANGE to 1V.	Accuracy should be $\pm 3\%$ of 10^{-8} A full scale.	-	-	-

TABLE 6-1. (cont'd)
Calibration Procedures.

Para. 6-3	Specification or Adjustment	Description	Measurement	Sub- Assembly	Figure	Test Point
x.	Current Range Accuracy ($10^{10}\Omega$ Shunt)	Verify OUTPUT accuracy with SHUNT RESISTOR set to 10^{10} and RANGE to 1V. Repeat above using 10mV RANGE. ($10^{-12}A$).	Accuracy should be $\pm 3\%$ of full scale. Accuracy should be $\pm 4\%$ of full scale.	-	-	-
y.	Current Range Accuracy ($10^{12}\Omega$ Shunt)	Verify OUTPUT accuracy with SHUNT RESISTOR set to 10^{12} and RANGE to 1V.	Accuracy should be $\pm 4\%$ of full scale.	-	-	-
z.	Current Rise Time	Set RANGE to 1V FUNCTION to CURRENT INTEGRATE METER to OFF POWER to AC SHUNT RESISTORS to 10^{12} Set Damping to MAX: Apply $+10^{-12}A$ input current using Picoampere source. Observe 10-90% rise time using oscilloscope.	10-90% Rise Time to be less than 44 sec.	-	-	-
aa.	Frequency Response	Set RANGE to 10mV FUNCTION to VOLTAGE METER to OFF POWER to AC SHUNT RESISTOR to 10^6 Apply 10 Hz sinewave to Input using Function Generator (G). Adjust signal for 1.6V p-p as observed at OUTPUT using Oscilloscope (H). Set Function Generator (G) for 1Hz. Increase the frequency of Function Generator until OUTPUT is reduced to 1.1V p-p. (3 dB down).	- - OUTPUT should remain at 1.6V p-p. Frequency at 3 dB down should be 35 Hz or higher.	- - -	- - -	- - -
bb.	Drift Check	NOTE: The Model 640 power must be off for at least 2 hours prior to this check. Connect Recorder (L) to the Model 640 OUTPUT. With Dust Cover in place allow a 60 minute warm-up. Set RANGE to 100 MICROVOLTS FUNCTION to VOLTAGE SHUNT to 10^6 NOTE: Maintain a constant ambient temperature if possible. Otherwise monitor temperature change to compensate for 35 $\mu V/^\circ C$ drift. After warm-up period the drift should not exceed 35 μV per 24 hours.	- - Drift less than 35 μV per 24 hours.	- - -	- - -	- - -

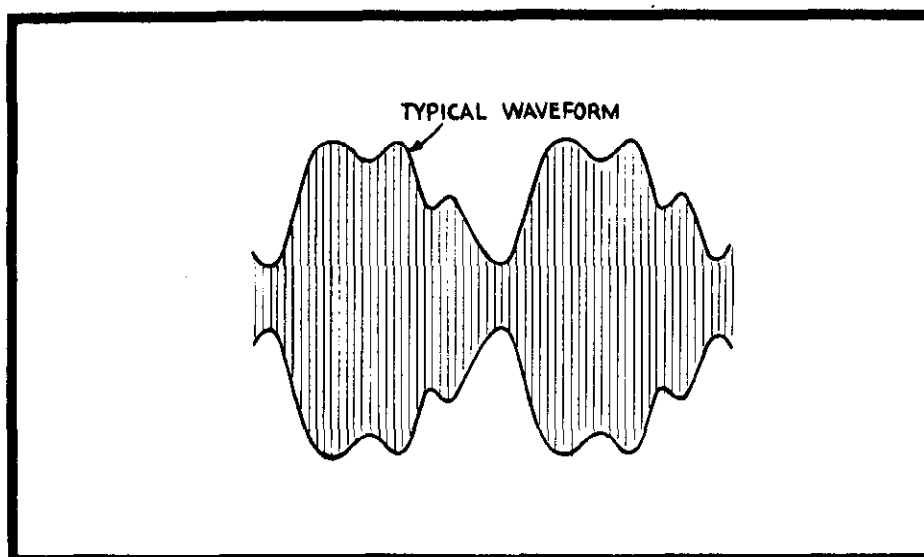


FIGURE 28. Typical Oscillator Waveform.

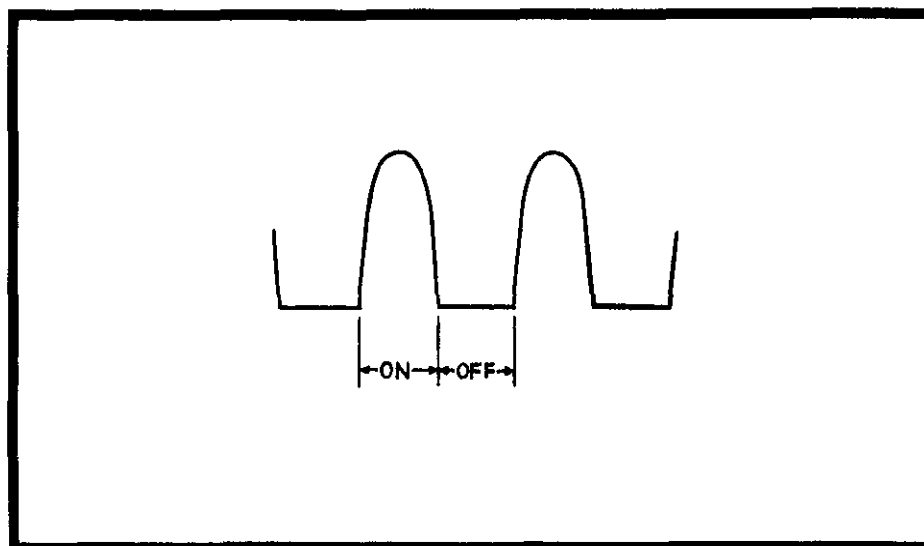


FIGURE 29. Proper Symmetry Adjustment.

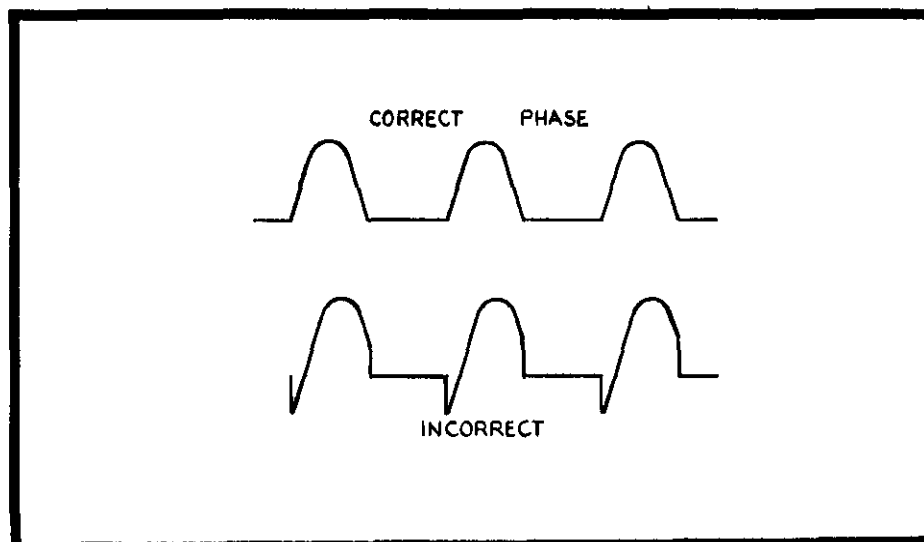


FIGURE 30. Proper Phase Adjustment.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST: This section contains a list of components used in this instrument for user reference. The Replaceable Parts List describes the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number),

Manufacturer's Part Number, and the Keithley Part Number. Also included is a Figure Reference Number where applicable. The complete name and address of each Manufacturer is listed in the CODE-TO-NAME Listing following the parts list.

TABLE 7-1.
Abbreviations and Symbols

A	ampere	F	farad	Ω	ohm
CbVar	Carbon Variable	Fig	Figure	p	pico (10^{-12})
CerD	Ceramic Disc	GCB	Glass enclosed Carbon	PC	Printed Circuit
Cer Trimmer	Ceramic Trimmer	k	kilo (10^3)	Poly	Polystyrene
Comp	Composition	μ	micro (10^{-6})	Ref.	Reference
DCb	Deposited Carbon	M	Meg (10^6)	TCu	Tinner Copperweld
Desig.	Designation	Mfr.	Manufacturer	V	volt
EAL	Electrolytic, Aluminum	MtF	Metal Film	W	watt
ETB	Electrolytic, tubular	My	Mylar	WW	Wirewound
ETT	Electrolytic, tantalum	No.	Number	WWVar	Wirewound Variable

7-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as discussed in Section 3. Table 7-2 identifies all schematic part numbers included.

Sales Service Department, Keithley Instruments, Inc. or your nearest Keithley representative.

b. When ordering parts, include the following information.

7-3. HOW TO USE THE REPLACEABLE PARTS LIST. This Parts List is arranged such that the individual types of components are listed in alphabetical order. Main Chassis parts are listed followed by printed circuit boards and other subassemblies.

1. Instrument Model Number.
2. Instrument Serial Number.
3. Part Description.
4. Schematic Circuit Designation.
5. Keithley Part Number.

7-4. HOW TO ORDER PARTS.

a. Replaceable parts may be ordered through the

c. All parts listed are maintained in Keithley Spare Parts Stock. Any part not listed can be made available upon request. Parts identified by the Keithley Manufacturing Code Number 80164 should be ordered directly from Keithley Instruments, Inc.

TABLE 7-2.

Description	Circuit Designation	Schematic Part No.
Remote Head	PC-151, PC-153, PC-247, PC-249	21381E
Power Supply	PC-147, PC-148, PC-149	21382E
Switching (Main Chassis)	PC-150	21383E

TABLE 7-3.
Circuit Designation Series.

Series	Description	Circuit Desig.	Page No.
100	Remote Head, Amplifier	PC-151, PC-153, PC-249	44
200	-	PC-153	-
300	Power Supply	PC-147, PC-148, PC-149	41
400	Main Chassis	PC-150	38
500	Remote Head, Oscillator	PC-247	47

TABLE 7-4.
Mechanical Parts List.

Description	Quantity Per Assembly	Keithley Part No.	Fig. No.
1) Chassis	1	20727C	32
11) Front Panel	1	20725B	31, 32
Top Cover Assembly	---	20906C	31
12) Cover, Sheet Metal	1	20905C	
13) Screws	4	---	
Handle Assembly	---	---	31
14) Handle	1	HH-18	
15) Screws #6-32x3/8" R.H. Slotted	2	---	
Bottom Cover Assembly	---	19298C	32
2) Cover	1	19340B	
3) Fastener	2	FA-54	
Feet Assembly	---	---	32
4) Feet	4	FE-5	
5) Ball	4	FE-6	
6) Screws #8-32x3/8" Phillips, Pan Head	4	---	
Tilt Bail Assembly	---	---	32
7) Bail	1	17147B	
8) Right Assembly	1	19206B	
9) Left Assembly	1	19205B	
10) Screws #6-32x1/4" Phillips, Pan Head	2	---	

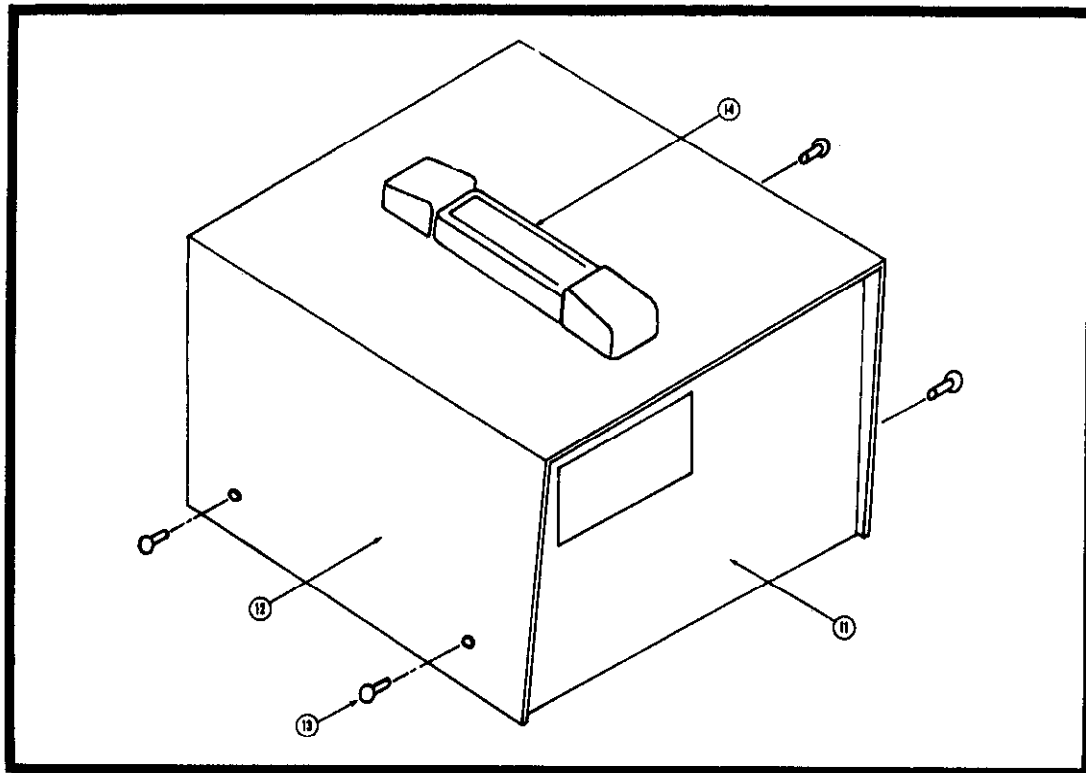


FIGURE 31. Top Cover Assembly.

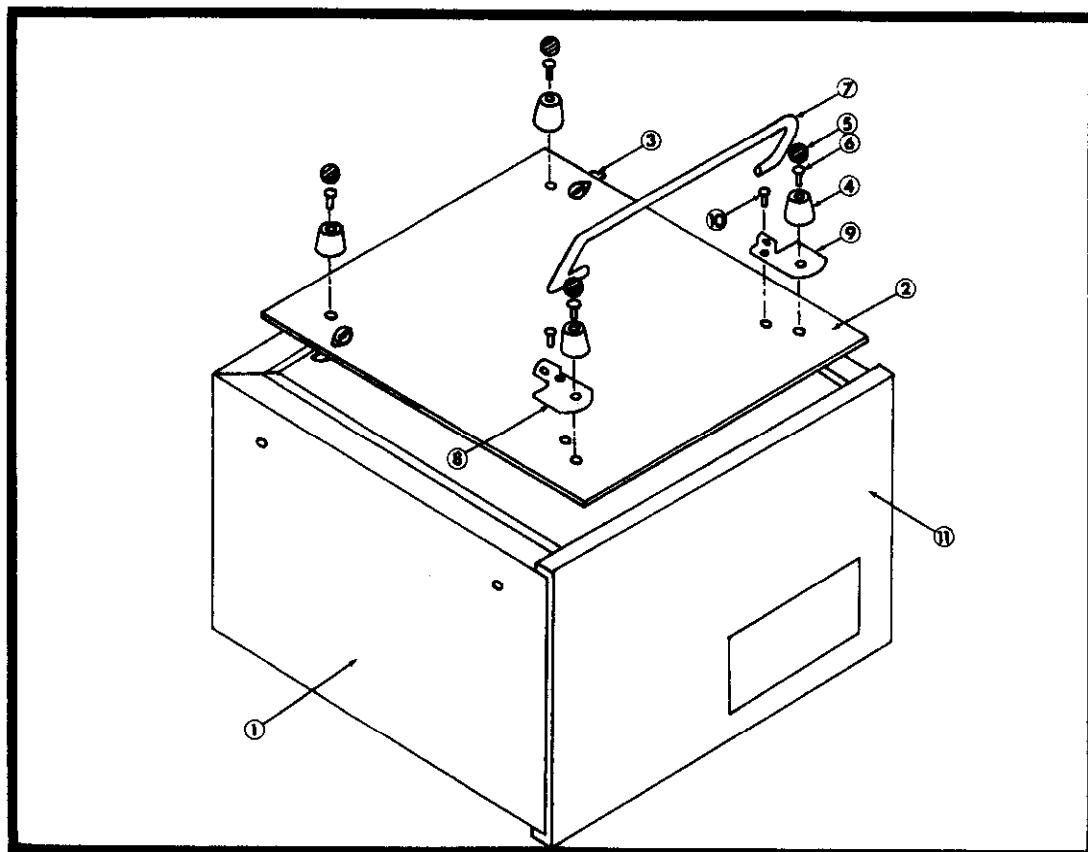


FIGURE 32. Bottom Cover Assembly.

MAIN CHASSIS PARTS LIST
(Refer to Schematic 21383E for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
C401	.82 μ F	20 V	ETT	05397	KOR27J20K	C80-.82M	25
C402	4.7 μ F	20 V	ETT	05397	K4R7J20K	C80-4.7M	25
C403	4.7 μ F	20 V	ETT	05397	K4R7J20K	C80-4.7M	25
C404	.1 μ F	200 V	My	02777	P12M-C	C47-.1M	-
C405	.05 μ F	600 V	My	56289	6PS-S50	C62-.05M	20

*Nominal

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
D401	Zener	12954	1N709	DZ-21	25
D402	Silicon	01295	1N645	RF-14	25
D403	Silicon	01295	1N645	RF-14	25
D404	Zener	12954	1N715	DZ-22	20
D405	Zener	04713	1N936	DZ-5	23
D406	Zener	04713	1N936	DZ-5	23
D407	Zener	12954	1N706	DZ-1	25

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
J401	Connector, 9 pin card-edge	03612	PSC4SS9	CS-175-9	20
J402	Binding Post	05474	DF21B	BP-11B	20
J403	Binding Post, FEEDBACK	58474	DF21BLU	BP-11BLU	20
J404	Receptacle, Microphone, OUTPUT	02660	80PC2F	CS-32	4
---	Plug, Microphone, mate of J404	02660	80PC2M	CS-33	-
J405	Connector, Receptacle	02660	5740240	CS-196	4
P402	Connector, mate of J405	02660	---	CS-195	-
J406	Binding Post, GND	58474	DF21G	BP-11G	20
---	Shorting Link	24655	938L	BP-6	4
S401	Push Button Switch, ZERO CHECK	80164	---	SW-223	2
---	Knob Assembly, Zero Check	80164	---	16373A	2
S402	Rotary Switch less components, FUNCTION	80164	---	SW-227	2
---	Dial Assembly, Function Switch	80164	---	14838A	2
S403	Rotary Switch less components, RANGE	80164	---	SW-228	2
---	Rotary Switch with components, Range	80164	---	21336B	2
---	Dial Assembly, Range Switch	80164	---	21200A	2
S404	Rotary Switch less components, METER	80164	---	SW-225	2
---	Dial Assembly, Meter Switch	80164	---	14838A	2
S405	Rotary Switch less components, COARSE	80164	---	SW-224	4
---	ZERO	---	---	---	---
---	Rotary Switch with components, Coarse	80164	---	21361B	4
---	Zero	---	---	---	---
---	Knob Assembly, Coarse Zero Switch	80164	---	16373A	4
---	FINE ZERO Control (R431)	80164	62JA-1K-2W	RP42-1K	2
---	Knob Assembly, Fine Zero	80164	---	16994A	2

MAIN CHASSIS (cont'd)
MISCELLANEOUS (cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
S406	Slide Switch, 1V-1MA	80164	---	SW-45	4
S407	Rotary Switch less components, MEDIUM ZERO	80164	---	SW-209	4
---	Rotary Switch with components, Medium Zero	80164	---	21335B	4
---	Dial Assembly, Medium Zero Switch	80164	---	16993A	4
---	1 MA CAL Control (R423)	71450	AW-20K-5W	RP34-20K	4
---	Knob Assembly, 1 Ma Cal Control	80164	---	16373A	4
M401	Meter	80164	---	ME-71	20

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R401	500 kΩ	10%, 1/2 W	DCb	00327	N11A	R12-500K	25
R402	68 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-68K	25
R403	68 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-68K	25
R404	2 kΩ	1/4 W	Cb	09569	MTC23L1	RP59-2K	25
R405	50 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-50K	25
R406	10 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-10K	25
R407	12 kΩ	10%, 1/2 W	Comp	01121	EB	R1-12K	25
R408	560 kΩ	10%, 1/2 W	Comp	01121	EB	R1-560	25
R409	12 kΩ	10%, 1/2 W	Comp	01121	EB	R1-12K	25
R410	27 kΩ	10%, 1/2 W	Comp	01121	EB	R1-27K	25
R411	100 kΩ	10%, 1/2 W	Comp	01121	EB	R1-100K	25
R412	1 MΩ	10%, 1/2 W	Comp	01121	EB	R1-1M	25
R413	39 kΩ	10%, 1/2 W	Comp	01121	EB	R1-39K	25
R414	150 Ω	10%, 1/2 W	Comp	01121	EB	R1-150	25
R415	120 kΩ	10%, 1/2 W	Comp	01121	EB	R1-120K	25
R416	35 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-35K	25
R417	820 Ω	10%, 1/2 W	Comp	01121	EB	R1-820	25
R418	3 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-3K	25
R419	20 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-20K	20
R420	15 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-15K	20
R421	10 kΩ	20%, 2 W	WW	71450	1NS 115	RP50-10K	20
R422	910 Ω	0.5%, 1/2W	MtF	07716	CEC	R61-910	-
R423	20 kΩ	10%, 5 W	WWVar	71450	AW	RP34-20K	20
R424	8.6 kΩ	1%, 1/2 W	DCb	00327	N11A	R12-8.6K	20
R425	1.5 kΩ	1%, 1/2 W	WW	01686	E-30	R58-1.5K	23
R426	1.5 kΩ	1%, 1/2 W	WW	01686	E-30	R58-1.5K	23
R427	11 kΩ	1%, 1/2 W	WW	01686	E-30	R58-11K	23
R428	11 kΩ	1%, 1/2 W	WW	01686	E-30	R58-11K	23
R429	80 kΩ	1%, 1/2 W	WW	01686	E-30	R58-80	20
R430	80 kΩ	1%, 1/2 W	WW	01686	E-30	R58-80	20
R431	1 kΩ	5%, 2 W	WWVar	12697	62JA	RP42-1K	20
R432	1.11 kΩ	1/4%, 1/3W	WWenc	01686	7010	R105-1.11K	20
R433	1.11 kΩ	1/4%, 1/3W	WWenc	01686	7010	R105-1.11K	20
R434	1.11 kΩ	1/4%, 1/3W	WWenc	01686	7010	R105-1.11K	20
R435	1.11 kΩ	1/4%, 1/3W	WWenc	01686	7010	R105-1.11K	20

MAIN CHASSIS (cont'd)
RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R436	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R437	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R438	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R439	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R441	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R442	1.11 k Ω	1/4%, 1/3 W	WWenc	01686	7010	R105-1.11K	20
R443	320 Ω	0.1%, 1/2 W	WW	15905	1142	R67-320	-
R444	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R445	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R446	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R447	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R448	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R449	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R450	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R451	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R452	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R453	320 Ω	0.1%, 1/2 W	WW	15909	1142	R67-320	-
R454	9.7 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-9.7K	-
R455	2 k Ω	20%, 2 W	WW	71450	1NS 115	RP50-2K	20
R456	500 Ω	1%, 1/2 W	DCb	00327	N11A	R12-500	-
R457	27.3 k Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-27.3K	-
R458	9.1 k Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-9.1K	-

TRANSISTORS

Circuit Desig.		Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
Q401	N-Channel FET, Case TO-92	01295	SF5043	TG-40	* 25
Q402	N-Channel FET, Case TO-92	01295	SF5043	TG-40	
Q403	PNP, Case R-110	07263	S17638	TG-33	
Q404	PNP, Case R-110	07263	S17638	TG-33	
Q405	N-Channel FET, Case TO-92	04713	MPF 103	TG-41	25
Q406	NPN	73445	A1380	TG-32	25
Q407	NPN	80164	---	21676A	25
Q408	PNP	02735	2N398A	TG-13	25
Q409	NPN	80164	---	21676A	25

*Matched pair, order TG-40 for pair.

POWER SUPPLY PARTS
(Refer to Schematic No. 21382E for circuit designations).

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
C301	.01 μ F	200 V	My	13050	SM1A	C47-.01M	22
C302	50 μ F	50 V	ETT	37942	TC39	C39-50M	22
C303	50 μ F	50 V	ETT	37942	TC39	C39-50M	22
C304	Not Used						
C305	100 μ F	25 V	EAL	56289	89D226	C94-100M	23
C306	50 μ F	50 V	ETT	37942	TC39	C39-50M	23
C307	100 μ F	25 V	EAL	56289	89D226	C94-100M	23
C308	Not Used						
C309	330 pF	1000V	CerD	71590	DD331-10%	C22-330P	23
C310	2.2 μ F	50 V	ETB	05397	J2R2J50S	C149-2.2M	23
C311	.02 μ F	1000V	CerD	56289	10SS-S20	C22-.02M	23
C312	.0022 μ F	1000V	CerD	72982	811000X5F0222	C22-.0022M	23
C313	.01 μ F	600 V	CerD	56289	10SS-S10	C22-.01M	23
C314	100 μ F	25 V	EAL	56289	89D226	C94-100M	23
C315	100 μ F	25 V	EAL	56289	89D226	C94-100M	23
C316	Not Used						
C317	Not Used						
C318	.02 μ F	1000V	CerD	56289	10SS-S20	C22-.02M	23
C319	.01 μ F	1000V	CerD	56289	10SS-S10	C22-.01M	23
C320	100 μ F	25 V	EAL	56289	89D226	C94-100M	23
C321	500 μ F	25 V	EAL	24309	JC8100258P	C211-500M	22
C322	.0033 μ F	1000V	CerD	56289	10SS-D33	C22-.0033M	22
C323	500 μ F	25 V	EAL	56289	JC8100258P	C211-500M	22
C324	*100 μ F	40 V	EAL	73445	C437AR/G100	C150-100M	-

*Nominal

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
D301	Silicon	01295	1N645	RF-14	22
D302	Silicon	01295	1N645	RF-14	22
D303	Silicon	01295	1N645	RF-14	22
D304	Silicon	01295	1N645	RF-14	22
D305	Not Used				
D306	Not Used				
D307	Silicon	01295	1N645	RF-14	22
D308	Silicon	01295	1N645	RF-14	23
D309	Silicon	01295	1N645	RF-14	23
D310	Silicon	01294	1N645	RF-14	23
D311	Silicon	01295	1N645	RF-14	23
D312	Silicon	01295	1N645	RF-14	23
D313	Silicon	01295	1N645	RF-14	23
D314	Zener	04713	1N935	DZ-7	23
D315	Silicon	01295	1N645	RF-14	22
D316	Silicon	01295	1N645	RF-14	22
D317	Silicon	02735	1N3256	RF-22	22
D318	Silicon	02735	1N3256	RF-22	22
D319	Zener	12954	1N709	DZ-21	22
D320	Silicon	01295	1N645	RF-14	22
D321	Silicon	01295	1N645	RF-14	22
D322	Zener	12954	1N709	DZ-21	22
D323	Silicon	01295	1N645	RF-14	20

POWER SUPPLY (cont'd)
MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
BT301	Battery Assembly	80164	---	23731A	20
F301 (117V)	Fuse, .25A, 3 AG	75915	313.250	FU-17	-
F301 (234V)	Fuse, .125A, Slow blow	71400	MDL	FU-20	-
F302	Fuse, Battery, 1A, 3 AG	75915	312001	FU-7	-
---	Fuse Holder	75915	34201	FH-3	-
---	Fuse Holder	75915	346001	FH-9	-
P301	Cord Set	80164	---	CO-5	4
S301	Rotary Switch less components, POWER	80164	---	SW-226	2
---	Rotary Switch with components, POWER	80164	---	21337B	-
---	Dial Assembly, POWER Switch	80164	---	18393A	-
S302	Slide Switch, 117-234 V	80164	---	SW-151	4
J301	Connector, PC board 148	03612	PSC4SS2212	CS-182-9	20
J302	Connecto PC board 149	03612	PSC4SS2212	CS-182-2	20
T301	Transformer	80164	---	TR-102	-
T302	Transformer	80164	---	TR-101	20
T303	Transformer	80164	---	TR-110	20

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R301	47 Ω	10%, 1/2 W	Comp	01121	EB	R1-47	22
R302	470 Ω	10%, 1/2 W	Comp	01121	EB	R1-470	22
R303	10 k Ω	10%, 1/2 W	Comp	01121	EB	R1-10K	23
R304	10 Ω	1%, 1/2 W	DCb	00327	N11A	R12-10	23
R305	4.7 Ω	10%, 1/2 W	Comp	01121	EB	R1-4.7	23
R306	4.7 k Ω	10%, 1/2 W	Comp	01121	EB	R1-4.7K	23
R307	Not Used						
R308	47 k Ω	10%, 1/2 W	Comp	01121	EB	R1-47K	23
R309	Not Used						
R310	100 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-100K	23
R311	27 k Ω	10%, 1/2 W	Comp	01121	EB	R1-27K	23
R312	47 k Ω	10%, 1/2 W	Comp	01121	EB	R1-47K	23
R313	47 k Ω	10%, 1/2 W	Comp	01121	EB	R1-47K	23
R314	100 k Ω	10%, 1/2 W	Comp	01121	EB	R1-100K	23
R315	82 k Ω	10%, 1/2 W	Comp	01121	EB	R1-82K	23
R316	100 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-100K	23
R317	100 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-100K	23
R318	10 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-10	23
R319	Not Used						
R320	4.7 k Ω	10%, 1/2 W	Comp	01121	EB	R1-4.7K	23
R321	Not Used						
R322	100 Ω	10%, 1/2 W	Comp	01121	EB	R1-100	23
R323	2.7 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-2.7K	23
R324	100 k Ω	10%, 1/2 W	Comp	01121	EB	R1-100K	23
R325	47 k Ω	10%, 1/2 W	Comp	01121	EB	R1-47K	23
R326	22 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-22K	23
R327	10 k Ω	20%, 2 W	WWVar	71450	1NS 115	RP50-10K	23
R328	91 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-91K	23
R329	56 Ω	10 W		91637	HLM-10	R138-56	23
R330	2.7 k Ω	10%, 1/2 W	Comp	01121	EB	R1-2.7K	23

POWER SUPPLY (cont'd)
RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R331	600 Ω	1%, 1/2 W	DCb	00327	N11A	R12-600	22
R332	1.8 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-1.8K	22
R333	1 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-1K	22
R334	2.7 k Ω	10%, 1/2 W	Comp	01121	EB	R1-2.7K	22
R335	1.8 k Ω	10%, 1/2 W	Comp	01121	EB	R1-1.8K	22
R336	2.73 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-2.73K	22
R337	390 Ω	10%, 1/2 W	Comp	01121	EB	R1-390	22
R338	1 k Ω	20, 2 W	WWVar	71450	INS 115	RP50-1K	22
R339	1.4 k Ω	1%, 1/2 W	DCb	00327	N11A	R1-1.4K	22
R340	2.2 k Ω	10%, 1/2 W	Comp	01121	EB	R1-2.2K	22
R341	3.3 k Ω	10%, 1/2 W	Comp	01121	EB	R1-3.3K	22
R342	20 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-30K	22
R343	20 k Ω	1%, 1/2 W	DCb	00327	N11A	R12-20K	22
R344	33 Ω	10%, 1 W	Comp	01121	GB	R2-33	20
R345	4.7 Ω	10%, 1/2 W	Comp	01121	EB	R1-4.7	23

TRANSISTORS

Circuit Desig.		Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
Q301	PNP	02735	2N1183A	TG-31	22
Q302	PNP	02735	2N1183A	TG-31	22
Q303	NPN, Case TO-5	02734	40317	TG-43	23
Q304	NPN, Case TO-106	07263	2N3565	TG-39	23
Q305	NPN, Case TO-106	07263	2N3565	TG-39	23
Q306	NPN, Case TO-106	07263	2N3565	TG-39	23
Q307	NPN, Case TO-106	07263	2N3565	TG-39	23
Q308	NPN, Case TO-106	07263	2N3565	TG-39	23
Q309	NPN, Case TO-106	07263	2N3565	TG-39	23
Q310	NPN, Case TO-106	07263	2N3565	TG-39	23
Q311	NPN, Case TO-5	02734	40317	TG-43	23
Q312	NPN, Case TO-106	07263	2N3565	TG-39	23
Q313	NPN, Case TO-106	07263	2N3565	TG-39	23
Q314	NPN, Case TO-106	07263	2N3565	TG-39	23
Q315	NPN, Case TO-106	07263	2N3565	TG-39	23
Q316	PNP	01295	2N1381	TG-8	22
Q317	PNP	04713	2N1535	TG-7	20
Q318	PNP	01295	2N1381	TG-8	22
Q319	PNP	01295	2N1381	TG-8	22
Q320	PNP, Case R-110	07263	S17638	TG-33	22
Q321	PNP, Case R-110	07263	S17638	TG-33	22
Q322	PNP, Case R-110	07263	S17638	TG-33	22

REMOTE HEAD PARTS
(Refer to Schematic 21381E for circuit designations).

Amplifier, PC-151, PC-153, PC-249

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
*C101	150 pF	500 V	Poly	71590	CPR-150J	C138-150P	-
*C102	6.5 pF	---	---	80164	---	C31-5P & C77-1.5P	-
*C103	---	---	---	80164	---	13410A	-
C104	10 pF	20 V	ETT	05397	K10J20K	C80-10M	26
C105	20 pF	---	---	80164	21557B	21557B	-
C106	Not Used						
C107	2.2 μ F	20 V	ETT	05397	K2R2J20K	C80-2.2M	24
C108	5 pF	1000V	CerD	71590	DD-050-10%	C22-5P	24
C109	2.2 μ F	20 V	ETT	05397	K2R2J20K	C80-2.2M	24
C110	Not Used						
C111	.1 μ F	50 V	My	84411	601PE	C41-.1M	24
C112	10 μ F	20 V	ETT	05397	K10J20K	C80-10M	24
C113	2.2 μ F	20 V	ETT	05397	K2R2J20K	C80-2.2M	24
C114	5 pF	1000V	CerD	71590	DD-050-10%	C22-5P	24
C115	Not Used						
C116	2.2 μ F	20 V	ETT	05397	K2R2J20K	C80-2.2M	24
C117	.1 μ F	50 V	My	84411	601PE	C41-.1M	24
C118	10 μ F	20 V	ETT	05397	K10J20K	C80-10M	24
C119	.02 μ F	1000V	CerD	56289	10SS-S20	C22-.02M	24
C120	.02 μ F	1000V	CerD	56289	10SS-S20	C22-.02M	24
C121	Vibrating Capacitor		---	80164	---	VC-2	-
C122	.001 μ F	1000V	CerD	72982	801000X5F0102K	C22-.001M	-
C123	.001 μ F	1000V	CerD	72982	801000X5F0102K	C22-.001M	-
C124	15-60pF	500 V	CerD	72982	538-011-P3PO-112R	C158-15/60P	-
C125	100 pF	600 V	CerD	72982	ED-100	C22-100P	-
C126	10 μ F	600 V	CerD	71590	TCZ	C77-10M	-
C127	100 pF	1000V	CerD	71590	DD-101-10%	C22-100P	-
C128	0.1 μ F	50 V	My	84411	601 PE	C41-.1M	-
C129	.001 μ F	1000V	CerD	72982	801000X5F0102K	C22-.001M	-
C130	Not Used						
C131	1.5 pF	600 V	CerT	80164	C123-1.5P	C123-1.5P	-

* Nominal Value.

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
D101	Silicon	01295	1N645	RF-14	26
D102	Silicon	01295	1N645	RF-14	26
D201	Silicon	73445	1N3182	RF-31	-
D202	Silicon	01295	1N914	RF-28	-
D203	Silicon	01295	1N914	RF-28	-

REMOTE HEAD (cont'd)
MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
J101	Connector, Receptacle (Mfg. No.57-40240)	02660	5740240	CS-196	-
P401	Connector, Plug, mate of J101 (Mfg. No. 57-30240)	02660	5730240	CS-195	-
J102	Connector, Plug, PC-153	80164	---	CS-197	-
P102	Connector, Pin, mate of J102	80164	---	CS-198	-
J103	Test Jack, FEEDBACK	80164	---	TJ-1	3
J104	Test Jack Connector Pin	80164	---	CS-198	-
J105	Input Connector Contact Assembly	80164	---	20613A	3
---	Input Cup, Adapter Assembly consisting of an adapter cap, (20569A) a contact cap (20568A) and a UHF connector (CS-64)	80164	---	21146B	-
---	Dust cover	80164	---	20911A	-
J106	Connector, Plug	80164	---	CS-197	-
P106	Connector Pin, mate of J106	80164	---	CS-198	-
J107	Connector, Plug	80164	---	CS-197	-
P107	Connector Pin, mate of J107	80164	---	CS-198	-
J108	Connector, S101	80164	---	CS-197	-
P108	Connector Pin, mate of J108	80164	---	CS-198	-
J109	Connector, S101	80164	---	CS-197	-
P109	Connector Pin, mate of J109	80164	---	CS-198	-
S101	Push Button Switch, ZERO CHECK (input head)	80164		SW-223	3
---	Knob Assembly, Zero Check	80164	---	16373A	3
S102	Rotary Switch less components, SHUNT RESISTOR	80164	---	SW-237	3
---	Rotary Switch with components, Shunt Resistor	80164	---	21143B	3
QA101	Integrated Circuit	12040	LM201	IC-2	-
K101	Solenoid Assembly	80164	---	21553B	-
K102	Reed Relay	27682	GP1A650MW	RL-31	-
L101	Choke	80164	---	CH-13	-

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R101	1 MΩ	1%, 1/2 W	McF	07716	CEC	R113-1M	-
R102	10 ⁸ Ω	1%	Comp	03888	HR 1000	R144-10 ⁸	-
R103	10 ¹⁰ Ω	---	GCB	63060	RX-1	R20-10 ¹⁰	-
R104	10 ¹² Ω	---	GCB	63060	RX-1	R20-10 ¹²	-
R105	10 MΩ	10%, 1/4 W	Comp	44655	RC07	R76-10M	-
R106	1 MΩ	10%, 1/4 W	Comp	44655	RC07	R76-1M	24
R107	10 ⁸ Ω	20%, 1/2 W	Comp	75042	GBT	R37-10 ⁸	24
R108	7.5 MΩ	40%, 0.3 W	Cb	71450	SERIES 70	RP71-7.5M	24
R109	10 ⁸ Ω	20%, 1/2 W	Comp	75042	GBT	R37-10 ⁸	24
R110	68.1kΩ	1%, 1/8 W	McF	07716	CEA	R88-68.1K	24
R111	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	24
R112	47 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-47K	24
R113	12 kΩ	10%, 1/4 W	Comp	01121	CB	R76-12K	24
R114	5.6 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-5.6K	24
R115	68 kΩ	10%, 1/4 W	Comp	01121	CB	R76-68K	24

REMOTE HEAD (cont'd)
RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R116	12 kΩ	10%, 1/4 W	Comp	01121	CB	R76-12K	24
R117	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	24
R118	8.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-8.2K	24
R119	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	24
R120	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100	24
R121	12 kΩ	10%, 1/4 W	Comp	01121	CB	R76-12K	24
R122	68 kΩ	10%, 1/4 W	Comp	01121	CB	R76-68K	24
R123	68 kΩ	10%, 1/4 W	Comp	01121	CB	R76-68K	24
R124	68 kΩ	10%, 1/4 W	Comp	01121	CB	R76-68K	24
R125	68 kΩ	10%, 1/4 W	Comp	01121	CB	R76-68K	24
R126	10 MΩ	10%, 1/4 W	Comp	44655	RC07	R76-10M	24
R127	12 kΩ	10%, 1/4 W	Comp	01121	CB	R76-12K	24
R128	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	24
R129	68 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-68K	24
R130	47 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-47K	24
R131	270 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-270K	24
R132	150 kΩ	10%, 1/4 W	Comp	01121	CB	R76-150K	24
R133	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	24
R134	8.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-8.2K	24
R135	100 Ω	10%, 1/4 W	Comp	44655	RC07	R76-100	24
R136	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	24
R137	18 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-18K	24
R138	18 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-18K	24
R139	390 Ω	10%, 1/4 W	Comp	44655	RC07	R76-390	24
R140	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	24
R141	10 kΩ	10%, 1/4 W	Comp	01121	CB	R76-10K	24
R142	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	24
R143	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	24
R144	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	24
R145	22 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-22K	24
R146	180 kΩ	10%, 1/4 W	Comp	01121	CB	R76-180K	24
R147	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	24
R148	150 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-150K	24
R149	390 Ω	10%, 1/4 W	Comp	44655	RC07	R76-390	24
R150	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	24

TRANSISTORS

Circuit Desig.		Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
Q101	N-Channel FET	04713	2N4220	TG-42	21
Q102	NPN, Case TO-92	04713	2N5089	TG-62	21
Q103	NPN, Case TO-92	04713	2N5089	TG-62	21
Q104	NPN, Case TO-92	04713	2N5089	TG-62	21
Q105	NPN, Case TO-92	04713	2N5089	TG-62	21
Q106	PNP, Case TO-92	04713	2N5087	TG-61	21
Q107	N-Channel FET, Case TO-92	04713	MPF103	TG-41	21
Q108	NPN, Case TO-92	04713	2N5089	TG-62	21
Q109	NPN, Case TO-92	04713	2N5089	TG-62	21
Q110	PNP, Case TO-92	04713	2N5087	TG-61	21
Q111	PNP, Case R-110	07263	S17638	TG-33	21
Q112	PNP, Case R-110	07263	S17638	TG-33	21

REMOTE HEAD (cont'd)
 Oscillator, PC-247

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
C501	10 μ F	35 V	ETT	05397	K10E35	C170-10M	27
C502	7-25 pF	350 V	Trimmer	72982	538-011-93R	C89-7-25P	27
*C503	100 pF	200 V	Poly	84171	2PJ-101G	C108-100P	27
C504	10 pF	500 V	Poly	71590	CPR-10J	C138-10P	27
C505	5 pF	200 V	Poly	00686	E1013-1	C31-5P	27
C506	47 pF	500 V	Poly	71590	CPR-47J	C138-47P	27
C507	47 pF	1000V	CerD	71590	DD-470-10%	C22-47P	27
C508	1 μ F	35 V	ETT	05397	K1E35	C170-1M	27
*C509	100 μ F	200 V	Poly	84171	2PJ-101G	C108-100P	27
C510	.001 μ F	1000V	CerD	72982	801000X5F0102K	C22-.001M	27
C511	10 μ F	35 V	ETT	05397	K10E35	C170-10M	27
C512	.01 μ F	1000V	CerD	56289	10SS-S10	C22-.01M	27
C513	10 μ F	35 V	ETT	05397	K10E35	C170-10M	27
C514	.0047 μ F	1000V	CerD	56289	10SS-D47	C22-.0047M	27
C515	.01 μ F	1000V	CerD	56289	10SS-S10	C22-.01M	27
C516	10 pF	1000V	CerD	71590	DD-100-10%	C22-10P	27
C517	.01 μ F	200 V	My	13050	SM1A	C47-.01M	27
C518	100 pF	1000V	CerD	71590	DD-101-10%	C22-100P	27
C519	.047 μ F	200 V	My	13050	SM1A	C47-.047M	27
C520	10 μ F	35 V	ETT	05397	K10E35	C170-10M	27

DIODES

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
D501	Silicon	01295	1N914	RF-28	27
D502	Silicon	01295	1N914	RF-28	27
D503	Silicon	01295	1N914	RF-28	27
D504	Silicon	01295	1N914	RF-28	27

INTEGRATED CIRCUITS

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
QA501	Integrated Circuit	07263	U5B770939X	IC-1	27
QA502	Integrated Circuit	07263	U5B770939X	IC-1	27
QA503	Integrated Circuit	07263	U5B770939X	IC-1	27

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R501	10 Ω	10%, 1/4 W	Comp	44655	RC07	R76-10	27
R502	1 M Ω	1%, 1/2 W	MtF	07716	CEC	R94-1M	27
R503	32.4 K Ω	1%, 1/8 W	MtF	07716	CEA	R88-475	27
R504	32.4 K Ω	1%, 1/8 W	MtF	07716	CEA	R88-32.4K	27
R505	9.31 K Ω	1%, 1/8 W	MtF	07716	CEA	R88-9.31K	27

*Nominal Value, Selected during calibration.

REMOTE HEAD (cont'd)
 OSCILLATOR
 RESISTORS (cont'd)

Circuit Desig.	Value	Rating	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
R506	1 k Ω	20%, .75 W	Germet	73138	77 PR	RP64-1K	27
*R507	301 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-301K	27
R508	10 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-10K	27
R509	10 Ω	10%, 1/4 W	Comp	44655	RC07	R76-10	27
R510	1 M Ω	10%, 1/4 W	Comp	44655	RC07	R76-1M	27
R511	5.62 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-5.62K	27
R512	1.5 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-1.5K	27
R513	442 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-442K	27
R514	22.1 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-22.1K	27
R515	2.21 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-2.21K	27
R516	22 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-22K	27
R517	10 k Ω	20%, 2 W	---	10582	115-117	RP58-10K	27
R518	402 Ω	1%, 1/8 W	MtF	07716	CEA	R88-402	27
R519	442 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-442K	27
R520	14.7 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-14.7K	27
R521	10 k Ω	20%, 2 W	---	10582	115-117	RP58-10K	27
R522	10 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-10K	27
R523	100 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-100K	27
R524	10 k Ω	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R525	10 k Ω	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R526	49.9 Ω	1%, 1/8 W	MtF	07716	CEA	R88-49.9	27
R527	1 k Ω	1%, 1/8 W	MtF	07716	CEA	R88-1K	27
R528	10 k Ω	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R529	10 Ω	10%, 1/4 W	Comp	44655	RC07	R76-10	27
R530	10 k Ω	10%, 1/4 W	Comp	44655	RC07	R76-10K	27

TRANSFORMERS

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
T501	---	80164	TR-132	TR-132	27
T502	---	80164	TR-132	TR-132	27

TRANSISTORS

Circuit Desig.	Type	Mfr. Code	Mfr. Part No.	Keithley Part No.	Fig. Ref.
Q501	Silicon, NPN, Case TO-92	04713	2N5089	TG-62	27
Q502	Silicon, NPN, Case TO-92	04713	2N5089	TG-62	27
Q503	N-Channel FET, Case TO-92	04713	MPF103	TG-41	27
Q504	PNP, Case R-110	07263	1S17638	TG-33	27
Q505	PNP, Case R-110	07263	1S17638	TG-33	27
Q506	PNP	01295	2N1381	TG-8	27
Q507	PNP	01295	2N1381	TG-8	27

*Nominal Value, Selected during calibration.

CODE-TO-NAME LIST

CODE TO NAME List of Suggested Manufacturers.

Reference: Federal Supply Code for Manufacturers, Cataloging Handbook H4-2.

00656	Aerovox Corp. 740 Belleville Ave. New Bedford, Mass. 02741	07137	Transistor Electronics Corp. Hwy. 169 - Co. Rd. 18 Minneapolis, Minn. 55424	14659	Sprague Electric Co. P.O. Box 1509 Visalia, Calif. 93278
00686	Film Capacitors, Inc. 100 Eighth St. Passaic, N.J.	07263	Fairchild Camera & Inst. Corp. 313 Frontage Road Mountain View, Calif.	15238	ITT Semiconductors Div. of ITT Corp. Lawrence, Mass. 01841
01121	Allen-Bradley Corp. 1201 South 2nd St. Milwaukee, Wisc. 53204	07716	IRC, Inc. 2850 Mt. Pleasant Burlington, Iowa 52601	15909	Daven Div. of T.A. Edison Ind. McGraw Edison Co. Livingston, N.J.
01295	Texas Instruments, Inc. Semiconductor-Components Div. Dallas, Texas 75231	08811	GL Electronics Div. of GL Industries, Inc. Westville, N.J. 08093	16170	Teledyne Systems Co. Communications Div. Los Angeles, Calif. 90066
01686	RCL Electronics, Inc. 195 McGregor St. Manchester, N.H. 03102	09052	Gulton Industries, Inc. Alkaline Battery Div. Metuchen, N.J.	17554	Components, Inc. Smith St. Bridford, Ma. 04005
02101	Varo Inc. Electrokinetics Div. Santa Barbara, Calif. 93102	09823	Burgess Battery Co. Div. of Servel Inc. Freeport, Ill.	23020	General Reed Co. 174 Main St. Metuchen, N.J. 08840
02660	Amphenol Corp. 2801 South 25th Ave. Broadview, Ill. 60153	09922	Burndy Corp. Richards Ave. Norwalk, Conn. 06852	24655	General Radio Co. 22 Baker Ave. West Concord, Mass. 01781
02734	Radio Corp. of America Defense Electronic Products Camden, N.J.	10582	CTS of Asheville Inc. Mills Gap Road Skyland, N.C.	27682	Hathaway Instruments, Inc. 5800 E. Jewell Ave. Denver, Colorado 80222
02735	Radio Corp. of America Receiving Tube Div. Somerville, N.J.	11502	IRC Inc. Greenway Road Boone, N.C. 28607	28520	Heyman Mfg. Co. 147 N. Michigan Ave. Kenilworth, N.J.
02777	Hopkins Engineering Co. 12900 Foothill Blvd. San Fernando, Calif. 91342	11837	Electro Scientific Indus., Inc. 13645 NW Science Park Dr. Portland, Or. 97229	29309	Richey Electronics Inc. 1307 Dickerson Rd. Nashville, Tenn. 37213
02985	Tepro Electric Corp. 5 St. Paul St. Rochester, N.Y. 14604	12040	National Semiconductor Corp. Commerce Drive Danbury, Conn. 06813	35529	Leeds and Northrup 4901 Stanton Ave. Philadelphia, Pa. 19144
03508	General Electric Co. Semiconductor Products Dept. Syracuse, N.Y. 13201	12065	Transitron Electronic Corp. 144 Addison St. East Boston, Mass.	37942	Mallory, P. R. and Co., Inc. 3029 E. Washington St. Indianapolis, Ind. 46206
04009	Arrow-Hart & Hegeman Electric Co. 103 Hawthorne St. Hartford, Conn. 06106	12697	Clarostat Mfg. Co., Inc. Lower Washington St. Dover, N.H. 03820	44655	Ohmite Mfg. Co. 3601 Howard St. Skokie, Ill. 60076
04713	Motorola Semiconductor Prod. Inc. 5005 E. McDowell Rd. Phoenix, Ariz. 85008	12954	Dickson Electronics Corp. 302 S. Wells Fargo Ave. Scottsdale, Ariz.	53201	Sangamo Electric Co. 1301 North 11th Springfield, Ill. 62705
05079	Transistor Electronics, Inc. 1000 West Road Bennington, Vt. 05201	13050	Potter Co. Highway 51 N. Wesson, Miss. 39191	54294	Shallcross Mfg. Co. 24 Preston St. Selma, N.C.
05397	Union Carbide Corp. Electronics Div. New York, N.Y. 10017	13327	Solitron Devices, Inc. 256 Oak Tree Road Tappan, N.Y. 10983	56289	Sprague Electric Co. North Adams, Massachusetts
06751	Components, Inc. Arizona Div. Phoenix, Ariz. 85019	13934	Midwac Corp. 602 Main Oshkosh, Nebr. 69154	58474	Superior Electric Co., The 383 Middle St. Bristol, Conn. 06012
06980	Varian Assoc. EIMAC Div. 301 Industrial Way San Carlos, Calif. 94070	14655	Cornell-Dubilier Electric Corp. 50 Paris Street Newark, N.J.	61637	Union Carbide Corp. 270 Park Ave. New York, N.Y. 10017

CODE TO NAME List (Continued).

63060	Victoreen Instrument Co. 5806 Hough Ave. Cleveland, Ohio 44103	75042	IRC Inc. 401 North Broad St. Philadelphia, Pa. 19108	86684	Radio Corp. of America Electronic Components & Devices Harrison, N.J.
70309	Allied Control Co., Inc. 2 East End Ave. New York, N.Y.	75915	Littlefuse, Inc. 800 E. Northwest Hwy. Des Plaines, Ill. 60016	87216	Philco Corp. Lansdale Div., Church Rd. Lansdale, Pa. 19446
70903	Belden Mfg. Co. 415 So. Kilpatrick Chicago, Ill. 60644	76055	Mallory Controls, Div. of Mallory P. R. & Co., Inc. Frankfort, Ind.	90201	Mallory Capacitor 3029 East Washington Indianapolis, Ind. 46206
71002	Birnbach Radio Co., Inc. 147 Hudson St. New York, N.Y.	76493	Miller, J. W. Co. 5915 S. Main St. Los Angeles, Calif. 90003	90303	Mallory Battery Co. Tarrytown, New York
71279	Cambridge Thermionic Corp. 430 Concord Avenue Cambridge, Mass.	76545	Mueller Electric Co. 1583 E. 31st St. Cleveland, Ohio 44114	91637	Dale Electronics, Inc. P.O. Box 609 Columbus, Nebr. 68601
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.	77764	Resistance Products Co. 914 S. 13th St. Harrisburgh, Pa. 17104	91662	Elco Corp. Willow Grove, Pennsylvania
71450	CTS Corp. 1142 W. Beardsley Ave. Elkhart, Ind.	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.	91737	Gremar Mfg. Co., Inc. 7 North Ave. Wakefield, Mass.
71468	ITT Cannon Electric, Inc. 3208 Humbolt St. Los Angeles, Calif. 90031	80164	Keithley Instruments, Inc. 28775 Aurora Road Cleveland, Ohio 44139	91802	Industrial Devices Inc. 982 River Rd. Edgewater, N.J. 07020
71590	Centralab Div. of Globe-Union, Inc. Milwaukee, Wisc. 53212	80294	Bourns, Inc. 6135 Magnolia Ave. Riverside, Calif. 92506	91929	Honeywell Inc. Micro Switch Div. Freeport, Ill. 61032
71785	Cinch Mfg. Co. and Howard B. Jones Div. Chicago, Ill. 60624	81073	Grayhill, Inc. 561 Hillgrove Ave. La Grange, Ill. 60525	93332	Sylvania Electric Products, In Semiconductor Products Div. Woburn, Mass.
72619	Dialight Corp. 60 Stewart Ave. Brooklyn, N.Y. 11237	81483	International Rectifier Corp. 1523 East Grand Ave. El Segundo, Calif.	93656	Electric Cord Co. 1275 Bloomfield Ave. Caldwell, N.J.
72653	G-C Electronics Co. 400 S. Wyman Rockford, Ill. 61101	82389	Switchcraft, Inc. 5527 N. Elston Ave. Chicago, Ill. 60630	94144	Raytheon Co., Industrial Operation Components Div. Quincy, Mass.
72699	General Instrument Corp. Capacitor Division Newark, N.J. 07104	83125	General Instrument Corp. Capacitor Division Darlington, S.C. 29532	94154	Tung-Sol Electric, Inc. Newark, New Jersey
72982	Erie Technological Prods Inc. 644 W. 12th St. Erie, Pa. 16512	83330	Smith, Herman H., Inc. 812 Snediker Ave. Brooklyn, N.Y. 11207	94310	Tru-Ohm Products Memcor Components Div. Huntington, Ind. 46750
73138	Beckman Instruments, Inc. Halipot Division Fullerton, Calif. 92634	83594	Burroughs Corp. Electronic Components Div. Plainfield, N.J. 07061	94696	Magnecraft Electric Co. 5579 North Lynch Chicago, Ill.
73445	Amperex Electronic Co., Div. of North American Philips Co., Inc. Hicksville, N.Y.	83701	Electronic Devices, Inc. Brooklyn, New York	95348	Gordos Corp. 250 Glenwood Ave. Bloomfield, N.J. 07003
73690	Elco Resistor Co. 1158 Broadway New York, N.Y.	84171	Arco Electronics, Inc. Community Drive Great Neck, N.Y. 11022	95712	Dage Electric Co., Inc. Hurricane Road Franklin, Ind.
74276	Signalite Inc. 1933 Heck Ave. Neptune, N.J. 07753	84411	TRW Capacitor Div. 112 W. First St. Ogallala, Nebr.	97933	Raytheon Co. Components Div. Semiconductor Operation Mountain View, Calif.
74970	Johnson, E. F., Co. 297 Tenth Ave. S.W. Waseca, Minn. 56093	84970	Sarkes Tarzian, Inc. E. Hillside Dr. Bloomington, Ind.	99120	Plastic Capacitors, Inc. 2620 N. Clybourn Ave. Chicago, Ill.

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