complete manual

Model 660 can sell

INSTRUCTION MANUAL

MODEL 660

GUARDED DC
DIFFERENTIAL VOLTMETER

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination.

To exercise this warranty, contact your Keithley field engineering representative. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments and its international distributors maintain complete repair facilities.

To insure prompt repair or recalibration service, please contact your Keithley field representative before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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*Yellow Change Notice sheet is included only for instrument modifications affecting the Instruction Manual.

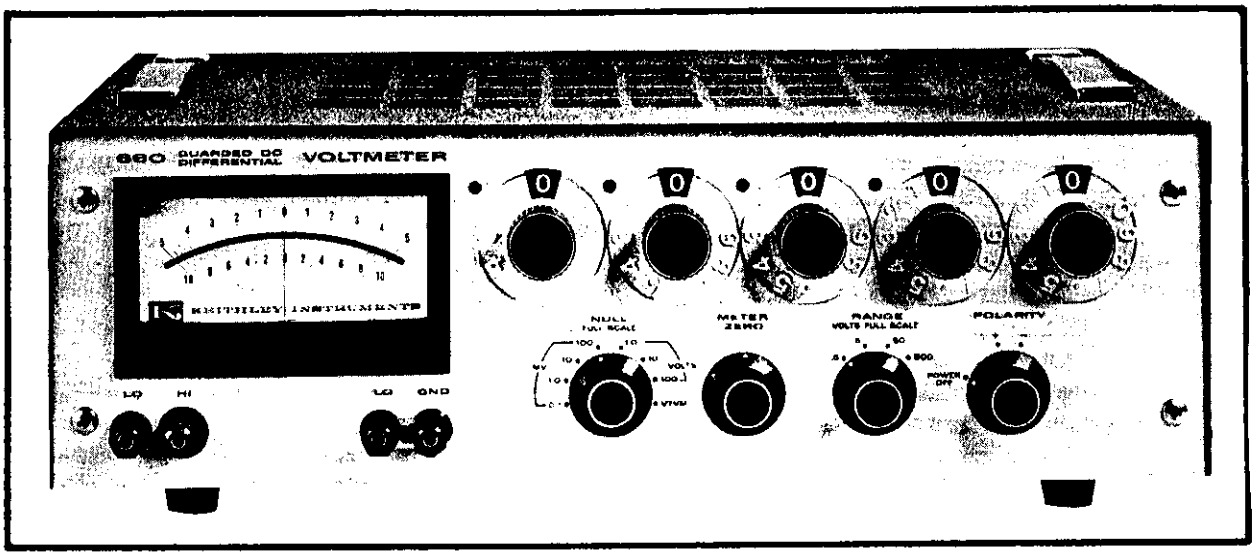


FIGURE 1. Keithley Instruments Model 660 Guarded DC Differential Voltmeter.

SECTION 1. GENERAL DESCRIPTION

1-1. DESCRIPTION.

a. The Keithley Model 660 Guarded DC Differential Voltmeter is a convenient, self-contained potentiometric system that accurately measures dc voltages. It has ±0.02% limit of error from 100 millivolts to 500 volts full scale, 0.005% repeatability, and a reference supply stable to 0.005% indefinitely without manual standardization. Maximum null sensitivity is ±100 microvolts full scale; resolution is within 2 microvolts.

b. Features for convenient use include: five in-line readout dials with automatically lighted decimal points; 10 to 25-millivolt recorder output; input polarity switch; floating operation up to 500 volts off ground; fast overload recovery; better than 45 decibels of 60-cps rejection.

1-2. OPERATING MODES. The Model 660 can be used as a potentiometer or as a conventional vacuum tube voltmeter. As a potentiometer, it can measure from 100 millivolts to 500 volts full scale with ±0.02% limit of error and from 100 microvolts to 100 millivolts full scale within 20 microvolts. As a VTVM, the Model 660 can measure from 100 microvolts to 500 volts full scale with an accuracy of ±3% of full scale. It can also measure resistances from 10 megohms to 50,000 megohms within ±5%.

1-3. APPLICATIONS.

a. The Model 660 is used for measurements over a wide range. Typical applications in the microvolt region are the matching of semi-conductors and the monitoring of noise, transients and drift. High level voltage applications include power supply and meter calibration, and tube potential measurements.

b. Overall stability of 0.01% indefinitely makes the Model 660 useful in measurements of extended duration. Measurements of long-term power supply stability, long-term drift runs, and monitoring during environmental and reliability tests are possible uses.

c. The null-detector output permits use with potentiometric recorders and digital voltmeters equipped with automatic print-out. The Model 660 is useful in quality control, product development, inspection and production.

d. Floating operation to 500 volts is provided for measurements such as plate potential differences of balanced amplifiers.

1-4. ACCESSORIES.

a. Model 6601A High Voltage Divider is a 100:1 divider which extends the range of the Model 660 to 5000 volts. The divider accuracy is ±0.01% and its input resistance is 10 megohms. The overall limit of error of the Model 660 with the Model 6601A is ±0.03%. Paragraph 2-5 gives operating instructions for the Divider.

b. Model 4000 Rack Mounting Kit, containing two brackets and a top cover, adapts the Model 660 for standard 19-inch rack mounting. For rack mounting, the Model 660 is 19 inches wide x 13-1/2 inches deep x 5 inches high. Refer to paragraph 2-12 for installing instructions.

1-5. SPECIFICATIONS.

AS AN ULTRA-STABLE POTENTIOMETER:

LIMIT OF ERROR: ±0.02% of input voltage or 20 microvolts, whichever is greater, after 15-minute warm-up.

REPEATABILITY: Within 0.005%.

COMBINED STABILITY OF KELVIN-VARLEY DIVIDER AND REFERENCE VOLTAGE SUPPLY: ±0.01% indefinitely, after 1-hour warm-up. Temperature coefficient does not exceed 0.002% per °C.

MAXIMUM NULL SENSITIVITY: 100 microvolts full scale with 2.0-microvolt resolution.

INPUT RESISTANCE: Infinite at null, from 0 to 500 volts.

POLARITY: Positive or negative, selectable by switch.

FLOATING OPERATION: May be operated with up to 500 volts between LO and GND (chassis ground).

RESISTANCE — LOW TO GROUND: 10^8 ohms shunted by 0.05 microfarad.

RESOLUTION CHART:

Input Voltage Range (volts)	Maximum Dial Resolution (millivolts)	Maximum Usable Full-Scale Null Sensitivity (millivolts)	Maximum Meter Resolution (microvolts)
50 - 500	10	10	100
5 - 50	1	1	10
0.5 - 5	0.1	0.1	2
0 - 0.5	0.01	0.1	2

AS A SENSITIVE VTVM:

Voltage Ranges (positive or negative)	Input Resistance
500 volts	10 megohms
50 volts	10 megohms
5 volts	10 megohms
0.5 volt	10 megohms

Null Ranges	Input Resistance (Slewing)
100 volts	10 megohms
10 volts	10 megohms
1 volt	10 megohms
100 millivolts	1 megohm
10 millivolts	1 megohm
1 millivolt	1 megohm
0.1 millivolt	100 kilohms

NOTE: Input resistance on 0.1-millivolt range can be increased; see paragraph 2-8.

VTVM ACCURACY: ±3% of full scale on all ranges.

DRIFT: Less than 10 microvolts, non-cumulative, after 15-minute warm-up.

60 CPS REJECTION: Greater than 45 db.

GENERAL CHARACTERISTICS:

STABILITY OF REFERENCE VOLTAGE SUPPLY: ±0.005% indefinitely, after 1-hour warm-up.

STABILITY OF ZENER REFERENCE: 20 ppm per year and five ppm per ^{o}C.

LINE TRANSIENT REGULATION: Less than 5 ppm for 10% variation from 117 volts.

ACCURACY OF DIVIDER: 0.005%.

CHARACTERISTICS OF NULL DETECTOR OUTPUT:

Output: Adjustable 10 to 25 millivolts dc full scale, all ranges.
Output Resistance: 300 ohms maximum.
Noise: 2 microvolts peak-to-peak (referred to input).

Note: Recorder used must have input fully isolated — 10^{10} ohm minimum leakage.

CONNECTORS: Input: Binding posts on front panel.
Output: Banana jacks on rear.

TUBE COMPLEMENT: One OG3, five 12AX7, one 12BH7, two 12B4A, one 6CM8.

POWER: 105-125 volts or 210-250 volts, 50-60 cps, 75 watts.

DIMENSIONS (Bench): 5-1/2 inches high x 17-1/2 inches wide x 13-1/2 inches deep.

NET WEIGHT: 24 pounds.

1-6. EQUIPMENT SHIPPED. The Model 660 Guarded DC Differential Voltmeter is factory-calibrated and is shipped with all components in place. All units are shipped for bench use. Model 4000 Kit may be ordered for rack mounting; refer to paragraph 2-12 for assembly instructions. The shipping carton also contains the Instruction Manual.

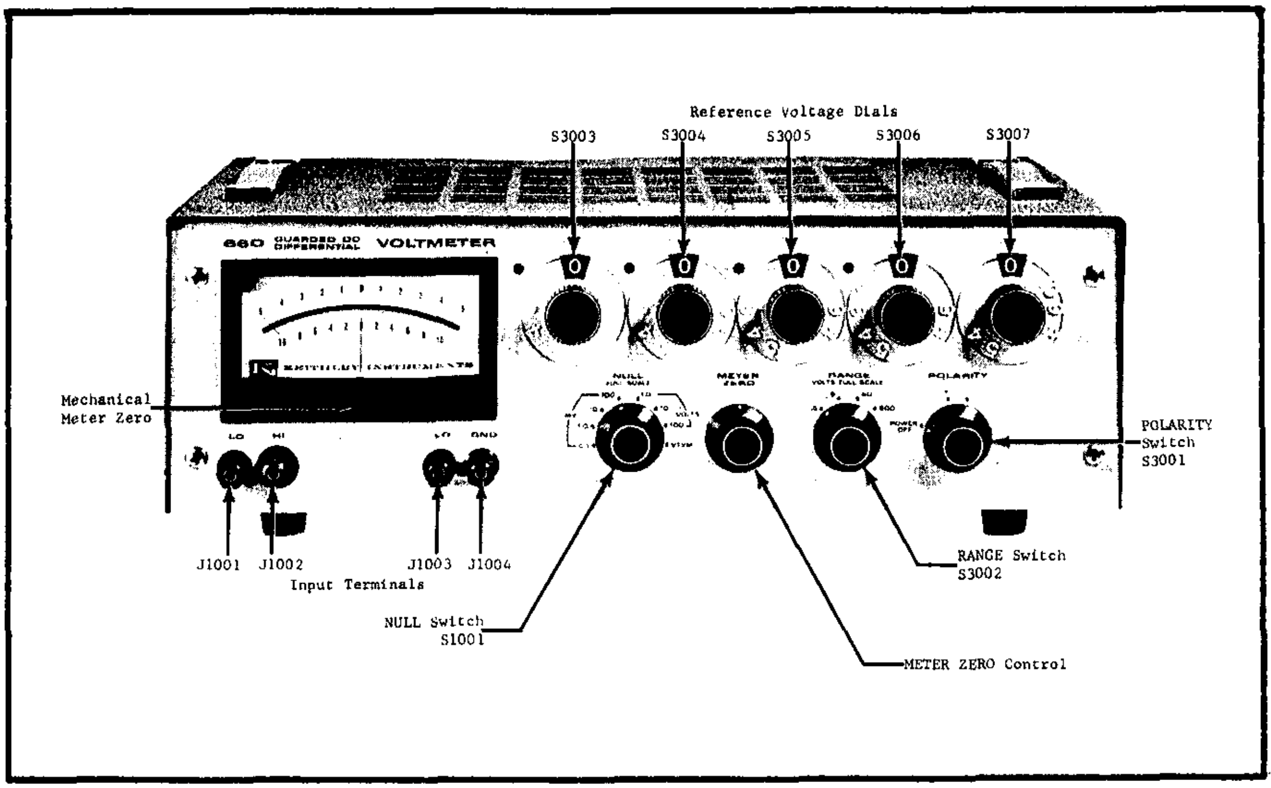


FIGURE 2. Model 660 Front Panel Controls and Terminals. Designations refer to Parts List.

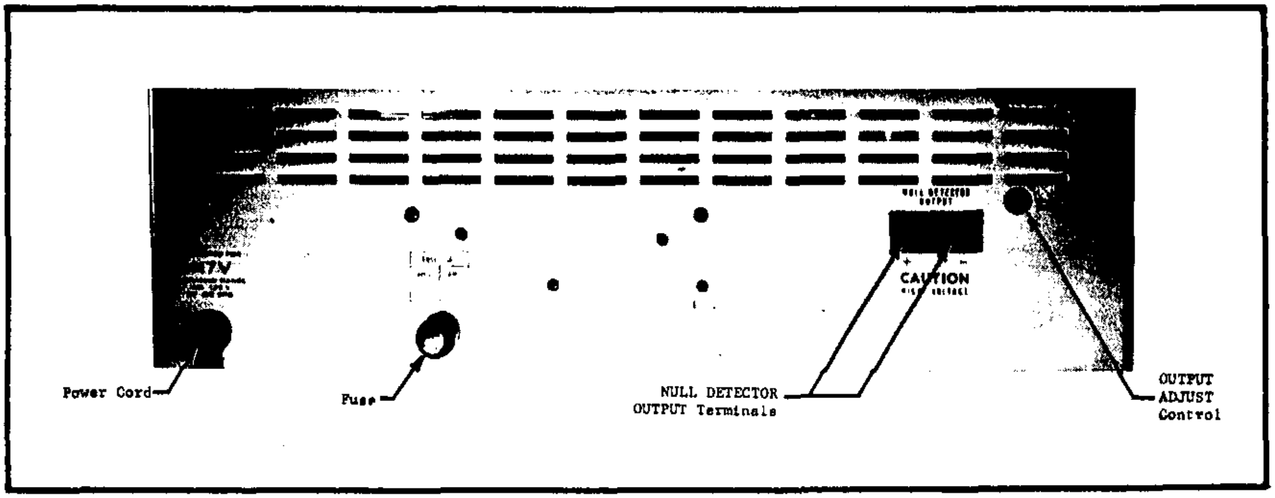


FIGURE 3. Model 660 Rear Controls and Terminals.

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS. (See Figure 2.)

a. POLARITY Switch. The POLARITY Switch turns the instrument on and selects the input polarity. The Switch reverses the polarity of the internal reference voltage supply so both positive and negative voltages may be measured; it does not reverse the meter polarity.

b. NULL Switch. The NULL Switch sets the null detector sensitivity for seven decade ranges from 0.1 millivolt to 100 volts full scale. When the Switch is in the VTVM position, the Model 660 operates as a conventional vacuum tube voltmeter for the four ranges of the RANGE Switch.

c. RANGE Switch. The RANGE Switch adjusts the sensitivity of the VTVM in four steps: 0.5, 5, 50 and 500 volts full scale. It also determines the voltage across the Kelvin-Varley divider and the position of the decimal point light — which also serves as a pilot light — between the five Reference Voltage Dials.

d. Reference Voltage Dials. Five in-line dials at the top of the front panel set the reference voltage when the Model 660 is used as a potentiometer.

e. METER ZERO Control. The METER ZERO Control adjusts the meter pointer to zero. The control is needed on only the 0.1 and 1.0-millivolt null ranges; on the other ranges, the pointer will normally be on zero without adjustment. The control has a range of approximately ± 50 microvolts.

f. Input Terminals. At the lower left front panel, the black LO terminal is to be connected to the low impedance terminal of the unknown voltage and the red HI terminal is to be connected to the high impedance terminal. A second set of terminals marked LO and GND is provided for grounding the LO input terminal to the chassis when desired. The LO terminals are connected together internally.

2-2. REAR CONTROLS AND TERMINALS. (See Figure 3.)

a. Fuse. For 105-125 volt operation, the Model 660 uses a 1-ampere 3 AG fuse. For 210-250 volt operation, the Model 660 uses a 0.5-ampere 3 AG fuse.

b. Power Cord. The Model 660 is for a 105-125 volt, 50-60 cps line source, unless otherwise specified on the rear panel. A three-wire power cord is used.

c. NULL DETECTOR OUTPUT. Two terminals, marked + and -, supply a dc signal from the null detector.

d. OUTPUT ADJUST. A screwdriver control next to the OUTPUT terminals adjusts the null detector output between 10 and 25 millivolts full scale.

2-3. PRELIMINARY PROCEDURES.

a. Connect the Model 660 power cord to a 105-125 volt, 50-60 cps line source. Set the controls as follows:

RANGE	500
NULL	VTVM
POLARITY	+
Reference Voltage Dials	Zero

The decimal light between the third and fourth dials will light. Allow the instrument to warm up for 15 minutes to meet the specified accuracy on all ranges.

b. With the input terminals open, set the NULL Switch to 0.1 MV and zero the meter with the METER ZERO Control. The stability of the Model 660 is such that no adjustment should be required in eight hours after a 15-minute warm-up. Then return the NULL Switch to VTVM.

2-4. OPERATING PROCEDURES.

a. The Model 660 is used first as a VTVM to determine the approximate value of the unknown voltage. It is then used in the potentiometric mode to determine the voltage to ±0.02%.

b. VTVM Operating Procedures.

1. Eleven full-scale ranges are available for VTVM operation. When the NULL Switch is at VTVM, the RANGE Switch determines one of four full-scale ranges. By putting the five Reference Voltage Dials at zero, the Model 660 can then operate as a VTVM on the seven null ranges.

2. Connect the unknown voltage to the input terminals, using the LO terminal for the low impedance terminal of the unknown. Refer to Figure 4.

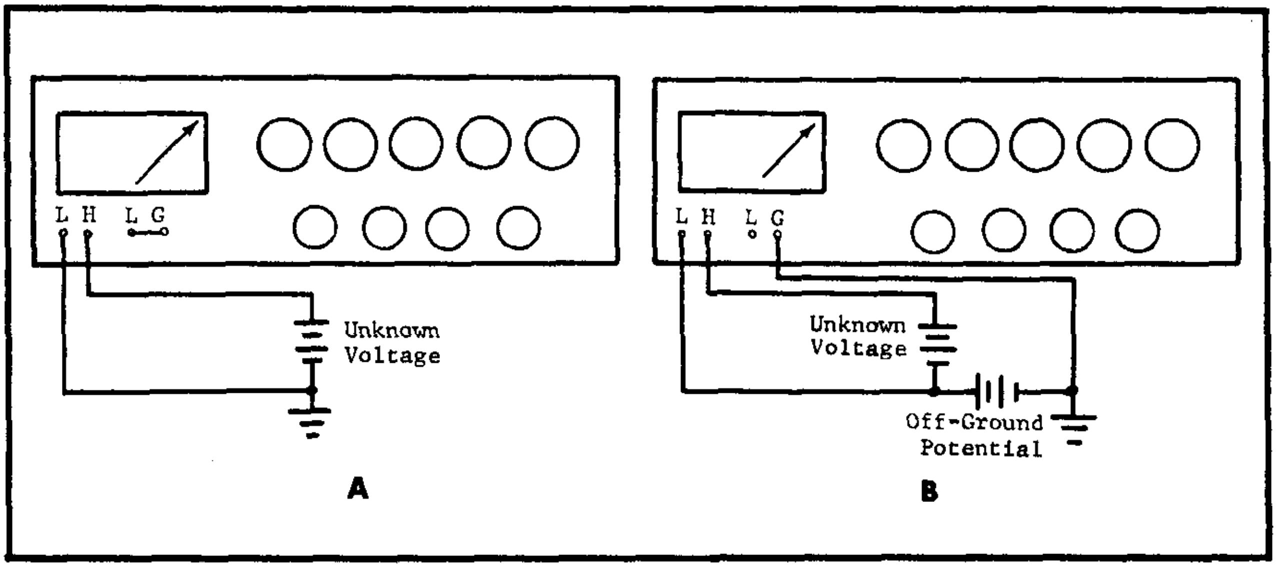


FIGURE 4. Input Connections to Model 660. The two diagrams show the input circuit for measuring at ground and for floating.

In A, the unknown voltage has one terminal at ground. The shorting link is between the LO and GND terminals of the Model 660.

In B, the unknown voltage has both terminals off ground potential. Note this floating or off-ground potential must be less than 500 volts. Also note the shorting link is not used.

3. Switch the RANGE Switch to the most sensitive range for an on-scale meter deflection.

c. Potentiometric Operating Procedures.

NOTE

Avoid large overload voltages on the null detector. No permanent damage will occur even with 500-volt overloads, but some open circuit offset will be caused in the null detector. The offset, due to the polarization of the input filter capacitors, will disappear after about an hour.

1. Leave the RANGE Switch at the last setting used in the VTVM operation. If the VTVM reading is negative, reverse the POLARITY Switch.

2. Set the first two Reference Voltage Dials to the first two digits of the unknown voltage found in the VTVM operation.

3. Set the NULL Switch to the initial null setting shown in Table 1. Adjust the Voltage Reference Dials progressively for zero meter deflection while increasing the null detector's sensitivity with the NULL Switch. Deflections to the right indicate the voltage being measured is more positive than the Reference Voltage Dial setting.

RANGE Setting	Initial NULL Setting	Most Sensitive NULL Setting
500 volts	100 volts	10 millivolts
50 volts	10 volts	1.0 millivolt
5 volts	1 volt	0.1 millivolt
0.5 volt	100 millivolts	0.1 millivolt

TABLE 1. Recommended Null Sensitivities and Settings.

NOTE

The most accurate resistors in the Kelvin-Varley divider are in the first two Reference Voltage Dials. Therefore, to obtain the most accurate readings, use the first two dials whenever possible.

4. The value of the unknown voltage is read directly from the Reference Voltage Dials.

a) The Dial reading will be within the specified limit of error if the NULL Switch is at the most sensitive setting (Table 1) for the range used and if the meter is as close to null as possible. The meter need not be actually at null.

b) For Dial settings below $4999\overline{10}$, only the five Dials need be read to be within specifications. However, the meter may be read as an approximation of a sixth digit.

c) For Dial settings above $4999\overline{10}$, the first Dial is not used and the voltage is read directly from the remaining four Dials.

d) Use the meter as a null indicator when balancing voltages. For Dial settings above 499910, the meter approximates a fifth dial reading. However, the loading effect of the Kelvin-Varley divider on the meter causes some quantative inaccuracies when the meter is off null. (See paragraph 2-8).

2-5. MODEL 6601A HIGH VOLTAGE DIVIDER.

a. The Model 6601A extends the range of the Model 660 to 5000 volts full scale. The ratio of the Divider is 100:1, ±0.01%; the input resistance is 10 megohms. The limit of error when the Model 660 is used with the Model 6601A is ±0.03%.

NOTE

Maximum input into the Model 6601A is 5000 volts.

b. Set the Model 660 RANGE Switch to 50 volts. The meter will read to 5000 volts full scale. Connect the HI and LO Divider terminals to the HI and LO Voltmeter terminals, respectively. Connect the unknown voltage to the Divider INPUT, and use the Model 660 as outlined in paragraph 2-4.

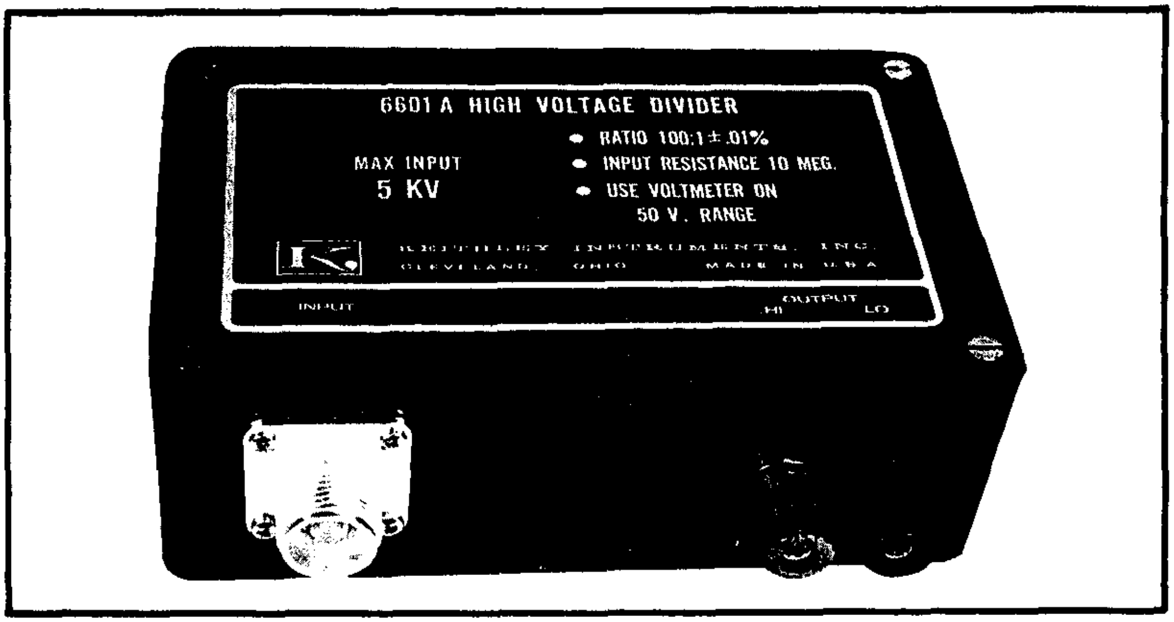


FIGURE 5. Model 6601A High Voltage Divider.

2-6. RECORDER OUTPUT.

a. Recommended recorders for use with the Model 660 are the F.L. Moseley Autograf 680 series recorder and the Minneapolis Honeywell recorder (10mv-0-10mv scale, 50 kilohms input resistance). Any recorder used must be able to float 500 volts off ground and its input must be fully isolated (10^{10} ohm minimum leakage resistance to ground).

b. Before attaching the recorder, set all Reference Voltage Dials to zero. Disconnect the unknown voltage and short both Model 660 input terminals. Set the NULL Switch to 10 MV. Connect the recorder to the OUTPUT terminals on the Model 660 rear panel.

c. Set the Reference Voltage Dials to 10 millivolts to apply an accurate 10-millivolt potential to the null detector on the 10-millivolt null range. This will provide a full-scale recorder output which can be matched to the recorder's range between 10 and 25 millivolts by adjusting the OUTPUT ADJUST Control.

d. To obtain accurate results and/or to prevent damage to the instruments, the recorder must be able to float off-ground with the Model 660. Leakage and pickup between the two instruments should also be minimized.

1. Make sure neither recorder terminal is grounded. Use a 3-wire grounded power line for the recorder. If a 2-wire line is used, connect the recorder chassis and the Model 660 chassis with a separate lead.

2. Minimize all sources of leakage between the output terminals, the recorder and ground. Use polystyrene or Teflon-insulated wire where possible. If the connecting wires are shielded, connect the shield to the LO terminal.

3. Avoid long leads between the Model 660 and the recorder.

4. If difficulty is encountered in off-ground measurements, such as unstable readings, connect a 10-microfarad capacitor between the LO and GND terminals on the Model 660 front panel.

NOTE

Do not short either Model 660 output terminal to the case; this may damage the Kelvin-Varley divider.

e. If there is substantial recorder jitter on the 0.1-millivolt null range, place a filter between the Model 660 and the recorder. Refer to Figure 6 for this connection. Note the filter must also be insulated from ground.

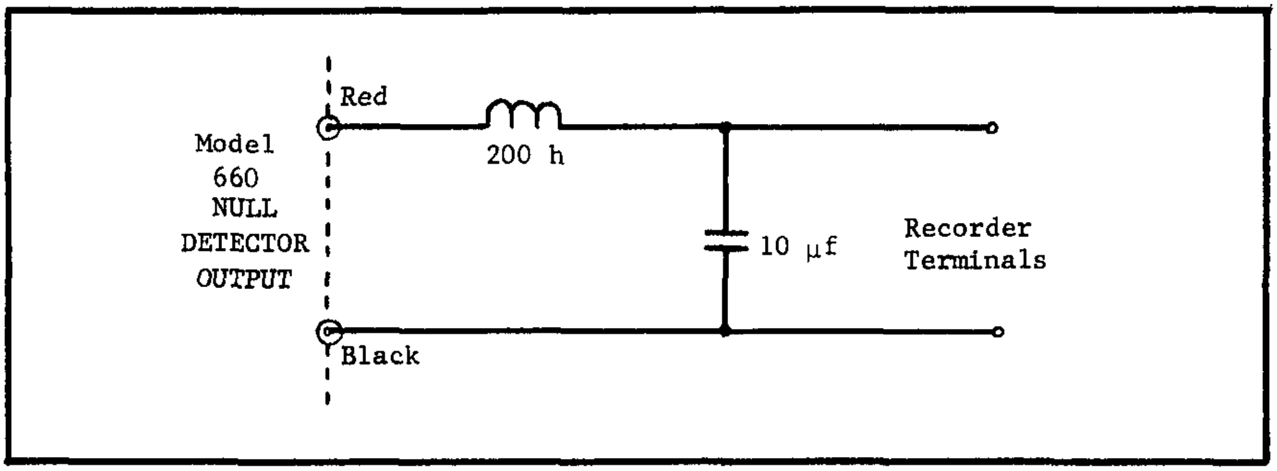


FIGURE 6. Recorder Filter. A filter between the Model 660 and the recorder may be necessary when using the 0.1-millivolt null detector range.

2-7. MEASURING RESISTANCES.

a. Procedures: The Model 660 can be used to rapidly measure resistances from 10 megohms to 50,000 megohms with an accuracy of ±5%. To measure resistance, connect the resistor across the Model 660 HI and LO terminals. Use a short isolated lead to the HI terminal to prevent measuring leakage between the leads. Set the RANGE Switch to 500. Then determine the value of the resistor as follows:

1. For resistances between 10 megohms and 100 megohms, set the NULL Switch to 10 volts; adjust the Reference Voltage Dials to obtain a full-scale meter deflection. Subtract 10.000 from the dial setting to obtain the value of the resistor in megohms.

2. For resistances between 100 megohms and 1,000 megohms, set the NULL Switch to 1 volt; adjust the Reference Voltage Dials to obtain a full-scale meter deflection. Subtract 1.0000 from the dial setting and multiply the difference by ten to obtain the value of the resistor in megohms.

3. For resistances between 1,000 megohms and 50,000 megohms, set the NULL Switch to 1 volt; adjust the Reference Voltage Dials to obtain a convenient deflection on the meter. Calculate the value of the resistor using,

$$R_x = \frac{10\ E_d}{V}\ \text{megohms} \qquad \text{Eq. 1}$$

Where R_x is the unknown resistance;
E_d is the Reference Voltage Dial setting in volts;
V is the null detector meter reading in volts.

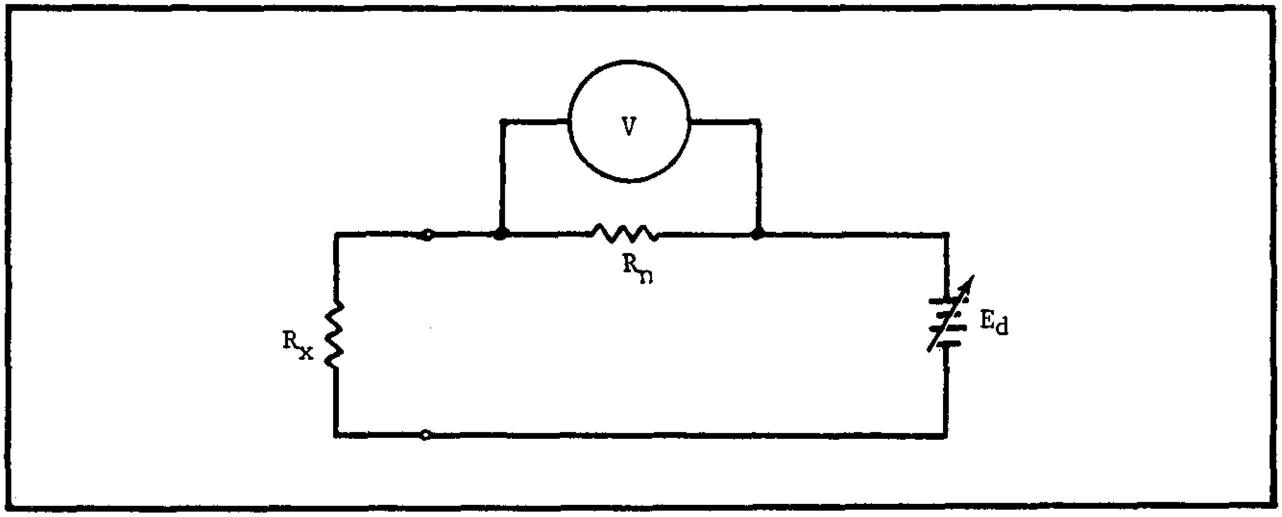


FIGURE 7. Simplified Model 660 Circuit for Measuring Resistances. R_x is the unknown resistance. R_n is the input resistance of the null detector; V is the null detector; E_d is the buckout voltage.

b. Theory: The above method for determining the value of an unknown resistor is based upon the equation for the circuit (see Figure 7). If an unknown resistance is across the Model 660 input terminals, then

$$E_d = i\ (R_x + R_n) \qquad \text{Eq. 2}$$

where E_d is the Reference Voltage Dial setting in volts;
i is the current in the circuit;
R_x is the unknown resistance;
R_n is the input resistance of the null detector meter in ohms.

The current can be written $i = V/R_n$, where V is the null detector meter reading in volts. Equation 2 now becomes

$$R_x = R_n\left(\frac{E_d}{V}\right) - R_n \qquad \text{Eq. 3}$$

If measurements are made on the 1 to 100-volt null ranges, the input resistance, R_n, is 10 megohms. Equation 3 becomes

$$R_x = 10^7\left(\frac{E_d}{V} - 1\right) \qquad \text{Eq. 4}$$

2-8. EFFECTS DUE TO KELVIN-VARLEY OUTPUT RESISTANCE.

a. When the Model 660 is used for nulling on the 0.1-millivolt range, the last Reference Voltage Dial may appear to be inaccurate. The apparent error is due to a voltage drop across the Kelvin-Varley divider. This effect involves only the null detector sensitivity and not the accuracy of the dial setting. When the Model 660 is as near to null as possible, the Reference Voltage Dial setting is correct within the instrument's specifications. There is no error at null.

b. The effect is most apparent on the 0.1-millivolt null range. A 0.1-millivolt off-null setting of the reference voltage will not produce a full-scale deflection on the meter. The output resistance of the Kelvin-Varley divider is significant compared to the shunt resistance across the null detector meter, and the IR drop across the divider will cause the meter to be in error from 1% to 38%. On the 100, 10 and 1-millivolt null ranges, a setting of 100, 10 and 1 millivolt off-null respectively, can show up as an error of up to 6% for Reference Voltage Dial settings near 25000. The effect cannot be observed on the other null ranges of the Model 660.

c. The amount of deflection on the meter is equal to the ratio

$$\frac{R_n}{R_n + R_{kv}}$$

where R_n is the shunt resistance across the meter (10 megohms for the 100 to 1-volt null ranges, 1 megohm for the 100 to 1-millivolt null ranges, and 100 kilohms for the 0.1-millivolt null range);

R_{kv} is the output resistance of the Kelvin-Varley divider, which is a maximum of 62.4 kilohms at settings of 24545 and 25455 and a minimum of 100 ohms at settings of 49998 and 00002.

d. The input resistance on the 0.1-millivolt range may be increased by substituting a 1-megohm, 1/2-watt resistor (Keithley Part No. R12-1M) for the 100-kilohm input resistor, R1003, if the source resistance is not more than

100 kilohms. The higher input resistor will increase the input noise of the instrument open circuited only. The effect of line transients will also be more apparent.

2-9. LOADING AND OFF-NULL RESISTANCE.

a. The input resistance of the voltmeter for the seven null ranges varies from 10 megohms to 100 kilohms as given in the Specifications. This resistance, however, is not the effective input resistance of the Model 660. Its input resistance is considerably higher due to the potentiometric principle of operation. The value is given by

$$R_{in} = \frac{E_d R_n}{V} \qquad \text{Eq. 5}$$

where R_{in} is the effective input resistance of the Model 660;
E_d is the voltage indicated on the Reference Voltage Dials;
R_n is the shunt resistance or input resistance of the null detector meter;
V is the null detector meter reading.

b. To find the loading effect the Model 660 will have on a circuit, equation 5 may be used to compute the effective input resistance of the instrument. At null, the input resistance is infinite. Off null, the input resistance is usually high compared to the internal resistance of the unknown voltage, and the loading will not be enough to affect the accuracy of the measurement. For example, the Model 660 input resistance is 10^{10} ohms if the Reference Voltage Dials are set at 1.0000 volt on the 1-millivolt null range for a reading off null by 10% of full scale.

2-10. THERMAL EMF PRECAUTIONS. Observe standard thermocouple techniques to reduce thermal emf errors for measurements using the most sensitive null ranges. Since the Model 660 can read to 0.5 microvolt, thermal emf's can introduce considerable errors into the measurements. In general, use pure copper leads throughout the system when measuring in the microvolt range. For extensive measurements in the microvolt region, request the article, DC Microvolt Measurements, from Keithley Instruments, Inc.

2-11. AC EFFECTS ON MEASUREMENTS. To minimize errors from ac signals present in the unknown voltage, the Model 660 employs a chopper-stabilized null detector operating at a 42-cps chopping rate with a two-section R-C filter at the input. Very large ac components on the measuring lines, however, may reduce off-null sensitivity. Also, heavy 60-cps pickup will be observed as needle quiver. If ac components affect measurements by the Model 660, additional filtering is required. For an ac signal of a single frequency, a twin T filter is effective. For an ac variable frequency, an ordinary low-pass filter may be used.

2-12. RACK MOUNTING. (See Figure 8.)

a. The Model 660 is shipped for bench use with four feet and a tilt-bail. The Model 4000 Rack Mounting Kit converts the instrument to rack mounting to the standard EIA (RETMA) 19-inch width.

b. To convert the Model 660, remove the four screws at the bottom of each side of the instrument case. Lift off the top cover assembly with the handles;

save the four screws. To remove the feet and tilt bail from the bottom cover assembly, turn the two screws near the back. The two pawl-type fasteners will release the cover and allow it to drop off. Remove the feet and the tilt bail and replace the cover (2).

c. Attach the pair of rack angles (3) to the cabinet with the four screws (4) previously removed. Insert the top cover assembly (1) in place and fasten to the chassis with the two pawl-type fasteners at the rear. Store the top cover with handles, feet and tilt-bail for future use.

Item, (See Fig. 8)	Description	Keithley Part No.	Quantity
1	Cover Assembly	14623B	1
2	Cover Assembly, Bottom (Supplied with Model 660)	14590B	1
3	Angle, Rack	14624B	2
4	Screw, Slot Head, 10-32 UNC-2x1/4 (Supplied with Model 660)	---	4
5	Front Panel (Supplied with Model 660)	---	1

TABLE 2. Parts List for Model 4000 Rack Mounting Kit.

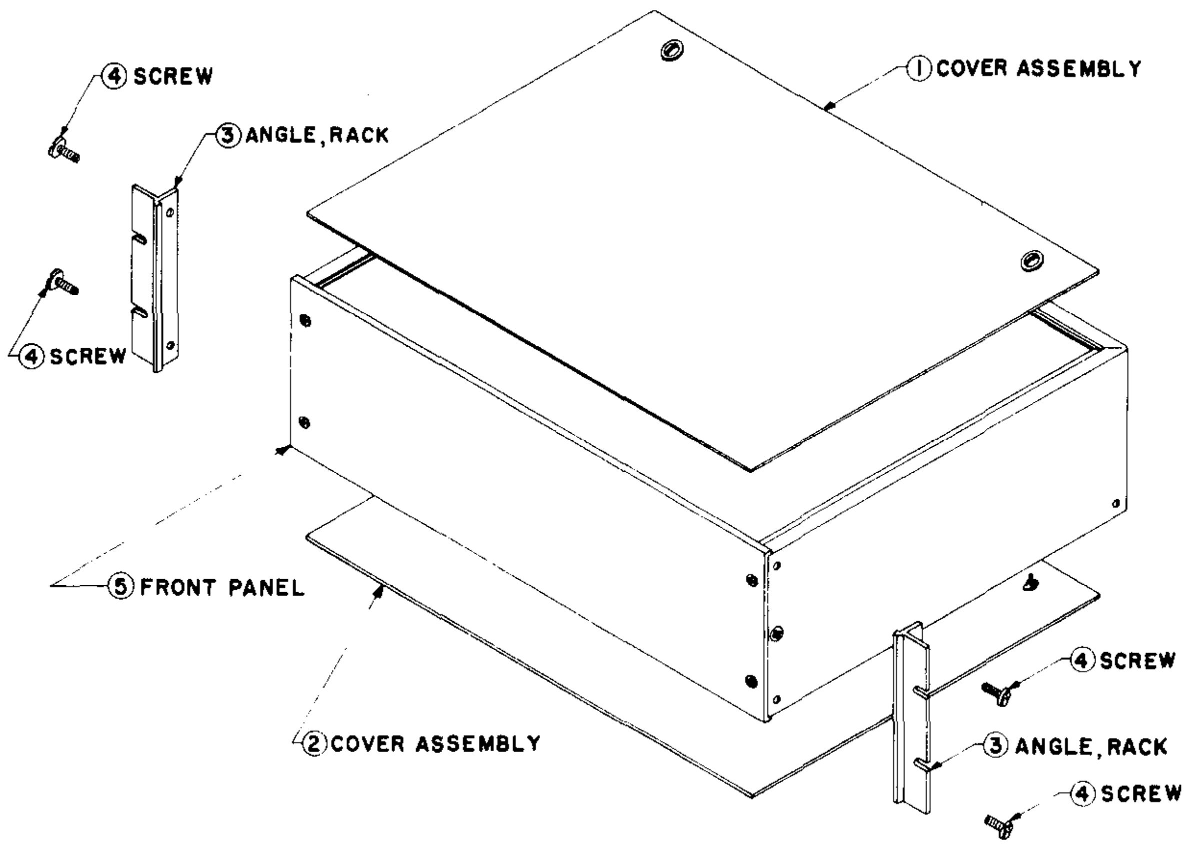


FIGURE 8. Exploded View for Rack Mounting.

2-13. PLACING IN RACK. The Model 660, once converted for rack mounting, easily fits into the rack. It is recommended, however, that a blower be used in the rack enclosure in which the Model 660 is mounted. The instrument specifications state a 0.002% per °C temperature coefficient. A temperature rise of 5 °C (9 °F) will cause a 0.01% error.

2-14. 234-VOLT OPERATION. The Model 660 can be quickly and easily converted to operate from a 234-volt line source. It is normally supplied with the power transformer primary windings connected in parallel for 117-volt operation. To convert, reconnect the primary windings in series as shown on the schematic diagram: the brown lead to the black-white. Replace the 1-ampere fuse with a 0.5-ampere fuse. Power line frequency can be 50 to 400 cps for either voltage.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Model 660 Differential Voltmeter measures voltage by the potentiometric method. The ultra-stable 500-volt reference voltage supply (see Figure 9) is used with the 5-dial Kelvin-Varley divider to null the unknown voltage. The difference between the divider output and the unknown voltage is indicated by the null detector — a chopper-stabilized vacuum-tube voltmeter. At null the unknown voltage equals the reference voltage and can be directly read from the five in-line dials of the Kelvin-Varley divider. The input and null detector are fully guarded to avoid leakage.

NOTE

The circuit designations referred to in the following paragraphs are for the schematic diagram 15199H found at the back of this manual.

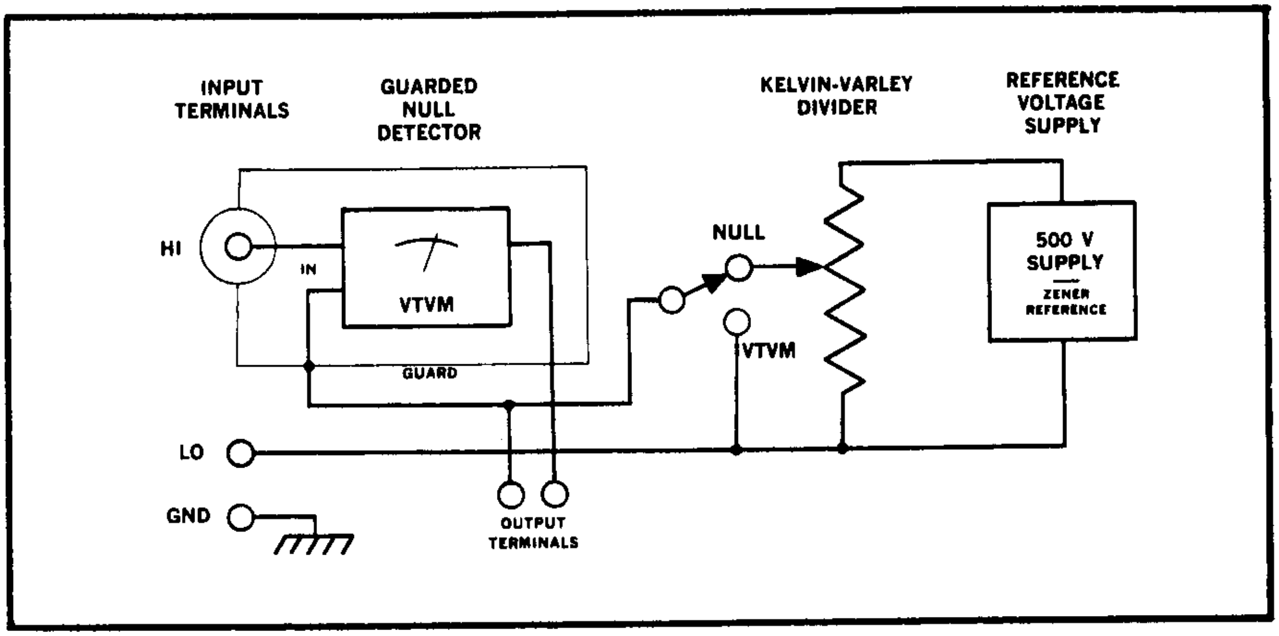


FIGURE 9. Simplified Circuit Diagram of the Model 660.

3-2. REFERENCE POWER SUPPLY.

a. Unregulated voltage from the transformer T3001 is rectified by a silicon half-wave rectifier, D3004, and is filtered by capacitors C3003, C3004 and C3005. The voltage then is applied to the preregulator series pass tube, V3005.

b. The output voltage of V3005 is regulated by comparing a sample voltage from divider string, R3015, R3016 and R3017, to the reference, regulator tube V3007. The difference between the two potentials is amplified by V3006. The amplifier output drives the grid of V3005 in the proper phase to nullify input variations. The ac feedback loop, containing capacitor C3007, is used for better high frequency and transient response.

c. The regulated output of V3005 is applied to the second series tube, V3004, for final regulation. To obtain a stable, accurate voltage, the 500-volt output of V3004 is sampled by a divider network of wirewound resistors, R3034, R3036, R3037, R3049 and R3050. The divider network ratio is adjusted with potentiometer R3035 to better than 0.01%. Light modulator E3002 compares the sample voltage from the divider network to the voltage across the ultra-stable zener diode, D3009. Any difference between the sampled voltage and the voltage of D3009 is chopped by E3002 and amplified by a two-stage ac-coupled amplifier, V3001. The amplified output of V3001 is converted to a dc signal by light modulator, E3001, and then is amplified by the two-stage differential dc amplifier, V3002 and V3003. The amplifier output is applied to the grid of the series tube, V3004, in the proper phase to nullify input variations. Capacitor C3009 is used in the ac feedback circuit.

d. The temperature-compensated zener diode, D3009, was used as the circuit's basic reference since typical variations are limited to less than 20 ppm per year and 5 ppm per ^{o}C. Thus, a highly stable reference is provided with respect to both time and temperature. The zener diode will also withstand extreme shock and vibration.

e. The regulated 500 volts from V3004 either is applied directly to the Kelvin-Varley divider or it is divided to 50, 5, or 0.5 volts by very stable wirewound resistor networks. The RANGE Switch, S3002, determines which network is used. The 50-volt range divider network consists of R3040, R3041 and R3042; the 5-volt, of R3040, R3044 and R3045; and the 0.5-volt, of R3040, R3047 and R3048. Potentiometers R3041, R3044 and R3047 are used to accurately set the voltage division on each range.

3-3. KELVIN-VARLEY DIVIDER.

a. The Kelvin-Varley divider precisely divides the reference voltage for nulling an unknown voltage. It is, in effect, a constant input impedance decade potentiometer consisting of resistors R3051 through R3099. The resistors within each decade are matched; the decades are matched for each instrument.

b. Each decade of the Kelvin-Varley divider, except the first, R3051, through R3056, parallels two resistors of the preceeding string. Between the two contacts of the first Reference Voltage Switch, S3003, the total resistance is 40 kilohms (80 kilohms in parallel with the 80 kilohms total resistance of the four remaining strings). With the RANGE Switch set at 500, 100 volts dc will appear across the contacts of Reference Voltage Switches S3004, 10 volts across S3005, 1 volt across S3006, and 0.1 volt across S3007.

3-4. NULL DETECTOR.

a. The Model 660 uses a null detector with a chopper stabilized, feedback amplifier. The input signal is attenuated, if necessary, and sent through a two-stage R-C filter. The signal is then amplified and measured by the null detector meter.

b. The null detector has basically three full-scale sensitivities, 0.1, 1 and 10 millivolts. Above the 10-millivolt range, the input is divided by resistors R1002 through R1007 to the 10-millivolt level. The full-scale sensitivities are determined by which of three feedback resistors, R1037, R1038 or R1039, is in the circuit. A two-stage R-C filter, consisting of

R1008, C1001, R1009 and C1002, is used to decrease the ac input components. The input filter attenuation ratio is 35db at 60 cps. The light modulators are driven by a 42-cps multi-vibrator. Using a drive source harmonically unrelated to the standard line frequency minimizes 60-cps pickup effects.

c. The light modulators E1001 and E1002 convert the difference between the filtered input voltage and the output of the Kelvin-Varley divider into an ac voltage, which is fed to a four-stage ac coupled amplifier, V1001 and V1002. The output of the amplifier is then demodulated by light modulator E1003 and applied to an R-C filter, R1034 and C1017. The null detector meter, M1001, indicates the value of the filtered signal.

d. One arm of the feedback network is formed by resistors R1043, R1040, R1041, R1042 and one of the feedback range resistors, R1037, R1038 or R1039. Resistor R1036 forms the second shunt arm. The feedback is applied to light modulator E1002. The low end of C1001 is also returned to the feedback point for faster speed of response.

e. A zero-control network is across resistor R1009 to buck out thermal emf's at the input on the two most sensitive ranges. The network consists of a 1.32-volt mercury battery, BT1001, and resistors R1010 through R1013. The zero control on the front panel, R1013, has approximately a 100-microvolt span.

f. The null detector output is obtained across resistors R1040 and R1043, which are in the feedback network. Potentiometer R1043 adjusts the output from 10 to 25 millivolts at full scale. The output voltage is proportional to the full-scale meter reading.

3-5. GUARDING. Guarding is accomplished by floating the null detector and the input circuitry at a voltage equal to the input voltage from a low impedance source. This full guarding eliminates leakage between the input terminal and ground. Such leakage in an unguarded circuit is difficult to avoid, even under laboratory conditions, and can result in sizeable errors. For example, in an unguarded circuit with a 1-megohm source, leakage of 10^8 ohms will introduce 0.1% error. A guarded circuit eliminates this element of error. The effectiveness of guarding in the Model 660 is demonstrated by setting the null detector on the 0.1-millivolt range, with the input circuit open, and the Reference Voltage Dials set to 500 volts. Even at this extreme condition there is no deflection on the meter, demonstrating there is no leakage.

SECTION 4. MAINTENANCE

4-1. GENERAL.

a. Section 4 contains the maintenance, troubleshooting and calibration procedures for the Model 660. It is recommended that these procedures be followed as closely as possible to maintain the accuracy and stability of the instrument.

b. The Model 660 needs no periodic maintenance beyond the normal care required of high-quality electronic equipment. Occasional verification of the limit of error should show if adjustments or calibration are needed.

4-2. PARTS REPLACEMENT. The Replaceable Parts List is Section 5 describes the electrical components in the Model 660. Replace components only as necessary, and use only reliable replacements which meet the specifications. Replace the resistors in the Kelvin-Varley divider, switches S3004 through S3007, only with Keithley matched resistors.

4-3. TROUBLESHOOTING.

a. The following procedures give instructions for repairing troubles which might occur in the Model 660. Use these procedures to troubleshoot and use only specified replacement parts. Table 3 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact Keithley Instruments or its representatives.

b. Paragraph 2-12 describes how to remove the Model 660 cover. Before proceeding with the troubleshooting, check the vacuum tubes in the instrument. Normally, replacing tubes will clear up the difficulty. All tubes can be readily tested on a grid-modulated tube tester. If replacing a tube does not correct the trouble, continue the procedures. Replacing tubes does not necessitate recalibration of the instrument.

c. Table 4 contains the more common troubles which might occur with the instrument. If the repairs indicated in the table do not clear up the trouble, the difficulty will have to be found through a point-by-point check of the circuits. Refer to the circuit description in Section 3 to find the more crucial components and to determine their function in the circuit. The complete circuit schematic, Diagram 15199H, is found in Section 5.

Instrument	Use
Keithley Model 503 Milliohmmeter	Ohmmeter for resistors less than 1 kΩ
Keithley Model 610A Electrometer	Dc voltmeter and ohmmeter
Keithley Model 662 Guarded dc Differential Voltmeter	Test Kelvin-Varley divider resistors
Grid-modulated tube tester	Test vacuum tubes

TABLE 3. Equipment Recommended for Troubleshooting Model 660. Use these instruments or their equivalents.

Difficulty	Probable Cause	Solution
Poor null meter sensitivity on millivolt ranges.	C1018 or R1046 out of adjustment.	Adjust per paragraph 4-4.
Needle quiver.	R1046 is out of adjustment.	Adjust per paragraph 4-4.
Meter rattle, drift or error is observed on all null ranges.	Tube V1001, V1002 or V2001 is faulty.	Check tube; replace if faulty.
Variations in line voltages cause Model 660 measurements to be out of specifications.	Tube V3005, V3006 or V3007 is defective.	Check tube; replace if faulty.
Reference voltage supply drifts, requiring frequent adjusting of the range controls, R3035, R3041, R3044, R3048.	V3001, V3002, V3003 or V3007 is defective.	Check tubes; replace if faulty.
	One of the divider resistors, R3034 through R3037, R3049 or R3050, is changing value rapidly during warm-up.	Test the resistors and replace any faulty components.
	Zener reference diode, D3009, is unstable.	Check zener diode per paragraph 4-5. Replace if faulty.
	Light modulator E3002 is defective.	Check light modulator by replacing.
Measurements out of tolerance on the 500-volt range.	Out of calibration.	Refer to paragraph 4-8 for recalibration.
	One of the divider resistors, R3034 to R3037, R3049 or R3050, is faulty.	Check stability for 24 hours. If 500-volt supply remains stable, replacement of resistors is not needed.

TABLE 4 (Sheet 1). Model 660 Troubleshooting.

Difficulty	Probable Cause	Solution
Measurements out of tolerance on the 500-volt range.	Noisy or unstable zener reference diode, D3009.	Check zener diode. Replace if faulty.
Measurements are out of specifications on one range other than 500-volt range.	A resistor in the range divider network is faulty.	Paragraph 3-2 e points out the resistors used for each range. Try to bring the ranges within specification by calibrating with the potentiometers in the network. See paragraph 4-8. If it does not work, check individual resistors.
Measurements are out of specifications on all ranges other than 500-volt range.	Resistor R3040 is faulty.	Replace the faulty resistor.
Measurements are out of specifications on any range when the Reference Voltage Dials are at any setting other than 499910.	One of the Kelvin-Varley divider resistors is faulty.	See paragraph 4-7.
Instrument is out of specifications on all ranges.	One of resistors R1001 through R1007 is faulty.	Check resistors; replace if faulty.

TABLE 4 (Sheet 2). Model 660 Troubleshooting.

4-4. ADJUSTMENT OF HUM BALANCING CONTROLS.

a. Adjusting Trimmer C1018.

1. Trimmer C1018 nulls out residual ac components in the power transformer, T3001. If this adjustment is not properly set, null sensitivity decreases. On the 0.1-millivolt null range, however, it is normal to have a maximum sensitivity of 62% of full scale when the Reference Voltage Dials are set near 25000. This is due to the loading of the null detector by the Kelvin-Varley divider (paragraph 2-8).

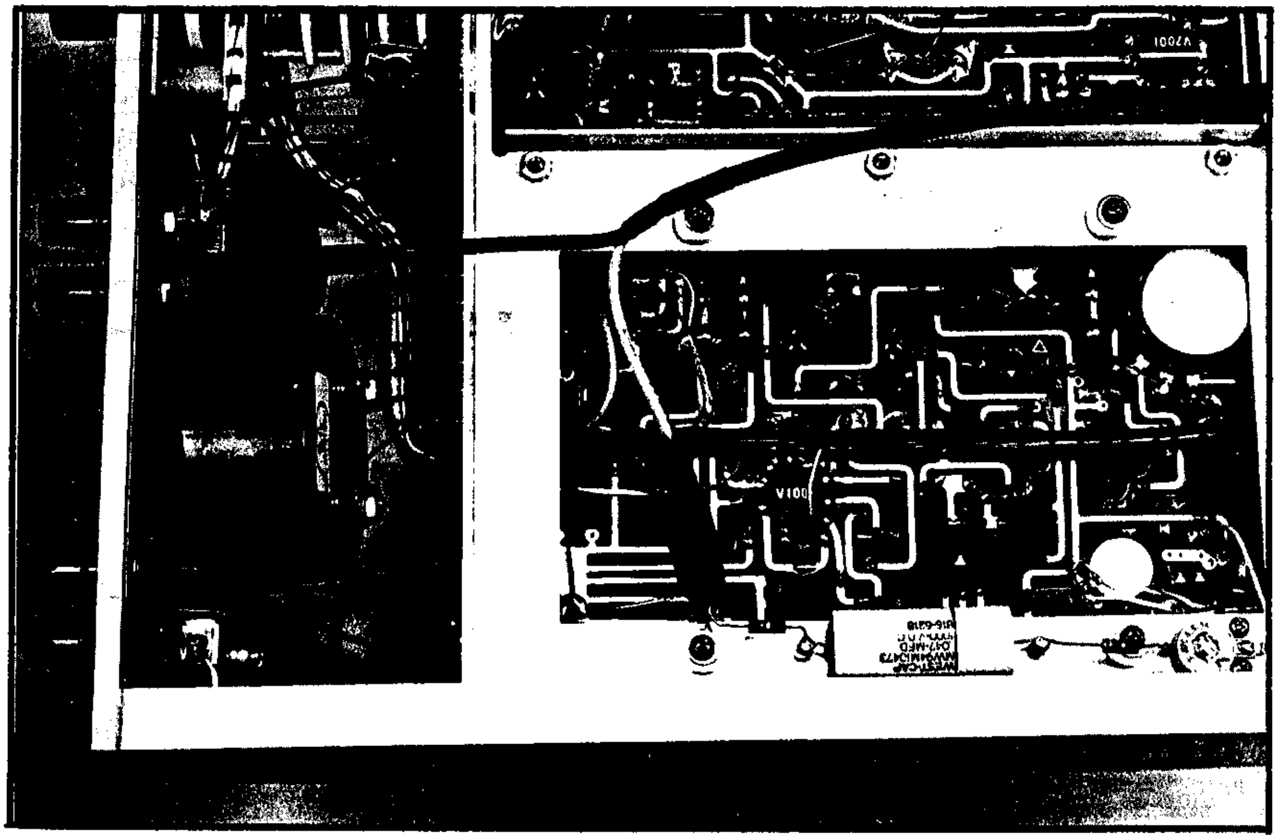
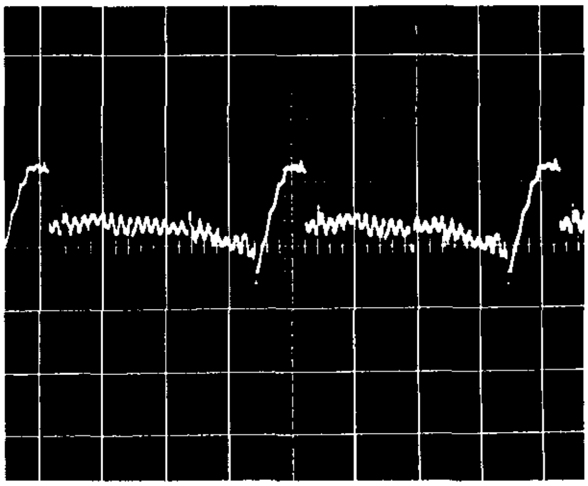


FIGURE 10. Attaching Oscilloscope Leads for Adjusting Trimmer. The oscilloscope is attached to the LO input terminal and the guard circuit.

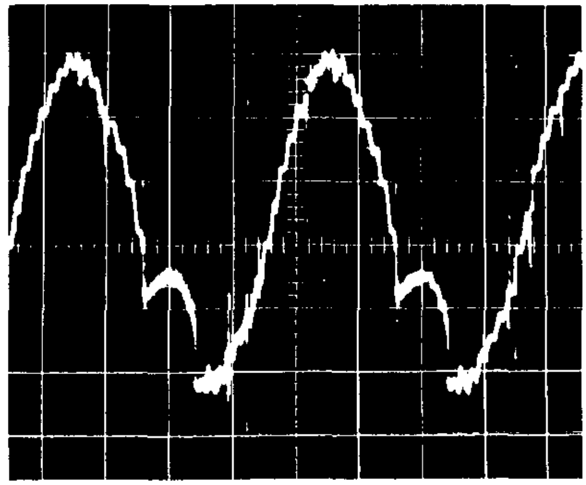
2. To adjust the trimmer, remove the bottom cover and attach an oscilloscope between the LO input terminal and the guard circuit (see Figure 10). With the Reference Voltage Dials set for either 24545 or 25455, the wave form should be similar to that shown in Figure 11. Adjust trimmer C1018 (Figure 19) until the wave form is correct.

NOTE

Trimmer C1018 and resistor R1045 are normally used in each instrument. In some instruments, however, component parameters are such that this adjustment is unnecessary and C1018 and R1045 are disconnected at manufacture.



a



b

FIGURE 11. Wave Forms for Adjusting Trimmer. The wave form with C1018 properly adjusted is shown in (a). The wave form with trimmer misadjusted is shown in (b). A Tektronix Type 503 Oscilloscope was used; horizontal sweep was 20 msec/cm; vertical, 10 mv/cm.

b. Adjusting HUM BAL Potentiometer R1046.

1. Potentiometer R1046 minimizes 60-cps pickup in the null detector. Misadjustment will reduce sensitivity and cause needle quiver.

2. To adjust the potentiometer, set the Reference Voltage Dials to zero and short the input terminals. Attach an oscilloscope to the junction of capacitor C1014 and resistor R1034 (from pin 6 of V1002). Figure 12 shows the wave form if potentiometer R1046 is adjusted for minimum output.

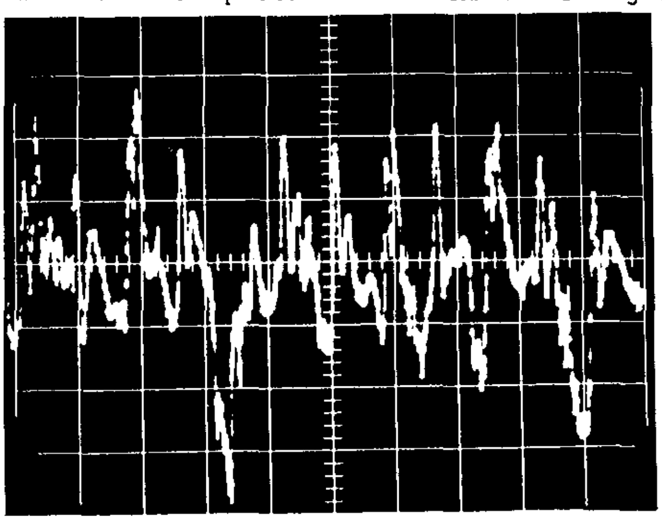


FIGURE 12. Wave Form with R1046 Adjusted. A Tektronix Type 503 Oscilloscope was used; horizontal sweep was 20 msec/cm; vertical, 500 mv/cm.

4-5. ZENER CURRENT TEST. When the reference voltage supply is operating properly, the zener current will be 10 milliamperes and the voltage across R3031 should be 100 millivolts.

4-6. CALIBRATION PROCEDURES.

a. The following procedures are recommended for calibrating the Model 660. Use the equipment recommended in Table 5. If proper facilities — especially important for calibrating an ±0.02% instrument — are not available or if difficulty is encountered, contact Keithley Instruments or its representatives to arrange for factory calibration.

b. Three procedures are covered: Kelvin-Varley divider verification, voltage range calibration, and reference voltage supply stability test.

c. If the Model 660 is not within specifications after the calibrations, follow the troubleshooting procedures or contact Keithley Instruments or its representatives.

Instrument	Use
Electro Scientific Industries Model SV-194B Voltage Calibrator, ±0.005% accuracy with corrections on certificate	Range Voltage Calibrator
Electro Scientific Industries Model RV-722 Kelvin-Varley Divider, linearity: settings of 0.1 to 1, Certificate Corrected to ±0.2 ppm	Voltage divider for range calibration
Keithley Instruments Model 150A Microvoltmeter	Null detector for range calibration
Keithley Instruments Model 241 Regulated High Voltage Supply	Power supply for range calibration
Keithley Instruments Model 662 Guarded DC Differential Voltmeter	Check voltages in Kelvin-Varley divider
Mosley Instruments Model 680 Direct Reading Recorder	Recorder for reference voltage supply stability
Weston Instruments Model 3 Type 7 Saturated Standard Cell	Range calibration and reference voltage supply stability
Weston Instruments Model 66 Oil Bath	Range calibration and reference voltage supply stability

TABLE 5. Recommended Equipment for Model 660 Calibration. Use these instruments or their equivalents.

4-7. KELVIN-VARLEY DIVIDER VERIFICATION.

a. There is no in-field calibration for the Kelvin-Varley divider; its accuracy can only be verified. The divider accuracy depends upon matching resistors and switches. At manufacture, each resistor within the first two Reference Voltage switches, S3003 and S3004, is matched to ±0.005%. The resistors in the switches are checked as a set to an accuracy of better than 0.005%. Individual resistors cannot be replaced without rematching the entire divider deck.

b. Kelvin-Varley Divider Accuracy Verification Procedures.

1. Use the Model 662 Differential Voltmeter or equipment with better limit of error to match the Model 660 under test. Connect the wiper arm of Switch S3007 of the instrument under test to the HI terminal of the Model 662. Connect both LO terminals.

NOTE

Be careful of high voltages when working within the Model 660. Up to 900 volts dc is present at various points.

2. Set the dials to random settings on both instruments. Settings should match to ±0.02%. This procedure, however, only indicates the Kelvin-Varley divider accuracy. The errors of the two instruments may be additive, causing a false verification. The Most accurate way is to use standard procedures for checking a Kelvin-Varley divider or to return the Model 660 to the factory.

3. If any resistor fails to test out, the entire divider string will have to be rematched.

4-8. RANGE CALIBRATION.

a. The reference voltage supply has a 500-volt output which can be attenuated to 50, 5 or 0.5 volts. This voltage is then divided by the Kelvin-Varley divider to provide the accurate buckout voltage. Each of the four voltage ranges is set by internally adjusting potentiometers R3035, R3041, R3044 and R3048 (Figure 15).

b. The ranges are calibrated by applying an accurate voltage to the Model 660 for each setting of the RANGE Switch. The Model 660 is set to furnish the equivalent buckout voltage, and the internal range potentiometer is adjusted until the voltmeter indicates a null.

NOTE

The accuracy of the Model 660 calibration will be no greater than the accuracy of the voltage source used for calibrating. Unless the user is familiar with techniques for obtaining greater accuracy than 0.01% (100 ppm), it is better to return the Model 660 to the factory for range calibration.

c. The most critical part in range calibration is establishing a reference source whose accuracy exceeds 0.01%. Use the Model SV-194B Voltage Calibrator for the 500, 50, 5 and 0.5-volt outputs. Establish the accuracy of these outputs by determining the corrections for the calibrator's CALIBRATION and OUTPUT dials at these outputs. The system's accuracy can be determined to approximately 10 ppm. Added to the accuracy of the standard cell, total accuracy should be approximately 20 ppm. Note, this will depend upon properly executed procedures.

d. Procedures to Establish System Accuracy.

1. Set up the system shown in Figure 13. Use the 9.9-megohm extender for only the 0.5 and 5-volt outputs. Have the Model SV-194B certified by the manufacturer to accuracy.

2. Establish the corrections for the CALIBRATION dial setting for Model SV-194B outputs of 500, 50, 5 and 0.5 volts. Set the Power Supply (preferably, the Model 241 which is 0.05% accurate) to 500 volts. Set the Kelvin-Varley Divider to a voltage equal to that of the standard cell. Adjust the Model SV-194B ratio dial until the Null Detector indicates a null. The difference between the settings of the Kelvin-Varley Divider and the ratio dial is the Model SV-194B correction factor at 500 volts. With this correction, the 500 volts may be set to within 20 ppm.

3. Connect the Null Detector to the 50, 5 and 0.5-volt taps of the Model SV-194B Calibrator in that order. Set the Kelvin-Varley Divider to corresponding voltages. Use the 9.9 megohm extender for the 5 and 0.5-volt outputs. (See Figure 13.) The difference read on the Null Detector is the correction factor for each of the three voltages. These voltages may also be set to within 20 ppm.

4. Use the four correction factors for calibrating the Model 660 range settings.

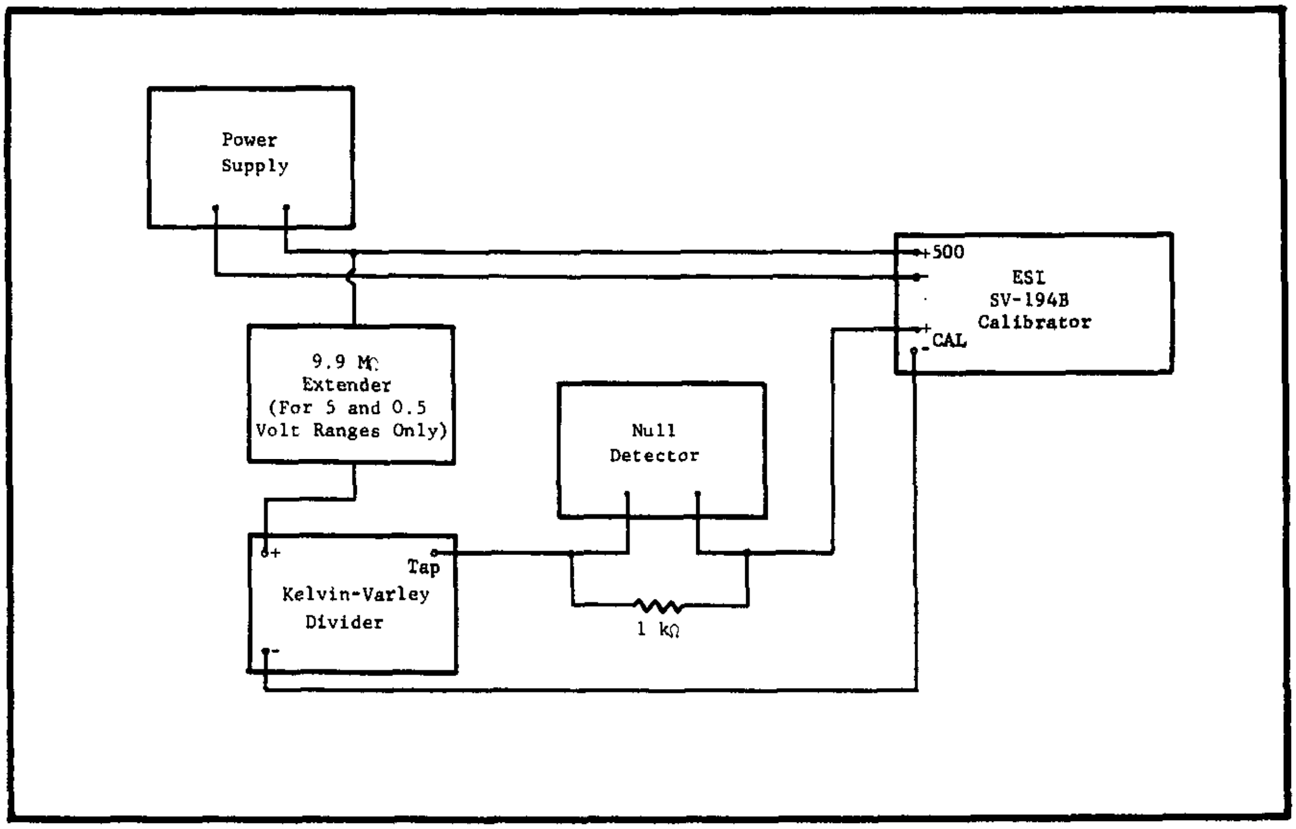


FIGURE 13. Block Diagram to Establish System Accuracy for Model 660 Range Calibration. Fully guard the entire system to prevent leakage errors. Use a 1-kilohm copper resistor to shunt the Null Detector. See Table 5 for recommended equipment.

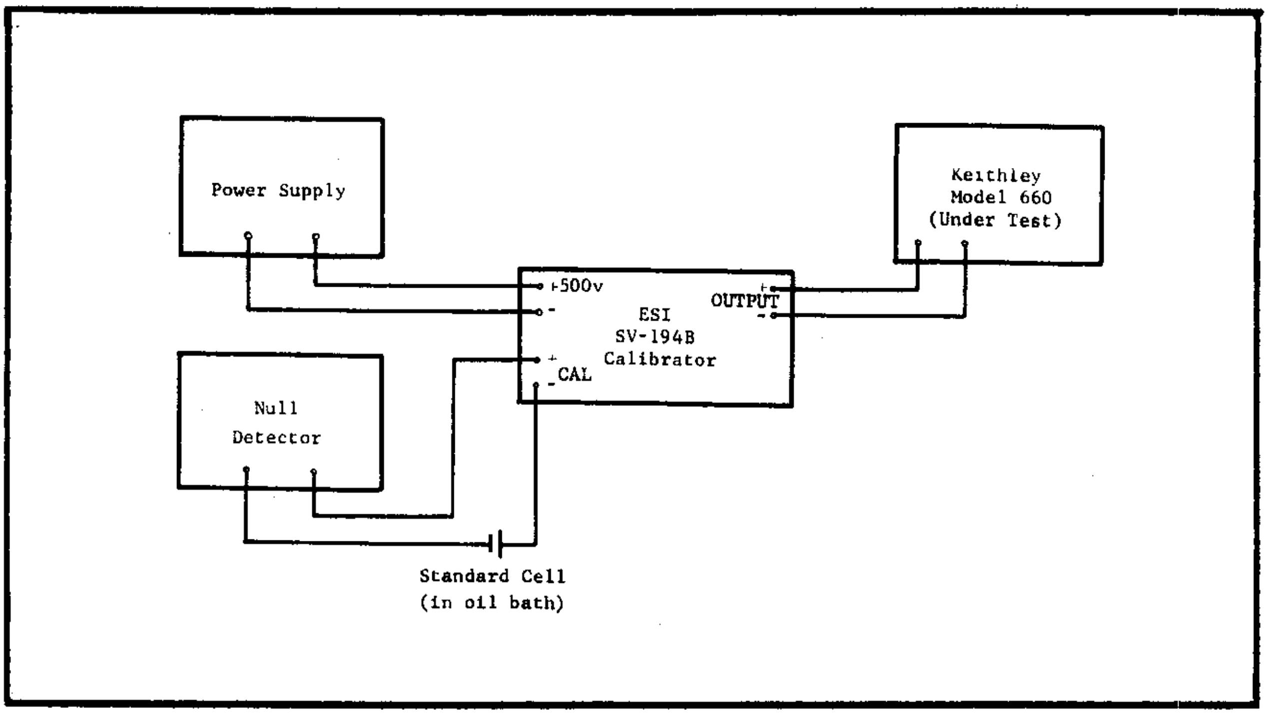


FIGURE 14. Block Diagram for Model 660 Range Calibration. Fully guard entire system to prevent leakage errors. See Table 5 for recommended equipment.

e. Procedures for Range Calibration.

1. Set up the system shown in Figure 14. The standard cell should be certified to 10 ppm. Use the dial correction factors found for each output. If the system accuracy was properly determined, the input voltage to the Model 660 should be correct to 20 ppm.

2. <u>500-volt Range Calibration</u>: Set the Model 660 as follows:

RANGE	500
Reference Voltage Dials	499.910
NULL	VTVM
POLARITY	+

Adjust the Voltage Calibrator to apply 500 volts dc to the Model 660. Turn the Model 660 NULL Switch to 10 MV and adjust the 500 V CAL potentiometer R3035 (Figure 15) for null on the Model 660.

3. <u>50-Volt Range Calibration</u>: Set the Model 660 as follows:

RANGE	50
Reference Voltage Dials	49.9910
NULL	10 MV
POLARITY	+

Adjust the Voltage Calibrator to apply 50 volts dc to the Model 660. Adjust the 50 V CAL potentiometer R3041 (Figure 15) for an off-null reading on the Model 660 equal to the correction factor at 50 volts.

4. <u>5-Volt Range Calibration</u>: Set the Model 660 as follows:

RANGE	5
Reference Voltage Dials	4.999$\overline{10}$
NULL	1 MV
POLARITY	+

Adjust the Voltage Calibrator to apply 5 volts dc to the Model 660. Adjust the 5 V CAL potentiometer R3044 (Figure 15) for an off-null reading on the Model 660 equal to the correction factor at 5 volts.

5. <u>0.5-Volt Range Calibration</u>: Set the Model 660 as follows:

RANGE	0.5
Reference Voltage Dials	.4999$\overline{10}$
NULL	0.1 MV
POLARITY	+

Adjust the Voltage Calibrator to apply 0.5 volt dc to the Model 660. Adjust the 0.5 V CAL potentiometer R3047 (Figure 15) for an off-null reading on the Model 660 equal to the correction factor at 0.5 volt.

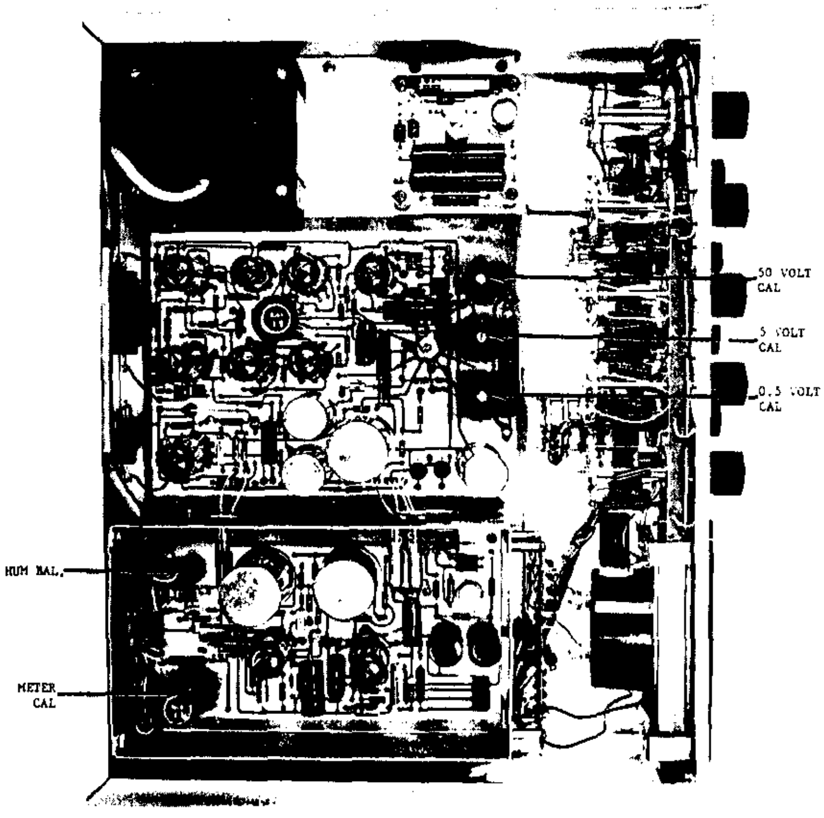


FIGURE 15. Model 660 Internal Controls. (Top View.)

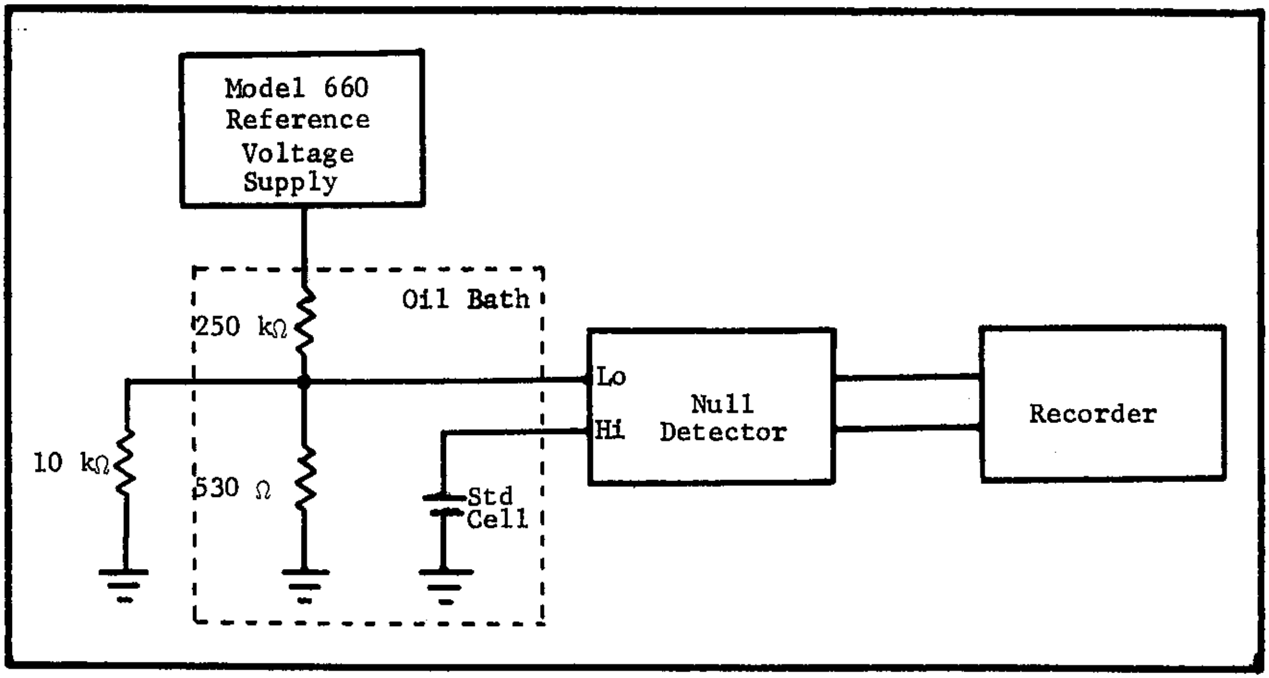


FIGURE 16. Circuit Diagram for Reference Voltage Supply Stability Test. The voltage across the 250-ohm resistor is slightly higher than the standard cell. Use the 10-kilohm potentiometer to shunt the divider voltage down. All resistors are wirewound. See Table 5 for recommended equipment.

4-9. REFERENCE VOLTAGE SUPPLY STABILITY TEST.

a. The reference voltage supply, consisting of the power transformer, the main supply (printed circuit PC55), and the reference section (printed circuit PC61), is factory calibrated for an output of 500 volts dc ±.005%. Its stability is ±0.005% indefinitely after a 1-hour warm-up. The 500-volt output is adjustable to meet specifications. If the stability of the supply is not within specifications, then troubleshooting for a faulty component or replacing the supply is probably required.

b. Routine calibration of the Model 660 does not require a stability test of the reference voltage supply. However, a stability test is recommended if one of the components in the supply is replaced.

c. For the 24-hour test, the 500-volt output of the reference voltage supply is divided and compared to a 1.02-volt saturated standard cell using a sensitive null detector. Variations between the reference voltage supply and the standard cell are detected by the Model 150A and are recorded on a recorder. Refer to Figure 16 for the block diagram of the test circuit.

d. In using the test circuit, the following points are important.

1. Saturated standard cells, though extremely stable with time, have a high temperature coefficient and require a controlled environment during use. Therefore, the Weston Oil Bath, which is maintained at +35°C ±0.05°C, is used for the test. Unsaturated standard cells have a lower temperature coefficient, but they do not have the long term stability required for this test.

2. The resistor divider network is constructed from wire of the same spool for an extremely close temperature coefficient match (4 ppm, typically). Additional stability results when the resistors are immersed in an oil bath to hold the ambient temperature variations to ±0.01%.

e. Procedures for the Reference Voltage Supply Stability Test.

1. After the saturated standard cell and the resistor divider network are placed in the oil bath and connected to the circuit, allow sufficient time for the cell to stabilize at +35°C. (Consult Keithley Instruments for details.) Set the Model 660 controls as follows:

RANGE	500
Reference Voltage Dials	499.910
NULL	10 MV
POLARITY	OFF

Connect the resistor divider network across the Model 660's reference voltage supply, the positive side of the divider input to the wiper arm of the last Reference Voltage Switch, S3007, and the negative side of the divider to the LO terminal on the Model 660 front panel.

2. Connect the Model 150A and the recorder as shown in Figure 16. Set the Model 150A to the 3-volt range. Advance the Model 660 POLARITY Switch to + to put 500 volts across the divider. If the Model 150A reads two volts, the standard cell and the divider voltages are improperly connected in series. If the circuit is correct, the Model 150A will read zero. Increase the Model 150A's sensitivity to the 0.1-millivolt range. If it reads more than 20 microvolts, adjust the 10-kilohm potentiometer shunting the divider.

NOTE

Any adjustment of potentiometer R3035 requires all other ranges be calibrated.

3. After a 1-hour warm-up, the drift of the entire system should not exceed ±50 microvolts in 24 hours (Figure 17).

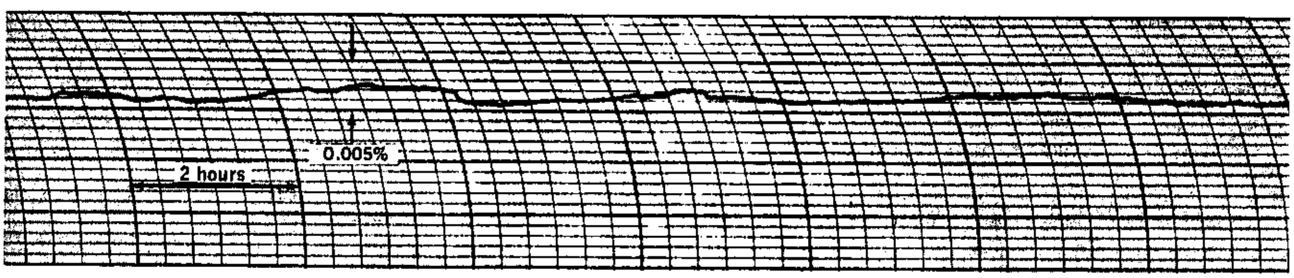


FIGURE 17. Stability Strip Chart for Model 660 Reference Voltage Supply. The chart covers over 15 hours. Fluctuations are well within ±0.005%. Note drift is non-cumulative. No compensation for variations of line voltage or other conditions was made.

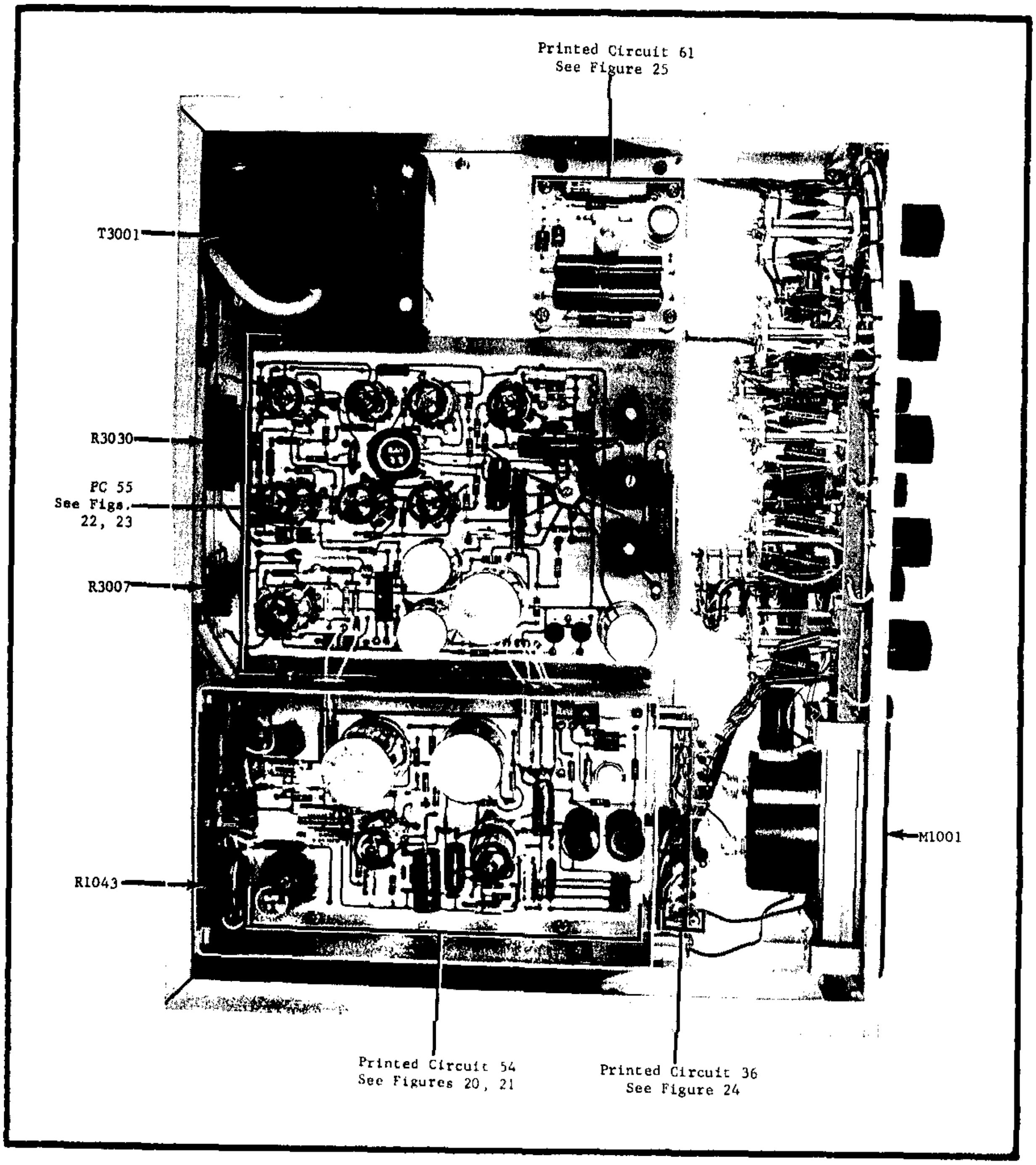


FIGURE 18. Top View of Model 660 Chassis. Location of components and printed circuits is shown above. Refer to Parts List for circuit designations.

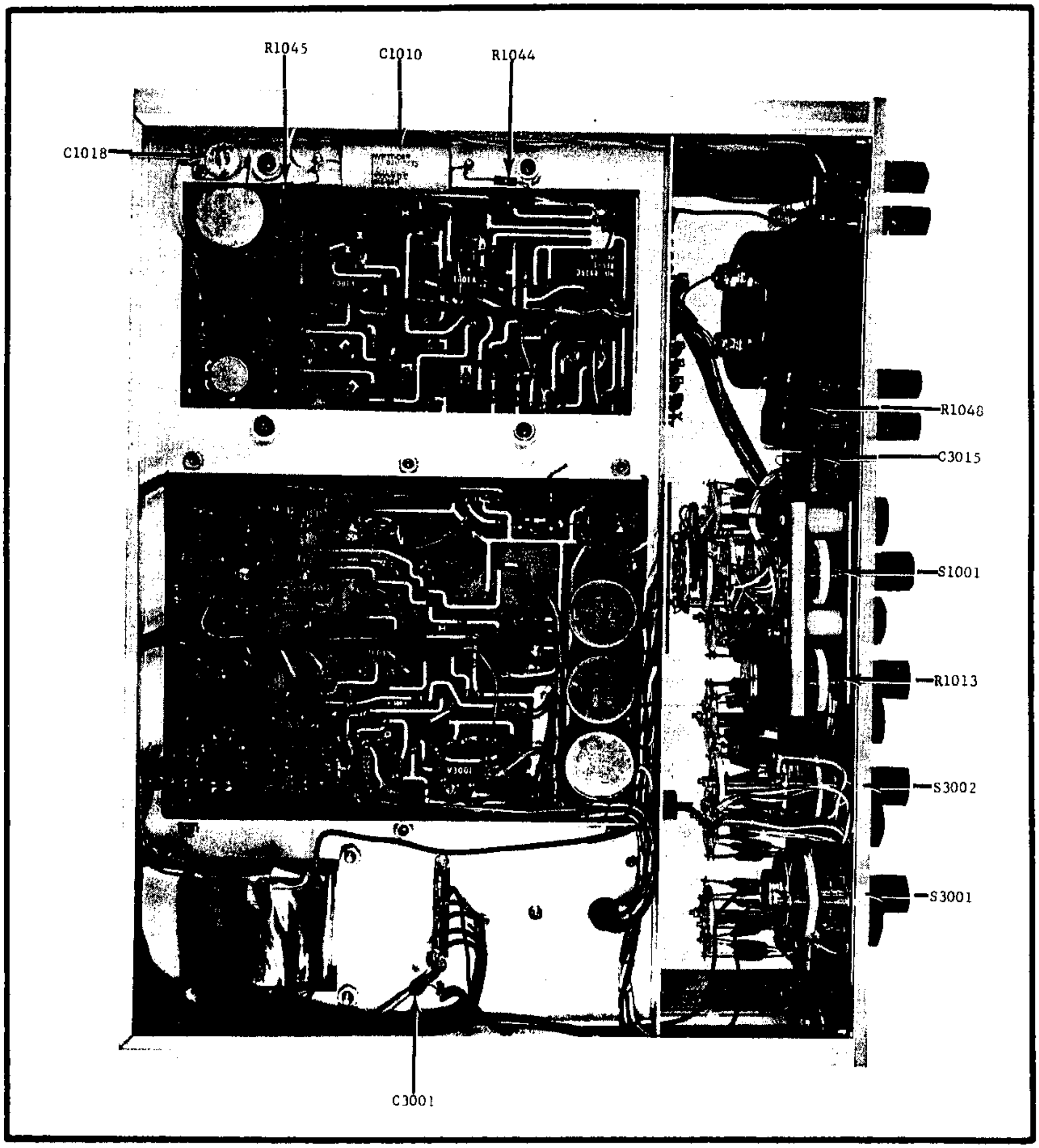


FIGURE 19. Bottom View of Model 660 Chassis. Location of components is shown in the figure. Refer to Parts List for circuit designations.

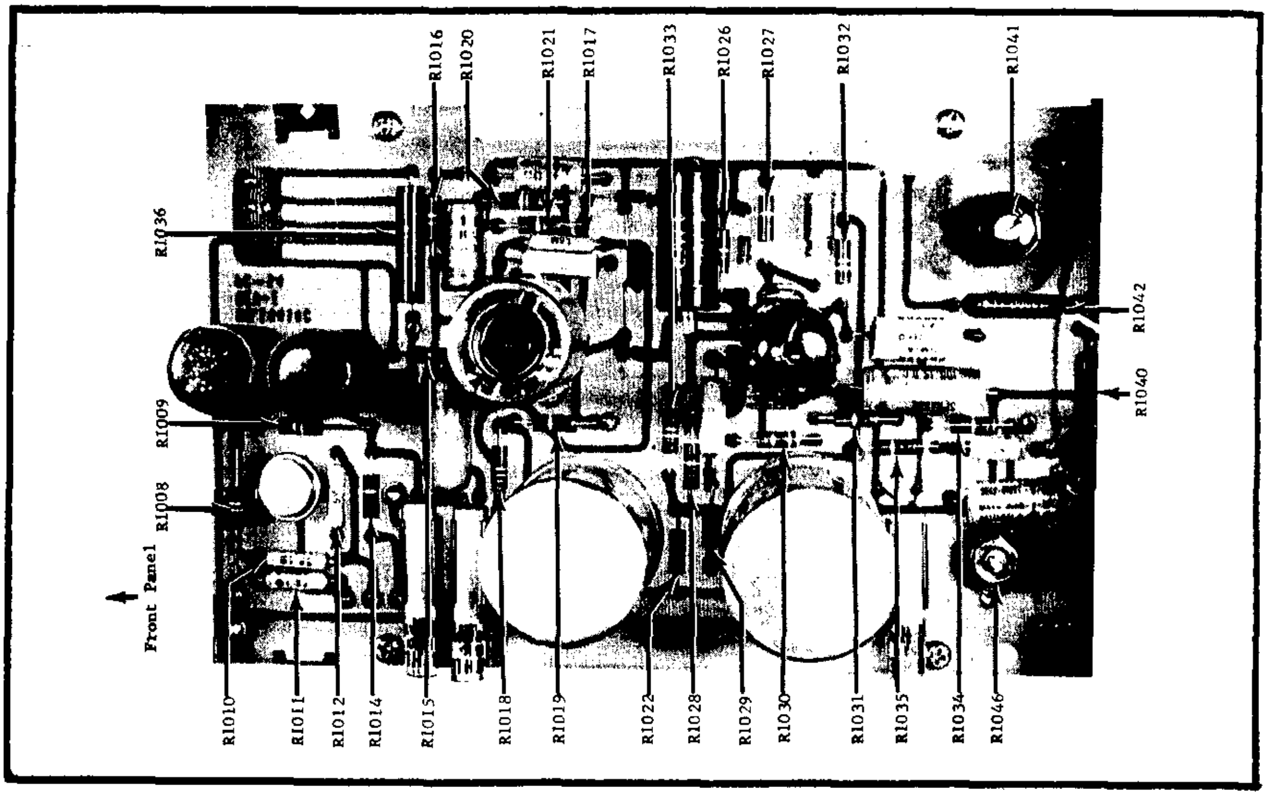


FIGURE 20. Resistor Locations on Printed Circuit 54. Other components are shown in Figure 21. Refer to Parts List for circuit designations.

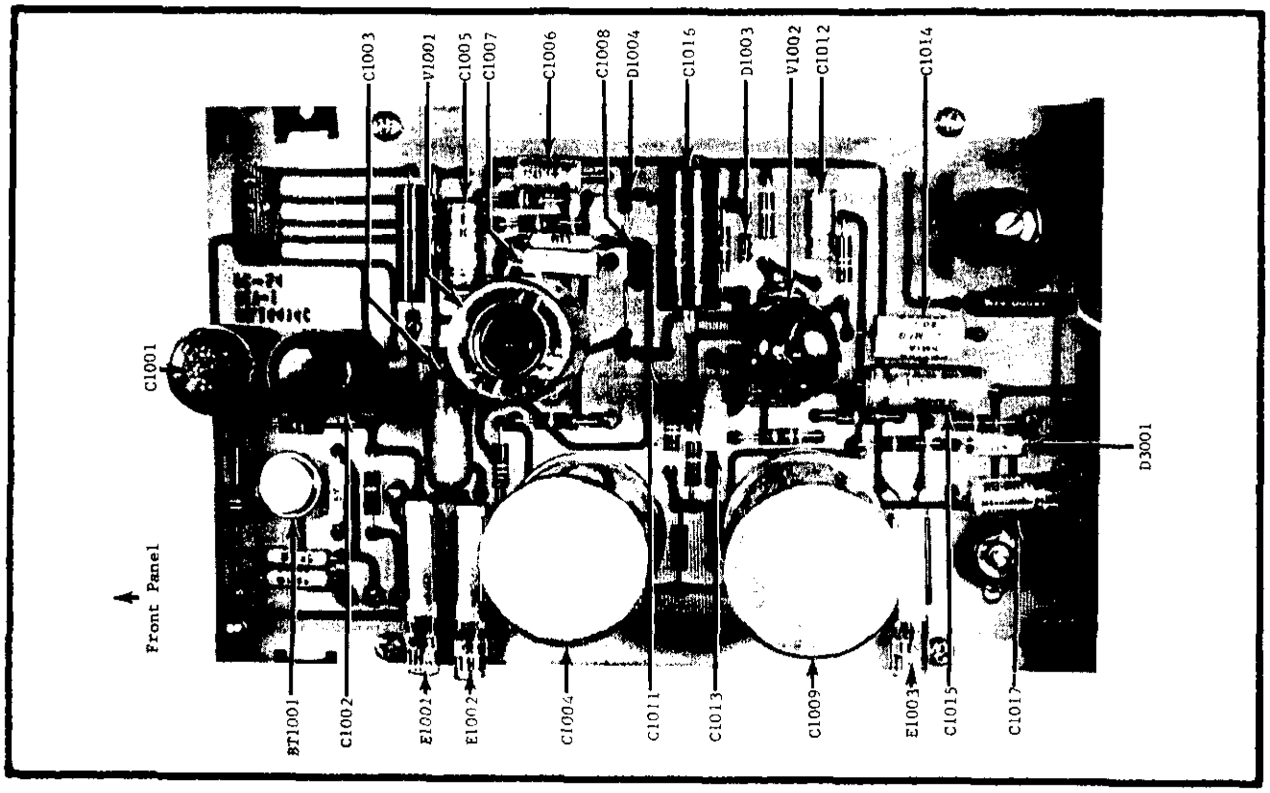


FIGURE 21. Battery, Capacitor, Modulator, Diode and Tube Locations on Printed Circuit 54. Resistors are shown in Figure 20.

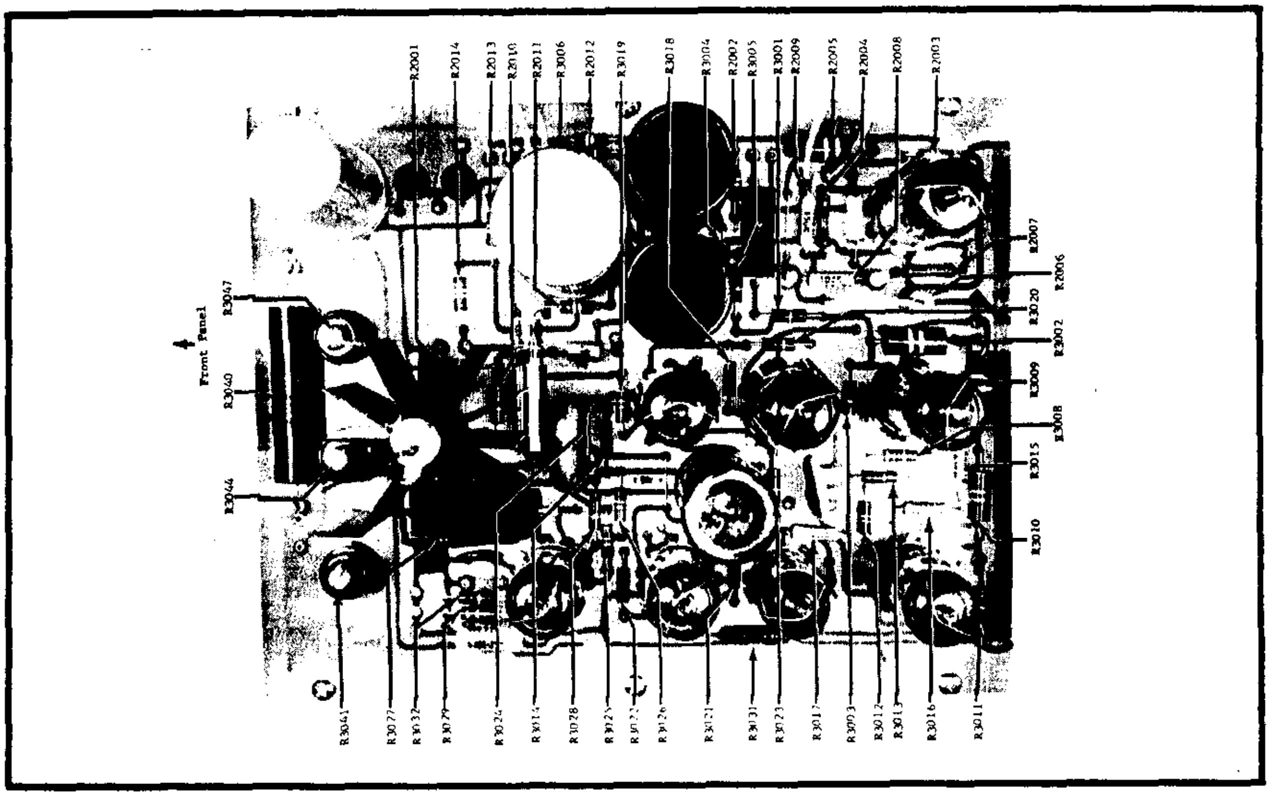


FIGURE 22. Resistor Locations on Printed Circuit 55. Other components are shown in Figure 23.

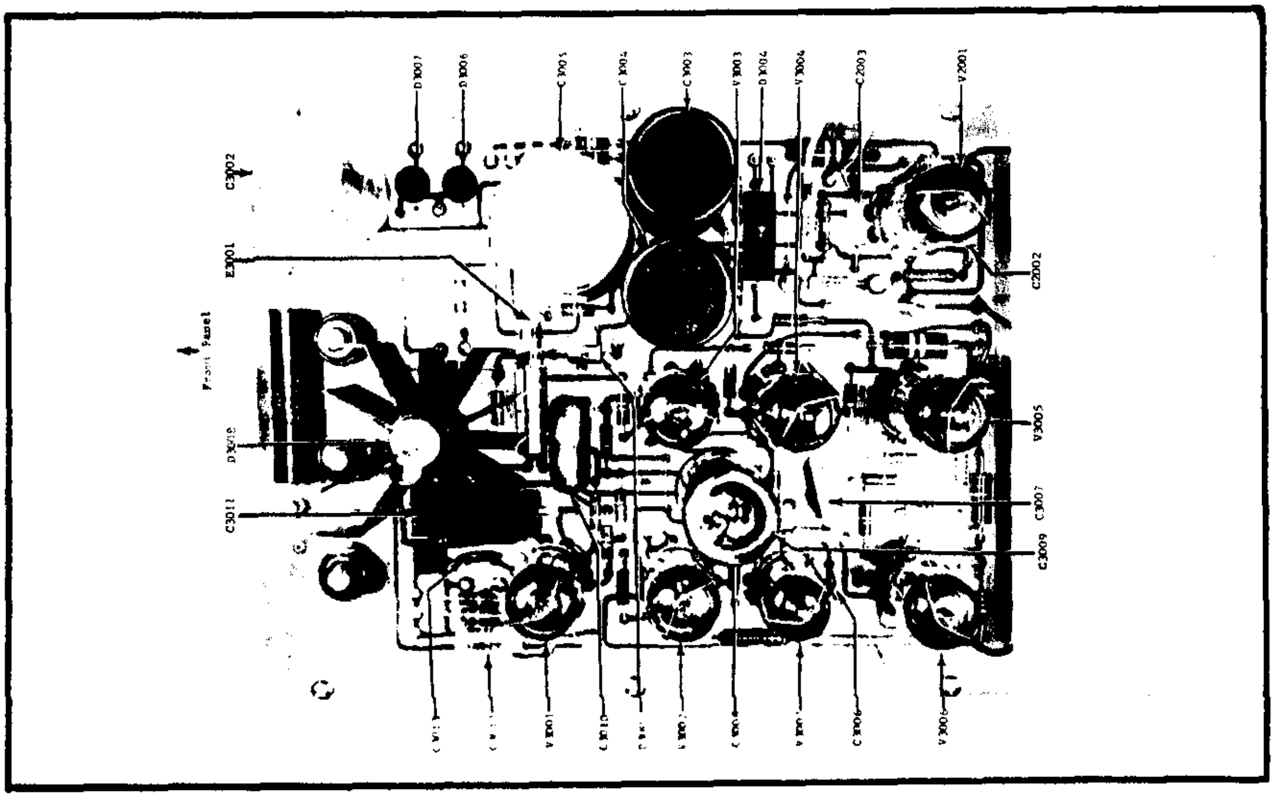


FIGURE 23. Capacitor, Modulator, Diode and Tube Locations on Printed Circuit 55. Resistors are shown in Figure 22.

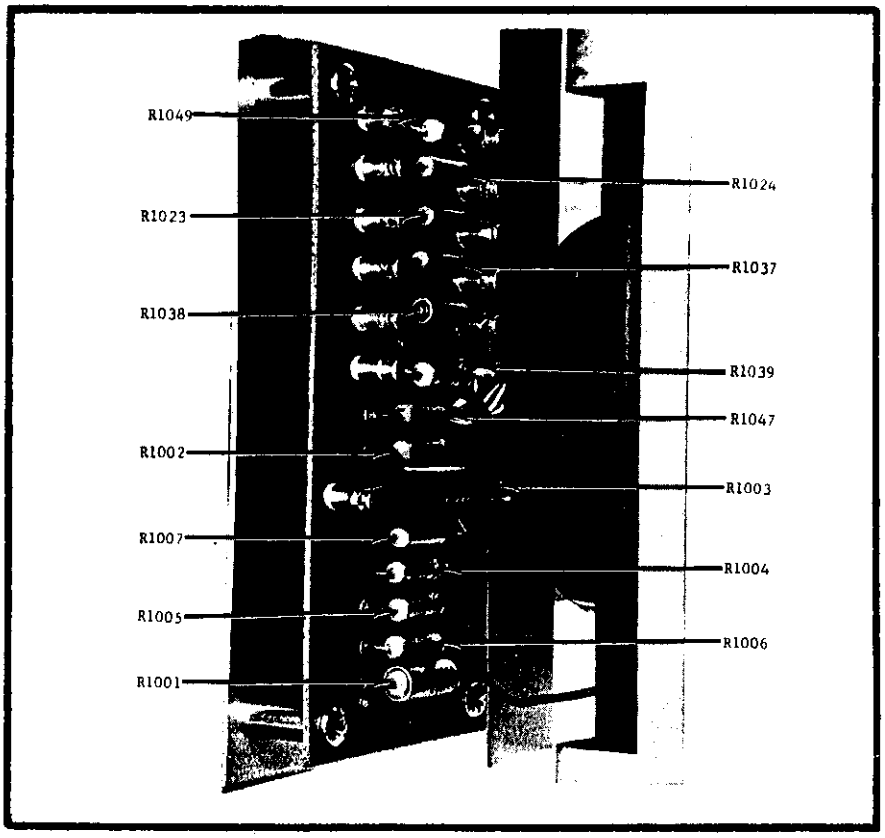


FIGURE 24. Resistor Locations on Printed Circuit 36. Resistor R1049 is not used in the Model 660.

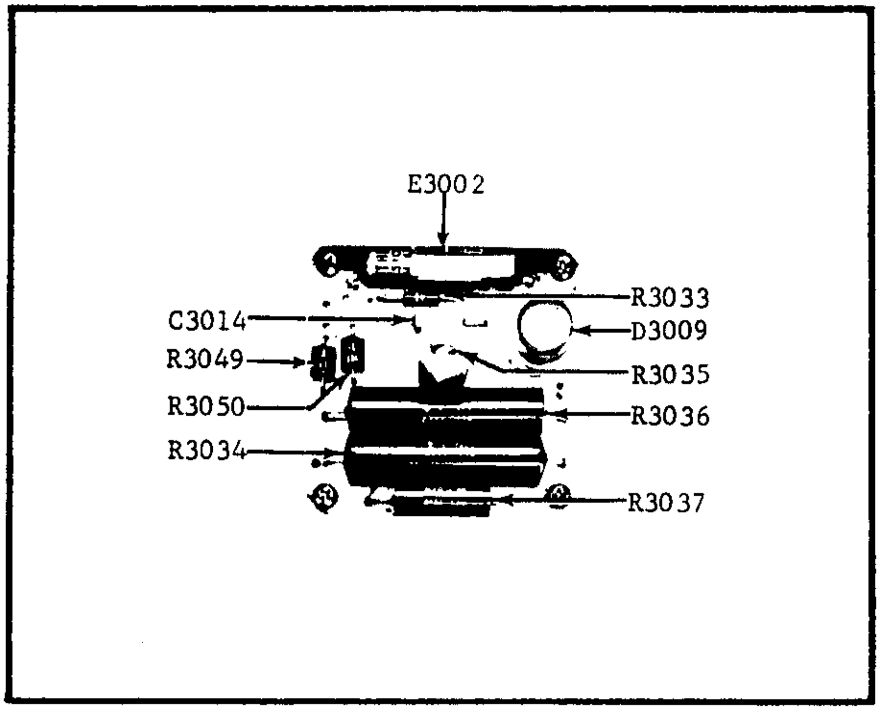


FIGURE 25. Component Locations on Printed Circuit 61. The values of resistors R3049 and R3050 are determined at factory calibration.

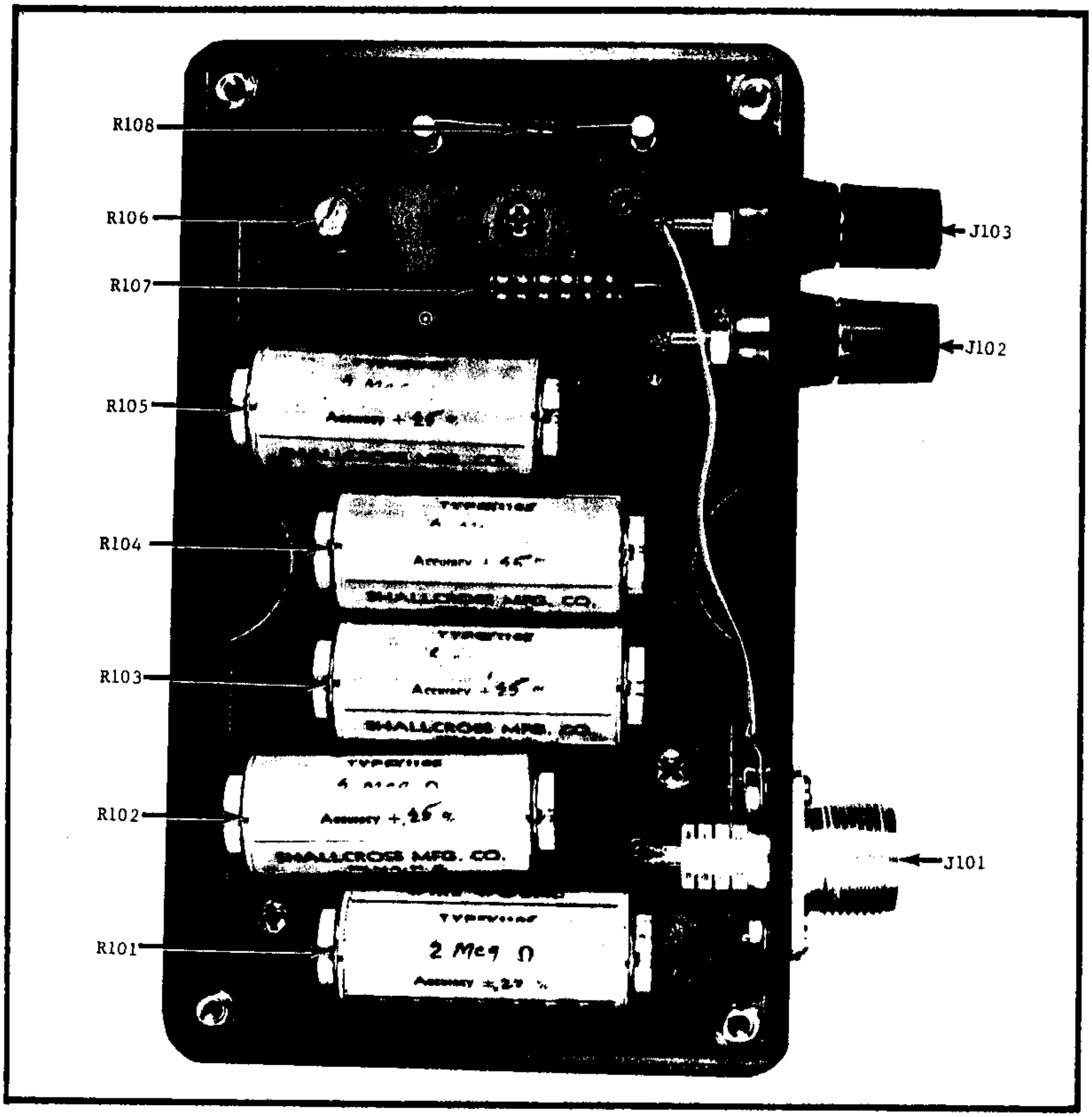


FIGURE 26. Model 6601A Component Locations.

SECTION 5. REPLACEABLE PARTS

5-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Models 660 and 6601A. The List gives the circuit designation, the part description, a suggested manufacturer and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 7.

5-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley distributor or the Sales Service Department, Keithley Instruments, Inc.

amp	ampere	MtF	Metal Film
CbVar	Carbon Variable	Mil. No.	Military Type Number
CerD	Ceramic, Disc	My	Mylar
Comp	Composition		
		Ω	ohm
DCb	Deposited Carbon		
		Poly	Polystyrene
EMC	Electrolytic, metal cased	p	pico (10^{-12})
ETB	Electrolytic, tubular		
ETT	Electrolytic, tantalum	μ	micro (10^{-6})
f	farad	v	volt
		Var	Variable
k	kilo (10^3)		
		w	watt
M or meg	mega (10^6) or megohms	WW	Wirewound
m	milli (10^{-3})	WWVar	Wirewound Variable
Mfg.	Manufacturer		

TABLE 6. Abbreviations and Symbols.

MODEL 660 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 15199H for circuit designations)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
C1001	1.0 μf	600 v	MtF	13050	C12-1.0M	21
C1002	1.0 μf	600 v	MtF	13050	C12-1.0M	21
C1003	.05 μf	600 v	My	56289	C62-.05M	21
C1004	80 μf	350 v	EMC	53021	C32-80M	21
C1005	200 μf	3 v	EMC	14655	C48-200M	21
C1006	10 μf	15 v	ETB	56289	C3-10M	21
C1007	.1 μf	600 v	MtF	02777	C47-0.1M	21
C1008	.05 μf	600 v	My	56289	C62-.05M	21
C1009	40/20 μf	450 v	EMC	56289	C36-40/20M	21
C1010	.047 μf	1000 v	Poly	96733	C67-.047M	19
C1011	.002 μf	600 v	CerD	72982	C22-.002M	21
C1012	10 μf	15 v	ETB	56289	C3-10M	21
C1013	.1 μf	600 v	MtF	02777	C47-0.1M	21
C1014	.25 μf	400 v	MtF	13050	C73-.25M	21
C1015	100 μf	15 v	ETB	56289	C3-100M	21
C1016	4 μf	250 v	EMC	14655	C27-4M	21
C1017	560 μf	6 v	ETT	12065	C95-560M	21
C1018	1.5/7 pf	500 v	Trimmer	71590	C76-1.5/7P	19
C2001	Not Used					
C2002	.022 μf	400 v	MtF	13050	C73-.022M	23
C2003	.022 μf	400 v	MtF	13050	C73-.022M	23
C3001	.001 μf	600 v	CerD	72982	C22-.001M	19
C3002	1000 μf	15 v	EMC	56289	C4-1000M	23
C3003	20 μf	450 v	EMC	37942	C36-20M	23
C3004	20 μf	450 v	EMC	37942	C36-20M	23
C3005	20/40 μf	450 v	EMC	56289	C36-40/20M	23
C3006	330 pf	600 v	CerD	72982	C22-330P	23
C3007	.01 μf	2000 v	CerD	56289	C88-.01M	23
C3008	.01 μf	600 v	CerD	72982	C22-.01M	23
C3009	1.0 μf	1000 v	MtF	13050	C14-1.0M	23
C3010	.05 μf	600 v	My	56289	C62-.05M	23
C3011	4 μf	250 v	EMC	14655	C27-4M	23
C3012	50 μf	6 v	EMC	56289	C17-50M	23
C3013	.0047 μf	600 v	CerD	01121	C22-.0047M	23
C3014	.022 μf	200 v	MtF	13050	C6-.022M	25
C3015	.05 μf	1600 v	My	14655	C87-.05M	19

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D1001	Not Used				
D1002	Not Used				
D1003	Silicon	1N645	01295	RF-14	21
D1004	Silicon	1N645	01295	RF-14	21
D3001	Silicon	1N3256	02735	RF-22	21
D3002	Not Used				
D3003	Not Used				
D3004	Silicon	1N2378	08520	RF-25	23
D3005	Silicon	1N3256	02735	RF-22	23
D3006	Silicon	1N1563A	04713	RF-19	23
D3007	Silicon	1N1563A	04713	RF-19	23
D3008	Zener	1N1601	81483	DZ-9	23
D3009	Zener	G3440	81483	DZ-8	25

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
BT1001	Battery, 1.32-volt Mercury (Mfg. No. PX13T2)	37942	BA-12	21
DS2001	Neon Pilot Light (Mfg. No. NE-2P)	08804	PL-2	
DS2002	Neon Pilot Light (Mfg. No. NE-2P)	08804	PL-2	
DS2003	Neon Pilot Light (Mfg. No. NE-2P)	08804	PL-2	
DS2004	Neon Pilot Light (Mfg. No. NE-2P)	08804	PL-2	
E1001	Light Modulator	80164	1510	21
E1002	Light Modulator	80164	1510	21
E1003	Light Modulator	80164	1511	21
E3001	Light Modulator	80164	1510	23
E3002	Light Modulator	80164	1510	25
F1001 (117v)	Fuse, 1.0 amp, 3 AG (Mfg. No. MDL)	71400	FU-10	3
F1001 (234v)	Fuse, 0.5 amp, 3 AG (Mfg. No. MDL)	71400	FU-6	3
---	Fuse Holder (Mfg. No. 34201)	75915	FH-3	
J1001	Binding Post, HI (Mfg. No. DF31RC)	58474	BP-8R	2
J1002	Binding Post, LO (Mfg. No. DF31BC)	58474	BP-8B	2
J1003	Binding Post, LO (Mfg. No. DF31BC)	58474	BP-8B	2
J1004	Binding Post, GND (Mfg. No. DF31BC)	58474	BP-8B	2
---	Shorting Link (Mfg. No. 938-L)	24655	BP-6	
---	Banana Jack, Red, NULL DETECTOR OUTPUT (Mfg. No. 108-745-1)	74970	BJ-3	3

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
---	Banana Jack, Black, NULL DETECTOR OUTPUT (Mfg. No. 108-745-2)	74970	BJ-4	3
M1001	Meter	80164	ME-38	18
P1001	Line Cord (Mfg. No. 4638-13)	82879	CO-2	3
---	Clamp	80164	CC-7	
S1001	Rotary Switch, Assembly less components, NULL	80164	15135B	19
---	Switch Assembly with components, NULL	80164	15136B	
---	Skirted Knob Assembly, Null Switch	80164	15110A	
S3001	Rotary Switch less components, POLARITY	80164	SW-119	19
---	Switch Assembly with components, POLARITY	80164	15138B	
---	Skirted Knob Assembly, Polarity Switch	80164	14838A	
S3002	Rotary Switch less components, RANGE	80164	SW-116	19
---	Switch Assembly with components, RANGE	80164	15137B	
---	Skirted Knob Assembly, Range Switch	80164	14838A	
---	Skirted Knob Assembly, Meter Zero Potentiometer	80164	14838A	
S3003	Switch Assembly with components, Readout	80164	14869B	2
---	Dial Assembly, 0-4 Readout	80164	14827A	
S3004	Switch Assembly with components, Readout	80164	15114B	2
---	Dial Assembly, 0-9 Readout	80164	14828A	
S3005	Switch Assembly with components, Readout	80164	15112B	2
---	Dial Assembly, 0-9 Readout	80164	14828A	
S3006	Switch Assembly with components, Readout	80164	15111B	2
---	Dial Assembly, 0-9 Readout	80164	14828A	
S3007	Switch Assembly with components, Readout	80164	15115B	2
---	Dial Assembly, 0-10 Readout	80164	14829A	
T3001	Transformer	80164	TR-50	18

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
R1001	10 MΩ	1%, 1/2 w	DCb	79727	R12-10M	24
R1002	1.25 MΩ	1%, 1/2 w	MtF	75042	R61-1.25M	24
R1003	100 kΩ	1%, 7 w	WW	91637	R43-100K	24
R1004	9010 Ω	1%, 1/2 w	DCb	79727	R12-9010	24
R1005	93 kΩ	1%, 1/2 w	DCb	79727	R12-93K	24

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
R1006	1.11 MΩ	1%, 1/2 w	DCb	79727	R12-1.11M	24
R1007	1 kΩ	1%, 1/2 w	DCb	79727	R12-1K	24
R1008	100 kΩ	10%, 1/2 w	Comp	01121	R1-100K	20
R1009	100 kΩ	10%, 1/2 w	Comp	01121	R1-100K	20
R1010	5 kΩ	1%, 1/2 w	DCb	79727	R12-5K	20
R1011	5 kΩ	1%, 1/2 w	DCb	79727	R12-5K	20
R1012	5 MΩ	1%, 1/2 w	DCb	79727	R12-5M	20
R1013	10 kΩ	10%, 2 w	WWVar	12697	RP27B-10K	19
R1014	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	20
R1015	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	20
R1016	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K	20
R1017	1.5 MΩ	10%, 1/2 w	Comp	75042	R61-1.5M	20
R1018	330 kΩ	10%, 1/2 w	Comp	01121	R1-330K	20
R1019	1.5 MΩ	10%, 1/2 w	Comp	01121	R1-1.5M	20
R1020	15 kΩ	10%, 1/2 w	Comp	01121	R1-15K	20
R1021	10 MΩ	10%, 1/2 w	Comp	01121	R1-10M	20
R1022	100 kΩ	10%, 1/2 w	Comp	01121	R1-100K	20
R1023	*100 kΩ	1%, 1/2 w	DCb	79727	R12-100K	24
R1024	*1 MΩ	1%, 1/2 w	DCb	79727	R12-1M	24
R1025	Not Used					
R1026	10 MΩ	10%, 1/2 w	Comp	01121	R1-10M	20
R1027	8.2 kΩ	10%, 1/2 w	Comp	01121	R1-8.2K	20
R1028	1.5 MΩ	10%, 1/2 w	Comp	01121	R1-1.5M	20
R1029	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	20
R1030	3.3 MΩ	10%, 1/2 w	Comp	01121	R1-3.3M	20
R1031	1.2 kΩ	10%, 1/2 w	Comp	01121	R1-1.2K	20
R1032	100 kΩ	10%, 1/2 w	Comp	01121	R1-100K	20
R1033	220 kΩ	10%, 1/2 w	Comp	01121	R1-220K	20
R1034	6.8 kΩ	10%, 1/2 w	Comp	01121	R1-6.8K	20
R1035	1 kΩ	10%, 1/2 w	Comp	01121	R1-1K	20
R1036	2 kΩ	1%, 1 w	WW	15909	R58-2K	20
R1037	*40 kΩ	1%, 1/2 w	DCb	79727	R12-40K	24
R1038	*400 kΩ	1%, 1/2 w	DCb	79727	R12-400K	24
R1039	4 MΩ	1%, 1/2 w	DCb	79727	R12-4M	24
R1040	80 Ω	1%, 1 w	WW	15909	R58-80	20
R1041	500 Ω	10%, 5 w	WWVar	71450	RP3-500	20
R1042	1.5 kΩ	1%, 1 w	WW	15909	R58-1.5K	20
R1043	200 Ω	10%, 2 w	WWVar	71450	RP22-200	18
R1044	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K	19
R1045	*10 MΩ	10%, 1/2 w	Comp	01121	R1-10M	19

*Nominal value, factory selected

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
R1046	1 kΩ	20%, 0.2 w	CbVar	71450	RP31-1K	20
R1047	113.6 kΩ	1%, 1/2 w	DCb	79727	R12-113.6K	24
R1048	100 MΩ	20%, 1/2 w	Comp	75042	R37-100M	19
R2001	180 kΩ	10%, 1/2 w	Comp	01121	R1-180K	22
R2002	150 kΩ	10%, 1/2 w	Comp	01121	R1-150K	22
R2003	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R2004	1 MΩ	1%, 1/2 w	DCb	79727	R12-1M	22
R2005	22 kΩ	10%, 2 w	Comp	01121	R3-22K	22
R2006	22 kΩ	10%, 2 w	Comp	01121	R3-22K	22
R2007	1 MΩ	1%, 1/2 w	DCb	79727	R12-1M	22
R2008	*52 kΩ	1%, 1/2 w	DCb	79727	R12-52K	22
R2009	150 kΩ	1%, 1/2 w	DCb	79727	R12-150K	22
R2010	180 kΩ	10%, 1/2 w	Comp	01121	R1-180K	22
R2011	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R2012	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R2013	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R2014	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R3001	220 Ω	10%, 1/2 w	Comp	01121	R1-220	22
R3002	100 kΩ	10%, 2 w	Comp	01121	R3-100K	22
R3003	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3004	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3005	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3006	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3007	5 Ω	3%, 25 w	WW	91637	R30-5	18
R3008	470 Ω	10%, 1/2 w	Comp	01121	R1-470	22
R3009	150 kΩ	10%, 2 w	Comp	01121	R3-150K	22
R3010	75 kΩ	10%, 1 w	Comp	01121	R2-75K	22
R3011	33 kΩ	10%, 1/2 w	Comp	01121	R1-33K	22
R3012	220 kΩ	10%, 1/2 w	Comp	01121	R1-220K	22
R3013	2.2 MΩ	10%, 1/2 w	Comp	01121	R1-2.2M	22
R3014	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3015	600 kΩ	1%, 1/2 w	DCb	79727	R12-600K	22
R3016	600 kΩ	1%, 1/2 w	DCb	79727	R12-600K	22
R3017	166.7 kΩ	1%, 1/2 w	DCb	79727	R12-166.7K	22
R3018	470 Ω	10%, 1/2 w	Comp	01121	R1-470	22
R3019	470 kΩ	10%, 1/2 w	Comp	01121	R1-470K	22
R3020	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3021	1 kΩ	10%, 1/2 w	Comp	01121	R1-1K	22
R3022	4.7 kΩ	10%, 1/2 w	Comp	01121	R1-4.7K	22
R3023	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3024	10 MΩ	10%, 1/2 w	Comp	01121	R1-10M	22
R3025	150 kΩ	10%, 1/2 w	Comp	01121	R1-150K	22

*Nominal value, factory selected

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
R3026	680 kΩ	10%, 1/2 w	Comp	01121	R1-680K	22
R3027	270 kΩ	10%, 1/2 w	Comp	01121	R1-270K	22
R3028	2.2 MΩ	10%, 1/2 w	Comp	01121	R1-2.2M	22
R3029	5.6 kΩ	10%, 1/2 w	Comp	01121	R1-5.6K	22
R3030	65.4 kΩ	0.1%, 50 w	WW	91637	R73-65.4K	18
R3031	100 Ω	0.1%, 1 w	WW	15909	R70-100	22
R3032	1 MΩ	10%, 1/2 w	Comp	01121	R1-1M	22
R3033	220 kΩ	10%, 1/2 w	Comp	01121	R1-220K	25
R3034	125 kΩ	0.1%, 2 w	WW	80164	15436A-125K	25
R3035	200 Ω	10%, 5 w	WWVar	71450	RP3-200	25
R3036	125 kΩ	0.1%, 2 w	WW	80164	15436A-125K	25
R3037	*4 kΩ	0.1%, 1/4 w	WW	80164	15436A-4K	25
R3038	200 Ω	1%, 1/2 w	DCb	79727	R12-200	
R3039	1.8 kΩ	1%, 1/2 w	DCb	79727	R12-1.8K	
R3040	250 kΩ	0.1%, 2 w	WW	80164	15432A-250K	22
R3041	1 kΩ	10%, 5 w	WWVar	71450	RP3-1K	22
R3042	32.32 kΩ	0.1%, 1/2 w	WW	80164	***	
R3043	18 kΩ	1%, 1/2 w	DCb	79727	R12-18K	
R3044	1 kΩ	10%, 5 w	WWVar	71450	RP3-1K	22
R3045	2.563 kΩ	0.1%, 1/2 w	WW	80164	***	
R3046	187 kΩ	1%, 1/2 w	DCb	79727	R12-187K	
R3047	1 kΩ	10%, 5 w	WWVar	71450	RP3-1K	22
R3048	250.9 Ω	0.1%, 1/2 w	WW	80164	***	
R3049	*	0.1%, 1/4 w	WW	01686	R95-*	25
R3050	*	0.1%, 1/4 w	WW	01686	R95-*	25
R3051 to R3056**	40 kΩ	0.02%, 1 w	WW	80164	**16318A-40K	
R3057 to R3067**	8 kΩ	0.02%, 1 w	WW	80164	**16318A-8K	
R3068 to R3078**	1.6 kΩ	0.05%, 1/2 w	WW	80164	**16318A-1.6K	
R3079 to R3089	320 Ω	0.1%, 1/2 w	WW	15909	R67-320	
R3090 to R3099	64 Ω	0.1%, 1/2 w	WW	15909	R67-64	

*Nominal value, factory selected

**These resistors supplied only as complete matched sets.

***Resistors designated R3042, R3045 and R3048 are supplied only as Resistor Set 14857A.

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V1001	12AX7	73445	EV-12AX7	21
V1002	6CM8	00011	EV-6CM8	21
V2001	12BH7	85599	EV-12BH7	23
V3001	12AX7	73445	EV-12AX7	23
V3002	12AX7	73445	EV-12AX7	23
V3003	12AX7	73445	EV-12AX7	23
V3004	12B4A	85599	EV-12B4A	23
V3005	12B4A	85599	EV-12B4A	23
V3006	12AX7	73445	EV-12AX7	23
V3007	0G3	73445	EV-0G3	23

MODEL 6601A REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 16321B for circuit designations)

TERMINALS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
J101	Receptacle, hn modified	80164	CS-79
--	Plug, hn, Mate of J101, Mil. No. UG-59A/U (Mfg. No. 7908)	91737	CS-80
J102	Binding Post, HI OUTPUT (Mfg. No. DF31RC)	58474	BP-8R
J103	Binding Post, LO OUTPUT (Mfg. No. DF31BC)	58474	BP-8B

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.	Fig. Ref.
R101	2 MΩ	0.1%, 1 w	WW	54294	R91-2M	26
R102	2 MΩ	0.1%, 1 w	WW	54294	R91-2M	26
R103	2 MΩ	0.1%, 1 w	WW	54294	R91-2M	26
R104	2 MΩ	0.1%, 1 w	WW	54294	R91-2M	26
R105	2 MΩ	0.1%, 1 w	WW	54294	R91-2M	26
R106	200 Ω	10%, 2 w	WWVar	71450	RP3-200	26
R107	100 kΩ	0.1%, 1 w	WW	54294	R90-100K	26
R108	*1 kΩ	1%, 1/2 w	Comp	00327	R12-1K	26

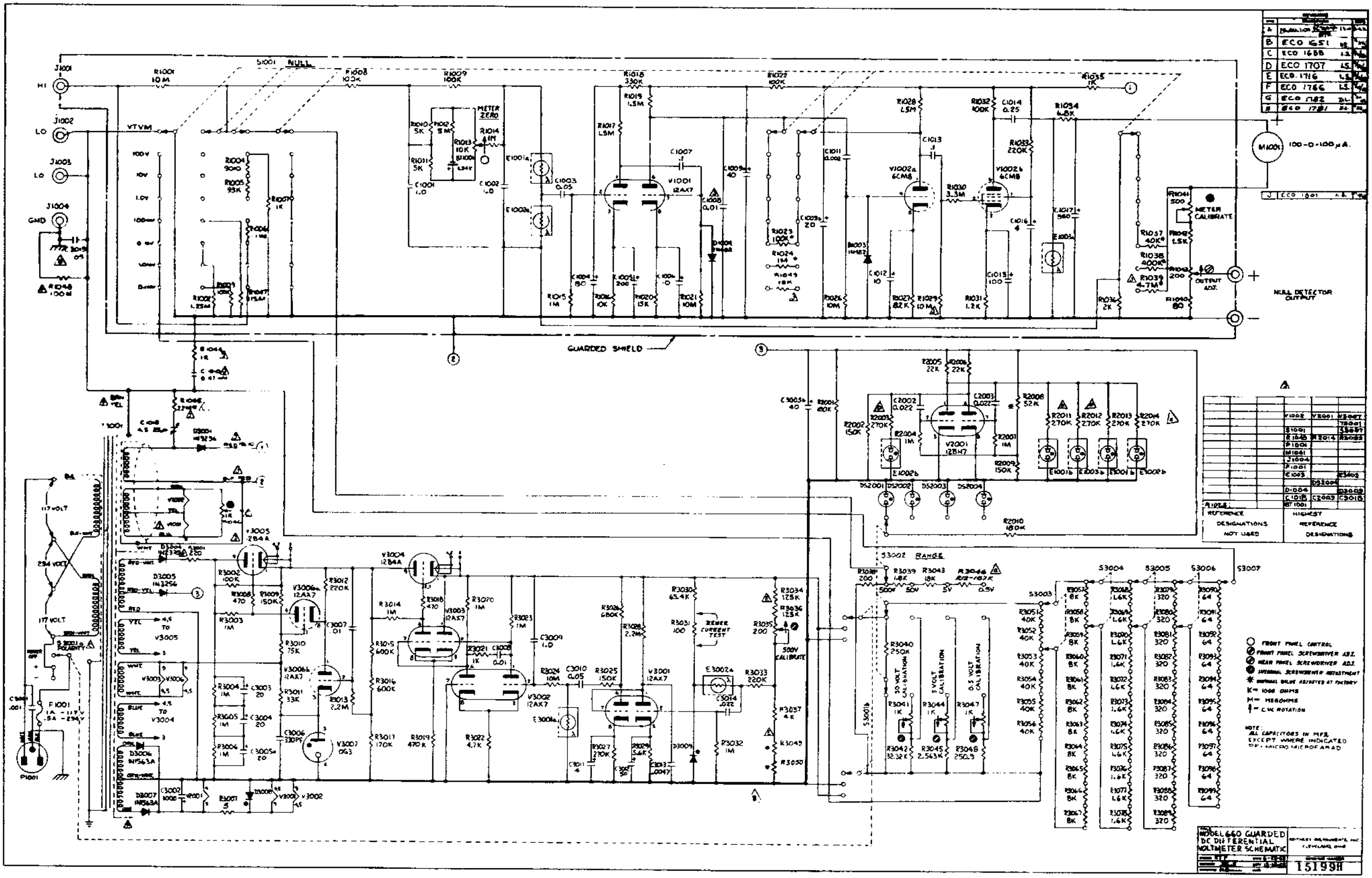
*Nominal value, factory selected

00011	Sylvania Electric Products, Inc. Buffalo Operations of Sylvania Electronic Systems Buffalo, N. Y.
00327	Welwyn International, Inc. Cleveland, Ohio
01121	Allen-Bradley Corp. Milwaukee, Wis.
01295	Texas Instruments, Inc. Semi-Conductor-Components Division Dallas, Texas
01686	RCL Electronics, Inc. Riverside, N. J.
02735	RCA Semiconductor and Materials Division of Radio Corp. of America Somerville, N. J.
02777	Hopkins Engineering Co. San Fernando, Calif.
04713	Motorola, Inc. Semiconductor Products Division Phoenix, Arizona
08520	Electronic Devices, Inc. North Ridgeville, Ohio
08804	Lamp Metals and Components Department G. E. Co. Cleveland, Ohio
12065	Transitron Electronic Corp. East Boston, Mass.
13050	Potter Co. Wesson, Miss.
14655	Cornell-Dubilier Electric Corp. Newark, N. J.
15909	Daven Co. Livingston, N. J.
24655	General Radio Co. West Concord, Mass.
37942	Mallory, P. R., and Co., Inc. Indianapolis, Ind.
53021	Sangamo Electric Co. Springfield, Ill.
54294	Shallcross Mfg. Co. Selma, N. C.
56289	Sprague Electric Co. North Adams, Mass
58474	Superior Electric Co., The Bristol, Conn.
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.
71450	CTS Corp. Elkhart, Ind.
71590	Centralab Division of Globe-Union, Inc. Milwaukee, Wis.
72982	Gudeman Co. Chicago, Ill.
73445	Amperex Electronic Co. Division of North American Philips Co., Inc. Hicksville, N. Y.
74970	Johnson, E. F., Co. Waseca, Minn.
75042	International Resistance Co. Philadelphia, Pa.
75915	Littelfuse, Inc. Des Plaines, Ill.
79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
80164	Keithley Instruments, Inc. Cleveland, Ohio
81483	International Rectifier Corp. El Segundo, Calif.
82879	Royal Electric Corp. Pawtucket, R. I.
85599	Tube Department G. E. Co. Schenectady, N. Y.

TABLE 7 (Sheet 1). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

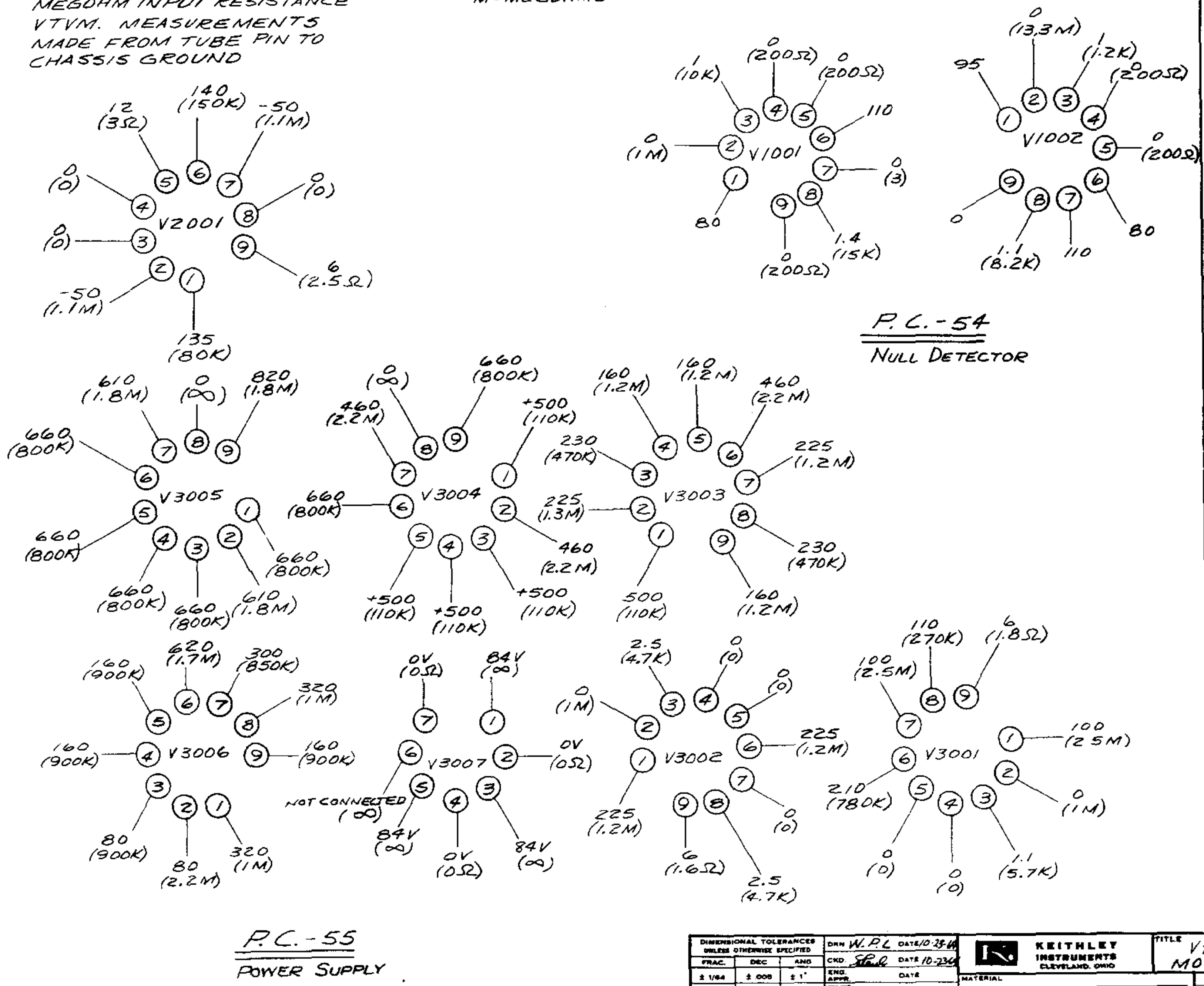
91637	Dale Electronics, Inc. Columbus, Nebr.	96733	San Fernando Electric Mfg. Co. San Fernando, Calif.
91737	Gremar Mfg. Co., Inc Wakefield, Mass.		

TABLE 7 (Sheet 2). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)


MODEL 660 GUARDED
DC DIFFERENTIAL
VOLTMETER SCHEMATIC
15199H
GUARDED SHIELD
NULL DETECTOR OUTPUT
METER CALIBRATE
METER ZERO
OUTPUT ADJ.
100-0-100 μA.
NULL
VTVM
RANGE
500V CALIBRATE
ZENER CURRENT TEST
50 VOLT CALIBRATION
5 VOLT CALIBRATION
0.5 VOLT CALIBRATION
HI
LO
LO
GND
117 VOLT
234 VOLT
117 VOLT
FRONT PANEL CONTROL
K= 1000 OHMS
M= MEGOHMS
NOTE:
ALL CAPACITORS IN MFD.
EXCEPT WHERE INDICATED
REFERENCE DESIGNATIONS NOT USED
HIGHEST REFERENCE DESIGNATIONS

READINGS TAKEN WITH 11 MEGOHM INPUT RESISTANCE VTVM. MEASUREMENTS MADE FROM TUBE PIN TO CHASSIS GROUND

K=1000
M=MEGOHMS



REVISIONS			
LTR	ECO No.	APPR	DATE
A			

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED				
FRAC.	DEC	ANG	DRN W.P.L	DATE 10-23-64
± 1/64	± .005	± 1°	CKD. [signature]	DATE 10-23-64
			ENG. APPR.	DATE
			PILOT RELEASE	DATE
DO NOT SCALE			PROD. RELEASE	DATE

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

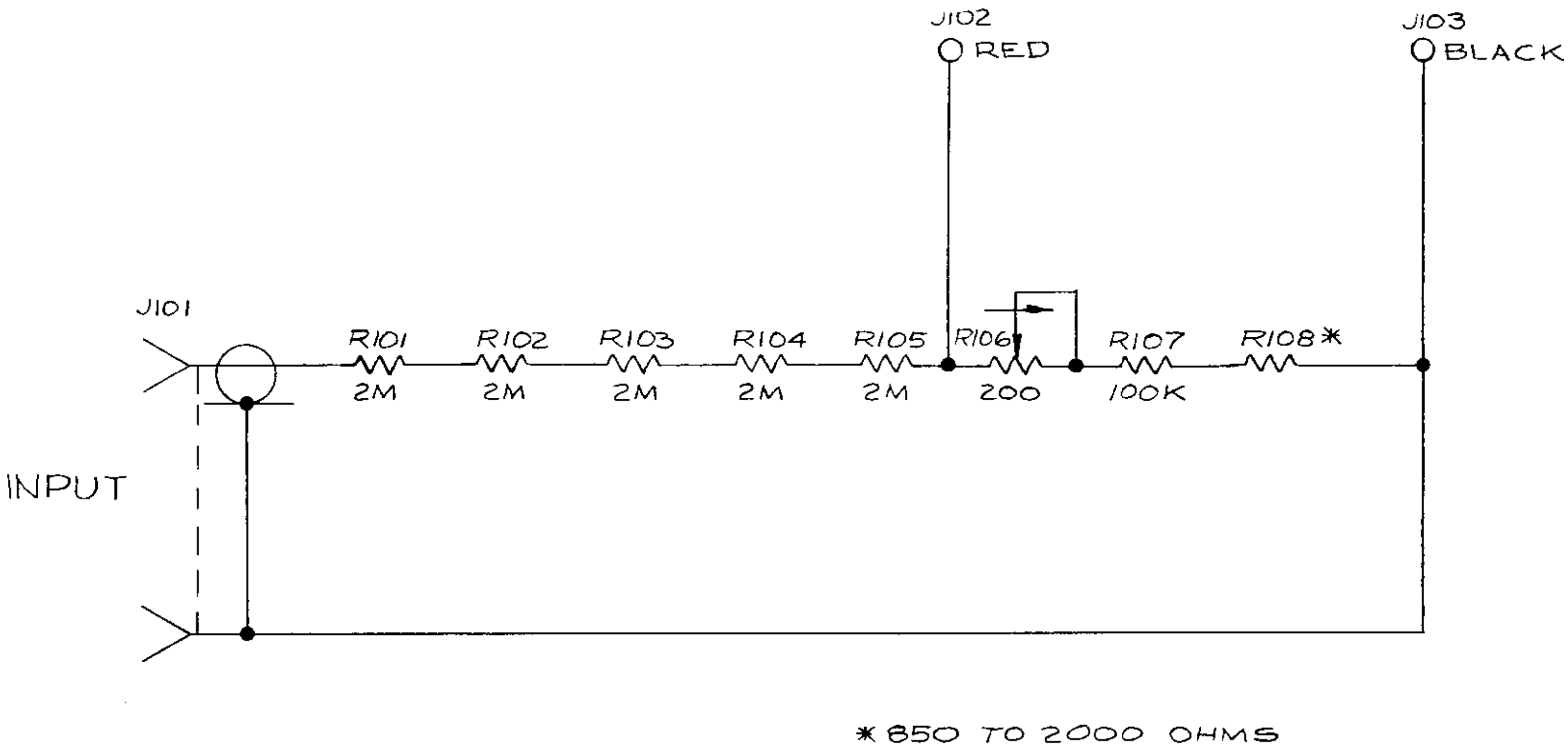
MATERIAL

FINISH

USED ON: MODEL 660 | NEXT ASSEMBLY | QUAN

TITLE: V&R CHART MODEL 660

PART NUMBER: 18268C



REVISIONS			
LTR.	ECO No.	APPR.	DATE
A			

MODEL	NEXT ASSEMBLY	QUAN
6601A	16267M	1

USED ON

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED		
FRAC.	DEC.	ANG.
± 1/64	± .005	± 1°

DO NOT SCALE

DRN. C.F.M. DATE 042963
CKD. [signature] DATE 4.29.63
ENG. APPR. [signature] DATE 4.29.63
PILOT RELEASE [signature] DATE 4.29.63
PROD. RELEASE DATE

KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

MATERIAL

FINISH

TITLE
SCHEMATIC, INPUT DIVIDER PROBE

PART NUMBER
16321B