

INSTRUCTION MANUAL  
MODELS 164, 164TT  
DIGITAL MULTIMETER

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## CONTENTS

| <u>Section</u>                  | <u>Page</u> |
|---------------------------------|-------------|
| SPECIFICATIONS -----            | iv          |
| 1. GENERAL INFORMATION -----    | 1           |
| 2. OPERATING INSTRUCTIONS ----- | 4           |
| 3. THEORY OF OPERATION -----    | 15          |
| 4. ACCESSORIES -----            | 22          |
| 5. SERVICING -----              | 24          |
| 6. CALIBRATION -----            | 30          |
| 7. REPLACEABLE PARTS -----      | 35          |
| SCHEMATICS -----                | 61          |

## ILLUSTRATIONS

| Figure No. | Title                                       | Page No. |
|------------|---|----------|
| 1          | Front Panel                                 | 1        |
| 2          | Front Panel Controls & Terminals, Model 164 | 3        |
| 3          | Rear Panel Controls & Terminals, Model 164  | 3        |
| 4          | Four-Terminal Resistance Measurements       | 8        |
| 5          | Timing Diagram for A/D Converter            | 12       |
| 6          | Typical Open-Collector Output               | 13       |
| 7          | Pin Designations For Printer Output         | 13       |
| 8          | Front & Rear Panels, Model 164TT            | 14       |
| 9          | Multimeter Block Diagram                    | 15       |
| 10         | Analog Amplifier Block Diagram              | 16       |
| 11         | A/D Converter Block Diagram                 | 18       |
| 12         | Integrator Simplified Diagram               | 19       |
| 13         | RANGE Knob Assembly                         | 25       |
| 14         | Chassis Assembly                            | 25       |
| 15         | Servicing of Chassis                        | 26       |
| 16         | PC Board Locations                          | 27       |
| 17         | Side View of Chassis                        | 28       |
| 18         | Chassis, Bottom View                        | 31       |
| 19         | Calibration Controls                        | 32       |
| 20         | Calibration of Milliohm Current Source      | 34       |
| 21         | Top Cover Assembly                          | 37       |
| 22         | Bottom Cover Assembly                       | 37       |
| 23         | Component Layout, PC-254                    | 50       |
| 24         | Component Layout, PC-251                    | 51       |
| 25         | Component Layout, PC-248                    | 51       |
| 26         | Component Layout, PC-255                    | 52       |
| 27         | Component Layout, PC-250                    | 52       |
| 28         | Component Layout, PC-287                    | 53       |
| 29         | Component Layout, PC-348                    | 54       |

## SPECIFICATIONS

calibrated at  $25^{\circ}\text{C} \pm 3^{\circ}\text{C}$ **AS A DC VOLTMETER**

**RANGE:**  $\pm 1$  microvolt per digit (1mV full range) to  $\pm 1000$  volts full range in seven decade ranges. 100% overranging to 1999 on all except the 1000-volt range.

**ACCURACY:**  $\pm(0.1\%$  of reading + 1 digit) on all ranges.

**INPUT RESISTANCE:** 10 megohms on the 10-millivolt and higher ranges, 1 megohm on the 1-millivolt range.

**AC REJECTION:**

**NMRR:** Greater than 80 dB above on digit for a voltage of line frequency or twice line frequency on the most sensitive range, decreasing to 60 dB on the 100-millivolt and higher ranges. 1000 volts peak-to-peak maximum.

**CMRR:** Greater than 120 dB above one digit at dc and 40 to 100 Hz ac. 500 volts dc, 100 volts peak-to-peak ac maximum.

**SETTLING TIME:** Less than 2 seconds to rated accuracy.

**MAXIMUM OVERLOAD:** 1000 volts continuous input on 1-volt to 1000-volt ranges, 1000 volts momentary, 300 volts continuous on lower ranges.

**AS A DC AMMETER**

**RANGE:**  $\pm 0.1$  nanoampere per digit (0.1 $\mu$ A full range) to  $\pm 1$  ampere full range in eight decade ranges. 100% overranging to 1999 on all ranges.

**ACCURACY:**  $\pm(0.2\%$  of reading + 1 digit) on the 100-nanoampere to 10-milliamperer ranges,  $\pm(0.3\%$  of reading + 1 digit) on the 0.1 and 1-ampere ranges.

**INPUT RESISTANCE:** 100 kilohms on the 0.1-microampere range, decreasing to 0.1 ohm on the 100-milliamperer and 1-ampere ranges.

**NMRR:** 60 dB above one digit for a current of line frequency or twice line frequency.

**MAXIMUM OVERLOAD:** 50 times full scale continuous on all ranges up to a maximum of 3 amperes.

**AS AN OHMMETER**

**RANGE:** 0.1 ohm per digit (100 $\Omega$  full range) to 1000 megohms full range in eight decade ranges. 100% overranging to 1999 on all ranges.

**ACCURACY:**  $\pm(0.3\%$  of reading + 1 digit + 0.1 ohm) on the 100-ohm to 1 megohm ranges, decreasing to  $\pm 10\%$  on the 100-megohm range. The 1000-megohm range is intended for relative resistance measurements only ( $\pm 50\%$ ).

**VOLTAGE ACROSS UNKNOWN:** 100 millivolts at full scale, 1.5 volts maximum into an open circuit.

**MAXIMUM OVERLOAD:** 20 volts momentary, 1 volt continuous.

**AS A MILLIOHMETER**

**RANGE:** 10 microhms per digit (10 milliohms full range) to 200 ohms in five decade ranges. 100% overranging to 1999 on all ranges.

**ACCURACY (OPERATE MODE):**  $\pm(0.3\%$  of reading + 0.1% of range).

**METHOD:** 4-terminal constant current.

**VOLTAGE ACROSS UNKNOWN:**

**VOLT-LIMIT MODE:** 1 millivolt at full range, 20 millivolts open circuit.

**OPERATE MODE:** 1 millivolt at full range, 15 V open circuit.

**MAXIMUM ALLOWABLE LEAD RESISTANCE:** 20 ohms current lead resistance; 100 ohms voltage lead resistance.

**MAXIMUM ALLOWABLE INPUT:** 20 volts momentary, 1 volt continuous.

**TRIP (164TT only)**

Two trips; one high limit and one low limit on all functions.

**LEVEL:**  $-200\%$  to  $+200\%$  of full range for each trip.

**SET:**  $\pm 0.1\%$  of full range read on 3-1/2 digit display.

**INDICATION:** Front panel lamps.

**MODE:** Non-latching.

**REPEATABILITY:**  $\pm 0.1\%$  of full range.

**REFERENCE STABILITY:**  $\pm 0.1\%$  per  $^{\circ}\text{C}$  of full range. (See GENERAL for instrument stability.)

**HYSTERESIS:** Less than 0.6% of full range.

**RESPONSE SPEED:** Negligible with respect to instrument settling time.

**OUTPUT:** One set of form A contacts per trip; 10 volt-amperes, 0.5 ampere, 120 volts rms ac maximum, 6 watts, 0.5 ampere, 12 volts dc maximum.

**CONTROLS:** Front panel push-button-lamp trip indicators; front panel trip level adjustments.

**CONNECTORS:** Rear panel barrier strip for trip outputs.

**GENERAL**

**ANALOG OUTPUT:**  $\pm 1$  volt dc at up to 1 milliamperer for full scale input, 100% overranging on all ranges except the 1000-volt range.

**POLARITY:** Automatic.

**ZERO STABILITY:**  $\pm 0.3$  microvolt/ $^{\circ}\text{C}$ ,  $\pm 2$  microvolts/day after 1-hour warm-up.

**OFFSET CURRENT:** Typically less than 10 picoamperes.

**ACCURACY STABILITY:**  $\pm 0.01\%$ / $^{\circ}\text{C}$  ( $\pm 0.06\%$ / $^{\circ}\text{C}$  on ohms;  $\pm 0.02\%$ / $^{\circ}\text{C}$  on milliohms). Accuracy (after a 30-minute warm-up) is maintained for at least 6 months.

**DISPLAY:** 3 digits plus 1 overrange digit; polarity and overload indication; 2 readings per second.

**ISOLATION:** Circuit ground to chassis ground: greater than 100 megohms shunted by less than 0.02 microfarad. Circuit ground may be floated up to  $\pm 500$  volts with respect to chassis ground in the voltage and current modes.

**POWER:** 105-125 or 210-250 V (switch selected), 50-60Hz, 25 W.

**DIMENSIONS, WEIGHT:** 6-1/2 in. high x 9 in. wide x 10-3/4 in. deep (160 x 225 x 270 mm). Net weight, 10 pounds (4.5 kg).

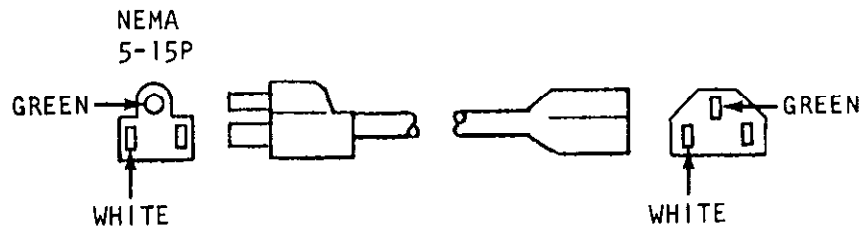
**ACCESSORIES SUPPLIED:** Model 1641 Kelvin Test Lead Set.



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CAUTION

To ensure the integrity of the chassis to earth ground connection only a Keithley part number C0-7 line cord should be used for replacement. If a different line cord is used ensure that the wiring polarity is the same as shown in the following diagram.



Keithley Models to which this warning applies: 160, 163, 164, 165, 171, 180, 190, 227, 616, 6162, 702, 780

## SECTION 1. GENERAL INFORMATION

### 1-1. GENERAL.

a. DMM Mode. The Model 164 serves as a line operated 3-1/2 digit multimeter having wide ranges for measurement of voltage, current, and resistance. In the DMM mode, the 164 offers seven dc voltage ranges (from 1 microvolt per digit to 1000 volts), eight dc current ranges (from 0.1 nanoampere per digit to 2 amperes), and eight resistance ranges (from 0.1 ohm per digit to 2000 megohms).

b. Milliohm-meter-Ohmmeter Mode. The Model 164 also provides five additional resistance ranges for measurements requiring resolution to 10 microhms per digit. Four-terminal measurement technique minimizes the effects of lead and contact resistance in low-resistance measurements.

c. Electronic High/Low Limit Trip Option. The Model 164TT provides independent electronic trip circuits for high and low limits. The trips are non-latching. In addition to front panel indicator lamps, the Model 164TT offers rear panel relay contacts.

d. Digital Output Accessory. The Model 1602 is a field-installable BCD output which may be used to interface the Model 164 with a digital printer or computer.

e. AC/DC Probe Accessory. The Model 1601 AC/DC Probe permits ac voltage measurements to 250 volts rms over a span of 45 Hz to 45kHz. A probe mounted switch enables selection of ac or dc operation without disconnecting the probe.

### 1-2. APPLICATIONS.

The Model 164 is a general purpose instrument - used in Basic Research, Electronics Development, and Process Control.

a. In the Research Lab - When used with a suitable probe, transducer, or electronic circuit, Model 164 can be used for digital indication of volts, amps, or ohms, or through conversion, any physical parameter such as temperature, pressure, and rpm.

b. In Electronics Development Activity - Useable for basic electrical measurements of voltage, current, or resistance.

c. In Process Control Activity - Adaptable for OEM equipment where repetitive measurements are needed with analog or digital printout. Optional electronic trips permit level control capability.

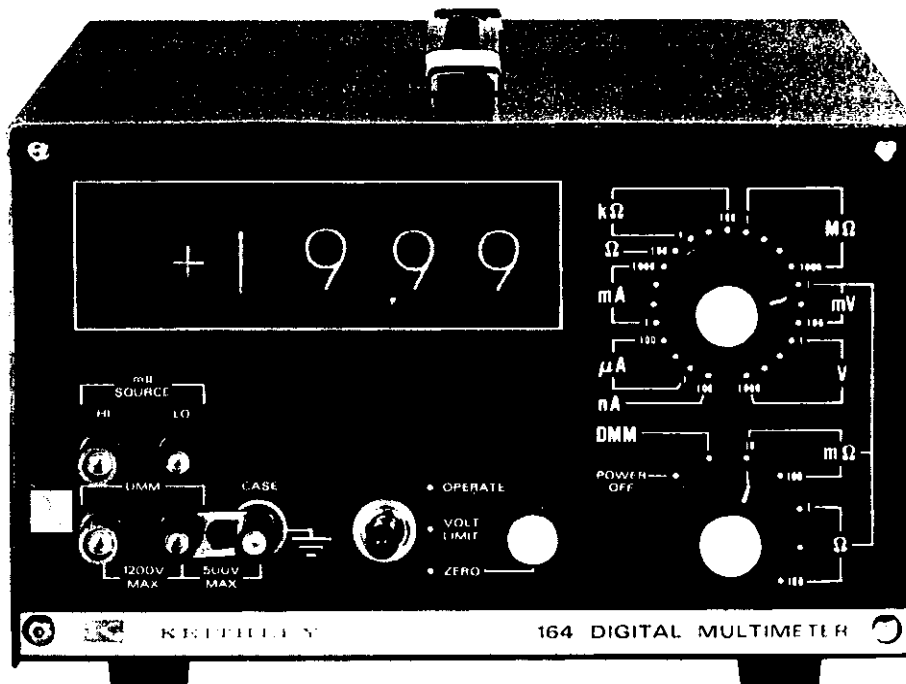


FIGURE 1. Front Panel.

TABLE 1-1.  
Front Panel Controls and Terminals

| Control                                      | Functional Description  | Paragraph |
|--|---|-----------|
| <u>RANGE SWITCH</u>                          | Sets the full range sensitivity and parameter to be measured (volts, amperes, or ohms in the DMM mode, or milliohms/ohms in the Milliohm-meter mode).   | 2-2b      |
| mV, V  | Provides seven voltage ranges from 1 millivolt full range to 1000 volts full range.   |           |
| nA, $\mu$ A, mA                              | Provides eight current ranges from 100 nanoampere full range to 1000 milliamperes full range.   |           |
| $\Omega$ , k $\Omega$ , M $\Omega$           | Provides eight resistance ranges from 100 ohms full range to 1000 meg-ohms full range.  |           |
| <u>MODE SWITCH</u>                           |   | 2-2a      |
| Power  | Controls ac line power to instrument  |           |
| DMM  | Sets instrument for DMM mode of operation   |           |
| m $\Omega$ , $\Omega$                        | Sets instrument for any one of five resistance ranges from 10 milliohm full range to 100 ohms full range. (Milliohm current source terminals must be connected to unknown.)                                       |           |
| <u>SOURCE SWITCH</u>                         |   | 2-2c      |
| Operate                                      | Sets instrument for normal milliohmmeter operation (non-voltage limit mode).  |           |
| Volt Limit                                   | Sets instrument for volt-limit operation such that maximum open-circuit voltage is limited to 20 millivolts. In this mode, measurement accuracy is degraded depending on the resistance to be measured. See 2-9e. | 2-9e      |
| Zero   | Sets instrument for compensating thermal emfs in the milliohmmeter mode. (Used in conjunction with the Zero control.)   |           |
| <u>ZERO CONTROL</u>                          | Permits adjustment of display zero.   | 2-2d      |
| <u>m<math>\Omega</math> SOURCE TERMINALS</u> |   | 2-1a      |
| Red  | Current source high (positive polarity)   |           |
| Black  | Current Source low (negative polarity)  |           |
| <u>DMM TERMINALS</u>                         |   | 2-1a      |
| Red  | Input high  |           |
| Black  | Input low   |           |
| Green  | Case ground   |           |

TABLE 1-2.  
Rear Panel Controls and Terminals

| Control                   | Functional Description  | Paragraph |
|---------------------------|---|-----------|
| Line Switch<br>(117-234V) | Sets instrument for either 117 or 234 volt line power.                  | 2-3a      |
| AC Power Receptacle       | Mates with 3-wire ac line cord.   | 2-4b      |
| Zero Control              | Screwdriver adjustment for zeroing on 1 mV                              | 2-3b      |
| Output Receptacle         | Analog Output. ( $\pm$ 1 volt dc at full range at up to 1 milliampere). | 2-12      |
| BCD Output Receptacle     | Optional BCD output available with Model 1602 Digital Output Kit.       | 2-14      |

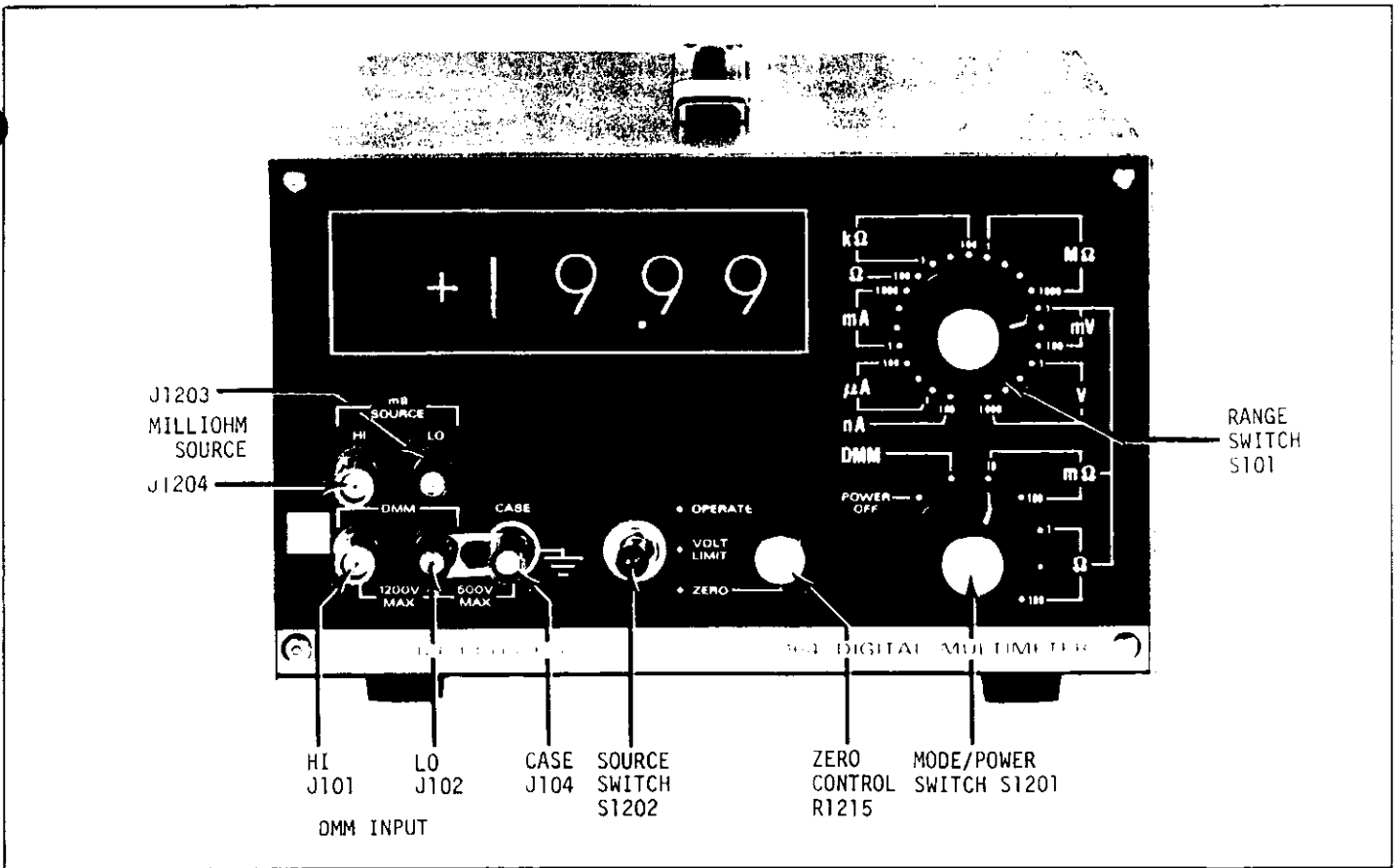


FIGURE 2. Front Panel Controls & Terminals, Model 164.

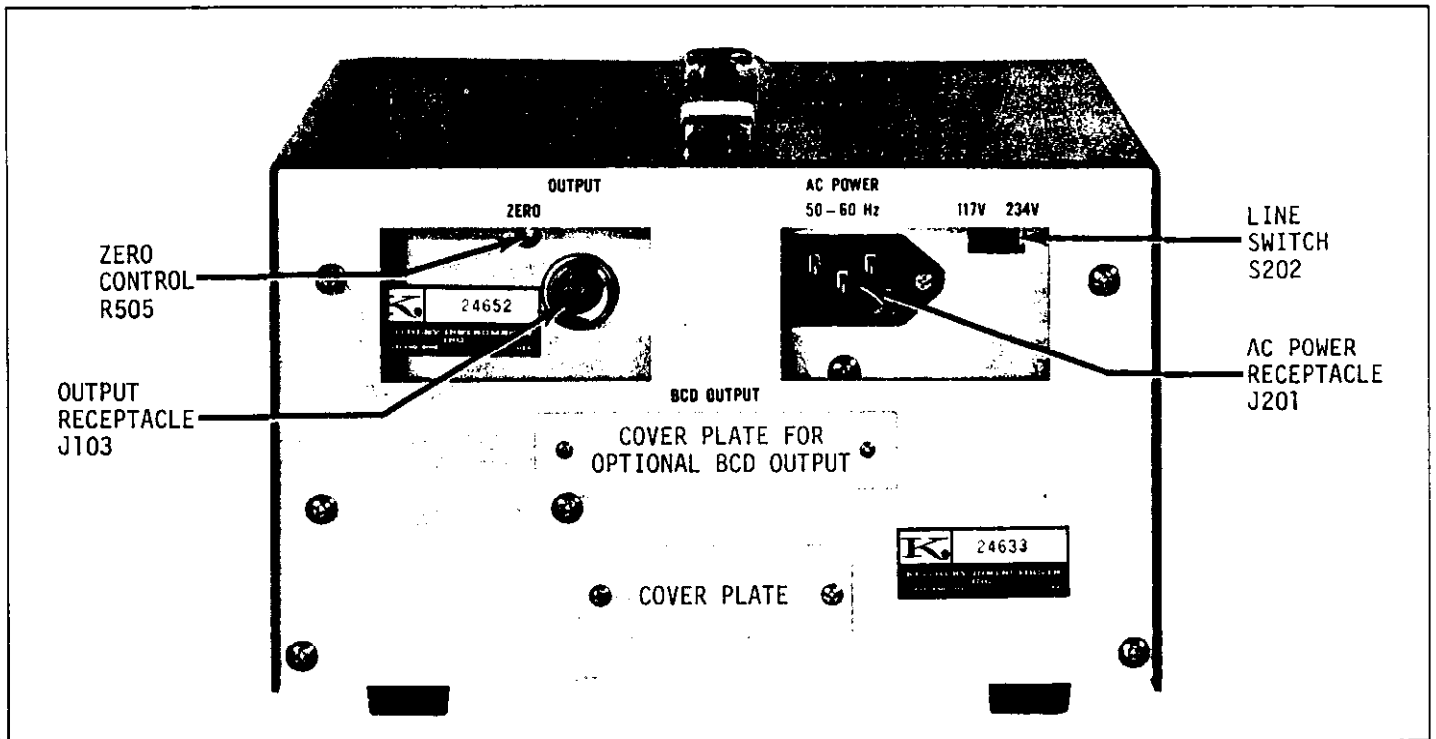


FIGURE 3. Rear Panel Controls & Terminals, Model 164.



## SECTION 2. OPERATING INSTRUCTIONS

## 2-1. INPUT CONNECTIONS.

## NOTE

a. Binding Post Terminals.

1. DMM Mode. Binding post terminals are provided on the front panel for connections to input HI (Red), input LO (Black), and chassis ground (Green). For voltmeter, ammeter, and ohmmeter measurements, the source should be connected between the lower set of red and black terminals. The green terminal may be connected to input LO by use of a shorting link when grounded operation is desired. See paragraph 2-11 for a discussion of floating operation.

2. Milliohmometer Mode. A separate pair of red and black terminals is provided for use when making four-terminal resistance measurements. The milliohm current source provides a positive dc current at the HI (Red) terminal and is used in conjunction with the DMM terminals. See paragraph 2-9 for a discussion of milliohmometer operation. The Model 1641 Kelvin Test Lead Set (furnished with the Model 164) simplifies connections to the resistance to be measured. The Test Lead provides clip-on connections for both voltage and current leads without the need for separate cables.

b. Noise Considerations. 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 1 mV and 10 mV 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 different contact materials (galvanic action).

1. Thermal EMFs. Thermal emfs (thermoelectric potentials) are generated by thermal differences between two junctions of dissimilar metals. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the instrument. The front or rear panel ZERO control can be used to buck out thermal offsets if necessary. 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. A-C Electric Fields. The presence of electric fields generated by power lines or other sources can have an effect on instrument operation. A-C voltages which are very large with respect to the full-scale range sensitivity could drive the a-c amplifier into saturation, thus producing an erroneous d-c output.

The instrument provides attenuation of line frequency noise superimposed on an input signal. The a-c rejection is specified as follows:

NMRR: Greater than 80 dB above one digit for a voltage of line frequency or twice line frequency on the most sensitive range, decreasing to 60 dB on the 100-millivolt and higher ranges. 1000 volts peak-to-peak maximum.

CMRR: Greater than 120 dB above one digit at dc and 40 to 100 Hz ac. 500 volts dc, 100 volts peak-to-peak ac maximum

Proper shielding as described in paragraph 2-1,c can minimize noise pick-up when the instrument is in the presence of excessive a-c fields or when very sensitive measurements are being made.

3. Magnetic Fields. The presence of strong magnetic fields can be a potential source of a-c noise. Magnetic flux lines which cut a conductor can produce large a-c 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. An effective 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,c.

c. Shielding.

1. Electric Fields. Shielding is usually necessary when the instrument is in the presence of very large a-c 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.

## 3. Other Considerations.

a) Voltmeter Measurements. Use shielded input leads when source resistances are greater than 1 megohm or when long input cables are used.

b) Current Measurements. On the mA current ranges, no special shielding precautions need be taken. However, on the  $\mu$ A and nA ranges, shielded input leads are recommended.

c) Resistance Measurements. Shielding of input leads and source are recommended for measurements on the 10 megohm through 1000 megohm ranges to prevent erroneous readings.

2-2. FRONT PANEL CONTROLS.

a. Power/Mode Switch. This switch permits selection of operating mode. The DMM position allows the Model 164 to be used as a voltmeter, ammeter, and ohmmeter. The  $m\Omega$  and  $\Omega$  positions allow the Model 164 to be used as a four-terminal resistance measuring instrument. The Power OFF position disconnects line power to the instrument.

b. Range Switch. This switch permits selection of function and full range in the DMM mode.

1. Dial Nomenclature. The range switch dial is marked in engineering units for voltage, current, and resistance, that is mV, V (Voltage), nA,  $\mu$ A, mA (Current) and  $\Omega$ , k $\Omega$ , M $\Omega$  (Resistance). For each parameter, rotating the knob clockwise switches to the less sensitive range. Decimal point is automatically positioned.

2. Voltage Function. The voltage sectors of the Range Switch are designated in millivolts (mV) and volts (V) for full ranges from 1 millivolt to 1000 volts. A full stop at the 1000 volt range prevents inadvertent switching to the nanoampere ranges with clockwise switch rotation.

3. Resistance Function. The resistance (ohms) sectors of the Range Switch are designated in ohms ( $\Omega$ ), kilohms (k $\Omega$ ), and Megohms (M $\Omega$ ) for full ranges from 100 ohms to 1000 megohms.

4. Current Function. The current (amperes) sectors of the Range Switch are designated in nanoamperes (nA), microamperes ( $\mu$ A), and milliamperes (mA), for full ranges from 100 nanoamperes to 1000 milliamperes.

c. Source Switch. This switch permits selection of Operate, Volt Limit, or Zero operation when using the  $m\Omega$ ,  $\Omega$  modes.

1. Operate Position. This position permits normal operation of the Model 164 as a four-terminal resistance measuring instrument.

2. Volt Limit Position. This position limits the open-circuit voltage of the milliohm current source to 20 millivolts. In this mode, measurement accuracy is degraded depending on the resistance to be measured. For example, if a full range resistance is connected (such as 1 $\Omega$  on the 1 $\Omega$  Range) the measurement accuracy is degraded by 5% since a 20 $\Omega$  resistance is shunting the input.

3. Zero Position. This position disconnects the current source from the unknown for zeroing the Model 164 in the milliohmmeter mode only.

d. Zero Control. This control is used in conjunction with the Source Switch (Zero Position) to zero the reading in the milliohmmeter mode. The control may also be used in the DMM mode for adjustments on the 1 mV and 10 mV ranges. (A rear panel zero adjustment is also provided for making coarse zero adjustments.) Place a short across voltmeter terminals before adjusting zero in Voltmeter mode.

2-3. REAR PANEL CONTROLS.

a. Line Switch. The 117/234V Switch sets the instrument for 117 or 234V rms line power, 50-60 Hz.

NOTE

Separate fuses are used for 117 or 234 volt operation. The fuses are installed on printed circuit board PC-254 (mother board) and can be serviced by removing the top cover. The Line Switch connects the appropriate fuse into the primary of transformer T201.

Fuse Specifications

- F201: 1/2 ampere, 3AG, SLO-BLO, Keithley Part No. FU-35.
- F202: 1/4 ampere, 3AG, SLO-BLO, Keithley Part No. FU-33.

b. Zero Control. This control is used for coarse zero adjustments and may be used in conjunction with the front panel ZERO Control. (Adjustment is usually necessary only for extreme changes of ambient temperature.) Place a short across voltmeter terminals before adjusting zero in Voltmeter mode.

2-4. PRELIMINARY OPERATION.

a. Line Voltage Selection. Set the Line Switch for the appropriate line voltage. For line voltages from 105 to 125 volts, set the Line Switch to 117V. For line voltages from 210 to 250 volts, set the Line Switch to 234V.

b. Line Cord. Connect the line cord to a source of 50-60 Hz line power within the ranges given above. For maximum operator safety, connect the ground wire of the line cord to earth ground. This will ensure that the CASE is at ground potential.

c. Warm-up. Set the Mode Switch to either DMM or any one of the MILLIOHMMETER positions to turn the instrument on. Allow a 1/2 hour warm-up period for measurements on 1 and 10 millivolt ranges.

d. Function/Range Selection. Select the Function and Sensitivity using the RANGE switch. In MILLIOHMMETER mode, the RANGE Switch is used in conjunction with the MODE Switch as described in paragraph 2-9.

2-5. **MODES OF OPERATION.** The Model 164 permits measurements in either of two modes of operation, 1) Multimeter Mode (DMM) or 2) Ohmmeter-Milliohm-meter Mode ( $\Omega$ , m $\Omega$ ).

a. **Multimeter Mode (DMM).** In the DMM mode, the Model 164 permits measurement of voltage, current, and resistance (to 0.1 $\Omega$  per digit) for conventional measurements. To select the DMM mode, set the Mode Switch to the DMM position. Then set the Range Switch to the appropriate function and range.

b. **Ohmmeter-Milliohm-meter Mode ( $\Omega$ , m $\Omega$ ).** In either the  $\Omega$  or m $\Omega$  modes, the Model 164 permits measurement of resistance using a four-terminal voltage-current method. To select the  $\Omega$  or m $\Omega$  modes, set the Mode Switch to the desired "ohms" position. Separate terminals are provided for current and voltage sensing. The Model 164 Kelvin Test Lead Set (furnished with the Model 164) simplifies connections to the resistance to be measured. The terminals identified as "m $\Omega$  SOURCE" provide a current in five decades from 10 microamperes to 100 milliamperes, corresponding to positions on the Mode Switch identified as 100 $\Omega$ , 10 $\Omega$ , 1 $\Omega$ , 100m $\Omega$ , or 10m $\Omega$ . The terminals normally used for DMM measurements are for voltage sensing when making four terminal resistance measurements. The Range Switch of the Model 164 must be set to the 1mV function when using the ohmmeter-milliohm-meter modes.

2-6. **VOLTMETER OPERATION (DMM Mode).** This mode of operation enables voltage measurements from  $\pm 1$  microvolt per digit (1 millivolt full range) to  $\pm 1000$  volts.

a. **Range Selection.** To select voltmeter operation set the Mode Switch to DMM, then set the Range Switch to the appropriate full range voltage. As a voltmeter, the Model 164 provides seven ranges as given in Table 2-1.

TABLE 2-1.  
Voltmeter Operation

| Range Setting | Full Range Display | Overrange Display |
|---------------|--------------------|-------------------|
| 1 mV          | 1.000 mV           | 1.999 mV          |
| 10 mV         | 10.00 mV           | 19.99 mV          |
| 100 mV        | 100.0 mV           | 199.9 mV          |
| 1 V           | 1.000 V            | 1.999 V           |
| 10 V          | 10.00 V            | 19.99 V           |
| 100 V         | 100.0 V            | 199.9 V           |
| 1000 V        | 1000. V            | 1000. V*          |

\*Maximum allowable input is 1000 volts continuous input on 1-volt to 1000-volt ranges. 1000 volts momentary, 300 volts continuous on lower ranges.

b. **Measurement Accuracy.** The voltage accuracy is  $\pm(0.1\%$  of reading + 1 digit) on all ranges.

c. **Overload Recovery.** The instrument will recover from 300-volt overloads within five seconds on the 1mV range. Up to 1000 volts peak may be applied momentarily on any range without damaging the instrument.

d. **Input Resistance.** The input has a resistance of 10 megohms on the 10 millivolt and higher ranges, 1 megohm on the 1-millivolt range. For 10mV and higher ranges, a 1000 ohm source resistance will introduce only 0.01% error. To maintain rated accuracy on the 1mV range, the source resistance should not exceed 100 ohms.

e. **Off-Ground Measurements.** The instrument low terminal can be floated  $\pm 500$  volts above CASE ground for voltage measurements. Refer to paragraph 2-11 for complete instructions.

f. **AC Voltage Adapter Probe.** The Model 1601 AC/DC Probe permits convenient a-c voltage measurements from 0.1 volt to 250 volts rms over a span of 45 Hz to 45 kHz. A probe-mounted switch provides convenient selection of a-c or d-c operation without disconnecting the probe. Therefore, the probe may be permanently attached.

2-7. **AMMETER OPERATION (DMM Mode).** This mode of operation enables current measurements from 0.1 nanoampere per digit (100 nanoamperes full range) to 2 amperes with 100% overranging on all ranges.

a. **Range Selection.** To select ammeter operation, set the Mode Switch to DMM, then set the Range Switch to the appropriate full range current. As an ammeter, the Model 164 provides eight ranges as given in Table 2-2.

b. **Connections.** Connect the input terminals so as to place the Multimeter in series with the current to be measured.

c. **Measurement Accuracy.** The current accuracy is specified as  $\pm 0.2\%$  of reading,  $\pm 1$  digit on all ranges. Since the accuracy is specified at the input terminals, the loading effects should also be considered. See Table 2-2 for values of shunt resistors.

d. **Off-Ground Measurements.** The Model 164 low terminal can be floated  $\pm 500$  volts above CASE ground for current measurements. Refer to paragraph 2-11 for complete instructions.

2-8. **OHMMETER OPERATION (DMM Mode).** This mode of operation enables resistance measurements from 0.1 ohm per digit (100 ohms full range) to 2000 megohms.

a. **Range Selection.** To select ohmmeter operation (DMM mode), set the Mode Switch to DMM, then set the Range Switch to the appropriate full range resistance. As an ohmmeter, the Model 164 provides eight ranges as given in Table 2-3.

b. **Voltage Across the Unknown.** Voltage drop is 100 millivolts at full range with 1.5 V max. into an open circuit. Thus the current through the unknown is determined by dividing the 100 millivolts by the full range resistance.

c. **Maximum Overload.** Maximum voltage across the input terminals is 20 volts momentary and 1 volt continuous.

d. **Accuracy.** As shown in Table 2-4.

TABLE 2-2.  
Ammeter Operation

| Range Setting | Full Range Display | Overrange Display | Shunt R           |
|---------------|--------------------|-------------------|-------------------|
| 100 nA        | 100.0 nA           | 199.9 nA          | 10 <sup>5</sup> Ω |
| 1 μA          | 1.000 μA           | 1.999 μA          | 10 <sup>4</sup> Ω |
| 10 μA         | 10.00 μA           | 19.99 μA          | 10 <sup>3</sup> Ω |
| 100 μA        | 100.0 μA           | 199.9 μA          | 10 <sup>2</sup> Ω |
| 1 mA          | 1.000 mA           | 1.999 mA          | 10 Ω              |
| 10 mA         | 10.00 mA           | 19.99 mA          | 1 Ω               |
| 100 mA        | 100.0 mA           | 199.9 mA          | 0.1 Ω             |
| 1000 mA       | 1000. mA           | 1999. mA          | 0.1 Ω             |

TABLE 2-3.  
Ohmmeter Operation

| Range Setting | Full Range Display | Overrange Display | Impressed Current |
|---------------|--------------------|-------------------|-------------------|
| 100 Ω         | 100.0 Ω            | 199.9 Ω           | 1 mA              |
| 1 kΩ          | 1.000 kΩ           | 1.999 kΩ          | 0.1 mA            |
| 10 kΩ         | 10.00 kΩ           | 19.99 kΩ          | 0.01 mA           |
| 100 kΩ        | 100.0 kΩ           | 199.9 kΩ          | 1 μA              |
| 1 MΩ          | 1.000 MΩ           | 1.999 MΩ          | 0.1 μA            |
| 10 MΩ         | 10.00 MΩ           | 19.99 MΩ          | 0.01 μA           |
| 100 MΩ        | 100.0 MΩ           | 199.9 MΩ          | 1 nA              |
| 1000 MΩ       | 1000. MΩ           | 1999. MΩ          | 0.1 nA            |

TABLE 2-4.  
Ohmmeter Accuracy

| Full Scale Range | Decimal Point Position | Accuracy of Reading* |
|------------------|------------------------|----------------------|
| 100 Ω            | XX.X                   | ±0.3% ± 0.1 Ω        |
| 1 KΩ             | .XXX                   | ±0.3%                |
| 10 KΩ            | X.XX                   | ±0.3%                |
| 100 KΩ           | XX.X                   | ±0.3%                |
| 1 MΩ             | .XXX                   | ±0.3%                |
| 10 MΩ            | X.XX                   | ±0.3%                |
| 100 MΩ           | XX.X                   | ±10%                 |
| 1000 MΩ          | XXX.                   | ±50%                 |

\*±1 digit on all ranges.

2-9. OHMMETER-MILLIOHMETER OPERATION ( $\Omega$ ,  $m\Omega$  Mode). In the  $\Omega/m\Omega$  modes, the Model 164 permits measurement of resistance from  $10\mu\Omega$  per digit to  $200\Omega$  using a four-terminal voltage-current method.

a. Summary of Operation.

1. Connect DMM and  $m\Omega$  Source terminals to resistance to be measured.
2. Set RANGE to  $1mV$
3. Set Mode Switch to desired range:  $10m\Omega$ ,  $100m\Omega$ ,  $1\Omega$ ,  $10\Omega$ , or  $100\Omega$ .
4. Set Source Switch to ZERO.
5. Adjust Zero Control for zero display.
6. Set Source Switch to OPERATE (except for VOLT-LIMIT operation). Refer to section 2-9e for Volt Limit Operation.

b. Connections. Separate pairs of terminals are provided for the current source and voltmeter to facilitate four-terminal resistance measurements. The terminals identified as " $m\Omega$  SOURCE" provide a current which may be selected in five decade steps from 10 microamperes to 100 milliamperes. The terminals normally used for DMM measurements (lower pair) are the voltmeter terminals.

c. Range Selection. In the  $m\Omega/\Omega$  mode, the current supplied at the " $m\Omega$  SOURCE" terminals (upper pair) may be selected in five decade steps from 10 microamperes to 100 milliamperes. When the Range switch is set to  $1mV$  sensitivity, then the five positions on the Mode switch correspond to full ranges of  $10m\Omega$ ,  $100m\Omega$ ,  $1\Omega$ ,  $10\Omega$ , or  $100\Omega$ . Since the full range resistance is determined by the current impressed at the " $m\Omega$  SOURCE" terminals and the voltage sensitivity,

the displayed reading must be interpreted by calculating Ohm's law where  $R = V/I$ . When using the  $1mV$  Range setting, no calculation is necessary since the Model 164 provides direct-reading ranges as marked on the Mode Switch. If any other voltage range is used (other than  $1mV$ ) the resistance must be determined by calculation since all decimal points will be lighted (therefore the decimal point location will be ambiguous). The direct-reading ranges available on the Model 164 are shown in Table 2-5.

d. Current Source. The current source in the Model 164 provides a constant current which may be selected in five decade steps from 10 microamperes to 100 milliamperes. The source can provide a compliance voltage up to 2 volts (in OPERATE mode only) on all  $m\Omega/\Omega$  mode settings. For example, the Model 164 may be used to furnish a current of 100 milliamperes to a load resistance of 20 ohms (giving a 2 volt drop). In the "OPERATE" mode, the Model 164 has an open-circuit voltage of approximately 15 volts. In the "VOLT LIMIT" mode, the Model 164 has an open circuit voltage of 20 millivolts.

NOTE

If the resistance to be measured is polarity sensitive, then care should be taken to connect the red (positive) terminal to the unknown so that the desired polarity is obtained. (Conventional current flow is out of the red terminal and into the black terminal.)

The effect of lead and contact resistance is minimized through the use of the four-terminal voltmeter-ammeter technique. A current source provides a known current through a pair of leads connected at one set of terminals. A sensitive voltmeter measures the voltage drop across the unknown resistance by means of a pair of leads connected at a second set of terminals.

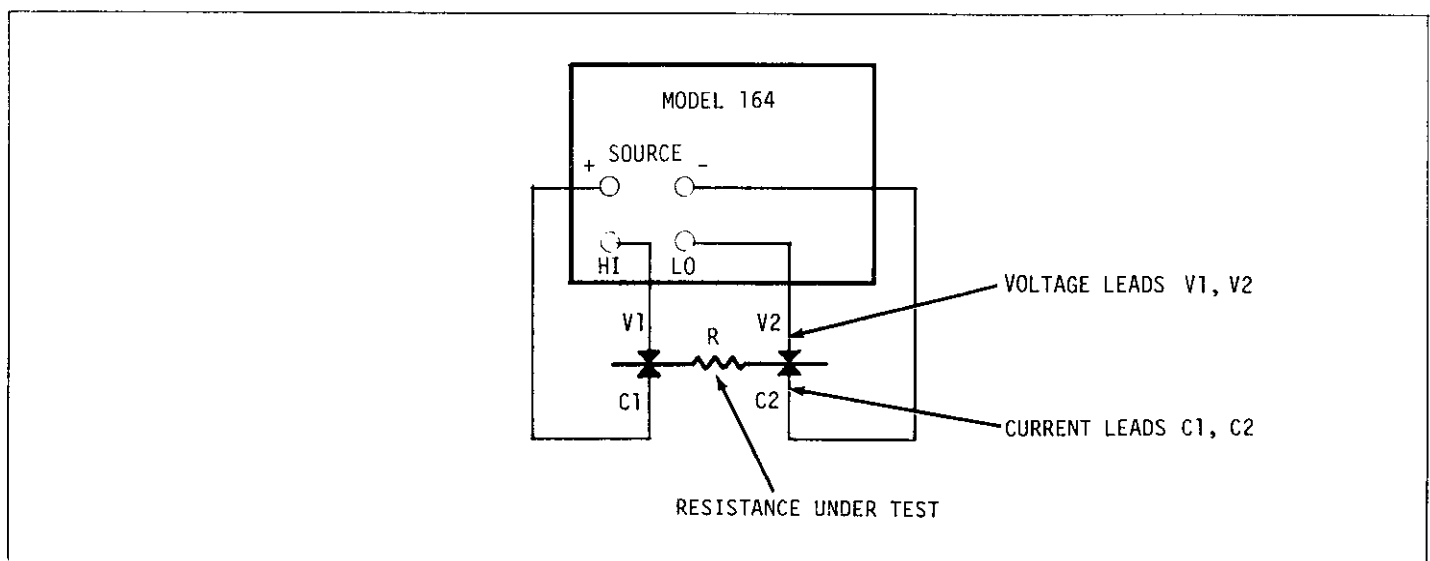


FIGURE 4. Four-Terminal Resistance Measurements

TABLE 2-5.  
Full Ranges in mΩ and Ω Modes

| Mode Setting | Range Setting* | Max. Reading<br>(with 100% overranging) | mΩ Source |
|--------------|----------------|---|-----------|
| 10 mΩ        | 1 mV*          | 19.99 mΩ                                | 100 mA    |
| 100 mΩ       | 1 mV*          | 199.9 mΩ                                | 10 mA     |
| 1 Ω          | 1 mV*          | 1.999 Ω                                 | 1 mA      |
| 10 Ω         | 1 mV*          | 19.99 Ω                                 | 0.1 mA    |
| 100 Ω        | 1 mV*          | 199.9 Ω                                 | 0.01 mA   |

\*Decimal location is valid only when 1mV range is selected.

e. Voltage Limit Operation. The VOLT LIMIT mode limits the open-circuit voltage across the mΩ SOURCE terminals to 20 millivolts. This feature is useful when testing relays and switches to determine if a "dry circuit" contact is present. (For a discussion of "dry circuit" measurements, refer to ASTM Specification B539-70.)

NOTE

Measurements performed in VOLT LIMIT mode should be used for approx. readings only since a portion of the mΩ Source current is shunted through the limit resistor (R1210, 1211, 1212, 1213, or 1214) as shown on schematic 26242D.

For "dry circuit" testing, set SOURCE switch to VOLT LIMIT. If an on-scale reading is indicated, then switch to OPERATE mode and record resistance of the display. If an over-range condition is indicated then a "dry circuit" open condition is present. Since the voltage is limited to 20 mV, the 164 cannot breakdown the contact resistance unless switched to OPERATE (where up to 15 volts can be applied).

IMPORTANT!

Care should be taken to avoid a transient current pulse which may result from an overshoot of the SOURCE Switch when switching from ZERO to VOLT LIMIT positions. When making dry circuit measurements, the recommended procedure is to check the reading in VOLT LIMIT mode, then switch to ZERO to adjust for zero offsets before taking a reading in OPERATE.

CAUTION

The transient voltage which can be generated by overshoot of the SOURCE Switch could be as large as 15 volts. This voltage transient may be sufficient to explode devices such as detonators and squibs if measured in the milliohmmeter mode.

TABLE 2-7.  
Power Dissipation in OPERATE Mode

| Mode Setting | Power at Full Range | Power at 100% overrange |
|--------------|---------------------|-------------------------|
| 10 mΩ        | 100 microwatts      | 200 microwatts          |
| 100 mΩ       | 10 microwatts       | 20 microwatts           |
| 1 Ω          | 1 microwatt         | 2 microwatts            |
| 10 Ω         | 0.1 microwatt       | 0.2 microwatt           |
| 100 Ω        | 0.01 microwatt      | 0.02 microwatt          |

f. Power Dissipation in Unknown. The power dissipated in the unknown is a function of the current impressed by the Model 164 current source. Power developed, worst-case, is dependent on the range selected and the compliance limit.

1. Volt Limit Mode. In this mode, the compliance voltage limit is set at 20 millivolts. The worst case power dissipation would be a function of  $V \times I$  as shown in Table 2-6.

TABLE 2-6.  
Worst Case Power Dissipation - Volt Limit Mode

| Mode Setting | Volt Limit | Power Dissipation |
|--------------|------------|-------------------|
| 10 mΩ        | 20 mV      | 2 milliwatts      |
| 100 mΩ       | 20 mV      | 200 microwatts    |
| 1 Ω          | 20 mV      | 20 microwatts     |
| 10 Ω         | 20 mV      | 2 microwatts      |
| 100 Ω        | 20 mV      | 0.2 microwatt     |

2. OPERATE Mode. In OPERATE mode, the power dissipation is a function of range selected as shown in Table 2-7.

g. Milliohmmeter Zero Adjust. Set the Source Switch to ZERO, the Mode Switch to 100Ω (or the desired range), and the Range Switch to 1 mV. Connect the unknown to the four terminals as described in paragraph 2-9a. Adjust the Milliohmmeter Zero control to give a zero reading with a flashing ± display.

NOTE

**h. V-I Characteristic Measurements.** The Model 164 provides five decade currents for use when voltage versus current measurements are required. Since the mΩ current source in the Model 164 has a compliance voltage range up to 2 volts, the Model 164 can be used for material testing or semiconductor diode checkout using the ranges given in Table 2-8.

The maximum continuous input voltage is 1000 volts on the 1000 volt range.

**b. Ammeter Digital Display.**

1. When the Range Switch is placed in Ampere positions 100 nA through 1000 mA, the Multimeter digital display indicates the voltage across a calibrated, self-contained resistor. The Range Switch automatically selects the calibrated range resistor for current measurements from  $1 \times 10^{-7}$  to 1 ampere full range.

2. The Range Switch is designated in convenient engineering units, nA (nanoamperes), μA (microamperes) and mA (milliamperes) with the decimal point automatically positioned in the display.

3. The full-scale current is determined by the Range Switch. Refer to Table 2-9 for the full-range current ranges available on the Model 164.

TABLE 2-8.  
V-I Characteristic Measurements

| Mode Setting | Current | Range Setting | Full Range |
|--------------|---------|---------------|------------|
| 10 mΩ        | 100 mA  | 1 mV          | 10 mΩ      |
| 100 mΩ       | 10 mA   | 1 mV          | 100 mΩ     |
| 1 Ω          | 1 mA    | 1 mV          | 1 Ω        |
| 10 Ω         | 0.1 mA  | 1 mV          | 10 Ω       |
| 100 Ω        | 0.01 mA | 1 mV          | 100 Ω      |
| 10 mΩ        | 100 mA  | 10 mV*        | 100 mΩ*    |
| 100 mΩ       | 10 mA   | 10 mV*        | 1 Ω*       |
| 1 Ω          | 1 mA    | 10 mV*        | 10 Ω*      |
| 10 Ω         | 0.1 mA  | 10 mV*        | 100 Ω*     |
| 100 Ω        | 0.01 mA | 10 mV*        | 1000 Ω*    |
| 10 mΩ        | 100 mA  | 100 mV*       | 1 Ω*       |
| 100 mΩ       | 10 mA   | 100 mV*       | 10 Ω*      |
| 1 Ω          | 1 mA    | 100 mV*       | 100 Ω*     |
| 10 Ω         | 0.1 mA  | 100 mV*       | 1000 Ω*    |
| 100 Ω        | 0.01 mA | 100 mV*       | 10 kΩ*     |
| 10 mΩ        | 100 mA  | 1 V*          | 10 Ω*      |
| 100 mΩ       | 10 mA   | 1 V*          | 100 Ω*     |
| 1 Ω          | 1 mA    | 1 V*          | 1000 Ω*    |
| 10 Ω         | 0.1 mA  | 1 V*          | 10 kΩ*     |
| 100 Ω        | 0.01 mA | 1 V*          | 100 kΩ*    |

\*NOTE: Decimal point location is not indicated when the Range Switch is set to any position other than mV, since all decimal points will be lighted. However, decimal point can be determined by a sample calculation of  $V \div I$  for a given range.

2-10. DIGITAL DISPLAY OPERATION.

**a. Voltmeter Digital Display.**

1. When the Range Switch is placed in Voltage positions 1 mV through 1000V, the digital display indicates the actual voltage measured.

2. The Range Switch is designated in convenient engineering units, mV (millivolts) and V (volts) with the decimal point automatically positioned in the display.

3. The full voltage range is determined by the Range Switch.

4. An overrange display up to a maximum of 1999 is provided by an overrange "1" indicator. For an input greater than 1999, all digits will be blanked except the overrange "1" indicator. The polarity indicator will remain lighted indicating the correct polarity. To remove an overload condition, change the Range Switch to a less sensitive position or decrease the input signal magnitude.

TABLE 2-9.  
Current Display

| Ampere Range       | Range Switch Designation |
|--------------------|--------------------------|
| $1 \times 10^{-7}$ | nA                       |
| $1 \times 10^{-6}$ | μA                       |
| $1 \times 10^{-5}$ | μA                       |
| $1 \times 10^{-4}$ | μA                       |
| $1 \times 10^{-3}$ | mA                       |
| $1 \times 10^{-2}$ | mA                       |
| $1 \times 10^{-1}$ | mA                       |
| 1                  | mA                       |

**c. Ohmmeter Display.**

1. When the Range Switch is placed in Ohms positions 100 Ω through 1000 MΩ, the Multimeter digital display designates the voltage across the unknown resistor with a fixed current applied.

2. The Range Switch is designated in convenient engineering units, Ω (ohms), KΩ (kilohms) and MΩ (megohms) with the decimal point automatically positioned in the readout.

3. The full-scale resistance is determined by the Range Switch. Refer to Table 2-10 for the full-range resistance ranges available on the Model 164.

TABLE 2-10.  
Resistance Display

| Ohms Range      | Range Switch Designation |
|-----------------|--------------------------|
| $1 \times 10^2$ | Ω                        |
| $1 \times 10^3$ | KΩ                       |
| $1 \times 10^4$ | KΩ                       |
| $1 \times 10^5$ | KΩ                       |
| $1 \times 10^6$ | MΩ                       |
| $1 \times 10^7$ | MΩ                       |
| $1 \times 10^8$ | MΩ                       |
| $1 \times 10^9$ | MΩ                       |

## 2-11. FLOATING OPERATION.

a. The low terminal can be floated above CASE ground by removing the shorting link between the LO and CASE. Isolation from circuit ground to chassis ground is greater than 100 megohms shunted by less than 0.02 microfarad. Circuit ground may be floated up to  $\pm 500$  volts with respect to chassis ground in the voltage and current modes.

b. When the instrument is used for off-ground voltage or current measurements, the low terminal is at floating potential. The instrument case ground should be connected to earth ground through the line and ground terminal. The shorting link between LO and CASE must be disconnected.

2-12. ANALOG OUTPUT. The instrument has an analog output of  $\pm 1$  volt (non-inverting) at up to 1 milli-ampere for recording purposes. For off-ground operation, the analog  $\pm 1$  volt OUTPUT should not be connected unless an external recorder is capable of floating at  $\pm 500$  volts with greater than 100 megohms isolation.

## 2-13. ZERO ADJUSTMENTS.

a. Short the input terminals with a low terminal connection - preferably a short copper wire or clip lead.

b. Set the front panel Range Switch to the 1 mV range.

c. Set the front panel zero control (R1215) to the full clockwise position.

d. If the digital display does not indicate  $\pm 11$  to  $\pm 13$  mV, use the rear panel ZERO Control to adjust the instrument.

e. Readjust front panel zero. Zero is indicated by flashing  $\pm$  polarity lights.

f. Check for zero reading on all ranges from 10 mV to 1000 V.

## NOTE

If there is an off zero reading on the 1 volt range, it will be necessary to adjust the CURRENT OFFSET ADJ. on the underside of the chassis. Refer to Figure 18.

g. Set the Range Switch to Ohms positions 1000 M $\Omega$  to 100  $\Omega$  while checking the readout so that zero is indicated on all ranges.

## NOTE

If clip leads are used on the input terminals, the lead resistance may be indicated on the 100  $\Omega$  range since the last digit sensitivity is 0.1  $\Omega$  per digit.

h. Set the Range Switch to Amperes positions 1000 mA to 100 nA while checking the readout so that zero is indicated on all ranges.

i. Remove the short circuit at the input terminals.

1. Volts Ranges. The instrument will normally read off zero a small amount on the 1 mV through 100 mV ranges because of sensitivity to random noise. The readout should remain at zero on the ranges 1V through 1000V.

2. Ohms Ranges. All Ohms ranges should indicate a readout overload where all digits except a "1" in the overrange position are blanked.

3. Amperes Ranges. All current ranges should indicate a zero readout, except for noise fluctuations.

j. After the preceding checkout is made, the instrument should be useable for all measurements with no further adjustments necessary.

## 2-14. DIGITAL OUTPUTS AND EXTERNAL CONTROLS.

a. General.

1. The Model 1602 Digital Output Kit provides optional BCD outputs and controls.

2. Included is a 50-pin PRINTER/CONTROL Connector (receptacle) for mounting on the instrument rear panel.

3. An output buffer card plugs into a prewired connector on the chassis for either factory or user installation. Buffer card replaces PC-255 inter-connecting card.

b. Output Codes and Levels.

1. The PRINTER/CONTROL Outputs are Binary Coded Decimal (BCD) Signals with 1-2-4-8 standard code.

2. The standard signal levels are as follows:

Output Logic "1" See Table 2-11 (pg. 12)

Output Logic "0" See Table 2-11 (pg. 12)

3. The Buffer Stages utilize "Open Collector" output transistors.

c. Output Information.

The Model 1602 Digital Output Kit provides various BCD outputs and controls as described in Tables 2-11 and 2-12.



TABLE 2-11.

Model 1602 Outputs

DIGITAL OUTPUT: BCD (1, 2, 4, 8) open collector logic (Motorola MC 858P) represents each of 3 digits, overrange digit, overload ("1"), polarity (+ = "1"), and decimal position (2 bits).

OUTPUT LOGIC LEVELS:

Output Logic "1": open transistor collector to ground with less than 100 microamperes leakage. +6 volts maximum allowable applied voltage.  
 Output Logic "0": transistor switch closure to ground with less than 0.5 volt saturation voltage. +35 milliamperes maximum allowable current.

TIMING OUTPUTS:

Clock: Internal clock pulses (10 kHz count rate).  
 Count Interval: Logic "0" appears during count interval (i.e. pulse width is proportional to analog input signal).  
 Flag: Logic "1" appears for a 300 millisecond interval out of a conversion time of 500 milliseconds. No change in buffer storage is made outside this interval.

REMOTE CONTROLS:

Strobe: Open circuit to ground inhibits all output lines from conducting (closure to ground enables conduction).  
 Hold: Closure to ground retains result of last conversion in both the output register and the display.

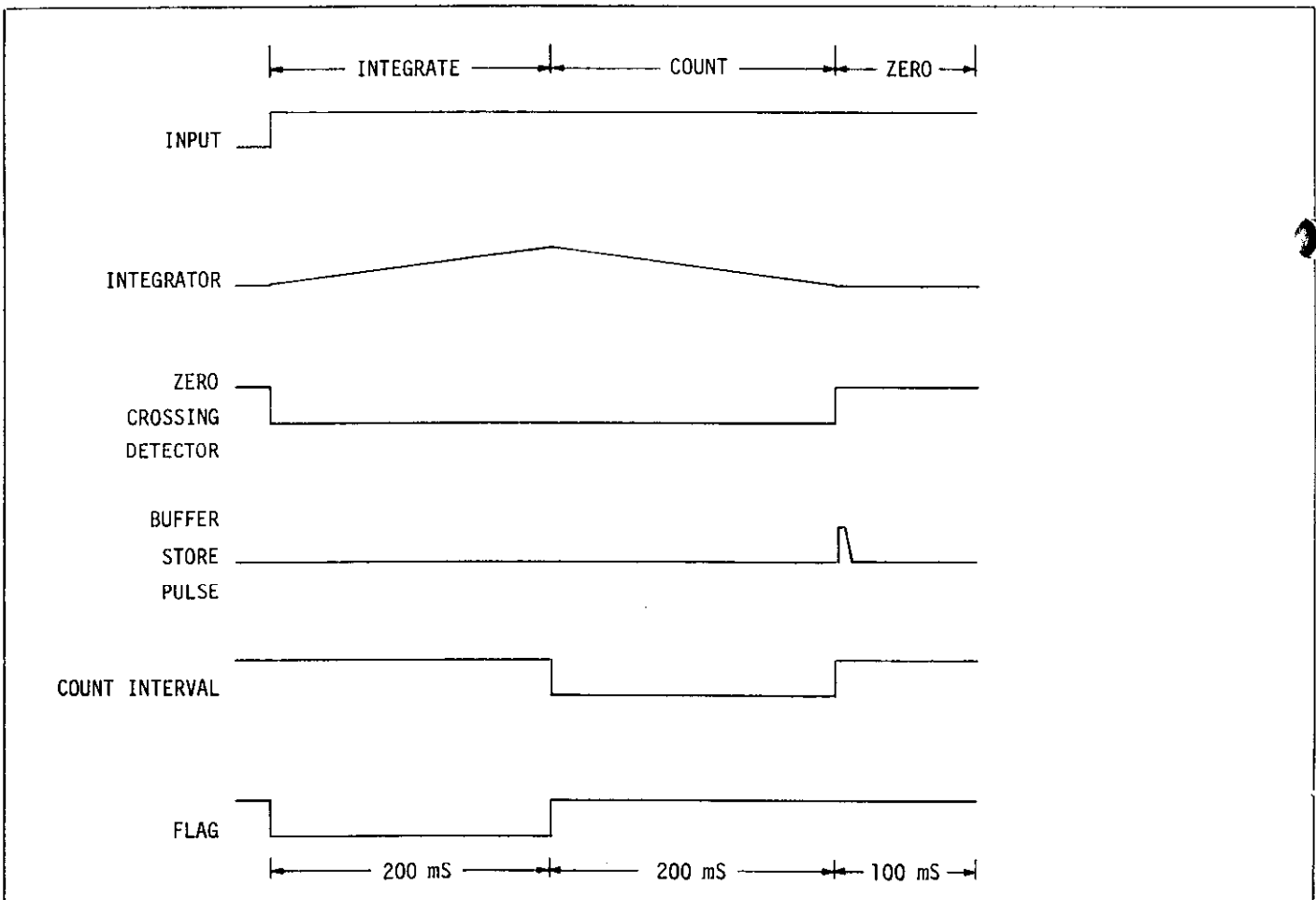


FIGURE 5. Timing Diagram for A/D Converter.

TABLE 2-12.  
Model 1602 PRINTER/CONTROL Connector Pin Identification

| Pin No. | Output          | Function        | Pin No. | Output | Function        |
|---------|-----------------|-----------------|---------|--------|-----------------|
| 1       | $1 \times 10^0$ | Data            | 26      | Common | ---             |
| 2       | $2 \times 10^0$ | Data            | 27      | Common | ---             |
| 3       | $4 \times 10^0$ | Data            | 28      | Blank  | ---             |
| 4       | $8 \times 10^0$ | Data            | 29      | 10 kHz | Clock           |
| 5       | $1 \times 10^1$ | Data            | 30      | Blank  | ---             |
| 6       | $2 \times 10^1$ | Data            | 31      | Blank  | ---             |
| 7       | $4 \times 10^1$ | Data            | 32      | Blank  | ---             |
| 8       | $8 \times 10^1$ | Data            | 33      | Blank  | ---             |
| 9       | $1 \times 10^2$ | Data            | 34      | Blank  | ---             |
| 10      | $2 \times 10^2$ | Data            | 35      | Blank  | ---             |
| 11      | $4 \times 10^2$ | Data            | 36      | Blank  | ---             |
| 12      | $8 \times 10^2$ | Data            | 37      | Blank  | ---             |
| 13      | $1 \times 10^3$ | Data            | 38      | Blank  | ---             |
| 14      | + = Logic "1"   | Polarity        | 39      | Blank  | ---             |
| 15      | $1 \times 10^0$ | Decimal Point   | 40      | Blank  | ---             |
| 16      | $2 \times 10^0$ | Decimal Point   | 41      | Blank  | ---             |
| 17      | Blank           | ---             | 42      | Blank  | ---             |
| 18      | Logic "1"       | Overload        | 43      | Blank  | ---             |
| 19      | Blank           | ---             | 44      | ---    | ---             |
| 20      | Count Interval  | See Table 2-11. | 45      | Blank  | ---             |
| 21      | Blank           | ---             | 46      | Blank  | ---             |
| 22      | Blank           | ---             | 47      | Hold   | See Table 2-11. |
| 23      | Flag            | See Table 2-11. | 48      | Blank  | ---             |
| 24      | Common          | ---             | 49      | Strobe | See Table 2-11. |
| 25      | Common          | ---             | 50      | Blank  | ---             |

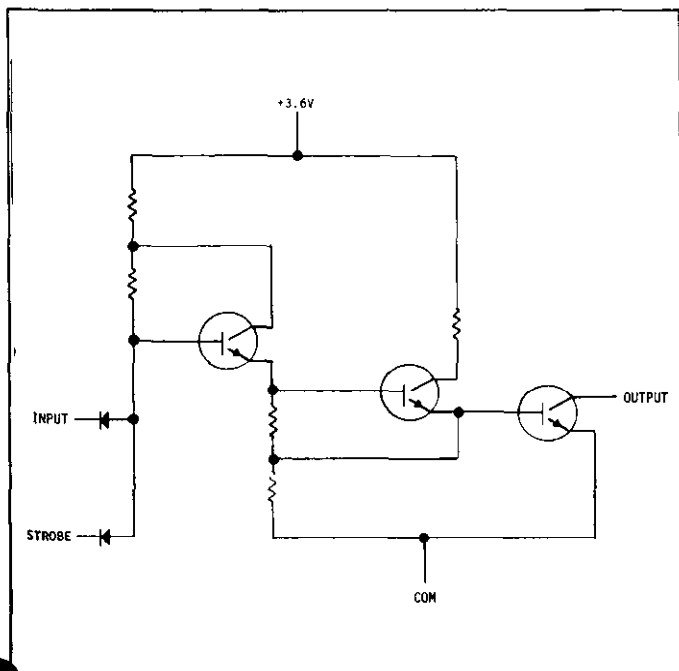


FIGURE 6. Typical Open-Collector Output.

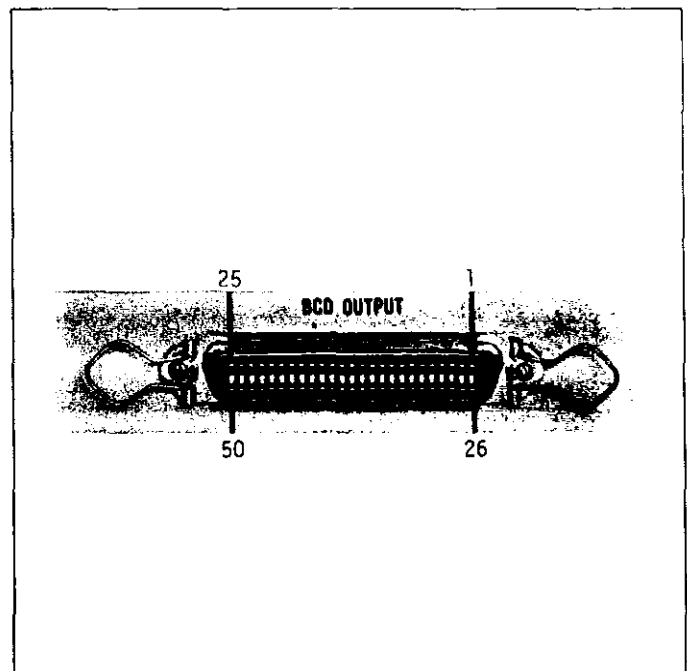


FIGURE 7. Pin Designation For Printer Output.

2-15. TRIP OPERATION (Model 164TT). The Model 164TT is identical to the standard Model 164 except for the addition of high and low limit non-latching trip circuits.

a. Trip Limits. The Model 164TT has two independently adjustable trips; one high limit and one low limit type, non-latching.

b. Trip Levels. -200% to +200% of full range for each trip. For example, if the high trip level were set to trip at a display reading of +1000, the Model 164 would indicate a "Trip" level whenever the display exceeded +1000 regardless of the function or decimal point location.

c. Trip Setting. The Model 164TT provides front panel screwdriver adjustments for the high and low trip circuits.

1. HI Trip. The front panel trip indicator lamp serves as a HI level trip indicator and a momentary contact pushbutton. When the button is depressed, the Model 164TT will display the trip reference setting. The display indicates both the polarity and reference level setting of the trip circuit. A small chisel blade screwdriver is needed to make the adjustment.

2. LO Trip. The front panel indicator lamp serves as a LO level trip indicator and a momentary contact pushbutton. When the button is depressed,

the Model 164 will display the trip reference setting. The display indicates both the polarity and reference level setting of the trip circuit. A small chisel blade screwdriver is needed to make the adjustment.

3. Set Precision. The Model 164TT will indicate a trip condition when the reading is within a tolerance  $\pm 0.1\%$  of full range with respect to the reference setting. Repeatability is  $\pm 0.1\%$  of full range. Reference stability is  $\pm 0.1\%$  of full range/ $^{\circ}\text{C}$ .

4. Hysteresis. The trip circuit has a hysteresis of less than 0.6% of full range. For example, once the trip circuit is "tripped" the input signal must vary by at least 0.6% of full range before the trip can reset.

d. Trip Indication.

1. HI and LO Indicators. The Model 164TT provides visual indication of trip point via front panel indicator lamps.

2. Trip Contacts. One set of form A contacts are furnished for each trip. Rear panel terminals are provided.

3. Contact Ratings. 10 volt-amperes, 0.5 ampere, 120 volts rms ac maximum. 6 watts, 0.5 ampere, 12 volts dc maximum.

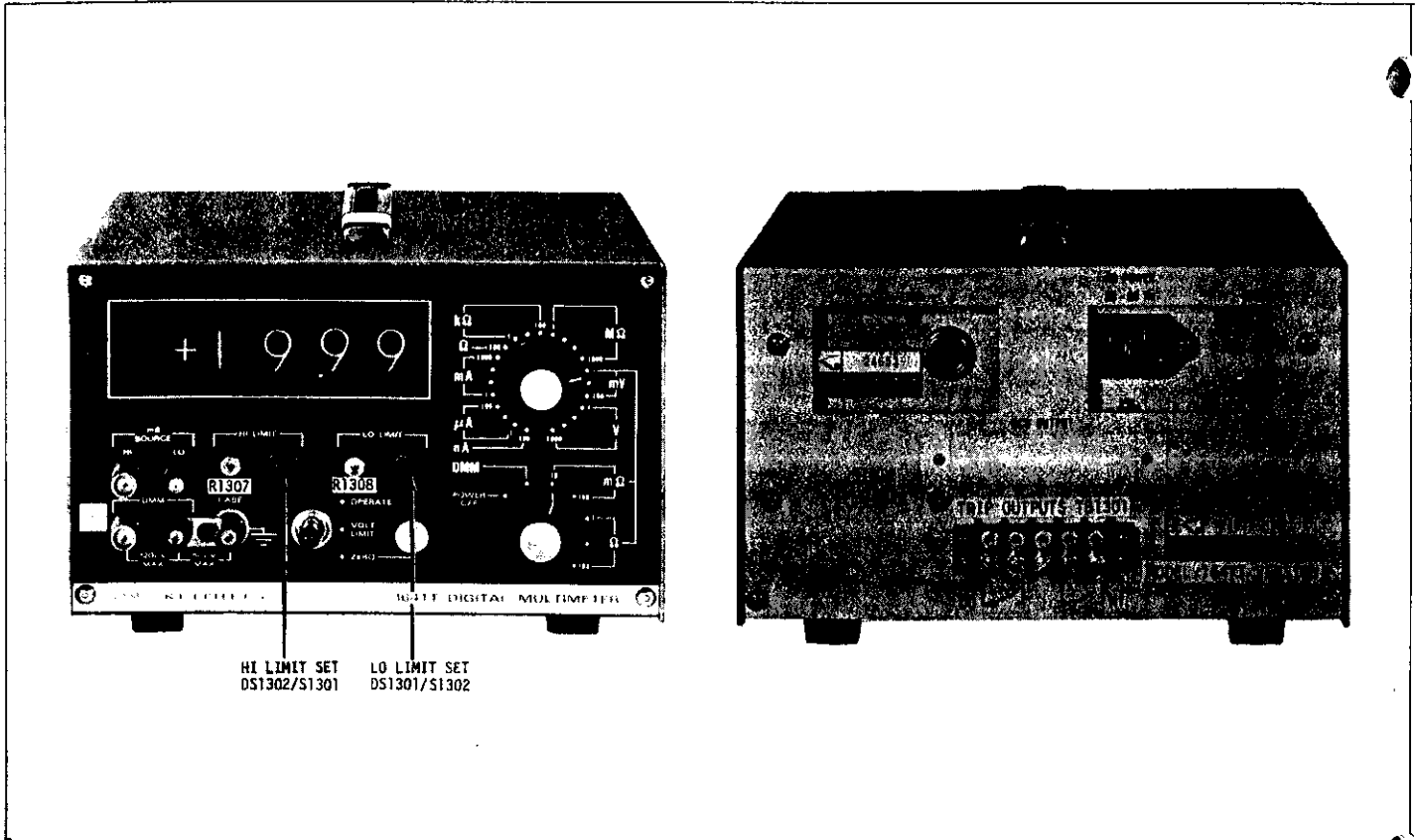


FIGURE 8. Front & Rear Panels, Model 164TT.

### SECTION 3. THEORY OF OPERATION

#### 3-1. GENERAL.

a. DMM Mode. The basic digital voltmeter consists of two sections packaged together in one chassis: 1) analog amplifier 2) analog to digital converter. The analog amplifier utilizes a modulator/demodulator technique to achieve high dc stability. The analog-to-digital converter is a dual-slope converter with two readings/second conversion rate.

b. Milliohmmeter Mode. The milliohmmeter circuitry includes a current source which provides current in decade steps from 10 microamperes to 100 milliamperes. Two additional terminals are provided on the front panel to permit four-terminal resistance measurements. The voltmeter circuitry of the basic instrument is used to monitor the voltage drop across the DMM terminals.

3-2. ANALOG AMPLIFIER OPERATION. A simplified block diagram of the analog amplifier is shown in Figure 10.

a. Voltage Amplifier Operation. The amplifier has a full-range sensitivity which is selected from 1 millivolt to 100 millivolts. Above 100 millivolts, the input signal is divided down to the 100 mV full-scale level. The signal flow path can be described as follows: An input signal applied at the Input High terminal is attenuated by a resistor divider. The signal is filtered and applied to a modulator circuit. The a-c signal is then applied and demodulated. A final variable gain d-c amplifier provides a d-c signal for the Analog output and A-to-D converter. The output is feedback to provide overall gain stability.

1. Input Resistor Divider. The input signal is attenuated by a divider network for RANGE Switch 1V, 10V, 100V and 1000V full-range positions.

2. Filter Network. The filter network provides filtering of Normal Mode noise.

3. Modulator Circuit. This circuit converts the low level d-c input to an a-c signal.

4. A-C Amplifier. This circuit uses negative feedback to provide gain accuracy and stability.

5. Demodulator Circuit. The demodulator is synchronized with the input modulator. It converts the amplified a-c signal to the d-c signal.

6. D-C Amplifier. This amplifier provides additional gain to drive the A to D converter and Analog recorder output.

7. Chopper Drive Circuit. This circuit generates the drive voltage for the mod-demod choppers.

b. Ammeter Operation (DMM Mode). The instrument operates as an ammeter by detecting the voltage drop across a known shunt resistor. The sensitivity and resistor values are shown in Table 3-1.

c. Ohmmeter Operation (DMM Mode). The instrument provides a known constant current which is applied to the unknown resistance. The voltage output is proportional to the resistance measured.

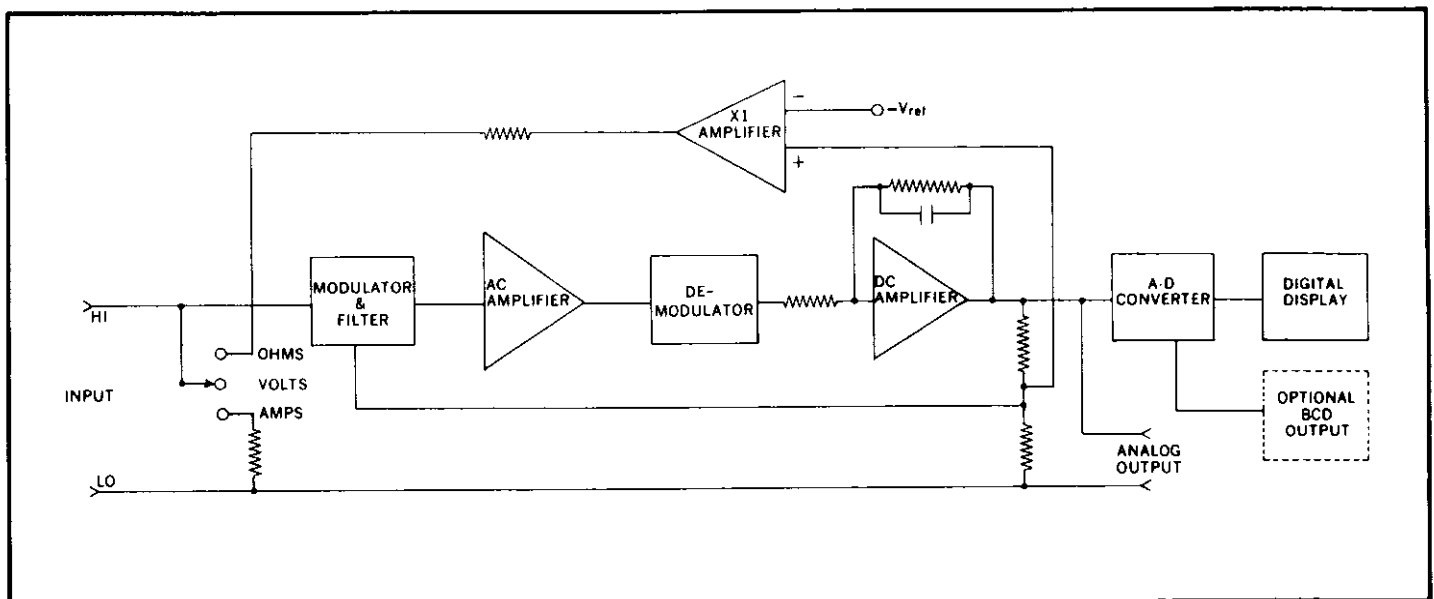


FIGURE 9. Multimeter Block Diagram.

## 3-3. ANALOG AMPLIFIER CIRCUITRY.

a. General. The circuits described in this section are located on the following sub-assemblies:

1. Mother Board, PC-254.
2. Analog Amplifier, PC-251.
3. Connector Board, PC-255.

b. Voltage Amplifier Circuit. The voltage amplifier circuit is composed of a chopper amplifier with fractional feedback. The feedback resistors are selected by the Range Switch so as to maintain low feedback current. The feedback network, composed of resistors R513, R516, R519, and R703, is formed from the output of the d-c amplifier to the low side of the modulator.

1. Input Resistor Divider. The chopper amplifier has a minimum gain of 10 and a full-scale output voltage of  $\pm 1$  volt. Thus it is necessary to attenuate signals greater than 100 millivolts to prevent saturation of the chopper amplifier. The input attenuator resistors R101, R102, and R103 through R111 are switched by the Range Switch S101.

2. Filter Network. The filter network provides NMRR as specified for line frequency voltages (either 50 or 60 Hz). The filter is a 2-section RC ladder filter composed of resistors R501 and R502 and capacitors C501 and C502.

3. Modulator Circuit. The modulator circuit utilizes MOS FET chopper switches to provide low offset voltage and current, low input noise, and low drive power. A series-shunt chopper configuration maintains high input impedance. Transistors Q701 and Q702 form the chopper.

4. A-C Amplifier. The a-c amplifier is a low noise amplifier composed of transistors Q703 and Q704 and an integrated circuit QA702.

5. Demodulator Circuit. The demodulator utilizes an FET shunt switch which is synchronized with the input modulator. The FET Q705 switching action creates a rectified d-c signal with a large chopper frequency a-c component. Resistors R717 and R718 with capacitor C710 provide a filtering action of the demodulated signal.

6. D-C Amplifier. The d-c amplifier utilizes an integrated circuit QA703 to provide d-c gain and capability of up to 1 milliamperes at the analog output.

7. Chopper Drive Circuit. The chopper frequency signal is derived from the Oscillator circuit. Transistors Q706 and Q707 provide opposite phase square waves used to drive MOS-FET chopper transistors Q701 and Q702. Transistor Q708 provides a demodulator drive signal for FET Q705 which is synchronous with the modulator drive signals. Flip-Flop circuits QA701A and QA701B divide down the 909.09 Hz from the oscillator by 4:1 for a chopper drive of approximately 227.3 Hz.

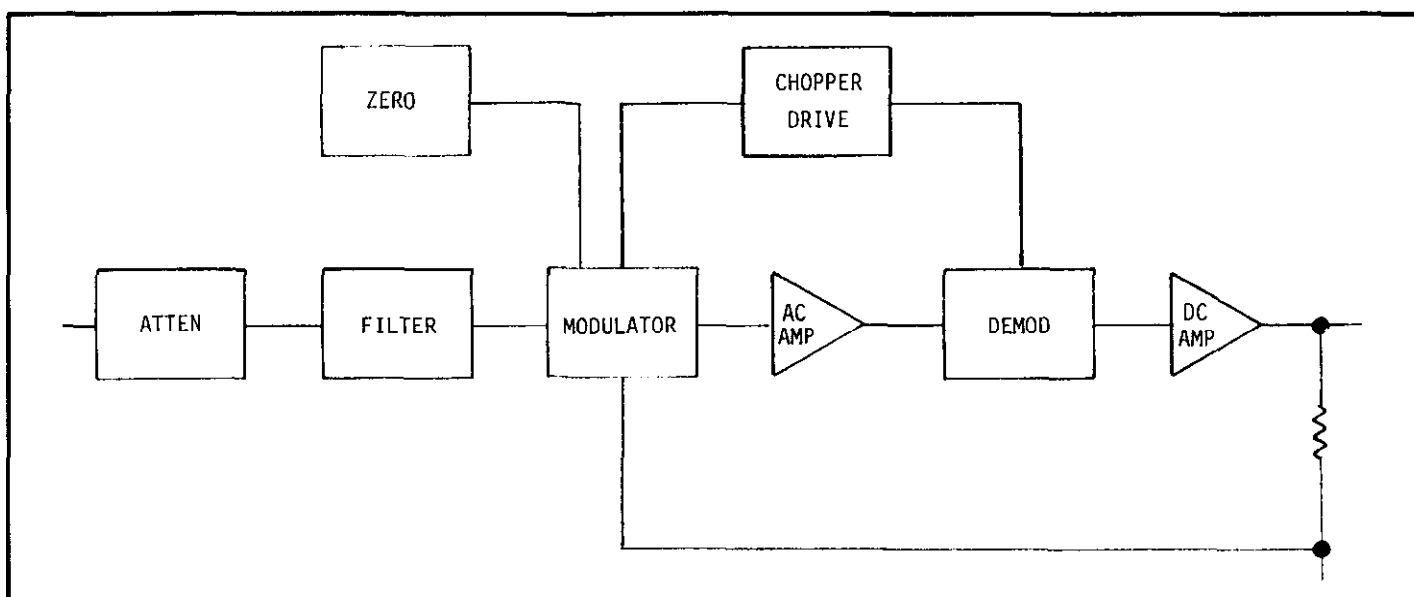


FIGURE 10. Analog Amplifier Block Diagram.

8. Zero Adjustment Circuit. This circuit provides limited adjustment of zero offset. It is composed of potentiometer R505 and resistors R503, R504, R506, R508, and R509 (See schematic 26244E) and R1215, R1216 (see schematic 26242D).

c. Ammeter Circuit (DMM Mode). The instrument utilizes the chopper amplifier described above with various Range shunt resistors R116 through R122. The chopper amplifier functions as a voltage amplifier to provide an analog recorder output and drive for the A-to-D converter.

TABLE 3-1.

| Full Range Sensitivity | Shunt Resistor (Ohms) | Full Range Voltage Drop |
|------------------------|-----------------------|-------------------------|
| 1 x 10 <sup>-7</sup>   | 10 <sup>5</sup>       | 10 mV                   |
| 1 x 10 <sup>-6</sup>   | 10 <sup>4</sup>       | 10 mV                   |
| 1 x 10 <sup>-5</sup>   | 10 <sup>3</sup>       | 10 mV                   |
| 1 x 10 <sup>-4</sup>   | 10 <sup>2</sup>       | 10 mV                   |
| 1 x 10 <sup>-3</sup>   | 10                    | 10 mV                   |
| 1 x 10 <sup>-2</sup>   | 1                     | 10 mV                   |
| 1 x 10 <sup>-1</sup>   | .1                    | 10 mV                   |
| 1                      | .1                    | 100 mV                  |

d. Ohmmeter Circuit (DMM Mode). The instrument provides a constant-current using a voltage reference amplifier and series resistor R. The reference voltage E limits the open-circuit voltage to 1.5 volts maximum. The voltage reference is composed of integrated circuit QA704 and reference diode D702.

e. Milliohm Source. (See schematic 26242D)

1. AC voltage from T1201 is rectified by bridge D1201, filtered and supplied to the pre-regulator QA1201. This is a three-terminal 15 volt regulator. The 15 volt output is connected through the series pass transistor Q1201 to the Hi terminal of the mΩ Source, J1204.

2. The pass transistor is controlled by the operational amplifier QA1202. One input to QA1202 is +10 volts (referred to power supply common). This is obtained from two zener diodes, D1202 and D1203 and a divider network R1202, R1203, and R1204. R1203 is a potentiometer to permit compensation for the tolerance of the zener diodes and the offset voltage of QA1202. The other input is the voltage drop across the selected current sensing resistor, one of R1205 through R1209, which is in series with the LO terminal, J1203.

3. When the current regulator is in balance, the drop across the current sensing resistor is equal to the reference voltage and the current delivered by the mΩ Source terminals is the proper value.

4. If the current source has no load, the voltage across the terminals will approach 15 volts. When testing switches or relay contacts for "dry circuit" applications, the voltage must be limited to 20mV or less. This is done by setting S1202 in the Volt Limit position. The output current is then divided between the load and one of the volt limit resistors, R1210 through R1214. Even with open-circuited load, the voltage at the source terminals will not exceed 20mV.

3-4. ANALOG-TO-DIGITAL CONVERTER OPERATION.

a. General. The analog-to-digital converter uses a dual-slope technique which has inherent line-frequency noise rejection. The analog signal is applied to the integrator for 200 milliseconds which is an even multiple of the line frequency of 50 or 60 Hz. The analog signal is then removed from the integrator input. The voltage on the integrator is then driven to zero to complete the voltage-to-time conversion. The time interval to reach a "Zero Crossing" is counted and displayed on the "Digital Readout" in proportion to the original analog signal. Before the sequence is repeated, the integrator is rezeroed.

b. The A-to-D Converter is composed of eight major circuits as follows:

1. Oscillator or Clock
2. BCD Counter
3. Program/Decoder
4. Integrator
5. Zero Crossing Detector
6. Buffer/Storage Register
7. Decoder/Driver
8. Numerical Readout.

c. Oscillator or Clock. The Oscillator produces pulses at a rate of 10 kilohertz for either 50 or 60 Hz operation.

d. BCD Counter. The BCD Counter counts the Clock pulses with a total range of 5000 counts. The Counter is composed of 4 individual counters designated 1, 10, 100, and 1000.

1. The "1", "10", and "100" counters have a capacity of ten counts each.
2. The "1000" counter has a capacity of five counts.
3. The total capacity of all four counters is 5000 counts.

e. Program/Decoder. The Program/Decoder circuit produces event commands to control the overall sequence of events for a complete A-to-D conversions.

TABLE 3-2.  
Summary of Event Commands

| Command | Function  |
|---------|-----------|
| 2       | ZERO      |
| 3,4     | INTEGRATE |
| 0,1     | COUNT     |

f. Integrator. The Integrator circuit operation is composed of three periods.

1. Zero Period. During this period the integrator amplifier is zeroed by a feedback rezeroing circuit as shown in Figure 12. Switches S<sub>a</sub>, S<sub>b</sub>, S<sub>d</sub> are open to prevent integrator charging.
2. Integration Period. During this period, switches S<sub>b</sub>, S<sub>c</sub>, and S<sub>d</sub> are open. Switch S<sub>a</sub> is closed to permit charging by the analog voltage for an even multiple of the line frequency.

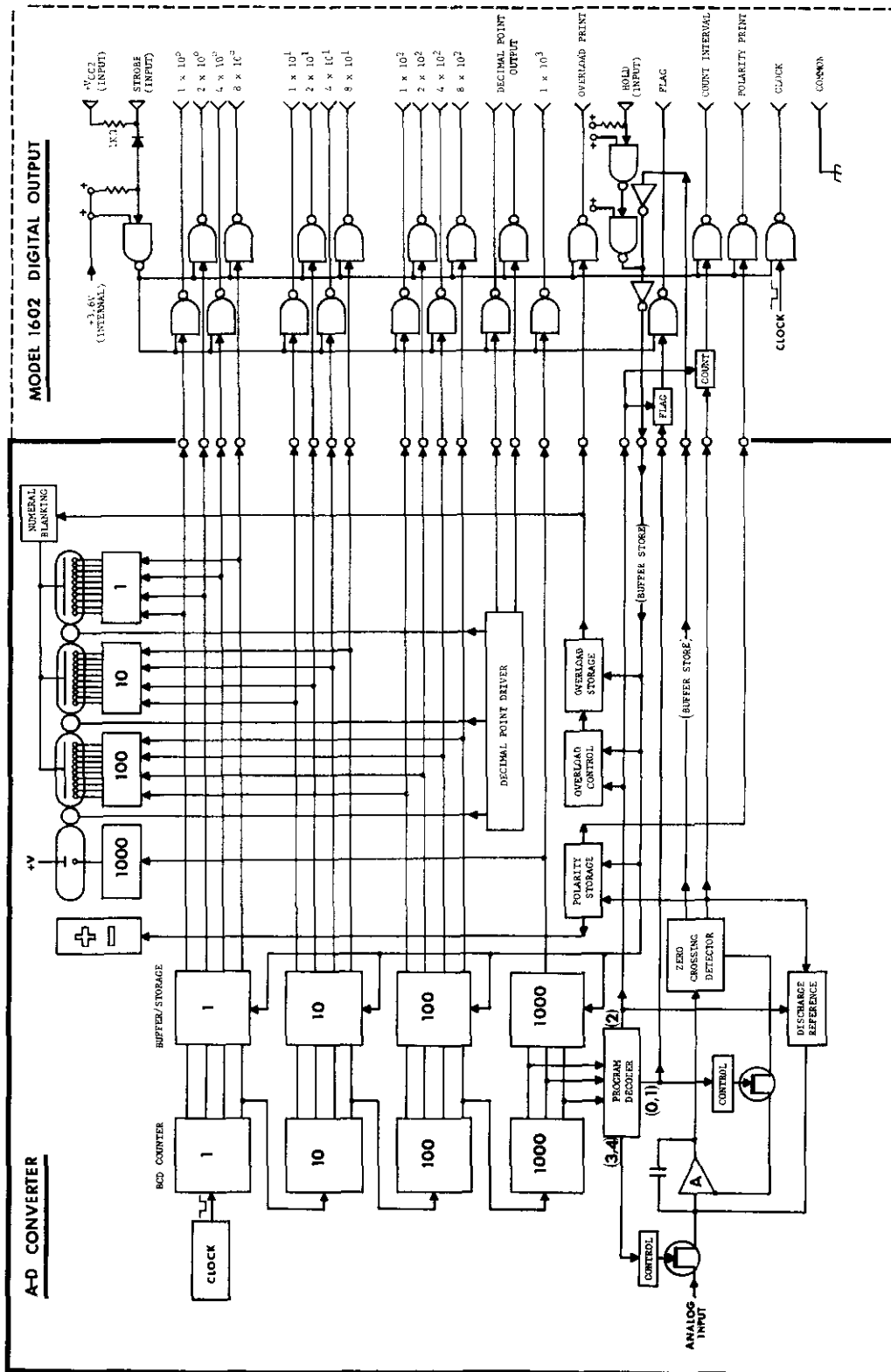


FIGURE 11. A/D Converter Block Diagram.

3. Discharge Period. During this period, switch  $S_a$  is open to prevent further charging by the analog signal. Either switch  $S_c$  or  $S_d$  is closed to drive the Integrator voltage to zero. A reference current of opposite polarity to the input current is applied through either switch  $S_c$  or  $S_d$ . The Discharge Period ends when the Zero Crossing Detector circuit detects a zero Integrator output.

g. Zero Crossing Detector. The Zero Crossing Detector circuit provides a "High" or "Low" level output depending on the polarity of the detected input. Refer to Table 3-3 for a description of voltage outputs of the Zero Crossing Detector.

TABLE 3-3.  
Zero Crossing Detector Output Levels.

| M  | N     | B     | C     |
|----|-------|-------|-------|
| 0V | -0.5V | +1.5V | 0V    |
| 0V | +3.5V | 0V    | +1.5V |

h. Buffer/Storage Register. The Buffer/Storage Register is composed of "flip-flops" arranged to copy the states of the various BCD counters. The Buffer/Storage Register requires a Buffer Store command before any information can be transferred. The "flip-flop" circuits provide coded information for Decoder/Driver and BCD outputs.

i. Decoder/Driver. The Decoder/Driver circuit decodes the BCD information from the Storage Register into ten-line decimal code. The Driver circuit then drives the proper numeral in each of the Numerical Readout tubes.

j. Numerical Readout. The Numerical Readout consists of four numerical indicators and one polarity indicator driven by the Decoder/Driver, Polarity and Overload Drivers.

k. Summary of Operation. The operation of the A-to-D Converter can be described by considering a typical conversion cycle. The Clock provides pulses at a rate of 10 kilohertz. The BCD Counter serves as a master timing control for the A-to-D conversion cycle. The timing is accomplished by the "1000" counter which has five coded states, namely 0, 1, 2, 3, and 4. The Program/Decoder controls the sequency of commands based on the coded states from the BCD Counter. The decoded commands are described as shown in Table 3-2. The "2" command initiates the integrator ZERO period which removes any residual charge on the integrator capacitor. The "3,4" command initiates the INTEGRATE period which permits an integration of the analog signal. At the end of the INTEGRATE period, the "0,1" command initiates the COUNT period. When the "3,4" command is given, the integrator is charged by the analog signal for a period of 200 milliseconds. When the "0,1" command is given, the analog signal is removed and the integrator output is driven to zero by a reference current. The Zero Crossing Detector senses a zero crossing of the Integrator output and removes the reference current. The Detector provides outputs as shown in Table 3-3. The +1.5 volt levels are provided for control of the Integrator and Polarity Storage Register. A pulse command is also produced to initiate a Buffer/Store. When the Buffer/Store command is given, the Buffer/Storage Register copies the BCD Counter states at that instant of time. The BCD coded information in the Register is then available for the Decoder/Driver and external printout. The Decoder/Driver decodes the Buffer/Storage output and drives the Numerical Readout for a digital display. The conversion cycle is completed when the BCD Counter reaches 2000 counts and the Program/Decoder provides a "2" command to initiate a new conversion cycle.

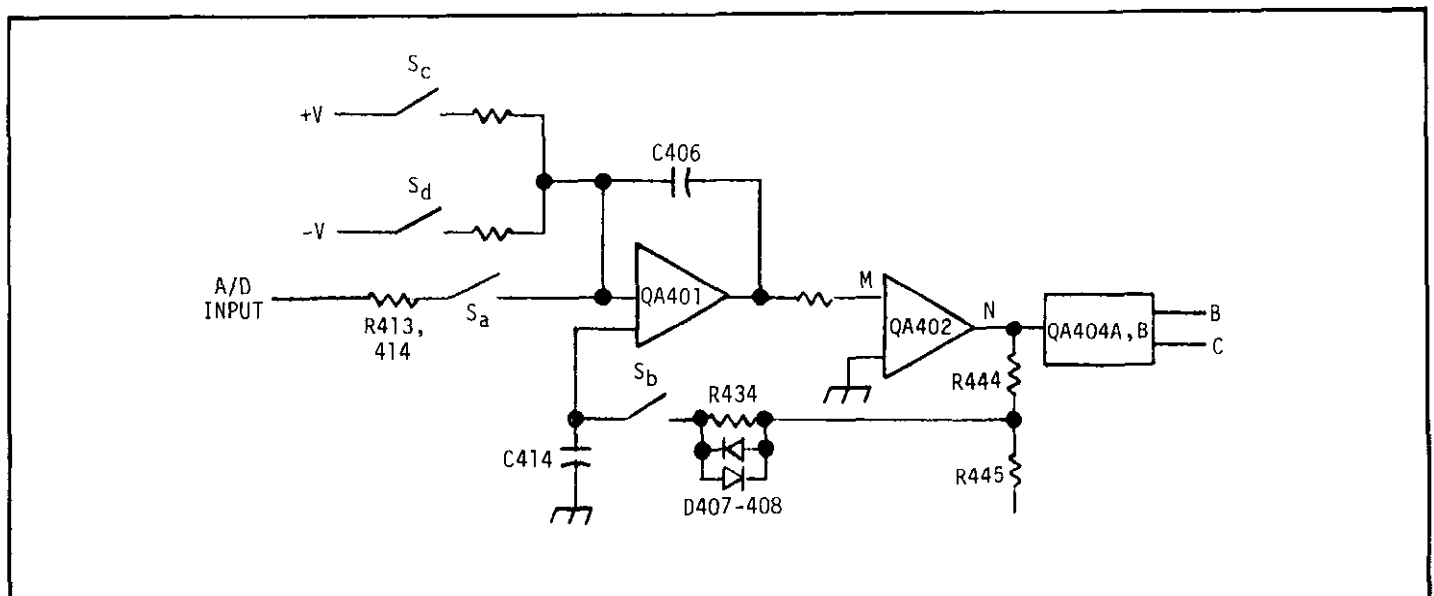


FIGURE 12. Integrator Simplified Diagram.



## 3-5. ANALOG-TO-DIGITAL CONVERTER CIRCUITRY.

a. General. The circuits described in this section are located on the following sub-assemblies.

1. Tube Board, PC-248
2. Integrator Board, PC-250
3. Oscillator Circuit, PC-254.

b. Oscillator Circuit. The Oscillator circuit is located on a portion of printed circuit assembly PC-254. Transistors Q601 and Q602, capacitors C601, C602, and C603 and resistors R606 and R607 form an oscillator. Potentiometer R605 is used to provide internal screwdriver adjustment of the oscillator frequency. Transistor Q603 serves as an emitter-follower to reduce output impedance. The chopper drive is obtained by dividing down the oscillator frequency from 10 Kilohertz to 909.09 Hz using integrated circuit QA801, a 11:1 Divider circuit.

c. Tube Board. The Tube board contains portions of five major circuits: the BCD Counter, the Program/Decoder, the Buffer/Storage Register, the Decoder Driver, and the Numerical Readout.

## 1. BCD Counter.

a) The Decade Counters designated "1", "10", and "100" are composed of individual integrated circuit modules QA308, QA309, and QA310 respectively.

b) The "1000" Counter is composed of integrated circuit modules QA301A, QA302A, and QA302B.

2. Program/Decoder. This circuit is composed of gates QA304A, QA304C, QA305 (B, C, D, E, F) QA306A and QA307B.

3. Buffer/Storage Register. This circuit is composed of integrated circuit modules QA311, QA312, and QA313.

4. Decoder Driver. This circuit is composed of integrated circuits QA314, QA315, and QA316.

5. Numerical Readout. V301, V302, V303 are Readout Tubes for Units, Tens, and Hundreds respectively.

6. Other circuits contained on the Tube Board are described as follows:

a) Overrange Indicator Circuit. This circuit is composed of integrated circuit module QA301B, transistor Q301 and overload indicator DS301.

b) Polarity Indicator Circuit. This circuit is composed of transistors Q305 and Q306 and Polarity indicator module DS302.

c) Display Rate/Hold Circuit. Gates QA303 (A, B, C, D) and QA304B, QA306B, and QA307A provide capability for Display Rate and Hold functions when used with additional Output Buffer circuits.

d. Integrator Board. The Integrator Board contains portions of three major circuits: the Integrator circuit, the Zero Crossing Detector Circuit, and the Feedback Rezeroing Circuit.

1. Integrator Circuit. The operation of the Integrator is controlled by the positions of switches S<sub>a</sub>, S<sub>b</sub>, S<sub>c</sub>, and S<sub>d</sub> (as shown in Figure 12). Switch S<sub>a</sub> is Q401. Switch S<sub>b</sub> is transistor Q411. Transistors Q404, Q405, Q408, Q409, and Q410 are control circuits arranged to control the proper FET switches depending on the signals at pins 12 and 13. The integrator amplifier consists of transistors Q402 and Q403 and integrated circuit QA401. The feedback capacitor is C406. Switches S<sub>c</sub> and S<sub>d</sub> control the current for 9-volt zener diodes D401 and D402. Resistors R403, R404, R405, R409, R410, and R411 are full-scale calibration resistors. Potentiometers R402 and R408 are internal screwdriver calibration adjustments.

2. Zero Crossing Detector Circuit. The high gain amplifier is composed of cascaded amplifiers QA402 and QA403. Diode D411 provides a 6-volt bias supply for QA403 and the output resistor network R444 and R445. The level-splitter circuit consists of diodes D414 and D415, resistors R443 and R446 and gates QA404 (A and B).

3. Feedback Rezeroing Circuit. This circuit provides rezeroing of the Integrator circuit using negative feedback from the Zero Crossing Detector output. Transistor Q411 is the equivalent of Switch S<sub>b</sub> in Figure 10. Resistor R434 and capacitor C414 form a feedback-loop filter circuit. Diodes D407 and D408 provide fast response for large input offsets due to input overloads.

## 3-6. POWER SUPPLIES.

a. ±15 Volt Supply.

1. The 15 volt supplies tap a-c power from a secondary winding of transformer T201. Diodes D203 (A, B, C, and D) and capacitors C204, C205, C209, and C210 compose a full-wave rectifier with filtering.

2. The +15 volt regulator circuit utilizes integrated circuit QA201 which drives transistor Q206 to series regulate the output voltage. Potentiometer R209 provides calibration adjustment of +15 volt supply. (Internal screwdriver adjustment).

3. Transistors Q211 and Q212 form a differential amplifier which compares the voltage at R218 with respect to low. The difference voltage is amplified by transistor Q210 and fed to Darlington transistor pair, Q207 and Q208, which series regulate the -15 volt output. Transistor Q209 limits the current output to approximately 200 milliamps.

b. +3.6 Volt Supply.

1. The +3.6 volt supply taps a-c power from a secondary of transformer T201. Diodes D201 and D202 and capacitor C201 form a full-wave rectifier with filtering.

2. Transistor Q205 amplifies the difference between the +3.6 output and a reference voltage derived from the +15 volt supply and determined by resistors R203 and R204. The difference voltage is applied by transistor Q204 which drives a Darlington transistor pair, Q201 and Q202. The Darlington pair series regulates the +3.6 volt output.

3. Transistor Q203 limits the output current to about 3 amperes.

c. +210 Volt Output. The +210 volt supply is an unregulated voltage supply using the half-wave filtered voltage at diode D206 and capacitor C212.

d. +170 Volt Output.

1. Regulator. The +170 volts is derived from the +210 volts at emitter of Q302 which series regulates the +170V. Transistor Q303 provides a reference for the base of transistor Q302.

2. Blanking Circuit. This circuit controls the +170 voltage for the three right hand readout tubes. The "Q" output of QA307B drives the base of transistor Q304 for normal regulator operation. When an overload occurs, the "Q" output is low turning off transistor Q304. This results in a drop of the +170 volt output causing blanking of the readout tubes.

e. Milliohm Source Supply. The primary windings of T1201 are connected in parallel with transformer T201. AC power for both is supplied from line connector P201 via fuse F201 and switch S1201. The dual primary windings are connected in parallel by switch S202 for 117 volt operation and in series for 234 volt operation. In addition, fuse F202 is connected in the circuit for 234 volts.

3-7. ELECTRONIC TRIP CIRCUITRY. The two trip circuits in the 164TT are essentially the same, differing only in that the LO trip output transistor is an NPN type while the HI trip output transistor is a PNP. The analog signal at J103 (schematic 26244E) is a one volt signal for full scale input to the DMM. This signal is applied to the inverting inputs of QA1301 and QA1302 through resistors R1309 and R1314. The reference voltage used to determine the trip point is derived from zener diode D1301. The HI limit is set by R1307 and the LO limit by R1308. These limit voltages, either of which may be set from -2 volts to +2 volts, are applied to the non-inverting inputs of QA1301 and QA1302 through resistors R1310 and R1315. If the HI limit is set at +1.0 volt and the analog output is less than +1.0 volt, the output of QA1302 will be positive and the HI output transistor Q1302, will be cut off. When the analog output exceeds +1.0 volt, the output of QA1302 will become negative, turning on Q1302 and causing relay K1302 to close and lighting the front-panel trip lamp DS1302. A small voltage is developed across R1320 which is connected back to the non-inverting input of QA1302 through resistor R1317. This provides some hysteresis so the relay will not drop out until the input is somewhat less than the trip point. The LO limit circuit functions the same way except the output of QA1301 is normally negative. Since the driver transistor Q1301 is an NPN, it is cut off by this voltage. Setting the trip points is done by holding in S1301 or S1302 and adjusting the corresponding limit control, R1307 or R1308. When the HI limit switch S1301 is operated, the analog output of the DMM is disconnected from the A/D converter. The output of QA1302 is connected to the A/D converter and also to the inverting input of QA1302, making it into a unity-gain voltage follower for the trip point voltage applied to the non-inverting input. Thus the A/D converter indicates the magnitude of the trip point voltage.

## SECTION 4. ACCESSORIES

## MODEL 1601 AC-DC PROBE

GENERAL. The Model 1601 is a combination ac-dc probe that enables the user to measure voltages from 45 Hz to 45kHz when used with the Model 164. The slide switch (S101) can be used to select either AC mode or straight-through DC Mode.

## SPECIFICATIONS:

DC MODE: Straight-through probe does not alter any Model 160 or 163 specifications except: 1. 150 picofarads input capacitance, 2. 0.5 ampere maximum current, 3. 0.3 ohm resistive offset, 4.  $\pm 20$  microvolts thermal offset.

## AC MODE (Voltage only):

ACCURACY (400 Hz):  $\pm 1\%$  of reading or  $\pm 0.1$  volt, whichever is greater (rms of sine wave to dc conversion).

FREQUENCY RESPONSE:  $-2\%$  at 45 Hz and 45kHz.

RANGE: 250 volts rms maximum.

MAXIMUM OVERLOAD: Peak ac plus dc bias must not exceed 400 volts.

INPUT IMPEDANCE: 0.5 megohm, shunted by less than 20 picofarads.

OUTPUT IMPEDANCE: Output must be shunted by 10.2 megohms  $\pm 1\%$  for rated accuracy (Model 160 and 163 impedance on 1000, 100 and 10-volt ranges). 10% variation in the 10.2 megohms causes 1% additional error.

CONNECTOR: Shielded Banana Plug

DIMENSIONS, WEIGHT: 6" long x 3/4" diameter (150 x 20 mm), 3-ft. (1 m) cable, net weight 1/4 pound (0.1 Kg).

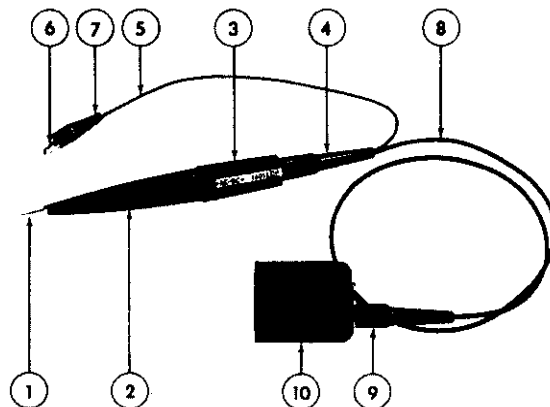
ELECTRICAL PARTS LIST: (See schematic 24669C)

| Circuit Desig. | Description                | Mfr. Code | Mfr. Desig. | Keithley Part No. |
|----------------|----------------------------|-----------|-------------|-------------------|
| J101           | Banana Plug (2 req'd)      | 74970     | 108-750-2   | BG-3              |
| S101           | Switch, AC-DC              | 80164     | -           | SW-334            |
| C101           | Capacitor, .047 $\mu$ F    | 97419     | M2W-F       | C197-.047M        |
| C102           | Capacitor, 0.1 $\mu$ F     | 13050     | MW1A        | C86-.1M           |
| D101           | Transistor                 | 07263     | 2N3565      | TG-39             |
| D102           | Transistor                 | 07263     | 2N3565      | TG-39             |
| D103           | Diode                      | 04713     | 1N4006      | RF-38             |
| R101           | Resistor, 3.92M $\Omega$   | 91637     | DC-1/4      | R178-3.92M        |
| R102           | Resistor, Selected in Test | 07716     | CEA         | R88               |
| R103           | Resistor, 1M $\Omega$      | 91637     | MFF-1/8     | R179-1M           |
| R104           | Resistor, 100 $\Omega$     | 44655     | RC07        | R76-100           |

MAINTENANCE: Since the probe assembly should provide good service with normal handling, no maintenance is usually necessary. The probe body (Items 2 and 3) is fastened together at the factory using a special solvent. Therefore the probe should not be disassembled. If repair is necessary, contact the Keithley Representative in your area.

## MECHANICAL PARTS LIST:

| Item No. | Description              | Keithley Part No. |
|----------|--------------------------|-------------------|
| 1        | Tip                      | 24654B            |
| 2        | Body, Front              | 24656C            |
| 3        | Body, Rear               | 24655C            |
| 4        | Strain Relief            | 18676B            |
| 5        | Cable, Ground (13" long) | SC-33             |
| 6        | Clip, Alligator (Ground) | AC-10             |
| 7        | Insulator (Black)        | AC-11             |
| 8        | Cable (40" long)         | SC-30             |
| 9        | Strain Relief            | 18676B            |
| 10       | Can Shield               | 25128A            |



Model 1603 Extender Card Kit

Description:

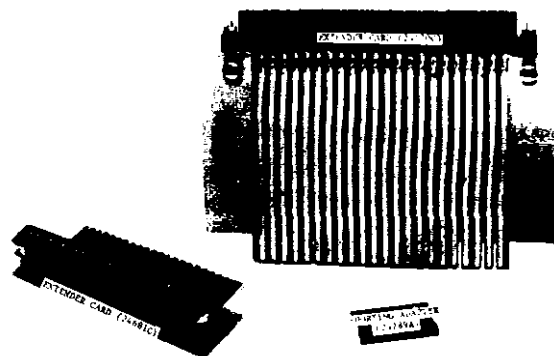
The 1603 Kit consists of two types of printed circuit board extender cards and a shorting adapter.

Parts List:

- 1 Extender Card, 44-pin, Keithley No. 24681C
- 2 Extender Card, 22-pin, Keithley No. 24570B
- 3 Shorting Adapter, Keithley No. 24789A

Application:

These extender cards facilitate testing and troubleshooting of Models 164 and 164TT. Access to all pin connections is provided. The shorting adapter is not useable with Models 164 and 164TT.

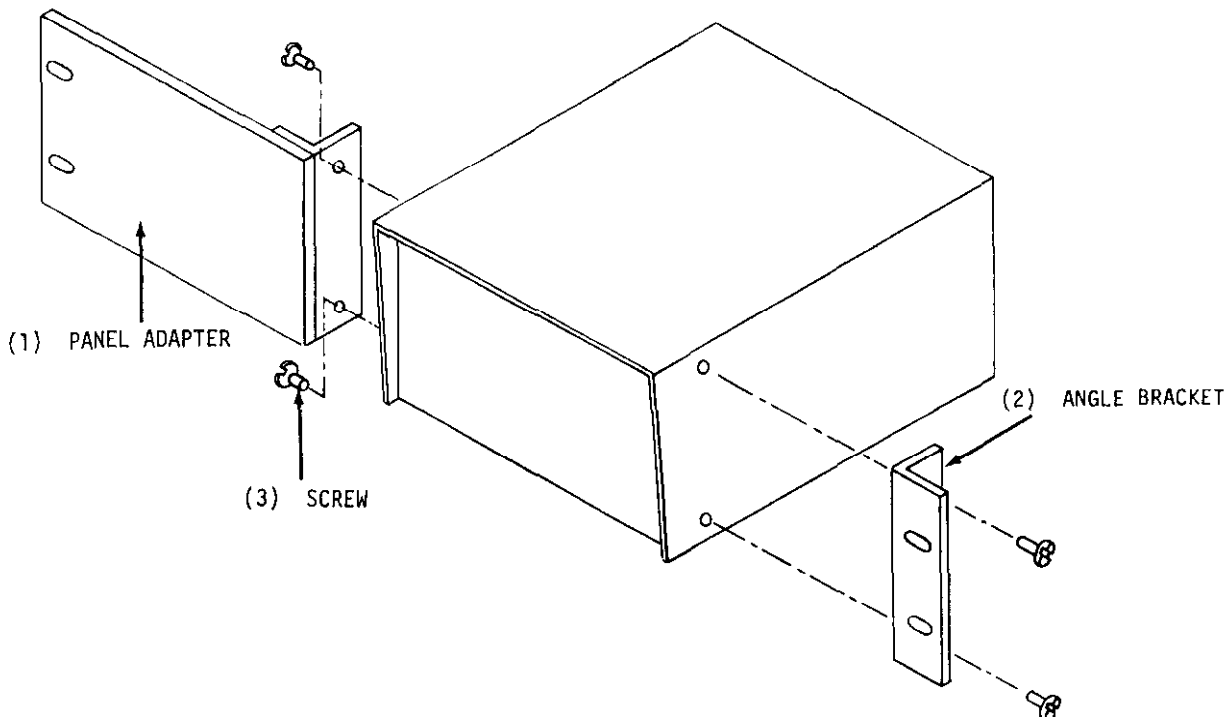


Model 1000 Rack Mounting Kit

General: The Keithley Model 1000 Rack Mounting Kit includes all necessary parts for rack mounting one instrument in a 19 inch panel. Rack height is 5-1/4 inches with 11 inches depth measured from the front panel.

Parts List:

| Item | Description        | Keithley Part No.    |
|------|--------------------|----------------------|
| 1    | Panel Adapter      | 26063B               |
| 2    | Angle Bracket      | 26062B               |
| 3    | Screw (4 required) | #8 32x3/8", Phil Hd. |



## SECTION 5. SERVICING

5-1. GENERAL. This section contains procedures for servicing the instrument in the event of a malfunction.

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

5-3. PARTS REPLACEMENT. Replace components using only those parts specified in the REPLACEABLE PARTS LIST or their equivalents.

5-4. ASSEMBLY

### 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 the instrument and discharge power supply capacitors through a low value resistor.

a. Top Cover Assembly. To gain access to test points and adjustments on printed circuit board PC-254, remove the top cover by unfastening six slotted-head screws as shown in Figure 21.

b. Chassis Assembly. To gain access to the remaining printed circuit boards the following procedure should be used.

1. Remove the front panel Range knob assembly as shown in Figure 14. Loosen the two set screws holding the switch coupler to the switch shaft using a 1/16 hex size (Allen Head) screw driver. Figure 13 shows the proper orientation of the Range knob for reassembly.

2. Remove the front panel Allen Head screws in two places as shown in Figure 14 using a 3/32 hex size screw driver.

3. Remove the rear panel Phillips head screws in two places as shown in Figure 14.

4. Remove connector J906 which is wired between PC-254 and PC-348. Replace connector with longer jumper cable (furnished in the Model 1603 Extender Card Kit) which will apply power to the instrument.

5. Separate the circuit board assembly from the chassis as shown in Figure 15.

c. Printed Circuit Board Installation. The location of all circuit boards is shown in Figure 16. To gain access to circuit boards PC-248, PC-250, and PC-255 the following procedure should be used.

1. Remove the two Phillips head screws from the underside of PC-254 as shown in Figure 16.

2. Remove the slotted screw and nut holding PC-248 and PC-250.

3. Remove the long slotted screw and fastener as shown in Figure 16.

4. Remove the two standoffs holding PC-248 and PC-250.

5. Remove circuit board PC-255 and replace with Extender Card 24681C (from Model 1603 Extender Card Kit).

5-5. CALIBRATION CONTROLS.

a. Offset Current Adjust (R733). This control is a screw driver adjustment accessible from the bottom cover as shown in Figure 18.

b. Ohms Cal Adjust (R738). This control is a screw driver adjustment accessible from the bottom cover as shown in Figure 18.

c. DC Balance Adjust (R722). This control is an adjustment accessible from the bottom cover as shown in Figure 18. Caution! Use an insulated screw driver to avoid contacting the chassis.

d. 15V Adj. (R209). This control is located on PC-254. Remove the top cover for access to the control.

e. CLOCK Adj. (R605). This control is located on PC-254. Remove the top cover for access.

f. 1V, 10V, 100V, 1000V Controls (R111, R108, R106, R104). These controls are also located on PC-254.

g. +CAL, -CAL Adjust. These controls are located on PC-250.

5-6. COMPONENT LAYOUTS AND OUTLINE DRAWINGS.

a. Component Layouts. The component layouts identify all parts on the printed circuit boards using circuit designations from the schematic diagrams.

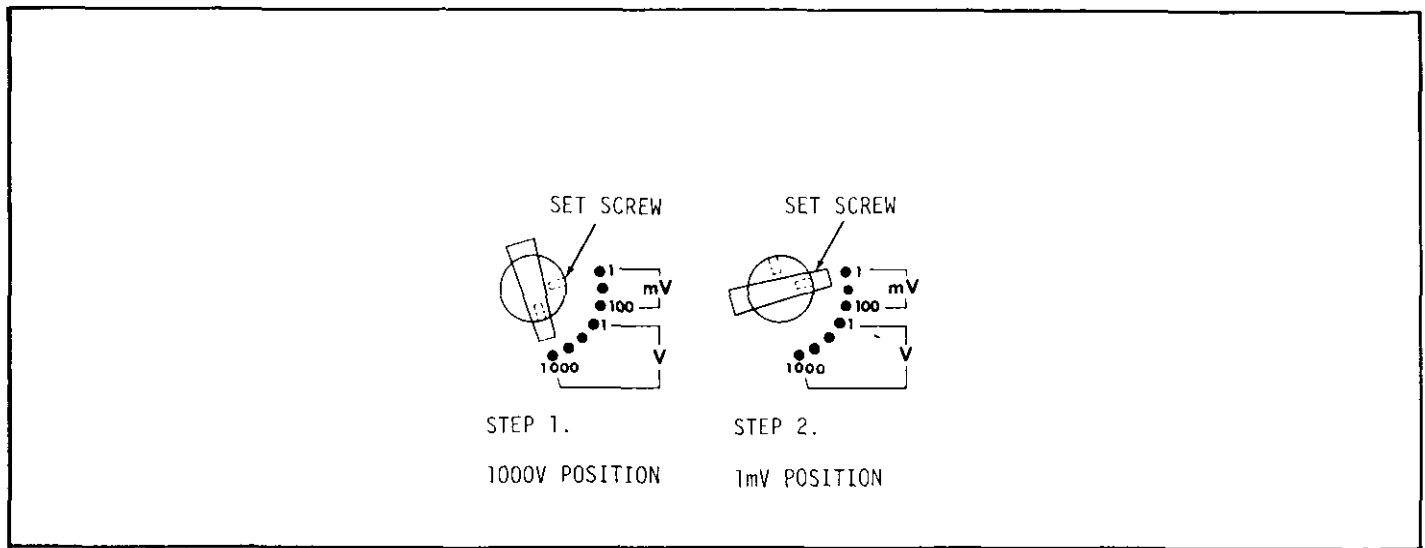


FIGURE 13. RANGE Knob Assembly.

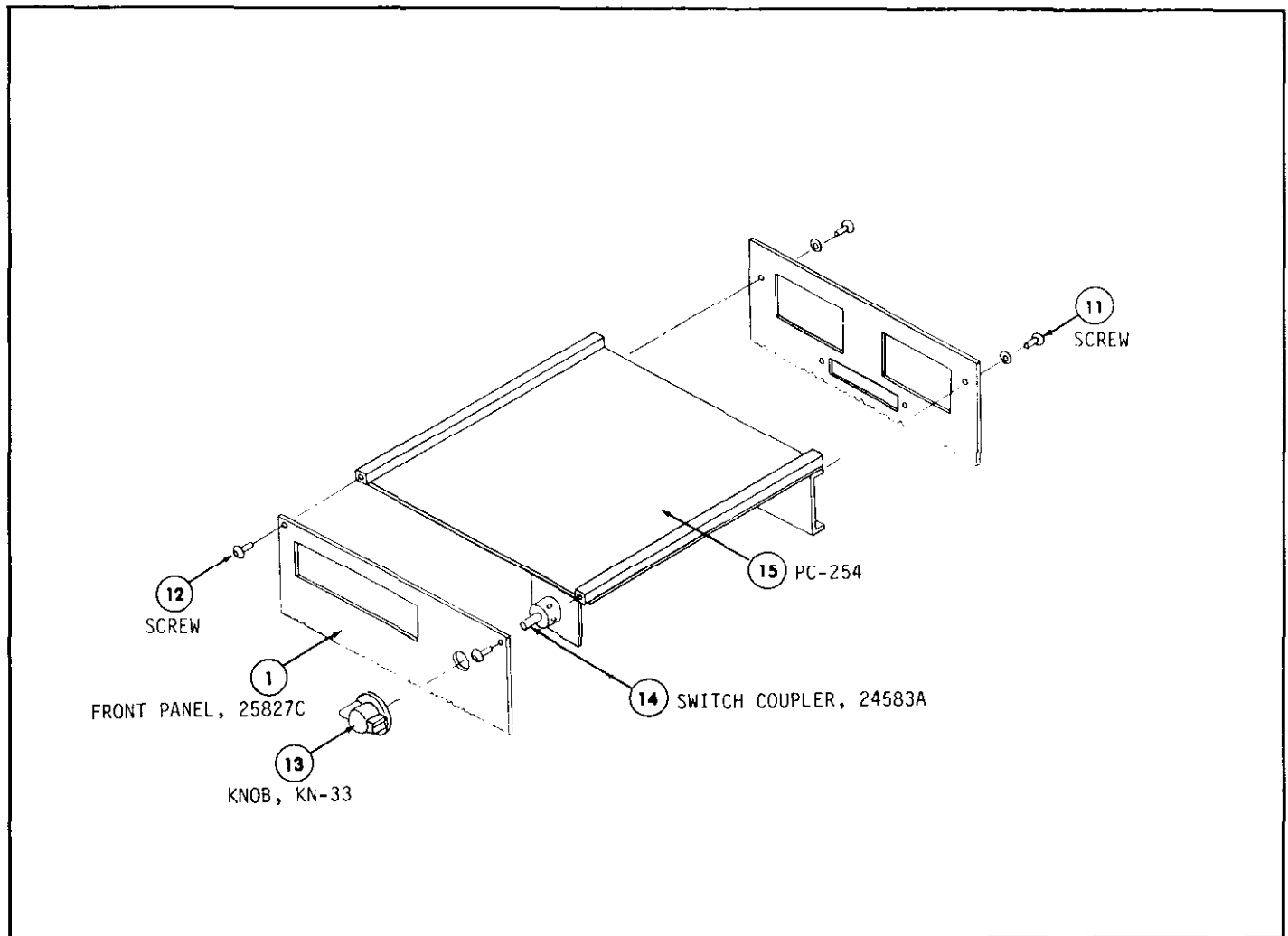


FIGURE 14. Chassis Assembly.

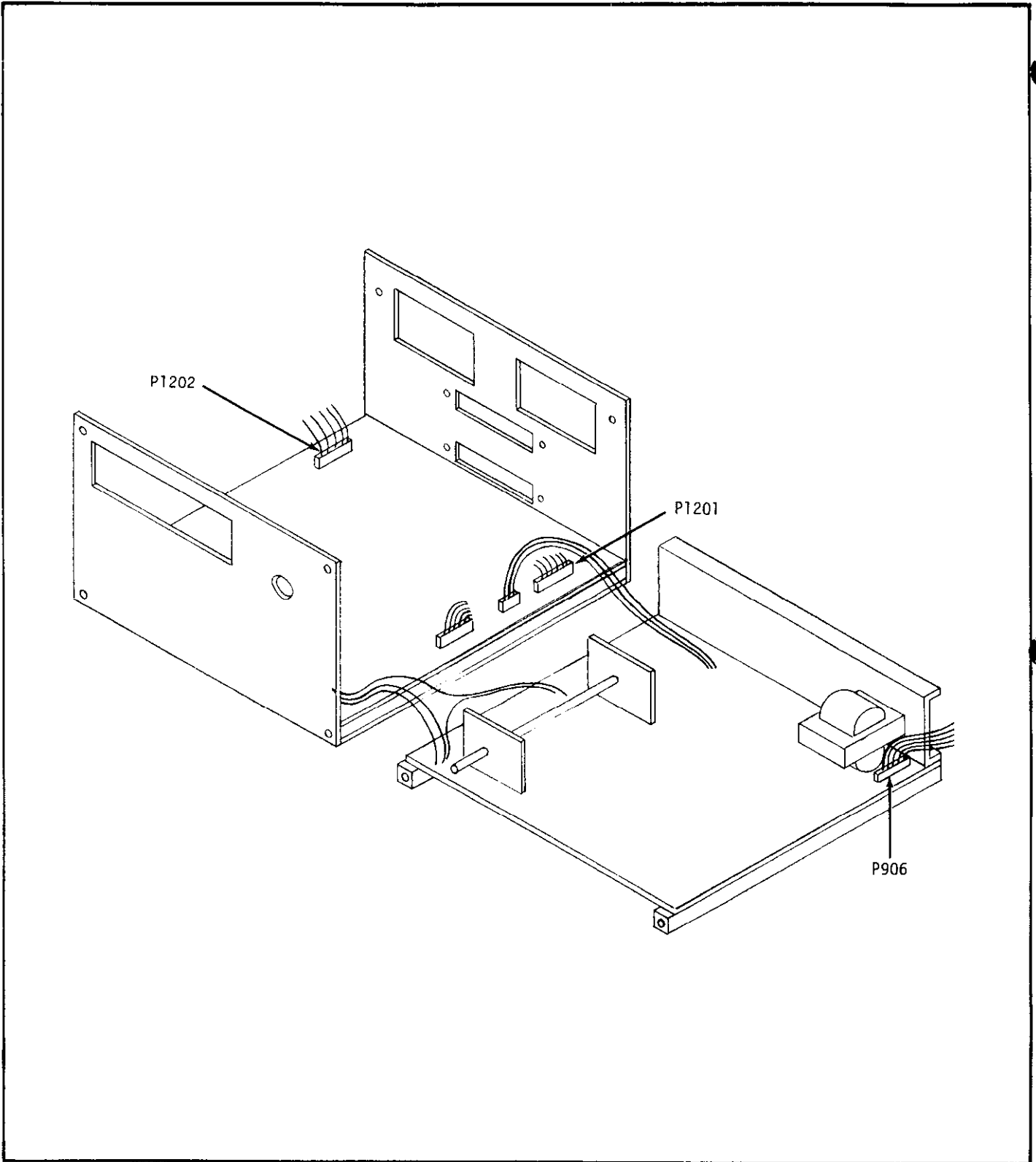


FIGURE 15. Servicing of Chassis.

TABLE 5-1.  
Chassis Part Identification

| Item No. | Description           | Keithley Part No. |
|----------|-----------------------|-------------------|
| 1        | Front Panel           | 25827C            |
| 11       | Screw, Hex socket     | #8 x 3/8          |
| 12       | Screw, Phillips head  | #8 x 5/8          |
| 13       | Knob                  | KN-33             |
| 14       | Switch coupler        | 24583A            |
| 15       | Printed Circuit Board | PC-254            |
| 16       | Switch, S101          | SW-319            |
| 17       | Cable harness         | ---               |
| 20       | Printed Circuit Board | PC-251            |
| 21       | Printed Circuit Board | PC-255            |
| 22       | Printed Circuit Board | PC-248            |
| 23       | Printed Circuit Board | PC-250            |
| 24       | Screw, slotted        | #4 x 2-1/4        |
| 25       | Fastener, hex nut     | #4-40             |
| 26       | Standoff (2 req'd)    | 24193A            |
| 27       | Screw, Phillips head  | #6 x 5/16         |
| 28       | Screw, slotted        | #6 x 5"           |
| 29       | Fastener              | FA-107            |

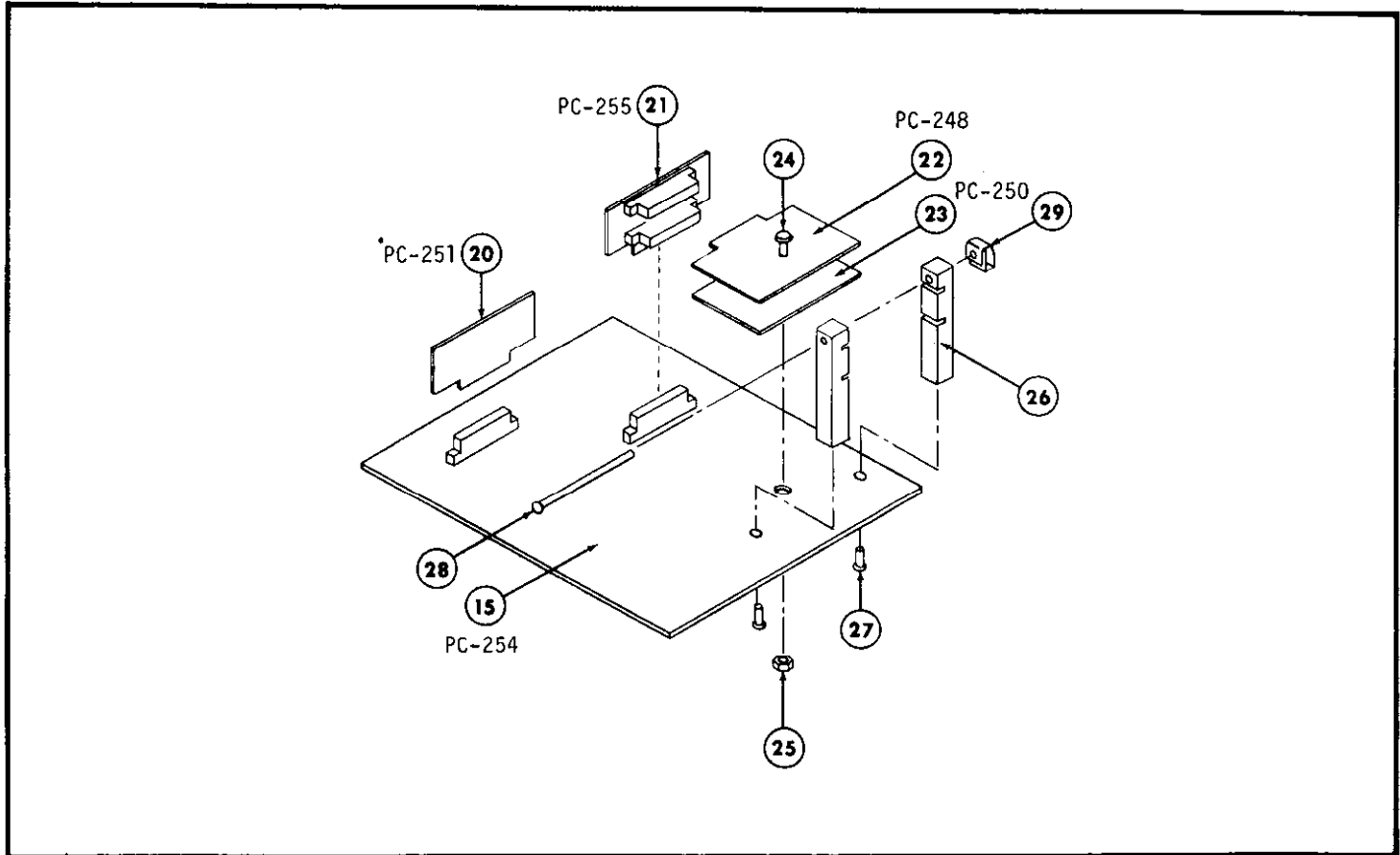


FIGURE 16. PC Board Locations.



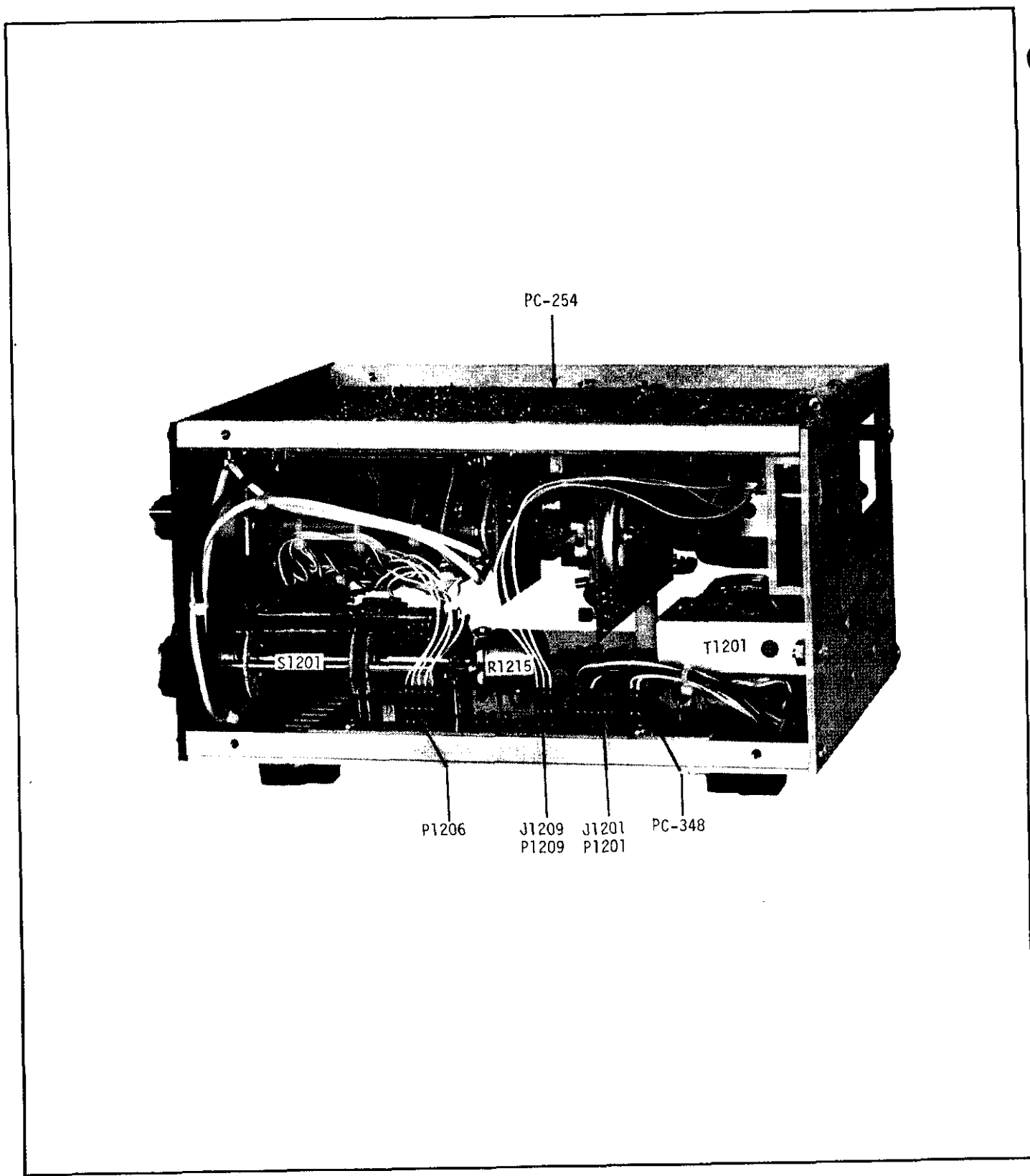


FIGURE 17. Side View of Chassis.

TABLE 5-2.  
Trouble-Shooting Procedure

| Difficulty  | Probable Cause                                       | Solution   |
|---|--|--|
| No front panel display illumination.                            | Power failure  | Check fuse. If blown, check for an internal short (broken wire, loose hardware, etc.). Replace fuse by removing top cover and unsoldering pig-tail fuse.   |
| " "   | 210V supply failure                                  | Check 210V supply voltage on PC-254. If low, check rectifier diode D206. Replace with Keithley Part No. RF-17.   |
| " "   | Line switch set at 234V with 117V line input.        | Set switch to 117V.  |
| Overload Indication when input is shorted.                      | Analog amplifier out of balance.                     | Check integrated circuit QA703 on analog board PC-251. Replace with Keithley Part No. IC-2. If difficulty remains, check MOS FET transistor Q701 and Q702. Replace with Keithley Part No. TG-51.<br><br>NOTE: These transistors are sensitive to static charges. Therefore, drain static charge from hands and/or tools using a foil grounding surface. Disconnect the soldering iron from power before using. |
| " "   | Transistors Q402 and Q403                            | Check for zero voltage level on pin 6 of integrated circuit QA401. If not at zero, replace transistors with Keithley Part No. TG-71.   |
| " "   | Oscillator Circuit (Clock)                           | Check CLOCK frequency at CLOCK test point. Frequency should be 10kHz $\pm$ 20 Hz. If out of tolerance, recalibrate as in Section 6. If clock frequency is missing, check transistors Q601, Q602, and Q603. Replace with Keithley Part No. TG-62.   |
| Ohms ranges inaccurate. (Voltage ranges are normal)             | Ohms reference amplifier                             | Check integrated circuit QA704.<br><br>NOTE: Integrated circuit may have failed due to voltage applied in ohms mode. Replace QA704 with Keithley Part No. IC-2. Also replace resistor R745 with Keithley Part No. R168-10K. Recalibrate OHMS circuit. Select R739 as necessary.  |
| Current reading inaccurate on one range only                    | Shunt resistor out of tolerance.                     | Replace shunt resistor for that particular range. Resistors R116 through R122.   |
| Overrange "1" not lighted when it should indicate.              | Transistor Q301 or integrated circuit QA301.         | Replace transistor Q301 if shorted from collector to emitter (Keithley Part No. TG-67). Otherwise, replace QA301 with Keithley Part No. IC-9.  |
| Overrange "1" lighted continuously when it should not indicate. | Transistor Q301 or integrated circuit QA301.         | Replace as above.  |
| Polarity signs remain lighted or do not light at all.           | Transistors Q305 and Q306. Integrated circuit QA305. | Replace transistors Q305 and Q306 with Keithley Part No. TG-67. Replace QA305 with Keithley No. IC-7.  |
| Digital Readouts incorrect.                                     | Decoder driver circuit                               | Replace either QA314, QA315, or QA316 with Keithley Part No. IC-3. (These integrated circuits are <u>not</u> soldered because of plug-in sockets.)   |
| " "   | Decade Counter circuit                               | Replace either QA308, QA309, or QA310 with Keithley Part No. IC-17   |
| " "   | Buffer Storage circuit                               | Replace either QA311, QA312, or QA313 with Keithley Part No. IC-16.  |

**SECTION 6. CALIBRATION**

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

6-2. TEST EQUIPMENT. Use test equipment recommended in Table 6-1 for accuracy verification.

6-3. PROCEDURES.

a. Preliminary.

1. Warm-up Period. With Power Switch ON, allow the instrument to warm-up for a minimum of 30 minutes.

2. Power Supply Checkout. All the power supply voltages can be measured at test points on printed circuit board PC-254 as shown in Figure 18.

TABLE 6-2.  
Power Supply Voltages

| Nominal Voltage | Test Point | Voltage Limits   |
|-----------------|------------|------------------|
| +15.00V dc      | +15V       | +14.95 to +15.05 |
| -15.0V dc       | -15V       | -14.6 to -15.4   |
| +3.6V dc        | +3.6V      | +3.4 to +3.8     |
| +210V dc        | +210V      | +205 to +230     |
| +170V dc        | +170V      | +165 to +175     |

b. Adjustments.

1. Power Supply. The +15V supply should be adjusted for +15.00V dc  $\pm 0.050V$  using potentiometer R209 on PC-254 as shown in Figure 18. The -15V and +3.6V supplies cannot be adjusted since the +15V supply is used as a reference voltage.

TABLE 6-1.  
Test Equipment

| Code Letter | Instrument Type         | Specification                                       | Manufacturer and Model No.                    | Use  |
|-------------|-------------------------|---|---|--|
| A           | Voltmeter, Digital      | $\pm 1\mu V$ to $\pm 1000V \pm 0.1\%$ of reading    | Keithley, Model 160                           | Zero Adjustment  |
| B           | Voltmeter, Differential | limit of error $\pm 0.01\%$ of reading or $10\mu V$ | Keithley, Model 662                           | Voltage Calibration<br>Current Calibration<br>Resistance Calibration |
| C           | Voltage Source          | .003% voltage mode<br>10, 100, 1000 volts           | Fluke, Model 3330B<br>Voltage Source          | Voltage Calibration<br>10, 100, 1000 volts                           |
|             |                         |   | ESI type SR-1010<br>Divider Ratio             | .001, .01, .1, 1 volts   |
| D           | Resistance Box          | $\pm 0.02\%$ accuracy<br>10 megohms maximum         | General Radio<br>Type 1433<br>Decade Resistor | Resistance and<br>Current Calibration                                |
| E           | Current Source          | .006% accuracy<br>0.1 mA to 100 mA                  | Fluke, Model 3330B<br>Current Source          | Current Calibration<br>0.1mA to 100mA ranges                         |
|             |                         | .003% voltage mode                                  | Fluke, Model 3330B<br>Voltage Source (1.01V)  | Current Calibration  |
|             |                         | .02% resistance accuracy                            | General Radio<br>Type 1433<br>Decade Resistor | .001 to .01mA ranges   |

2. Clock Frequency. Measure the clock frequency at the "CLOCK" test point on PC-254 as shown in Figure 16. The frequency should be adjusted for a nominal 10kHz,  $\pm 20$  Hz using potentiometer R605 on PC-254 as shown in Figure 18.

3. Zero Adjust. Temporarily disconnect front panel zero control R1215 by removing connector J1209 (located on PC-348). Place a shorting wire across the Input Terminals (red and black). Connect voltmeter (A) to the analog OUTPUT (J103). Adjust the rear-panel ZERO Control (R505) for zero on the 1 mV range.

4. The output should be adjusted to zero within  $\pm 1$  millivolt.

5. DC Balance. With voltmeter (A) connected to the OUTPUT adjust the OFFSET CURRENT ADJ. Control (R733) for zero on the 1V range. The OUTPUT should be adjusted within  $\pm 1$  millivolt on the 1mV range and within  $\pm 0.1$  millivolt on the 1V range. Repeat the adjustments of R505 and R733 until the OUTPUT is within tolerance on both the 1mV and 1V ranges simultaneously. NOTE

If the OUTPUT cannot be adjusted to within  $\pm 1$ mV on the 1mV range place a jumper between input low and the junction of R503 and C504 on PC-254. Then set RANGE switch to 100mV and adjust DC balance pot R722 (on PC-251) for zero at the OUTPUT. Remove jumper from R503 and repeat steps 4 and 5. After R505 and R733 are properly set, replace J1209 on PC-348 and adjust front panel zero R1215 for flashing zero on the 1mV range. Then remove the input short.

6. Analog Calibration.

a). Voltage Ranges. Connect voltmeter (B) to the analog OUTPUT. Connect voltage source (C) to the Input Terminals (red and black). Measure the analog OUTPUT voltage for each range as described in Table 6-3. On the 100mV, 10mV, and 1mV ranges wire jumpers are used for calibration. On the 1V, 10V, 100V, and 1000V ranges potentiometers R111, R108, R106, and R104 should be adjusted.

b). Resistance Ranges (Model 160 only). Connect decade resistance box (D) to the Input Terminals. Measure the analog OUTPUT for each range as described in Table 6-4. Adjust the OHMS CAL potentiometer (R738) for an OUTPUT of +1V  $\pm 1.0$  millivolt on the 1k $\Omega$  range only. The remaining resistance ranges cannot be adjusted.

c). Current Ranges (Model 160 only). Connect current source (E) to the Input Terminals. Measure the analog OUTPUT for each current range as described in Table 6-5. No calibration adjustments can be made on any of the current ranges.

7. Digital Calibration.

a). Zero Check. Connect a shorting wire across Input Terminals. Adjust the front-panel ZERO Control so that the Digital Display reading is 0-0-0-0 on the 1mV range with the Polarity Indicator alternating plus and minus. Measure the analog OUTPUT voltage which should be within  $\pm 1$  millivolt of zero.

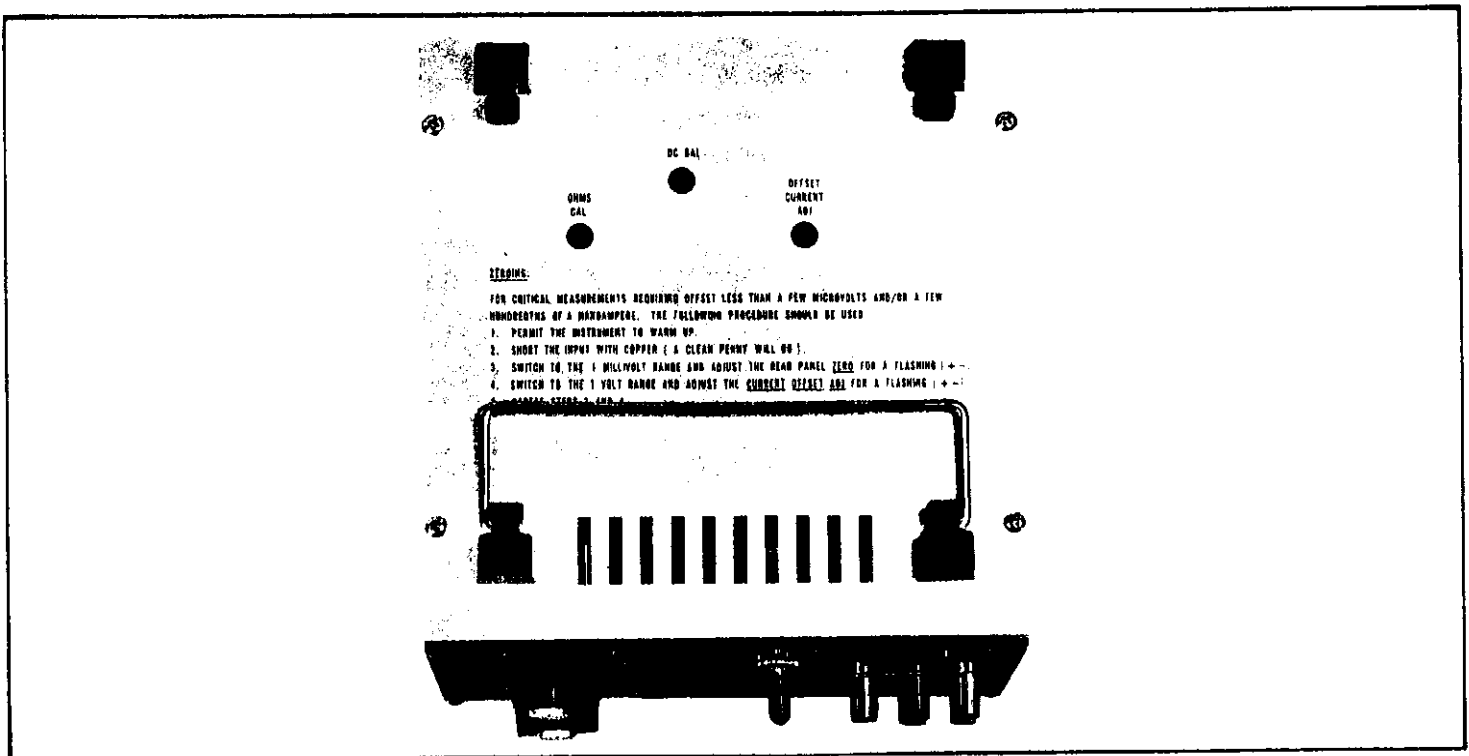


FIGURE 18. Chassis, Bottom View.

b). Full-Scale Indication. Connect voltage source (C) to the Input Terminals and adjust the source for +1.9992V measured at the analog OUTPUT. Adjust the -CAL Control (R402) so that the Digital Display has a reading which alternates between 1-9-9-9 and a blanked display (with only the over-range "1" lighted). Apply a negative input and adjust the +CAL Control (R408).

c). Linearity Adjustment. Connect an accurate voltage source (C) to the Input Terminals and adjust for an analog OUTPUT of +0.9992V on the 1V range. Verify that the Digital Display reading is 0-9-9-9. Readjust the voltage source for an analog OUTPUT of +0.9998V on the 1V range. Verify a change of the Digital Display from 0-9-9-9 to 1-0-0-0.

#### 8. Calibration of Milliohm Current Source.

a). Warm-up period. With Power Switch ON, allow the instrument to warm-up for a minimum of 30 minutes.

b). Connect resistance box to inputs using four lead wires -- two connected to mΩ SOURCE (current leads) and two connected to HI and LO (voltage leads).

c). Set R box to zero resistance and read residual resistance with 164. Set R box to 10.000 ohms including residual. Adjust R1203 for reading of 10.00 in Operate position after zeroing out thermal EMF's in zero position.

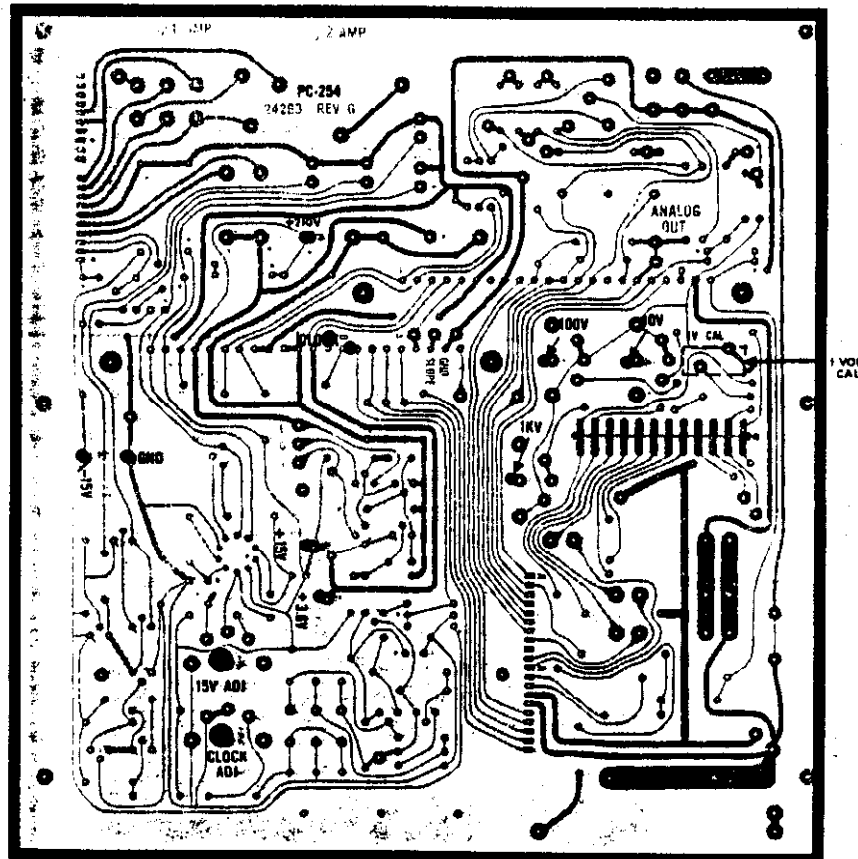


FIGURE 19. Calibration Controls.

TABLE 6-3.  
Voltage Range Calibration  
Summary of Calibration Controls and Test Points.

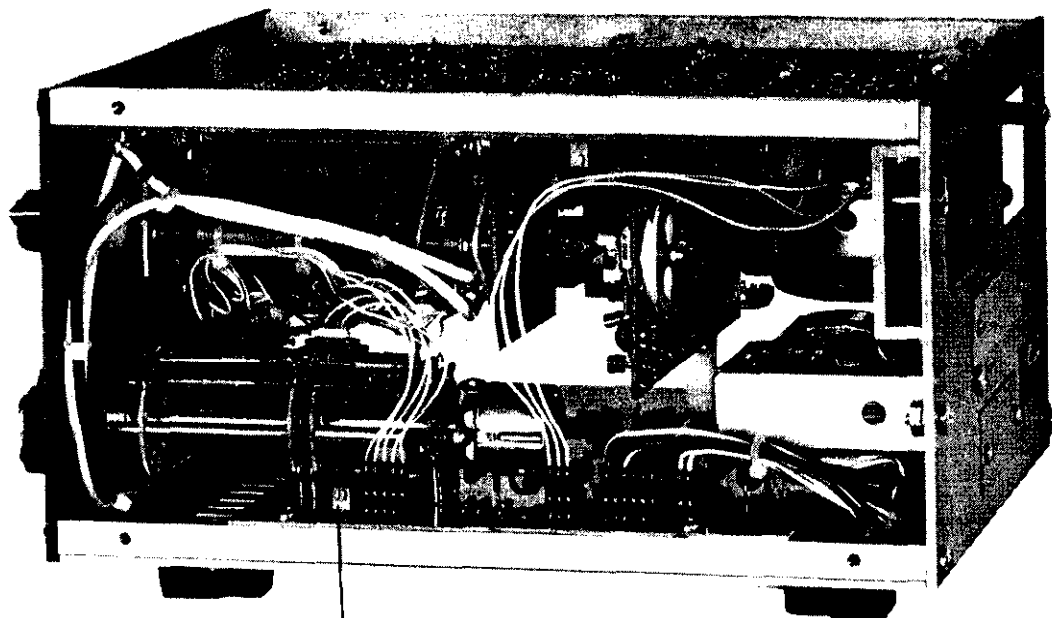
| Range Setting | Input Source | Source Accuracy | Analog OUTPUT Voltage | Analog OUTPUT Accuracy | Ref. Desig. | Control |
|---------------|--------------|-----------------|-----------------------|------------------------|-------------|---------|
| 100mV         | 100mV        | ±.01%           | 1.000V                | ±1mV                   | R520, R521  | Jumper  |
| 10mV          | 10mV         | ±.01%           | 1.000V                | ±1mV                   | R517, R518  | Jumper  |
| 1mV           | 1mV          | ±.01%           | 1.000V                | ±1mV                   | R514, R515  | Jumper  |
| 1 V           | 1 V          | ±.01%           | 1.000V                | ±1mV                   | R111        | 1V CAL  |
| 10 V          | 10 V         | ±.01%           | 1.000V                | ±1mV                   | R108        | 10V     |
| 100 V         | 100 V        | ±.01%           | 1.000V                | ±1mV                   | R106        | 100V    |
| 1000 V        | 1000 V       | ±.01%           | 1.000V                | ±1mV                   | R104        | 1000V   |

TABLE 6-4.  
Resistance Range Calibration  
Summary of Calibration Controls and Test Points.

| Range Setting | Input Source | Source Accuracy | Analog OUTPUT Voltage | Analog OUTPUT Accuracy | Ref. Desig. | Control  |
|---------------|--------------|-----------------|-----------------------|------------------------|-------------|----------|
| 1KΩ           | 1KΩ          | ±.01%           | 1.000V                | ± 1mV                  | R738        | OHMS CAL |
| 100 Ω         | 100 Ω        | ±.02%           | 1.000V                | ± 1mV                  | ----        | None     |
| 10KΩ          | 10KΩ         | ±.02%           | 1.000V                | ± 4mV                  | ----        | None     |
| 100KΩ         | 100KΩ        | ±.02%           | 1.000V                | ± 3mV                  | ----        | None     |
| 1MΩ           | 1MΩ          | ±.02%           | 1.000V                | ± 3mV                  | ----        | None     |
| 10MΩ          | 10MΩ         | ±.4%            | 1.000V                | ± 40mV                 | ----        | None     |
| 100MΩ         | 100MΩ        | ±1%             | 1.000V                | ±100mV                 | ----        | None     |
| 1000MΩ        | 1000MΩ       | ±3%             | 1.000V                | ±500mV                 | ----        | None     |

TABLE 6-5.  
Current Range Calibration

| Range Setting | Input Source | Source Accuracy | Analog OUTPUT Voltage | Analog OUTPUT Accuracy |
|---------------|--------------|-----------------|-----------------------|------------------------|
| 0.1μA         | 0.1μA        | ±.02%           | 1.000V                | ± 2mV                  |
| 1μA           | 1μA          | ±.02%           | 1.000V                | ± 2mV                  |
| 10μA          | 10μA         | ±.02%           | 1.000V                | ± 2mV                  |
| 100μA         | 100μA        | ±.02%           | 1.000V                | ± 2mV                  |
| 1mA           | 1mA          | ±.02%           | 1.000V                | ± 2mV                  |
| 10mA          | 10mA         | ±.02%           | 1.000V                | ± 2mV                  |
| 100mA         | 100mA        | ±.02%           | 1.000V                | ± 3mV                  |
| 1000mA        | 1000mA       | ±.02%           | 1.000V                | ± 3mV                  |
| 1000mA        | 100mA        | ±.02%           | 0.100V                | ±0.3mV                 |



R1203  
mΩ SOURCE

FIGURE 20. Calibration of Milliohm Current Source.

## 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), Manufac-

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

TABLE 7-1.  
Abbreviations and Symbols

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

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

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. The parts for the instrument's Main Chassis are listed followed by printed circuit boards and other sub-assemblies. Refer to Table 7-3 for listing of circuit designation series assigned to each major sub-assembly.

7-4. HOW TO ORDER PARTS.

a. Replaceable parts may be ordered through the Sales Service Department, Keithley Instruments, Inc. or your nearest Keithley representative.

b. When ordering parts, include the following information.

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

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 Number |
|-----------------------------|---------------------|-----------------------|
| Switching - Main Chassis    | Front Panel         | 26243E                |
| Power Supply                | PC-254              | 26245D                |
| Connectors                  | PC-254, PC-255      | 26246D                |
| Analog Amplifier            | PC-251              | 26244E                |
| Integrator Board            | PC-250              | 24690E                |
| Tube Board                  | PC-248              | 24688D                |
| Tube Board                  | PC-248              | 24689D                |
| Milliohm Source             | PC-348              | 24642D                |
| Trip Circuit (Model 164TT)  | PC-348              | 26225D                |
| Digital Output (Model 1602) | PC-287              | 24685D                |
| AC-DC Probe (Model 1601)    | --                  | 24669C                |



TABLE 7-3.

| Circuit<br>Desig. | Description           | Connector<br>Plug-In | Series    | Page<br>No. |
|-------------------|-----------------------|----------------------|-----------|-------------|
| --                | Main Chassis          | --                   | 100       | 38-46       |
| PC-254            | Power Supply          | --                   | 200       | 38-46       |
| PC-248            | Tube Board            | J802                 | 300       | 38-46       |
| PC-250            | Integrator Board      | J801                 | 400       | 38-46       |
| PC-254            | Input Filter          | --                   | 500       | 38-46       |
| PC-254            | Oscillator            | --                   | 600       | 38-46       |
| PC-251            | Analog Amplifier      | J902                 | 700       | 38-46       |
| PC-255            | Connector Board       | J901                 | 800       | 38-46       |
| PC-254            | Connectors            | --                   | 900       | 38-46       |
| PC-348            | mΩ Source, Dual Trips | --                   | 1200,1300 | 38-46,47    |

TABLE 7-4.  
Mechanical Parts List

| Description                               | Quantity<br>Per Assembly | Keithley<br>Part No. |
|---|--------------------------|----------------------|
| 1) Front Panel                            | 1                        | 25827C               |
| 2) Rear Panel                             | 1                        | 25828C               |
| Top Cover Assembly                        | ---                      | 26028B               |
| 3) Cover, Sheet Metal                     | 1                        | 26021D               |
| 4) Screws, #6 x 3/8 slotted, pan head     | 4                        | ---                  |
| Handle Assembly                           | ---                      | ---                  |
| 5) Handle                                 | 1                        | HH-18                |
| 6) Screws #6-32 x 3/8" R. H. Slotted      | 2                        | ---                  |
| Bottom Assembly                           | ---                      | 26029B               |
| 7) Bottom                                 | 1                        | 26024C               |
| 8) Fastener                               | 2                        | FA-54                |
| Feet Assembly                             | ---                      | ---                  |
| 9) Feet                                   | 4                        | 24322B               |
| 10) Ball                                  | 4                        | FE-6                 |
| 11) Screws #6 x 7/16" Phillips, Flat Head | 4                        | ---                  |
| Tilt Bail Assembly                        | ---                      | ---                  |
| 12) Bail                                  | 1                        | 17147B               |
| 13) Kep Nut                               | 4                        | ---                  |

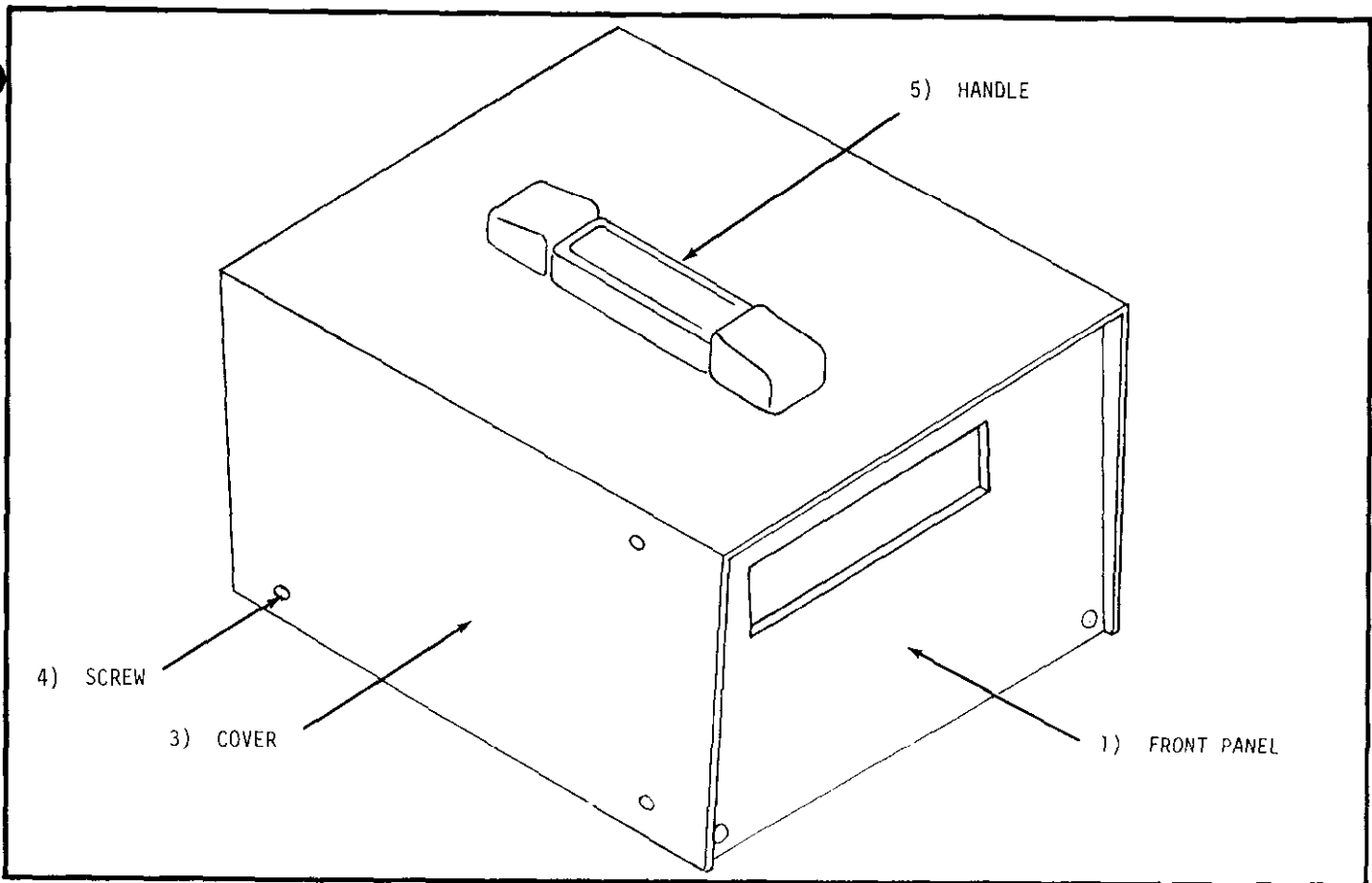


FIGURE 21. Top Cover Assembly.

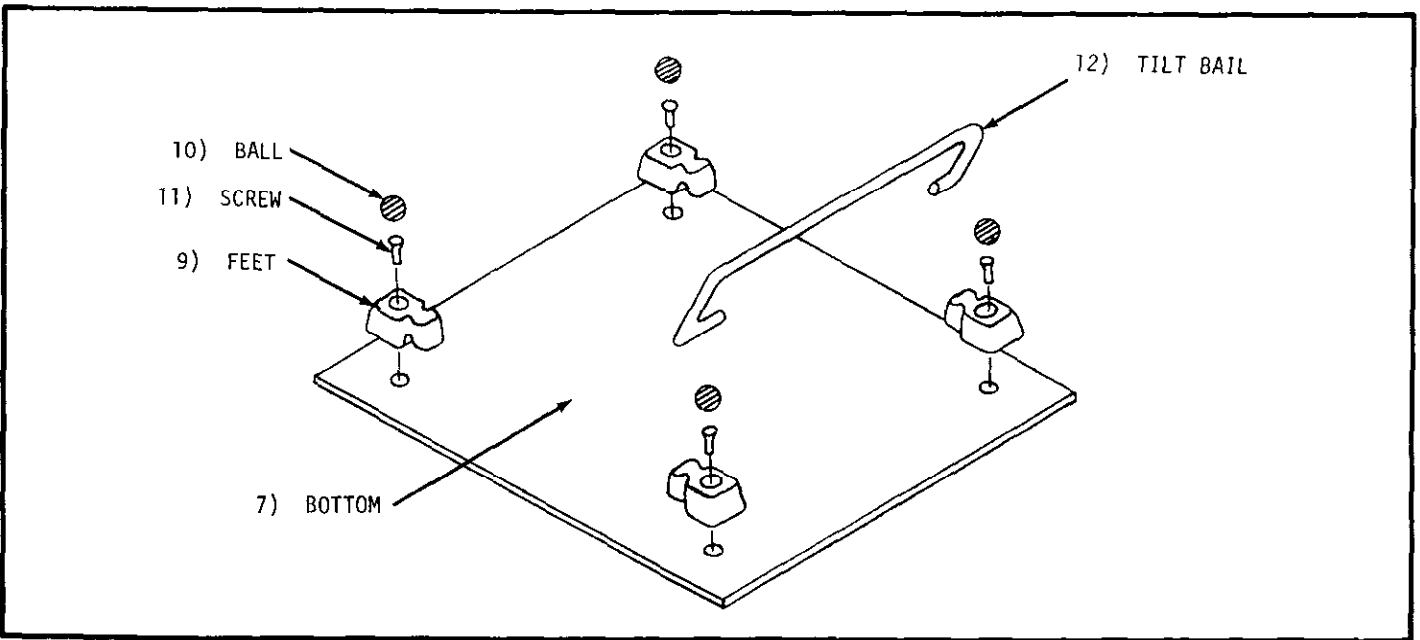


FIGURE 22. Bottom Cover Assembly.

Models 164, 164TT. (See schematics 26243E, 26245D,  
26246D, 26244E, 24690E, 24688D, 24689D, 24642D).

## CAPACITORS

| Circuit Desig. | Description                 | Mfr. Code | Mfr. Desig.         | Keithley Part No. | Qty.  |
|----------------|-----------------------------|-----------|---------------------|-------------------|-------|
| C101           | .0047 $\mu$ F, 500V, CerD.  | 72982     | 801-Z5UO-472M       | C22-.0047M        | 7     |
| C102           | .0047 $\mu$ F, 500V, CerD.  | 72982     | 801-Z5UO-472M       | C22-.0047M        | ..    |
| C103           | .0047 $\mu$ F, 500V, CerD.  | 72982     | 801-Z5UO-472M       | C22-.0047M        | ..    |
| C201           | 2000 $\mu$ F, 15V, EAL.     | 29309     | 3675020015C         | C93-2000M         | 1     |
| C202           | 220pF, 1000V, CerD.         | 71590     | DD-221              | C64-220P          | 3     |
| C203           | 150pF, 1000V, CerD.         | 71590     | DD-151              | C64-150P          | 1     |
| C204           | 200 $\mu$ F, 35V, EAL.      | 90201     | MTV200N35           | C177-200M         | 4     |
| C205           | 200 $\mu$ F, 35V, EAL.      | 90201     | MTV200N35           | C177-200M         | ..    |
| C206           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | 11    |
| C207           | 470pF, 1000V, CerD.         | 71590     | DD-471              | C64-470P          | 1     |
| C208           | 125 $\mu$ F, 15V, ETB.      | 73445     | C426-125 $\mu$ F    | C3-125M           | 2     |
| C209           | 200 $\mu$ F, 35V, EAL.      | 90201     | MTV200N35           | C177-200M         | ..    |
| C210           | 200 $\mu$ F, 35V, EAL.      | 90201     | MTV200N35           | C177-200M         | ..    |
| C211           | 125 $\mu$ F, 15V, ETB.      | 73445     | C426-125 $\mu$ F    | C3-125M           | ..    |
| C212           | 15 $\mu$ F, 300V, EAL.      | 90201     | PTC015M300          | C173-15M          | 1     |
| C301           | .0022 $\mu$ F, 500V, CerD.  | 72982     | 831-Z5UO-222M       | C22-.0022M        | 2     |
| C302           | 100pF, 1000V, CerD.         | 71590     | DD-101              | C64-100P          | 2     |
| C303           | 0.22 $\mu$ F, 10V, ETT.     | 17554     | TSD210226           | C180-0.22M        | 1     |
| C304           | 10pF, 1000V, CerD.          | 71590     | DD-100              | C64-10P           | 3     |
| C401           | 10pF, 1000V, CerD.          | 71590     | DD-100              | C64-10P           | ..    |
| C402           | 10pF, 1000V, CerD.          | 71590     | DD-100              | C64-10P           | ..    |
| C403           | 100pF, 1000V, CerD.         | 71590     | DD-101              | C64-100P          | ..    |
| C404           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C405           | 1.5pF, 600V, CerD.          | 71590     | TCZ-15              | C77-1.5P          | 1     |
| C406           | 1 $\mu$ F, 100V, My.        |           | MF825               | C185-1M           | 1     |
| C407           | .001 $\mu$ F, 1000V, CerD.  | 72982     | 808-000-Z5R0102K    | C64-.001M         | 1     |
| C408           | Not Used                    | .....     | .....               | .....             | ..... |
| C409           | 220pF, 1000V, CerD.         | 71590     | DD-221              | C64-220P          | ..    |
| C410           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C411           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C412           | 22 $\mu$ F, 10V, ETT.       | 17554     | TSD2-10             | C180-22M          | 1     |
| C413           | 5pF, 1000V, CerD.           | 71590     | DD-050              | C64-5P            | 1     |
| C414           | 1 $\mu$ F, 50V, CerF.       | 72982     | 8131050651105M      | C237-1M           | 1     |
| C415           | .0047 $\mu$ F, 500V, CerD.  | 72982     | 801-Z5UO-472M       | C22-.0047M        | ..    |
| C416           | 390pF, 1000V, CerD.         | 71590     | DD-391              | C64-390P          | 1     |
| C417           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C418           | 0.1 $\mu$ F, 250V, MtF.     | 73445     | C280AE              | C178-.1M          | 3     |
| C419           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C420           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C501           | 0.1 $\mu$ F, 200V, My.      | 13050     | SM2A-.1 $\mu$ F     | C143-.1M          | 2     |
| C502           | 0.1 $\mu$ F, 200V, My.      | 13050     | SM2A-.1 $\mu$ F     | C143-.1M          | ..    |
| C503           | 2 $\mu$ F, 100V, My.        |           | MF1195-2 $\mu$ F    | C188-2M           | 1     |
| C601           | .047 $\mu$ F, 200V, My.     | 13050     | SM2A-.047 $\mu$ F   | C143-.047M        | 1     |
| C602           | 500pF, 500V, Silver Mica.   | 14655     | CD19FD501F03        | C209-500P         | 2     |
| C603           | 500pF, 500V, Silver Mica.   | 14655     | CD19FD501F03        | C209-500P         | ..    |
| C604           | 1500pF, 500V, Silver Mica.  | 14655     | CD19FD152F03        | C209-1500P        | 1     |
| C605           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20             | C179-10M          | ..    |
| C701           | Not Used                    | .....     | .....               | .....             | ..... |
| C702           | 0.01 $\mu$ F, 200V, My.     | 13050     | SMLA-.01 $\mu$ F    | C47-.01M          | 1     |
| C703           | 10 $\mu$ F, 20V, ETT.       | 17554     | TSD1-20-10 $\mu$ F  | C179-10M          | ..    |
| C704           | 0.0047 $\mu$ F, 500V, CerD. | 72982     | 801-Z5UO-472M       | C22-.0047M        | ..    |
| C705           | 1.2 $\mu$ F, 20V, ETT.      | 17554     | TSD1-20-1.2 $\mu$ F | C179-1.2M         | 2     |
| C706           | 1.2 $\mu$ F, 20V, ETT.      | 17554     | TSD1-20-1.2 $\mu$ F | C179-1.2M         | ..    |

Models 164, 164TT.  
CAPACITORS (Cont'd)

| Circuit Desig. | Description           | Mfr. Code | Mfr. Desig.      | Keithley Part No. | Qty. |
|----------------|-----------------------|-----------|------------------|-------------------|------|
| C707           | 0.0047µF, 500V, CerD. | 72982     | 801-Z5U0-472M    | C22-.0047M        | ..   |
| C708           | 220pF, 1000V, CerD.   | 71590     | DD-221           | C64-220P          | ..   |
| C709           | 0.1µF, 250V, MtF.     | 73445     | C280AE-.1µF      | C178-.1M          | ..   |
| C710           | 0.22µF, 250V, MtF.    | 73445     | C280AE-.22µF     | C178-.22M         | 1    |
| C711           | 0.1µF, 250V, MtF.     | 73445     | C280AE-.1µF      | C178-.1M          | ..   |
| C801           | 0.001µF, 1000V, CerD. | 72982     | 808000-Z5R0-102K | C64-.001M         | 1    |
| C1201          | 470µF, 40V, EAL       | Amperex   | ET471X040A2      | C150-470M         | 1    |
| C1202          | 0.0022µF, 500V, CerD. | 72982     | 831Z5U0-222M     | C22-.0022M        | ..   |
| C1203          | 0.01µF, 50V, My       | 84411     | 601PE-.01µF      | C41-.01M          | 1    |

DIODES

| Circuit Desig. | Description                               | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---|-----------|-------------|-------------------|------|
| D201           | Rectifier                                 | 13327     | 1N4139      | RF-34             | 2    |
| D202           | Rectifier                                 | 13327     | 1N4139      | RF-34             | ..   |
| D203           | Full Wave Bridge Rectifier.               | 83701     | PD-10       | RF-36             | 2    |
| D204           | Rectifier                                 | 01295     | 1N645       | RF-14             | 8    |
| D205           | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D206           | Rectifier                                 | 01295     | 1N3255      | RF-22             | 1    |
| D401           | Zener, 9V, 1/2W                           | 04713     | 1N936       | DZ-5              | 3    |
| D402           | Zener, 9V, 1/2W                           | 04713     | 1N936       | DZ-5              | ..   |
| D403           | Transistor, Base-Emitter NPN, Case TO-106 | 07263     | 2N3565      | TG-39             | 2    |
| D404           | Transistor, Base-Emitter NPN, Case TO-106 | 07263     | 2N3565      | TG-39             | ..   |
| D405           | Rectifier                                 | 01295     | 1N914       | RF-28             | 13   |
| D406           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D407           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D408           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D409           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D410           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D411           | Zener, 9.1V                               | 06751     | 1N713A      | DZ-38             | 1    |
| D412           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D413           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D414           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D415           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D416           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D417           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D501           | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D502           | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D601           | Rectifier                                 | 01295     | 1N914       | RF-28             | ..   |
| D701           | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D702           | Zener, 9V, 1/2W                           | 04713     | 1N936       | DZ-5              | ..   |
| D1201          | Bridge Rectifier, 2A, 100 PIV             | .....     | PD10        | RF-36             | ..   |
| D1202          | Zener, 6.2V, 0.4W                         | 06751     | 1N823       | DZ-36             | 2    |
| D1203          | Zener, 6.2V, 0.4W                         | 06751     | 1N823       | DZ-36             | ..   |
| D1204          | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D1205          | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |
| D1206          | Rectifier                                 | 01295     | 1N645       | RF-14             | ..   |

LAMPS & FUSES

| Circuit Desig. | Description       | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|-------------------|-----------|-------------|-------------------|------|
| S301           | Lamp, (OVERRANGE) | 80164     | PL-42       | PL-42             | 1    |

REPLACEABLE PARTS

MODELS 164, 164TT

Models 164, 164TT.  
LAMPS & FUSES (Cont'd)

| Circuit Desig. | Description                     | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---------------------------------|-----------|-------------|-------------------|------|
| DS302          | Lamp, (POLARITY).               | 80164     | PL-48       | PL-48             | 1    |
| F201           | Fuse, 1/4A, 250V, 3AG, Slo-Blo. | 71400     | MDV-1/4A    | FU-33             | 1    |
| F202*          | Fuse, 1/2A, 125V, 3AG, Slo-Blo. | 75915     | 315-500     | FU-35             | 1    |

\*Alternate

CONNECTORS

| Circuit Desig. | Description                       | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty.  |
|----------------|-----------------------------------|-----------|-------------|-------------------|-------|
| J101           | Binding Post, (HI) Red.           | 58474     | DF21RC      | BP-11R            | 1     |
| J102           | Binding Post (LO) Black           | 58474     | DF21BC      | BP-11B            | 1     |
| J103           | Connector, Analog Output.         | 02660     | 80PC2F      | CS-32             | 1     |
| J104           | Binding Post, (CASE) Green.       | 58474     | DF21GC      | BP-11G            | 1     |
| J201           | Connector, Female, Berg           |           |             |                   |       |
| J202           | Connector, 5-pin.                 | 22526     | 20052       | CS-237            | 5     |
| J203           | Test Point.                       |           |             |                   |       |
| J204           | Test Point.                       |           |             |                   |       |
| J205           | Test Point.                       |           |             |                   |       |
| J801           | Connector, 22-pin, card-edge type | 09922     | PSC4SS2212  | CS-182            | 3     |
| J802           | Connector, 44-pin, card-edge type | 09922     | PSC4DD2212  | CS-205            | 1     |
| J901           | Connector, 22-pin, card-edge type | 09922     | PSC4SS2212  | CS-182            | ..    |
| J902           | Connector, 22-pin, card-edge type | 09922     | PSC4SS2212  | CS-182            | ..    |
| J903           | Receptacle, 10-pin.               | 22526     | 20052       | CS-237            | ..    |
| J904           | Receptacle, 10-pin.               | 22526     | 20052       | CS-237            | ..    |
| J905           | Receptacle, 10-pin.               | 22526     | 20052       | CS-237            | ..    |
| J906           | Receptacle, 10-pin.               | 22526     | 20052       | CS-237            | ..    |
| J1201          | Housing, 10-pin                   | 22526     | 20052       | CS-237            | ..    |
| J1202          | Housing, 5-pin.                   | 22526     | 20370       | CS-251            | ..    |
| J1203          | Binding Post, (LO), Black         | 58474     | DF21BC      | BP11BLK           | 1     |
| J1204          | Binding Post, (HI), Red           | 58474     | DF21RC      | BP11R             | 1     |
| J1205          | Housing, 2-pin.                   |           |             | CS-261            | ..    |
| J1206          | Housing, 5-pin.                   | 22526     | 20370       | CS-251            | ..    |
| J1207          | Berg Pin, Female.                 |           |             |                   |       |
| J1208          | Housing, 3-pin.                   | 22526     | 65039034    | CS-270            |       |
| J1209          | Housing, 3-pin.                   | 22526     | 65039034    | CS-270            |       |
| J1210          | Housing, 3-pin.                   | 22526     | 65039034    | CS-270            |       |
| P201           | Receptacle, 3-pin, Line Voltage   | 82389     | EAC301      | CS-254            | 1     |
| P1201          | Berg Pins (10).                   | 80164     |             | 24249A            | 10    |
| P1202          | Berg Pins (5)                     | 80164     |             | 24249A            | 5     |
| P1203          | Not Used.                         | .....     | .....       | .....             | ..... |
| P1204          | Not Used.                         | .....     | .....       | .....             | ..... |
| P1205          | Berg Pins (2)                     | 80164     |             | 24249A            | 2     |
| P1206          | Berg Pins (5)                     | 80164     |             | 24249A            | 5     |
| P1207          | Berg Pin (1).                     | 80164     |             | 24249A            | 1     |
| P1208          | Berg Pins (3)                     | 80164     |             | 24249A            | 3     |
| P1209          | Berg Pins (3)                     | 80164     |             | 24249A            | 3     |

TRANSISTORS

| Circuit Desig. | Description             | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|-------------------------|-----------|-------------|-------------------|------|
| Q201           | Power, NPN, Case TO-66. | 02735     | 40312       | TG-54             | 1    |
| Q202           | NPN, Case TO-104.       | 02734     | 2N5183      | TG-68             | 1    |
| Q203           | NPN, Case TO-106.       | 07363     | 2N3565      | TG-39             | 2    |
| Q204           | NPN, Case TO-106.       | 07263     | 2N3565      | TG-39             | 1    |

Models 164, 164TT.  
TRANSISTORS (Cont'd)

| Circuit Desig. | Description                 | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty.  |
|----------------|-----------------------------|-----------|-------------|-------------------|-------|
| Q205           | PNP, Case R110.             | 07263     | S17638      | TG-33             | 6     |
| Q206           | NPN, Case TO-5.             | 02734     | 40317       | TG-43             | 2     |
| Q207           | PNP, Case R110.             | 07263     | S17638      | TG-33             | ..    |
| Q208           | NPN, Case TO-5.             | 02734     | 40319       | TG-50             | 1     |
| Q209           | PNP, Case R110.             | 07263     | S17638      | TG-33             | ..    |
| Q210           | PNP, Case R110.             | 07263     | S17638      | TG-33             | ..    |
| Q211           | PNP, Case R110.             | 07263     | S17638      | TG-33             | ..    |
| Q212           | PNP, Case R110.             | 07263     | S17638      | TG-33             | ..    |
| Q301           | NPN, Case TO-104.           | 07263     | 2N5184      | TG-67             | 3     |
| Q302           | NPN, Case TO-5.             | 02735     | 40346       | TG-44             | 2     |
| Q303           | NPN, Case TO-5.             | 02735     | 40346       | TG-44             | ..    |
| Q304           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | 6     |
| Q305           | NPN, Case TO-104.           | 07263     | 2N5184      | TG-67             | ..    |
| Q306           | NPN, Case TO-104.           | 07263     | 2N5184      | TG-67             | ..    |
| Q401           | N-Chan, Fet                 | 04713     | 2N4220      | TG-42             | 4     |
| Q402           | FET, Case TO-92             | 01295     | T1S70       | TG-71             | 2     |
| Q403           | FET, Case TO-92             | 01295     | T1S70       | TG-71             | ..    |
| Q404           | PNP, Case TO-106.           | 07263     | 2N5139      | TG-66             | 3     |
| Q405           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | ..    |
| Q406           | Not Used.                   | .....     | .....       | .....             | ..... |
| Q407           | Not Used.                   | .....     | .....       | .....             | ..... |
| Q408           | N-Chan, FET                 | 04713     | 2N4220      | TG-42             | ..    |
| Q409           | PNP, Case TO-106.           | 07263     | 2N5139      | TG-66             | ..    |
| Q410           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | ..    |
| Q411           | N-Chan, FET                 | 04713     | 2N4220      | TG-42             | ..    |
| Q412           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | ..    |
| Q413           | PNP, Case TO-106.           | 07263     | 2N5139      | TG-66             | ..    |
| Q414           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | ..    |
| Q415           | PNP, Case TO-106.           | 07263     | 2N5139      | TG-66             | ..    |
| Q416           | NPN, Case TO-106.           | 07263     | 2N5134      | TG-65             | ..    |
| Q601           | NPN, Case TO-92             | 04713     | 2N5089      | TG-62             | 6     |
| Q602           | NPN, Case TO-92             | 04713     | 2N5089      | TG-62             | ..    |
| Q603           | NPN, Case TO-92             | 04713     | 2N5089      | TG-62             | ..    |
| Q701           | N-Chan FET (Selected*)      | 94145     | RN1030      | TG-51 (24598A)*   | 2     |
| Q702           | N-Chan FET (Selected*)      | 94145     | RN1030      | TG-51 (24598A)*   | ..    |
| Q703           | NPN, Case TO-92 (Selected*) | 04713     | 2N5089*     | TG-62 (24219A)*   | ..    |
| Q704           | PNP, Case TO-92             | 04713     | 2N5087      | TG-61             | 2     |
| Q705           | N-Chan FET                  | 04713     | MPF-103     | TG-41             | 1     |
| Q706           | NPN, Case TO-92             | 04713     | 2N5089      | TG-62             | ..    |
| Q707           | NPN, Case TO-92             | 04713     | 2N5089      | TG-62             | ..    |
| Q708           | PNP, Case TO-92             | 04713     | 2N5087      | TG-61             | ..    |
| Q1201          | Transistor.                 | 07263     | 40317       | TG-43             | ..    |

INTEGRATED CIRCUITS

| Circuit Desig. | Description                     | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---------------------------------|-----------|-------------|-------------------|------|
| QA201          | Regulator, 10-pin Case TO-100   | 07263     | U5R772-339  | IC-14             | 1    |
| QA301          | Dual J-K Flip-Flop, 14-pin DIP. | 04713     | MC891P      | IC-9              | 4    |
| QA302          | Dual J-K Flip-Flop, 14-pin DIP. | 04713     | MC891P      | IC-9              | ..   |
| QA303          | Quad 2-input NOR, 14-pin DIP.   | 04713     | MC824P      | IC-5              | 3    |
| QA304          | Quad 2-input NOR, 14-pin DIP.   | 04713     | MC824P      | IC-5              | ..   |
| QA305          | Hex Inverters, 14-pin DIP       | 04713     | MC889P      | IC-7              | 1    |
| QA306          | Dual J-K Flip-Flop, 14-pin DIP. | 04713     | MC891P      | IC-9              | ..   |
| QA307          | Dual J-K Flip-Flop, 14-pin DIP. | 04713     | MC891P      | IC-9              | ..   |
| QA308          | Decade Counter, 14-pin DIP.     | 04713     | MC880P      | IC-17             | 3    |
| QA309          | Decade Counter, 14-pin DIP.     | 04713     | MC880P      | IC-17             | ..   |

Models 164, 164TT.  
INTEGRATED CIRCUITS (Cont'd)

| Circuit Desig. | Description                                  | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|--|-----------|-------------|-------------------|------|
| QA310          | Decade Counter, 14-pin DIP . . . . .         | 04713     | MC880P      | IC-17             | ..   |
| QA311          | Quad Latch, 16-pin DIP . . . . .             | 04713     | MC867P      | IC-16             | 3    |
| QA312          | Quad Latch, 16-pin DIP . . . . .             | 04713     | MC867P      | IC-16             | ..   |
| QA313          | Quad Latch, 16-pin DIP . . . . .             | 04713     | MC867P      | IC-16             | ..   |
| QA314          | Decoder/driver, 16-pin DIP . . . . .         | 07263     | UGB996079X  | IC-3              | 3    |
| QA315          | Decoder/driver, 16-pin DIP . . . . .         | 07263     | UGB996079X  | IC-3              | ..   |
| QA316          | Decoder/driver, 16-pin DIP . . . . .         | 07263     | UGB996079X  | IC-3              | ..   |
| QA401          | Amplifier, 8-pin, Case TO-99 . . . . .       | 07263     | U5B770939X  | IC-1              | 3    |
| QA402          | Amplifier, 8-pin, Case TO-99 . . . . .       | 07263     | U5B770939X  | IC-1              | ..   |
| QA403          | Diff. Comparator, 8-pin, Case TO-99. . . . . | 07263     | U5B771039X  | IC-4              | 1    |
| QA404          | Quad 2-input, NAND, 14-pin DIP . . . . .     | 04713     | MC824P      | IC-5              | ..   |
| QA701          | Dual J-K Flip-Flop, 14-pin DIP . . . . .     | 04713     | MC890P      | IC-8              | 1    |
| QA702          | Amplifier, 8-pin, Case TO-99 . . . . .       | 07263     | U5B770939X  | IC-1              | ..   |
| QA703          | Amplifier, 8-pin, Case TO-99 . . . . .       | 12040     | LM301AH     | IC-2              | 2    |
| QA704          | Amplifier, 8-pin, Case TO-99 . . . . .       | 12040     | LM301AH     | IC-2              | ..   |
| QA801          | Binary Counter, 14-pin DIP . . . . .         | 04713     | MC-877P     | IC-21             | 1    |
| QA1201         | Regulator, Case TO-220 . . . . .             | 04713     | MC7815CP    | IC-96             | 1    |
| QA1202         | Amplifier, 8-pin, Case TO-99 . . . . .       | 12040     | LM308H      | IC-67             | 1    |

RESISTORS

| Circuit Desig. | Description   | Mfr. Code | Mfr. Desig.                   | Keithley Part No.   | Qty. |
|----------------|---|-----------|-------------------------------|---------------------|------|
| R101           | 10M $\Omega$ , 1%, 1/2W, MtF . . . . .              | 07716     | MEH-10M $\Omega$              | R170-10M            | 1    |
| R102           | 200k $\Omega$ , 1%, 1/2W, MtF . . . . .             | 07716     | MEH-200K $\Omega$             | R94-200K            | 1    |
| R103           | 1k $\Omega$ , 0.1%, 1/2W, MtF . . . . .             | 91637     | MFF-1K $\Omega$               | R169-1K             | 2    |
| R104           | 50 $\Omega$ , 20%, 2W, WW . . . . .                 | 71450     | INS-115-50 $\Omega$           | RP50-50             | 1)   |
| R105           | 10k $\Omega$ , 0.1%, 1/2W, MtF . . . . .            | 91637     | MFF-10K                       | R169-10K            | 2    |
| R106           | 500 $\Omega$ , 20%, 2W, WW . . . . .                | 71450     | INS-115-500 $\Omega$          | RP50-500            | 1    |
| R107           | 100k $\Omega$ , 0.1%, 1/2W, MtF . . . . .           | 91637     | MFF-100K $\Omega$             | R169-100K           | 2    |
| R108           | 5k $\Omega$ , 20%, 2W, WW . . . . .                 | 71450     | INS-115-5K $\Omega$           | RP50-5K             | 2    |
| R109           | 1M $\Omega$ , 0.1%, 1/2W, MtF . . . . .             | 91637     | MFF-1M $\Omega$               | R169-1M             | 2    |
| R110           | 100k $\Omega$ , 1%, 1/8W, MtF . . . . .             | 07716     | CEA-100K $\Omega$ -1%         | R88-100K            | 4    |
| R111           | 50k $\Omega$ , 20%, 1.75W, Cermet . . . . .         | 73138     | 77PR-50K $\Omega$             | RP64-50K            | 1    |
| R112           | 10 <sup>7</sup> $\Omega$ , 1%, 1W, DCb. . . . .     | 91637     | DC-1-10 <sup>7</sup> $\Omega$ | R13-10 <sup>7</sup> | 1    |
| R113           | 10 <sup>9</sup> $\Omega$ , 20%, 1/2W, Comp. . . . . | 75042     | GBT-10 <sup>8</sup> $\Omega$  | R37-10 <sup>9</sup> | 2    |
| R114           | 10 <sup>8</sup> $\Omega$ , 1%, 2W, DCb. . . . .     | 91637     | DC-2-10 <sup>8</sup> $\Omega$ | R14-10 <sup>8</sup> | 1    |
| R115           | 1M $\Omega$ , 0.1%, 1/2W, MtF . . . . .             | 91637     | MFF-1M $\Omega$               | R169-1M             | ..   |
| R116           | 100k $\Omega$ , 0.1%, 1/2W, MtF . . . . .           | 91637     | MFF-100K $\Omega$             | R169-100K           | ..   |
| R117           | 10k $\Omega$ , 0.1%, 1/2W, MtF . . . . .            | 91637     | MFF-10K $\Omega$              | R169-10K            | ..   |
| R118           | 1k $\Omega$ , 0.1%, 1/2W, MtF . . . . .             | 91637     | MFF-1K $\Omega$               | R169-1K             | ..   |
| R119           | 99.9 $\Omega$ , 0.1%, 1/2W, MtF . . . . .           | 91637     | MFF-99.9 $\Omega$             | R169-99.9           | 1    |
| R120           | 0.1 $\Omega$ , 0.1%, 5W, WW . . . . .               | 02985     | TS-5W-.1 $\Omega$             | R167-.1             | 1    |
| R121           | 1 $\Omega$ , 0.1%, 1/4W, WW . . . . .               | 01686     | 7009-1 $\Omega$               | R95-1               | 1    |
| R122           | 10 $\Omega$ , 0.1%, 1/4W, WW . . . . .              | 01686     | 7009-10 $\Omega$              | R95-10              | 1    |
| R123           | 220 $\Omega$ , 10%, 1/4W, Comp. . . . .             | 01121     | CB-221-10%                    | R76-220             | 1    |
| R201           | 6.8k $\Omega$ , 10%, 1/4W, Comp . . . . .           | 01121     | CB-682-10%                    | R76-6.8K            | 1    |
| R202           | 0.2 $\Omega$ , 10%, TCu . . . . .                   | 91637     | CW-2-.2 $\Omega$              | R151-0.2            | 1    |
| R203           | 10k $\Omega$ , 1%, 1/8W, MtF . . . . .              | 07716     | CEA-10K-1%                    | R88-10K             | 3    |
| R204           | 2.49k $\Omega$ , 1%, 1/8W, MtF . . . . .            | 07716     | CEA-2.49K-1%                  | R88-2.49K           | 1    |
| R205           | 1k $\Omega$ , 10%, 1/4W, Comp . . . . .             | 01121     | CB-102-10%                    | R76-1K              | 5    |
| R206           | 3 $\Omega$ , 1%, 1/2W, DCb. . . . .                 | 91637     | DCF-1/2-3 $\Omega$            | R12-3               | 2    |
| R207           | 1.8k $\Omega$ , 10%, 1/4W, Comp . . . . .           | 01121     | CB-182-10%                    | R76-1.8K            | 1    |
| R208           | 3.32k $\Omega$ , 1%, 1/8W, MtF . . . . .            | 07716     | CEA-3.32K-1%                  | R88-3.32K           | 1    |
| R209           | 1k $\Omega$ , 20%, 2W, WW . . . . .                 | 71450     | INS-115-1K                    | RP50-1K             | 1    |
| R210           | 3.01k $\Omega$ , 1%, 1/8W, MtF . . . . .            | 07716     | CEA-3.01K-1%                  | R88-3.01K           | 3    |
| R211           | 15k $\Omega$ , 10%, 1/4W, Comp. . . . .             | 01121     | CB-153-10%                    | R76-15K             | 1    |
| R212           | 7.5k $\Omega$ , 1%, 1/8W, MtF . . . . .             | 07716     | CEA-7.5K-1%                   | R88-7.5K            | 8    |

Models 164, 164TT.  
RESISTORS (Cont'd)

| Circuit Desig. | Description               | Mfr. Code | Mfr. Desig.   | Keithley Part No. | Qty.  |
|----------------|---------------------------|-----------|---------------|-------------------|-------|
| R213           | 10Ω, 10%, 1/2W, Comp      | 01121     | EB-100-10%    | R1-10             | 1     |
| R214           | 33kΩ, 10%, 1/4W, Comp     | 01121     | CB-333-10%    | R76-33K           | 8     |
| R215           | 3Ω, 1%, 1/2W, DCb         | 91637     | DCF-1/2-3Ω    | R12-3             | ..    |
| R216           | 33kΩ, 10%, 1/4W, Comp     | 01121     | CB-333-10%    | R76-33K           | ..    |
| R217           | 33kΩ, 10%, 1/4W, Comp     | 01121     | CB-333-10%    | R76-33K-10%       | ..    |
| R218           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5K-1%   | R88-7.5K-1%       | ..    |
| R219           | 82Ω, 10%, 1/2W, Comp      | 01121     | EB-82R-10%    | R1-82             | 1     |
| R220           | 1MΩ, 10%, 1/4W, Comp      | 01121     | CB-105-10%    | R76-1M            | 2     |
| R301           | 100kΩ, 10%, 1W, Comp      | 01121     | GB-104-10%    | R2-100K           | 1     |
| R302           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | 9     |
| R303           | 3.3kΩ, 10%, 1/4W, Comp    | 01121     | CB-332-10%    | R76-3.3K          | 2     |
| R304           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R305           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R306           | 100kΩ, 10%, 1/2W, Comp    | 01121     | EB-104-10%    | R1-100K           | 1     |
| R307           | 47kΩ, 10%, 1/4W, Comp     | 01121     | CB-473-10%    | R76-47K           | 3     |
| R308           | Not Used                  | .....     | .....         | .....             | ..... |
| R309           | 80.6kΩ, 1%, 1/2W, MtF     | 07716     | CEC-80.6K-1%  | R94-80.6K         | 1     |
| R310           | 7.87kΩ, 1%, 1/8W, MtF     | 07716     | CEA-7.8K-1%   | R88-7.87K         | 1     |
| R311           | 1kΩ, 10%, 1/4W, Comp      | 01121     | CB-102-10%    | R76-1K            | ..    |
| R312           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R313           | 10kΩ, 1%, 1/2W, MtF       | 07716     | CEC-10K-1%    | R94-10K           | 3     |
| R314           | 10kΩ, 1%, 1/2W, MtF       | 07716     | CEC-10K-1%    | R94-10K           | ..    |
| R315           | 10kΩ, 1%, 1/2W, MtF       | 07716     | CEC-10K-1%    | R94-10K           | ..    |
| R401           | 10kΩ, 10%, 1/4W, Comp     | 01121     | CB-103-10%    | R76-10K           | 6     |
| R402           | 10kΩ, 20%, Cermet         | 73138     | 77PR-10KΩ     | RP64-10K          | 2     |
| R403           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R404           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R405           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R406           | Selected*Ω, 1%, 1/8W, MtF | 91637     | MFF-1/8-*     | R177*             | ..    |
| R407           | 10kΩ, 10%, 1/4W, Comp     | 01121     | CB-103-10%    | R76-10K           | ..    |
| R408           | 10kΩ, 20%, Cermet         | 73138     | 77PR10KΩ      | RP64-10K          | ..    |
| R409           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R410           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R411           | 7.5kΩ, 1%, 1/8W, MtF      | 07716     | CEA-7.5KΩ-1%  | R88-7.5K          | ..    |
| R412           | Selected*Ω, 1%, 1/8W, MtF | 91637     | MFF-1/8-*     | R177*             | ..    |
| R413           | 49.9kΩ, 1%, 1/8W, MtF     | 91637     | MFF-1/8-49.9K | R177-49.9K        | 2     |
| R414           | 49.9kΩ, 1%, 1/8W, MtF     | 91637     | MFF-1/8-49.9K | R177-49.9K        | ..    |
| R415           | 100kΩ, 10%, 1/4W, Comp    | 01121     | CB-104-10%    | R76-100K          | 6     |
| R416           | 100kΩ, 10%, 1/4W, Comp    | 01121     | CB-104-10%    | R76-100K          | ..    |
| R417           | 1kΩ, 10%, 1/4W, Comp      | 01121     | CB-102-10%    | R76-1K            | ..    |
| R418           | 301kΩ, 1%, 1/8W, MtF      | 07716     | CEA-301K-1%   | R88-301K          | 2     |
| R419           | 301kΩ, 1%, 1/8W, MtF      | 07716     | CEA-301K-1%   | R88-301K          | ..    |
| R420           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R421           | 680Ω, 10%, 1/4W, Comp     | 01121     | CB-681-10%    | R76-680           | 3     |
| R422           | 33kΩ, 10%, 1/4W, Comp     | 01121     | CB-333-10%    | R76-33K           | ..    |
| R423           | 4.7kΩ, 10%, 1/4W, Comp    | 01121     | CB-472-10%    | R76-4.7K          | 4     |
| R424           | 4.7kΩ, 10%, 1/4W, Comp    | 01121     | CB-472-10%    | R76-4.7K          | ..    |
| R425           | Not Used                  | .....     | .....         | .....             | ..... |
| R426           | Not Used                  | .....     | .....         | .....             | ..... |
| R427           | Not Used                  | .....     | .....         | .....             | ..... |
| R428           | 680Ω, 10%, 1/4W, Comp     | 01121     | CB-681-10%    | R76-680           | ..    |
| R429           | 4.7kΩ, 10%, 1/4W, Comp    | 01121     | CB-472-10%    | R76-4.7K          | ..    |
| R430           | 33kΩ, 10%, 1/4W, Comp     | 01121     | CB-333-10%    | R76-33K           | ..    |
| R431           | 4.7kΩ, 10%, 1/4W, Comp    | 01121     | CB-472-10%    | R76-4.7K-10%      | ..    |
| R432           | 100kΩ, 10%, 1/4W, Comp    | 01121     | CB-104-10%    | R76-100K          | ..    |
| R433           | 100kΩ, 10%, 1/4W, Comp    | 01121     | CB-104-10%    | R76-100K          | ..    |
| R434           | 100kΩ, 10%, 1/4W, Comp    | 01121     | CB-104-10%    | R76-100K          | ..    |
| R435           | 47Ω, 10%, 1/4W, Comp      | 01121     | CB-47R-10%    | R76-47            | 4     |
| R436           | 47Ω, 10%, 1/4W, Comp      | 01121     | CB-47R-10%    | R76-47            | ..    |
| R437           | 2.2kΩ, 10%, 1/4W, Comp    | 01121     | CB-222-10%    | R76-2.2K          | 3     |
| R438           | 1.5kΩ, 10%, 1/4W, Comp    | 01121     | CB-152-10%    | R76-1.5K          | ..    |



Models 164, 164TT.  
RESISTORS (Cont'd)

| Circuit<br>Desig. | Description                                  | Mfr.<br>Code | Mfr.<br>Desig.        | Keithley<br>Part No. | Qty.  |
|-------------------|--|--------------|-----------------------|----------------------|-------|
| R439              | 47Ω, 10%, 1/4W, Comp . . . . .               | 01121        | CB-47R-10%            | R76-47               | ..    |
| R440              | 47Ω, 10%, 1/4W, Comp . . . . .               | 01121        | CB-47R-10%            | R76-47               | ..    |
| R441              | 8.87kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-8.87K-1%          | R88-8.87K            | 1     |
| R442              | 3.01kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-3.01K-1%          | R88-3.01K            | ..    |
| R443              | 2.2kΩ, 10%, 1/4W, Comp . . . . .             | 01121        | CB-222-10%            | R76-2.2K             | ..    |
| R444              | 2.49kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-2.49K-1%          | R88-2.49K            | 1     |
| R445              | 10kΩ, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-10K-1%            | R88-10K              | ..    |
| R446              | 2.2kΩ, 10%, 1/4W, Comp . . . . .             | 01121        | CB-222-10%            | R76-2.2K             | ..    |
| R447              | 237Ω, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-237-1%            | R88-237              | 2     |
| R448              | 56kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-563-10%            | R76-56K              | 2     |
| R449              | 1kΩ, 1%, 1/8W, MtF . . . . .                 | 07716        | CEA-1K-1%             | R88-1K               | 2     |
| R450              | 4.99kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-4.99K-1%          | R88-4.99K            | 2     |
| R451              | 27kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-273-10%            | R76-27K              | 1     |
| R452              | 82kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-823-10%            | R76-82K              | 1     |
| R453              | 33kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-333-10%            | R76-33K              | ..    |
| R454              | 680Ω, 10%, 1/4W, Comp . . . . .              | 01121        | CB-681-10%            | R76-680              | ..    |
| R455              | 237Ω, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-237-1%            | R88-237              | ..    |
| R456              | 56kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-563-10%            | R76-56K              | ..    |
| R457              | 4.99kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-4.99K-1%          | R88-4.99K            | ..    |
| R458              | 100kΩ, 10%, 1/4W, Comp . . . . .             | 01121        | CB-104-10%            | R76-100K             | ..    |
| R501              | 150kΩ, 10%, 1/2W, Comp . . . . .             | 01121        | EB-150K-10%           | R1-150K              | 1     |
| R502              | 10kΩ, 10%, 1/2W, Comp . . . . .              | 01121        | EB-10K-10%            | R1-10K               | 1     |
| R503              | 1MΩ, 1%, 1/8W, MtF . . . . .                 | 07716        | CEA-1MΩ-1%            | R88-1M               | 1     |
| R504              | 49.9kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-49.9K-1%          | R88-49.9K            | 2     |
| R505              | 100kΩ, 20%, Cermet . . . . .                 | 73138        | 77PR-100K             | RP64-100K            | 1     |
| R506              | 49.9kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-49.9K-1%          | R88-49.9K            | ..    |
| R507              | Not Used . . . . .                           | .....        | .....                 | .....                | ..... |
| R508              | 1.5kΩ, 1%, 1/8W, MtF . . . . .               | 07716        | CEA-1.5K-1%           | R88-1.5K             | 2     |
| R509              | 1.5kΩ, 1%, 1/8W, MtF . . . . .               | 07716        | CEA-1.5K-1%           | R88-1.5K             | ..    |
| R510              | 10MΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-106-10%            | R76-10M              | 1     |
| R511              | 10 <sup>8</sup> Ω, 20%, 1/2W, Comp . . . . . | 75042        | GBT-10 <sup>8</sup> Ω | R37-10 <sup>8</sup>  | 1     |
| R512              | 10 <sup>9</sup> Ω, 20%, 1/2W, Comp . . . . . | 75042        | GBT-10 <sup>9</sup> Ω | R37-10 <sup>9</sup>  | ..    |
| R513              | 89.9kΩ, 0.1%, 1/2W, MtF . . . . .            | 91637        | MFF-89.9K             | R169-89.9K           | 1     |
| R514              | 100Ω, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-100-1%            | R88-100              | 3     |
| R515              | 100Ω, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-100-1%            | R88-100              | ..    |
| R516              | 8.99kΩ, 0.1%, 1/2W, MtF . . . . .            | 91637        | MFF-8.99K             | R169-8.99K           | 1     |
| R517              | 10Ω, 10%, 1/4W, Comp . . . . .               | 01121        | CB-10R-10%            | R76-10               | 2     |
| R518              | 10Ω, 10%, 1/4W, Comp . . . . .               | 01121        | CB-10R-10%            | R76-10               | ..    |
| R519              | 899Ω, 0.1%, 1/2W, MtF . . . . .              | 91637        | MFF-899               | R169-899             | 1     |
| R520              | 1Ω, 1%, 1/2W, DCb . . . . .                  | 91637        | DCF-1/2-1Ω            | R12-1                | 2     |
| R521              | 1Ω, 1%, 1/2W, DCb . . . . .                  | 91637        | DCF-1/2-1Ω            | R12-1                | ..    |
| R601              | 3.01kΩ, 1%, 1/8W, MtF . . . . .              | 07716        | CEA-3.01K-1%          | R88-3.01K            | ..    |
| R602              | 113kΩ, 1%, 1/8W, MtF . . . . .               | 07716        | CEA-113K-1%           | R88-113K             | 1     |
| R603              | 100Ω, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-100-1%            | R88-100              | ..    |
| R604              | 6.98kΩ, 0.1%, 1/8W, MtF . . . . .            | 91637        | MFF-1/8-6.98K         | R168-6.98K           | 1     |
| R605              | 5kΩ, 20%, 2W, WW . . . . .                   | 71450        | INS-115-5K            | RP50-5K              | ..    |
| R606              | 32.4kΩ, 0.1%, 1/8W, MtF . . . . .            | 91637        | MFF-1/8-32.4K         | R168-32.4K           | 2     |
| R607              | 32.4kΩ, 0.1%, 1/8W, MtF . . . . .            | 91637        | MFF-1/8-32.4K         | R168-32.4K           | ..    |
| R608              | 1.5kΩ, 10%, 1/4W, Comp . . . . .             | 01121        | CB-152-10%            | R76-1.5K             | ..    |
| R609              | 3.9kΩ, 10%, 1/4W, Comp . . . . .             | 01121        | CB-152-10%            | R76-3.9K             | 1     |
| R610              | 47Ω, 10%, 1/4W, Comp . . . . .               | 01121        | CB-152-10%            | R76-47               | 1     |
| R611              | 10kΩ, 1%, 1/8W, MtF . . . . .                | 07716        | CEA-10K-1%            | R88-10K              | ..    |
| R701              | 47kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-473-10%            | R76-47K              | ..    |
| R702              | 1kΩ, 10%, 1/4W, Comp . . . . .               | 01121        | CB-102-10%            | R76-1K               | ..    |
| R703              | 100Ω, 0.05%, 1/4W, WW . . . . .              | 17870        | 1352-100Ω             | R157-100             | 1     |
| R704              | 1MΩ, 10%, 1/4W, Comp . . . . .               | 01121        | CB-105-10%            | R76-1M               | ..    |
| R705              | 1kΩ, 10%, 1/4W, Comp . . . . .               | 01121        | CB-102-10%            | R76-1K               | ..    |
| R706              | 100kΩ, 1%, 1/8W, MtF . . . . .               | 07716        | CEA-100K-1%           | R88-100K             | ..    |
| R707              | 10kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-103-10%            | R76-10K              | ..    |
| R708              | 33kΩ, 10%, 1/4W, Comp . . . . .              | 01121        | CB-333-10%            | R76-33K              | ..    |

Models 164, 164TT.  
RESISTORS (Cont'd)

| Circuit Desig. | Description              | Mfr. Code | Mfr. Desig.   | Keithley Part No. | Qty.  |
|----------------|--------------------------|-----------|---------------|-------------------|-------|
| R709           | 3.3kΩ, 10%, 1/4W, Comp   | 01121     | CB-332-10%    | R76-3.3K          | ..    |
| R710           | 10kΩ, 10%, 1/4W, Comp    | 01121     | CB-103-10%    | R76-10K           | ..    |
| R711           | 1MΩ, 10%, 1/4W, Comp     | 01121     | CB-105-10%    | R76-1M            | 1     |
| R712           | 10kΩ, 10%, 1/4W, Comp    | 01121     | CB-103-10%    | R76-10K           | ..    |
| R713           | 1.5kΩ, 10%, 1/4W, Comp   | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R714           | 470kΩ, 10%, 1/4W, Comp   | 01121     | CB-474-10%    | R76-470K          | 1     |
| R715           | 33kΩ, 10%, 1/4W, Comp    | 01121     | CB-333-10%    | R76-33K           | ..    |
| R716           | 100kΩ, 10%, 1/4W, Comp   | 01121     | CB-104-10%    | R76-100K          | ..    |
| R717           | 56kΩ, 10%, 1/4W, Comp    | 01121     | CB-563-10%    | R76-56K           | 1     |
| R718           | 47kΩ, 10%, 1/4W, Comp    | 01121     | CB-473-10%    | R76-47K           | ..    |
| R719           | 68kΩ, 10%, 1/4W, Comp    | 01121     | CB-683-10%    | R76-68K           | 2     |
| R720           | 680Ω, 10%, 1/4W, Comp    | 01121     | CB-681-10%    | R76-680           | 2     |
| R721           | 680Ω, 10%, 1/4W, Comp    | 01121     | CB-681-10%    | R76-680           | ..    |
| R722           | 500Ω, 1/4W, Carbon       | 76055     | MTC52L1-500Ω  | RP59-500          | 1     |
| R723           | 68kΩ, 10%, 1/4W, Comp    | 01121     | CB-683-10%    | R76-68K           | ..    |
| R724           | 100kΩ, 10%, 1/4W, Comp   | 01121     | CB-104-10%    | R76-100K          | ..    |
| R725           | 47Ω, 10%, 1/4W, Comp     | 01121     | CB-47R-10%    | R76-47            | 2     |
| R726           | 470Ω, 10%, 1/4W, Comp    | 01121     | CB-471-10%    | R76-470           | 2     |
| R727           | 4.75kΩ, 1%, 1/8W, MtF    | 07716     | CEA-4.75K-1%  | R88-4.75K         | 2     |
| R728           | 49.9kΩ, 1%, 1/8W, MtF    | 07716     | CEA-49.9K-1%  | R88-49.9K         | 2     |
| R729           | 100kΩ, 10%, 1/4W, Comp   | 01121     | CB-104-10%    | R76-100K          | ..    |
| R730           | 1kΩ, 1%, 1/8W, MtF       | 07716     | CEA-1K-1%     | R88-1K            | ..    |
| R731           | 4.75kΩ, 1%, 1/8W, MtF    | 07716     | CEA-4.75K-1%  | R88-4.75K         | ..    |
| R732           | 10kΩ, 10%, 1/4W, Comp    | 01121     | CB-103-10%    | R76-10K           | ..    |
| R733           | 50kΩ, 20%, 0.75W, Cermet | 73138     | 77PR-50KΩ     | RP64-50K          | 1     |
| R734           | 49.9kΩ, 1%, 1/8W, MtF    | 07716     | CEA-49.9K-1%  | R88-49.9K         | ..    |
| R735           | 100kΩ, 1%, 1/8W, MtF     | 07716     | CEA-100K-1%   | R88-100K          | ..    |
| R736           | 100kΩ, 10%, 1/4W, Comp   | 01121     | CB-104-10%    | R76-100K          | ..    |
| R737           | 1kΩ, 1%, 1/8W, MtF       | 07716     | CEA-1K-1%     | R88-1K            | ..    |
| R738           | 2kΩ, 20%, 0.75W, Cermet  | 73138     | 77PR-2K       | RP64-2K           | 1     |
| R739           | 8.06kΩ, 0.1%, 1/8W, MtF  | 91637     | MFF-1/8-8.06K | R168-8.06K        | 1     |
| R740           | 9.9kΩ, 0.1%, 1/8W, MtF   | 91637     | MFF-1/8-9.9K  | R168-9.9K         | 1     |
| R741           | 100Ω, 0.1%, 1/8W, MtF    | 91637     | MFF-1/8-100   | R168-100          | 1     |
| R742           | 10kΩ, 0.1%, 1/8W, MtF    | 91637     | MFF-1/8-10K   | R168-10K          | 3     |
| R743           | 10kΩ, 0.1%, 1/8W, MtF    | 91637     | MFF-1/8-10K   | R168-10K          | ..    |
| R744           | Not Used                 | .....     | .....         | .....             | ..... |
| R745           | 10kΩ, 0.1%, 1/8W, MtF    | 91637     | MFF-1/8-10K   | R168-10K          | ..    |
| R746           | 1.5kΩ, 10%, 1/4W, Comp   | 01121     | CB-152-10%    | R76-1.5K          | ..    |
| R747           | 47Ω, 10%, 1/4W, Comp     | 01121     | CB-47R-10%    | R76-47            | ..    |
| R748           | 470Ω, 10%, 1/4W, Comp    | 01121     | CB-471-10%    | R76-470           | ..    |
| R801           | 10kΩ, 10%, 1/4W, Comp    | 01121     | CB-103-10%    | R76-10K           | ..    |
| R1201          | 25Ω, 5%, 5W, WW          | 91637     | RS-5-25Ω      | R4A-25            | 1     |
| R1202          | 806Ω, 1%, 1/2W, MtF      | 07716     | CEC-806-1%    | R94-806           | 1     |
| R1203          | 500Ω, 0.75W, Cermet      | 73138     | 77PR-500      | RP64-500          | 1     |
| R1204          | 4.02kΩ, 1%, 1/2W, MtF    | 07716     | CEC-4020-1%   | R94-4020          | 1     |
| R1205          | 100Ω, 0.1%, 10W, WW      | 02985     | TS-10W-100    | R221-100          | 1     |
| R1206          | 1kΩ, 0.1%, 1W            | 01686     | 7040-1K       | R70-1K            | 1     |
| R1207          | 10kΩ, 0.1%, 1W           | 01686     | 7040-10K      | R70-10K           | 1     |
| R1208          | 100kΩ, 0.02%, 1W, WW     | 15909     | 1252-100K     | R152-100K         | 1     |
| R1209          | 1MΩ, 0.1%, 1W            | 01686     | 7040-1M       | R70-1M            | 1     |
| R1210          | 0.12Ω, 5%, 2W, WW        | 75042     | BWH-2W-.12Ω   | R201-.12          | 1     |
| R1211          | 1.8Ω, 5%, 2W, WW         | 75042     | BWH-2W-1.8Ω   | R201-1.8          | 1     |
| R1212          | 20Ω, 1%, 1/2W, MtF       | 07716     | CEC-20-1%     | R94-20            | 1     |
| R1213          | 200Ω, 1%, 1/2W, MtF      | 07716     | CEC-200-1%    | R94-200           | 1     |
| R1214          | 2kΩ, 1%, 1/2W, MtF       | 07716     | CEC-2K-1%     | R94-2K            | 1     |
| R1215          | 50kΩ, 20%, 2W, Cermet    | 71450     | 550-50KΩ      | RP74-50K          | 1     |
| R1216          | 3.33MΩ, 1%, 1/2W, DCB    | 91637     | DCF-1/2-3.33M | R12-3.33M         | 1     |
| R1217          | 2.2kΩ, 10%, 1/2W, Comp   | 01121     | EB-2.2KΩ-10%  | R1-2.2K           | 1     |
| R1218          | 226Ω, 1%, 1/2W, MtF      | 07716     | CEC-226-1%    | R94-226           | 1     |

Models 164, 164TT.  
MISCELLANEOUS

| Circuit<br>Desig. | Description                      | Mfr.<br>Code | Mfr.<br>Desig. | Keithley<br>Part No. | Qty   |
|-------------------|----------------------------------|--------------|----------------|----------------------|-------|
| S101              | Switch, Rotary (RANGE) . . . . . | 80164        | SW-319A        | SW-319A              | 1     |
| S201              | Not Used . . . . .               | .....        | .....          | .....                | ..... |
| S202              | Switch . . . . .                 | 80164        | SW-318         | SW-318               | 1     |
| S1201             | Mode Switch, Rotary. . . . .     | 80164        | SW-372         | SW-372               | 1     |
| S1202             | Source Switch, Toggle. . . . .   | 80164        | SW-197         | SW-197               | 1     |
| T201              | Transformer. . . . .             | 80164        | TR-130         | TR-130               | 1     |
| T1201             | Transformer. . . . .             | 80164        | TR-138         | TR-138               | 1     |
| V301              | Tube, Readout. . . . .           | 80164        | EV-841         | EV-841               | 3     |
| V302              | Tube, Readout. . . . .           | 80164        | EV-841         | EV-841               | ..    |
| V303              | Tube, Readout. . . . .           | 80164        | EV-841         | EV-841               | ..    |

Model 164TT Version Only.  
(See schematic 26225D)

| Circuit Desig. | Description                               | Mfr. Code | Mfr. Desig.  | Keithley Part No. | Qty.  |
|----------------|---|-----------|--------------|-------------------|-------|
| Cl301          | Capacitor, 470pF, 500V, CerD. . . . .     | 56289     | .....        | C22-470P          | 2     |
| Cl302          | Capacitor, 470pF, 500V, CerD. . . . .     | 56289     | .....        | C22-470P          | ..    |
| DI301          | Diode, zener, 6.2V, 0.4W. . . . .         | 06751     | 1N823        | DZ-36             | 1     |
| DI302          | Diode . . . . .                           | 01295     | 1N645        | RF-14             | 2     |
| DI303          | Diode . . . . .                           | 01295     | 1N645        | RF-14             | ..    |
| DS1301         | Pilot Lamp, LO LIMIT. . . . .             | 07137     | RBL41A1344   | PL-45             | 2     |
| DS1302         | Pilot Lamp, HI LIMIT. . . . .             | 07137     | RBL41A1344   | PL-45             | ..    |
| J907           | Connector, Housing, 10-pin. . . . .       | 22526     | 20052        | CS-237            |       |
| J1301          | Connector, Housing, 3-pin . . . . .       | 22526     | 65039034     | CS-270            |       |
| J1302          | Connector, Housing, 3-pin . . . . .       | 22526     | 65039034     | CS-270            |       |
| J1303          | Connector, Housing, 5-pin . . . . .       | 22526     | 20370        | CS-251            |       |
| J1304          | Connector, Housing, 5-pin . . . . .       | 22526     | 20370        | CS-251            |       |
| J1305          | Connector, Housing, 5-pin . . . . .       | 22526     | 20370        | CS-251            |       |
| K1301          | Relay, Form A (SPST-NO) . . . . .         | 23020     | 191-TE1A1-5S | RL-44             | 2     |
| K1302          | Relay, Form A (SPST-NO) . . . . .         | 23020     | 191-TE1A1-5S | RF-44             |       |
| P1301          | Connector, Berg Pins (3). . . . .         | 80164     | .....        | 24249A            | 3     |
| P1302          | Connector, Berg Pins (3). . . . .         | 80164     | .....        | 24249A            | 3     |
| P1303          | Connector, Berg Pins (5). . . . .         | 80164     | .....        | 24249A            | 5     |
| P1304          | Connector, Berg Pins (5). . . . .         | 80164     | .....        | 24249A            | 5     |
| P1305          | Connector, Berg Pins (5). . . . .         | 80164     | .....        | 24249A            | 5     |
| Q1301          | Transistor, NPN, Case TO-92 . . . . .     | 04713     | 2N3903       | TG-49             | 1     |
| Q1302          | Transistor, PNP, Case TO-92 . . . . .     | 04713     | 2N3905       | TG-53             | 1     |
| QA1301         | Integrated Circuit, 8-pin DIP . . . . .   | 07263     | UGT7741393   | IC-42             | 2     |
| QA1302         | Integrated Circuit, 8-pin DIP . . . . .   | 07263     | UGT7741393   | IC-42             | ..    |
| R1301          | 1k $\Omega$ , 1%, 1/2W, MtF. . . . .      | 07716     | CEC-1k-1%    | R94-1K            | 2     |
| R1302          | 200 $\Omega$ , 1%, 1/2W, MtF. . . . .     | 07716     | CEC-200-1%   | R94-200           | 2     |
| R1303          | 200 $\Omega$ , 1%, 1/2W, MtF. . . . .     | 07716     | CEC-200-1%   | R94-200           | ..    |
| R1304          | 1k $\Omega$ , 1%, 1/2W, MtF. . . . .      | 07716     | CEC-1k-1%    | R94-1K            | ..    |
| R1305          | 2.74k $\Omega$ , 1%, 1/2W, MtF. . . . .   | 07716     | CEC-2.74K-1% | R94-2.74K         | 2     |
| R1306          | 2.74k $\Omega$ , 1%, 1/2W, MtF. . . . .   | 07716     | CEC-2.74K-1% | R94-2.74K         | ..    |
| R1307          | 2k $\Omega$ , 0.75W, Var . . . . .        | 73138     | 78LR2K56BW   | RP95-2K           | 2     |
| R1308          | 2k $\Omega$ , 0.75W, Var . . . . .        | 73138     | 78LR2K56BW   | RP95-2K           | ..    |
| R1309          | 10k $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-103-10%   | R76-10K           | 4     |
| R1310          | 10k $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-103-10%   | R76-10K           | ..    |
| R1311          | 4.7k $\Omega$ , 10%, 1/4W, Comp. . . . .  | 01121     | CB-472-10%   | R76-4.7K          | 2     |
| R1312          | 10M $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-106-10%   | R76-10M           | 2     |
| R1313          | 680 $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-681-10%   | R76-680           | 2     |
| R1314          | 10k $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-103-10%   | R76-10K           | ..    |
| R1315          | 10k $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-103-10%   | R76-10K           | ..    |
| R1316          | 4.7k $\Omega$ , 10%, 1/4W, Comp. . . . .  | 01121     | CB-472-10%   | R76-4.7K          | ..    |
| R1317          | 10M $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-106-10%   | R76-10M           | ..    |
| R1318          | 680 $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-681-10%   | R76-680           | ..    |
| R1319          | 120 $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-121-10%   | R76-120           | 2     |
| R1320          | 120 $\Omega$ , 10%, 1/4W, Comp . . . . .  | 01121     | CB-121-10%   | R76-120           | ..    |
| S1301          | Switch, Pushbutton (See DS1301) . . . . . | .....     | .....        | .....             | ..... |
| S1302          | Switch, Pushbutton (See DS1302) . . . . . | .....     | .....        | .....             | ..... |
| TB1301         | Terminal Board. . . . .                   |           |              |                   |       |

Model 1602 Digital Output, PC-287.  
(See schematic 24685D)

CAPACITORS

| Circuit Desig. | Description                    | Mfr. Code | Mfr. Desig.    | Keithley Part No. | Qty. |
|----------------|--------------------------------|-----------|----------------|-------------------|------|
| C1001          | 1.2μF, 20V, ETT . . . . .      | 17554     | TSD1-20        | C179-1.2M         | 1    |
| C1002          | .001μF, 1000V, CerD . . . . .  | 72982     | 801000X5F0102K | C22-.001M         | 1    |
| C1003          | .0022μF, 1000V, CerD . . . . . | 72982     | 811000X5F0222K | C22-.0022M        | 1    |

CONNECTORS

| Circuit Desig. | Description                                 | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---|-----------|-------------|-------------------|------|
| J1001          | Receptacle, 10-Pin. . . . .                 | 22526     | 20052       | CS-237            | 3    |
| J1002          | Receptacle, 10-Pin. . . . .                 | 22526     | 20052       | CS-237            | ..   |
| J1003          | Receptacle, 10-Pin. . . . .                 | 22526     | 20052       | CS-237            | ..   |
| J1004          | Receptacle, 22-Pin. . . . .                 | 09922     | PSC4SS2212  | CS-182            | 1    |
| J1005          | Receptacle, 44-Pin. . . . .                 | 09922     | PSC4DD2212  | CS-205            | 1    |
| J1006          | Receptacle, 50-Pin. . . . .                 | 02660     | 57405001    | CS-221            | 1    |
|                | Plug, Mate of J1006 (Not Supplied). . . . . | 02660     | 57305001    | CS-220            | 1    |

DIODES

| Circuit Desig. | Description         | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---------------------|-----------|-------------|-------------------|------|
| D1001          | Germanium . . . . . | 15238     | 1N87        | RF-39             | 5    |
| D1002          | Germanium . . . . . | 15238     | 1N87        | RF-39             | ..   |
| D1003          | Germanium . . . . . | 15238     | 1N87        | RF-39             | ..   |
| D1004          | Germanium . . . . . | 15238     | 1N87        | RF-39             | ..   |
| D1005          | Germanium . . . . . | 15238     | 1N87        | RF-39             | ..   |
| D1006          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1007          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1008          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1009          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1010          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1011          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |
| D1012          | Silicon . . . . .   | 01295     | 1N914       | RF-28             | ..   |

INTEGRATED CIRCUITS

| Circuit Desig. | Description                                     | Mfr. Code | Mfr. Desig. | Keithley Part No. | Qty. |
|----------------|---|-----------|-------------|-------------------|------|
| QA1001         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | 6    |
| QA1002         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | ..   |
| QA1003         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | ..   |
| QA1004         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | ..   |
| QA1005         | Inverter-Flip-Flop, 14-pin DIP, TO-116. . . . . | 04713     | MC887P      | IC-23             | 1    |
| QA1006         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | ..   |
| QA1007         | Quad, NAND Gate, 14-pin DIP, TO-116 . . . . .   | 04713     | MC858P      | IC-22             | ..   |
| QA1008         | Binary Counter, 14-pin DIP, TO-116. . . . .     | 04713     | MC877P      | IC-21             | 1    |

Model 1602 Digital Output, PC-287.  
(See schematic 24685D)

RESISTORS

| Circuit Desig. | Description                                    | Mfr. Code | Mfr. Desig.        | Keithley Part No. | Qty. |
|----------------|--|-----------|--------------------|-------------------|------|
| R1001          | 3.3k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-332-10%       | R76-3.3K          | 3    |
| R1002          | 1.5k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-152-10%       | R76-1.5K          | 2    |
| R1003          | 1.5k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-152-10%       | R76-1.5K          | ..   |
| R1004          | 3.3k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-332-10%       | R76-3.3K          | ..   |
| R1005          | 1.5k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-152-10%       | R76-3.3K          | ..   |
| R1006          | 1k $\Omega$ , 10%, 1/4W, Comp. . . . .         | 44655     | RC07-102-10%       | R76-1K            | 1    |
| R1007          | 560k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-561-10%       | R76-560           | 1    |
| R1008          | 10k $\Omega$ , 10%, 1/8W, Comp. . . . .        | 01121     | BB-103-10%         | R143-10K          | 2    |
| R1009          | 10k $\Omega$ , 10%, 1/8W, Comp. . . . .        | 01121     | BB-103-10%         | R143-10K          | ..   |
| R1010          | 100k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-104-10%       | R76-100K          | 2    |
| R1011          | 27k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-273-10%       | R76-27K           | 2    |
| R1012          | 15k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-153-10%       | R76-15K           | 3    |
| R1013          | 47k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-473-10%       | R76-47K           | 1    |
| R1014          | 15k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-153-10%       | R76-15K           | ..   |
| R1015          | 8.45k $\Omega$ , 1%, 1/8W, M $\pm$ F . . . . . | 07716     | CEA-8.45k $\Omega$ | R88-8.45K         | 1    |
| R1016          | 100k $\Omega$ , 10%, 1/4W, Comp. . . . .       | 44655     | RC07-104-10%       | R76-100K          | ..   |
| R1017          | 27k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-273-10%       | R76-27K           | ..   |
| R1018          | 15k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-153-10%       | R76-15K           | ..   |
| R1019          | 10k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-103-10%       | R76-10K           | 2    |
| R1020          | 10k $\Omega$ , 10%, 1/4W, Comp. . . . .        | 44655     | RC07-103-10%       | R76-10K           | ..   |

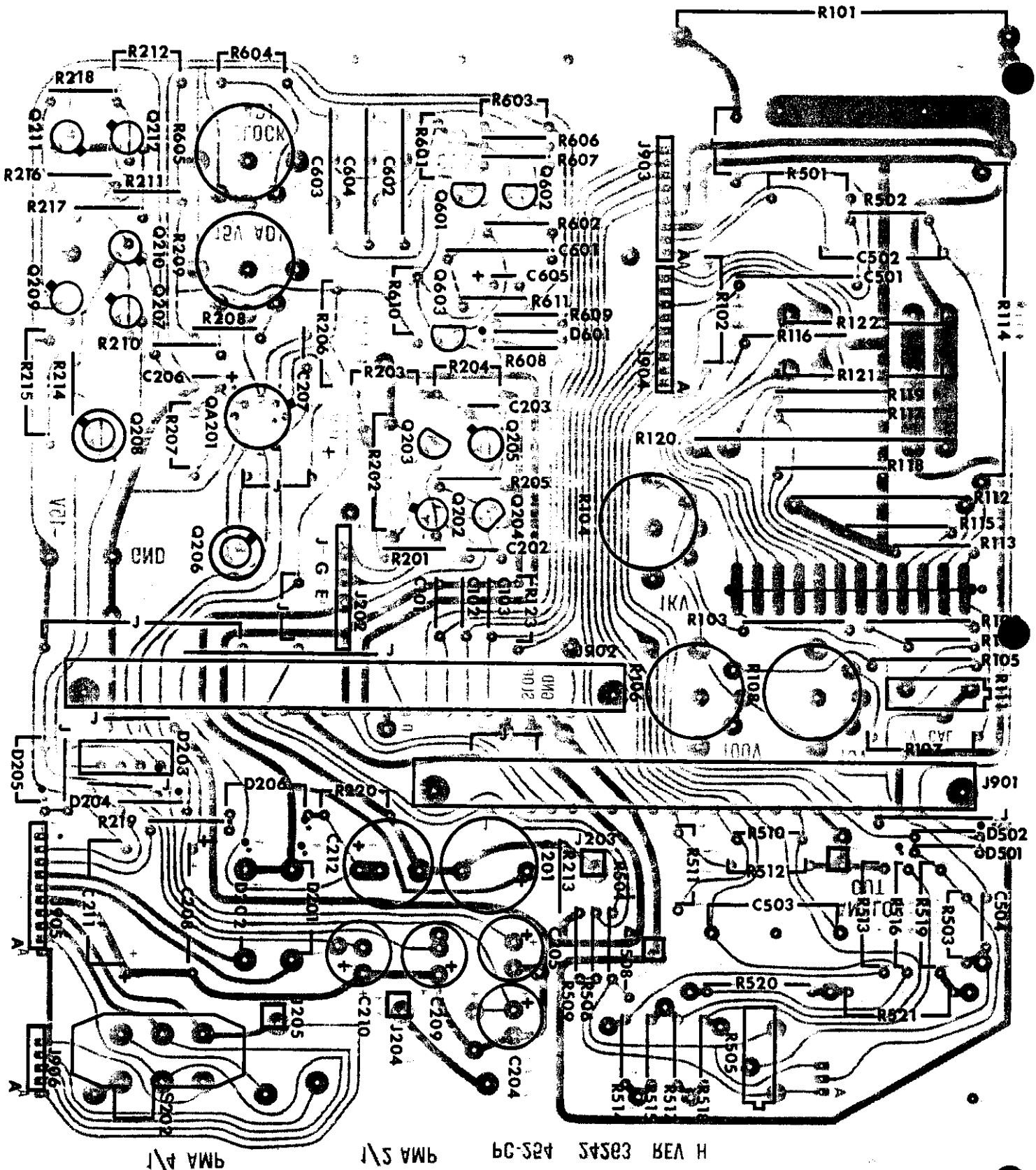


FIGURE 23. Component Layout, PC-254

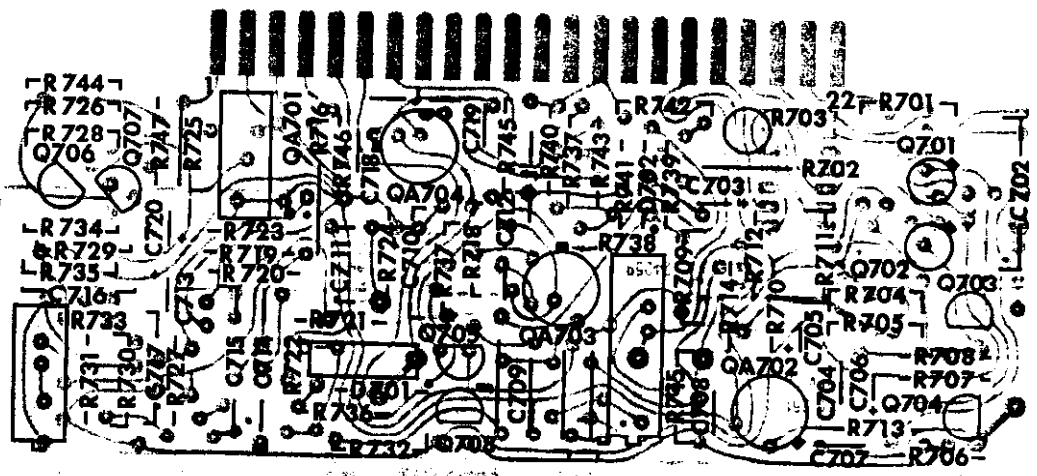


FIGURE 24. Component Layout, PC-251

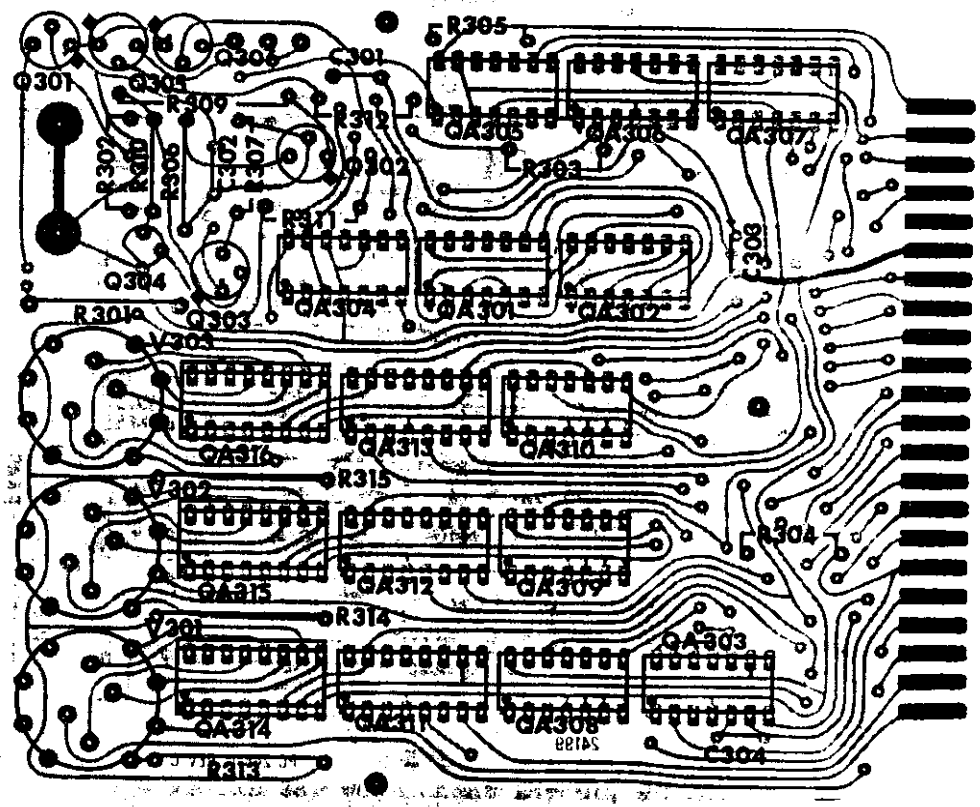


FIGURE 25. Component Layout, PC-248



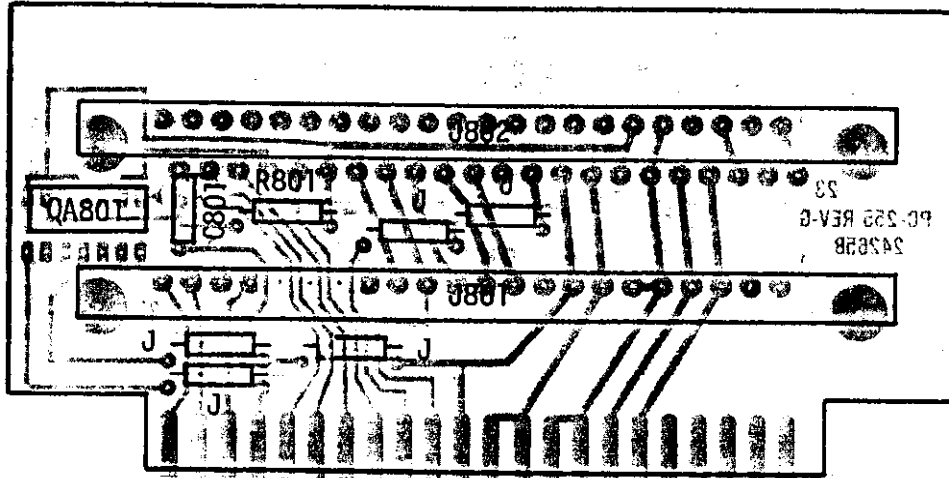


FIGURE 26. Component Layout, PC-255.

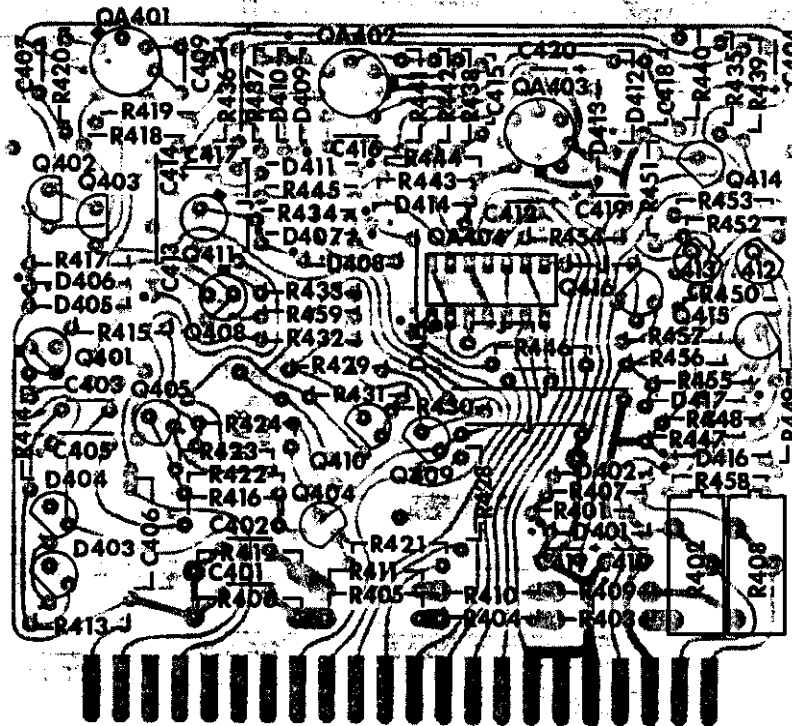


FIGURE 27. Component Layout, PC-250

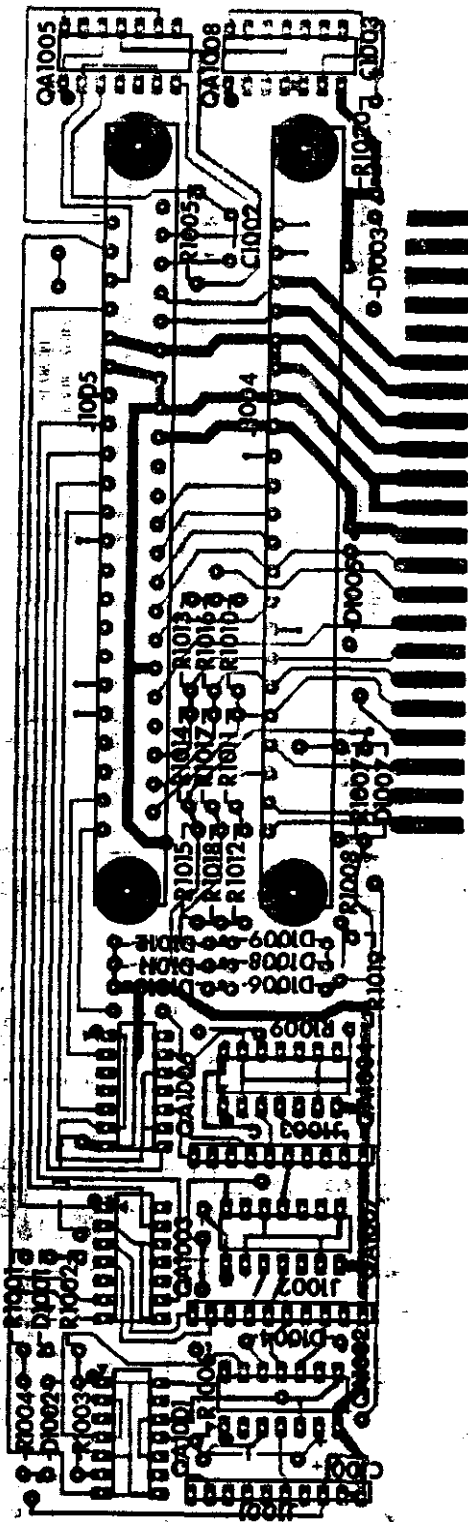


FIGURE 28. Component Layout, PC-287

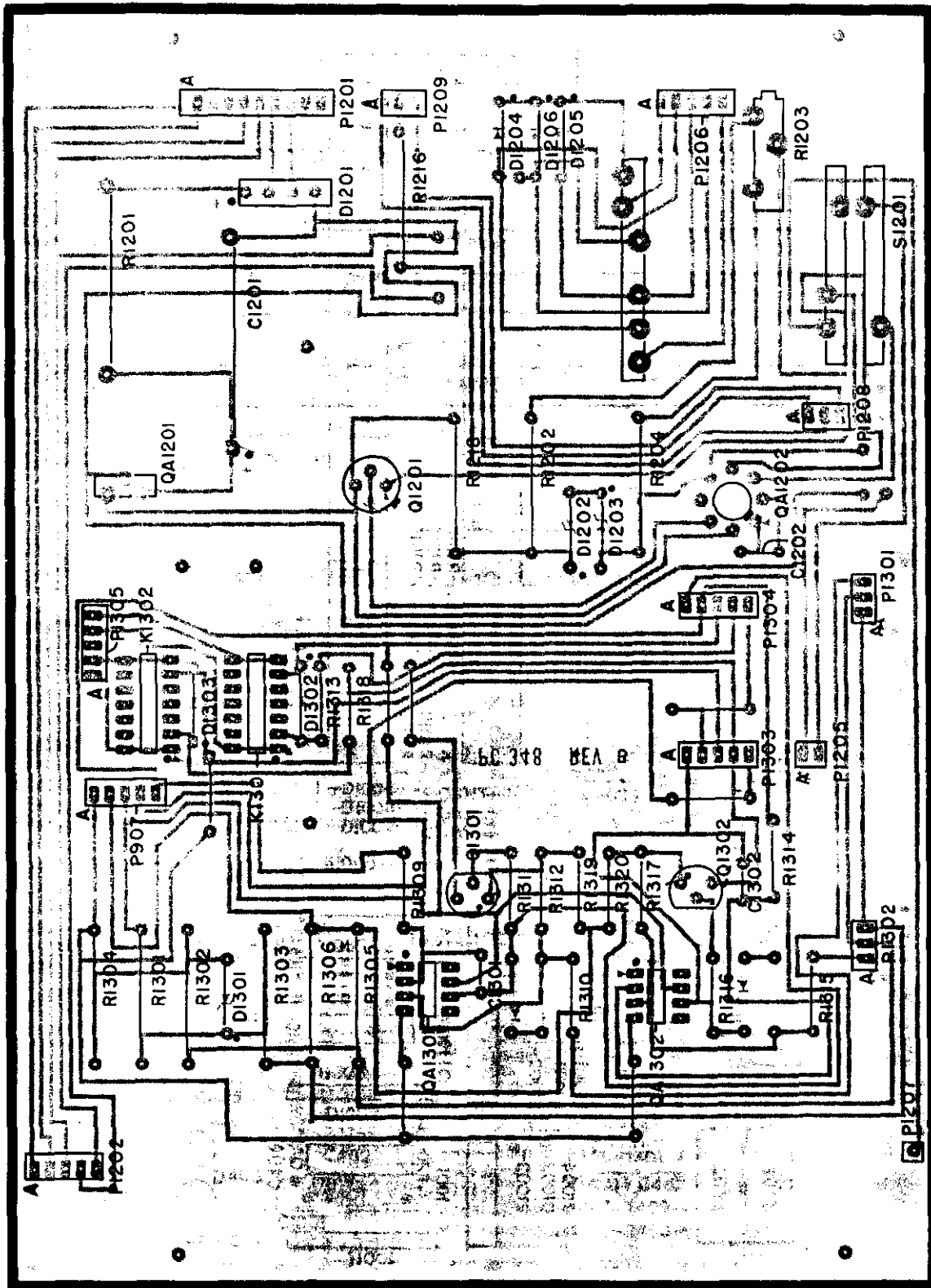
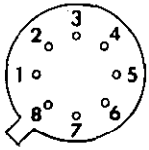
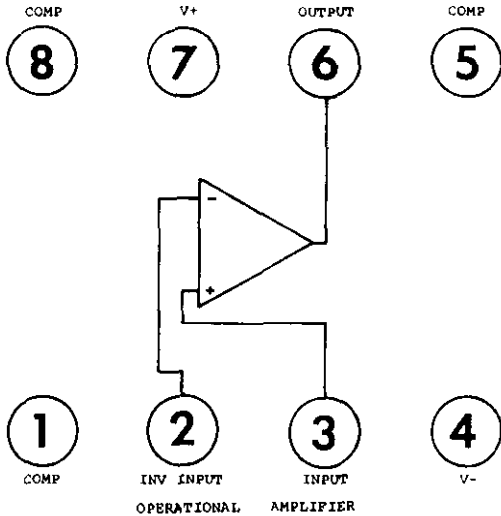


FIGURE 29. Component Layout, PC-348

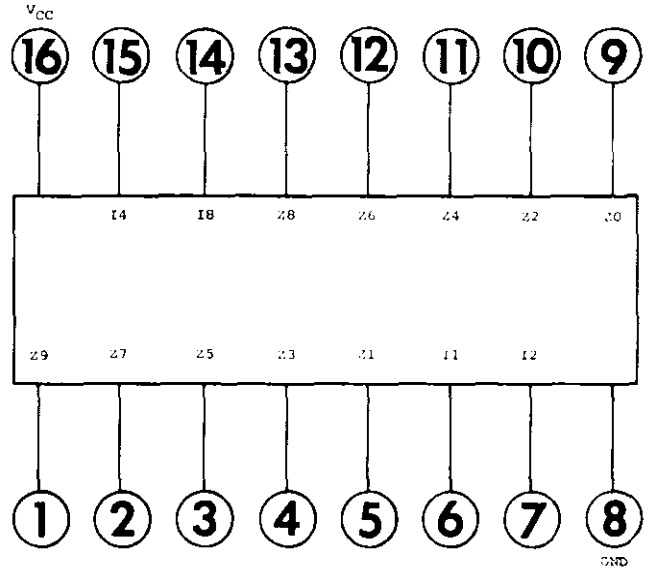
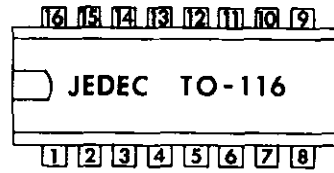
### KEITHLEY PART NO. IC-1,2



TO-99

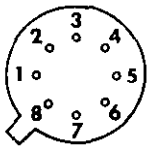


### KEITHLEY PART NO. IC-3

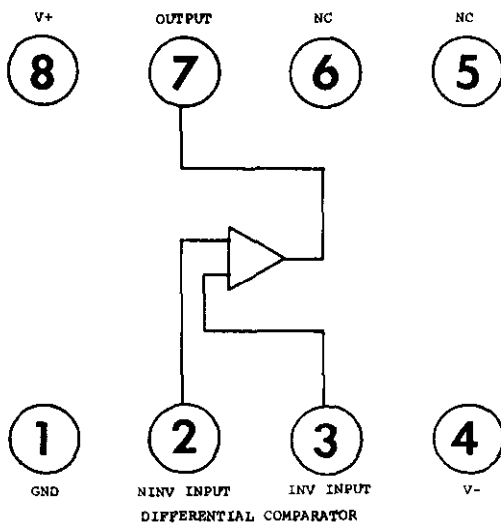


DECIMAL DECODER/DRIVER

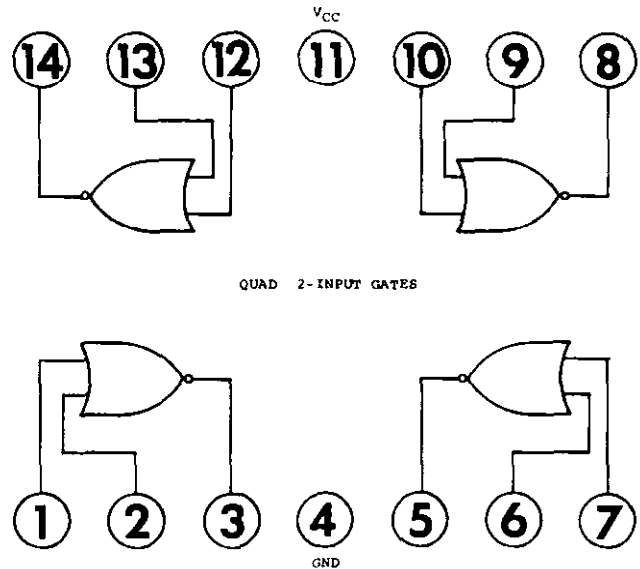
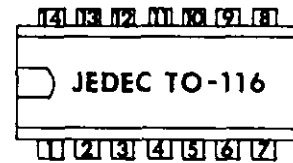
### KEITHLEY PART NO. IC-4



TO-99

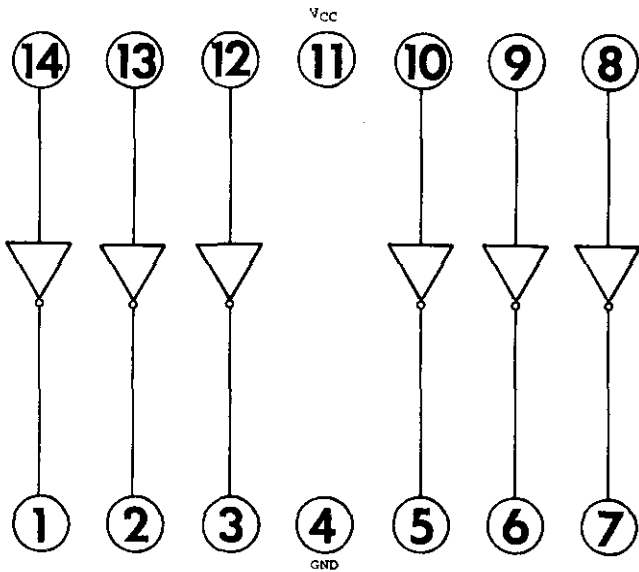
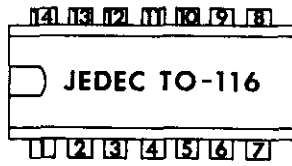


### KEITHLEY PART NO. IC-5



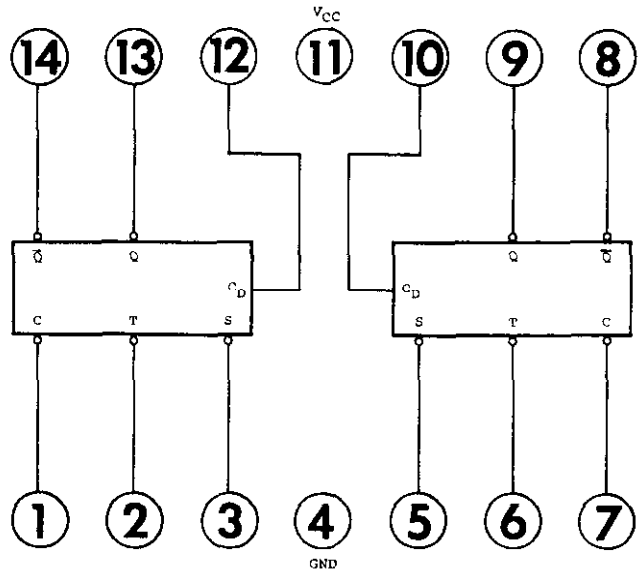
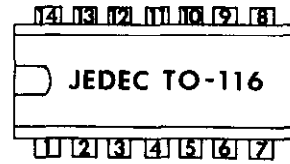
QUAD 2-INPUT GATES

### KEITHLEY PART NO. IC-7



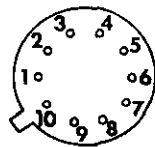
HEX INVERTER AMPLIFIER

### KEITHLEY PART NO. IC-8,9

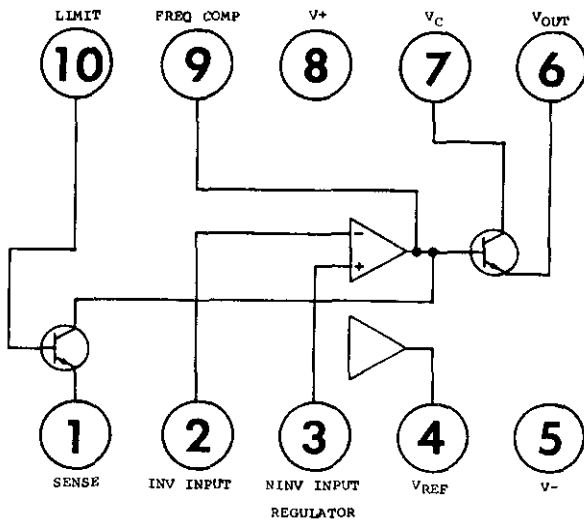


DUAL J-K FLIP FLOPS

### KEITHLEY PART NO. IC-14

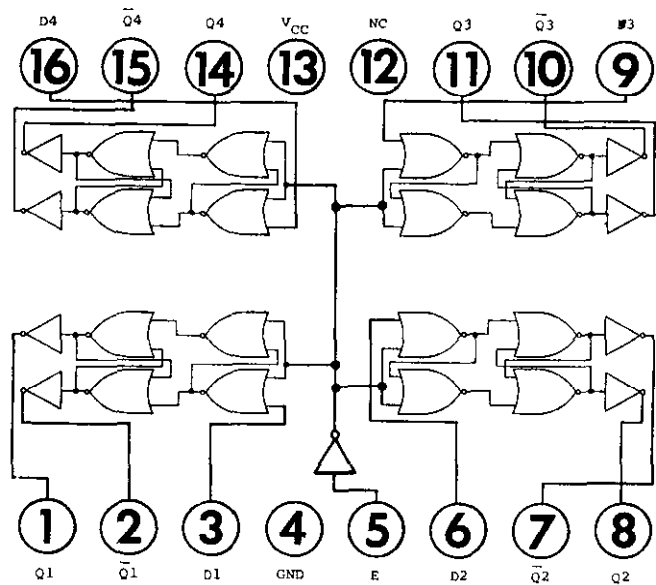
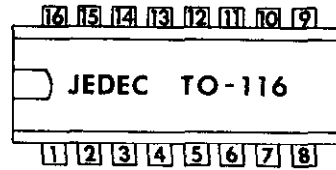


TO-100



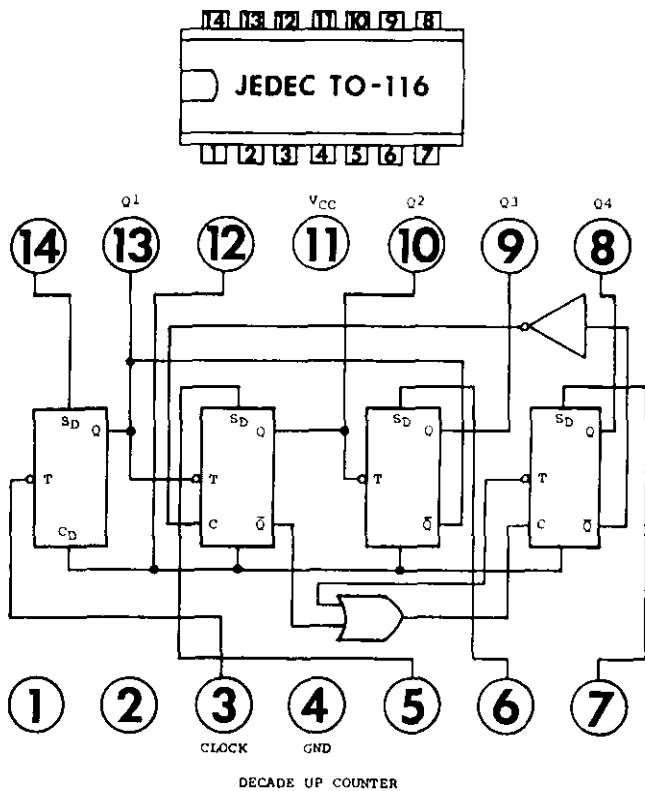
REGULATOR

### KEITHLEY PART NO. IC-16

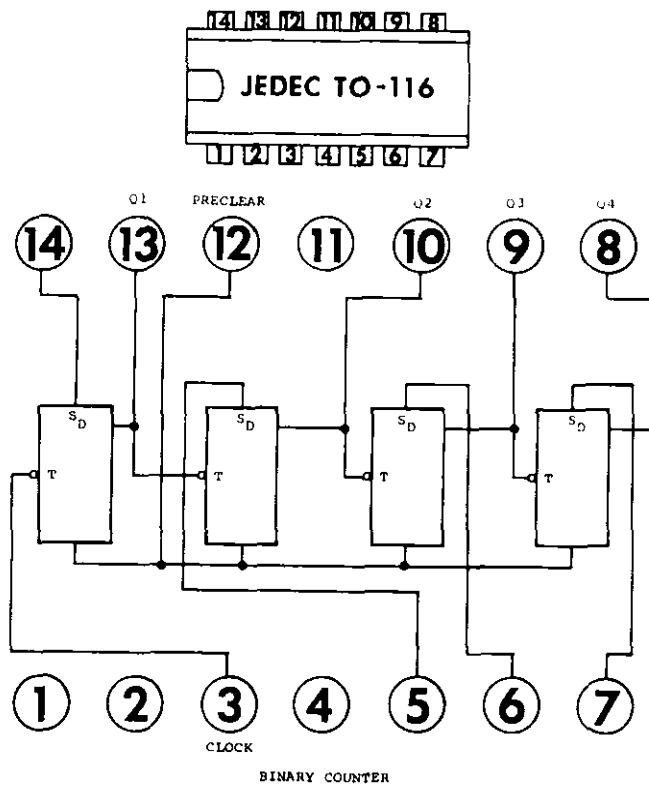


QUAD LATCH

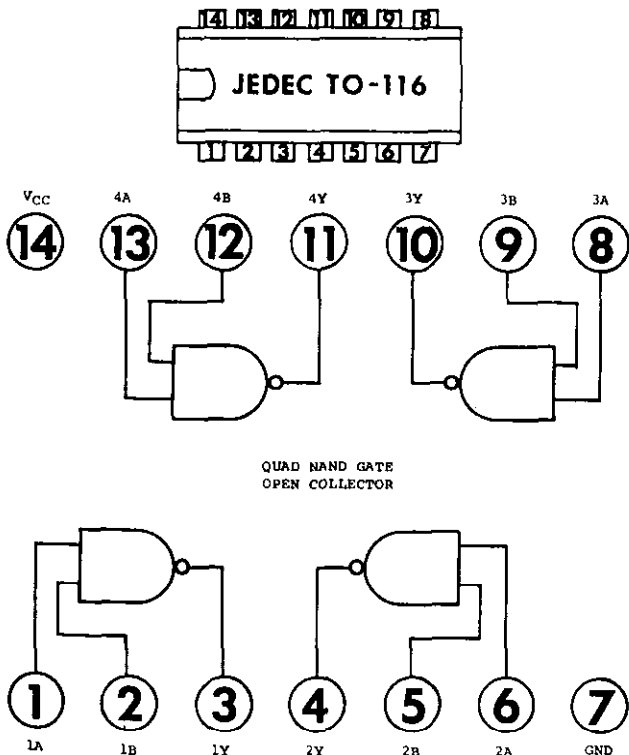
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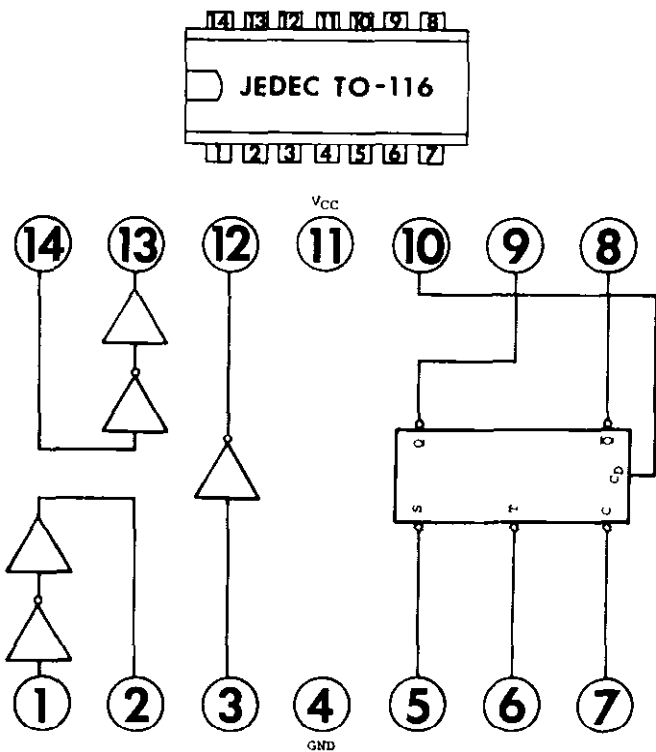
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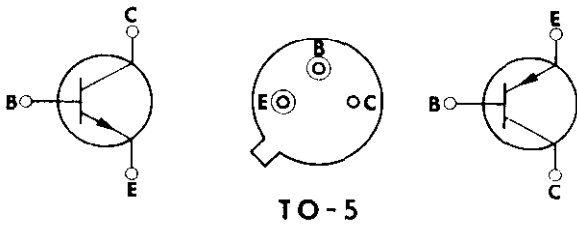
### KEITHLEY PART NO. IC-22



### KEITHLEY PART NO. IC-23

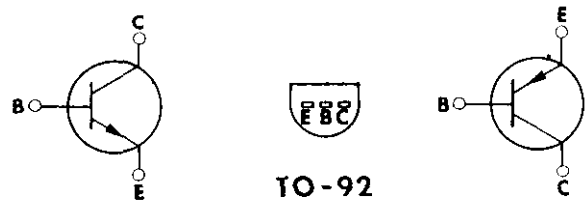


**LEAD DESIG. TO-5**



**TO-5**

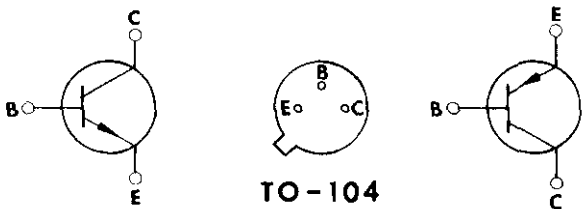
**LEAD DESIG. TO-92**



**TO-92**

BOTTOM VIEW

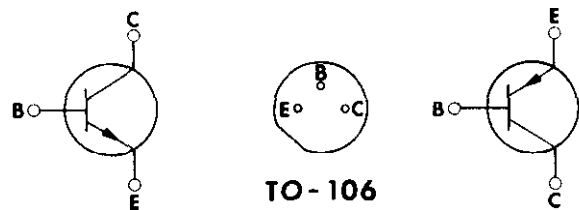
**LEAD DESIG. TO-104**



**TO-104**

BOTTOM VIEW

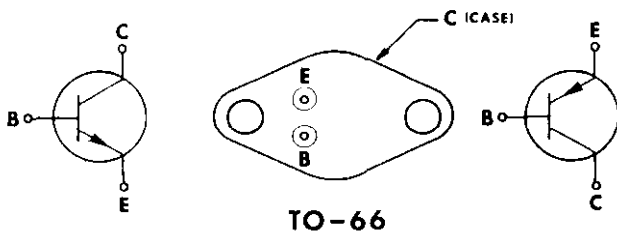
**LEAD DESIG. TO-106**



**TO-106**

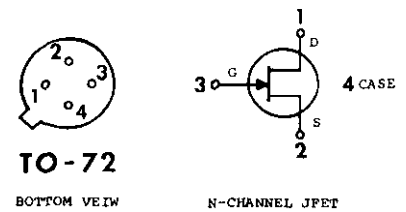
BOTTOM VIEW

**LEAD DESIG. TO-66**



**TO-66**

**KEITHLEY PART NO. TG-42**

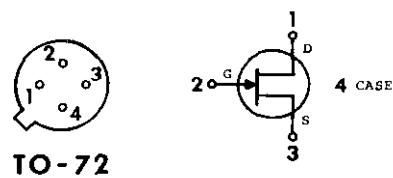


**TO-72**

BOTTOM VIEW

N-CHANNEL JFET

**KEITHLEY PART NO. TG-51**

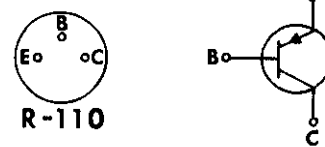


**TO-72**

BOTTOM VIEW

N-CHANNEL FET

**KEITHLEY PART NO. TG-33**



**R-110**

BOTTOM VIEW

## CODE-TO-NAME LIST

CODE TO NAME List of Suggested Manufacturers.

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

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

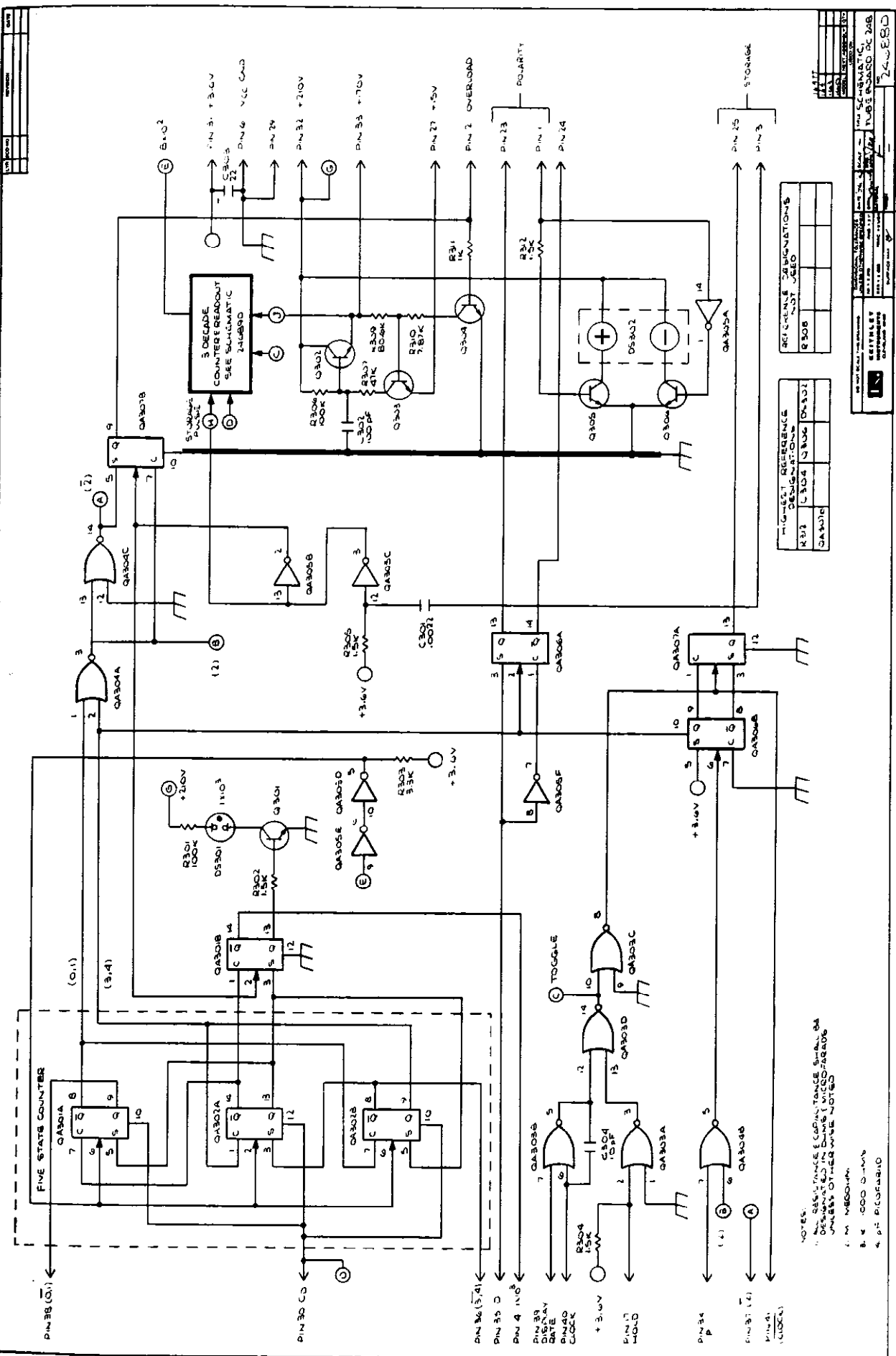


## REPLACEABLE PARTS

## CODE TO NAME List (Continued).

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

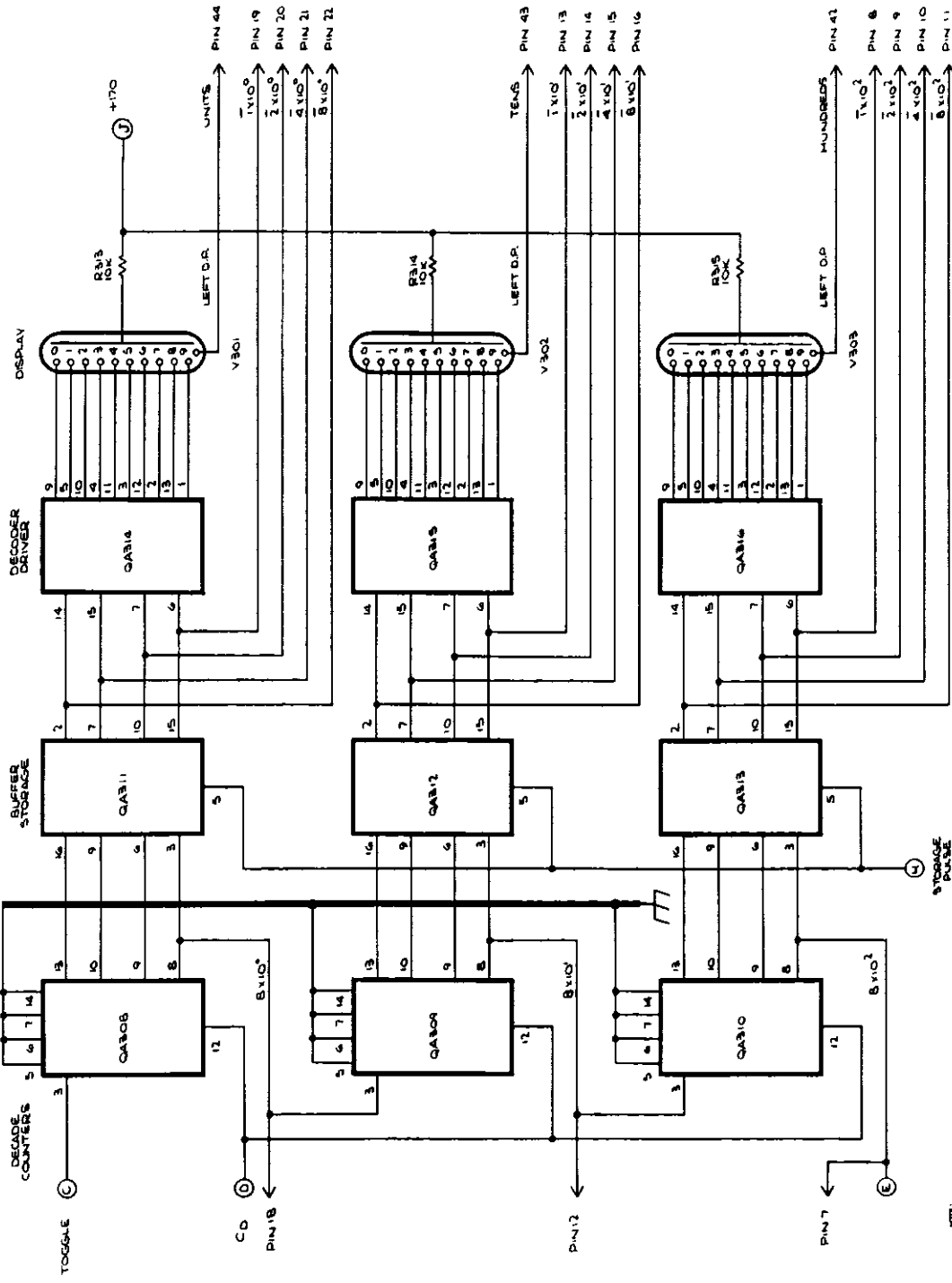
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| Q657                          | Q658  |
| Q659                          | Q660  |
| Q661                          | Q662  |
| Q663                          | Q664  |
| Q665                          | Q666  |
| Q667                          | Q668  |
| Q669                          | Q670  |
| Q671                          | Q672  |
| Q673                          | Q674  |
| Q675                          | Q676  |
| Q677                          | Q678  |
| Q679                          | Q680  |
| Q681                          | Q682  |
| Q683                          | Q684  |
| Q685                          | Q686  |
| Q687                          | Q688  |
| Q689                          | Q690  |
| Q691                          | Q692  |
| Q693                          | Q694  |
| Q695                          | Q696  |
| Q697                          | Q698  |
| Q699                          | Q700  |
| Q701                          | Q702  |
| Q703                          | Q704  |
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| Q719                          | Q720  |
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| Q725                          | Q726  |
| Q727                          | Q728  |
| Q729                          | Q730  |
| Q731                          | Q732  |
| Q733                          | Q734  |
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| Q737                          | Q738  |
| Q739                          | Q740  |
| Q741                          | Q742  |
| Q743                          | Q744  |
| Q745                          | Q746  |
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| Q749                          | Q750  |
| Q751                          | Q752  |
| Q753                          | Q754  |
| Q755                          | Q756  |
| Q757                          | Q758  |
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| Q761                          | Q762  |
| Q763                          | Q764  |
| Q765                          | Q766  |
| Q767                          | Q768  |
| Q769                          | Q770  |
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| Q773                          | Q774  |
| Q775                          | Q776  |
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| Q791                          | Q792  |
| Q793                          | Q794  |
| Q795                          | Q796  |
| Q797                          | Q798  |
| Q799                          | Q800  |
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| Q811                          | Q812  |
| Q813                          | Q814  |
| Q815                          | Q816  |
| Q817                          | Q818  |
| Q819                          | Q820  |
| Q821                          | Q822  |
| Q823                          | Q824  |
| Q825                          | Q826  |
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| Q847                          | Q848  |
| Q849                          | Q850  |
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| Q863                          | Q864  |
| Q865                          | Q866  |
| Q867                          | Q868  |
| Q869                          | Q870  |
| Q871                          | Q872  |
| Q873                          | Q874  |
| Q875                          | Q876  |
| Q877                          | Q878  |
| Q879                          | Q880  |
| Q881                          | Q882  |
| Q883                          | Q884  |
| Q885                          | Q886  |
| Q887                          | Q888  |
| Q889                          | Q890  |
| Q891                          | Q892  |
| Q893                          | Q894  |
| Q895                          | Q896  |
| Q897                          | Q898  |
| Q899                          | Q900  |
| Q901                          | Q902  |
| Q903                          | Q904  |
| Q905                          | Q906  |
| Q907                          | Q908  |
| Q909                          | Q910  |
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| Q913                          | Q914  |
| Q915                          | Q916  |
| Q917                          | Q918  |
| Q919                          | Q920  |
| Q921                          | Q922  |
| Q923                          | Q924  |
| Q925                          | Q926  |
| Q927                          | Q928  |
| Q929                          | Q930  |
| Q931                          | Q932  |
| Q933                          | Q934  |
| Q935                          | Q936  |
| Q937                          | Q938  |
| Q939                          | Q940  |
| Q941                          | Q942  |
| Q943                          | Q944  |
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| Q947                          | Q948  |
| Q949                          | Q950  |
| Q951                          | Q952  |
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| Q955                          | Q956  |
| Q957                          | Q958  |
| Q959                          | Q960  |
| Q961                          | Q962  |
| Q963                          | Q964  |
| Q965                          | Q966  |
| Q967                          | Q968  |
| Q969                          | Q970  |
| Q971                          | Q972  |
| Q973                          | Q974  |
| Q975                          | Q976  |
| Q977                          | Q978  |
| Q979                          | Q980  |
| Q981                          | Q982  |
| Q983                          | Q984  |
| Q985                          | Q986  |
| Q987                          | Q988  |
| Q989                          | Q990  |
| Q991                          | Q992  |
| Q993                          | Q994  |
| Q995                          | Q996  |
| Q997                          | Q998  |
| Q999                          | Q1000 |

NOTES:  
 1. SEE PIN 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135,

|     |    |      |
|-----|----|------|
| REV | NO | DATE |
|     |    |      |
|     |    |      |
|     |    |      |



NOTE:  
 1. ALL RESISTANCE & CAPACITANCE SHALL BE IN OHMS UNLESS OTHERWISE SPECIFIED.  
 2. I. 100 OHMS

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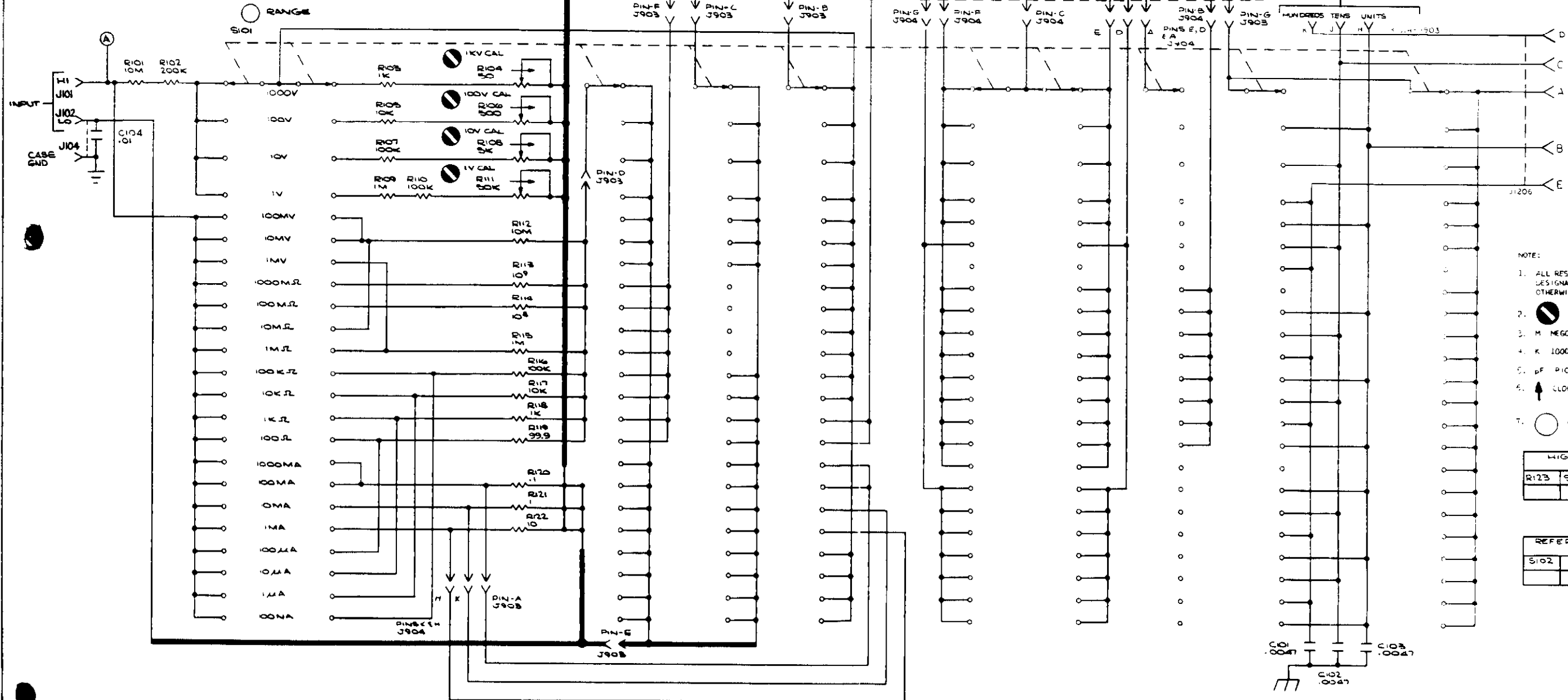
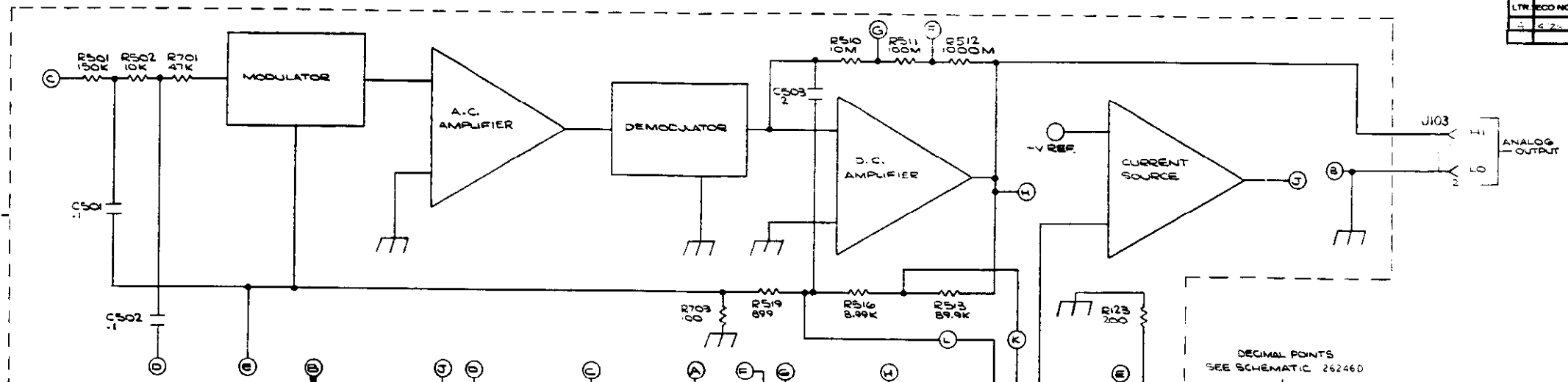
14177

RESISTOR NETWORK

24689D

| LTR. ECO NO. | REVISION | DATE    |
|--------------|----------|---------|
| 5 4 2        | RELEASED | 10/4/74 |

BLOCK DIAGRAM FOR ANALOG CIRCUIT REF ONLY (26244E)

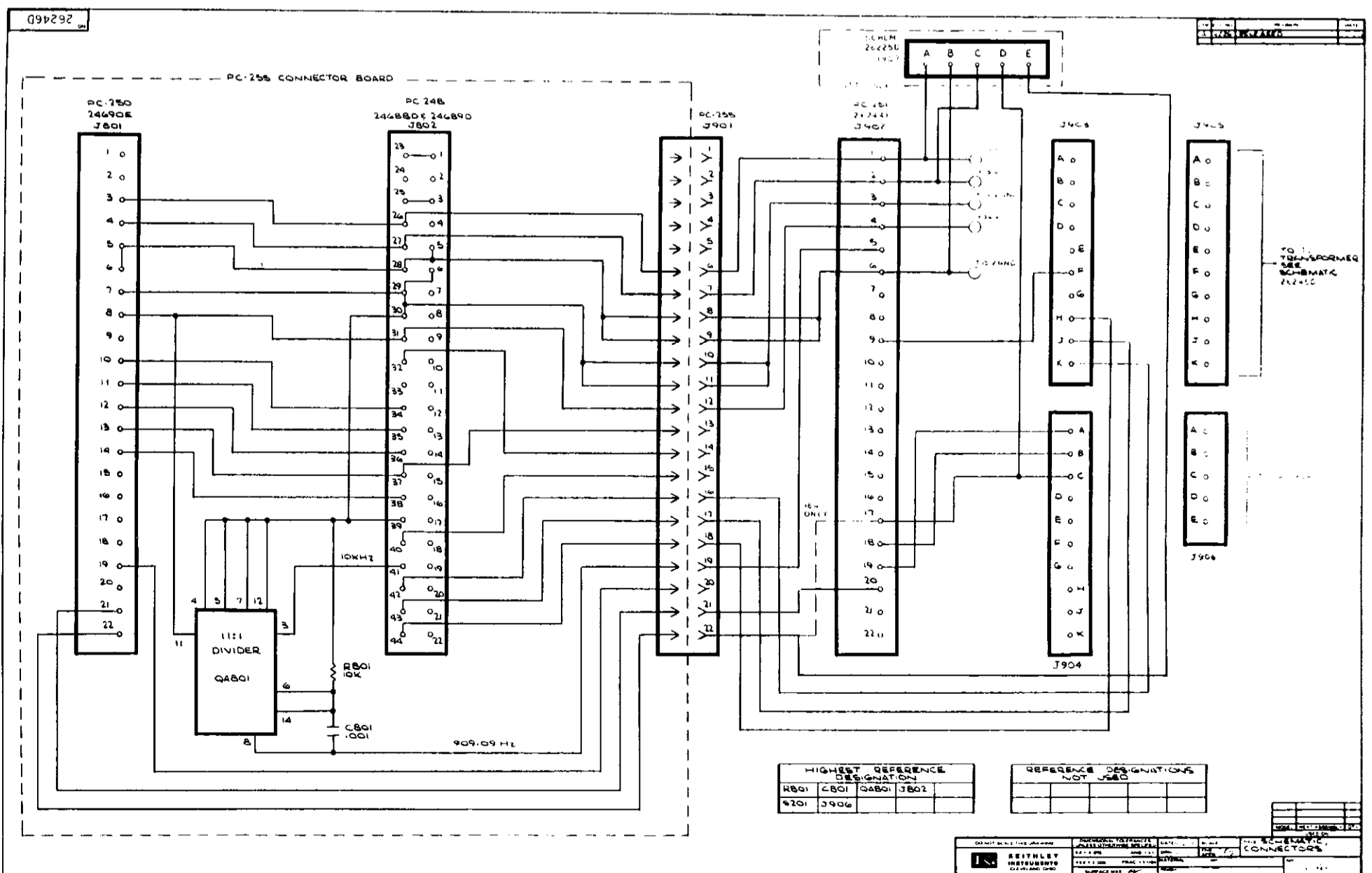
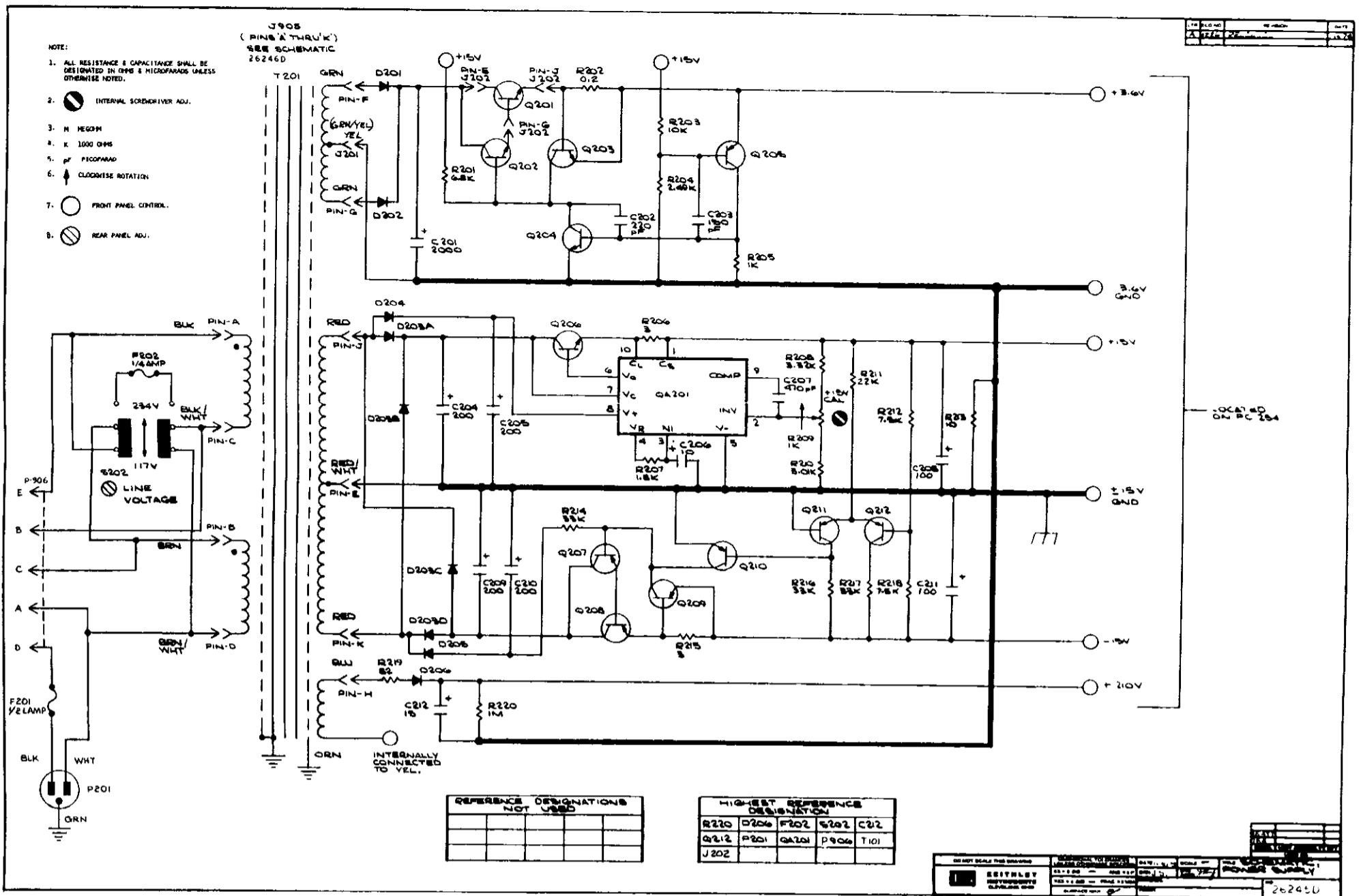


- NOTE:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED
  2. INTERNAL SCREWDRIVER ADJ.
  3. M. MEGOHM
  4. K. 1000 OHMS
  5. P. PICO FARAD
  6. CLOCKWISE ROTATION
  7. FRONT PANEL CONTROL.

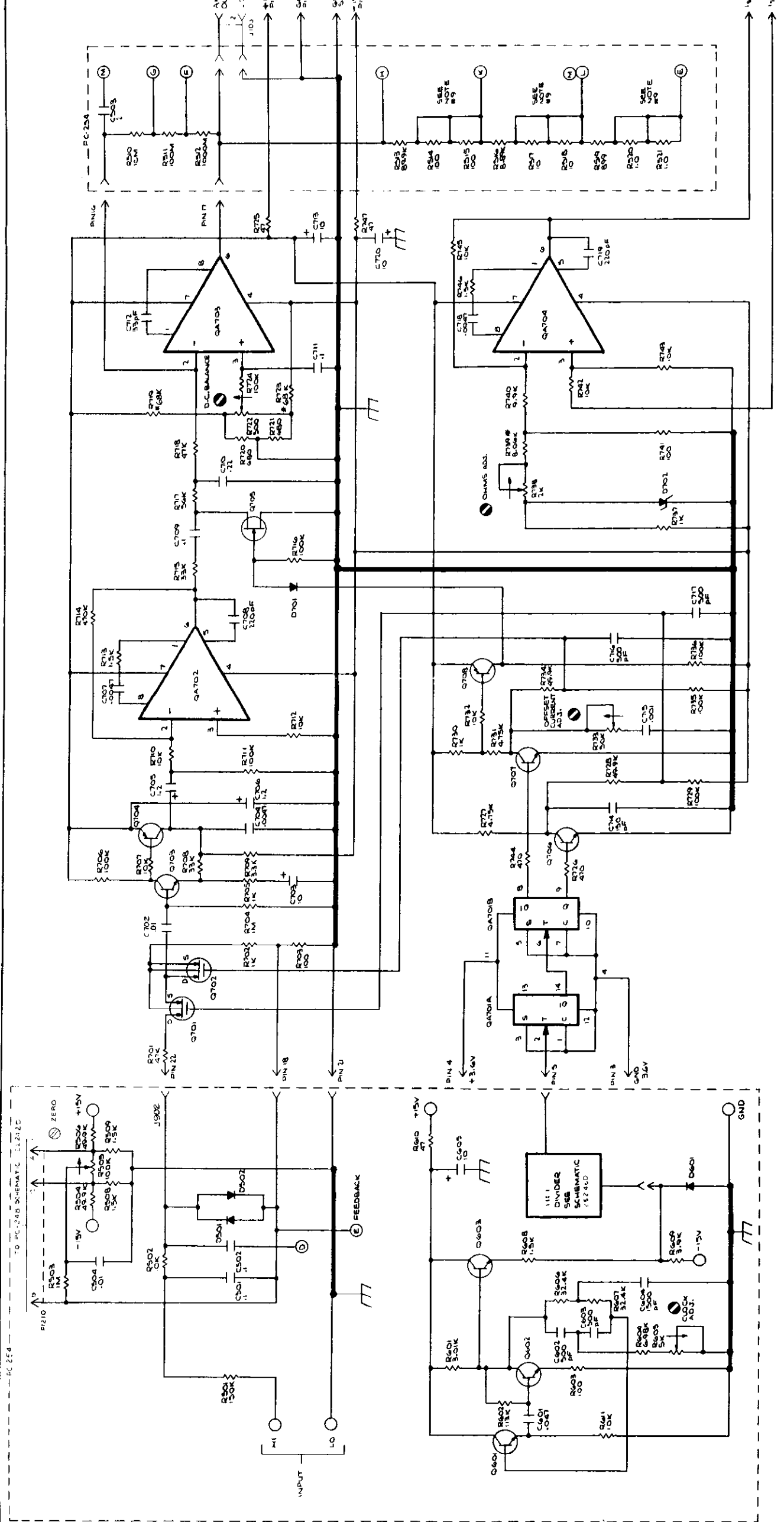
| HIGHEST REFERENCE DESIGNATION |      |      |      |       |
|-------------------------------|------|------|------|-------|
| R123                          | S102 | C104 | J904 | J1206 |
|                               |      |      |      |       |

| REFERENCE DESIGNATIONS NOT USED |  |  |  |  |
|---------------------------------|--|--|--|--|
| S102                            |  |  |  |  |
|                                 |  |  |  |  |

|   |  |   |  |                        |
|---|--|---|--|------------------------|
| <b>KEITHLEY</b><br>INSTRUMENTS<br>CLEVELAND, OHIO | DIMENSIONAL TOLERANCES<br>UNLESS OTHERWISE SPECIFIED:<br>XX ± .010 — ANG ± .010<br>XXX ± .005 — PRAC ± .005<br>SURFACE MAX | DATE: _____<br>DRAWN BY: _____<br>CHECKED BY: _____<br>MATERIAL: _____<br>FINISH: _____ | SCALE: _____<br>TITLE: <b>SCHEMATIC, SWITCHING</b> | PART NO: <b>26243E</b> |
|   | DO NOT SCALE THIS DRAWING  |   |  |                        |
|   | MODELS, NEXT ASSY, CITY, USED ON   |   |  |                        |



| ITER | REV | DATE  |
|------|-----|-------|
| 1    | 1   | 11/72 |



- NOTE:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROOHMS UNLESS OTHERWISE NOTED.
  2. INTERNAL SCHEMATIC ADJ.
  3. REAR PANEL ADJ.
  4. M FREEDOM
  5. K 1000 OHMS
  6. P PICOGRAM
  7. C COUNTER ROTATION
  8. \* INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION.
  9. SUMMER CUPROD DURING FINAL CALIBRATION IS NECESSARY.

HIGHEST SCHEMATIC DESIGNATIONS

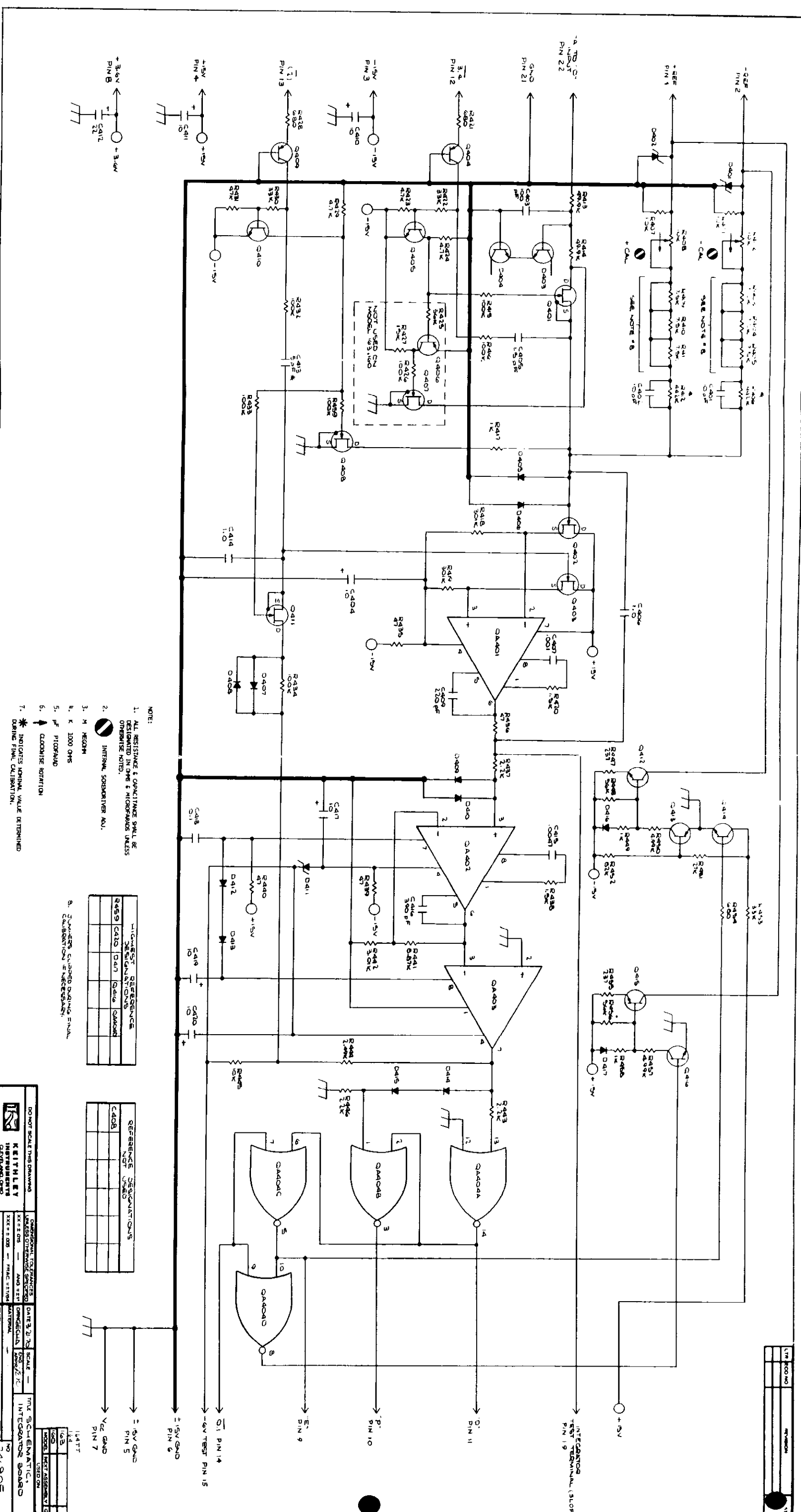
|      |      |      |      |
|------|------|------|------|
| R321 | C304 | J701 | D302 |
| R311 | C405 | D403 | Q403 |
| D407 | C710 | Q703 | Q404 |

SCHEMATIC DESIGNATIONS

|       |       |
|-------|-------|
| C701  | D5301 |
| R507  |       |
| J 901 |       |

DO NOT SCALE THIS DRAWING  
 KEITHLEY INSTRUMENTS  
 CLEVELAND OHIO

|       |                                   |
|-------|-----------------------------------|
| DATE  | 11/72                             |
| REV   | 1                                 |
| ITER  | 1                                 |
| SCALE | AS SHOWN                          |
| TITLE | PRECISION ANALOG AMPLIFIER PC-254 |
| NO    | 26244E                            |

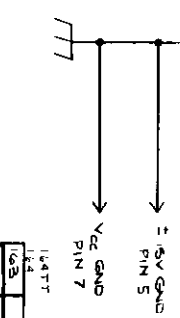


NOTE:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROHMMS UNLESS OTHERWISE NOTED.
2. INTERNAL SHORTCIRCUIT AU.
3. M. NEGOM
4. K. 1000 OHMS
5.  $\mu$ F. MICROHMMS
6. CLOSURE NOTATION
7. \* INDICATES NOMINAL VALUE DETERMINED DURING FINAL DISSECTION.

| MICROHMMS | RESISTANCE | DESIGNATION | OHMS | RESISTANCE | DESIGNATION | OHMS |
|-----------|------------|-------------|------|------------|-------------|------|
| 2459      | C410       | D41         | 1000 | Q408       | Q408        | 1000 |
|           |            |             |      |            |             |      |
|           |            |             |      |            |             |      |

| RESISTANCE | DESIGNATION | OHMS | RESISTANCE | DESIGNATION | OHMS |
|------------|-------------|------|------------|-------------|------|
| C408       |             |      |            |             |      |
|            |             |      |            |             |      |
|            |             |      |            |             |      |



DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

COMPONENT TOLERANCES UNLESS OTHERWISE SPECIFIED: RESISTORS - 1% (1% RESISTORS - 5%); CAPACITORS - 5% (1% CAPACITORS - 5%)

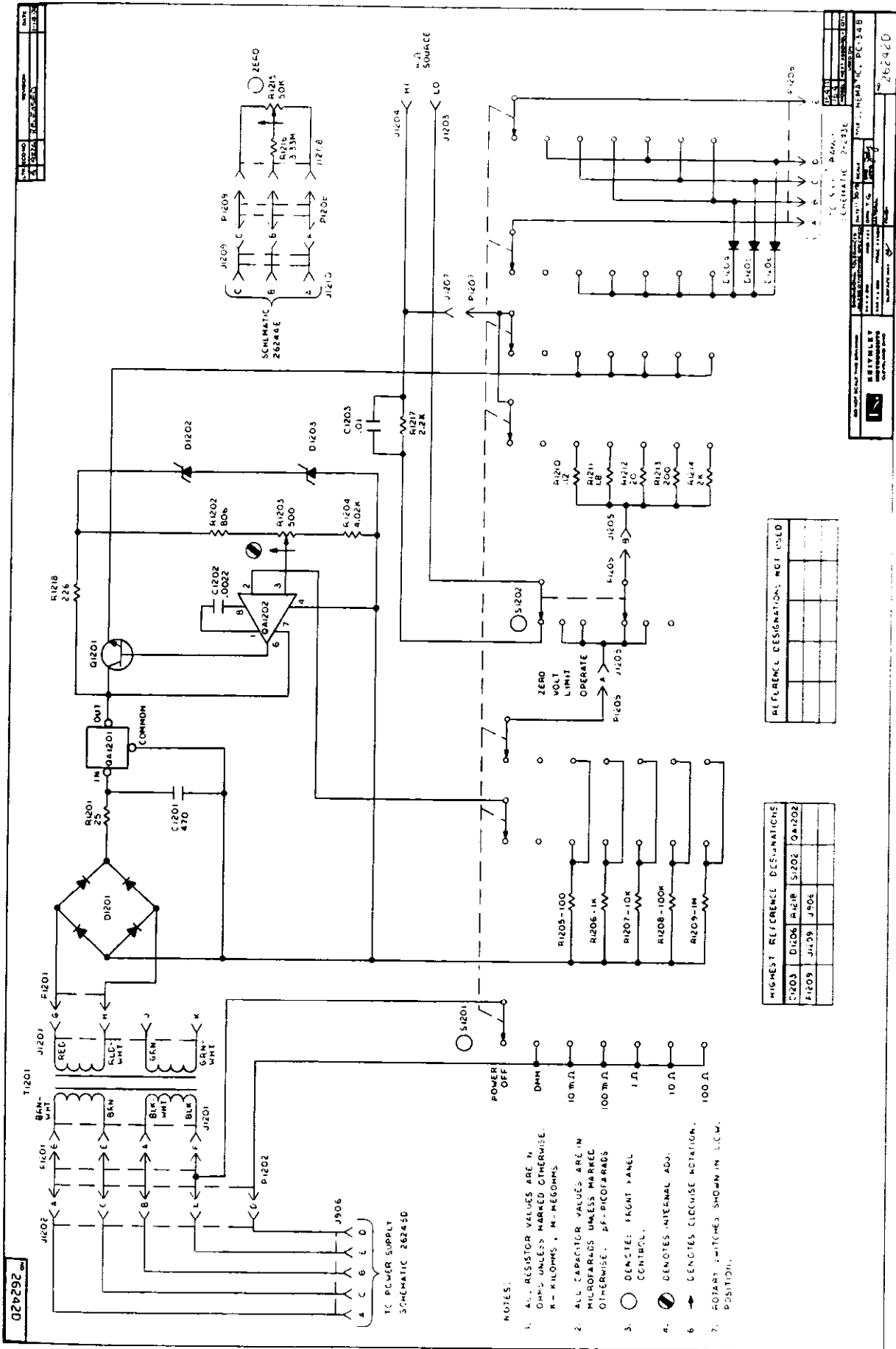
DATE: 1/2/68

SCALE: 1" = 1" (1" = 1")

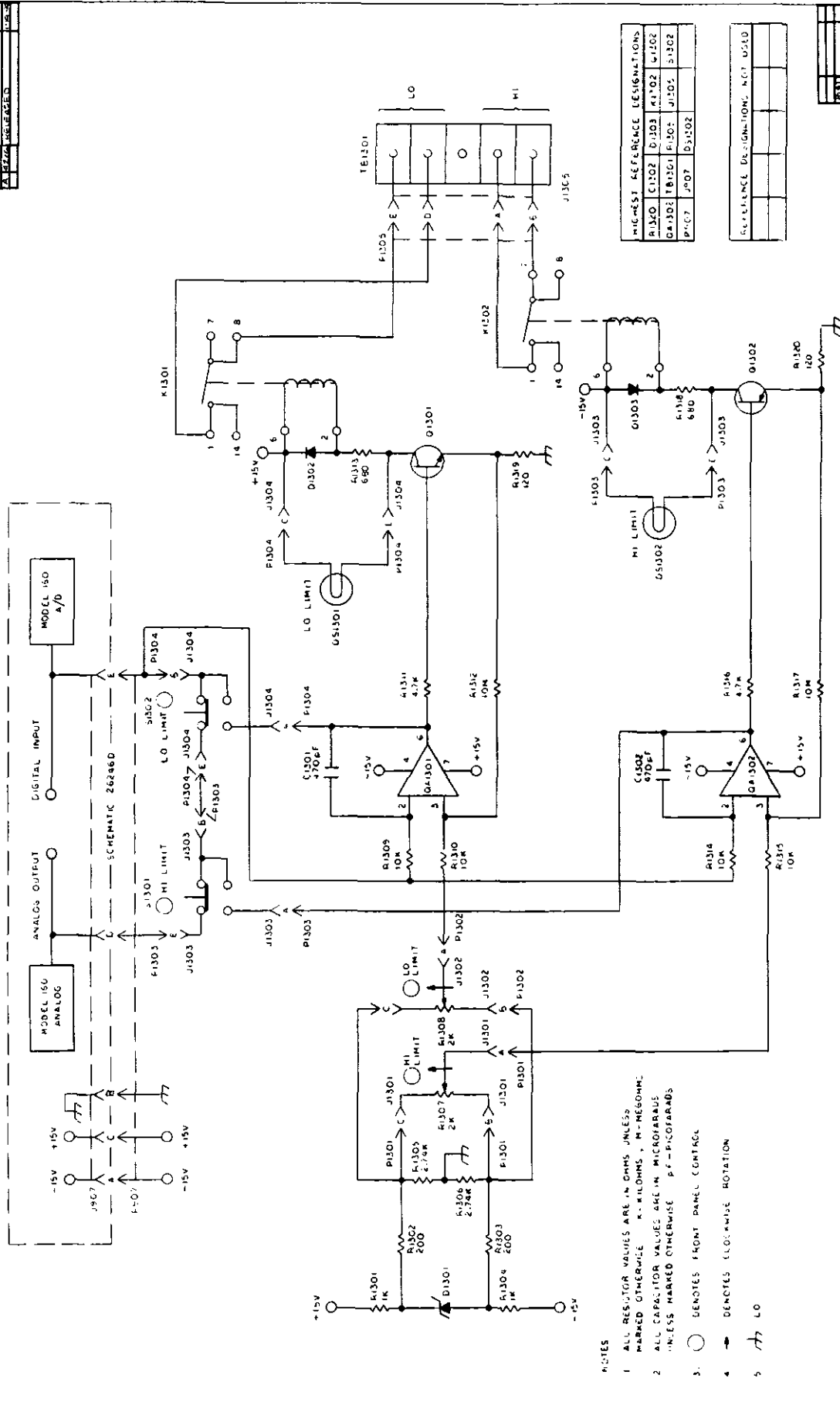
INT. SCHEMATIC: INTERCONNECTOR BOARD

NO. 2490E

| REV. | DESCRIPTION |
|------|-------------|
| 1    |             |
| 2    |             |
| 3    |             |
| 4    |             |
| 5    |             |
| 6    |             |
| 7    |             |
| 8    |             |
| 9    |             |
| 10   |             |







- NOTES
- 1 ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE K = KILOHMS, M = MEGOHMS
  - 2 ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE P = PICOFARADS
  - 3 DENOTES FRONT PANEL CONTROL
  - 4 DENOTES LOG-NUMERIC ROTATION
  - 5 LO

MINI-MAX REFERENCE DESIGNATIONS

|        |        |        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|--------|--------|
| R1301  | C1302  | D1302  | R1303  | R1304  | R1305  | R1306  | R1307  |
| 0A1301 | 0A1302 | 0A1303 | 0A1304 | 0A1305 | 0A1306 | 0A1307 | 0A1308 |
| C1301  | C1302  | C1303  | C1304  | C1305  | C1306  | C1307  | C1308  |
| D1301  | D1302  | D1303  | D1304  | D1305  | D1306  | D1307  | D1308  |

REFERENCE DESIGNATIONS NOT USED

|  |  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|
|  |  |  |  |  |  |  |  |
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SCHEMATIC 26248D

DATE: 10/68

DESIGNED BY: E. J. SPAN

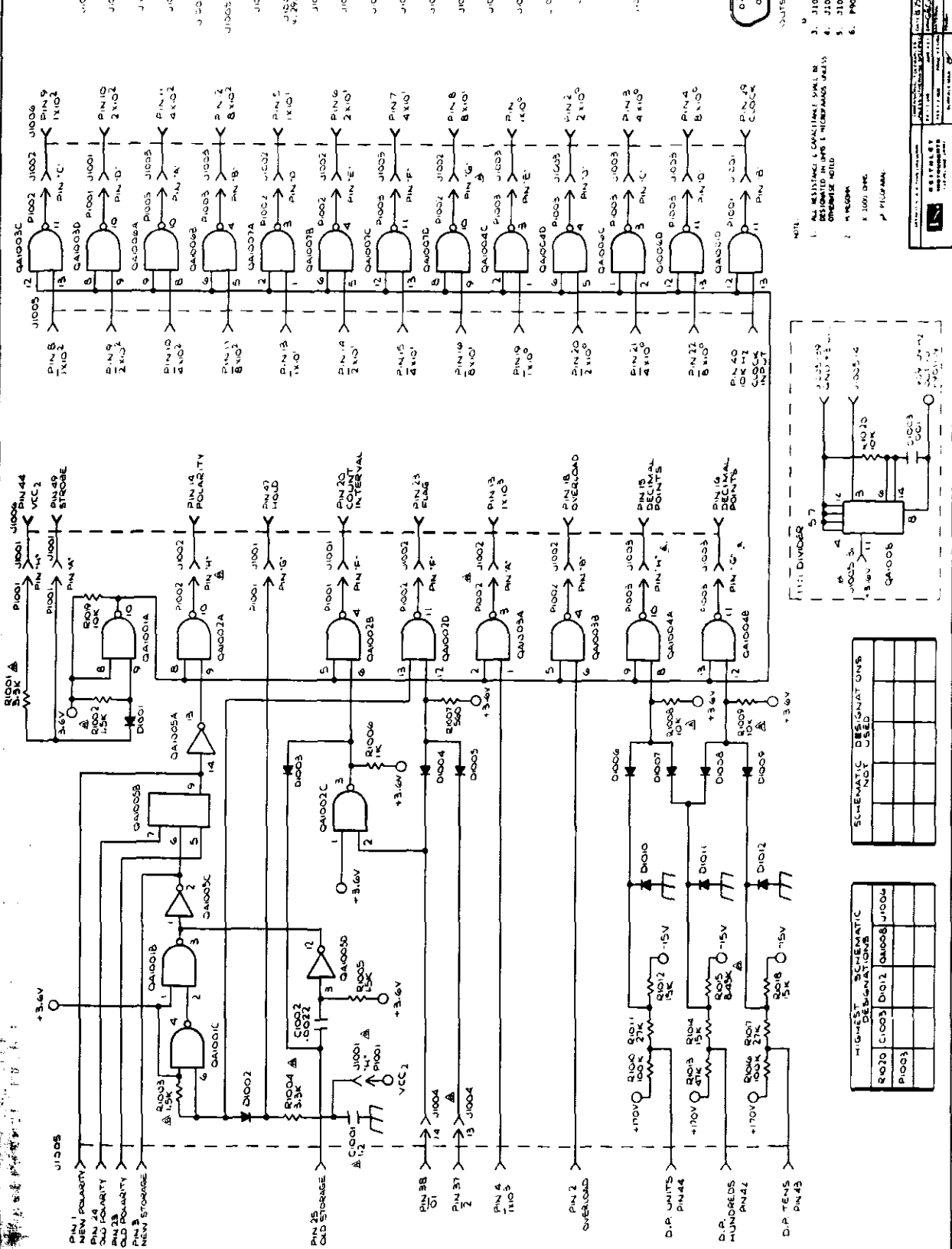
CHECKED BY: E. J. SPAN

ASSEMBLY: 26248D

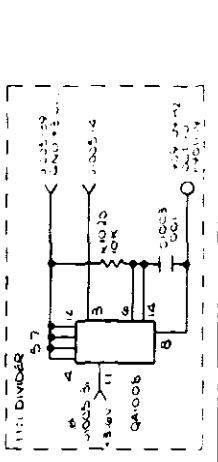
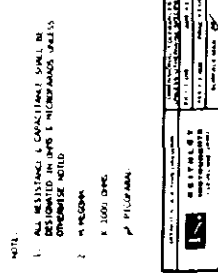
TEST POINTS: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

26225D

|     |         |
|-----|---------|
| REV | DATE    |
| 1   | 1/17/64 |
| 2   | 1/23/64 |
| 3   | 2/10/64 |
| 4   | 2/10/64 |
| 5   | 2/10/64 |
| 6   | 2/10/64 |
| 7   | 2/10/64 |
| 8   | 2/10/64 |
| 9   | 2/10/64 |
| 10  | 2/10/64 |



- NOTE:
1. ALL RESISTORS & CAPACITORS SHALL BE DESIGNATED IN THIS SCHEMATIC UNLESS OTHERWISE NOTED.
  2. 1/4 WATT
  3. 1/100 OHM
  4. 1/100 OHM
  5. 1/100 OHM
  6. PIN 30-39 HARD EDGE CONNECTOR



HIGH-TYPE DESIGNATIONS

|       |       |       |        |       |
|-------|-------|-------|--------|-------|
| 2020  | C1003 | D1012 | QA0008 | J1004 |
| PI003 |       |       |        |       |

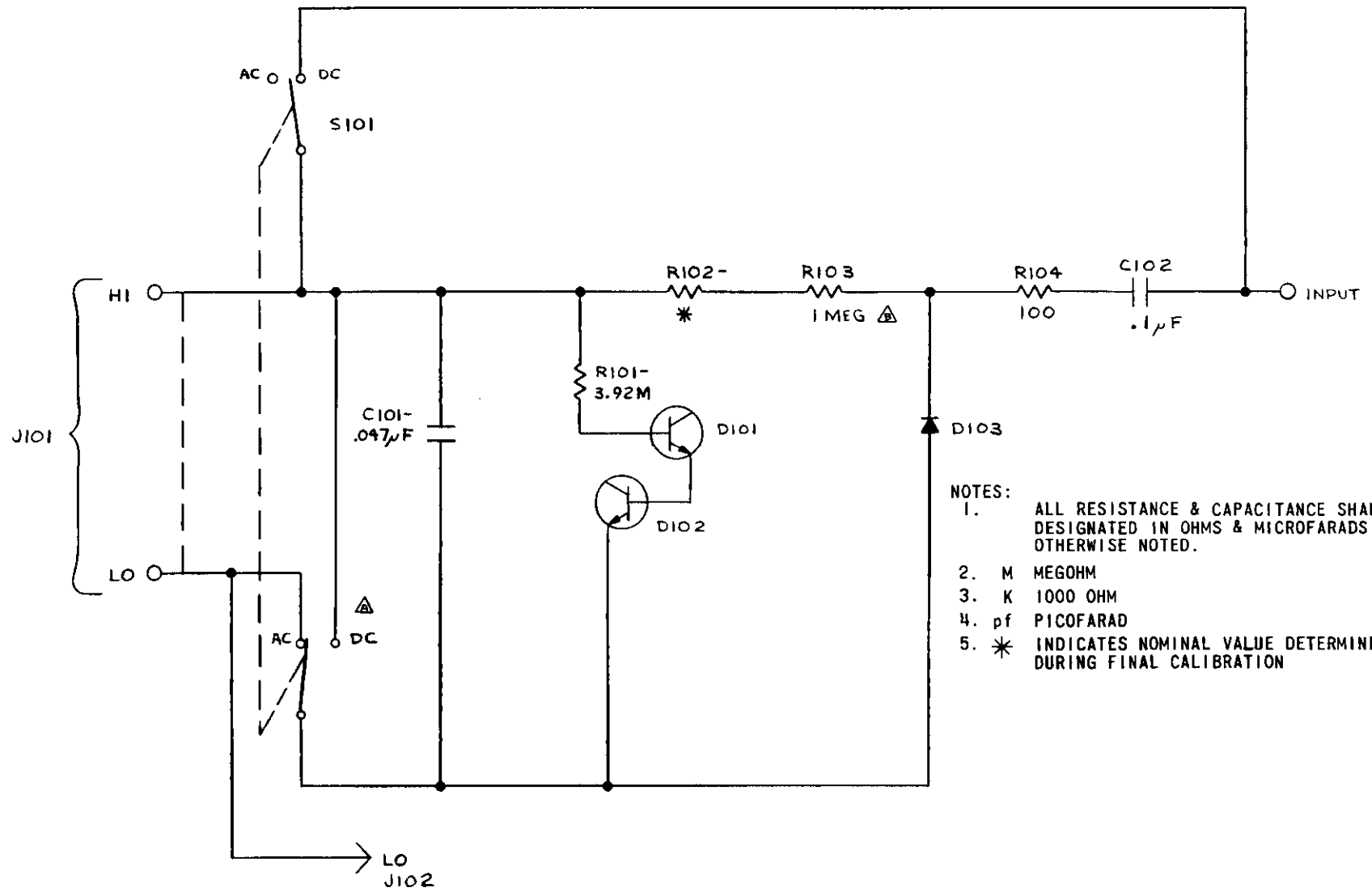
SCHEMATIC DESIGNATIONS

|  |  |  |  |  |
|--|--|--|--|--|
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|  |  |  |  |  |
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24685D

246690

| LTR | ECO NO  | REVISION                   | DATE    |
|-----|---------|----------------------------|---------|
| A   | 1001225 | ADDED POLE TO S101         | 5-20-70 |
| B   | 1001289 | CHG R103-453K TO R103-1MEG | 10-1-70 |



- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
  2. M MEGOHM
  3. K 1000 OHM
  4. pf PICOFARAD
  5. \* INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION

| REFERENCE DESIGNATIONS NOT USED |  |  |  |  |
|---------------------------------|--|--|--|--|
|                                 |  |  |  |  |
|                                 |  |  |  |  |
|                                 |  |  |  |  |

| HIGHEST REFERENCE DESIGNATION |      |      |      |      |
|-------------------------------|------|------|------|------|
| J102                          | S101 | C102 | R104 | D103 |
|                               |      |      |      |      |
|                               |      |      |      |      |

|   |   |  |                                       |
|---|---|--|---------------------------------------|
| <br><b>KEYSLEY</b><br>INSTRUMENTS<br>CLEVELAND OHIO | DIMENSIONS & TOLERANCES<br>UNLESS OTHERWISE SPECIFIED | DATE 5-11-70<br>DESIGNED BY RGJ<br>CHECKED BY <i>hca</i> | SCALE<br>TITLE SCHEMATIC, AC-DC PROBE |
|   | MATERIAL<br>FINISH                                    | MODEL 1601<br>NEXT ASSEMBLY QTY 1<br>USED ON             | 246690                                |



## KEITHLEY INSTRUMENTS, INC.

INSTRUCTION MANUAL  
CHANGE NOTICE  
MODEL 164 DIGITAL MULTIMETER

INTRODUCTION: Since Keithley Instruments is continually improving product performance and reliability, it is often necessary to make changes to Instruction Manuals to reflect these improvements. Also, errors in Instruction Manuals occasionally occur that require changes. Sometimes, due to printing lead time and shipping requirements, we can't get these changes immediately into printed Manuals. The following new change information is supplied as a supplement to this Manual in order to provide the user with the latest improvements and corrections in the shortest possible time. Many users will transfer this change information directly to a Manual to minimize user error. All changes or additions are indicated in *italics*.

CHANGES:PAGE 48

|       |           |       |               |       |    |
|-------|-----------|-------|---------------|-------|----|
| D1001 | Germanium | 15238 | <i>1N3592</i> | RF-39 | 5  |
| D1002 | Germanium | 15238 | <i>1N3592</i> | RF-39 | .. |
| D1003 | Germanium | 15238 | <i>1N3592</i> | RF-39 | .. |
| D1004 | Germanium | 15238 | <i>1N3592</i> | RF-39 | .. |
| D1005 | Germanium | 15238 | <i>1N3592</i> | RF-39 | .. |

PAGE 45

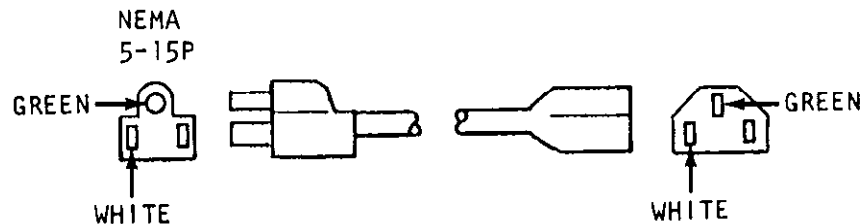
|       |                               |      |                 |                   |   |
|-------|-------------------------------|------|-----------------|-------------------|---|
| R1207 | 10k $\Omega$ , 0.1%, 1W       | DALE | <i>MFF-10K</i>  | <i>R-169-10K</i>  | 1 |
| R1208 | 100k $\Omega$ , 0.02%, 1W, WW | DALE | <i>MFF-100K</i> | <i>R-169-100K</i> | 1 |
| R1209 | 1M $\Omega$ , 0.1%, 1W        | DALE | <i>MFF-1M</i>   | <i>R-169-1M</i>   | 1 |



KEITHLEY INSTRUMENTS, INC.

CAUTION

To ensure the integrity of the chassis to earth ground connection only a Keithley part number C0-7 line cord should be used for replacement. If a different line cord is used ensure that the wiring polarity is the same as shown in the following diagram.



Keithley Models to which this warning applies: 160, 163, 164, 165, 171, 180, 190, 227, 616, 6162, 702, 780

KEITHLEY INSTRUMENTS, INC.  
28775 AURORA ROAD  
CLEVELAND, OHIO 44139  
**SERVICE FORM**

MODEL NO. \_\_\_\_\_ SERIAL NO. \_\_\_\_\_ P.O. NO. \_\_\_\_\_ DATE \_\_\_\_\_ R-  
NAME \_\_\_\_\_ PHONE \_\_\_\_\_  
COMPANY \_\_\_\_\_  
ADDRESS \_\_\_\_\_ CITY \_\_\_\_\_ STATE \_\_\_\_\_ ZIP \_\_\_\_\_

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. \_\_\_\_\_  
\_\_\_\_\_

4. Describe input signal source levels, frequencies, etc. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. List and describe all cables used in the experiment (length, shielding, etc.). \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6. List and describe all other equipment used in the experiment. Give control settings for each. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. Environment:  
Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) \_\_\_\_\_  
What power line voltage is used? \_\_\_\_\_ Variation? \_\_\_\_\_ Frequency? \_\_\_\_\_  
Ambient temperature? \_\_\_\_\_ °F. Variation? \_\_\_\_\_ °F. Rel. Humidity? \_\_\_\_\_  
Other \_\_\_\_\_

8. Additional Information. (If special modifications have been made by the user, please describe below.) \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_