

model

INSTRUCTION MANUAL
MODEL 630
POTENTIOMETRIC ELECTROMETER

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We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

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

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SECTION 1. GENERAL DESCRIPTION

1-1. DESCRIPTION

a. The Keithley Model 630 Potentiometric Electrometer is a convenient, self-contained potentiometer. It measures from 300 millivolts to 500 volts dc with 0.01% limit of error from source resistances as high as 10^{10} ohms, and below 300 millivolts within 30 microvolts. The unit need not be constantly calibrated or manually restandardized for a full year; the limit of error is specified for one year.

b. Using the guarded, vibrating-reed null detector, the Model 630 has a minimum (slewing) input resistance of 10^{13} ohms, on the 1-millivolt to 1-volt ranges, increasing to over 10^{15} ohms at 1% off null and to infinite resistance at null. With this extremely high input resistance, the Model 630 draws an absolute minimum of current to avoid loading and polarizing the source.

c. Features for convenient use include: 5 in-line readout dials with automatically lighted decimal points; one-volt, one-milliampere output for full-scale deflection on all ranges except the 1-millivolt; input polarity switch; floating operation up to 500 volts off chassis ground; better than 60 db line-frequency rejection on the 1-millivolt range. Also, full guarding minimizes leakage problems.

1-2. OPERATING MODES. The Model 630 can be used as a five-dial potentiometer or as a vibrating-reed electrometer. As a potentiometer, it can measure from 300 millivolts to 500 volts full scale with $\pm 0.01\%$ limit of error and from 1 millivolt full scale to 300 millivolts within 30 microvolts. As a vibrating-reed electrometer, the Model 630 can measure from 1 millivolt full scale to 500 volts within $\pm 3\%$ full scale.

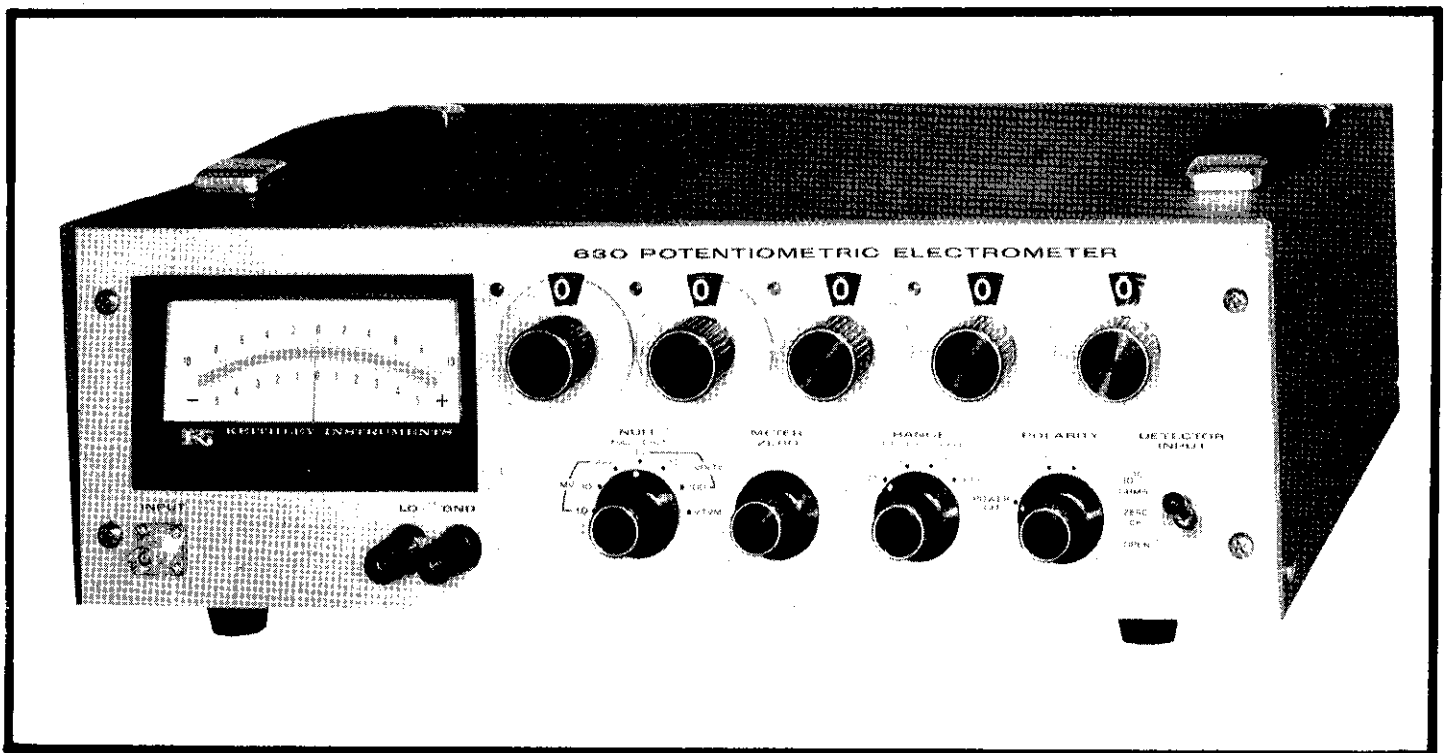


FIGURE 1. Keithley Instruments Model 630 Potentiometric Electrometer.

1-3. APPLICATIONS.

a. Due to its very high input resistance, the Model 630 is very useful in making accurate dc measurements from high resistance sources frequently encountered in electrochemical and physical-chemical research. It is especially useful for measuring potentials from piezo-electric crystals, electro-chemical cells, grids and plates of tubes, biological cells and pH electrodes. The Model 630 is also ideally suited for making Hall-effect and fuel-cell studies, silicon resistivity and capacitor charge measurements, and for measuring gate potentials of field effect transistors.

b. The null-detector output permits use with potentiometric recorders and digital voltmeters equipped with automatic print-out. The Model 630 is useful in quality control, product development, inspection and production.

1-4. SPECIFICATIONS.

AS A POTENTIOMETRIC ELECTROMETER:

LIMIT OF ERROR: $\pm 0.01\%$ of reading or 30 microvolts, whichever is greater, after 30-minute warm-up. Accuracy is exclusive of null-detector drift.

LONG-TERM STABILITY: Will operate within stated limit of error for one year.

TEMPERATURE COEFFICIENT: Does not exceed 0.001% per °C.

REPEATABILITY: Within 0.0025% or 30 microvolts, whichever is greater.

MAXIMUM NULL SENSITIVITY: 1 millivolt full scale with 30-microvolt resolution.

INPUT RESISTANCE: Infinite at null, from 0 to 500 volts. 10^{15} ohms at 1% off null from 0 to 500 volts with DETECTOR INPUT Switch in OPEN position.

FLOATING OPERATION: 500 volts maximum off chassis ground.

INPUT ISOLATION: Circuit ground to chassis ground: 10^8 ohms shunted by 0.05 microfarad.

AS A VIBRATING REED ELECTROMETER:

VOLTAGE RANGES: 0.5 volt full scale to 500 volts in four decade ranges.

NULL RANGES: 1 millivolt full scale to 100 volts in six decade ranges.

INPUT RESISTANCE: 10^{13} ohms or 10^{10} ohms selectable by switch, 1-millivolt to 1-volt ranges; 10^{10} ohms, 5 to 500-volt ranges.

ELECTROMETER ACCURACY: $\pm 3\%$ of full scale on all ranges, exclusive of noise and drift.

ZERO DRIFT: Less than 2 millivolts per 24 hours after 2-hour warm-up. Long term drift is non-cumulative.

RISE TIME (10% to 90%): Less than 2.5 seconds on any range with 10^{10} ohm source resistance.

LINE-FREQUENCY REJECTION: Greater than 60 db on the 1-millivolt range, decreasing to 35 db on the 500-volt range.

GENERAL CHARACTERISTICS:

LINE STABILITY: Better than 5 ppm for 10% change in line voltage.

RECORDER OUTPUT:

Output: 1 volt, 1 milliamperes for full-scale meter deflection on all ranges except on 1-millivolt range, where it is 10% less.

Noise: 30 microvolts peak-to-peak referred to input up to 1 cps.

Note: Recorder used must have fully isolated input, 10^{10} ohms minimum to ground.

POLARITY: Positive or negative, selectable by switch.

CONNECTORS: Input: Special Triaxial. Output: Banana jacks.

POWER: 105-125 or 210-250 volts (switch selected); 50, 60 or 400 cps; 50 watts.

DIMENSIONS, WEIGHT: 5-1/2 inches high x 17-1/2 inches wide x 13-1/2 inches deep; net weight, 24 pounds.

ACCESSORIES SUPPLIED: Model 6302 Input Cable consisting of a mating plug and 3-foot triaxial cable.

1-5. ACCESSORIES.

a. Model 6301 Guarded Probe with 3-foot connecting cable allows measurements to be made more conveniently. Using the Probe does not affect any Model 630 specification.

b. Model 4000 Rack Mounting Kit, containing two brackets and a top cover, converts the Model 630 to fit standard 19-inch racks. Rack mounted, the Model 630 is 5-1/4 inches high x 19 inches wide x 13-1/2 inches deep. Section 6 has assembly instructions.

c. Model 6013 pH Electrode Adapter, which has a 2-foot cable and triaxial connector, accepts Leeds & Northrop and Beckman pH electrode connectors. The Adapter allows accurate and convenient pH potential measurements with the Model 630.

1-6. EQUIPMENT SHIPPED. The Model 630 Potentiometric Electrometer is factory-calibrated and is shipped with all components in place. All units are shipped for bench use. Model 4000 Kit may be ordered for rack mounting; refer to Section 6 for assembly instructions. The shipping carton also contains the Instruction Manual and the Model 6302 Mating Connector with 3-foot triaxial cable.

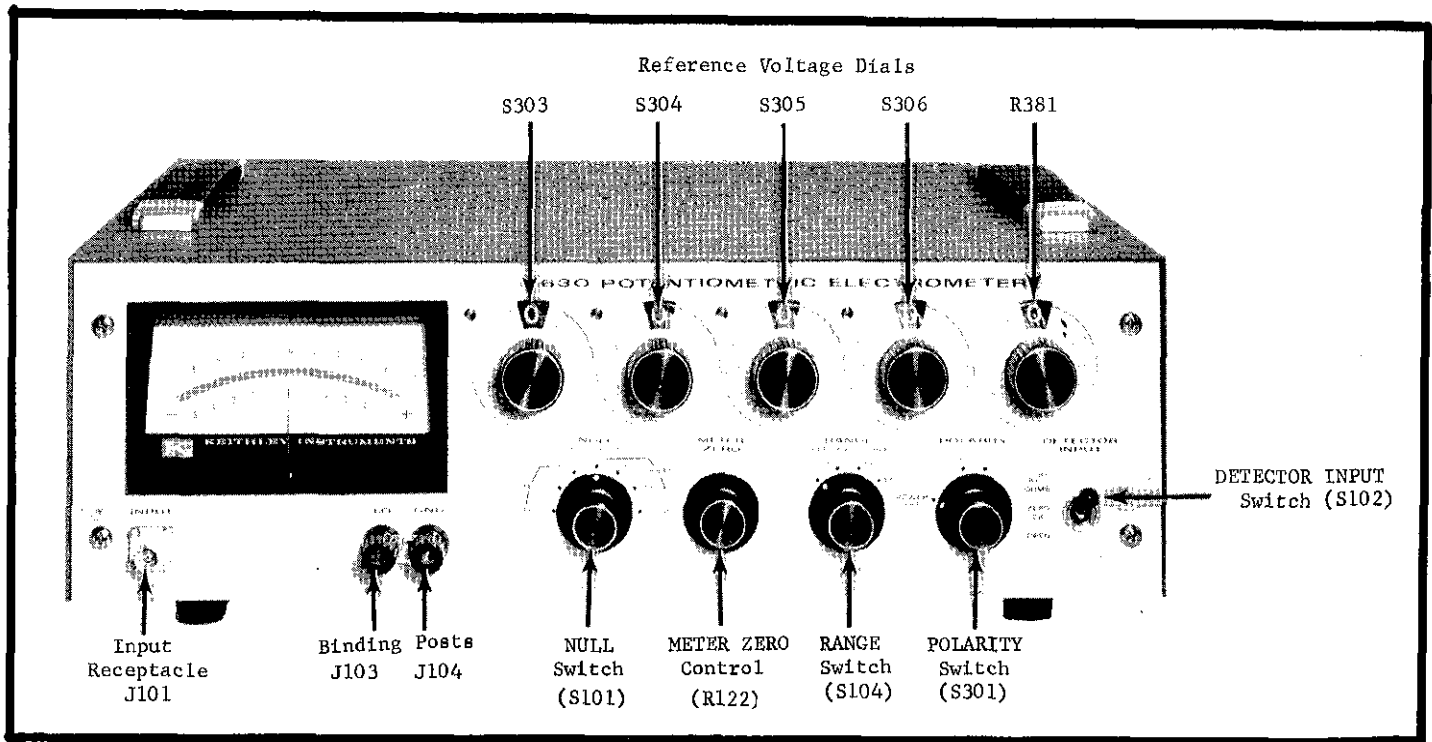


FIGURE 2. Model 630 Front Panel Controls and Terminals. The designations refer to the Replaceable Parts List and schematic diagram.

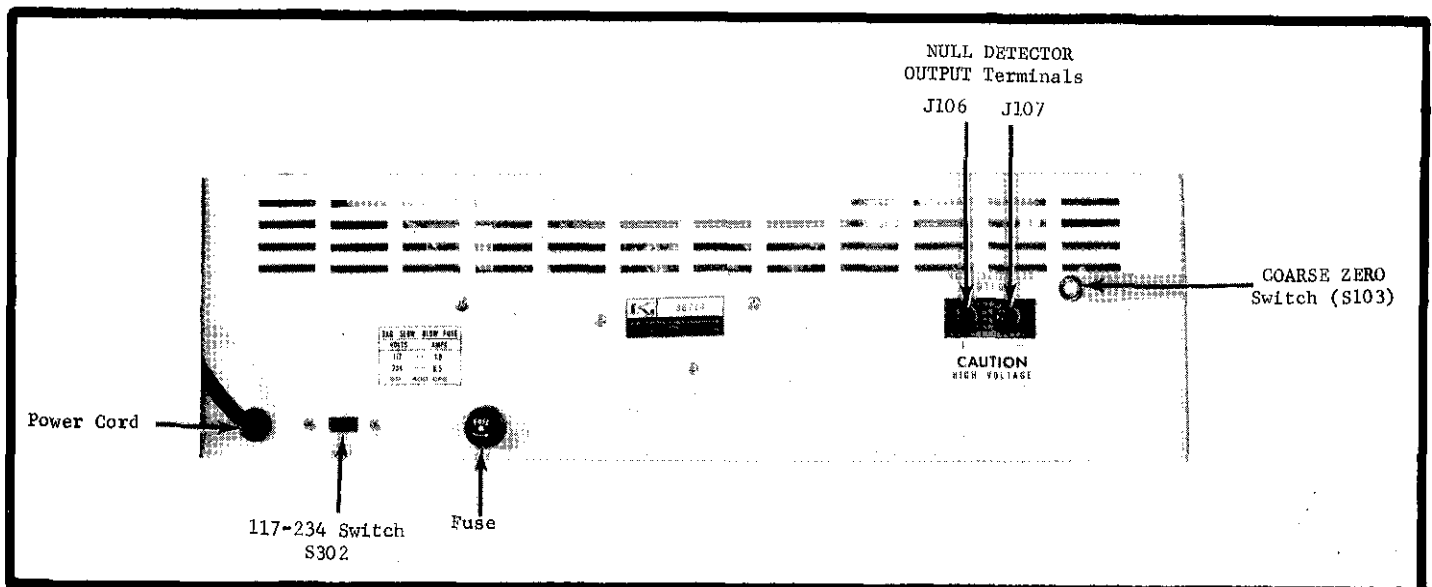


FIGURE 3. Model 630 Rear Panel Controls and Terminals.

SECTION 2. OPERATION

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

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

b. DETECTOR INPUT Switch. A 3-position toggle switch allows selection of the Model 630 input resistance and also allows checking the meter zero.

1) Setting the Switch to 10^{10} OHMS sets the input resistance at 10^{10} ohms for all ranges.

2) Setting the Switch to OPEN sets the input resistance at 10^{13} ohms for the 1-millivolt through 1-volt ranges. The input resistance remains at 10^{10} ohms for the ranges above 1 volt.

3) Setting the Switch to ZERO CK internally disconnects the input from the vibrating capacitor and shunts the capacitor to the amplifier low. This allows meter zeroing on any range without removing the input signal.

c. NULL Switch. The NULL Switch sets the null detector sensitivity for six decade ranges from 1.0 millivolt full scale to 100 volts. When the Switch is in the VTVM position, the Model 630 operates as a vibrating-reed electrometer for the four ranges of the RANGE Switch.

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

e. Reference Voltage Dials. Five in-line dials at the top of the front panel set the reference voltage when the Model 630 is used as a potentiometer. The first four switches have decade steps as indicated on the dial. The last dial is continuously adjustable.

f. METER ZERO Control. The METER ZERO Control adjusts the meter needle to zero. The Control allows precise meter zeroing on all ranges when the DETECTOR INPUT Switch is set to ZERO CK. The Control has a range of approximately ± 20 millivolts.

g. Input Terminals. The Model 630 uses a special triaxial receptacle for its INPUT Receptacle. The Receptacle is similar to a bnc connector, but requires using the furnished Model 6302 Input Cable. Using a standard bnc connector could damage the INPUT Receptacle. A set of binding posts marked LO and GND is provided for grounding the LO input terminal to the chassis when desired. The LO terminal and the shell of the triaxial INPUT Receptacle are internally connected.

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

a. Fuse. For 105-125 volt operation, the Model 630 uses a 1-ampere 3 AG fuse. For 210-250 volt operation, the Model 630 uses a 0.5-ampere 3 AG fuse.

b. Power Cord. The Model 630 is designed for a 105-125 volt, 60-cps line source, unless otherwise specified on the rear panel. The 3-wire power cord with the NEMA approved 3-prong plug provides a ground connection for the cabinet. A 3:2 prong adapter is provided.

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

d. COARSE ZERO Switch. A screwdriver adjustment is provided for bucking out the contact potential of the vibrating-reed capacitor. The Switch has a ± 100 millivolt span in ten 20-millivolt steps.

e. 117-234 Switch. The screwdriver-operated slide switch sets the Model 630 for 117 or 234-volt ac power lines.

2-3. PRELIMINARY PROCEDURES.

a. Check the 117-234 Switch and the Fuse for the proper ac line voltage. Connect the power cord.

b. Set the Model 630 front panel controls as follows:

DETECTOR INPUT Switch	ZERO CK
RANGE Switch	500
NULL Switch	VTVM
POLARITY Switch	+
Reference Voltage Dials	Zero

The decimal light between the third and fourth Dials will light. Allow the instrument to warm up 30 minutes to meet the specified accuracy on all ranges.

c. Set the NULL Switch to 1.0 MV. Zero the meter with the METER ZERO Control. Normally, using the COARSE ZERO Control on the rear panel is not necessary. Return the NULL Switch to VTVM.

NOTE

Check meter zero periodically. Null detector drift can be up to 2 millivolts per day, which will cause inaccuracies in continuous readings. Setting the DETECTOR INPUT Switch to ZERO CK disconnects the input signal source from the instrument, avoiding polarization. It is not necessary to disconnect the input.

2-4. OPERATING PROCEDURES.

a. The Model 630 is used first as a voltmeter to determine the approximate value of the unknown voltage. It is then used in the potentiometric mode to determine the voltage to $\pm 0.01\%$.

NOTE

Vibrating capacitors are extremely sensitive to shock and vibration. When making a measurement, place the Model 630 on a vibration free, rigid structure or on some material which will minimize vibration. Also, tightly tie down the input cable and any attached circuitry; any cable flexure will generate electrostatic charges which the Model 630 will detect.

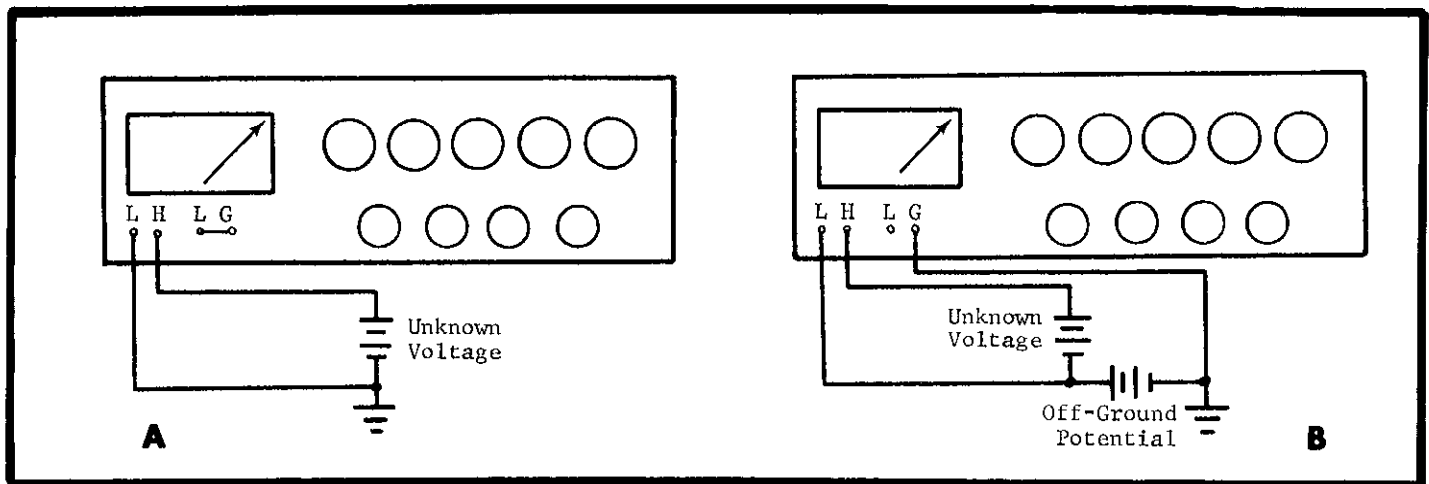


FIGURE 4. Input Connections to Model 630. The two diagrams show the input circuit for measuring at ground and for floating.

In A, the unknown voltage has one terminal at ground. The shorting link is between the LO and GND Posts of the Model 630.

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

b. The Model 630's high input resistance allows circuit measurements without causing circuit loading. (See paragraph 2-6.) On the 1-millivolt to 1-volt null ranges, the input resistance can be set to 10^{13} or 10^{10} ohms with the DETECTOR INPUT Switch. Use the OPEN (10^{13} ohm input) setting for high source resistances; use the 10^{10} OHMS setting to avoid pickup problems or to increase response speed. On ranges above 1 volt, the input resistance is 10^{10} ohms for either setting.

NOTE

When making measurements on devices with high contact resistances (such as silicon), completely isolate the power supply from ground to avoid measuring the drop across the contact resistance.

c. Voltmeter Operating Procedures.

1. Ten full-scale ranges are available for VTVM operation. When the NULL Switch is at VTVM, the RANGE Switch determines one of four full-scale ranges. By putting the five Reference Voltage Dials at zero, the Model 630 can then operate as a voltmeter on the six null ranges.

2. Connect the unknown voltage to the INPUT Receptacle, using the Model 6302 Input Cable or the Model 6301 Guarded Probe. When using the guarded probe, use a separate lead to the LO Terminal.

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

d. Potentiometric Operating Procedures.

NOTE

Avoid large overload voltages on the null detector. No damage occurs even with 500-volt overloads, but some open circuit offset will be caused in the null detector. The offset will disappear after about 5 minutes.

1. Leave the RANGE Switch at the last setting used in the voltmeter operation. If the voltmeter reading is negative, reverse the POLARITY Switch position.
2. Set the first two Reference Voltage Dials to the first two digits of the unknown voltage found in the voltmeter operation.

NOTE

When switching between the 50-volt and 500-volt ranges and when changing the POLARITY Switch, the meter will sometimes temporarily read off-scale. This is due to transients introduced when the circuit is interrupted and it does not indicate a faulty instrument.

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

RANGE Switch Setting	Initial NULL Switch Setting	Most Sensitive NULL Switch Setting
500 V	100 V	10 MV
50 V	10 V	1.0 MV
5 V	1.0 V	1.0 MV
0.5 V	100 MV	1.0 MV

TABLE 1. Recommended Model 630 Null Sensitivities and Settings.

NOTE

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

4. The value of the unknown voltage is read directly from the Reference Voltage Dials.
 - a) The dial reading will be within the specified limit of error if the NULL Switch is at the most sensitive setting (Table 1) for the range used and if the meter indicates as close to null as possible.
 - b) When the first Reference Voltage Dial is used, only the five Dials need to be read to be within specifications ($\pm 0.01\%$ of reading or 30 microvolts). However, the meter may be read as an approximation of a sixth digit.
 - c) When the first Reference Voltage Dial is not used, read the voltage directly from the remaining four dials.
 - d) Use the meter as a null indicator when balancing voltages. When the first Reference Voltage Dial is not used, the meter approximates a fifth dial reading.

2-5. RECORDER OUTPUT.

a. Recommended recorder for use with the Model 630 is the Keithley Model 370. Any recorder used must be able to float 500 volts off ground and its input must be fully isolated (10^{10} ohm minimum leakage resistance to ground). The Model 370 meets these requirements.

b. Before attaching the recorder, set all Reference Voltage Dials to zero. Disconnect the unknown voltage and short the Model 630 high input to the low. Set the NULL Switch to 10 MV. Connect the recorder to the OUTPUT Terminals on the Model 630 rear panel. The 370 Recorder mates directly with the Model 630 using the 3701 Cable.

c. Set the Reference Voltage Dials to 10 millivolts to apply an accurate 10-millivolt potential to the null detector on the 10-millivolt null range. This will provide a full-scale recorder output of 1 volt at 1 milliamperes. On the 1-millivolt null range, the recorder may load the Model 630 output. On this range, output resistance is 100 ohms.

d. To obtain accurate results and/or to prevent damage to the instruments, the recorder must be able to float off-ground with the Model 630. Leakage and pickup between the two instruments should also be minimized. The Model 370 meets these requirements.

NOTE

On the 1-millivolt range there is a 10% loading error if the recorder draws 1 ma of current. Thus the output for full scale deflection will be .90 volt, 1 ma.

1. Make sure neither recorder terminal is grounded. Use a 3-wire grounded power line for the recorder. If a 2-wire line is used, connect the recorder chassis and the Model 630 chassis with a separate lead.

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

3. Avoid long leads between the Model 630 and the recorder.

NOTE

Do not short either Model 630 output terminal to the case; this may damage the Kelvin-Varley divider.

2-6. EFFECTIVE INPUT RESISTANCE.

a. The Model 630 input resistance varies. It can be set either 10^{13} or 10^{10} ohms for the 1-volt and lower ranges, and it is 10^{10} ohms for ranges above 1 volt. These, however, are not the Model 630's effective input resistances. Its input resistance is considerably higher due to the potentiometric principle of operation. When reference voltage (Reference Voltage Dial setting) is much greater than meter readings the value is

$$R_{in} = R_n \left(\frac{E_d}{V} \right) \quad \text{Equation 1}$$

Where R_{in} is the effective input resistance of the Model 630;
 E_d is the setting of the Reference Voltage Dials in volts;
 R_n is the input resistance of the null detector in ohms;
 V is the null detector meter reading in volts.

b. To find the loading effect the Model 630 will have on a circuit, use Equation 1 to compute its effective input resistance. At null, where $V = 0$, the input resistance is infinite. Off null, the Model 630 input resistance is usually much greater than the source resistance, and loading will not be enough to affect the measurement accuracy. The graph in Figure 6 shows the Model 630 effective input resistance for the 1-millivolt to 1-volt null ranges with the DETECTOR INPUT Switch set to OPEN. Note that the input resistance for a reading 1.0% off null is 10^{15} ohms.

NOTE

For a fuller treatment of paragraphs 2-6 and 2-7, send for Keithley Instruments Product Note, "The Effective Input Resistance of Potentiometric Voltmeters."

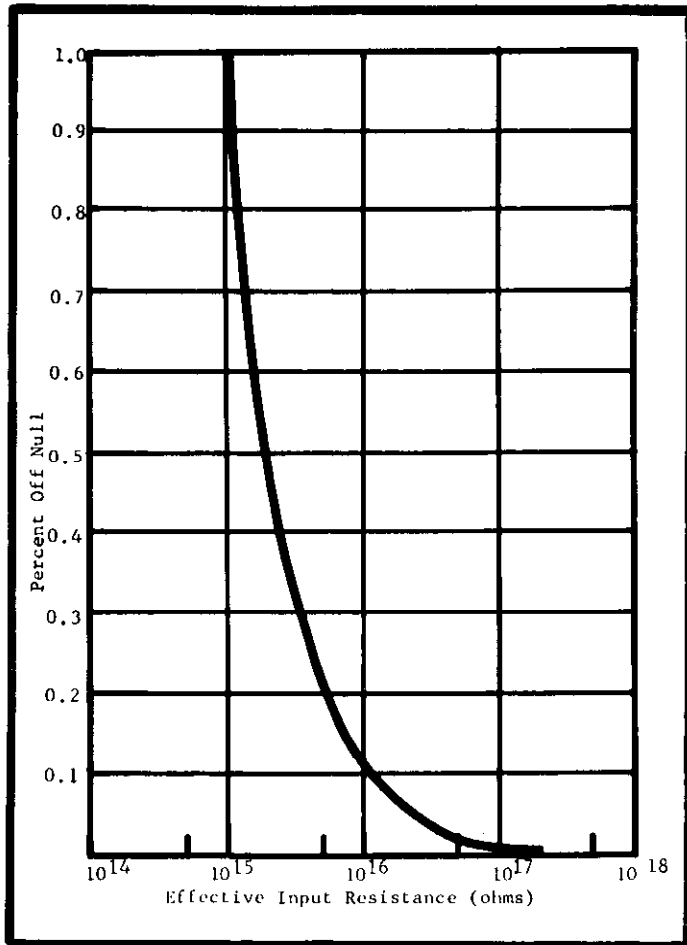


FIGURE 6. Model 630 Effective Input Resistance. The graph shows the effective input resistance for the 1-millivolt to 1-volt ranges when the DETECTOR INPUT Switch is set to OPEN. Percent off null is $100 V/E_d$ as defined in Equation 1.

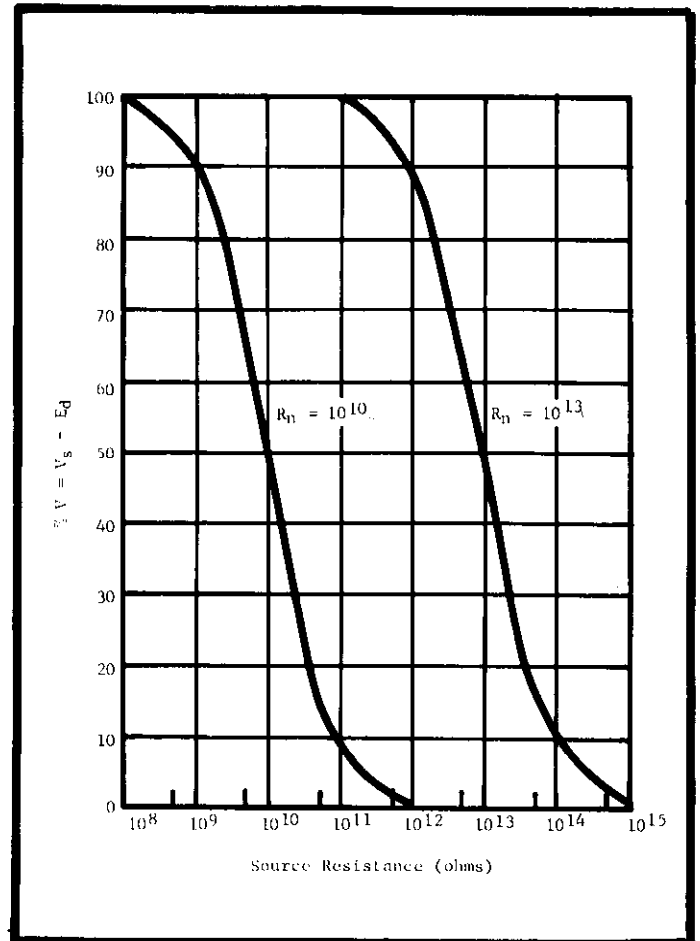


FIGURE 7. Effect of Source Resistance on Model 630 Null Sensitivity. The graphs are for the two null detector input resistance settings. Ideally, $V = V_s - E_d$ as defined in equation 2. The graphs indicate the percent of the actual difference between the source and reference voltages the meter will indicate.

2-7. NULL SENSITIVITY AND SOURCE RESISTANCE.

a. Source resistance affects null sensitivity. Because of its high input resistance, the Model 630 is less affected. The following paragraphs show the value of using a potentiometric electrometer for accurate measurements from a high resistance source.

b. The equation below gives the relationship of the meter reading to source resistance:

$$V = \left(\frac{V_s - E_d}{R_s + R_n} \right) R_n \quad \text{Equation 2}$$

where V_s is the source voltage in volts;

R_s is the source resistance in ohms;

V is the null detector meter reading in volts;

E_d is the setting of the Reference Voltage Dials in volts;

R_n is the input resistance of the null detector in ohms

With no source resistance, the null detector meter will read exactly the difference between the reference voltage and the source voltage ($V = V_s - E_d$). For increasing source resistance, the meter will indicate only a portion of the difference between the two voltages. This discrepancy becomes more important the more off null a reading is.

c. Figure 7 contains graphs showing the effect source resistance has on off-null readings for the Model 630. The curves are the percent the meter reads the voltage difference. At 100%, $V = V_s - E_d$. Note that as the Model 630 approaches null, the meter indication as an absolute value becomes insignificant regardless of source resistance. For instance, if the Model 630 is 0.1 millivolt off null on the 1-millivolt range and the source resistance is such that the meter indicates only 10% of actual value, the meter will be within .09 millivolt. At .01 millivolt off null, the meter will be within 9 microvolts.

NOTE

When the Model 630 is as near to null as possible, the Reference Voltage Dial setting is always correct within the instrument's specified limit of error.

2-8. AC EFFECTS ON MEASUREMENTS. The Model 630 has greater than 60 db line frequency rejection on its 1-millivolt range. Greater line frequency pickup may reduce off-null sensitivity and cause needle quiver or a zero shift. To reduce this, use an R-C filter at the input. The component values depend on the source resistance. A good compromise might be a 10^9 resistor and a 100-picofarad capacitor. With a 10^{10} ohm source, this adds only about two seconds to the rise time.

NOTE

Use a larger R or C if rise time is not important. Always use a polystyrene capacitor or one with as good an insulation resistance to avoid degenerating the input resistance.

2-9. CURRENT MEASUREMENTS.

a. When used with a high-value precision resistor, the Model 630 Potentiometric Electrometer can be used to accurately measure currents as low as 10^{-13} amperes. The choice

of the shunt resistor depends upon the current to be measured and the setting of the Model 630 (Refer to Table 2).

b. Current measuring procedure:

1. Shunt the Model 630 input with a selected resistor R. (See Table 2 for resistor values).

2. Set the Reference Voltage Dial Setting to zero and the DETECTOR INPUT Switch to OPEN.

3. Switch the Model 630 sensitivity to the lowest setting to obtain an on-scale reading.

4. The Meter reading is the voltage drop V across the shunt resistor R.

5. Use the Model 630 as a potentiometer and bring the meter to a null with the Reference Voltage Dials. Record the Reference Voltage Dial reading E_d .

6. Calculate the current I_a using the equation,

$$I_a = \frac{1}{R} \left(\frac{E_d V}{E_d - V} \right)$$

where I_a is the current to be measured in amperes;

R is the shunt resistance in ohms;

V is the meter reading (from step 4 above) in volts;

E_d is the setting of the Reference Voltage Dials in volts.

NOTE

It is recommended that shunt resistors no larger than 10^{11} ohms be used. With a larger resistor the response is extremely slow. An offset which is large enough to affect accuracy may not show up immediately due to the slow response.

c. The accuracy of the measurement is $\pm 3\%$ plus the accuracy of the shunt resistor, if the above procedure is followed. However, when using a 10^{11} shunt resistor the accuracy of measurement may be $\pm 4\%$ plus the accuracy of the shunt resistor. It is necessary to calculate the current to compensate for the loading effect of the shunt resistor.

Current Range in amperes	Shunt Resistor in ohms	NULL Setting in millivolts
10^{-13}	10^{10}	1
10^{-13}	10^{11}	10
10^{-12}	10^9	1
10^{-12}	10^{10}	10
10^{-12}	10^{11}	100
10^{-11}	10^8	1
10^{-11}	10^9	10
10^{-11}	10^{10}	100
10^{-11}	10^{11}	1000

TABLE 2. Recommended Shunt Resistors for Use in Current Measurements.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Model 630 Potentiometric Electrometer measures voltage by the potentiometric (null) method. The variable known voltage is an ultra-stable 500-volt reference supply used in conjunction with a precision 5-dial Kelvin-Varley divider. Electronic referencing of the 500-volt output to a zener diode standard maintains the reference supply's stability and accuracy. This method eliminates repeated manual standardization. The difference between the divider output and the unknown voltage is indicated by the null detector, a vibrating-reed electrometer. At null the unknown voltage can be read directly from the in-line dials of the Kelvin-Varley divider. The input and null detector are fully guarded to avoid leakage.

NOTE

Refer to Schematic Diagram 18261E for circuit designations.

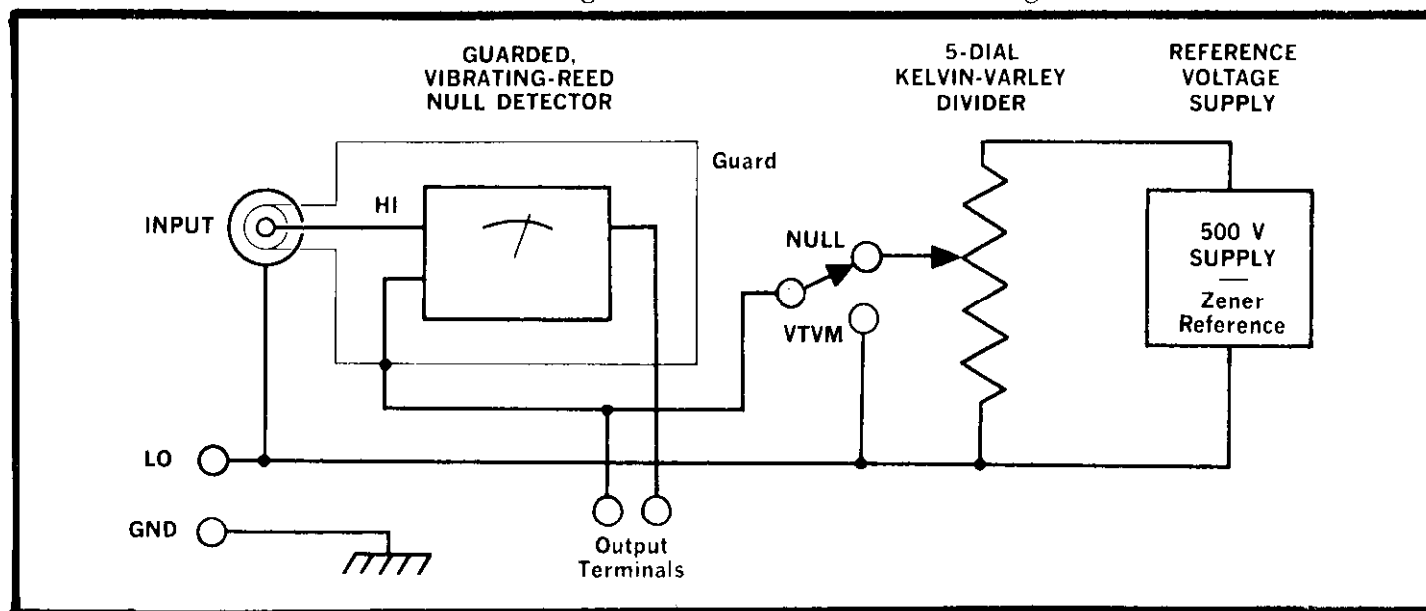


FIGURE 8. Simplified Model 630 Circuit Diagram.

3-2. REFERENCE VOLTAGE SUPPLY.

a. Unregulated voltage from transformer T201 is rectified by a silicon half-wave rectifier, D301, and is filtered by capacitors C302 and C303A. The voltage then is applied to the regulator series pass tube, V3004. Regulator tube V3005 is used to keep the screen of V3004 at a constant potential.

b. To obtain a stable, accurate voltage, the 500-volt output of V3004 is sampled by a divider network of wirewound resistors, R325 to R330. The divider network ratio is adjusted with potentiometer R327 to better than 0.01%. Light modulator E302 compares the sample voltage from the divider network to the voltage across zener diode, D302. Any difference between the two voltages is chopped by E302 and amplified by a 2-stage ac-coupled amplifier, V3001. The amplified output of V3001 is converted to a dc signal by light modulator E301 and then is amplified by the two-stage differential dc amplifier, V3002 and V3003. The amplifier output is applied to the grid of the series tube, V3004, to

nullify input variations. Capacitor C305 is used in the ac feedback circuit.

c. The temperature-compensated zener diode, D302, is used as the basic reference since typical variations are limited to less than 20 ppm per year and 5 ppm per °C. Thus, a highly stable reference which eliminates manual standardization is provided with respect to both time and temperature. The zener diode will also withstand shock and vibration.

d. The regulated 500-volt output of V3004 is either applied directly to the Kelvin-Varley divider or it is divided to 50, 5 or 0.5 volts by very stable wirewound resistor networks. The RANGE Switch, S104, determines which network is used. The 50-volt range divider consists of resistors R333, R334, and R335; the 5-volt, or R333, R337 and R338; and the 0.5-volt of R333, R339 and R340. Using potentiometers R334, R337 and R339 accurately sets the voltage division on each range.

3-3. KELVIN-VARLEY DIVIDER.

a. The Kelvin-Varley divider precisely divides the reference voltage for nulling an unknown voltage. It is, in effect, a constant input impedance decade potentiometer, consisting of resistors R341 through R381. The resistors within each decade are matched; the decades are matched for each instrument.

b. Each decade of the Kelvin-Varley divider, except the first, R341 through R346, parallels two resistors of the preceding string. Between the two contacts of the first Reference Voltage Switch, S303, the total resistance is 40 kilohms (80 kilohms in parallel with the 80 kilohms total resistance of the four remaining strings). With the RANGE Switch set at 500, 100 volts dc will appear across the contacts of Reference Voltage Switch S304, 10 volts across S305, 1 volt across S306, and 0.1 volt across R381.

3-4. NULL DETECTOR.

a. The Model 630 uses a null detector which has a vibrating capacitor at the input. The input signal is attenuated, if necessary, and filtered. This signal is modulated by a specially constructed capacitor, VC101, having one stationary plate and one moveable plate. The signal is then amplified and applied to the meter.

b. Input resistance is greater than 10^{13} ohms when the DETECTOR INPUT Switch is set to OPEN for the 1-millivolt through 1-volt ranges. For null ranges greater than 1 volt, the input signal is attenuated by resistors R101 through R104. Therefore, above 1 volt, the input resistance is a constant 10^{10} ohms. To maintain high resistance, switching with the DETECTOR INPUT Switch (S102) is done using reed relays, K101 to K103.

c. The null detector has full-scale sensitivity from 1 millivolt to 1 volt. Above 1 volt, resistors R101 through R104 divide the input by a 500:1 ratio. The full-scale sensitivity is determined by which of six feedback resistors, R147 through R152, is in the circuit. An R-C filter — R107 and capacitor C101 — decreases the ac input components. A twin-T filter, tuned for 94 cps, is connected between the plate and grid of tube V1002. The filter, consisting of R130, R132, R133, C110, C111 and C112, provides negative feedback for frequencies other than 94 cps. The vibrating capacitor, VC101, is driven at 94 cps to further minimize ac pick-up effects.

d. The vibrating capacitor VC101 converts the difference between the input signal and the Kelvin-Varley divider output into an ac voltage, which is amplified by tubes V1001, V1002, and half of V1003. The amplified voltage is demodulated by a bridge, diodes D106 through D109, and filtered by resistor R144 and capacitor C121. The dc voltage is fed

through a cathode follower, half of tube V1003, and drives the meter.

1. VC101 has a moveable plate driven by an electromagnet which varies the distance between the two plates. Since the capacitance varies in inverse proportion to the distance between the plates, a time varying capacitance is produced.

2. If a charge is placed on the capacitor its value is

$$Q = CE$$

Equation 3

where Q is the charge;

C is the capacitance;

E is the voltage across the capacitor.

In terms of the voltage, the equation becomes $E = Q/C$. If Q is constant and C varies periodically, E must also vary. Therefore, an ac voltage which is proportional to the magnitude of the input voltage will be produced.

e. Resistors R147 through R152 form the feedback network, which divides the output voltage for all voltmeter and null ranges except the 500-volt and 1-volt ranges. Total output is fed back for these two ranges. The feedback voltage is returned to the low end of the vibrating capacitor to provide stability.

f. The Model 630 uses a "driven guard" at its input: the feedback voltage is also applied to the second conductor of the input cable. The potential between the input high and low is the difference between the applied and feedback voltages. Therefore, the cable capacitance charges only to the difference between the two voltages. This reduces the effect of cable capacitance, providing faster response speed.

g. The zero-control network consists of a 1.35-volt mercury battery, B101, and resistors R109 through R123. The rear panel COARSE ZERO Switch, S103, has a span of ± 100 millivolts in 20-millivolt steps. The front panel METER ZERO potentiometer, R112, has a ± 20 millivolt span.

h. The recorder output is developed across the top end of meter M101. It is one volt for a full-scale meter deflection for all ranges above 1 millivolt. However, using a recorder with a 1-milliamper movement reduces the output to 0.9 volt on the 1-millivolt range since the output impedance is 100 ohms on this range.

3-5. OSCILLATOR.

a. The oscillator drives the vibrating capacitor and bridge demodulator and supplies the filament voltage for tubes V1001 and V1002.

b. The output of transistor Q203, connected as a regulator, is divided and compared to zener diode D207. Any voltage difference is amplified by transistors Q205 and Q206, operating as a differential voltage amplifier. The signal is further amplified by transistors Q204, Q202, and Q201 and applied to the regulator, Q203.

c. A dc-to-ac converter forms the voltage to drive the vibrating capacitor, VC101, and the bridge demodulator, diodes D106 through D109. Transistors Q207 and Q208 form a switching network to supply an interrupted dc voltage to transformer T202. An extra winding from the transformer supplies feedback to the network to sustain switching action. Resistor R213 determines the feedback magnitude.

3-6. GUARDING. Guarding is accomplished by floating the null detector and the input circuitry at a voltage equal to the input voltage from a low impedance source. This full guarding eliminates leakage between the input terminal and ground. Such leakage in an unguarded circuit is difficult to avoid, under laboratory conditions, and can result in sizeable errors. For example, in an unguarded circuit with a 1-megohm source, leakage of 10^8 ohms will introduce 1% error. A guarded circuit eliminates this element of error.

SECTION 4. SERVICING

4-1. GENERAL. Section 4 contains the maintenance and troubleshooting procedures for the Model 630. Follow these procedures as closely as possible to maintain the accuracy and stability of the instrument.

4-2. SERVICING SCHEDULE. The Model 630 needs no periodic maintenance beyond the normal care required of high-quality electronic equipment. No part should need replacement under ordinary use except a pilot lamp, fuse or, occasionally, a vacuum tube.

4-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 7 describes the electrical components in the Model 630. Replace components only as necessary, and use only reliable replacements which meet the specifications.

b. Replace resistors within any one of the first three Kelvin-Varley divider decades only as an assembly. Refer to the Replaceable Parts List for the part number for resistors R341 to R368. Resistors R325, R326 and R328, resistors R333, R335, R338 and R340 and resistors R329 and R330 are also parts of assemblies. Reorder using the Keithley part number (see Section 7) and replace all resistors in the assembly. Because of its importance in maintaining power supply stability, order zener diode D302 only from Keithley Instruments, Inc., or its representative. Refer to paragraph 4-6 for instructions to replace the zener. If replacing the vibrating capacitor, VC101, order only from Keithley Instruments, Inc., or its representative.

4-4. TROUBLESHOOTING.

a. The following procedures are for repairing troubles which might occur in the Model 630. Use these procedures to troubleshoot and use only specified replacement parts. Table 3 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact Keithley Instruments, Inc. or its representative.

Instrument	Use
Keithley Model 153 dc Microvolt-Ammeter, 3% accuracy, minimum 200 megohm input resistance, 1 volt to 500 volts.	Circuit checking
Keithley Model 610B Electrometer	Check grid bias at cathode follower
Keithley Model 502A Ohmmeter	Check resistance
Hewlett-Packard 200CD Oscillator	Check frequency
Tektronix Type 503 Oscilloscope	Check wave forms
Grid-modulated tube tester	Test vacuum tubes

TABLE 3. Equipment Recommended for Model 630 Troubleshooting. Use these instruments or their equivalents.

Difficulty	Probable Cause	Solution
Meter rattle, drift, or error is observed on all null ranges	Tube V1001, V1002 or V1003 is faulty	Check tubes; replace if faulty
	-6v power supply is drifting or oscillator circuit is faulty	Check power supply stability, PC104, and oscillator frequency (paragraph 5-7). If faulty component cannot be located, return instrument to factory.
Excessive drift on most sensitive range	Faulty VC101	Replace VC101
	Battery B101 is faulty	Replace B101
Line voltage variations cause measurements to be out of specifications	Tube V3005 is defective	Check tube; replace if faulty
Reference voltage supply drifts after 30-minute warm-up, requiring frequent adjusting of the range controls, R327, R334, R337 and R339	V3001, V3002, V3003 or V3004 is defective	Check tubes; replace if faulty
	One of the divider resistors, R325 to R330, is changing value rapidly during warm-up	Return the instrument for factory check-out
	Zener diode, D302, is unstable	Return the instrument for factory check-out
	Light modulator, E302, is defective	Check light modulator by replacing.
Measurements out of tolerance on all ranges	Out of calibration	Refer to paragraph 5-5 for recalibration
	One of the divider resistors, R325 to R330, is faulty	Return the instrument for factory check-out
Measurements are out of specifications on one range other than 500-volt range	Resistor in the range divider network is faulty	Paragraph 3-2 d points out the resistors used for each range. Try to bring the ranges within specifications by calibrating with the potentiometers in the network. See paragraph 5-5. If this does not work, check individual resistors.

TABLE 4. (Sheet 1). Model 630 Troubleshooting

Difficulty	Probable cause	Solution
Measurements are out of specifications on all ranges other than 500-volt range	Resistor R333 is faulty	Replace the faulty resistor
Excessive ac interference	R131 out of adjustment	Adjust per paragraph 4-8
Non-symmetrical response on polarity switching and low sensitivity on most sensitive ranges	Oscillator frequency has drifted	Check frequency. Reset to approximately 94 cps. (Refer to paragraph 5-7).
Instrument does not respond to a signal and offset on all ranges	Relay K102B is defective	Check operation of relay. If faulty replace with Keithley relay or return to factory
Greatly increased sensitivity on 10 and 100 null ranges and 5, 50 and 500V VTVM ranges	Relay K101B is defective	Check operation of relay. If faulty replace with new relay from Keithley or return to factory.
500V supply operates but null detector is completely inoperable	Fuse F201 is blown	Check for possible short in -6v supply (PC104).
Measurements are out of specifications on any range when the Reference Voltage Dials are at any setting other than 4 9 9 9 10	One of the Kelvin-Varley divider resistors is faulty	See paragraph 5-3

TABLE 4. (Sheet 2). Model 630 Troubleshooting.

b. Paragraph 6-2 describes how to remove the Model 630 cover. Before proceeding with the troubleshooting, check the vacuum tubes. Normally, replacing tubes will clear up the difficulty. All tubes can be readily tested on a grid-modulated tube tester. If replacing a tube does not correct the trouble, continue the procedures. Replacing tubes does not necessitate recalibration of the instrument.

c. Table 4 contains the more common troubles which might occur. If the repairs indicated in the Table do not clear up the trouble, the difficulty will have to be found through a point-by-point check of the circuits. Refer to the circuit description in Section 3 to find the more crucial components and to determine their function in the circuit. The complete circuit schematic, 18261E, is found in Section 7.

4-5. ADJUSTING GRID BIAS OF CATHODE FOLLOWER. The grid bias of the cathode follower, V1003 (Figure 15), should be -3 volts. Use the Keithley Model 610B to check this value $\pm 5\%$. If necessary, adjust the DC BAL potentiometer, R157 (Figure 16), to this value.

4-6. ZENER DIODE REPLACEMENT. Zener diode, D302, is a reference for the voltage divider, resistors R325 to R330. The values of resistors R329 and R330 (Figure 20) are determined by the reference voltage across diode D302. When the zener is replaced, the value of these two resistors may have to be changed.

4-7. METER ADJUSTMENT.

a. Potentiometer R155 (Figure 16) is the internal meter sensitivity adjustment. It sets the current through the meter to indicate a full-scale deflection for a full-scale applied voltage.

b. Warm up the Model 630 for 30 minutes. Set the NULL Switch to the 1-volt range and set the Reference Voltage Dials to 1.0000. Adjust potentiometer R155 until the meter reads full scale.

4-8. ADJUSTING QUADRATURE CONTROL.

a. Large quadrature components in the null detector can cause poor ac rejection, sluggish response, and, in some cases, unsymmetrical readings on the most sensitive ranges. Use the QUAD ADJ potentiometer, R131 (Figure 16), to buck out these components when necessary. While a large component is troublesome, the quadrature need not be completely eliminated.

b. To adjust the potentiometer, set the Reference Voltage Dials to zero and the DETECTOR INPUT Switch to ZERO CK. Attach an oscilloscope to the junction of C116 and R134 (from pin 6 of V1002, Figure 15). Adjust potentiometer, R131, for the correct wave form (Figure 9).



FIGURE 9. Wave Form with R131 Adjusted. A Type 503 Oscilloscope was used; horizontal sweep was 5 msec/cm; vertical, 2 v/cm.

SECTION 5. CALIBRATION

5-1. GENERAL.

a. The following procedures are recommended for calibrating the Model 630. Use the equipment recommended in Table 5. If proper facilities — especially important for calibrating an $\pm 0.01\%$ instrument — are not available or if difficulty is encountered, contact Keithley Instruments, Inc., or its representative to arrange for factory calibration.

b. The following procedures are covered: Kelvin-Varley divider verification, divider calibrate adjustment, voltage range calibration, reference voltage supply stability test and oscillator adjustment.

c. If the Model 630 is not within specifications after the calibration, follow the troubleshooting procedures or contact Keithley Instruments, Inc., or its representative.

Instrument	Use
Electro Scientific Industries Model SV194B Voltage Calibrator, $\pm 0.005\%$ accuracy with corrections on certificate	Range voltage calibration
Electro Scientific Industries Model RV722 Decade Voltage Divider; terminal linearity ± 1 ppm; certificate corrected to ± 0.2 ppm	Voltage divider for range calibration
Electro Scientific Industries Model LC875B Lead Compensator	Range voltage calibration
Hewlett-Packard Model 200CD Oscillator	Monitor oscillator frequency
Keithley Instruments Model 150B Microvolt Ammeter	Null detector for range calibration
Keithley Instruments Model 241 Regulated High Voltage Supply	Voltage supply for range calibration
Keithley Instruments Model 662 Guarded dc Differential Voltmeter	Check voltages in Kelvin-Varley divider
Keithley Instruments Model 370 Recorder	Recorder for reference voltage supply stability
Tektronix Type 503 Oscilloscope	Check wave forms
Weston Instruments Model 3 Type 7 Saturated Standard cell	Range calibration and reference voltage supply stability
Weston Instruments Model 66 Oil Bath	Range calibration and reference voltage supply stability

TABLE 5. Equipment Recommended for Model 630 Calibration. Use these instruments or their equivalents.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
Divider Calibrate	R104	15	5-4
Quad Adjustment	R131	16	4-8
Meter Calibrate	R155	16	4-7
DC Balance	R157	16	4-5
Oscillator	R210	18	5-7
500-volt Calibrate	R327	20	5-5
50-volt Calibrate	R334	20	5-5
5-volt Calibrate	R337	20	5-5
0.5-volt Calibrate	R339	20	5-5

TABLE 6. Model 630 Internal Controls. The Table lists all internal controls, the figure picturing the location and the paragraph describing the adjustment.

5-2. CALIBRATION SCHEDULE.

a. Recalibrate the Model 630 yearly. This normally means performing the voltage range calibration (paragraph 5-5). The other verifications need not be done.

b. Verify the Kelvin-Varley divider (paragraph 5-3) only if trouble is suspected in it, or if components in the divider have been replaced. Also make the voltage range calibration after verifying the divider accuracy.

c. Check the reference voltage supply stability (paragraph 5-6) only if trouble is suspected in the supply or if some of its components have been replaced.

5-3. KELVIN-VARLEY DIVIDER VERIFICATION.

a. There is no in-field calibration for the Kelvin-Varley divider; its accuracy can only be verified. The divider accuracy depends upon matching resistors and switches. At manufacture, each resistor within the first two Reference Voltage switches, S303 and S304, is matched to $\pm 0.00125\%$. The resistors in the switches are checked as a set to an accuracy of better than 0.0025% . Individual resistors cannot be replaced without rematching the string at Keithley Instruments.

b. Kelvin-Varley Divider Accuracy Verification Procedures.

1. Use the Model 662 Differential Voltmeter or equipment with better limit of error to match the Model 630 under test. Connect the low end of potentiometer R381 of the Model 630 to the HI terminal of the Model 662. Connect both LO terminals.

NOTE

Be careful of high voltages when working within the Model 630. Up to 900 volts dc is present at various points.

2. Set the dials to random settings on both instruments. Settings should match to $\pm 0.01\%$. This procedure, however, only indicates the Kelvin-Varley divider accuracy. The errors of the two instruments may be additive, causing a false verification. The most accurate way is to use standard procedures for checking a Kelvin-Varley divider or to return the Model 630 to Keithley Instruments, Inc., for checking.

3. If any resistor fails to test out, the entire divider string will have to be re-matched at the factory.

5-4. INPUT DIVIDER CALIBRATION. Above 1 volt the input is divided by a constant 500:1 ratio. R103 is pre-selected to approximate this ratio and R104 is adjusted to trim to this ratio more closely. A misadjustment will show up if the Model 630 maintains specified accuracy on the 1-volt and lower ranges but appears in error for the higher ranges. To check the divider ratio, use the Model 241 to apply a 500-volt signal to the Model 630 input. The Model 630 meter should have a full scale deflection on its 500-volt range. If it does not, trim R104 (Figure 15) until the meter indicates full scale.

5-5. RANGE CALIBRATION.

a. The reference voltage supply has a 500-volt output which can be attenuated to 50, 5 or 0.5 volts. This voltage is then divided by the Kelvin-Varley divider to provide the accurate buckout voltage. Each of the four voltage ranges is set by internally adjusting potentiometers R327, R334, R337 and R339 (Figure 20).

b. The ranges are calibrated by applying an accurate voltage to the Model 630 for each setting of the RANGE Switch. The Model 630 is set to furnish the equivalent buckout voltage, and the internal range potentiometer is adjusted until the voltmeter indicates a null.

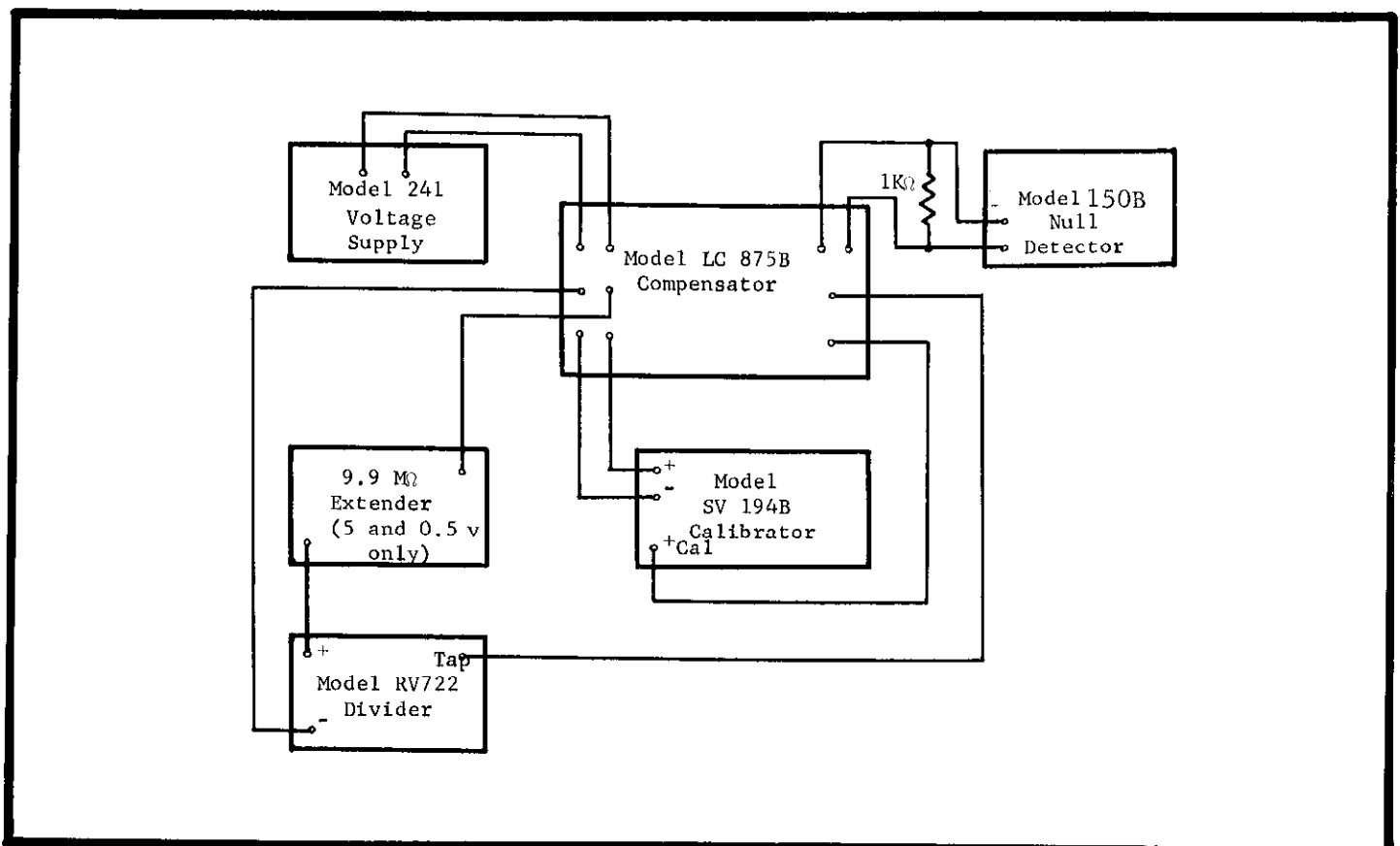


FIGURE 10. Block Diagram to Establish System Accuracy for Model 630 Range Calibration. Fully guard the entire system to prevent leakage errors. Use a 1-kilohm copper resistor to shunt the null detector. See Table 5 for recommended equipment.

NOTE

The accuracy of the Model 630 calibration will be no greater than the accuracy of the voltage source used for calibrating. Unless the user is familiar with techniques for obtaining accuracy greater than 0.002% (20 ppm), it is better to return the Model 630 to the factory for range calibration.

c. The most critical part in range calibration is establishing a reference source whose accuracy exceeds 0.002%. Use the Model SV194B Voltage Calibrator for the 500, 50, 5 and 0.5-volt outputs. Establish the accuracy of these outputs by determining the corrections for the calibrator's CALIBRATION and OUTPUT dials at these outputs. The system's accuracy can be determined to approximately 10 ppm. Added to the accuracy of the standard cell, total accuracy should be approximately 12 ppm. Note that this depends upon properly executed procedures.

d. Procedures to Establish System Accuracy.

1. Set up the system shown in Figure 10. Use the 9.9-megohm extender for only the 0.5 and 5-volt output.

2. Establish the corrections for the CALIBRATION dial setting for Model SV194B outputs of 500, 50, 5 and 0.5 volts. Set the Model 241 Voltage Supply to 500 volts. Set the Model RV722 Divider to a voltage equal to that of the standard cell. Adjust the Model SV194B ratio dial until the null detector indicates a null. The difference between the settings of the Model RV722 Divider and the ratio dial is the Model SV194B correction factor at 500 volts. With this correction, the 500 volts may be set to within approximately 12 ppm.

3. Connect the null detector to the 50, 5 and 0.5-volt taps of the Model SV194B Calibrator in that order. Set the Model RV722 Divider to corresponding voltages. Use the 9.9-megohm extender for the 5 and 0.5-volt outputs. (See Figure 10). The difference read on the null detector is the correction factor for each of the three voltages. These voltages may also be set to within 12 ppm.

4. Use the four correction factors for calibrating the Model 630 range setting.

e. Procedures for Range Calibration.

1. Set up the system shown in Figure 11. The standard cell should be certified to 10 ppm. Use the dial correction factors found for each output. If the system accuracy was properly determined, the input voltage to the Model 630 should be correct to 20 ppm.

2. 500-volt Range Calibration: Set the Model 630 controls as follows:

DETECTOR INPUT Switch	10 ¹⁰ OHMS
RANGE Switch	500
Reference Voltage Dials	4 9 9.9 9 10
NULL Switch	VTVM
POLARITY Switch	+

Adjust the Voltage Calibrator to apply 500 volts to the Model 630. Turn the Model 630 NULL Switch to 10 MV and adjust the 500 V CAL potentiometer, R327 (Figure 20), for null on the Potentiometric Electrometer.

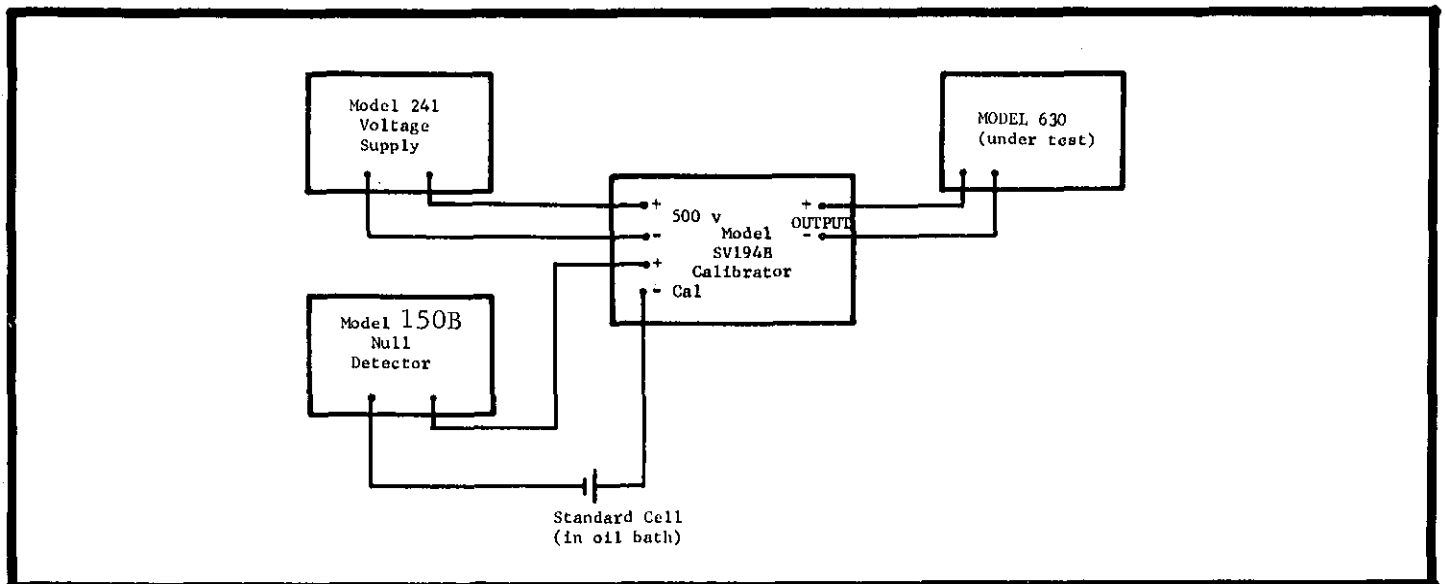


FIGURE 11. Block Diagram for Model 630 Range Calibration. Fully guard the entire system to prevent leakage errors. See Table 5 for recommended equipment.

3. 50-volt Range Calibration: Set the Model 630 controls as follows:

DETECTOR INPUT Switch	10^{10} OHMS
RANGE Switch	50
Reference Voltage Dials	4 9.9 9 9 10
NULL Switch	10 MV
POLARITY Switch	+

Adjust the Voltage Calibrator to apply 50 volts dc to the Model 630. Adjust the 50 V CAL potentiometer, R334 (Figure 20), for an off-null reading on the Model 630 equal to the correction factor at 50 volts.

4. 5-volt Range Calibration: Set the Model 630 controls as follows:

DETECTOR INPUT Switch	10^{10} OHMS
RANGE Switch	5
Reference Voltage Dials	4.9 9 9 9 10
NULL Switch	1 MV
POLARITY Switch	+

Adjust the Voltage Calibrator to apply 5 volts dc to the Model 630. Adjust the 5 V CAL potentiometer, R337 (Figure 20), for an off-null reading on the Model 630 equal to the correction factor at 5 volts.

5. 0.5-volt Range Calibration: Set the Model 630 controls as follows:

DETECTOR INPUT Switch	10^{10} OHMS
RANGE Switch	0.5
Reference Voltage Dials	.4 9 9 9 9 10
NULL Switch	0.1 MV
POLARITY Switch	+

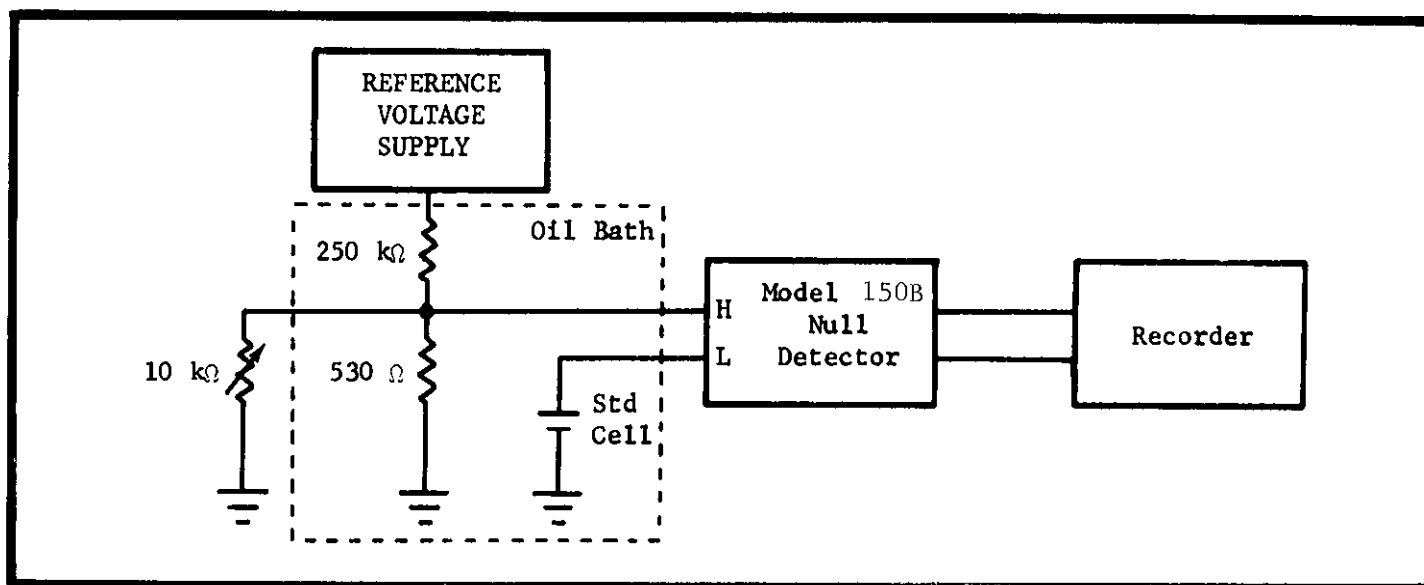


FIGURE 12. Circuit Diagram for Model 630 Reference Voltage Supply Stability Test. The voltage across the 530-ohm resistor is slightly higher than the standard cell. Use the 10-kilohm potentiometer to shunt the divider voltage down. All resistors are wirewound. See Table 5 for recommended equipment.

Adjust the Voltage Calibrator to apply 0.5 volt dc to the Model 630. Adjust the 0.5 V CAL potentiometer, R339 (Figure 20), for an off-null reading on the Model 630 equal to the correction factor at 0.5 volt.

5-6. REFERENCE VOLTAGE SUPPLY STABILITY TEST.

a. The reference voltage supply, consisting of the power transformer and the main supply (printed circuit PC92), is factory calibrated for an output of 500 volts dc greater than 0.002%. The 500-volt output is adjustable to meet specifications. If the stability of the supply is not within specifications, then troubleshoot for a faulty component.

b. Routine calibration of the Model 630 does not require a stability test of the reference voltage supply. However, a stability test is recommended if one of the components in the supply is replaced.

c. For the 24-hour test, the 500-volt output of the reference voltage supply is divided and compared to a 1.02-volt saturated standard cell using a sensitive null detector. Variations between the reference voltage supply and the standard cell are detected by the Model 150A and are recorded on a recorder. Refer to Figure 12 for the block diagram of the test circuit.

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

1. Saturated standard cells, though extremely stable with time, have a high temperature coefficient and require a controlled environment during use. Therefore, the Weston Oil Bath, which is maintained at $+35^{\circ} \pm 0.01^{\circ}\text{C}$, is used for the test. Unsaturated standard cells have a lower temperature coefficient, but they do not have the long term stability required for this test.

2. The resistor divider network is constructed from wire of the same spool for an extremely close temperature coefficient match (4 ppm, typically). Additional stability

results when the resistors are immersed in an oil bath to hold the ambient temperature variations to $\pm 0.01\%$.

e. Procedures for the Reference Voltage Supply Stability Test.

1. After the saturated standard cell and the resistor divider network are placed in the oil bath, allow sufficient time for the cell to stabilize at $+35^{\circ}\text{C}$. (Consult Keithley Instruments, Inc., or its representative for details.) Connect the standard cell to the circuit after turning on the 500-volt supply. Set the Model 630 controls as follows:

DETECTOR INPUT Switch	10^{10} OHMS
RANGE Switch	500
Reference Voltage Dials	4 9 9.9 9 10
NULL Switch	10 MV
POLARITY Switch	OFF

Connect the resistor divider network across the Model 630's reference voltage supply, the positive side of the divider input to the wiper arm of the last Reference Voltage Switch, S306, and the negative side of the divider to the L0 terminal on the Model 630 front panel.

2. Connect the Model 150B and the recorder as shown in Figure 12. Set the Model 150B to the 3-volt range. Advance the Model 630 POLARITY Switch to + to put 500 volts across the divider. If the Model 150B reads two volts, the standard cell and the divider voltages are improperly connected in series. If the circuit is correct, the Model 150B will read zero. Increase the Model 150B's sensitivity to the 0.1-millivolt range. If it reads more than 20 microvolts, adjust the 500 V CAL potentiometer, R327 (Figure 20), shunting the divider.

NOTE

Any adjustment of potentiometer R327 requires all other ranges to be calibrated.

3. After 1-hour warm-up, the drift of the entire system should not exceed ± 25 microvolts in 24 hours.

5-7. OSCILLATOR ADJUSTMENT.

a. The oscillator circuit drives the light modulator, vibrating capacitor and bridge, demodulator. Before adjusting the oscillator, make sure the reference voltage supply is operating correctly.

b. Connect the Type 503 Oscilloscope Vertical Input to the plate and low side of tube V1003 (Figure 15) and the Horizontal Input to the Model 200CD Oscillator. Adjust the oscillator frequency to approximately 94 cps with potentiometer R210 (Figure 18). The Model 630 oscillator is then adjusted for minimum meter noise — normally within a cycle of 94 cps. Disconnect the Oscilloscope before adjusting potentiometer R210. The Oscilloscope will cause a small loading error.

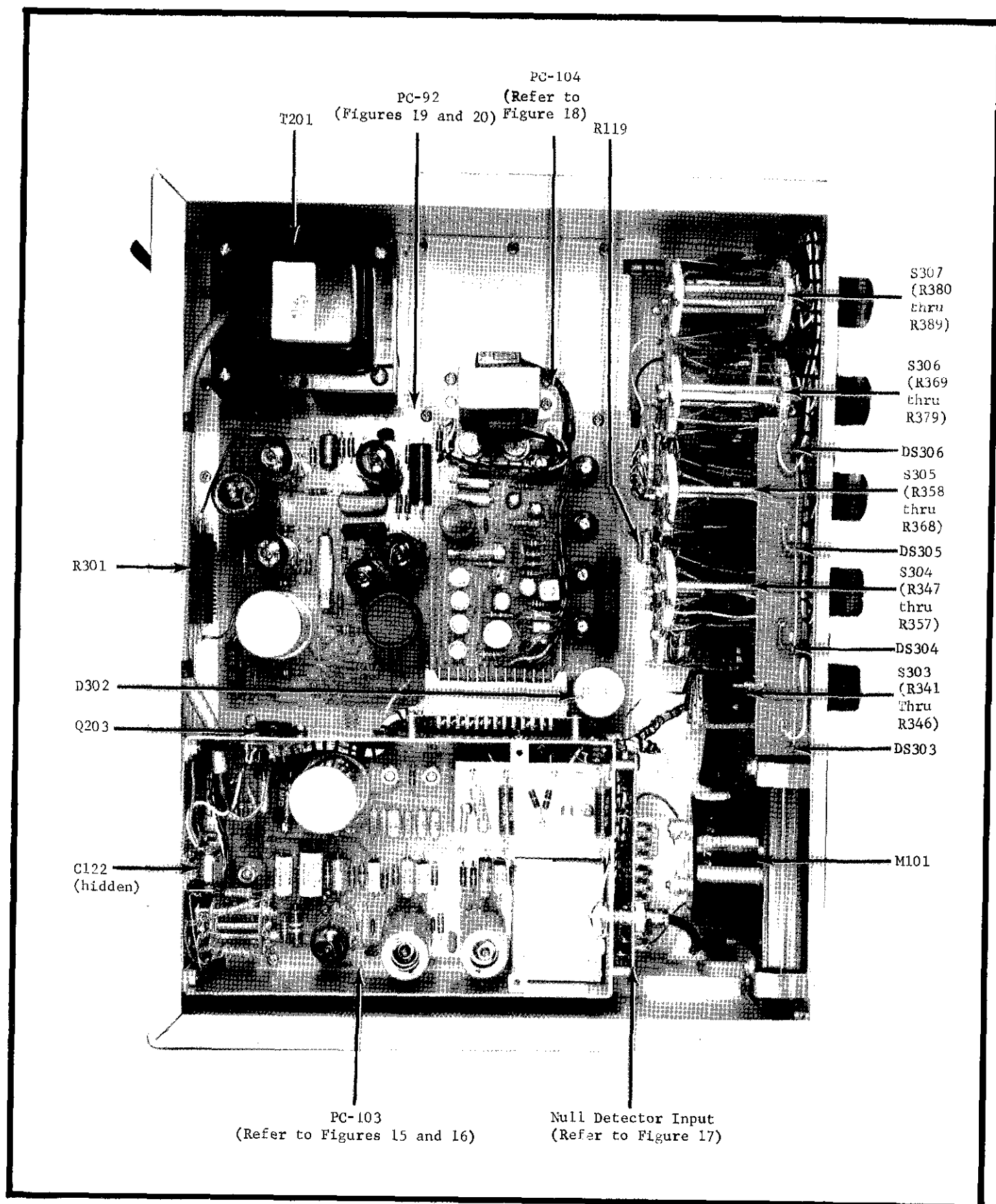


FIGURE 13. Top view of Model 630 Chassis. Front panel faces to the right.

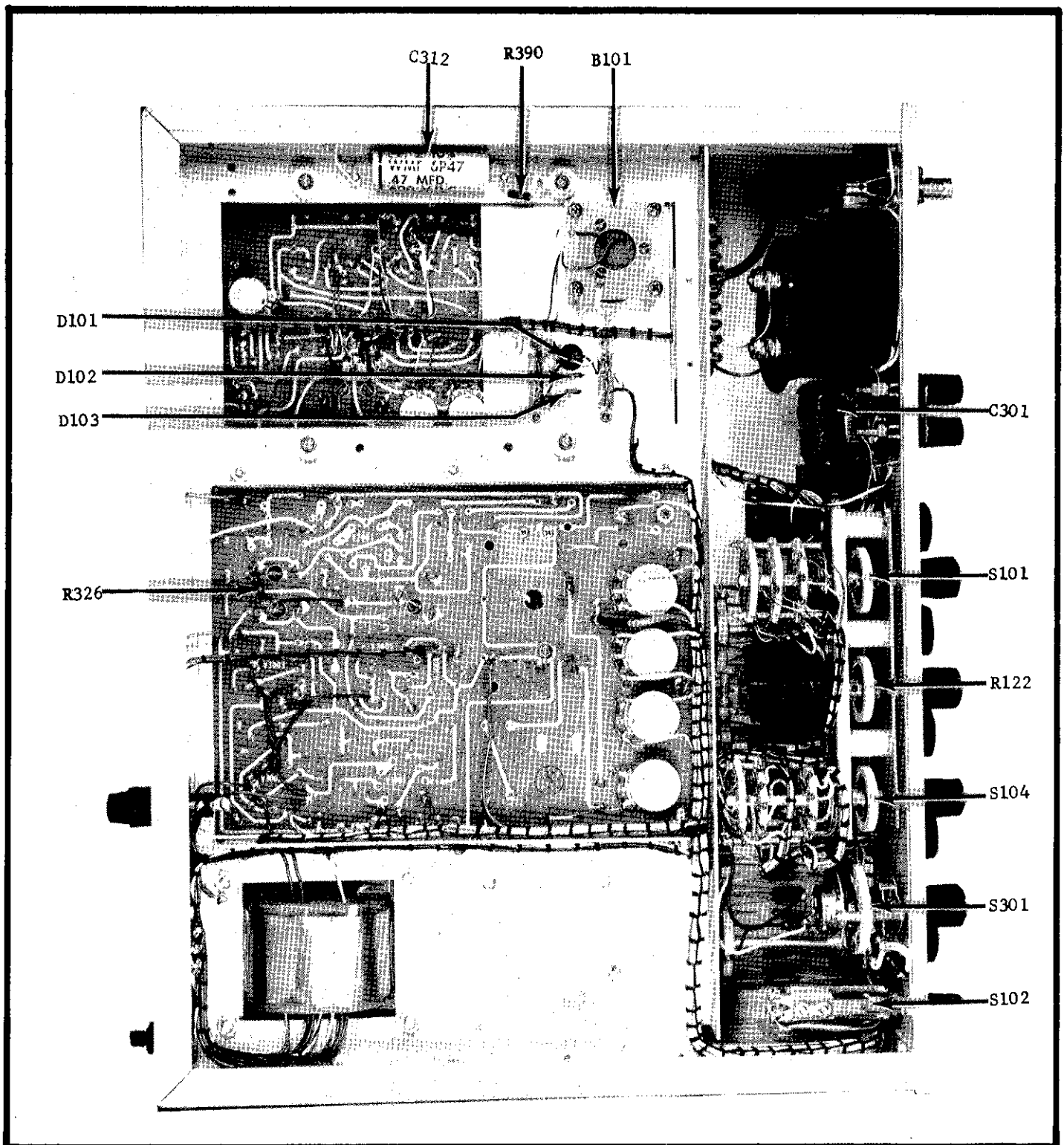


FIGURE 14. Bottom View of Model 630 Chassis. Front panel faces to the right. Figure 13 shows the top view.

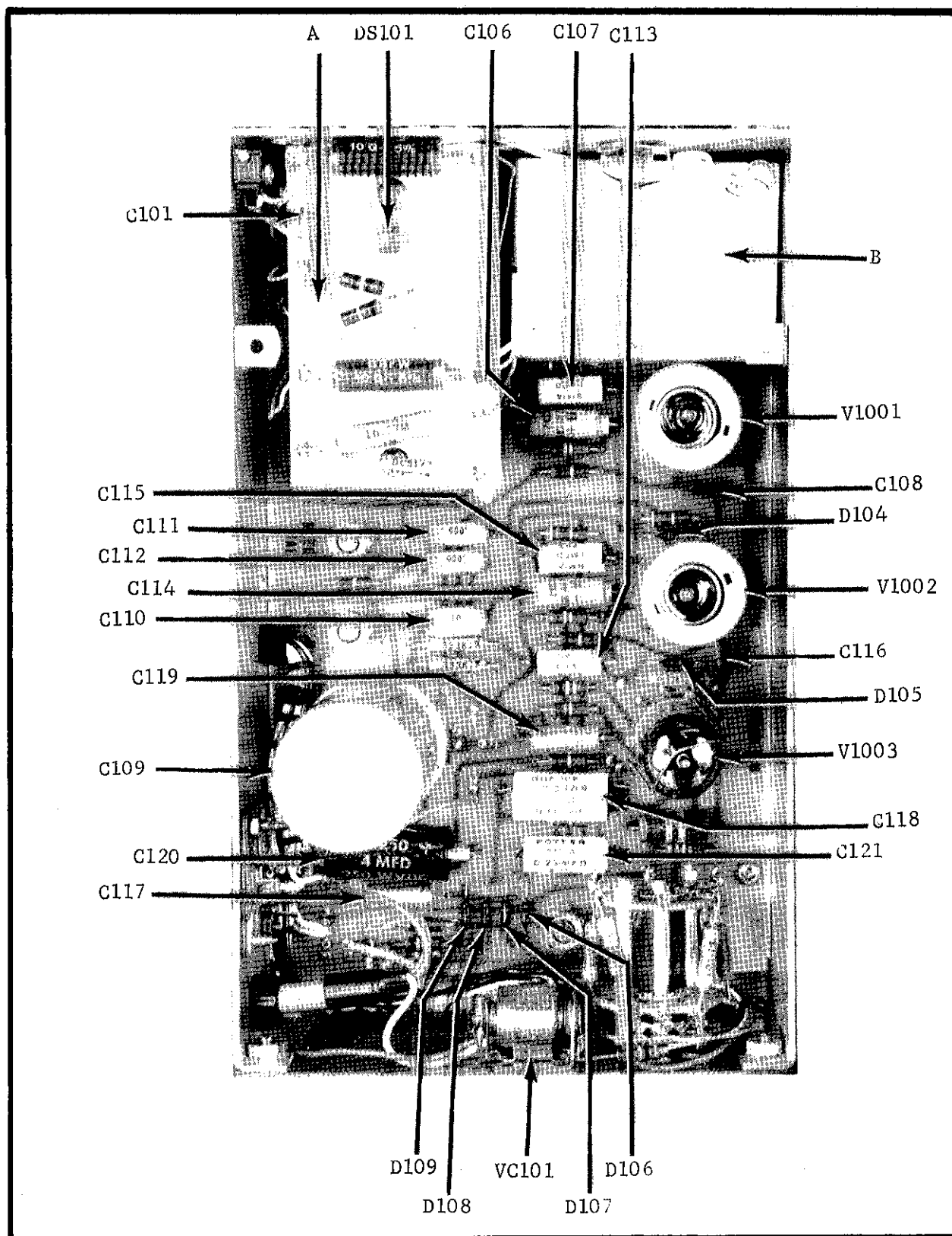


FIGURE 15. Capacitor, Tube and Diode Locations on Printed Circuit PC-103. Refer to Figure 16 for Resistor Locations. Hidden from view, in locations A and B are, potentiometer R104, resistors R124 and R154, and capacitors C103 and C105.

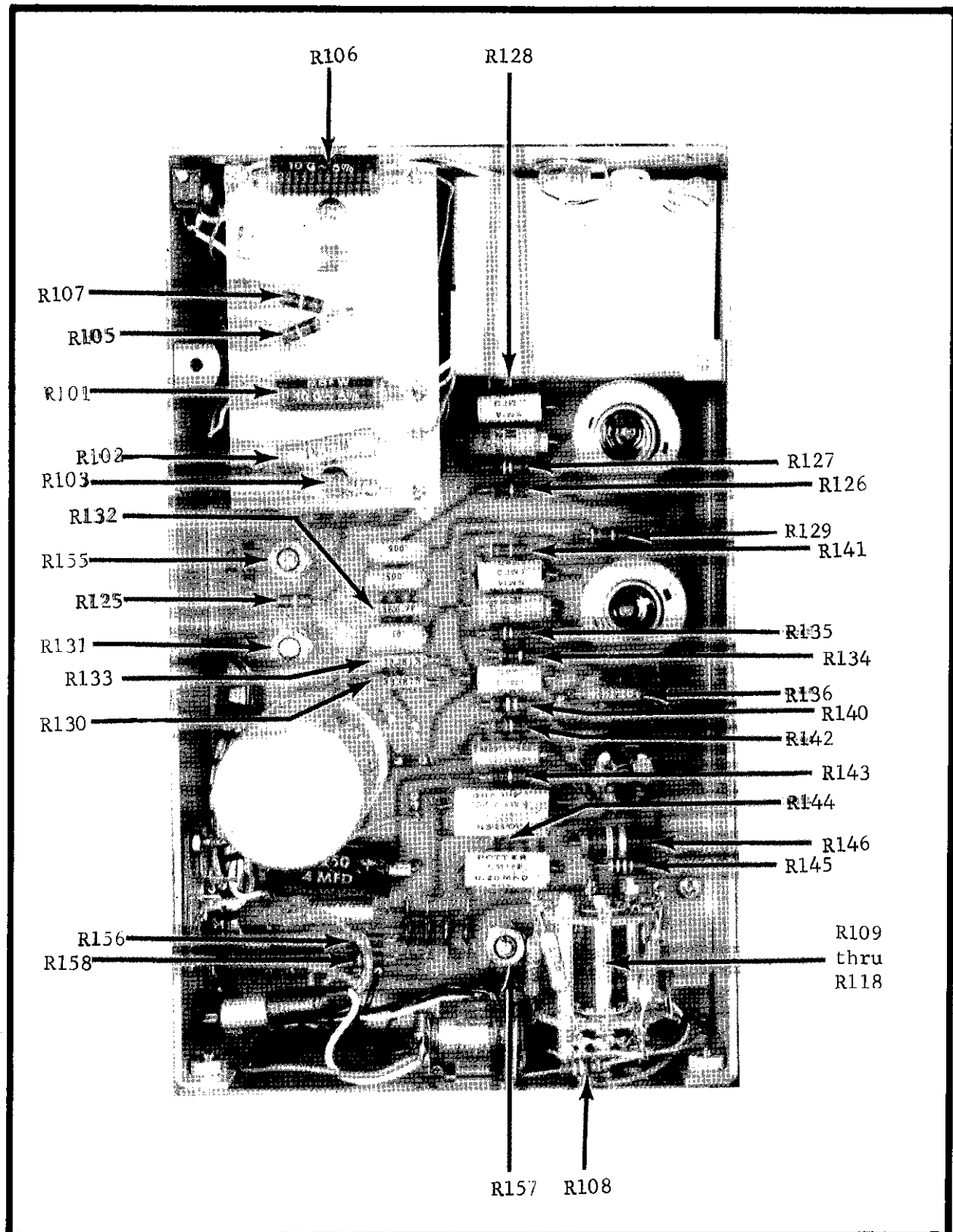


FIGURE 16. Resistor Locations on PC-103. Refer to Figure 15 for Capacitor, Diode and Tube Locations.

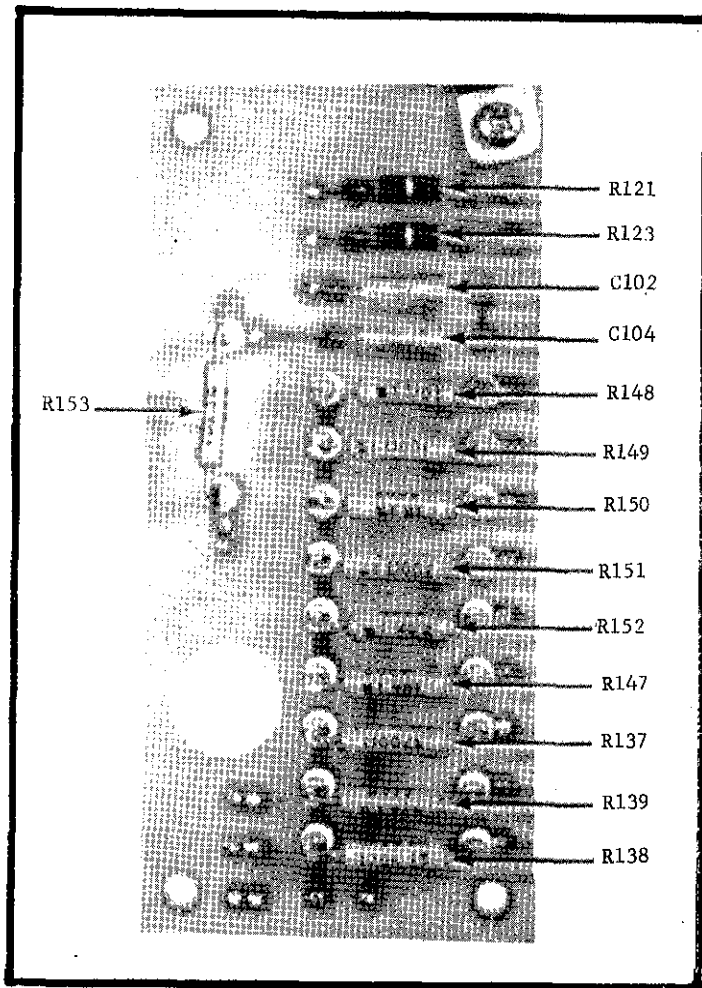


FIGURE 17. Component Locations on Null Detector Input.

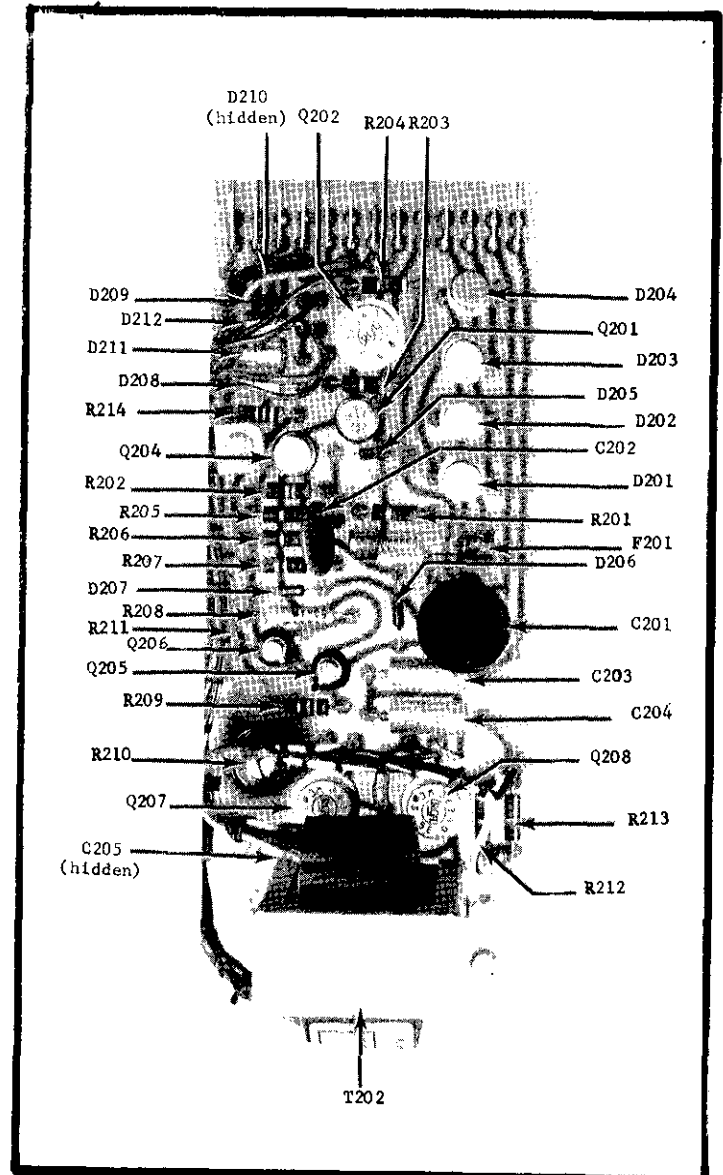


FIGURE 18. Component Locations on -6.3 volt Power Supply, PC104.

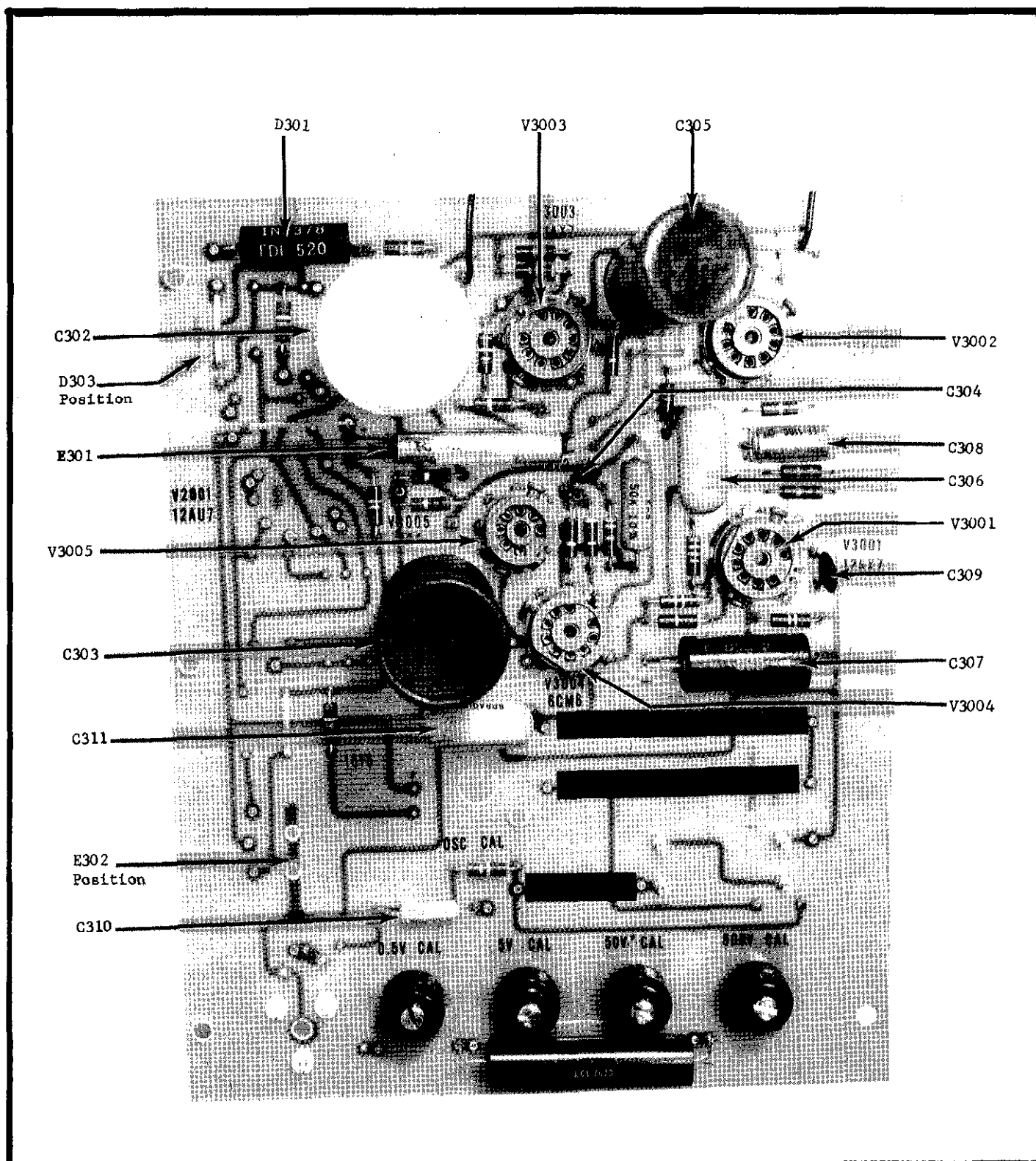


FIGURE 19. Capacitor, Diode, Modulator and Tube Locations on Printed Circuit Board PC-92. Refer to Figure 20 for Resistor Locations.

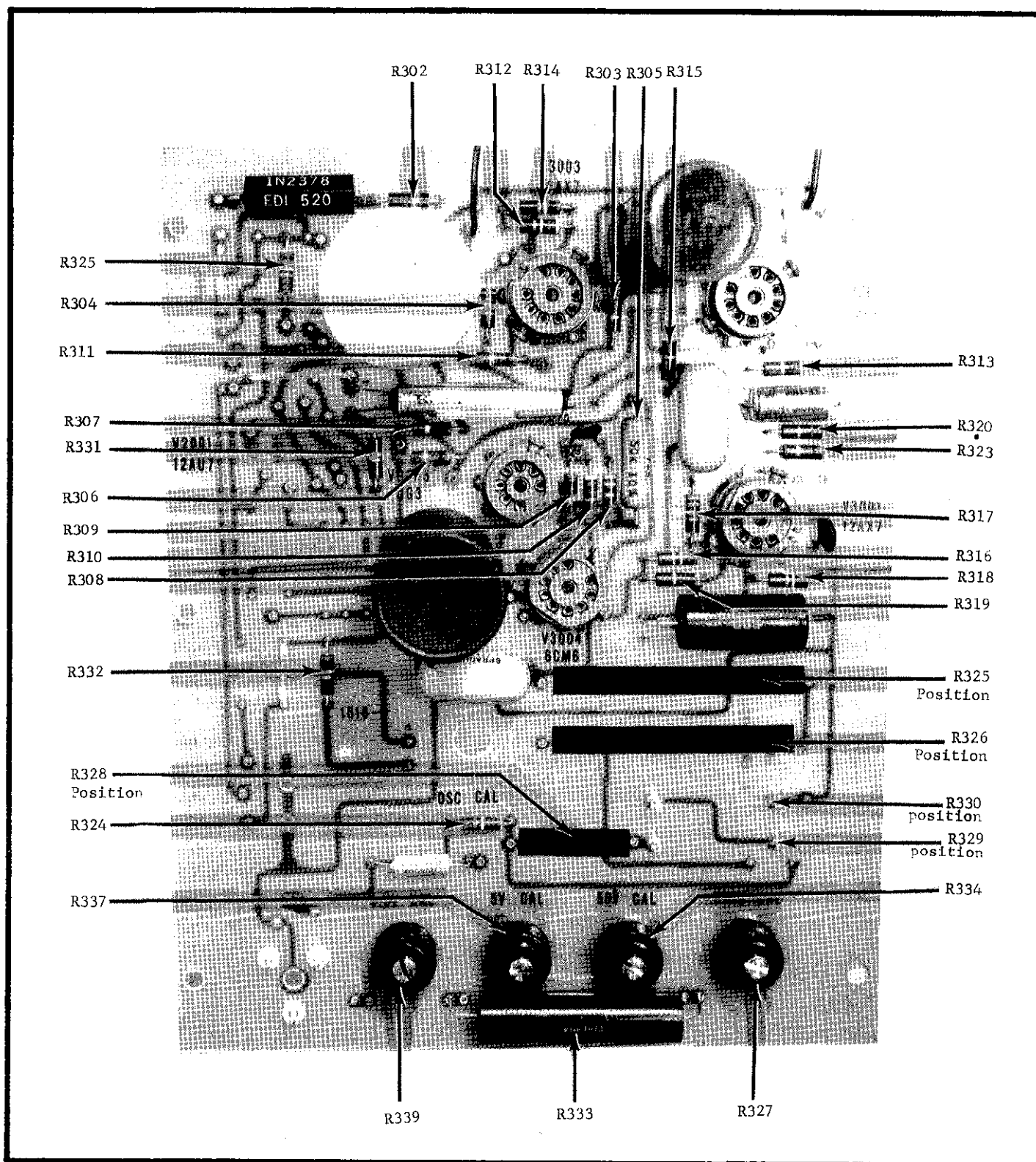


FIGURE 20. Resistor Locations on Printed Circuit Board PC-92. Refer to Figure 19 for Capacitor, Diode, Modulator and Tube Locations.

SECTION 6. ACCESSORIES

6-1. MODEL 6301 GUARDED PROBE. (Figure 21)

a. The Model 6301 is a guarded probe and shielded lead to make measurements with the Model 630 more convenient. It does not alter any Model 630 specification. The lead is furnished with 3 feet of low-noise cable, terminated by a special triaxial type plug. The plug connects directly into the Model 630 Input Receptacle.

b. Using the Model 6301 Probe allows point by point measurements. Its operation with the Model 630 is explained in paragraph 2-4.

6-2. RACK MOUNTING. (See Figure 22)

a. The Model 630 is shipped for bench use with four feet and a tilt-bail. The Model 4000 Rack Mounting Kit converts the instrument to rack mounting to the standard EIA (RETMA) 19-inch width.

b. To convert the Model 630, remove the four screws at the bottom of each side of the instrument case. Lift off the top cover assembly with the handles; save the four screws. To remove the feet and tilt bail from the bottom cover assembly, turn the two screws near the back. The two pawl-type fasteners will release the cover and allow it to drop off. Remove the feet and the tilt bail and replace the cover (2).

c. Attach the pair of rack angles (3) to the cabinet with the four screws (4) previously removed. Insert the top cover assembly (1) in place and fasten to the chassis with the

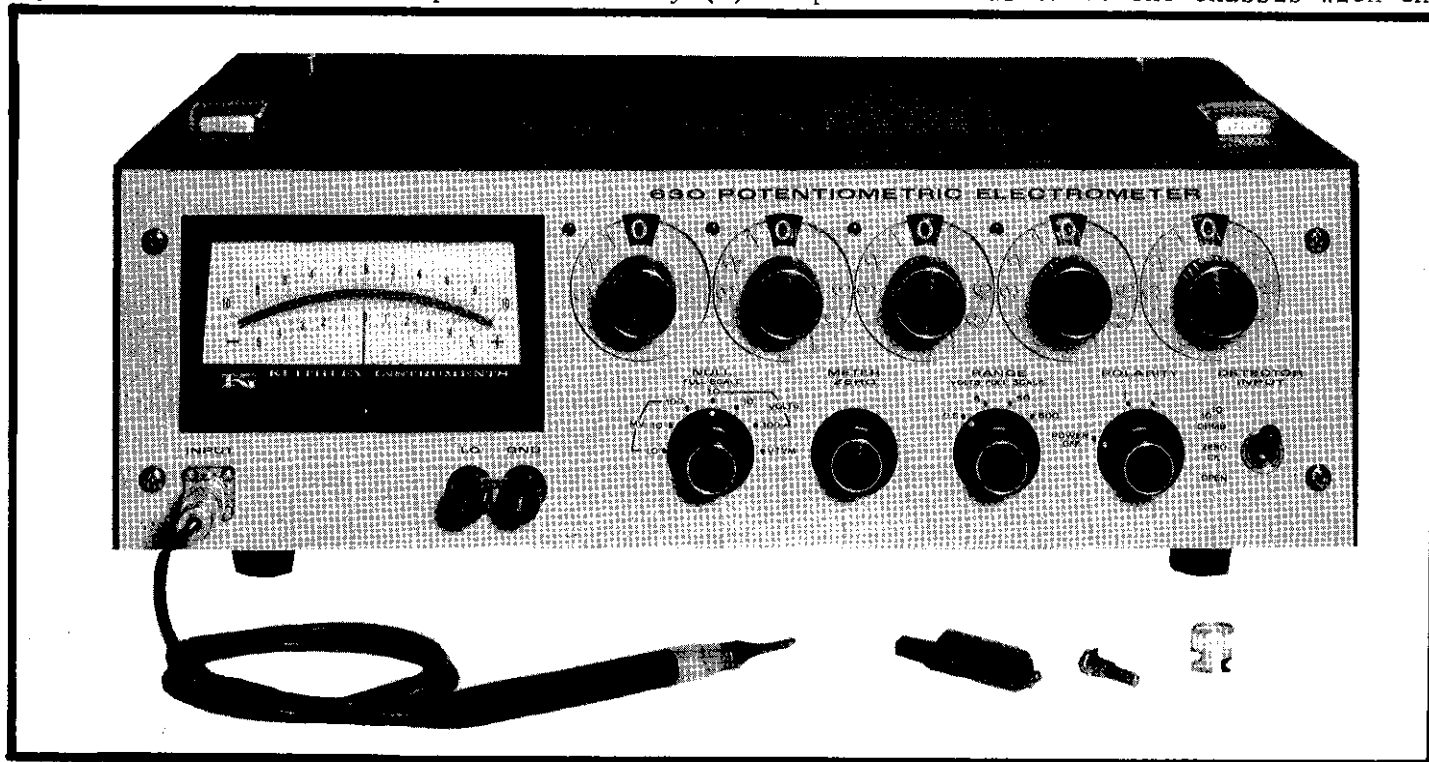


FIGURE 21. Keithley Instruments Model 6301 Guarded Probe with the Model 630. Besides the probe tip, the Model 6301 can have banana plug, alligator clip, and bnc-type connections. Unscrew tip to make the connection.

two pawl-type fasteners at the rear. Store the top cover with handles, feet and tilt-bail for future use.

6-3. PLACING IN RACK. The Model 630, once converted for rack mounting, easily fits into the rack. It is recommended, however, that a blower be used in the rack enclosure in which the Model 630 is mounted. The instrument specifications state a 0.002% per °C temperature coefficient. A temperature rise of 5 °C (9 °F) will cause a 0.01% error.

Item (See Fig. 22)	Description	Keithley Part No.	Quantity
1	Cover Assembly	14623B	1
2	Cover Assembly, Bottom (Supplied with Model 630)	14590B	1
3	Angle, Rack	14624B	2
4	Screw, Slot Head, 10-32 UNC-2 x 1/4 (Supplied with Model 630)	----	4
5	Front Panel (Supplied with Model 630)	----	1

TABLE 7. Parts List for Model 4000 Rack Mounting Kit.

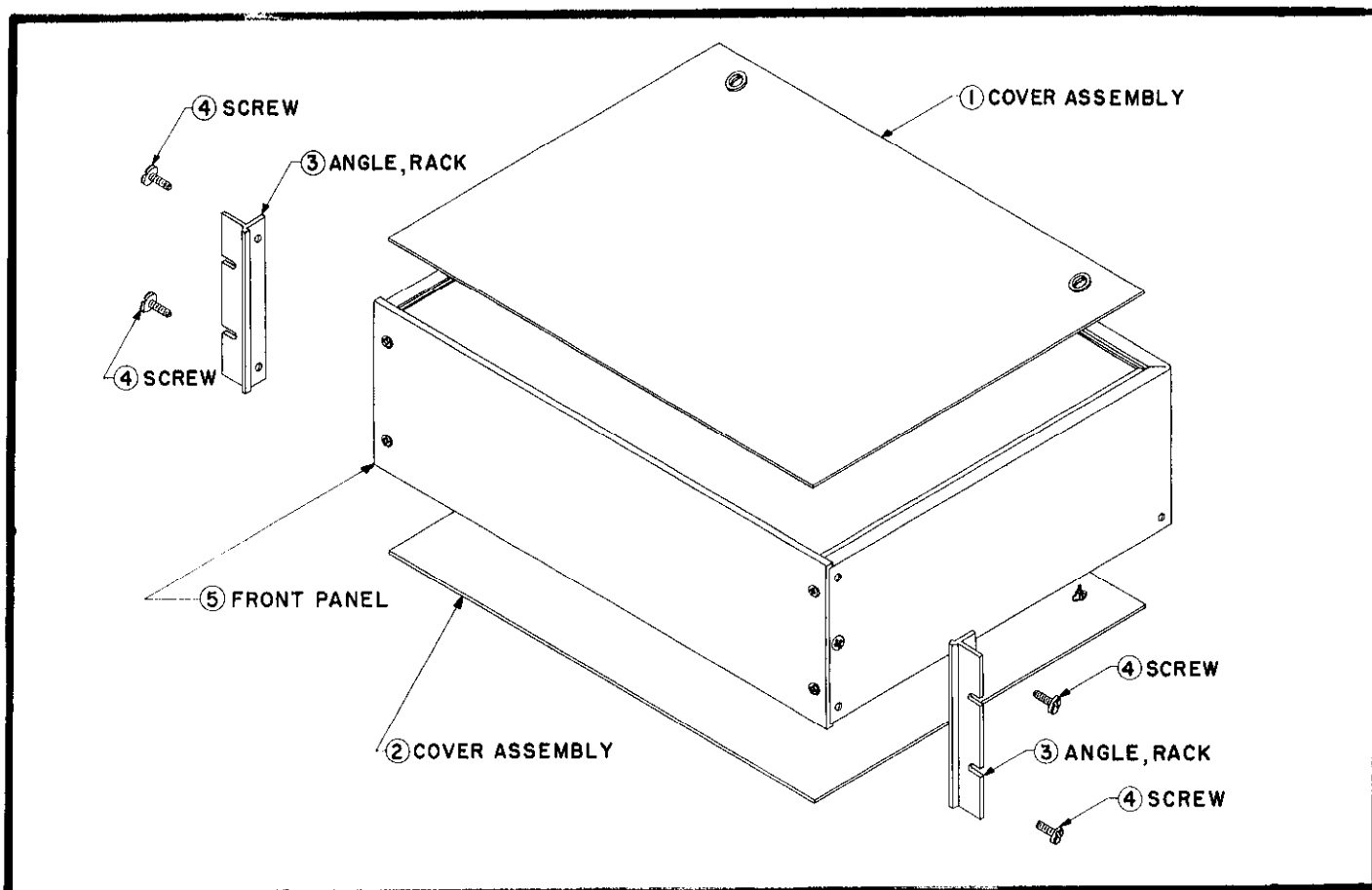


FIGURE 22. Exploded View for Rack Mounting with Model 4000 Kit. Refer to Table 7 for parts.

6-4. MODEL 6013 pH ELECTRODE ADAPTER. The Model 6013 pH Electrode Adapter is designed to allow accurate and convenient pH potential measurements with the Model 630 Electrometer. The Model 6013 accepts Leeds & Northrop and Beckman pH Electrode connectors. The Adapter uses Teflon insulation and is fully guarded to insure that the accuracy of the Model 630 is in no way affected.

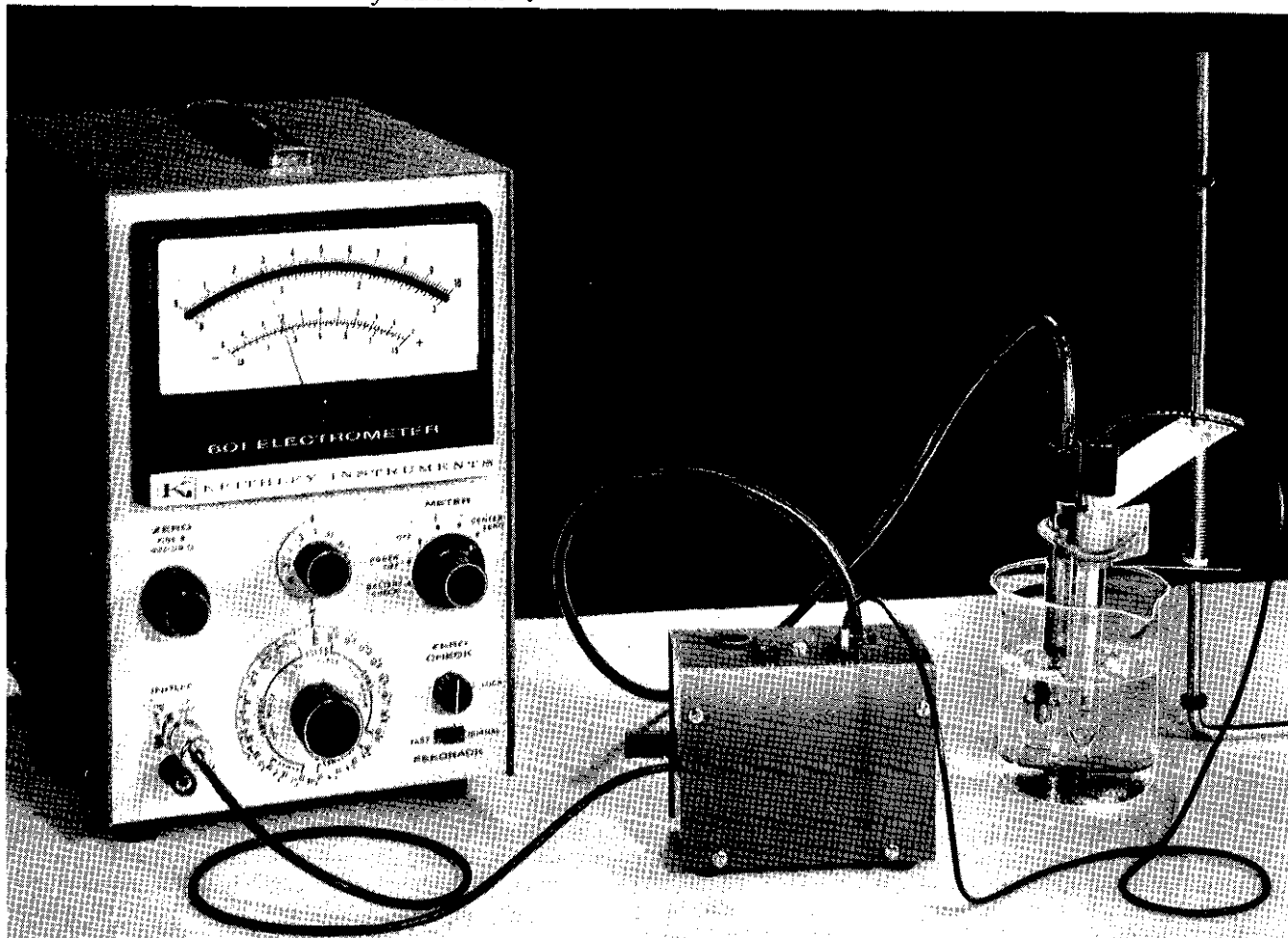


FIGURE 23. Model 6013 pH Electrode Adapter Connected to pH Electrodes. The Model 6013, shown here with the Keithley Model 601 Electrometer, is used similarly with the Model 630.

6-5. MODEL 370 RECORDER.

a. The Model 370 Recorder is uniquely compatible with the Model 630 as well as other Keithley electrometers, picoammeters and microvoltmeters. The Recorder is a high quality economical instrument that epitomizes the performance of the Model 630 and many other Keithley instruments, even in the most critical applications. The Model 370 can be used with the Model 630 to record over the Model 630's entire range.

b. The Model 630 has the output necessary to drive the Recorder directly (1 volt, 1 milliamper), thus eliminating the need for a pre-amplifier. The Model 370 floats ± 500 volts off ground, enabling the Model 630 to be used to its specified off-ground voltage. The Recorder is specially shielded to avoid pickup of extraneous signals. The response

time of the Model 370 Recorder is 0.5 second; linearity is $\pm 1\%$ of full scale. Ten chart speeds — from 3/4 inch per hour to 12 inches per minute — are selectable with front panel controls. The 6-inch chart has a rectilinear presentation. The Model 370 Recorder has a self-priming inking system. Chart paper and ink refills are easy to install.

c. The Model 370 is very easy to use with the Model 630. Just connect the Model 630's OUTPUT Receptacle to the Model 370 with the furnished 3701 Input Cable and adjust an easily accessible control for full-scale recorder deflection.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 630 and its accessories. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are in Table 9.

7-2. HOW TO ORDER PARTS.

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

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

amp	ampere	M	mega (10^6)
		m	milli (10^{-3})
Cb	Carbon	Mfg.	Manufacturer
CbF	Carbon Film	Mil. No.	Military Type Number
CbVar	Carbon Variable	My	Mylar
CerD	Ceramic Disc		
Comp	Composition	Ω	ohm
CompV	Composition Variable		
DCb	Deposited Carbon	P	pico (10^{-12})
		Poly	Polystyrene
EAL	Electrolytic, Aluminum	Ref.	Reference
EMC	Electrolytic, Metal Cased		
ETB	Electrolytic, tubular	μ	micro (10^{-6})
ETT	Electrolytic, tantalum		
		v	volt
f	farad	w	watt
Fig.	Figure	WW	Wirewound
		WWVar	Wirewound Variable
k	kilo (10^3)		

Table 8. Abbreviations and Symbols.

MODEL 630 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 18261E for circuit designations)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	22 pf	500 v	Poly	71590	CPR-22J	C138-22P	15
C102	56 μ f	6 v	ETT	01295	5MC566BP006A4	C70-56M	17
C103	47 pf	500 v	Poly	71590	CPR-47J	C138-47P	15
C104	56 μ f	6 v	ETT	01295	5MC566BP006A4	C70-56M	17
C105	47 pf	500 v	Poly	71590	CPR-47J	C138-47P	15
C106	2 μ f	50 v	ETT	37942	TC302	C39-2M	15
C107	0.1 μ f	400 v	My	13050	0100SM1A	C73-.1M	15
C108	1500 pf	600 v	CerD	72982	ED-1500	C22-1500P	15
C109	20/60/100 μ f	300/250/250 v	EMC	37942	FP335A	C100-100-60-20	15
C110	.01 μ f	400 v	Poly	12673	22P	C135-.01M	15
C111	.005 μ f	400 v	Poly	12673	22P	C134-.005M	15
C112	.005 μ f	400 v	Poly	12673	22P	C134-.005M	15
C113	0.1 μ f	400 v	My	13050	0100SM1A	C73-.1M	15
C114	2 μ f	50 v	ETT	37942	TC302	C39-2M	15
C115	0.1 μ f	400 v	My	13050	0100SM1A	C73-.1M	15
C116	.01 μ f	600 v	CerD	72982	ED-.01	C22-.01M	15
C117	100 μ f	10 v	ETT	05397	K100J10S	C78-100M	15
C118	0.5 μ f	400 v	My	13050	SM1A	C117-.5M	15
C119	100 μ f	10 v	ETT	05397	K100J10S	C78-100M	15
C120	4 μ f	250 v	ETB	14655	BBR4-250	C27-4M	15
C121	0.25 μ f	400 v	My	13050	SM1A	C73-.25M	15
C122	1 μ f	25 v	CerD	56289	5C13	C85-1M	13
C201	1000 μ f	15 v	EAL	56289	89B224	C93-1000M	18
C202	.0068 μ f	600 v	CerD	72982	ED-680	C22-.0068M	18
C203	100 μ f	10 v	ETT	05397	K100J10S	C78-100M	18
C204	100 μ f	10 v	ETT	05397	K100J10S	C78-100M	18
C205	0.47 μ f	25 v	CerD	56289	5C11	C85-.47M	18
C301	.05 μ f	600 v	My	56289	6PS-S50	C62-.05M	14
C302	20 μ f	450 v	EMC	39742	FP144	C36-20M	19
C303	20 μ f	450 v	EMC	56289	TVL2762	C36-40-20M	19
C304	.001 μ f	600 v	CerD	72982	ED-.001	C22-.001M	19
C305	1 μ f	1000 v	My	13050	Z4009B	C14-1M	19
C306	.05 μ f	600 v	My	56289	6PS-S50	C62-.05M	19
C307	4 μ f	250 v	ETB	14655	BBR4-250	C27-4M	19

CAPACITORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C308	50 μ f	6 v	EMC	56289	TE1100	C17-50M	19
C309	.0047 μ f	600 v	CerD	72982	ED-.0047	C22-.0047M	19
C310	.0022 μ f	1000 v	CerD	56289	5GAD22	C72-.0022M	19
C311	.05 μ f	600 v	My	56289	6PS-S50	C62-.05M	19
C312	.47 μ f	600 v	My	14655	WMF6P47	C101-.47M	14

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	14
D102	Silicon	1N645	01295	RF-14	14
D103	Silicon	1N645	01295	RF-14	14
D104	Silicon	1N645	01295	RF-14	15
D105	Silicon	1N645	01295	RF-14	15
D106	Silicon	1N645	01295	RF-14	15
D107	Silicon	1N645	01295	RF-14	15
D108	Silicon	1N645	01295	RF-14	15
D109	Silicon	1N645	01295	RF-14	15
D201	Silicon	MR1031B	04713	RF-30	18
D202	Silicon	MR1031B	04713	RF-30	18
D203	Silicon	MR1031B	04713	RF-30	18
D204	Silicon	MR1031B	04713	RF-30	18
D205	Zener	1N713	12954	DZ-14	18
D206	Silicon	1N645	01295	RF-14	18
D207	Zener	DZ40731A	12954	DZ-13	18
D208	Silicon	1N3256	02735	RF-22	18
D209	Silicon	1N645	01295	RF-14	18
D210	Silicon	1N645	01295	RF-14	18
D211	Silicon	1N3256	02735	RF-22	18
D301	Silicon	1N2378	08520	RF-25	19
D302	Zener	—	80164	DZ-24	13
D303	Silicon	1N3256	02735	RF-22	19
D304	Silicon	1N3256	02735	RF-22	

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
B101	Battery, 1.35 v (Mfg. No. RM-1W)	09569	BA-15	14
—	Battery Holder (Mfg. No. 2101)	94139	BH-15	
DS101	Neon Lamp (Mfg. No. NE-81)	08804	PL-6	15
DS301	Neon Lamp	80164	1512	
DS302	Neon Lamp	80164	1516	
DS303	Neon Glow Lamp (Mfg. No. A1C)	08804	PL-31	13
DS304	Neon Glow Lamp (Mfg. No. A1C)	08804	PL-31	13
DS305	Neon Glow Lamp (Mfg. No. A1C)	08804	PL-31	13
DS306	Neon Glow Lamp (Mfg. No. A1C)	08804	PL-31	13
E301	Light Modulator	80164	1514	19
E302	Light Modulator	80164	1516	19
F201	Fuse, slow blow, 2 amp (Mfg. No. 313002)	75915	FU-25	18
F301 (117 v)	Fuse, slow blow, 1 amp (Mfg. Type MDL)	71400	FU-10	3
F301 (234 v)	Fuse, slow blow, 0.5 amp (Mfg. No. 312.500)	75915	FU-6	3
—	Fuse Holder (Mfg. No. 342012)	75915	FH-3	
J101	Receptacle, special triaxial INPUT	80164	CS-140	2
—	Mating connector for J101	80164		
J102	Binding Post, LO (Mfg. No. DF31BC)	58474	BP-8B	
J103	Binding Post, HI (Mfg. No. DF31GC)	58474	BP-8G	2
J104	Plug, bnc, mate of J105 (Mil. No. UG-88/U)	95712	CS-44	2
J105	Receptacle, bnc, mate of J104 (Mil. No. UG-1094/U)	95712	CS-15	
J106	Banana Jack, HI (Mfg. No. 108-745-1)	74970	BJ-3	3
J107	Banana Jack, LO (Mfg. No. 108-745-2)	74970	BJ-4	3
J108	Connector, mate of J201 (Mfg. No. 00-5002-013-103-002)	73690	CS-155	
J201	Connector, mate of J108 (Mfg. No. 02-013-013-5200)	73690	CS-156	
—	Shorting Link (Mfg. No. 938-L)	24655	BP-6	
M101	Meter	80164	ME-38	13
P301	Cord set, 6 feet (Mfg. No. 4638-13)	93656	CO-5	3

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
S101 —	Rotary Switch less components, NULL Knob Assembly, Null Switch	80164 80164	SW-162 14838A	2
S102	Toggle Switch, DETECTOR INPUT	80164	SW-197	2
S103 —	Rotary Switch less components, COARSE ZERO ZERO Knob Assembly, METER ZERO	80164 80164	SW-220 15110A	3
S104 --- ---	Rotary Switch less components, RANGE Rotary Switch with components, RANGE Knob Assembly, Range Switch	80164 80164 80164	SW-163 19376B 14838A	2
S301 --- ---	Rotary Switch less components, POLARITY Rotary Switch with components, POLARITY Knob Assembly, Polarity Switch	80164 80164 80164	SW-119 19161A 14838A	2
S302	Slide Switch, 117-234	80164	SW-151	3
S303 —	Rotary Switch with components, Readout Dial Assembly, 0-4 Readout	80164 80164	18355B 14827A	2
S304 --- ---	Rotary Switch less components, Readout Rotary Switch with components, Readout Dial Assembly, 0-9 Readout	80164 80164 80164	SW-118 17080B 14828A	2
S305 --- ---	Rotary Switch less components, Readout Rotary Switch with components, Readout Dial Assembly, 0-9 Readout	80164 80164 80164	SW-118 17081B 14828A	2
S306 --- ---	Rotary Switch less components, Readout Rotary Switch with components, Readout Dial Assembly, 0-9 Readout	80164 80164 80164	SW-118 19160B 14828A	2
S307** —	Rotary Switch less components, Readout Dial Assembly, 0-10 Readout	80164 80164	SW-127 14829A	2
T201	Power Transformer	80164	TR-67	13
T202	Inverter Transformer	80164	TR-80	18
VC101	Vibrating Capacitor	80164	VC-1	15

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	10 ¹⁰ Ω	5%, 1 w	CbF	77764	BBFW	R125-10 ¹⁰	16
R102	16.67 MΩ	1%, 1 w	DCb	91637	DC-1	R13-16.67M	16

*Nominal value, factory set.

**On instruments with 11-step switch. On instruments with continuous front panel switch, R381 is used instead.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R103	*2 M Ω	1%, 1/2 w	DCb	00327	N11A	R12-2M	16
R104	1 M Ω	20%, 0.2 w	CbVar	80294	3068S-1-105	RP40-1M	15
R105	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	16
R106	10 ¹⁰ Ω	5%, 1/2 w	DCb	00327	N11A	R125-10 ¹⁰	16
R107	10 ⁹ Ω	20%, 1/2 w	Comp	75042	GBT	R37-10 ⁹	16
R108	10 ⁹ Ω	20%, 1/2 w	Comp	75042	GBT	R37-10 ⁹	16
R109	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R110	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R111	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R112	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R113	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R114	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R115	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R116	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R117	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R118	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	16
R119	4.7 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-4.7K	13
R120	100 k Ω	10%, 1/2 w	Comp	01121	EB	R1-100K	
R121	8.2 k Ω	10%, 1/2 w	Comp	01121	EB	R1-8.2K	17
R122	10 k Ω	5%, 2 w	WW Var	12697	62JA	RP42-10K	2
R123	8.2 k Ω	10%, 1/2 w	Comp	01121	EB	R1-8.2K	17
R124	10 ⁹ Ω	20%, 1/2 w	Comp	75042	GBT	R37-10 ⁹	15
R125	10 ⁹ Ω	20%, 1/2 w	Comp	75042	GBT	R37-10 ⁹	16
R126	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	16
R127	15 k Ω	10%, 1/2 w	Comp	01121	EB	R1-15K	16
R128	4.7 M Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7M	16
R129	4.7 M Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7M	16
R130	333 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-333K	16
R131	1 k Ω	20%, .2 w	CompV	71450	70	RP31-1K	16
R132	166.7 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-166.7K	16
R133	333 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-333K	16
R134	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	16
R135	15 k Ω	10%, 1/2 w	Comp	01121	EB	R1-15K	16
R136	4.7 M Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7M	16
R137	4.7 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-4.7K	17
R138	470 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-470K	17
R139	47 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-47K	17
R140	4.7 M Ω	1%, 1/2 w	DCb	00327	N11A	R12-4.7M	16

*Nominal value, factory set.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R141	100 k Ω	10%, 1/2 w	Comp	01121	EB	R1-100K	16
R142	820 Ω	10%, 1/2 w	Comp	01121	EB	R1-820	16
R143	330 k Ω	10%, 1/2 w	Comp	01121	EB	R1-330K	16
R144	4.7 M Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7M	16
R145	15 k Ω	10%, 2 w	Comp	01121	IIB	R3-15K	16
R146	1.5 k Ω	10%, 1/2 w	Comp	01121	EB	R1-1.5K	16
R147	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	17
R148	10 Ω	1%, 1/2 w	DCb	00327	N11A	R12-10	17
R149	100 Ω	1%, 1/2 w	DCb	00327	N11A	R12-100	17
R150	1.11 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-1.11K	17
R151	200 Ω	1%, 1/2 w	DCb	00327	N11A	R12-200	17
R152	2.5 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-2.5K	17
R153	10 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-10K	17
R154	8.06 k Ω	1%, 1/8 w	MtF	07716	CEA	R88-8.06K	15
R155	2 k Ω	20%, .2 w	CompV	71450	70	RP31-2K	16
R156	10 k Ω	10%, 1/2 w	Comp	01121	EB	R1-10K	16
R157	1 k Ω	20%, .2 w	CompV	71450	70	RP31-1K	16
R158	10 k Ω	10%, 1/2 w	Comp	01121	EB	R1-10K	16
R201	1 k Ω	10%, 1/2 w	Comp	01121	EB	R1-1K	18
R202	10 k Ω	10%, 1/2 w	Comp	01121	EB	R1-10K	18
R203	4.7 k Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7K	18
R204	470 Ω	10%, 1/2 w	Comp	01121	EB	R1-470	18
R205	2.2 k Ω	10%, 1/2 w	Comp	01121	EB	R1-2.2K	18
R206	5.6 k Ω	10%, 1/2 w	Comp	01121	EB	R1-5.6K	18
R207	56 k Ω	10%, 1/2 w	Comp	01121	EB	R1-56K	18
R208	50 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-50K	18
R209	27 k Ω	10%, 1/2 w	Comp	01121	EB	R1-27K	18
R210	20 k Ω	10%, 5 w	WWVar	71450	AW	RP34-20K	18
R211	35 k Ω	1%, 1/2 w	DCb	00327	N11A	R12-35K	18
R212	47 Ω	10%, 1/2 w	Comp	01121	EB	R1-47	18
R213	680 Ω	10%, 1/2 w	Comp	01121	EB	R1-680	18
R214	39 k Ω	10%, 1/2 w	Comp	01121	EB	R1-39K	18
R301	10 ⁸ Ω	20%, 1/2 w	Comp	75042	GBT	R37-10 ⁸	13
R302	220 Ω	10%, 1/2 w	Comp	01121	EB	R1-220	20
R303	820 k Ω	10%, 1/2 w	Comp	01121	EB	R1-820K	20
R304	150 k Ω	10%, 1/2 w	Comp	01121	EB	R1-150K	20
R305	50 k Ω	1%, 5 w	WW	91637	RS-5	R4A-50K	20
R306	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20
R307	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R308	3.3 k Ω	10%, 1/2 w	Comp	01121	EB	R1-3.3K	20
R309	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20
R310	470 Ω	10%, 1/2 w	Comp	01121	EB	R1-470	20
R311	470 k Ω	10%, 1/2 w	Comp	01121	EB	R1-470K	20
R312	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20
R313	4.7 k Ω	10%, 1/2 w	Comp	01121	EB	R1-4.7K	20
R314	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20
R315	10 M Ω	10%, 1/2 w	Comp	01121	EB	R1-10M	20
R316	680 k Ω	10%, 1/2 w	Comp	01121	EB	R1-680K	20
R317	330 k Ω	10%, 1/2 w	Comp	01121	EB	R1-330K	20
R318	270 k Ω	10%, 1/2 w	Comp	01121	EB	R1-270K	20
R319	2.2 M Ω	10%, 1/2 w	Comp	01121	EB	R1-2.2M	20
R320	5.6 k Ω	10%, 1/2 w	Comp	01121	EB	R1-5.6K	20
R321	*	0.1%, 50 w	WW	91637	RH-50	R73-*	20
R322	*	0.25%, 1 w	WW	01686	T2	R130-*	20
R323	1 M Ω	10%, 1/2 w	Comp	01121	EB	R1-1M	20
R324	220 k Ω	10%, 1/2 w	Comp	01121	EB	R1-220K	20
R325	125 k Ω	0.1%, 2 w	WW	80164		(1)	20
R326	125 k Ω	0.1%, 2 w	WW	80164		(1)	14
R327	200 Ω	10%, 5 w	WWVar	71450	AW	RP3-200	20
R328	4.4 k Ω	0.1%, 1/4 w	WW	80164		(1)	20
R329	*	0.25%, 50 w	WW	80164		19102A	20
R330	*	0.25%, 50 w	WW	80164		19102A	20
R331	68 k Ω	10%, 1/2 w	Comp	01121	EB	R1-68K	20
R332	68 k Ω	10%, 1/2 w	Comp	01121	EB	R1-68K	20
R333	250 k Ω	0.1%, 2 w	WW	80164		(3)	20
R334	1 k Ω	10%, 5 w	WWVar	71450	AW	RP3-1K	20
R335	32.33 k Ω	0.1%, 1/2 w	WW	80164		(3)	
R336	180 k Ω	10%, 1/2 w	Comp	01121	EB	R1-180K	
R337	1 k Ω	10%, 5 w	WWVar	71450	AW	RP3-1K	20
R338	2.563 k Ω	0.1%, 1/2 w	WW	80164		(3)	
R339	1 k Ω	10%, 5 w	WWVar	71450	AW	RP3-1K	20
R340	250.9 Ω	0.1%, 1/2 w	WW	80164		(3)	
R341 to R346	40 k Ω	0.02%, 1 w	WW	80164		(4)	13

*Nominal value, factory set.

(1) R325, R326 and R328 comprise a matched set Keithley Part No. 15436A.

(2) See paragraph 4-6.

(3) R333, R335, R338 and R340 comprise a matched set, Keithley Part No. 15432A.

(4) Part of Assembly with S303, Keithley Part No. 18355B.

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R347 to R357	8 k Ω	.02%, 5 w	WW	80164		(5)	13
R358 to R368	1.6 k Ω	0.1%, 1 w	WW	80164		(6)	13
R369 to R379	320 Ω	0.1%, 1/2 w	WW	01686	7044	R67-320	13
R380** to R389	64 Ω	0.1%, 1/2 w	WW	01686	7044	R67-64	13
R381**	750 Ω	10%, 4 w	WWVar	12697	58M	RP49-750	2
R390	1 k Ω	10%, 1/2 w	Comp	01121	EB	R1-1K	14

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q201	2N1381	01295	TG-8	18
Q202	2N1183	02735	TG-11	18
Q203	2N1535	04713	TG-7	13
Q204	2N1381	01295	TG-8	18
Q205	A1380	73445	TG-32	18
Q206	A1380	73445	TG-32	18
Q207	2N1183	02735	TG-11	18
Q208	2N1183	02735	TG-11	18

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V1001	EF86	73445	EV-EF86	15
V1002	EF86	73445	EV-EF86	15
V1003	6U8	81454	EV-6U8	15
V3001	7025	73445	EV-7025	19
V3002	7025	73445	EV-7025	19
V3003	7025	73445	EV-7025	19
V3004	6CM6	00011	EV-6CM6	19
V3005	OG3	73445	EV-OG3	19

**On instruments with the discontinuous front panel dial, R380 has a nominal value, factory set, and R381 replaces the rest of the string.

(5) Part of Assembly with S304.

(6) Part of Assembly with S305.

MODEL 6302 REPLACEABLE PARTS LIST

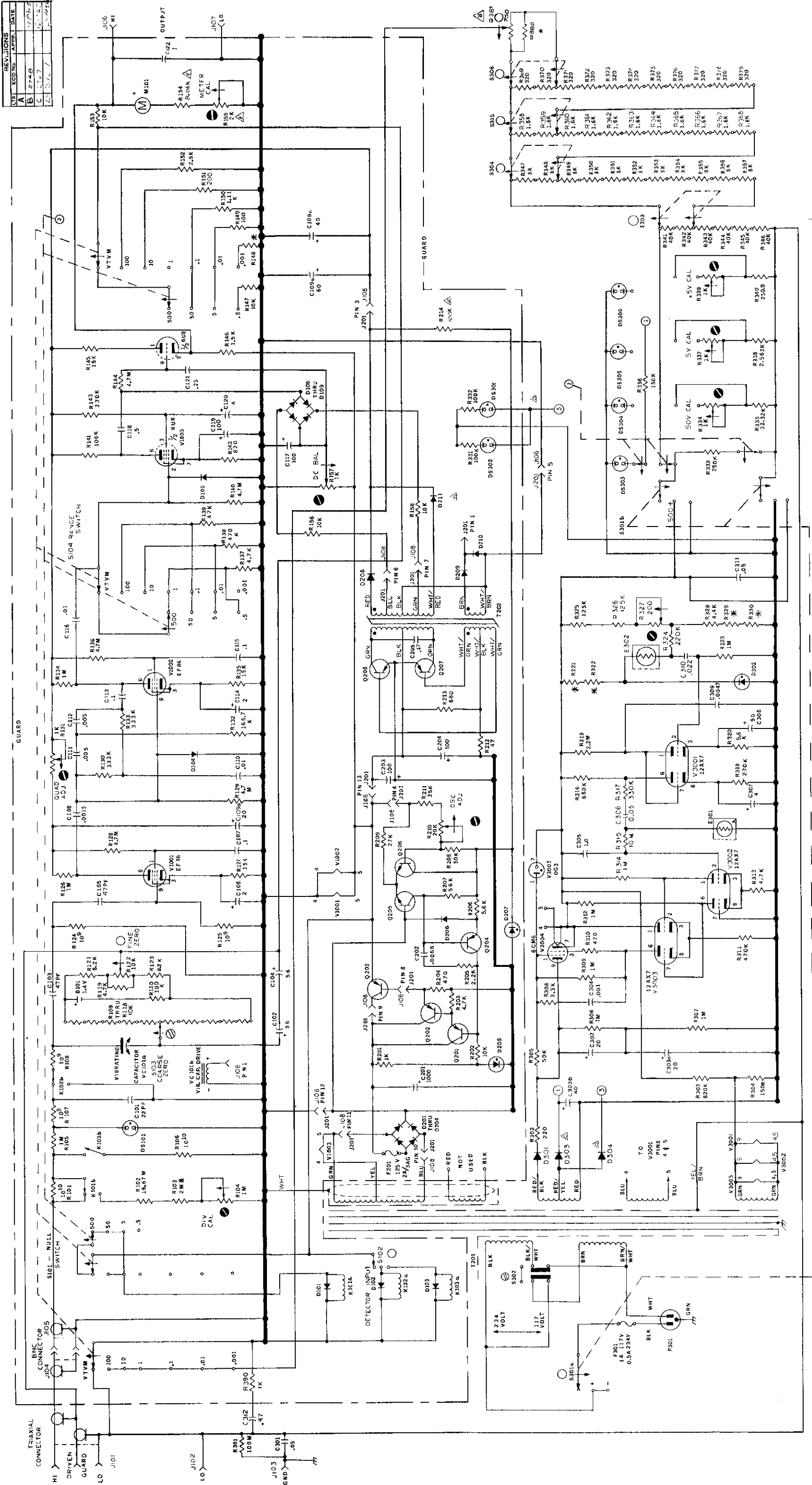
Description	Keithley Part No.
Alligator clip	AC-1
Insulated Banana Plug	BG-5
Test Lead Cable 48" long	SC-20
00011 Sylvania Electric Products, Inc. Buffalo Operations of Sylvania Electronic Systems Buffalo, N. Y.	09569 Mallory Battery Co. of Canada Ltd. Toronto, Ontario Canada
00327 Welwyn International, Inc. Cleveland, Ohio	12673 Wesco Division of Atlee Corp. Greenfield, Mass.
01121 Allen-Bradley Corp. Milwaukee, Wis.	12954 Dickson Electronics Corp. Scottsdale, Ariz.
01295 Texas Instruments, Inc. Semiconductor-Components Division Dallas, Texas	13050 Potter Co. Wesson, Mass.
01686 RCL Electronics, Inc. Riverside, N. J.	14655 Cornell-Dubilier Electric Corp. Newark, N. J.
02735 Radio Corp. of America Commercial Receiving Tube and Semiconductor Division Somerville, N. J.	24655 General Radio Co. West Concord, Mass.
04713 Motorola, Inc. Semiconductor Products Division Phoenix, Arizona	37942 Mallory, P. R., and Co., Inc. Indianapolis, Ind.
05397 Union Carbide Corp. Linde Division Kemet Dept. Cleveland, Ohio	56289 Sprague Electric Co. North Adams, Mass.
08520 Electronic Devices, Inc. North Ridgeville, Ohio	58474 Superior Electric Co., The Bristol, Conn.
08804 Lamp Metals and Components Department G. E. Co. Cleveland, Ohio	71400 Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.
	71450 CTS Corp. Elkhart Ind.
	71590 Centralab Division of Globe-Union, Inc. Milwaukee, Wis.

TABLE 9. (Sheet 1). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

72982	Erie Technological Products, Inc. Erie, Pa.	80164	Keithley Instruments, Inc. Cleveland, Ohio
73445	Amperex Electronic Co. Division of North American Philips Co., Inc. Hicksville, N. Y.	81454	Reade Mfg. Co. Jersey City, N. J.
73690	Elco Resistor Company New York, N. Y.	91637	Dale Electronics, Inc. Columbus, Nebr.
74970	Johnson, E. F., Co. Waseca, Minn.	93656	Electric Cord Co. Caldwell, N. J.
75042	International Resistance Co. Philadelphia, Pa.	94139	Keystone Electronics Co. Newark, N. J.
75915	Littelfuse, Inc. Des Plaines, Ill.	95712	Dage Electric Co., Inc. Franklin, Ind.
77764	Resistance Products Co. Harrisburg, Pa.		

TABLE 9 (Sheet 2). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1).

REV.	ECG	NO.	DATE
A	274-B	12/1/65	
B	274-C	12/1/65	
C	274-D	12/1/65	
D	274-E	12/1/65	



REFERENCE DESIGNATIONS NOT USED

D212					
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HIGHEST REFERENCE DESIGNATIONS

R 158	V3001	D109	T202	D304	J201
R 214	C122	F301	Q208	D3306	
R 281	D5101	F301	D211	S306	
B101	M101	V1003	F201	C312	
S104	K 103	V3005	E302	J101	

NOTES

1. FRONT PANEL CONTROL
2. INTERNAL SCREWDRIVER ADJ.
3. REAR PANEL SCREWDRIVER ADJ.
4. * INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION.

5. ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED.

6. K = 1000 OHMS
 7. P = PICO FARADS
 8. M = MEG OHMS
 9. * = CLOCKWISE ROTATION

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