INSTRUCTION MANUAL

MODEL 661

AC/DC GUARDED
DIFFERENTIAL VOLTMETER

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SECTION 1. GENERAL DESCRIPTION

1-1. DESCRIPTION.

a. The Keithley Model 661 AC/DC Guarded Differential Voltmeter is four instruments in one — dc potentiometer, ac potentiometer, dc VTVM and ac VTVM. As a dc instrument, its ranges are from 100 microvolts full scale to 500 volts. As an ac instruments, its ranges are from 1 millivolt full scale to 500 volts, and from 10 cps to 80 kc. Since the limit of error includes all stability considerations, the unit need not be periodically calibrated or manually restandardized for a full year.

b. Features for convenient use include: five in-line readout dials with automatically lighted decimal points; 10 to 25-millivolt recorder output; input polarity switch for dc voltages; floating operation up to 500 volts dc off chassis ground; line frequency rejection greater than 46 db. Also, full guarding for dc measurements minimizes leakage problems.

1-2. OPERATING MODES.

a. The Model 661 can be used as a dc potentiometer or as a dc conventional vacuum tube voltmeter. As a potentiometer, it measures from 100 millivolts full scale to 500 volts with ±0.01% limit of error and from 100 microvolts full scale to 100 millivolts within 10 microvolts. Input resistance is infinite at null over all ranges. As a VTVM, the Model 661 measures from 1 millivolt full scale to 500 volts with an accuracy of ±3% of full scale. Input resistance is 50 megohms from 0.5 to 500 volts.

b. The Model 661 can be used as an ac potentiometer or as a conventional average reading vacuum tube voltmeter. As a potentiometer, it measures from 1 millivolt full scale to 500 volts over 50 cps to 10 kc with a limit of error of ±(0.05% of reading + 0.005% of the voltage range). As a VTVM, the Model 661 measures from 10 millivolts full scale to 500 volts over 10 cps to 80 kc with an accuracy of ±3% of full scale. Input impedance for the 1 volt to 500-volt ranges is 1 megohm, 45 picofarads.

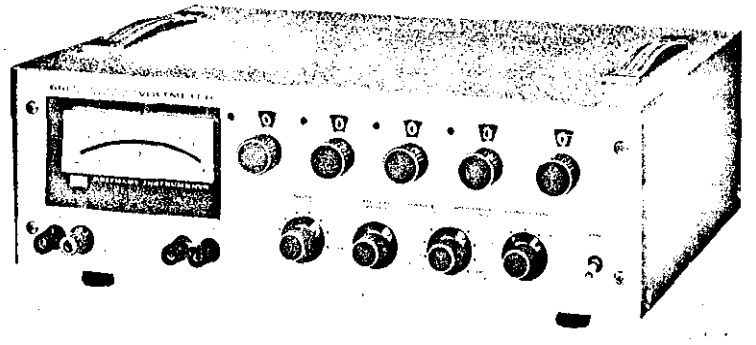


FIGURE 1. Keithley Instruments Model 661 AC/DC Guarded Differential Voltmeter.

1-3. SPECIFICATIONS.

AS A DC POTENTIOMETER:

LIMIT OF ERROR: ±0.01% of reading or 10 microvolts, whichever is greater, after 30-minute warm-up.

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

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

REPEATABILITY OR REVERSAL ERROR: ±0.001% or 10 microvolts, whichever is greater, with constant temperature and line voltage.

MAXIMUM NULL SENSITIVITY: 100 microvolts full scale with 2-microvolt resolution.

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

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

AS AN AC POTENTIOMETER:

VOLTAGE RANGES: 0.5, 5.0, 50.0 and 500.0 volts full scale.

WAVE-FORM RESPONSE: Averaging, calibrated in rms of a sine wave.

LIMIT OF ERROR (from 1 millivolt to 500 volts):

50 cps - 10 kc:	±(0.05% of reading + 0.005% of Voltage Range)
20 cps - 50 kc:	±(0.1% of reading + 0.01% of Voltage Range)
10 cps - 80 kc:	±(0.8% of reading + 0.08% of Voltage Range)

MAXIMUM USABLE NULL SENSITIVITY: 1 millivolt full scale with 10-microvolt resolution.

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

TEMPERATURE COEFFICIENT: Does not exceed 0.005%/°C.

REPEATABILITY: Within 0.01%.

INPUT IMPEDANCE: One megohm, 45 picofarads except on the 0.5-volt range, where it is one megohm, 50 picofarads.

LINE STABILITY: Better than 20 ppm for 10% change in line voltage.

AS A DC VACUUM TUBE VOLTMETER:

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

NULL RANGES: 100 microvolts full scale to 100 volts in seven decade ranges.

VTVM ACCURACY: ±3% of full scale on all ranges, except ±5% on 100-microvolt range, exclusive of noise and drift.

OPEN CIRCUIT OFFSET: Less than 5 microvolts on the 100-microvolt null range.

ZERO DRIFT: Less than 10 microvolts per 24 hours non-cumulative, after 30-minute warm-up.

INPUT RESISTANCE: 50 megohms, 0.5 to 500-volt ranges;
10 megohms, 0.1-volt range;
1 megohm, 0.1 to 10-millivolt ranges.

LINE FREQUENCY REJECTION: Greater than 46 dc (peak-to-peak) above full scale for 2% of full-scale change, 100-microvolt through 1-volt range. Greater than 70 db for 50% change, 100-microvolt through 10-millivolt range.

AS AN AC VACUUM TUBE VOLTMETER:

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.

ACCURACY: ±3% of full scale from 10 cps to 80 kc on 10-millivolt to 500-volt ranges, except ±5% of full scale from 20 cps to 50 kc on 1-millivolt range.

INPUT IMPEDANCE: One megohm, 45 picofarads; 1 to 500-volt ranges. One megohm, 50 picofarads; 1-millivolt to 0.5-volt ranges.

GENERAL CHARACTERISTICS:

RECORDER OUTPUT:
Output: Adjustable 10 to 25 millivolts dc for full-scale meter deflection.
Output Resistance: 300 ohms maximum
Noise: 2 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.

FUNCTION: Dc positive, negative, or ac, selectable by switch.

FLOATING OPERATION: 500 volts dc maximum off chassis ground.

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

MAXIMUM OVERLOAD: 500 volts, rms or dc.

CONNECTORS: Input: Binding Posts. Output: Banana jacks.

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

DIMENSIONS, WEIGHT: 5-1/2 inches high x 17-1/2 inches wide x 13-1/2 inches deep; net weight, 25 pounds.

1-4. APPLICATIONS.

a. Typical applications as a dc instrument include monitoring stability of most dc standards, conducting power-supply stability and regulation checks, testing zener diodes for stability and regulation, and accurately measuring thermocouple outputs.

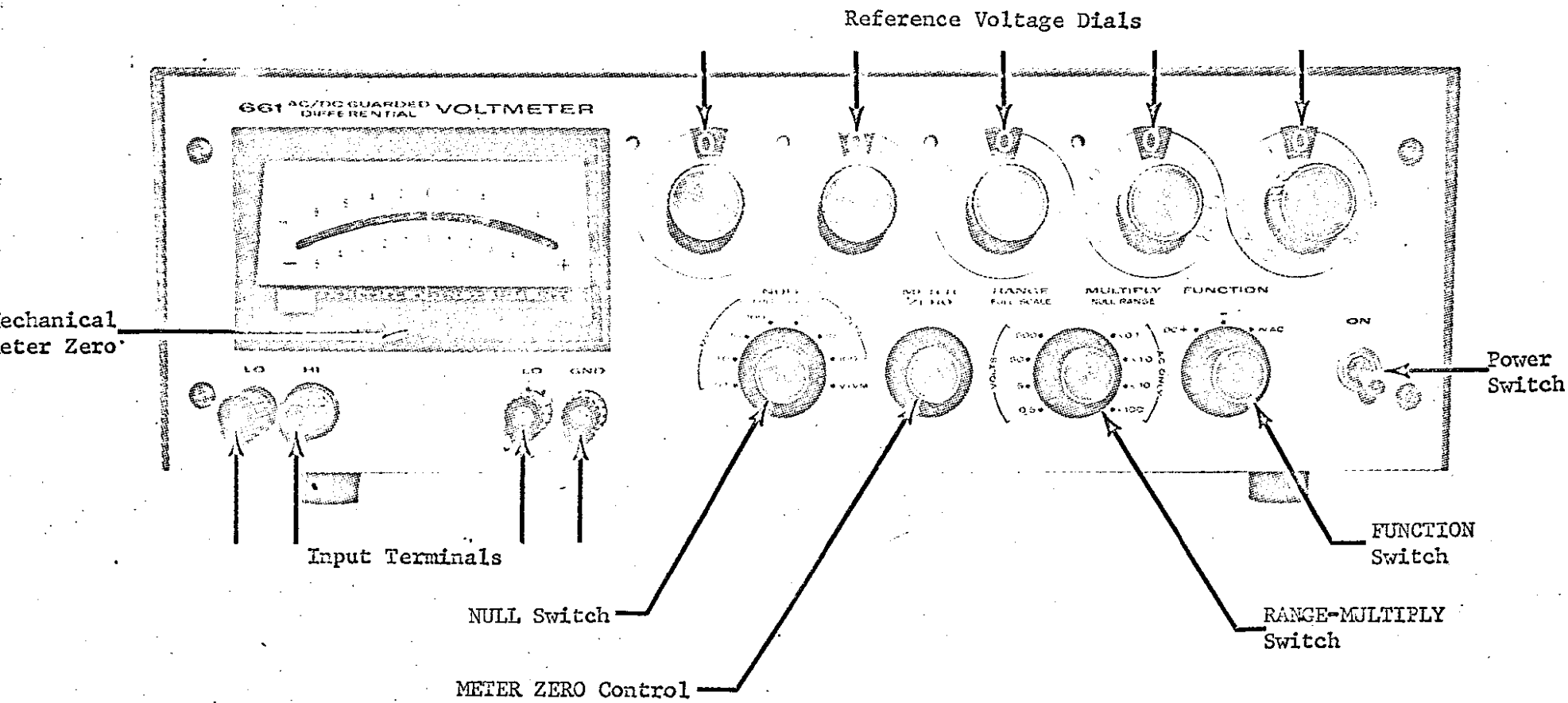
b. Typical applications as an ac instrument include uses in instrument maintenance (stability checks and calibration), ac power-supply verification, generator stability and accuracy measurements, ripple and hum determination, semiconductor circuit work, and oscillator monitoring.

1-5. ACCESSORIES.

a. Model 6601A High Voltage Divider is a 100:1 divider which extends the dc range of the Model 661 to 5000 volts. The divider accuracy is ±0.01% and its input resistance is 10 megohms. The overall limit of error of the Model 661 with the Model 6601A is ±0.02%. Section 7 gives operating instructions for the Divider.

b. Model 4000 Rack Mounting Kit, containing two brackets and a top cover, converts the Model 661 to fit standard 19-inch racks. Rack mounted, the Model 661 is 5-1/4 inches high x 19 inches wide x 13-1/2 inches deep. Section 7 has assembly instructions.

1-6. EQUIPMENT SHIPPED. The Model 661 AC/DC Guarded Differential Voltmeter is factory-calibrated and is shipped with all components in place. All units are shipped for bench use. Model 4000 Kit may be ordered for rack mounting; refer to Section 7 for assembly instructions. The shipping carton also contains the Instruction Manual.



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SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS.

a. Power Switch. A toggle switch turns the instrument on when it is set to the ON position.

b. FUNCTION Switch. The FUNCTION Switch selects one of three operating modes for the Model 661: to measure positive or negative dc voltages or to measure ac voltages.

c. NULL Switch. The NULL Switch sets the null detector sensitivity for the seven decade ranges from 0.1 millivolt to 100 volts full scale. When the Switch is in the VTVM position, the Model 661 operates as a conventional vacuum tube voltmeter for the four ranges of the RANGE Switch. The NULL Switch functions the same for both ac and dc operating modes.

d. RANGE-MULTIPLY Switch. The 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. When the Model 661 is in the ac operating mode, the full-scale null sensitivity is the product of the MULTIPLY setting (x0.1 to x100) times the NULL Switch setting. The MULTIPLY setting is determined by which of the four RANGE settings is used.

e. Reference Voltage Dials. Five in-line dials at the top of the front panel set the reference voltage when the Model 661 is used as an ac or dc potentiometer.

f. METER ZERO Control. The METER ZERO Control adjusts the meter needle to zero for the dc mode only. The control is needed on only the 0.1 and 1.0-millivolt null ranges; on the other ranges, the needle will normally be on zero without adjustment. The control has a range of approximately $\pm$30 microvolts.

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

2-2. REAR CONTROLS AND TERMINALS.

a. Fuse. For 105-125 volt operation, the Model 661 uses a 1-ampere 3 AG fuse. For 210-250 volt operation, the Model 661 uses a 0.5-ampere 3 AG fuse.

b. Power Cord. The Model 661 is designed for a 105-125 volt, 50-400 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. An adapter for operation from 2-terminal outlets is provided.

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

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

e. 117-234 Switch. The screwdriver-operated slide switch sets the Model 661 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 661 as follows:

Power Switch	On
FUNCTION Switch	Desired Operating Mode
RANGE-MULTIPLY Switch	500
NULL Switch	VTVM
Reference Voltage Dials	Zero

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

c. In the dc operating mode with the input terminals open, set the NULL Switch to 0.1 MV and zero the meter with the METER ZERO Control. Then return the NULL Switch to VTVM. The stability of the Model 661 is such that no adjustment should be required in eight hours after a 30-minute warm-up.

NOTE

There is no need to check the zero in the ac mode. If it is checked there will be approximately a 100-microvolt offset. This has no effect on accuracy. The offset does not occur when a signal is applied.

2-4. DC OPERATING PROCEDURES.

a. The Model 661 is used first as a VTVM to determine the approximate value of the unknown voltage. It is then used in the potentiometric mode to determine the voltage to ±0.01%.

NOTE

The Model 6601A High Voltage Divider extends the Model 661 range to 5000 volts for dc potentials only.

b. DC VTVM Operating Procedures.

1. Eleven full-scale ranges are available for VTVM operation. When the NULL Switch is at VTVM, the RANGE-MULTIPLY Switch determines one of four full-scale ranges. By putting the five Reference Voltage Dials at zero, the Model 661 can then operate as a VTVM on the seven null ranges.

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

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

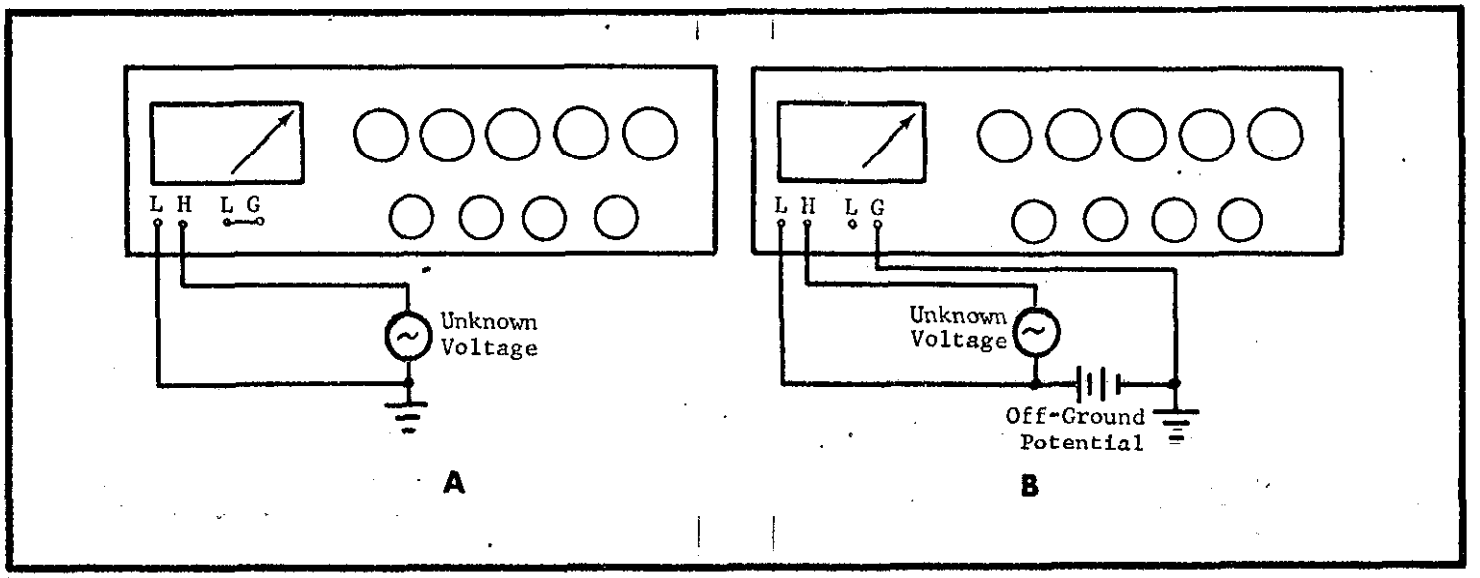


FIGURE 2. Input Connections to Model 661. The two diagrams show the input circuit for measuring at ground and for floating.

In A, the unknown voltage has one terminal at ground. The shorting link is between the LO and GND Posts of the Model 661.

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

c. DC Potentiometric Operating Procedures.

NOTE

Avoid large overload voltages on the null detector. No permanent damage will occur even with 500-volt overloads, but some open circuit offset will be caused in the null detector. The offset, due to the polarization of the input filter capacitors, will disappear after about 5 minutes.

1. Leave the RANGE-MULTIPLY Switch at the last setting used in the VTVM operation. If the VTVM reading is negative, set the FUNCTION Switch to the opposite dc polarity position.

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

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

RANGE MULTIPLY 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 V	0.1 MV
0.5 V	100 MV	0.1 MV

TABLE 1. Recommended Null Sensitivities and Settings for DC Potentials.

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. Null does not have to be reached.

b) When the first Reference Voltage Dial is used, only the five Dials need be read to be within specifications (±0.01% of reading or 10 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. However, the loading effect of the Kelvin-Varley divider on the meter causes some quantative inaccuracies when the meter is off null. (See paragraph 2-7).

2-5. AC OPERATING PROCEDURES.

a. The Model 661 is used first as a VTVM to determine the approximate value of the unknown voltage. It is in the potentiometric mode to determine the voltage more accurately. The ac operation is similar to the dc operation except for the null multipliers.

b. AC VTVM Operating Procedures.

1. Ten full-scale ranges are available for VTVM operation. When the NULL Switch is at VTVM, the RANGE-MULTIPLY Switch determines one of four full-scale ranges. By putting the five Reference Voltage Dials at zero, the Model 661 can then operate as a VTVM on six null ranges. The full-scale range for these six ranges is the NULL Switch setting times the MULTIPLY setting of the RANGE-MULTIPLY Switch. For example, when the RANGE-MULTIPLY Switch is at 50 V and the NULL Switch is at 10 MV, the full-scale null range is 100 millivolts. Table 2 lists the switch settings for optimum results for the ten ac voltmeter ranges.

NOTE

When changing the RANGE-MULTIPLY Switch to lower multiplier values, make sure the RANGE values on the Switch are higher than the input voltage. Otherwise, the ac converter will be overloaded.

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

3. Switch the RANGE-MULTIPLY Switch to the most sensitive range for an on-scale meter deflection. The meter will always show a deflection in the + direction.

AC Voltmeter Range	RANGE-MULTIPLY Switch Setting	NULL Switch Setting
500 volts	500 V	VTVM
50 volts	50 V	VTVM
5 volts	5 V	VTVM
0.5 volt	0.5 V	VTVM
100 volts	500 V	1 V
10 volts	50 V	1 V
1 volt	5 V	1 V
100 millivolts	0.5 V	1 V
10 millivolts	0.5 V	100 MV
1 millivolt	0.5 V	10 MV

TABLE 2. Switch Settings for AC Voltmeter Ranges. Using the above settings, the converter is operated at as high a level as possible. These settings are for the best operating conditions, although alternate settings of the NULL and RANGE-MULTIPLY Switches are possible for the same ranges.

c. AC Potentiometric Operating Procedures.

1. Leave the RANGE-MULTIPLY Switch at the last setting used in the VTVM operation. Set the first two Reference Voltage Dials to the first two digits of the unknown voltage found in the VTVM operation.

2. Set the NULL Switch to the least sensitive range. Keep resetting the Reference Voltage Dials to read zero on the meter. Increase the null sensitivity to the most sensitive range possible.

NOTE

Do not set the NULL Switch beyond the 10 MV position for the ac operating mode. Better than 0.01% is readable on the 10-millivolt NULL Switch position. Beyond this range, the meter will probably fluctuate excessively because of instability of the ac input. An ac amplitude stability which is better than 0.01% does not often occur.

3. The Model 661 is an average reading device for ac voltages. It is calibrated to read the true rms value of a pure sine wave. Wave form distortion can cause an error in reading, which depends on the harmonics present and of their phase in relation to the fundamental. Table 3 indicates the range of error for a given percentage of a harmonic.

2-6. RECORDER OUTPUT.

a. Recommended recorders for use with the Model 661 are the F. L. Moseley Autograf 680 series recorder and the Minneapolis Honeywell recorder (10mv-0-10mv scale, 50 kilohms input resistance). Any recorder used must be able to float 500 volts off ground and its input must be fully isolated (10^{10} ohm minimum leakage resistance to ground).

b. Before attaching the recorder, set all Reference Voltage Dials to zero. Disconnect the unknown voltage and short both Model 661 input terminals. Set the NULL Switch to 10 MV. Connect the recorder to the OUTPUT terminals on the Model 661 rear panel.

Harmonic	Percent %/Distortion	Maximum Percent of Error from True RMS Value
Any even harmonic	0.1	0.000
	0.5	0.000 to -0.001
	1.0	0.000 to -0.005
	2.0	0.000 to -0.020
third harmonic	0.1	+0.033 to -0.033
	0.5	+0.167 to -0.168
	1.0	+0.328 to -0.338
	2.0	+0.667 to -0.687
fifth harmonic	0.1	+0.020 to -0.020
	0.5	+0.099 to -0.101
	1.0	+0.195 to -0.205
	2.0	+0.380 to -0.420

TABLE 3. Error Caused by Distortion from Sine Wave.

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

d. To obtain accurate results and/or to prevent damage to the instruments, the recorder must be able to float off-ground with the Model 661. Leakage and pickup between the two instruments should also be minimized.

1. Make sure neither recorder terminal is grounded. Use a 3-wire grounded power line for the recorder. If a 2-wire line is used, connect the recorder chassis and the Model 661 chassis with a separate lead.

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

3. Avoid long leads between the Model 661 and the recorder.

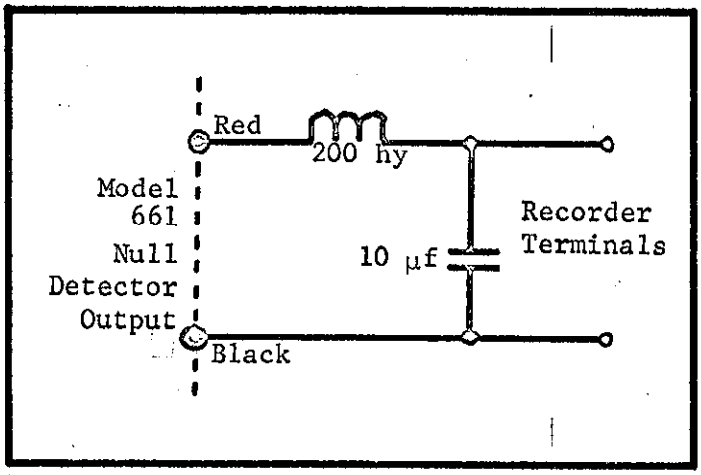


FIGURE 3. Recorder Filter. A filter between the Model 661 and the recorder may be necessary when using the 0.1-millivolt null detector range.

4. If difficulty is encountered in off-ground measurements, such as unstable readings, connect a 10-microfarad capacitor between the LO and GND terminals on the Model 661 front panel.

NOTE

Do not short either Model 661 output terminal to the case; this may damage the Kelvin-Varley divider.

e. If there is a substantial recorder jitter on the 0.1-millivolt null range, place a filter between the Model 661 and the recorder. Refer to Figure 3 for this connection. Note the filter must also be insulated from ground.

2-7. EFFECTS DUE TO KELVIN-VARLEY OUTPUT RESISTANCE.

a. When the Model 661 is used for nulling on the 0.1-millivolt range, the last Reference Voltage Dial may appear to be inaccurate. The apparent error is due to a voltage drop across the Kelvin-Varley divider. This effect involves only the null detector sensitivity and not the accuracy of the Dial setting. When the Model 661 is as near to null as possible, the Reference Voltage Dial setting is correct within the instrument's specifications. There is no effect present at null.

b. The effect is most apparent on the 0.1, 1 and 10-millivolt null ranges; a 0.1-millivolt off-null setting of the reference voltage will not produce a full-scale meter deflection. This is because the Kelvin-Varley divider output resistance is significant compared to the shunt resistance across the null detector meter. The IR drop across the divider will cause the meter to be in error from 1% to 6%, depending upon the Reference Voltage Dial settings. On the 100-millivolt range the maximum error is 1%. The effect cannot be observed on the other null ranges of the Model 661.

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

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

where R_n is the shunt resistance across the meter (50 megohms for the 100 to 1-volt null ranges, 10 megohms for the 100-millivolt range, and 1 megohm for the 10 to 0.1-millivolt ranges);

R_{kv} is the output resistance of the Kelvin-Varley divider, which is a maximum of 62.4 kilohms at Reference Voltage Dial settings of 2 4 5 4 5 and 2 5 4 5 5 and a minimum of 100 ohms at settings of 4 9 9 9 8 and 0 0 0 0 2.

2-8. LOADING AND OFF-NULL RESISTANCE.

a. The input resistance of the voltmeter for the seven dc null ranges varies from 50 to 1 megohm as given in the Specifications. This resistance, however, is not the effective input resistance of the Model 661. Its input resistance is considerably higher due to the potentiometric principle of operation. The value is given by

$$R_{in} = \frac{E_d R_n}{V} \qquad \text{Equation 1}$$

where R_{in} is the effective input resistance of the Model 661;
E_d is the setting of the Reference Voltage Dials in volts;
R_n is the shunt or input resistance of the null detector meter in ohms;
V is the null detector meter reading in volts.

b. To find the loading effect the Model 661 will have on a circuit, equation 1 may be used to compute the effective input resistance. At null, the input resistance is infinite. Off null, the input resistance is usually high compared to the internal resistance of the unknown voltage, and the loading will not be enough to affect the measurement accuracy. For example, the Model 661 input resistance is 10^{10} ohms if the Reference Voltage Dials are set at 1.0000 volt on the 1-millivolt null range for a reading off null by 10% of full scale.

2-9. THERMAL EMF PRECAUTIONS. Observe standard thermocouple techniques to reduce thermal emf errors for measurements using the most sensitive null ranges. Since the Model 661 can read to 0.5 microvolt, thermal emf's can introduce considerable errors into the measurements. In general, use pure copper leads throughout the system when measuring in the microvolt range. For extensive measurements in the microvolt region, request the article, DC Microvolt Measurements, from Keithley Instruments or its representative.

2-10. AC EFFECTS ON DC MEASUREMENTS. To minimize errors from ac signals present in the unknown voltage, the Model 661 employs a chopper-stabilized null detector operating at 42-cps chopping rate with a 3-section R-C filter at the input. Very large ac components on the measuring lines, however, may reduce off-null sensitivity. Also, heavy 60-cps pickup will be observed as needle quiver. If ac components affect measurements by the Model 661, additional filtering is required. For an ac signal of a single frequency, a twin-T filter is effective. For an ac variable frequency, use an ordinary low-pass filter.

Range	Input Resistance
500 volts	50 megohms
50 volts	50 megohms
5 volts	50 megohms
0.5 volt	50 megohms
100 volts	50 megohms
10 volts	50 megohms
1 volt	50 megohms
0.1 volt	10 megohms
10 millivolts	1 megohm
1 millivolt	1 megohm
0.1 millivolt	1 megohm

TABLE 4. Null Detector Input on DC Ranges.

SECTION 3. CIRCUIT DESCRIPTION

3-1. DC OPERATING CIRCUIT. The Model 661 Differential Voltmeter measures voltage by the potentiometric method. The ultra-stable 500-volt reference voltage supply (see Figure 4) is used with the 5-dial Kelvin-Varley divider to null the unknown voltage. The difference between the divider output and the unknown voltage is indicated by the null detector — a chopper-stabilized vacuum-tube voltmeter. At null the unknown voltage equals the reference voltage and can be directly read from the five in-line dials of the Kelvin-Varley divider. The input and null detector are fully guarded to avoid leakage.

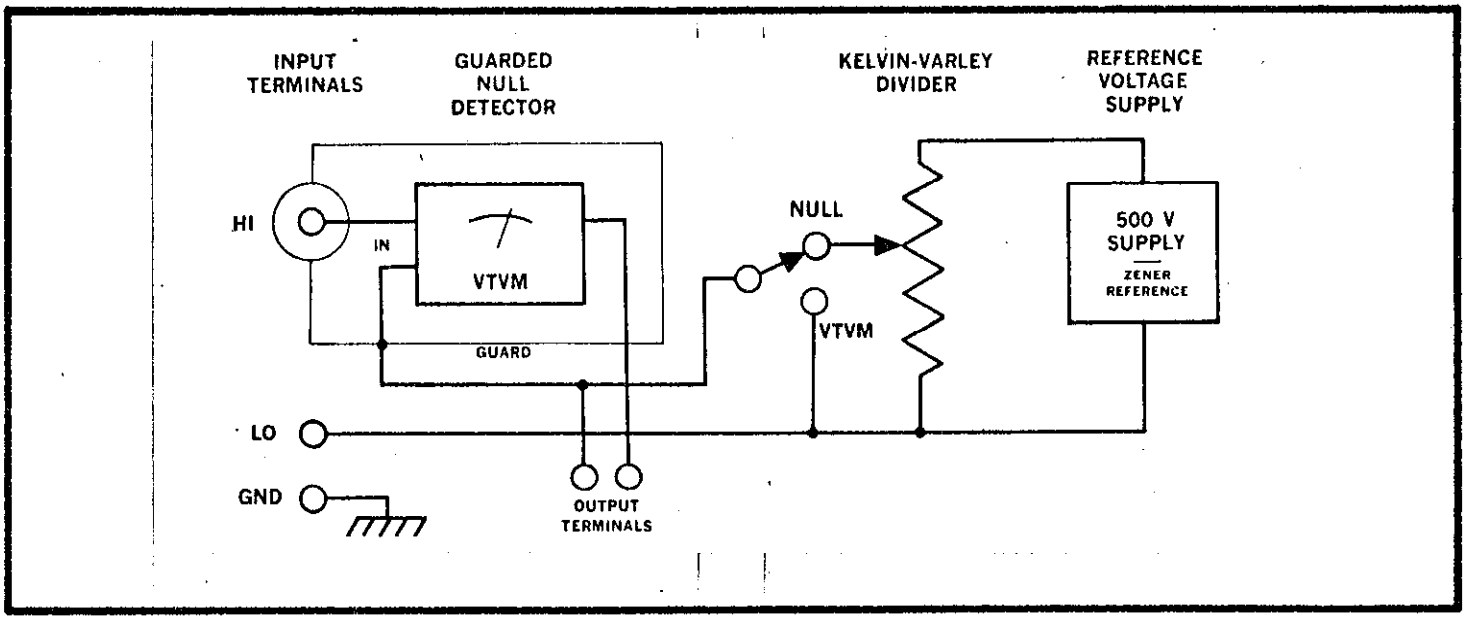


FIGURE 4. Simplified DC Circuit Diagram of the Model 661.

3-2. AC OPERATING CIRCUIT. The Model 661 uses much the same circuit in the ac operating mode as in the dc operating mode. The major difference is that the ac signal is converted to dc before it is compared to the reference voltage supply. See Figure 5. An ac attenuator reduces all ac input signals to one range — the 0.5-volt range. The ac converter converts the ac signal to a dc signal, equivalent to 5 volts dc at a full scale deflection. This signal is compared to the reference voltage supply output and compared by the null detector. The reference voltage supply operation for all ac ranges is equivalent to the 5-volt dc operating range.

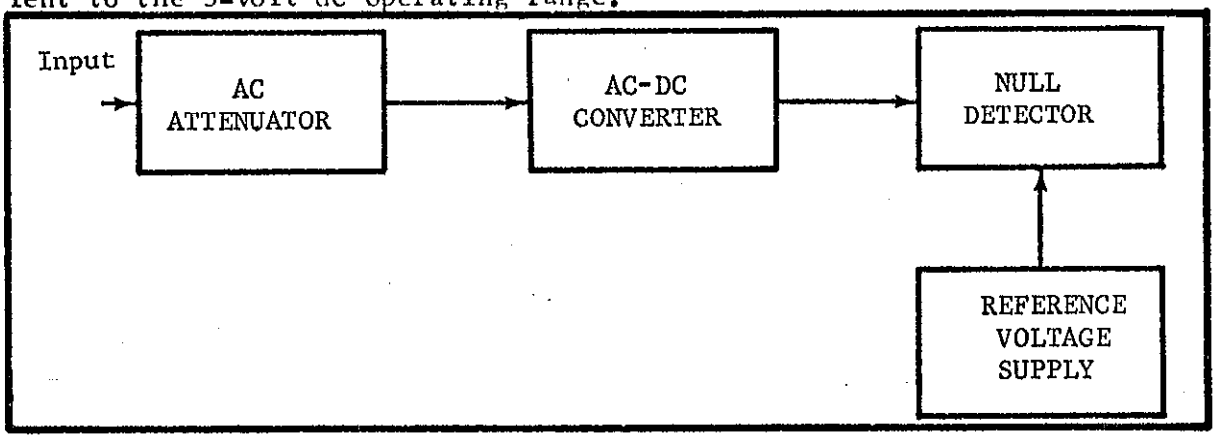


FIGURE 5. Simplified AC Circuit Diagram of the Model 661.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 661. 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 the address of the manufacturers listed in the "Mfg. Code" column are in Table 11.

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 from 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	milli (10^{-3})
		Mfg.	Manufacturer
CerD	Ceramic, disc	MtF	Metal Film
CerT	Ceramic, tubular	My	Mylar
Comp	Composition		
		p	pico (10^{-12})
DCb	Deposited Carbon	Poly	Polystyrene
EAl	Electrolytic, Aluminum	Ref.	Reference
EMC	Electrolytic, Metal Cased		
ETB	Electrolytic, tubular	μ	micro (10^{-6})
ETT	Electrolytic, tantalum	Ω	ohm
f	farad	v	volts
Fig.	Figure		
		w	watt
k	kilo (10^3)	WW	Wirewound
		WWVar	Wirewound Variable
M or meg	mega (10^6) or megohms		

TABLE 10. Abbreviations and Symbols

MODEL 661 REPLACEABLE PARTS LIST

(Refer to Schematic Diagrams 18759E, 18760E and 17342E)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C1001	0.1 µf	100 v	Poly	00656	1PJ-104J	C129-.1M	
C1002	0.1 µf	100 v	Poly	00656	1PJ-104J	C129-.1M	
C1003	605 µf	100 v	Poly	00656	1PJ-5035	C129-605M	
C1004	.05 µf	600 v	My	56289	6PS-S50	C62-.05M	
C1005	10 µf	15 v	ETB	56289	TE1155	C3-10M	
C1006	10 µf	15 v	ETB	56289	TE1155	C3-10M	
C1007	.002 µf	1000 v	CerD	72982	801Z5V202P	C22-.002M	
C1008	680 pf	1000 v	CerD	72982	801X5R681K	C22-680P	
C1009	40/20 µf	450 v	EMC	56289	TVL2762	C36-40/20M	
C1010	0.47 µf	600 v	My	14655	WMF6P47	C101-.47M	
C1011	.002 µf	1000 v	CerD	72982	801Z5V202P	C22-.002M	
C1012	10 µf	15 v	ETB	56289	TE1155	C3-10M	
C1013	.0047 µf	1000 v	CerD	72982	811Z5V472P	C22-.0047M	
C1014	1.0 µf	600 v	ETB	13050	Z4009	C12-1M	
C1015	125 µf	15 v	ETB	73445	C426	C3-125M	
C1016	4 µf	250 v	ETB	14655	BBR4-250	C27-4M	
C1017	600 µf	6 v	ETT	05079	TEZ600-6C2	C133-600M	
C1018	.05 µf	600 v	My	56289	6PS-S50	C62-.05M	
C1019	0.1 µf	100 v	Poly	00656	1PJ-104J	C129-.1M	
C2001	Not Used						
C2002	.01 µf	300 v	CerT	01884	MPX103K3	C61-.01M	
C2003	.01 µf	300 v	CerT	01884	MPX103K3	C61-.01M	
C3001	Not Used						
C3002	Not Used						
C3003	20 µf	450 v	EMC	37942	FP144	C36-20M	
C3004	40/20 µf	450 v	EMC	56289	TVL2762	C36-40/20M	
C3005	1.0 µf	1000 v	ETB	13050	Z4009B	C14-1.0M	
C3006	Not Used						
C3007	Not Used						
C3008	.002 µf	1000 v	CerD	56289	5GAD22	C72-.002M	
C3009	Not Used						
C3010	.05 µf	600 v	My	56289	6PS-S50	C62-.05M	
C3011	4 µf	250 v	ETB	14655	BBR4-250	C27-4M	
C3012	50 µf	6 v	ETB	56289	TE1100	C17-50M	
C3013	.0047 µf	1000 v	CerD	72982	811Z5V472P	C22-.0047M	
C3014	.022 µf	200 v	ETB	13050	MW1A	C6-.022M	
C3015	.05 µf	600 v	My	56289	6PS-S50	C62-.05M	

CAPACITORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C4001	10 pf	600 v	CerT	71590	TCZ	C77-10P	
C4002	100 µf	25 v	ETT	05079	W100-25C2U1	C96-100M	
C4003	1.0 µf	200 v	My	99120	AZ2-105Z	C119-1M	
C4004	.001 µf	1000 v	CerD	72982	801Z5V102P	C22-.001M	
C4005	.001 µf	1000 v	CerD	72982	801Z5V102P	C22-.001M	
C4006	56 µf	75 v	ETT	08804	69F-381-G7	C137-56M	
C4007	100 µf	25 v	ETT	05079	W100-25C2U1	C96-100M	
C4008	1.0 µf	200 v	My	99120	AZ2-105Z	C119-1M	
C4009	100 µf	15 v	EA1	56289	89D217	C93-100M	
C4010	100 µf	15 v	EA1	56289	89D217	C93-100M	
C4011	2 µf	200 v	My	13050	MW1A	C115-2M	
C4012	.001 µf	1000 v	CerD	72982	801Z5V102P	C22-.001M	
C5001	1.2-3.5 pf	850 v	Trimmer	74970	189-1-4	C121-1.2-3.5P	
C5002	1.2-3.5 pf	850 v	Trimmer	74970	189-1-4	C121-1.2-3.5P	
C5003	47 pf	600 v	CerT	80164		C123-47P	
C5004	1.2-3.5 pf	850 v	Trimmer	74970	189-1-4	C121-1.2-3.5P	
C5005	1.5 pf	600 v	CerT	80164		C123-1.5P	
C5006	2.2 pf	600 v	CerT	80164	301-034COHO229B	C123-2.2P	
C5007	18 pf	600 v	CerT	71590	TCZ-18	C77-18P	
C5008	820 pf	500 v	Mica	84171	DM19-821J	C97-820P	
C5009	820 pf	500 v	Mica	84171	DM19-821J	C97-820P	
C5010	0.25 µf	400 v	My	13050	SM1A	C73-.25M	
C5011	1.2-3.5 pf	850 v	Trimmer	74970	189-1-4	C121-1.2-3.5P	
C5012	1.5 pf	600 v	CerT	80164		C123-1.5P	
C5013	Not Used						
C5014	1.4-7.3 pf	850 v	Trimmer	74970	189-1-4	C121-1.4-7.3P	
C5015	4.7 pf	600 v	CerT	80164		C123-4.7P	
C5016	4.7 pf	600 v	CerT	80164		C123-4.7P	
C5017	Not Used						
C5018	2.2 pf	600 v	CerT	80164		C123-2.2P	
C5019	2.2 pf	600 v	CerT	80164		C123-2.2P	
C6001	40 µf						
C6002	.001 µf	1000 v	CerD	72982	801Z5V102P	C22-.001M	
C6003	1.0 µf						
C6004	0.25 µf	400 v	My	13050	SM1A	C73-.25M	
C6005	500/500 µf	150 v	EMC	53021	505-2603-01	C20-500-500	
C6006	330 pf	100 v	CerD	72982	831X5R331K	C22-330P	
C6007	2.7 µf	20 v	J	05397		C80-2.7M	
C6008	1000 µf	12 v	EMC	56289	DFP	C24-1000M	
C6009	40 µf	350 v	EMC	53021	505-1022-01	C19-40M	

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D1001	Silicon	1N645	01295	RF-14	
D3001	Silicon	1N3256	02735	RF-22	
D3002	Not Used				
D3003	Not Used				
D3004	Silicon	1N2378	08520	RF-25	
D3005	Silicon	1N3256	02735	RF-22	
D3006	Not Used				
D3007	Not Used				
D3008	Not Used				
D3009	Silicon	1N3157	12954	DZ-24	
D4001	Silicon	1N645	01295	RF-14	
D4002	Silicon	1N935	04713	DZ-7	
D4003	Zener	1N709	12954	DZ-21	
D4004	Not Used				
D4005	Silicon	1N914	01295	RF-28	
D4006	Zener	1N715	12954	DZ-22	
D4007	Silicon	1N914	01295	RF-28	
D6001	Silicon	1N3253	02735	RF-20	
D6002	Silicon	1N3253	02735	RF-20	
D6003	Silicon	1N3253	02735	RF-20	
D6004	Silicon	1N3253	02735	RF-20	
D6005	Zener	1N709	12954	DZ-21	
D6006	Zener	1N3027	12954	DZ-16	
D6007	Silicon	1N1563A	04713	RF-19	
D6008	Silicon	1N1563A	04713	RF-19	
D6009	Zener	1N709	12954	DZ-21	
D6010	Silicon	1N645	01295	RF-14	
D6011	Zener	17935	04713	DZ-7	

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
BT1001	Sodium Bias Cell 1.35 v (Mfg. No. PX-13)	37942	BA-16	
DS1001	Neon Lamp (Mfg. No. NE-P1)	08804	PL-6	
DS2001	Neon Lamp (Mfg. No. NE-2P)	08804	PL-2	
DS2002	Neon Lamp (Mfg. No. NE-2P)	08804	PL-2	
DS2003	Neon Lamp (Mfg. No. NE-2P)	08804	PL-2	
DS2004	Neon Lamp (Mfg. No. NE-2P)	08804	PL-2	
E1001a	Light Modulator	80164	1513	
E1001b	Light Modulator	80164	1513	
E1002a	Light Modulator	80164	1513	
E1002b	Light Modulator	80164	1513	
E1003a	Light Modulator	80164	1514	
E1003b	Light Modulator	80164	1514	
E3001a	Light Modulator	80164	1512	
E3001b	Light Modulator	80164	1514	
E3002a	Light Modulator	80164	1514	
E3002b	Light Modulator	80164	1514	
F1001(117v)	Fuse, slow blow, 1 amp (Mfg. Type MDL)	71400	FU-10	
F1001(234v)	Fuse, slow blow, 0.5 amp (Mfg. No. 312.500)	75915	FU-6	
----	Fuse Holder (Mfg. No. 342012)	75915	FH-3	
F6001	Fuse (Mfg. Type 361.002)	75915	FU-12	
----	Fuse Holder (Mfg. No. 387001)	75915	FH-1	
F6002	Fuse, fast acting (Mfg. No. 36101.5)	75915	FU-26	
----	Fuse Holder (Mfg. No. 387001)	75915	FH-1	
J1001	Binding Post (Mfg. No. PF31RC)	91407	BP-8R	
J1002	Binding Post (Mfg. No. PF31BC)	91407	BP-8B	
J1003	Binding Post (Mfg. No. PF31BC)	91407	BP-8B	
J1004	Binding Post (Mfg. No. PF31BC)	91407	BP-8B	
J4001	Connector		CS-167	
----	Connector			
J6001	Connector		CS-166	
----	Connector			
----	Shorting Link (Mfg. No. 938-L)	24655	BP-6	
M1001	Meter	80164	ME-38	

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
P1001	Cord Set, 6 feet (Mfg. No. 4638-13)	93656	CO-5	
S1001	Rotary Switch, less components, NULL	80164		
----	Knob assembly, Null	80164	14838A	
S3001	Rotary Switch, less components, FUNCTION	80164	SW-175	
----	Knob assembly, Function	80164	14838A	
S3002	Rotary Switch, less components, RANGE	80164	SW-191	
----	Knob assembly, Range	80164	17143A	
S3003	Rotary Switch, less components, Readout	80164	SW-174	
----	Rotary Switch, with components, Readout	80164	18810B	
----	Dial assembly, 0-4, Readout	80164	14827A	
S3004	Rotary Switch, less components, Readout	80164	SW-118	
----	Rotary Switch, with components, Readout	80164	18811B	
----	Dial assembly, 0-9, Readout	80164	14828A	
S3005	Rotary Switch, less components, Readout	80164	SW-170	
----	Rotary Switch, with components, Readout	80164	18817B	
----	Dial assembly, 0-9, Readout	80164	14828A	
S3006	Rotary Switch, less components, Readout	80164	SW-170	
----	Rotary Switch, with components, Readout	80164	18816B	
----	Dial assembly, 0-9, Readout	80164	14828A	
S3007	Rotary Switch, less components, Readout	80164	SW-174	
----	Rotary Switch, with components, Readout	80164	18810B	
----	Dial assembly, 0-10, Readout	80164	19185A	
S3008	Switch, lever SPST, ON	80164	17116A	
----	Rotary Switch, less components, METER ZERO	80164	RP19-15K	
----	Knob assembly, Meter Zero	80164	15110A	
T3001	Transformer	80164	TR-62	

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1001	50 MΩ	1%, 2 w	DCb	91637	DC-2	R14-50M	
R1002	1.5 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.5M	
R1003	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R1004	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-5K	
R1005	50 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-50K	
R1006	12.5 MΩ	1%, 1 w	DCb	91637	DC-1	R13-12.5M	
R1007	505 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-505K	
R1008	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R1009	470 kΩ	10%, 1/2 w	DCb	79727	CFE-15	R12-470K	
R1010	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R1011	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R1012	900 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-900K	
R1013	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R1014	15 kΩ	5%, 2 w	WWVar	12697	43C2	RP19-15K	
R1015	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R1016	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	
R1017	1.5 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5M	
R1018	200 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-200K	
R1019	1.5 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5M	
R1020	15 kΩ	10%, 1/2 w	Comp	01121	EB	R1-15K	
R1021	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R1022	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R1023	70 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-70K	
R1024	450 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-450K	
R1025	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R1026	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R1027	8.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-8.2K	
R1028	3.3 MΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3M	
R1029	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R1030	3.3 MΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3M	
R1031	1.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.2K	
R1032	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R1033	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R1034	12 kΩ	10%, 1/2 w	Comp	01121	EB	R1-12K	
R1035	1 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1K	
R1036	2 kΩ	1%, 1/2 w	WW	01686	E-30	R58-2K	
R1037	40 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-40K	
R1038	1.5 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5M	
R1039	4.7 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-4.7M	
R1040	500 Ω	10%, 5 w	WWVar	71450	AW	RP3-500	

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1041	80 Ω	1%, 1/2 w	WW	01686	E-30	R58-80	
R1042	1500 Ω	1%, 1/2 w	WW	01686	E-30	R58-1500	
R1043	200 Ω						
R1044	1 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1K	
R1045	450 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-450K	
R1046	1 kΩ	20%, .2 w	CompV	71450	CTS	RP31-1K	
R1047	1.14 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.14M	
R1048	100 MΩ	20%, 1/2 w	Comp	75042	GBT	R37-100M	
R2001	150 kΩ	10%, 1/2 w	Comp	01121	EB	R1-150K	
R2002	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R2003	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R2004	Not Used						
R2005	Not Used						
R2006	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R2007	150 kΩ	10%, 1/2 w	Comp	01121	EB	R1-150K	
R2008	50 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-50K	
R2009	150 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-150K	
R2010	50 kΩ	3%, 1/4 w	CbVar	80164		RP38-50K	
R2011	1.8 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.8M	
R2012	1.8 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.8M	
R2013	Not Used						
R2014	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R2015	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R3001	220 Ω	10%, 1/2 w	Comp	01121	EB	R1-220	
R3002	820 kΩ	10%, 1/2 w	Comp	01121	EB	R1-820K	
R3003	150 kΩ	10%, 1/2 w	Comp	01121	EB	R1-150K	
R3004	Not Used						
R3005	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3006	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3007	50 kΩ	10%, 2 w	Comp	01121	HB	R4A-50K	
R3008	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3009	Not Used						
R3010	Not Used						
R3011	Not Used						
R3012	Not Used						
R3013	Not Used						
R3014	Not Used						
R3015	Not Used						

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R3016	Not Used						
R3017	Not Used						
R3018	470 kΩ	10%, 1/2 w	Comp	01121	EB	R1-470K	
R3019	470 kΩ	10%, 1/2 w	Comp	01121	EB	R1-470K	
R3020	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3021	Not Used						
R3022	3.3 kΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3K	
R3023	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3024	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R3025	150 kΩ	10%, 1/2 w	Comp	01121	EB	R1-150K	
R3026	680 kΩ	10%, 1/2 w	Comp	01121	EB	R1-680K	
R3027	270 kΩ	10%, 1/2 w	Comp	01121	EB	R1-270K	
R3028	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R3029	5.6 kΩ	10%, 1/2 w	Comp	01121	EB	R1-5.6K	
R3030	65.4 kΩ	0.1%, 50 w	WW	91637	RH-50	R37-65.4K	
R3031	3 kΩ	10%, 1/2 w	Comp	01121	EB	R1-3K	
R3032	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M	
R3033	220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K	
R3034	125 kΩ	10%, 1/2 w	Comp	01121	EB	(1)	
R3035	200 Ω	10%, 2 w	WWVar	71450	P252-200	RP22-200	
R3036	125 kΩ	0.1%, 2 w	WW	80164		(1)	
R3037	4 kΩ	0.1%, 1/2 w	WW	80164		(1)	
R3038	1 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1K	
R3039	9 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-9K	
R3040	250 kΩ	0.1%, 1/2 w	WW	80164		(2)	
R3041	1 kΩ	10%, 5 w	WWVar	71450	AW	RP34-1K	
R3042	32.33 kΩ	0.1%, 1/2 w	WW	80164		(2)	
R3043	91 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-91K	
R3044	1 kΩ	10%, 5 w	WWVar	71450	AW	RP34-1K	
R3045	2.563 kΩ	0.1%, 1/2 w	WW	80164		(2)	
R3046	930 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-930K	
R3047	1 kΩ	10%, 5 w	WWVar	71450	AW	RP34-1K	
R3048	250.9 Ω	0.1%, 1/2 w	WW	01686	1250	(2)	
R3049	*	0.1%, 1/4 w	WW	01686	7009	R95-*	
R3050	*	0.1%, 1/4 w	WW	01686	7009	R95-*	
R3051 to R3056	40 kΩ			80164		(3)	

*Nominal value, factory set.
(1)R3034, R3036 and R3037 comprise a matched set, Keithley Part No. 15436A.
(2)R3040, R3042, R3045 and R3048 comprise a matched set, Keithley Part No. 15432A.
(3)Part of a Switch Assembly, Keithley Part No. 18810B.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R3057 to R3067	8 kΩ	.02%, 1/2 w	WW	80164		R100-8K	
R3068 to R3078	1.6 kΩ	.04%, 1/2 w	WW	80164		R99-1.6K	
R3079 to R3089	320 Ω	0.1%, 1/2 w	WW	01686	7044	R67-320	
R3090	750 Ω	±10%, 4 w	WWVar	12697	58M	RP49-750	
R3091	*	1%, 1/2 w	DCb	79727	CFE-15	R12-*	
R3092 to R3099	Not Used						
R3100	3.3 kΩ	10%, 1/4 w	Comp	01121	CB	R76-3.3K	
R4001	1.5 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.5M	
R4002	1.5 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5K	
R4003	348 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-348K	
R4004	3.33 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3.3M	
R4005	3.33 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3.3M	
R4006	1 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1K	
R4007	390 Ω	10%, 1/2 w	Comp	01121	EB	R1-390	
R4008	150 Ω	10%, 1/2 w	Comp	01121	EB	R1-150	
R4009	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-5K	
R4010	2 kΩ	10%, 1/2 w	WWVar	80294	30675-1-202	RP35-2K	
R4011	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M	
R4012	2.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2K	
R4013	10 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-10K	
R4014	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	
R4015	8.2 kΩ	10%, 1 w	Comp	01121	GB	R2-8.2K	
R4016	220 Ω	10%, 1/2 w	Comp	01121	EB	R1-220	
R4017	33 kΩ	10%, 1/2 w	Comp	01121	EB	R1-33K	
R4018	1.8 kΩ	10%, 2 w	Comp	01121	HB	R3-1.8K	
R4019	2.21 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-2.21K	
R4020	412 Ω	1%, 1/2 w	MtF	07716	CEC, T-9	R113-412	

*Nominal value, factory set.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R4021	57.6 Ω	1%, 1/2 w	MtF	07716	CEC, T-9	R113-57.6	
R4022	180 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-180K	
R4023	2.21 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-2.21K	
R4024	100 Ω	10%, 1/4 w	WW	80294	271-1-101	RP45-100	
R4025	Not Used						
R4026	1.2 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-1.2K	
R4027	*48 kΩ					R112-48K	
R4028	2.21 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-2.21K	
R4029	180 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-180K	
R4030	180 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-180K	
R4031	150 Ω	10%, 1/2 w	Comp	01121	EB	R1-150	
R4032	390 Ω						
R4033	47 Ω	10%, 2 w	Comp	01121	HB	R3-47	
R5001	909 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-909K	
R5002	110 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-110K	
R5003	5 kΩ	10%, 1/4 w	WW	80294	273-1-502	RP44-5K	
R5004	990 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-990K	
R5005	1 MΩ	.5%, 1/2 w	WW	01686	7020-HS	R118-1M	
R5006	9.76 kΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-9.76K	
R5007	500 Ω	10%, 1/4 w	WW	80294	273-1-501	RP44-500	
R5008	976 Ω	1%, 1/2 w	MtF	07716	CEC, T-9	R113-976	
R5009	1 kΩ	10%, 1/4 w	WW	80294	273-1-102	RP44-1K	
R5010	37.4 Ω	1%, 1/8 w	MtF	07716	CEA	R88-37.4	
R5011	1 MΩ	1%, 1/2 w	MtF	07716	CEC, T-9	R113-1M	
R6001	500 Ω	1%, 5 w	WW	91637	RS-5	R4A-500	
R6002	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R6003	1.5 kΩ	5%, 3 w	WW	44655	4400	R92-1.5K	
R6004	820 Ω	10%, 1/2 w	Comp	01121	EB	R1-820	
R6005	220 Ω	10%, 1/2 w	Comp	01121	EB	R1-220	
R6006	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K	
R6007	8.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-8.2K	
R6008	16.67 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-16.67K	
R6009	15 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-15K	
R6010	3 k	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R6011	1.5 Ω	1%, 5 w	WW	91637	RS-5	R4A-1.5	
R6012	330 Ω	5%, 3 w	WW	44655	4400	R92-330	
R6013	560 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-560	
R6014	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	
R6015	300 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-300	

*Nominal value, factory set.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R6016	3.3 kΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3K	
R6017	1.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.2K	
R6018	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	
R6019	4.7 kΩ	10%, 1/2 w	Comp	01121	EB	R1-4.7K	
R6020	200 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-200	
R6021	3 k	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R6022	600 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-600	

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q4001	2N963	01295	TG-27	
Q4002	2N706	16333	TG-28	
Q4003	2N2951	16333	TG-26	
Q4004	2N2951	16333	TG-26	
Q6001	2N2270	95303	TG-25	
Q6002	2N2270	95303	TG-25	
Q6003	A1294	73445	TG-29	
Q6004	A1294	73445	TG-29	
Q6005	2N1535	04713	TG-7	
Q6006	2N1183	02735	TG-11	
Q6007	2N1381	01295	TG-8	
Q6008	2N1381	01295	TG-8	
Q6009	2N1381	01295	TG-8	
Q6010	2N1381	01295	TG-8	

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V1001	7025	73445	EV-7025	
V1002	6CM8	00011	EV-6CM8	
V2001	12AU7	73445	EV-12AU7	
V3001	7025	73445	EV-7025	
V3002	7025	73445	EV-7025	
V3003	7025	73445	EV-7025	

*Nominal value, factory set.

VACUUM TUBES (Cont'd)

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V3004	6CM6	00011	EV-6CM6	
V3005	0G3	73445	EV-0G3	
V4001	7586	86684	EV-7586	

MODEL 6601A REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 16321B for circuit designations)

TERMINALS

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

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	2 MΩ	0.1%, 1 w	WW	54294	P116	R91-2M	
R102	2 MΩ	0.1%, 1 w	WW	54294	P116	R91-2M	
R103	2 MΩ	0.1%, 1 w	WW	54294	P116	R91-2M	
R104	2 MΩ	0.1%, 1 w	WW	54294	P116	R91-2M	
R105	2 MΩ	0.1%, 1 w	WW	54294	P116	R91-2M	
R106	200 Ω	10%, 2 w	WWVar	71450	AW	RP3-200	
R107	100 Ω	0.1% 1 w	WW	54294	P-36	R90-100K	
R108	*1 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1K	

*Nominal value, factory set.

00011	Sylvania Electric Products, Inc. Buffalo Operations of Sylvania Electronic Systems Buffalo, N. Y.	01121	Allen-Bradley Corp. Milwaukee, Wis.
		01295	Texas Instruments, Inc. Transistor Products Division Dallas, Texas
00656	Aerovox Corp. New Bedford, Mass.		

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

01686	RCL Electronics, Inc. Riverside, N. J.	37942	Mallory, P. R., and Co., Inc. Indianapolis, Ind.
01884	Dearborn Electronic Laboratories, Inc. Orlando, Fla.	44655	Ohmite Mfg. Co. Skokie, Ill.
02735	Radio Corp. of America Commercial Receiving Tube and Semiconductor Division Somerville, N. J.	53021	Sangamo Electric Co. Springfield, Ill.
		54294	Shallcross Mfg. Co. Selma, N. C.
04713	Motorola, Inc. Semiconductor Products Division Phoenix, Arizona	56289	Sprague Electric Co. North Adams, Mass.
05079	Transistor Electronics, Inc. Bennington, Vt.	58474	Superior Electric Co., The Bristol, Conn.
05397	Union Carbide Corp. Linde Division Kemet Dept. Cleveland, Ohio	71400	Bussman Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.
		71450	CTS Corp. Elkhart, Ind.
07716	International Resistance Co. Burlington, Iowa	71590	Centralab Division of Globe-Union, Inc. Milwaukee, Wis.
08520	Electronic Devices, Inc. North Ridgeville, Ohio	72982	Erie Technological Products, Inc. Erie, Pa.
08804	Lamp Metals and Components Department G. E. Co. Cleveland, Ohio	73445	Amperex Electronic Co. Division of North American Philips Co., Inc. Hicksville, N. Y.
12697	Clarostat Mfg. Co., Inc. Dover, N. H.	74970	Johnson E F Co. Waseca, Minn.
12954	Dickson Electronics Corp. Scottsdale, Ariz.	75042	International Resistance Co. Philadelphia, Pa.
13050	Potter Co. Wesson, Miss.	75915	Littelfuse, Inc. Des Plaines, Ill.
14655	Cornell-Dubilier Electric Corp. Newark, N. J.	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
16333	Motorola Inc. Solid State System Division Phoenix, Ariz.	80164	Keithley Instruments, Inc. Cleveland, Ohio
24655	General Radio Co. West Concord, Mass.		

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

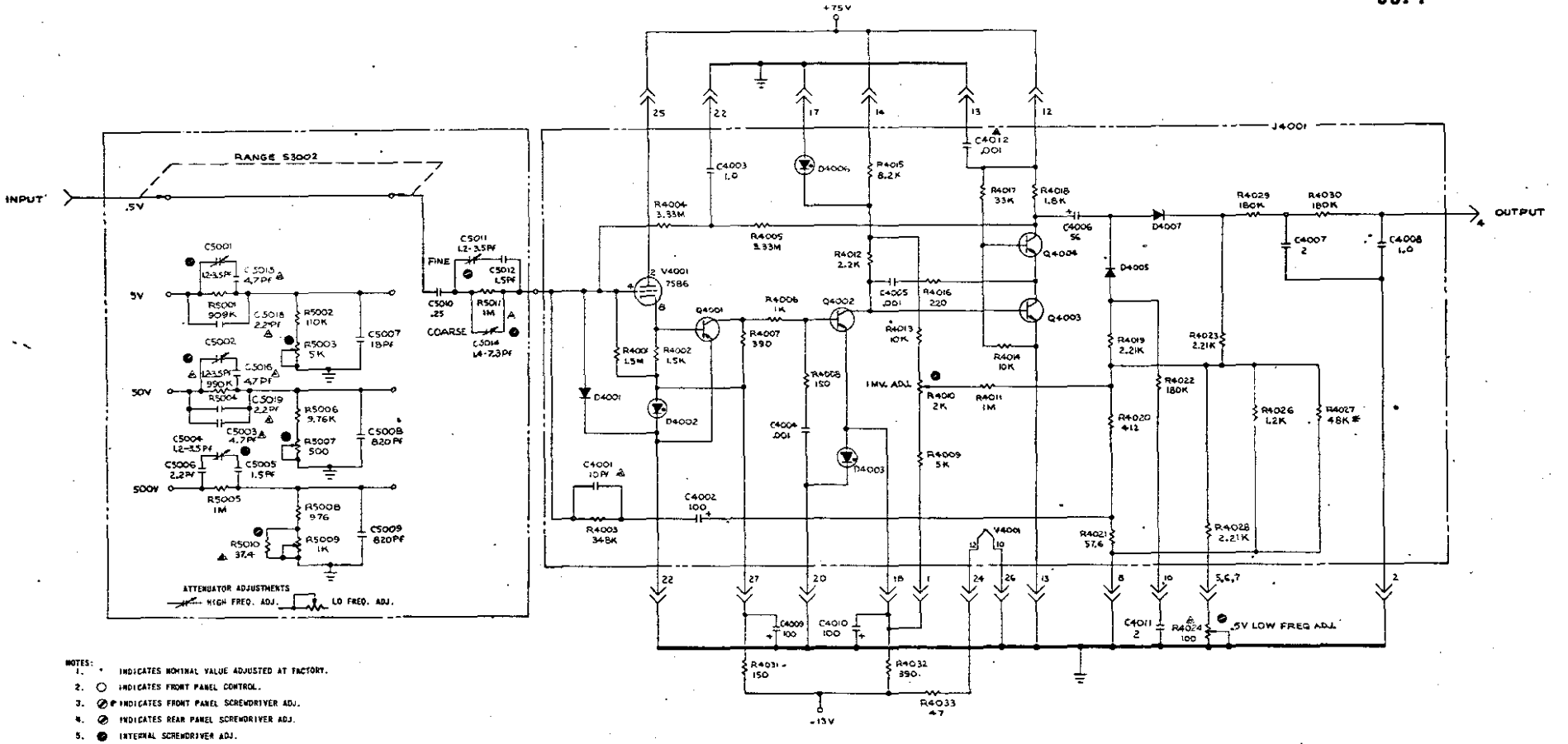
80294	Bourns Laboratories, Inc. Riverside, Calif.	91637	Dale Electronics, Inc. Columbus, Nebr.
84171	Arco Electronics, Inc. Great Neck, N. Y.	91737	Gremar Mfg. Co., Inc. Wakefield, Mass.
86684	Radio Corp. of America Electronic Components and Devices Harrison, N. J.	93656	Electric Cord Co. Caldwell, N. J.
91407	Superior Electric Co., The Oak Park, Ill.	95303	RCA Electron Tube Division of Radio Corp. of America Cincinnati, Ohio
		99120	Plastic Capacitors, Inc. Chicago, Ill.

TABLE 2 (Sheet 3). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

PRELIMINARY COPY

AC ATTENUATOR

AC CONVERTER



NOTES:

1. * INDICATES NOMINAL VALUE ADJUSTED AT FACTORY.
2. ○ INDICATES FRONT PANEL CONTROL.
3. ⊘ INDICATES FRONT PANEL SCREWDRIVER ADJ.
4. ⊘ INDICATES REAR PANEL SCREWDRIVER ADJ.
5. ⊘ INTERNAL SCREWDRIVER ADJ.
6. M MEGOHM
7. K 1000 OHM
8. pf PICOFARAD
9. ↻ CLOCKWISE ROTATION
10. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED.

HIGHEST REFERENCE DESIGNATION USED						REF. DESIGNATION NOT USED			
C4012	D4007	Q4004	R4033	S3002	J4001	D4006	R4035	C5013	
C5019			E5011		V4001			C5017	

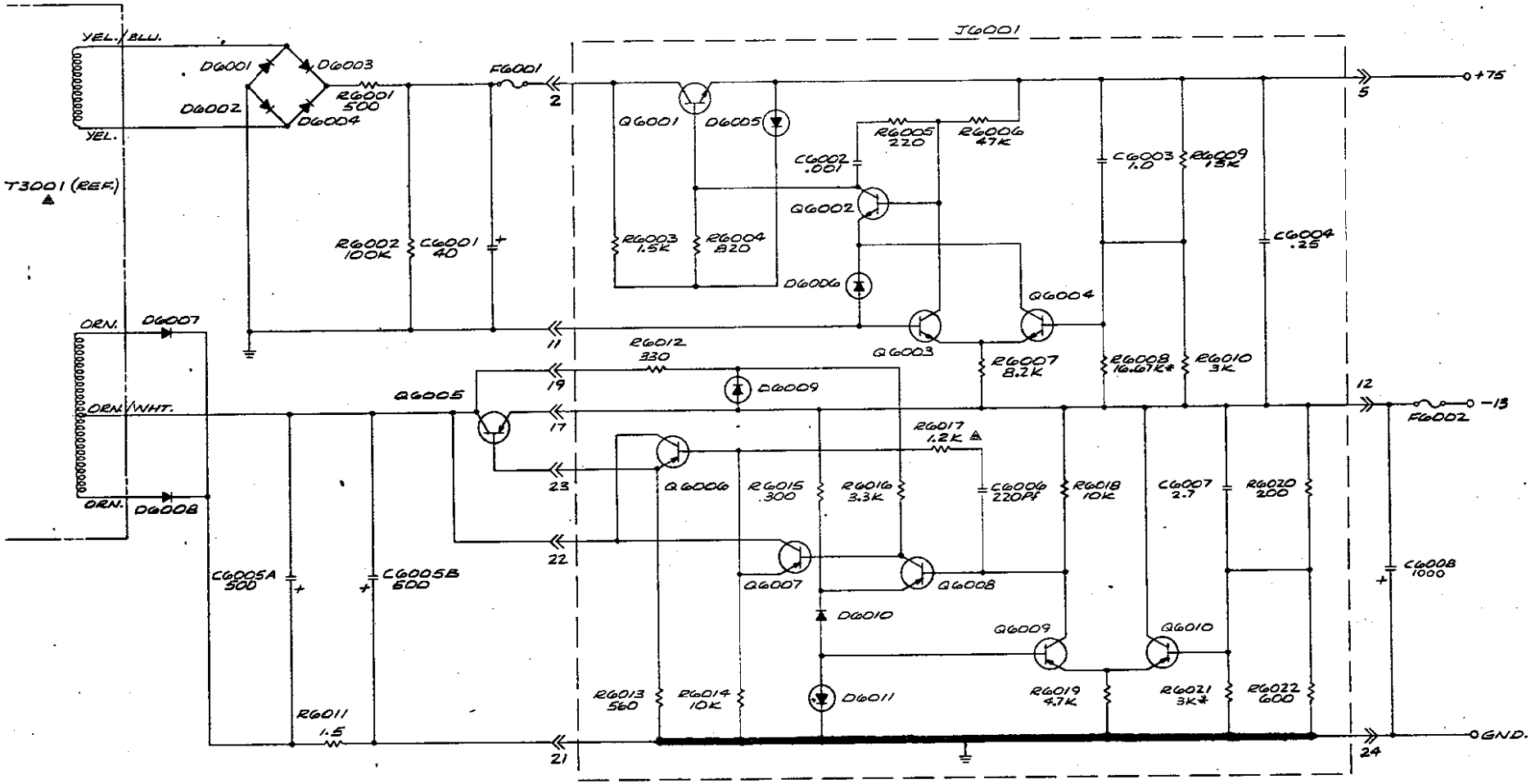
KEITHLEY INSTRUMENTS

SCHEMATIC

18-202

PRELIMINARY COPY

AC CONVERTER POWER SUPPLY



NOTES:

1. • INDICATES NOMINAL VALUE ADJUSTED AT FACTORY.
2. ○ INDICATES FRONT PANEL CONTROL.
3. ◐ INDICATES FRONT PANEL SCREWDRIVER ADJ.
4. ◐ INDICATES REAR PANEL SCREWDRIVER ADJ.
5. ◐ INTERNAL SCREWDRIVER ADJ.
6. M MEGOHM
7. K 1000 OHM
8. pf PICOFARAD
9. CLOCKWISE ROTATION
10. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED.

R6012
F6002
D6011
Q6010
C6008
J6001

DEFERENCE DESIG. NOT USED | HIGHEST REFERENCE DESIG. USED

KEITHLEY

5C