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SPECIFICATIONS

AS A VOLTMETER:

RANGE: 100 millivolts full scale (100 microvolts, least significant digit) to 100 volts in four decade ranges.

ACCURACY: ±0.2% of reading ±1 digit on all ranges exclusive of noise and drift.

ZERO DRIFT: Less than 1 millivolt in the first hour or subsequent 24-hour periods after 1-hour warm-up. Less than 150 microvolts per °C.

NOISE: ±1 digit with input shorted on most sensitive range.

INPUT IMPEDANCE: Greater than 10^{14} ohms shunted by 35 picofarads. Input resistance may also be selected in decade steps from 10 to 10^{11} ohms.

NMRR: Greater than 60 dB on the most sensitive range decreasing to 40 dB on the 100-volt range at line frequency.

AS AN AMMETER:

RANGE: 10^{-12} ampere full scale (10^{-15} ampere, least significant digit) to 0.1 ampere in 12 decade ranges.

ACCURACY: ±0.5% of reading, ±1 digit on 0.1 to 10^{-7} ampere ranges using optimum sensitivity control setting; ±2% of reading ±1 digit on 10^{-8} and 10^{-9} ampere ranges and ±4% of reading ±1 digit on 10^{-10} to 10^{-12} ampere ranges exclusive of noise and zero drift.

NOISE: ±4 digits with input open and shielded on most sensitive range.

OFFSET CURRENT: Less than 5 x 10^{-15} ampere.

AS AN OHMMETER:

RANGE: 10,000 ohms full scale (10 ohms, least significant digit) to 10^{14} ohms in eleven decade ranges.

ACCURACY: ±0.5% of reading, ±1 digit on 10^4 to 10^8 ohm ranges using optimum sensitivity control setting; ±4% of reading ±1 digit from 10^9 to 10^{14} ohms exclusive of noise and zero drift.

AS A COULOMBMETER:

RANGE: 10^{-11} coulomb full scale (10^{-14} coulomb, least significant digit) to 10^{-5} coulomb in seven decade ranges.

ACCURACY: ±5% of reading ±2 digits on all ranges. Drift due to offset current does not exceed 5 x 10^{-15} coulombs/second.

GENERAL:

DISPLAY: 4 digits from 0000 to 1999 on 0.1, 1.0, and 10.0 sensitivity settings; from 0000 to 999 on the 100.0 sensitivity setting.

POLARITY SELECTION & OVERLOAD INDICATION: Automatic.

OVERRANGING: 100% overranging on all ranges except when using sensitivity setting of 100.0.

DISPLAY RATE: 24 readings per second maximum (20 per second on 50 Hz models); adjustable to two readings per minute.

PRINTER OUTPUTS AND OUTPUT CONTROLS: Model 4401 accessory provides BCD output and external controls.

ISOLATION: Circuit ground to chassis ground: Greater than 10^6 ohms shunted by 0.2 microfarad. Circuit ground may be floated up to 100 volts with respect to chassis ground.

CMRR: For high open-circuit CMRR, residual unshielded capacitance between input high and chassis ground is less than 0.1 picofarad.

ANALOG OUTPUTS:

Unity gain: At dc, output is equal to input within 100 ppm, exclusive of noise and zero drift, for output currents of 100 microamperes or less.

1 mA: ±1 milliampere at up to 1 volt for full scale input, 100% overrange capability except on 100.0 sensitivity setting.

1 V: ±1 volt at up to 0.1 microampere for full scale input, 100% overrange capability except on 100.0 sensitivity setting.

CONNECTORS: Input: Teflon-insulated triaxial. Analog outputs: Unity Gain; Binding Posts. 1 mA; Switchcraft N113B. 1V; Amphenol 80 PC 2F. Printer output & controls: 50-pin Amphenol Micro-Ribbon.

DIMENSIONS, WEIGHT: 5¼" high x 19" wide x 10" deep (132 x 433 x 280 mm); net weight, 20 pounds (9,1 kg).

POWER: 105-125 or 210-250 volts (switch selected), 60 Hz; 50 Hz models available. 35 watts.

ACCESSORIES SUPPLIED:
Model 6011 Input Cable: 30" triaxial cable with triaxial connector and 3 alligator clips.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 615 Digital Electrometer is a fast, accurate and sensitive Electrometer with digital display. It is a versatile, completely solid-state instrument which measures a wide range of d-c voltage, current, resistance and charge. The Electrometer's input resistance of greater than 10^{14} ohms is the result of extensive instrument development with high input impedance transistors. The Model 615 has all the capabilities of conventional VTVMs, but it can also make many more measurements without circuit loading.

b. The Electrometer has four decade voltage ranges from 0.100 volt full scale to 100 volts, 12-decade current ranges from 10^{-12} ampere full scale to 0.1 ampere, 11 decade linear resistance ranges from 10^4 ohms full scale to 10^{14} ohms, and seven decade charge ranges from 10^{-11} coulomb full scale to 10^{-5} coulomb.

c. The Model 615 employs matched insulated-gate field-effect transistors followed by a transistor differential amplifier and complimentary output stage. A large amount of negative feedback is used for stability and accuracy.

1-2. FEATURES.

a. Unique input circuit provides overload protection up to 500 volts on most ranges without damage.

b. Time stability is better than 1 millivolt/day after 1-hour warmup. Less than 150 microvolts per °C zero drift with temperature.

c. Offset current less than 5×10^{-15} amperes minimizes zero offset with high source resistance.

d. A front panel ZERO CHECK Switch permits checking zero-offset without disturbing the measurement circuit.

e. Operation up to ±100 volts above case ground is possible without affecting the reading. Isolation from circuit low to case ground is greater than 10^6 ohms shunted by 0.2 microfarad.

f. Analog output provided for 1 mA full scale recorders such as the Keithley Model 370 Recorder or other floating instrument.

g. Digital display enables voltage measurements to ±0.2% of reading ±1 digit.

h. Polarity is automatically indicated on the display.

i. Display rate is adjustable from 24 readings per second to two readings per minute to accommodate the mode of data retrieval.

j. Analog-to-digital converter is a dual slope integrating type circuit to provide immunity to line power frequency pickup.

k. Model 4401 Printer Output Cards are available for factory or user installation. This option provides BCD outputs for significant digits, range, polarity, sensitivity and overrange. Various remote control lines are also provided. The Output Buffer cards are easily inserted into prewired, premounted card-edge connectors on the Model 615 chassis.

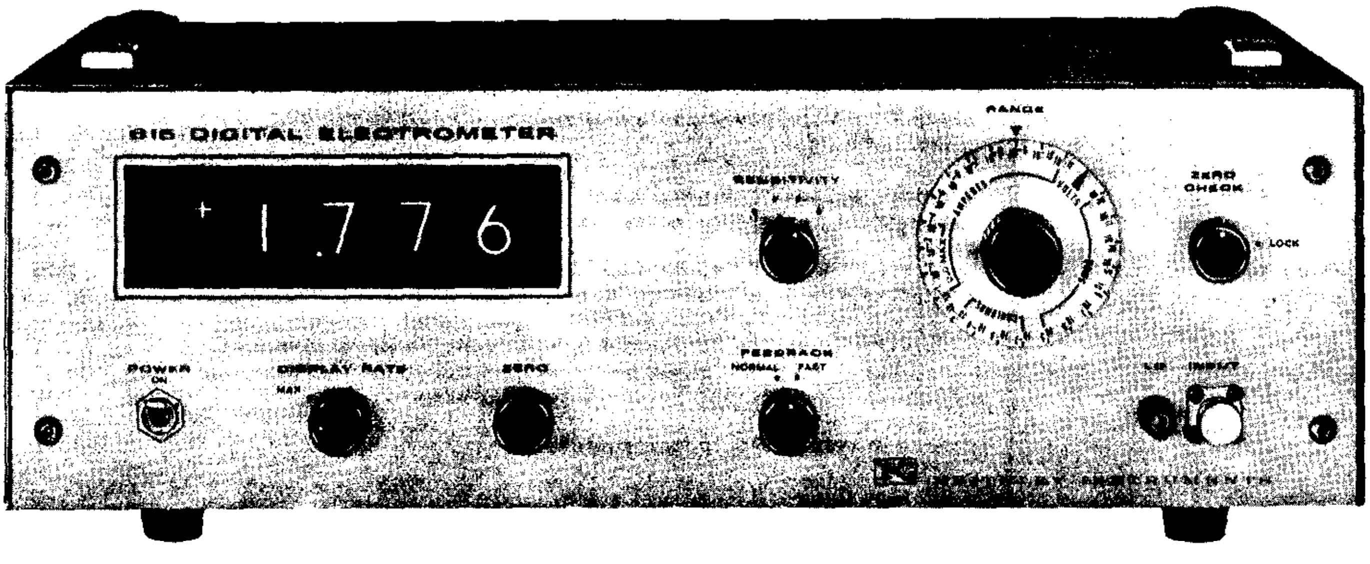


TABLE 2.
Model 615 Front Panel Controls and Terminals (Figures 1 & 3).

Control	Functional Description	Par.
SENSITIVITY Switch	Selects full-scale voltage sensitivity; also used to multiply current, resistance and charge ranges on the Range Switch. Automatically selects the proper decimal point position.	2-2,2-3
RANGE Switch	Selects the mode which is to be measured; voltage, current, resistance or charge.	2-2,2-3
FEEDBACK Switch	Selects either NORMAL or FAST modes of operation.	2-2,2-4,2-5
POWER Switch	Controls a-c line power to instrument (on/off).	2-2
DISPLAY RATE Control	Determines number of analog-to-digital conversions per second.	2-3
ZERO Control	Provides fine zero control adjustment.	2-2
ZERO CHECK Switch	Provides zero offset check without disturbing the source circuit.	2-2
INPUT Receptacle	Connects source to input. Receptacle is a Teflon insulated triaxial connector.	2-1
LO TERMINAL	Provides connection to input low.	2-1
±Display Lights	Indicates polarity of input signal.	2-3
Numerical Readout	Indicates magnitude of input signal.	2-3

TABLE 3.
Model 615 Rear Panel Controls and Terminals (Figure 2).

Control	Functional Description	Par.
COARSE ZERO Switch	Provides extended adjustment capability of the front panel ZERO Control.	2-2
1 MA OUTPUT Receptacle	Connects analog output to monitoring device.	2-9
PRINTER/CONTROL Connector	50 pin connector for BCD digital output: provides printer control and remote control when Model 4401 printer output cards are installed.	2-10
SPARE Receptacle	Blank hole with cover plate for mounting additional 50 pin connector.	---
X1 OUTPUT and GUARD Terminals	Provides extremely linear unity gain operation. Also used for guarded resistance measurements.	2-9
CASE GROUND Terminal	Connected to Model 615 cabinet and outside shell of input connector.	2-6
LO Terminal	Provides connection to input low and front panel LO connection.	2-6
1 VOLT OUTPUT	Provides 1 volt output for calibration purposes.	2-9
Line Cord	Connects line power to instrument.	2-2
Fuse	3 AG Slow Blow. 117 volt - 3/4 A. 234 volt - 3/8 A.	2-2
117-234V Switch	Sets instrument for either 117 or 234 volt a-c power operation.	2-2

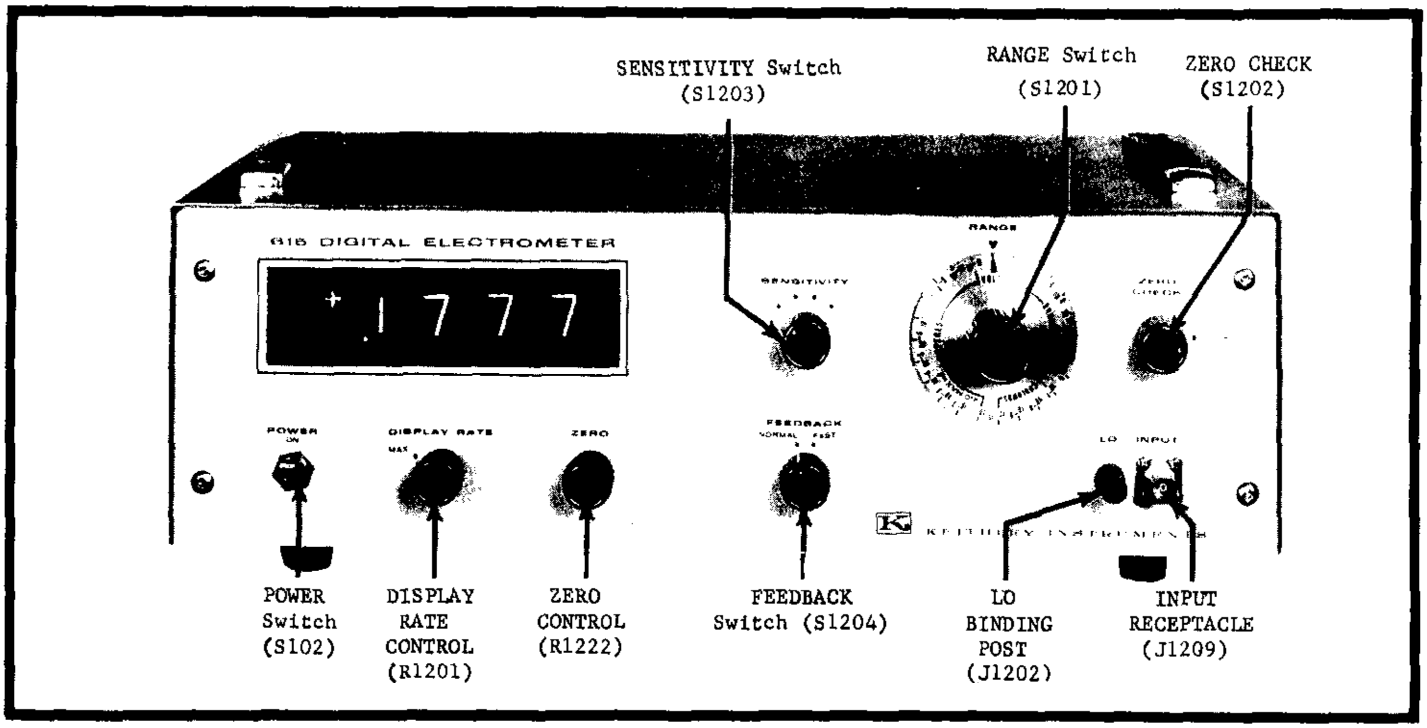


FIGURE 1. Model 615 Front Panel Controls and Terminals.

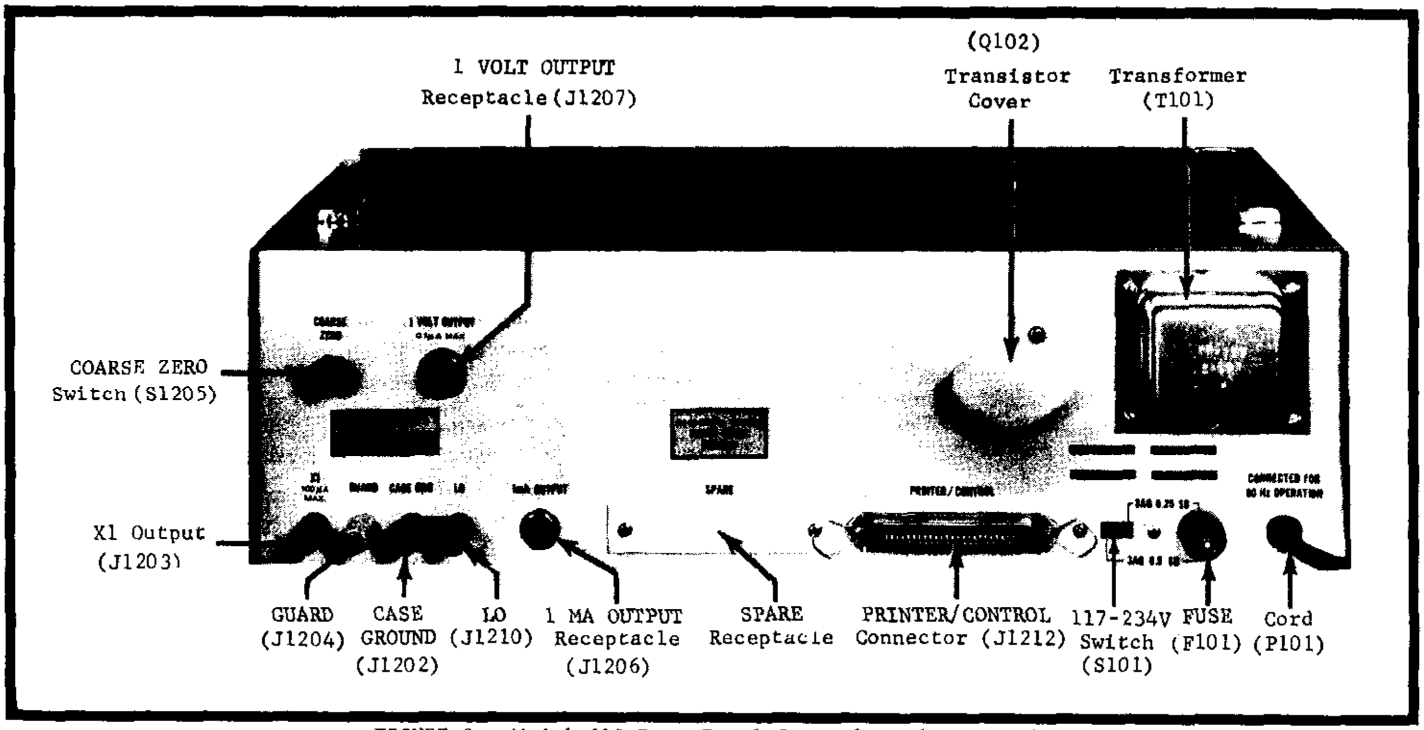


FIGURE 2. Model 615 Rear Panel Controls and Terminals.

SECTION 2. OPERATION

2-1. INPUT CONNECTIONS.

a. The INPUT Receptacle of the Model 615 is a Teflon insulated triaxial connector. The center terminal is the high impedance terminal; the inner shield is the low impedance terminal; the outer shield is case ground. (See Figure 3).

b. The front panel LO Terminal is connected to the inner shield or low impedance terminal. The LO Terminal is connected to the rear panel LO Terminal. When the shorting link on the rear panel is connected, the LO is connected to case ground.

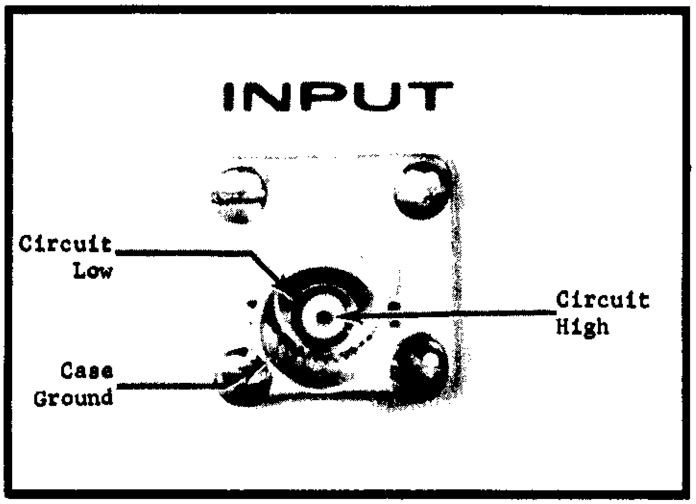


FIGURE 3. Model 615 Triaxial Input Receptacle.

c. The Model 6011 Input Cable (provided) is a 30" triaxial cable with triaxial connector and 3 alligator clips. See Table 4 for color coding of the alligator clips. The high impedance terminal is shielded by the inner braid of the triaxial cable up to the miniature alligator clip.

TABLE 4.
Color Coding of Alligator Clips for Model 6011 Input Cable.

Lead	Circuit	Terminal
heavy wire with red clip cover	Input high	Center
thin wire with black clip cover	Input low	Inner Shield
thin wire with green clip cover	Case Ground	Outer Shield

d. Carefully shield the input connection and the source being measured, since power line frequencies are well within the pass band of the Electrometer on all ranges. Unless the shielding is thorough, pickup may cause definite readout disturbances.

e. Use high resistance, low-loss materials - such as polyethylene, polystyrene or Teflon - for insulation. The insulation resistance of test leads and fixtures should be several orders of magnitude higher than the source resistance. Excessive leakage will reduce accuracy. Use a low-noise type cable which employs a graphite coating between the dielectric and the surrounding shield braid.

f. Any change in the capacitance of the measuring circuit to ground will cause disturbances in the reading, especially on the more sensitive ranges. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. If a continuous vibration is present, it may appear at the output as a sinusoidal signal and other precautions may be necessary to isolate the instrument and the connecting cable from the vibration.

NOTE

Clean, dry connections and cables are very important to maintain the value of all insulation materials. Even the best insulation will be compromised by dirt, dust, solder flux, films of oil or water vapor. A good cleaning agent is methyl alcohol, which dissolves most common dirt without chemically attacking the insulation. Dry the cables or connections after washing with alcohol or dry nitrogen if available. If available, Freon is an excellent cleaning agent.

g. The accessories described in Section 7 are designed to increase the accuracy and convenience of input connections. Use them to gain maximum capability of the Model 615.

h. For low impedance measurements — below 10^8 ohms or above 10^{-8} ampere — unshielded leads may be used.

i. When the Model 615 is used on the most sensitive current range with the FEEDBACK Switch at FAST, some insulators — such as Teflon — may produce random signals which show up as erratic readout deflections. Insulation used in the Model 615 is carefully selected to minimize these spurious signals.

j. It is advantageous to connect the Model 615 input to the source only when a reading is to be made. Use a high impedance transfer switch and well shielded chamber if available.

NOTE

In some cases, the offset current can charge the external test circuitry. One example of this occurs when measuring a capacitor's leakage resistance by observing the decay of the terminal voltage. If the leakage current is less than the offset current (less than 5 x 10^{-15} ampere), there may be no decay of the terminal voltage when the Electrometer is left connected across the capacitor's terminals.

k. The Model 6012 Triaxial-to-Coaxial Adapter enables using coaxial cables and accessories with the Model 615 by adapting the triaxial INPUT connector to the UHF coaxial type.

CAUTION

The Adapter connects circuit low to case ground. The Model 615 cannot be used off-ground when using the Adapter. The instrument cabinet will be at the same potential as the input low.

NOTE

Keep the shield cap (provided) on the INPUT Receptacle when the Electrometer is not in use to prevent overloads due to external noise pickup.

2-2. PRELIMINARY OPERATING PROCEDURES.

a. Check the 117-234V Switch for the proper AC line voltage.

b. Check for proper rated fuse.

c. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	VOLTS
SENSITIVITY Switch	Fully Clockwise Position
FEEDBACK Switch	NORMAL
POWER Switch	OFF

d. Connect the power cord. Place POWER Switch to ON position. After one-half hour warm-up, adjust the ZERO Control if necessary. Zero is indicated by continuously flashing ± polarity lights.

NOTE

The rear panel COARSE ZERO Control may be adjusted if a large zero offset is indicated.

e. After a few moments increase the voltage sensitivity by advancing the Switch to one position counterclockwise. Continue zeroing with the FINE ZERO Control.

f. The Model 615 may have excessive drift or zero offset after long periods of storage or after an overload. This may be corrected with the zero controls although drifting may continue for several hours.

NOTE

If the Model 615 has been stored for a long time, the offset current may exceed the specification when first used, but should decrease to below the specified amount after one or two hours of use. This is an inherent characteristic of the input transistors; the instrument is not faulty.

g. Although the offset current of the Electrometer is much below that found in conventional voltmeters, it can be observed on the readout since the offset current charges the input capacitance, the Electrometer appears to drift when the input is open. Use the ZERO CHECK Button to discharge the charge build-up.

h. Follow the particular procedures in paragraphs 2-3 to 2-7 for measuring voltage, current, resistance, and charge.

2-3. DIGITAL READOUT OPERATION.

a. Voltmeter Digital Readout.

1. When the RANGE Switch is placed in the VOLTS position, the Electrometer digital readout designates the actual voltage measured using four numerical digit readouts.

2. The SENSITIVITY Switch has four positions which control the lighted decimal point location and therefore the full scale voltage range. The full scale voltage range for each SENSITIVITY Switch position is shown in Table 5.

TABLE 5.

Range Volts	SENSITIVITY Switch Position	Decimal Point Position
0.1	Position 1 (fully counterclockwise)	.XXXX
1	Position 2	X.XXX
10	Position 3	XX.XX
100	Position 4 (fully clockwise)	XXX.X

3. The fourth (left most digit) readout permits an overrange display. The largest reading that can be displayed using all four digit readouts is 1999. If there is'an overload condition, then all readouts will blank (none of the digital readout tubes will be lighted). The polarity (±) display indica-

tors remain lighted during an overload condition indicating the correct polarity. Thus the Electrometer display will indicate correctly within specifications with no ambiguous overload display.

4. To remove the overload condition, change the SENSITIVITY Switch setting or decrease the input signal magnitude.

b. Ammeter Digital Readout.

1. When the RANGE Switch is placed in the AMMETER position, the Electrometer digital readout designates the voltage across an accurately known self-contained resistor. The RANGE Switch selects the calibrated range resistor for current measurements from 10^{-1} to 10^{-11} amperes. The range resistor is the reciprocal value of the Range setting. The readout indicates the voltage across the Range resistor.

2. The full scale current range is determined by multiplying the Range setting times the digital readout display. The SENSITIVITY Switch operates in the same fashion as for voltmeter measurements. (Refer to preceding paragraph 2-3, a).

3. The full scale current range for various front panel control settings is shown in Table 6.

TABLE 6.

Full Scale Range Amperes	RANGE Switch Setting	SENSITIVITY Switch Setting	Digital Readout
10^{-12}	10^{-11}	Position 1	.XXXX
10^{-11}	10^{-10}	Position 1	.XXXX
10^{-11}	10^{-11}	Position 2	X.XXX
10^{-10}	10^{-10}	Position 2	X.XXX
10^{-10}	10^{-9}	Position 1	.XXXX

c. Ohmmeter Readout.

1. When the RANGE Switch is placed in the OHMS position, the Electrometer digital readout designates the actual voltage across the unknown resistor as an accurately known current (internal to the Electrometer) is applied to the unknown.

2. The RANGE Switch selects the current for OHMS measurements. The current is the reciprocal value of the OHMS range setting from 10^5 to 10^{12} ohms. The SENSITIVITY Switch operates in the same fashion as for voltmeter measurements.

3. The actual resistance measurement is determined by multiplying the RANGE Switch setting times the digital readout display.

d. Coulombmeter Readout.

1. When the RANGE Switch is placed in the COULOMBS position, the Electrometer digital readout designates the actual voltage across a self-contained accurately known capacitor since the Electrometer is sensitive to the integral of the current applied from the external unknown source.

2. The coulomb measurement is determined by multiplying the RANGE Switch setting times the digital readout display.

e. DISPLAY RATE Control. (This control is a continuously variable control that permits the user to select the rate of analog-to-digital conversion). That is, the control determines the number of times a new reading will be recomputed per unit of time. This is useful for sampling a continuously varying input current as well as for controlling slower external devices such as paper tape punches and printers. With the DISPLAY Control in the MAX Position the display rate is 24 times per second (20 for 50 Hz models). When the control is varied clockwise, the rate decreases to a minimum of about 2 per minute in the extreme clockwise position. The front panel DISPLAY RATE Control applies to the digital circuitry only.

2-4. VOLTAGE MEASUREMENTS.

a. The Model 615 can measure an unknown voltage when the low impedance terminal is up to 100 volts off case ground. Safe operation of the Electrometer is insured by grounding the case. To use the Model 615 for off ground voltage measurements, disconnect the shorting link between LO and CASE GND Terminals on the rear panel. (Refer to Figure 2).

CAUTION

Operating the Model 615 at more than 100 volts off ground may permanently damage the instrument. The isolation between circuit low and ground could break down making the instrument unusable for safe off ground measurements.

Refer to Paragraph 2-6 for complete instructions for making off ground measurements.

b. The Model 615 has been designed to measure voltages up to 100 volts from very high resistance sources. However, the Model 615 can also be used for measurements from low source resistance and voltages up to 30 kilovolts with high voltage divider probe.

1. The input resistance can be decreased in order to reduce the effects of stray pickup with low source resistances. Refer to Paragraph 2-4, f for complete instructions.

2. For measurements of voltage up to 30 kilovolts refer to Paragraph 2-4, g which describes various divider probes available from Keithley.

c. The Model 615 can measure voltages in two modes: Normal Mode and Fast Mode.

1. Normal Mode. In the Normal Mode — FEEDBACK Switch at NORMAL — the unknown voltage is connected to the INPUT Receptacle. Input impedance with the RANGE Switch in VOLTS position is greater than 10^{14} ohms shunted by 35 picofarads.

2. Fast Mode. In the Fast Mode — FEEDBACK Switch at FAST — the effects of input cable capacitance may be reduced for measurements from very high source resistances. Guarded voltage measurements may also be made.

d. Normal Mode Voltage Measurements.

1. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	VOLTS
SENSITIVITY Switch	Fully Clockwise
FEEDBACK Switch	NORMAL

NOTE

To make off ground measurements, refer to Paragraph 2-6.

2. Connect the Model 6011 Triaxial Input Cable to the unknown voltage as follows:

a) The heavy wire with red clip cover should be connected to the source high potential.

b) The thin wire with black clip cover should be connected to the source low potential.

c) The thin wire with green clip cover should not be connected when the shorting link between LO and CASE Terminals on the rear panel is connected.

3. Unlock the ZERO CHECK Button to make a measurement.

4. Adjust the SENSITIVITY Switch counterclockwise to increase the Model 615 sensitivity. Readjust the ZERO control as necessary after each change in sensitivity.

5. The voltage measured is indicated directly on the digital display with the decimal point automatically indicated. The polarity is automatically indicated corresponding to the potential of the Electrometer input high with respect to input low.

NOTE

The Model 615 has 100% overranging on all ranges except for the 100 volt full range sensitivity. An overload on any range is indicated by a blanked digital display, a feature which averts erroneous readings when 200% of full range is exceeded. The digital display is lighted when the overload is removed.

e. Fast Mode Voltage Measurements.

1. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	VOLTS
SENSITIVITY Switch	Fully Clockwise
FEEDBACK Switch	FAST

NOTE

To make off ground measurements, refer to Paragraph 2-6.

2. Connect the Model 6011 Triaxial Input Cable to the unknown voltage as follows:

a) The heavy wire with red clip cover should be connected to the source high potential.

b) The thin wire with black clip cover should not be connected to source low. Instead, connect the shorting link between CASE GND and GUARD Terminals.

c) The thin wire with the green clip cover should be connected to circuit low.

NOTE

The low impedance input of the Model 615 may be connected for use as a guard between the source high and low circuits.

3. Unlock the ZERO CHECK Button to make a measurement.

4. Adjust the SENSITIVITY Switch counterclockwise to increase the Model 615 sensitivity. Readjust the zero setting as necessary after each change in sensitivity.

5. The voltage measured is indicated directly on the digital display with the decimal point automatically indicated. The polarity is automatically indicated corresponding to the potential of the Electrometer input high with respect to Guard.

f. Voltage Measurements From Low Resistance Sources. When the input resistance of the Model 615 is reduced, the Electrometer measurement will be less sensitive to stray electric fields for an open input. To decrease the Electrometer input resistance, set the front panel controls as follows:

RANGE Switch	10^{-11} AMPERES
FEEDBACK Switch	NORMAL

The input resistance is then the reciprocal value of the current range in ohms or 10^{11} ohms as in this example. The input resistance may be selected over the range 10 ohms to 10^{11} ohms using this technique. The full range voltage is selected by adjusting the SENSITIVITY Switch. The voltage measured is indicated directly on the digital display with the decimal point automatically indicated. Connect the electrometer input cable as stated in Paragraph 2-4, d.

g. Voltage Measurements Up to 30 Kilovolts.

1. Model 6102A 10:1 Divider Probe for measurements up to 1000 volts. This probe permits measurements with overall accuracy of ±4%. Input resistance is 10^{10} ohms maximum. The actual voltage is obtained by multiplying the Electrometer digital display times the divider ratio.

2. Model 6103A Divider Probe for measurements up to 30 kilovolts. This probe permits measurements with overall accuracy of ±6%. Input resistance is 10^{12} ohms maximum. The actual voltage is obtained by multiplying the Electrometer digital display times the divider ratio.

NOTE

The Model 6012 Triaxial-to-Coaxial Adapter must be used with Models 6102A and 6103A since the probes are terminated with a UHF connector. When using the Model 6012, the case ground is connected to input low so that the Electrometer may not be used for off ground measurements.

2-5. CURRENT MEASUREMENTS.

a. The Model 615 can measure an unknown current when the low impedance terminal is up to 100 volts off case ground. Safe operation of the Electrometer is insured by grounding the case. To use the Model 615 for off ground current measurements, disconnect the shorting link between LO and CASE GND Terminals on the rear panel. (Refer to Figure 2).

CAUTION

Operating the Model 615 at more than 100 volts off ground may permanently damage the instrument. The isolation between circuit low and ground could break down making the instrument unusable for safe off ground measurements.

Refer to Paragraph 2-6 for complete instructions for making off ground measurements.

b. The Model 615 can measure currents in two modes: Normal Mode and Fast Mode.

1. Normal Mode. In the Normal Mode — used on any range — the current is determined by measuring the voltage drop across a self-contained resistor shunting the electrometer amplifier input. This method permits a minimum noise measurement when response speed is not critical.

2. Fast Mode. In the Fast Mode — for use only below 10^{-5} ampere range — a self contained resistor is connected between the electrometer amplifier input and output (in the feedback loop). This method permits faster response speed since the effect of input capacitance is minimized. The input voltage drop is reduced to less than 100 microvolts on any range. Refer to Table 7 for typical Response and Noise performance for various values of input capacitance.

c. Normal Mode Current Measurements.

1. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	10^{-1} AMPERES
SENSITIVITY Switch	Fully Counterclockwise
FEEDBACK Switch	NORMAL

NOTE

To make off ground measurements, refer to Paragraph 2-6.

2. Connect the Model 6011 Triaxial Input Cable for measuring an unknown current as follows.

a) The heavy wire with red clip cover should be connected to the source high potential.

b) The thin wire with black clip cover should be connected so as to place the Electrometer in series with the current to be measured.

c) The thin wire with green clip cover should not be connected when the shorting link between LO and CASE GND Terminals on the rear panel is connected.

3. Unlock the ZERO CHECK Button to make a measurement.

4. Adjust the RANGE Switch to increase the Electrometer sensitivity for current measurements.

5. The full range current for the Electrometer is determined by multiplying the digital display times the RANGE Switch setting. The best accuracy for current measurements is obtained by using a

TABLE 7.
Typical Effects of External Input Capacitance on Response Speed and Noise Performance in Current Measurements with the Model 615.

Range	Rise Time (Seconds)			Output Noise (Peak-to-Peak)		
	No C	50pF	5000pF	No C	50pF	5000pF
10^{-14} to 10^{-11}	2.0	2.0	2.0	6×10^{-15}	1.5×10^{-14}	7×10^{-13}
10^{-10}	.45	.45	.45	8.5×10^{-14}	2×10^{-13}	2.5×10^{-12}
10^{-9}	.07	.07	.07	6.8×10^{-13}	3.2×10^{-12}	2×10^{-11}
10^{-8}	.015	.015	.015	6×10^{-12}	2.5×10^{-11}	2×10^{-10}
10^{-7}	.003	.003	.003	4×10^{-11}	8×10^{-11}	3×10^{-10}
10^{-6}	.003	.003	.003	1.5×10^{-10}	3.3×10^{-10}	8.5×10^{-10}

SENSITIVITY Switch setting which permits the use of the smallest value range resistor. The range resistor value is equivalent to the reciprocal of the RANGE Switch setting. The input voltage drop across the shunt resistor is indicated directly on the Electrometer digital display.

NOTE

The SENSITIVITY Switch settings permit an input voltage drop of 0.1, 1, 10, and 100 volts for current measurements in the Normal Mode. On the 10^{-9} to 10^{-11} AMPERES settings of the RANGE Switch, the resistors (10^9, 10^{10}, and 10^{11} ohms) used have a voltage coefficient of .02% per volt (nominal). If the SENSITIVITY Switch is adjusted for a 100 volt input drop, then an additional error of 2% occurs for the current measurement. Therefore it is recommended to select the smallest input drop possible to minimize voltage coefficient errors.

d. Fast Mode Current Measurements (for current below 10^{-5} amperes).

1. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	10^{-6} AMPERES
SENSITIVITY Switch	Fully Counterclockwise
FEEDBACK Switch	FAST

NOTE

To make off ground measurements refer to Paragraph 2-6.

2. Connect the Model 6011 Triaxial Input Cable for measuring an unknown current as in 2-5, c-2.

3. Unlock the ZERO CHECK Button to make a measurement.

NOTE

The ZERO CHECK Button provides a short across the feedback of the Electrometer Amplifier to enable zero adjustment. Do not apply a short circuit across the Electrometer input terminals since this will create unstable amplifier operation.

4. Adjust the RANGE Switch to increase the Electrometer sensitivity for current measurements.

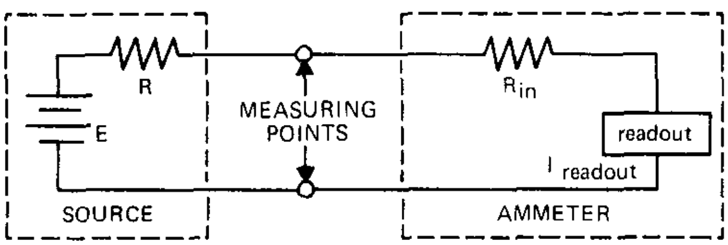
5. The full range current for the Electrometer is determined by multiplying the digital readout times the RANGE Switch setting. The best accuracy for current measurements is obtained by using a SENSITIVITY Switch setting which permits the use of the smallest value range resistor. The range resistor value is equivalent to the reciprocal of the RANGE Switch setting. The input voltage drop across the shunt resistor is indicated directly on the Electrometer digital display.

NOTE

The source resistance of the circuit to be measured should not be less than 0.1 times the range resistor used since adequate feedback voltage cannot be developed at the input and zero stability is adversely affected. The range resistor is the reciprocal of the AMPERES range in ohms.

CAUTION

For measurement of capacitor leakage currents using the Fast Mode, a very stable voltage supply must be used. With a capacitor connected across the input, the electrometer is extremely sensitive to voltage transients with a resultant increase in readout noise.



$$I = I_{readout} \frac{R + R_{in}}{R}$$

$$\% \text{ error in reading due to circuit loading} = -100 \frac{R_{in}}{R + R_{in}}$$

if $R_{in} << R$, $I \approx I_{readout}$ and % error ≈ 0

FIGURE 4. Error Due to Ammeter Resistance.

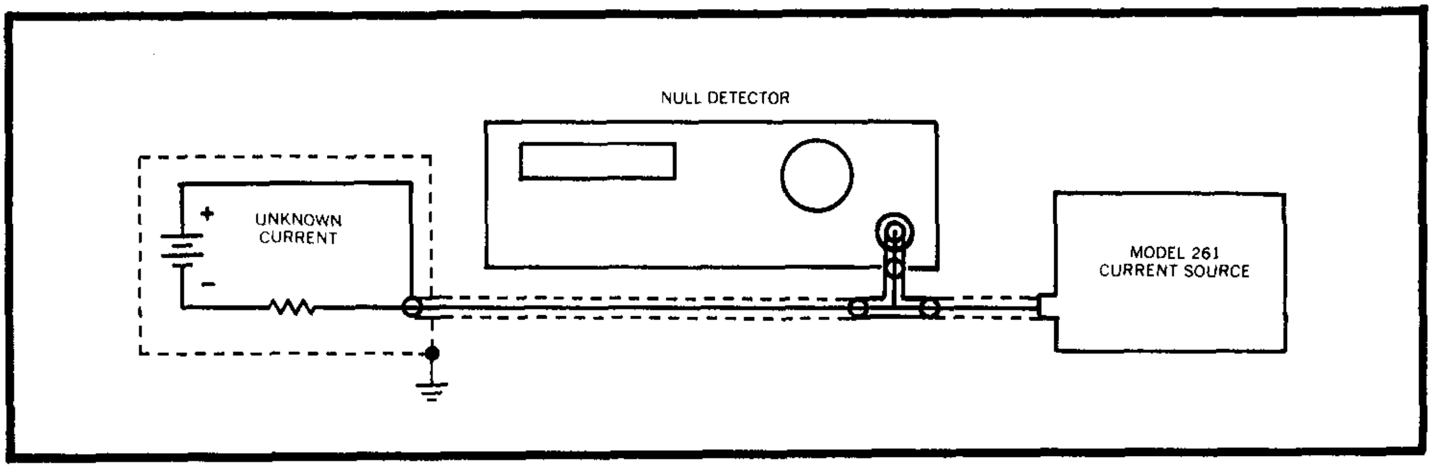


FIGURE 5. Galvanometric Current Measurements.

e. Galvanometric Current Measurement Method.

1. Operate the Electrometer in the Fast Mode as described in Paragraph 2-5, d.

2. Connect the Model 615 with an accurate reference current source as shown in Figure 5. Keithley Models 225 or 261 may be conveniently used as a bucking or zero suppression current source for this purpose.

3. Adjust the Current Source to obtain a null on the Electrometer digital readout. Increase the Electrometer sensitivity as needed. The value of the current which is suppressed is indicated on the Current Source setting.

NOTE

The connections for the Galvanometric Method require the following accessories.

1 - Model 261 Current Source
1 - Model 6012 Adapter
1 - UHF tee fitting, Part No. CS-171
1 - Low noise coaxial cable, Model 2611
1 - Low noise coaxial cable, Part No. 19072C.

2-6. OFF GROUND MEASUREMENTS.

a. The Model 615 can be used for measurements when the low impedance terminal is up to 100 volts off case ground. Safe operation of the Electrometer is insured by grounding the case. To use the Model 615 for off ground measurements, disconnect the shorting link between LO and CASE GND Terminals on the rear panel. (Refer to Figure 2).

CAUTION

Operating the Model 615 at more than 100 volts off ground may permanently damage the instrument. The isolation between circuit low and ground could break down making the instrument unusable for safe off ground measurements.

b. Normal Mode Measurements. Disconnect the shorting link between LO and CASE GND Terminals on the rear panel. Connect the Model 615 case securely to earth ground for maximum operator safety. Operate the Electrometer as described in Paragraphs 2-4 or 2-5.

c. Fast Mode Measurements. Disconnect the shorting link between LO and CASE GND Terminals on the rear panel. Connect the Model 615 case securely to earth ground for maximum operator safety. Operate the Electrometer as described in Paragraphs 2-4 or 2-5.

WARNING

The 1MA analog output can only be used with a recorder which will operate off ground such as the Keithley Model 370.

NOTE

The Model 615 cannot be operated off ground if the Model 6012 Adapter is used since the input low and chassis ground are connected.

2-7. RESISTANCE MEASUREMENTS.

a. The Model 615 can be used to measure resistance since the Electrometer permits accurate voltage or current measurements from high resistance sources. Resistance can be measured in the following three ways.

1. Normal Constant Current Technique.
2. Fast Constant Current Technique.
3. Volt-Ammeter Method.

b. Normal Constant Current Resistance Measurement.

1. In the constant current method, the Electrometer measures the voltage drop across the unknown resistance when a constant current is applied. The voltage drop is then proportional to the resistance of the unknown.

2. The Normal mode is recommended for measurements from 100 to 10^{11} ohms. Above 10^{11} ohms use the Fast Constant Current technique.

3. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	10^{11} OHMS
SENSITIVITY Switch	Fully Counterclockwise
FEEDBACK Switch	NORMAL

4. Connect the unknown resistance between the Electrometer input high and low as for Normal Mode Voltage Measurements.

5. Unlock the ZERO CHECK Button to make a measurement.

NOTE

Do not open circuit the Electrometer on the OHMS ranges; the input will develop a large voltage due to its constant current characteristic. Keep the input shorted or the ZERO CHECK Button locked.

6. The unknown resistance is determined by multiplying the digital display times the RANGE Switch setting. Use the smallest RANGE Switch setting for best possible accuracy.

7. The applied test voltage is indicated directly on the digital display in volts.

8. The test current is the reciprocal of the OHMS Range setting.

NOTE

Shield the input if the resistance sample exceeds 10^8 ohms.

c. Fast Constant Current Resistance Measurement. (Recommended for 10^{11} to 10^{14} ohms measurements).

1. The Fast Mode permits faster response speed when measuring very high resistances.

2. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	10^{11} OHMS
SENSITIVITY Switch	Fully Counterclockwise
FEEDBACK Switch	FAST

3. Connect the unknown resistance between the Electrometer input high and GUARD Terminal as for Fast Mode Voltage Measurements.

4. Unlock the ZERO CHECK Button to make a measurement.

5. The unknown resistance is determined by multiplying the digital display times the RANGE Switch setting.

6. The low terminal of the INPUT Receptacle is now a driven guard. It may be used to minimize the effects of capacity between high and low and errors due to leakage resistance between high and low.

7. The Model 6011 Input Cable, supplied with the Model 615, provides a convenient means of making guarded resistance measurements. Connect the shorting link between the CASE GROUND and GUARD Terminals on the rear panel. This allows the CASE GROUND or blue test lead terminal to be connected to the low impedance side of the unknown resistance. The inner shield or the black test clip is the GUARD Terminal.

d. Volt-Ammeter Resistance Measurement (to 10^{16} ohms).

1. In the Volt-Ammeter method the voltage applied to the sample is arbitrarily set at any convenient voltage. The current through the resistance sample is measured by the Electrometer. The resistance of the unknown is calculated in terms of the known voltage impressed and the resultant measured current.

2. This method requires the use of the following

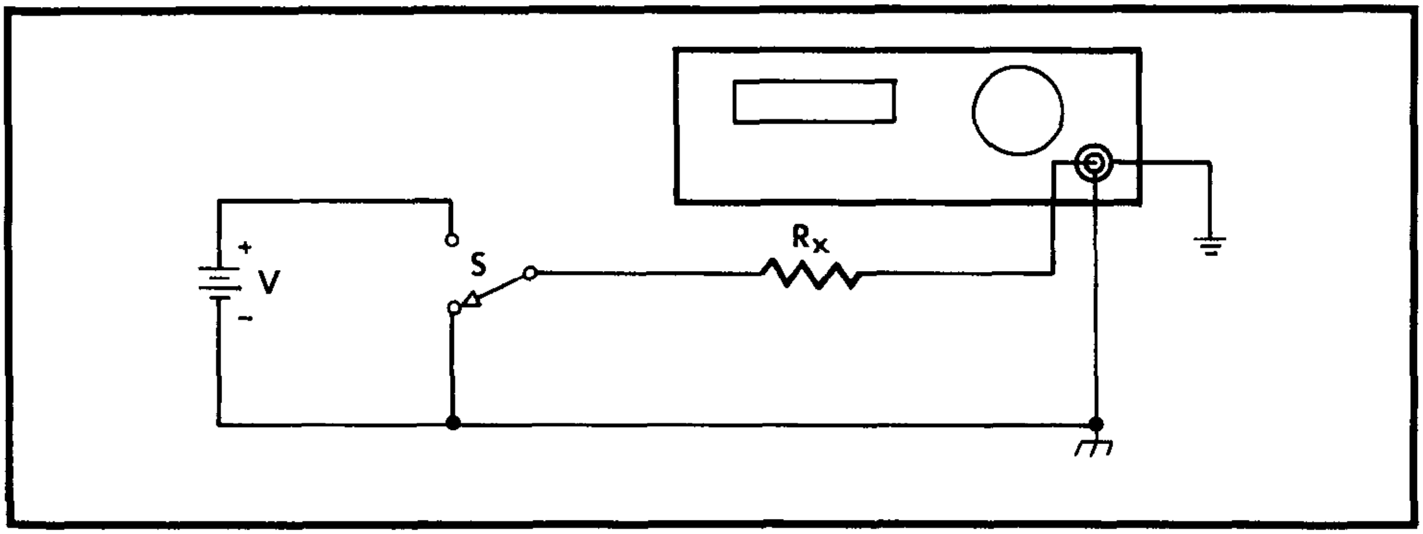


FIGURE 6. Volt-Ammeter Resistance Measurement.

instruments and accessories.

1 - Voltage Source, such as Keithley Models 240A or 241.
1 - Shielded Switch, such as Keithley Models 6104, 3011 or 4194.
1 - Test Cable, such as Model 6108
1 - Model 6012, UHF to Triax Adapter.

3. Connect the voltage source, switch, and unknown resistance as shown in Figure 6. Since the Electrometer is used for the measurement of current, refer to Paragraph 2-5 for complete instructions.

NOTE

Refer to Paragraph 2-6 for complete instructions for making off ground measurements.

4. To make a resistance measurement, place Switch S in the "OFF" position as shown in Figure 6. Adjust the voltage source for a predetermined voltage. Place Switch S in the "ON" position to apply the voltage across the unknown resistance. Allow a period of time for the current through the unknown resistance to stabilize. Unlock the ZERO CHECK Button to take a current reading. Adjust the RANGE Switch and SENSITIVITY Switch to obtain a satisfactory reading.

5. After a reading is made, place the ZERO CHECK Button to LOCK position and place Switch S to "OFF" position. Remove the unknown resistance and replace with a second sample if necessary.

NOTE

If the voltage applied to the sample is not 100 times the Electrometer input drop, then the unknown resistance is calculated as follows:

$$R_x = \frac{V_{Source} - V_{Input\ Drop}}{I_{Measured}} \qquad \text{Eq. 1}$$

where R_x = Unknown resistance,
V_{Source} = Applied voltage,
$V_{Input\ Drop}$ = Electrometer input voltage drop
and $I_{Measured}$ = Current measured by Electrometer.

2-8. CHARGE MEASUREMENTS.

a. Charge measurement or current integration can be accomplished using the Model 615 in the coulombmeter mode. The Electrometer indicates the voltage across a very accurate self-contained capacitor. The Electrometer output is therefore a voltage which is proportional to the integral of the applied current.

NOTE

For a more complete discussion of current integration, request the Keithley Product Note entitled "Using the Electrometer Voltmeter as a Current Integrating or Charge Measuring Instrument."

b. Set the front panel controls as follows:

ZERO CHECK Button	LOCK
RANGE Switch	10^{-7} COULOMBS
SENSITIVITY Switch	Fully Counterclockwise
FEEDBACK Switch	FAST

c. Connect the Electrometer to the current source to be measured as described in Paragraph 2-5.

d. Unlock the ZERO CHECK Button to make a measurement. Adjust the SENSITIVITY Switch to obtain a satisfactory reading. Changing the SENSITIVITY Switch setting does not affect the transfer of charge from the source to Electrometer.

e. The coulombmeter reading is determined by multiplying the digital display times the RANGE Switch COULOMBS setting. If the RANGE Switch must be changed to obtain a satisfactory reading, repeat steps b, c, and d above.

NOTE

The input offset current of the Electrometer contributes a charge of 5×10^{-15} coulomb per second and should be subtracted from the actual reading.

f. After a coulombmeter reading is made, discharge the integrating capacitor in the Electrometer by placing the ZERO CHECK Button to LOCK position. Discharge capacitor for at least 20 seconds on the 10^{-7} COULOMB range before making another measurement.

NOTE

For information concerning Static Charge measurements, request the Product Note entitled "Electrometer Static Charge Measurements". The Model 615 should be used with Keithley Models 2501 and 2503 Static Detector Probes for Static Charge Measurements. Do not attempt to use the Model 615 in the COULOMBS mode for Static Charge measurements since the Electrometer is very sensitive to charge transients.

2-9. RECORDER OUTPUTS.

a. The Model 615 provides several outputs for monitoring an analog or digital signal. The various outputs are summarized as follows.

1. 1MA OUTPUT. This output provides a 1 milliampere analog output corresponding to a full range input.

NOTE

The Keithley Model 370 may be conveniently used to obtain a chart record with 1% linearity. The Model 370 has 10 speeds, requires no preamp, and permits operation up to ±100 volts off ground when used with the Model 615. A special phone plug such as Switchcraft S-290 must be used with the Model 615.

2. 1 VOLT OUTPUT. This output provides a 1 volt analog output corresponding to a full range input. The 1 VOLT OUTPUT is useful for monitoring by oscilloscopes or voltmeters which will not load the Electrometer output to exceed 0.1 microamperes. This output is also used for calibration of the analog-to-digital converter.

3. X1 OUTPUT (Unity Gain). This output provides a unity gain signal for applications requiring very accurate measurements from high impedance sources. The output is equal to input within 100 ppm at dc, exclusive of noise and zero drift, for output currents of 100 microamperes or less.

4. DIGITAL OUTPUTS. Refer to Paragraph 2-10 for a complete description of the PRINTER/CONTROL connector and external controls.

b. Use of the X1 Output (Unity Gain).

1. Normal Mode Measurements.

a) Connect the Electrometer to the unknown voltage source as described in Paragraph 2-4, d for Normal Mode voltage measurements.

b) Connect an accurate voltmeter such as a 0.01% differential voltmeter between the X1 Output and the GUARD Terminal as shown in Figure 7.

c) Adjust the Model 615 ZERO Control to obtain a null reading on the differential voltmeter with the ZERO CHECK Switch in LOCK position.

2. Fast Mode Measurements.

a) Connect the Electrometer to the unknown voltage source as described in Paragraph 2-4, e for Fast Mode voltage measurements.

b) Connect a recorder or oscilloscope between the X1 Output and the GUARD Terminal. In the FAST Mode, the X1 Output Terminal is connected to input low. The GUARD Terminal provides an output for recording purposes.

2-10. DIGITAL OUTPUTS AND EXTERNAL CONTROLS.

a. General.

1. The Model 615 has provision for the installation of output buffer printed circuit boards to obtain Binary Coded Decimal (BCD) outputs. Two 44-pin card-edge connectors are installed and completely wired on the main PC board.

2. A factory-wired 50-pin PRINTER/CONTROL Connector is also provided on the rear panel. This connector is wired to provide signals as described in Table 8. This Amphenol (Blue Ribbon Series) connector can be ordered with special wiring configurations.

3. Output buffer cards available from Keithley as Model 4401 Printer Output Cards, may be ordered factory installed or ordered at a later date for user installation, since no soldering or rewiring is required. These Output Cards are available with other codes (Standard Code is 1-2-4-8) on a custom design basis.

4. Accessories.

a) Model 4401 Printer Output Cards, include two buffer output cards and a mating Amphenol connector.

b) A fifty line cable for hook-up to external devices (printers, computers, etc.) is available. Specify part number SC-51 and length desired.

b. Output Codes and Levels.

1. The PRINTER/CONTROL Outputs are Binary Coded Decimal (BCD) signals with 1-2-4-8 Standard Code.

2. The Standard signal levels are as follows:
Logic "0" $<$ +0.4 volt
Logic "1" $>$ +10 volts at up to 1 milliampere.

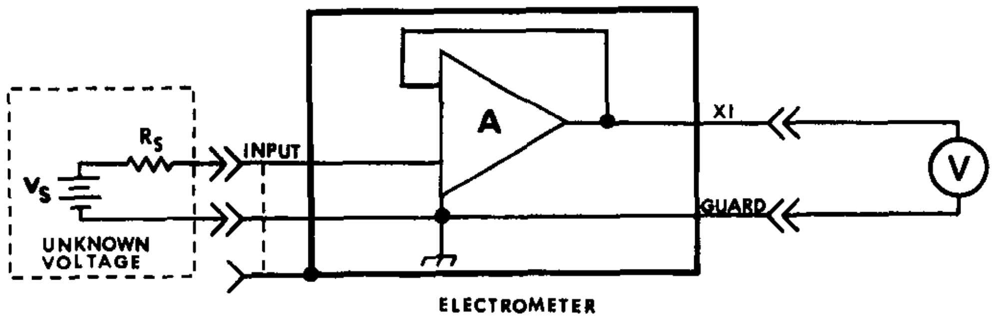


FIGURE 7. Use of X1 Output for Measurement from a High Resistance Source.

TABLE 8.
PRINTER/CONTROL Connector Pin Identification. (Refer also to Figure 8).

Pin No.	Output	Function	Pin No.	Output	Function
1	1 x 10^0	Data	26	4 x 10^0	Data
2	2 x 10^0	Data	27	8 x 10^0	Data
3	1 x 10^1	Data	28	4 x 10^1	Data
4	2 x 10^1	Data	29	8 x 10^1	Data
5	1 x 10^2	Data	30	4 x 10^2	Data
6	2 x 10^2	Data	31	8 x 10^2	Data
7	1 x 10^3	Data	32	Common	---
8	Common	---	33	8 x 10^3	Overload
9	1 x 10^0	Range	34	4 x 10^0	Range
10	2 x 10^0	Range	35	8 x 10^0	Range
11	1 x 10^1	Range	36	Common	---
12	Common	---	37	Common	---
13	1 x 10^0	Polarity	38	Common	---
14	+15V	---	39	+15V	---
15	1 x 10^0	Sensitivity	40	Common	---
16	2 x 10^0	Sensitivity	41	Common	---
17	+15V	---	42	-15V	---
18	+3.6V	---	43	Common	---
19	Blank	---	44	Grounded	Hold #1
20	Blank	---	45	Grounded	Hold #2
21	Blank	---	46	Grounded	Trigger
22	Blank	---	47	Blank	---
23	+14V Pulse	Print Command	48	Blank	---
24	+8V	Hi Reference	49	Blank	---
25	+2V	Low Reference	50	Blank	---

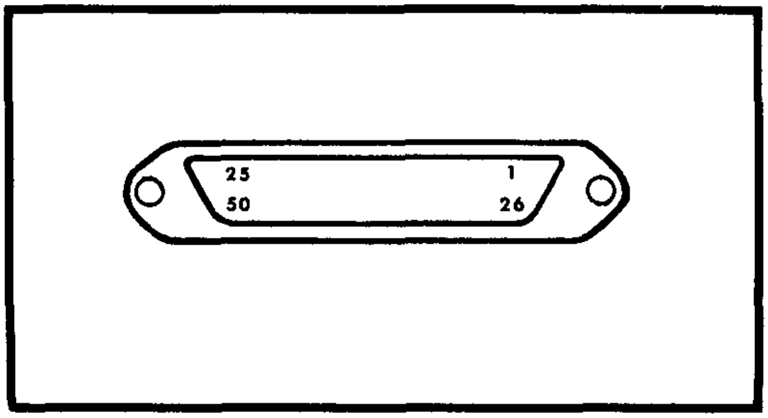


FIGURE 8. PRINTER/CONTROL Connector Terminal Identification

c. Output Information.

TABLE 9.
Model 4401 Printer Output Cards.

Model 4401 Printer Output Cards: Provide BCD output and external control of Model 615; may be purchased installed or separately for field installation (no wiring required).
Printer Outputs: BCD positive output represents each of the four digits, exponent, sensitivity, polarity and overrange. Standard code is 1-2-4-8. "0" < +0.4 volt; "1" > +10 volts at up to one milliampere; 0=0000.
Print Command: Positive pulse of 14 volts from a 2200-ohm source with 1 volt per microsecond rise time, 100 microseconds minimum pulse width. Print command given after each A to D conversion.
Remote Controls:
Hold #1: Closure to ground inhibits A to D conversion at that instant.
Hold #2: Closure to ground inhibits A to D conversion after reading has been completed.
Trigger: Closure to ground initiates one conversion when in Hold #2. Integration period starts 8.3 ms (10 ms on 50-Hz models) after "Trigger" or release of Hold #2.
Connector: 50-pin Amphenol Micro-Ribbon mounted on Model 615. Output mating connector supplied with 4401.

NOTE

The term "Closure to Ground" or "Grounded control line" means a short to common directly or through a saturated NPN transistor (V_{CE} < +0.4V). Only the "COMMON" as supplied at the PRINTER/CONTROL connector should be used for closures to ground.

1. Full Scale Magnitude. The full scale magnitude for the Model 615 is indicated by three front panel Numerical Readout indicator lights with corresponding BCD outputs as shown in Table 10.

TABLE 10.

Connector Pin No.	Output	Decimal Digits Generated
1	1×10^0	0,1
2	2×10^0	2,3
26	4×10^0	4,5,6,7
27	8×10^0	8,9
3	1×10^1	0,1
4	2×10^1	2,3
28	4×10^1	4,5,6,7
29	8×10^1	8,9
5	1×10^2	0,1
6	2×10^2	2,3
30	4×10^2	4,5,6,7
31	8×10^2	8,9

2. Overrange Indication. The fourth (from the right) Numerical Readout Indicator represents the overrange or most significant digit. An overload condition is shown by a blanked readout with only the polarity indicated. The Model 615 uses one BCD line to identify the overrange digit and overload condition as shown in Table 11.

TABLE 11.

Connector Pin No.	Output	Decimal Digits Generated
7	1×10^3	0,1
8	Common (2×10^3)	0
32	Common (4×10^3)	0
33	Overload (8×10^3)	8

3. Polarity Indication. The polarity is indicated automatically by the Polarity Indicator Lights and corresponding BCD output as shown in Table 12.

TABLE 12.

Connector Pin No.	Output	Decimal Digits Generated
13	Polarity (1×10^0)	0,1
14	+15V (2×10^0)	2
38	Common (4×10^0)	0
39	+15V (8×10^0)	8

Four pins may be used to obtain BCD polarity codes for external printers, where 1010 = + and 1011 = - printer characters.

4. Sensitivity Indication (Decimal Point Location). The SENSITIVITY Switch has four positions which automatically control the location of the lighted Decimal Point Indicator. The decimal point location is also represented by a BCD output as shown in Table 13.

TABLE 13.

Connector Pin No.	Output	Decimal Digits Generated
15	Position 1,2	0,1
16	Position 3,4	2,3
40	Common	-
41	Common	-

5. Range Indication (Exponent). The Model 615 provides BCD outputs corresponding to the exponent of the RANGE Switch as shown in Table 14.

TABLE 14.

Connector Pin No.	Output	Decimal Digits Generated
9	1×10^0 Exponent	0,1
10	2×10^0 Exponent	2,3
34	4×10^0 Exponent	4,5,6,7
35	8×10^0 Exponent	8,9
11	1×10^1 Exponent	0,1
12	Common	-
36	Common	-
37	Common	-

The print-out of the RANGE Switch exponent uses 2 columns to represent information for exponents from 00 thru 12. The exponent must be interpreted as positive or negative depending on the parameter (amperes, coulombs, or ohms).

6. The Model 615 with Model 4401 Printer Output Cards also provides remote control commands for external devices. These commands are described fully in Paragraph 2-10, d.

7. Examples of a typical printer output for various Model 615 readings are shown in Table 15. In the examples the printing device is assumed to contain fonts of digits 0 to 9. In this case, eight columns are needed to print all data.

d. External Control.

1. To obtain optimum system performance, it is often desirable to operate the Model 615 synchronously with other digital equipment, such as printers, paper tape punches, computers and other data handling devices. The Model 615 with 4401 Printer Cards installed provides several printer control commands for the purpose of synchronizing external equipment to achieve maximum conversion rates.

2. Several alternate approaches may be used in designing the overall system control scheme.

a) The Model 615 can be used to provide master control of external devices so that the maximum possible conversion rates can be obtained.

b) An external device can also be used for master control such as a high speed printer.

c) A completely independent "master clock" can be used for system control for maximum flexibility.

3. Description of external controls.

a) "HOLD 1". This control inhibits A to D conversion at the instant a closure to ground is made. The conversion cycle will resume immediately when the "HOLD 1" line is opened.

b) "HOLD 2". This control inhibits A to D conversion after a complete reading cycle. Further conversions are inhibited as long as a closure to ground is made. The conversion cycle will resume immediately when the "HOLD 2" line is opened.

c) "TRIGGER". This control initiates one complete conversion when "HOLD 2" line is grounded. Closure to ground may be momentary or any longer duration to initiate a conversion.

d) "PRINT COMMAND". This control provides a positive going pulse of 14 volts after a complete A to D conversion is made and all data line outputs are final readings.

4. Power Supply Voltages. The PRINTER/CONTROL Connector also provides power supply voltages of +15, -15, and +3.6 volts as shown in Table 16.

TABLE 16.

Voltage	Maximum Load Current	Pin No.
+3.6V	+50 mA	18
+15V	+10 mA	14,17,39
-15V	-10 mA	42

5. High and Low Reference. The PRINTER/CONTROL Connector provides two Reference Voltages, High (+8V) and Low (+2V). These levels may be used to define the "HIGH" and "LOW" digital output states for external printing or computer devices.

TABLE 15.

Front Panel Digital Readout	Range Switch Setting	Polarity	Significant Digit & Overload	Mag.	Sens.	Range Exp.	Interpretation
+0.275	10^{-5} AMPERES	+	0	275	1	05	$+.275 \times 10^{-5}$ amp
+1.347	10^9 OHMS	+	1	347	1	09	$+1.347 \times 10^9$ ohms
-086.4	VOLTS	-	0	864	3	00	-86.4 volts
-(blank)	10^{-11} AMPERES	-	8	000	-	11	negative overload
+(blank)	10^{-7} COULOMBS	+	8	000	-	07	positive overload
+00.00	VOLTS	+	0	000	2	00	+00.00 volts
-.1632	VOLTS	-	1	632	0	00	-.1632 volts
+19.99	10^{-7} AMPERES	+	1	999	2	07	$+19.99 \times 10^{-7}$ amp

e. Summary of Digital Outputs and Controls.

1. Standard Output Codes and Levels. The standard output code for Model 4401 Printer Output Cards is 1-2-4-8 Binary Coded Decimal (BCD). A binary coded decimal digit is represented by a four-bit binary code as shown in Table 17.

a) The "ON" state is defined as an output greater than +10 volts into a resistance load of 10 kilohms or greater.

b) The "OFF" state is defined as an output less than +0.4 volts.

TABLE 17.

Decimal Number	4 bit	3 bit	2 bit	1 bit
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

c) Refer to Figure 19 for a circuit diagram of the Model 4401 Standard Printer Output buffer stage.

2. PRINTER/CONTROL Connector. The PRINTER/CONTROL Connector used on the Model 615 provides for connections to 50 pins as shown in Table 8. The mating connector supplied with Model 4401 is an Amphenol Part Number 57-30500 or Keithley Part Number CS-220, available on special order.

3. Analog-to-Digital Conversion Cycle.

a) The analog-to-digital conversion cycle can be initiated in any one of three ways.

1. DISPLAY RATE Control Set at MAX. With the DISPLAY RATE Control set at MAX, the end of one complete conversion triggers a second conversion to obtain the maximum conversion rate of 24 readings per second.

2. DISPLAY RATE Control Set at Other Than MAX. With the DISPLAY RATE Control set at some position other than MAX, (uncalibrated control setting) the end of one complete conversion triggers a second conversion which is delayed by a specific time interval (DELAY). The time delay is a function of the position of a continuously variable control to provide a conversion rate from 24 readings per second to 2 readings per minute.

3. "HOLD 2" With TRIGGER Control. With the "HOLD 2" command grounded, a closure to ground of the "TRIGGER" command initiates one complete conversion cycle. A second conversion will follow only if the TRIGGER command is removed and re-applied a second time. The maximum conversion rate using an external trigger is 24 readings per second.

b) Conversion Cycle Timing. The Conversion Cycle is composed of three timing periods, namely, Integrator Zero, Integrator Sampling, and A-D Counting period. Refer to Timing Diagram Figure 9.

1. Integrator Zero Period (ZERO). When a trigger pulse initiates a new conversion cycle, the Integrator circuit is zeroed for a period not to exceed 8.33 milliseconds for 60 Hz operation. (The Integrator Zero Period is 10.00 milliseconds for 50 Hz operation).

2. Integrator Sampling Period (INTEGRATE). The Integrator Sampling Period follows automatically the Integrator Zero Period and lasts for a duration of 16.67 milliseconds for 60 Hz operation. The Integrator Sampling Period lasts for a duration of 20.00 milliseconds for 50 Hz operation.

3. A-D Counting Period (COUNT). The A-D Counting Period is initiated immediately following the Integrator Sampling Period. The actual counting time duration will depend on the actual integrator voltage up to a maximum of 2000 clock pulses or 16.67 milliseconds. Following the counting period a Buffer/Storage command is automatically generated in order to store the new reading in the output registers.

4. PRINT COMMAND. The PRINT COMMAND signal is used to trigger external printers or paper tape punches. The PRINT COMMAND signal is delayed 10 microseconds to allow the Storage Registers to settle. The PRINT COMMAND pulse width is approximately 100 microseconds with a 1 volt/microsecond rise time into a 1 kilohm load. The pulse amplitude is approximated by the following equation:

$$e_o = 14R/(R+2200). \qquad \text{Eq. 2}$$

where R is the output load resistor.

The "OFF" state is less than +0.4 volt with approximately 1 milliampere sink current.

NOTE

The data stored in the Output Registers will not change for at least 25 milliseconds for 60 Hz operation. If the front panel controls are changed, the Sensitivity or Range BCD output may be affected.

2-11. 117-234V LINE POWER OPERATION. The Model 615 is shipped for use with 117V a-c line power unless ordered for 234V operation. To convert any instrument for either 117V or 234V operation, use a screwdriver to set the 117-234V Switch on the rear panel. The

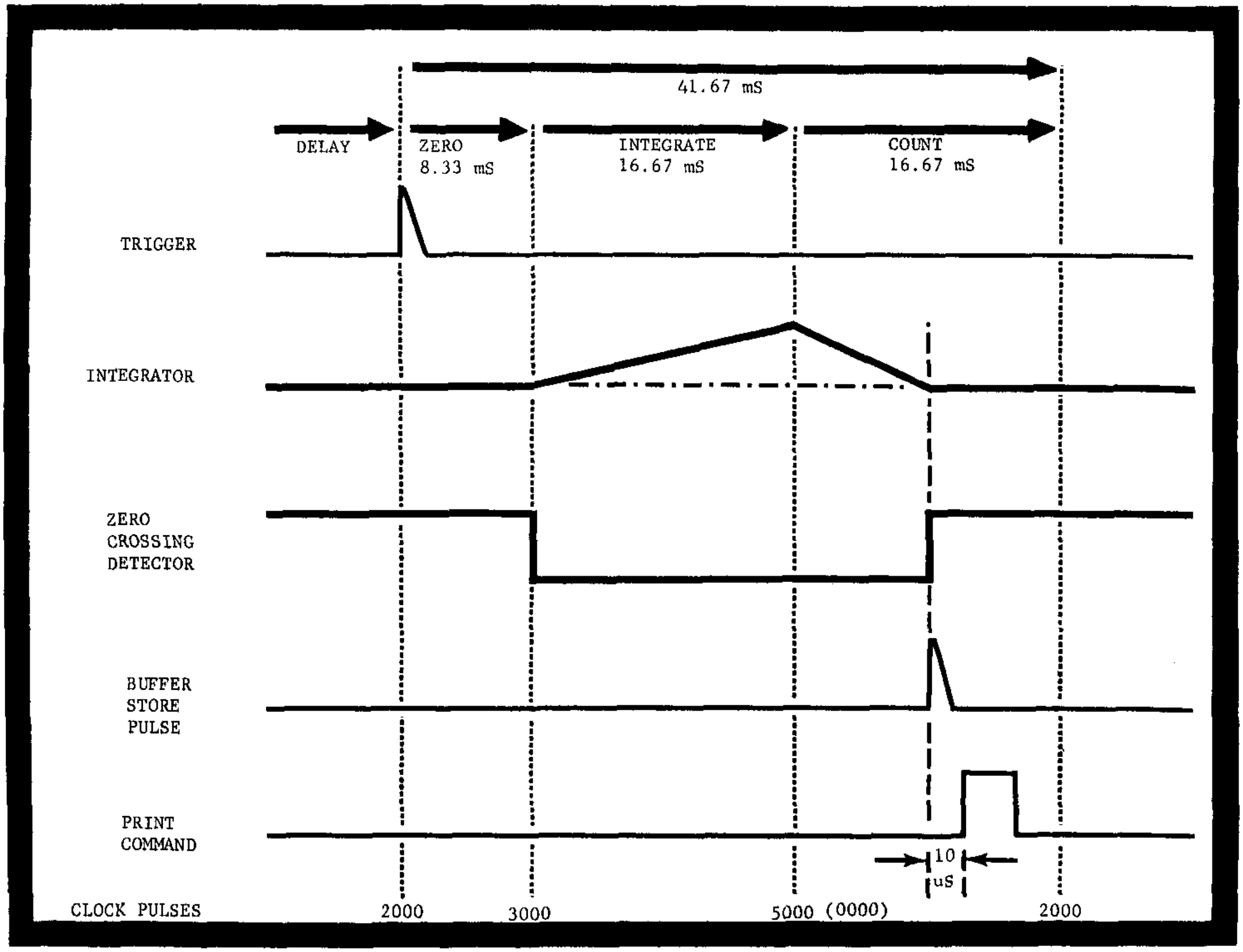


FIGURE 9. Timing Diagram for Model 615.

slide switch is identified for either 117 or 234V to avoid an incorrect setting. The proper fuse must be used for 117 or 234V and can be changed by removing the fuse holder cap on the rear panel. Refer to Table 3 for proper type of fuse required.

2-12. 50 HZ LINE POWER FREQUENCY OPERATION. The Model 615 is shipped for use with 60 Hz line power frequency unless ordered for 50 Hz operation. The Model 615 will operate at either 50 or 60 Hz but line frequency noise rejection will be degraded. Field conversion from 60 Hz to 50 Hz is not recommended since the A to D converter would require recalibration. To convert the line frequency operation, replace the oscillator crystal Y501 as shown in Table 18.

TABLE 18.

Line Power Frequency	Crystal Frequency	Keithley Part No.
50 Hz	100 Kilohertz	CR-2
60 Hz	120 Kilohertz	CR-1

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL.

a. The Keithley Model 615 Digital Electrometer consists of two separate sections (except for the power supplies) packaged together in one chassis for optimum performance and convenience: an Electrometer and an analog-to-digital converter.

b. The Electrometer is basically an extremely stable and linear DC voltmeter with a full-scale sensitivity of 100 millivolts and an input impedance of 10^{14} ohms shunted by 35 picofarads. By using the front panel controls, shunt resistors and capacitors are selected to make measurements over a total of 120 voltage, current, resistance, and coulomb ranges. Current and resistance are measured using precision resistance standards, from 10 ohm wirewound resistors to 10^{11} ohm glass-sealed, deposited carbon resistors. Coulombs are measured using close tolerance polystyrene film capacitor standards.

c. The analog-to-digital converter is a dual slope integrating type converter with medium conversion rate, cold cathode readout tubes, BCD output options and external control.

3-2. ELECTROMETER AMPLIFIER OPERATION.

a. The Model 615 electrometer amplifier employs matched insulated-gate field-effect transistors followed by a transistor differential amplifier with a high-voltage complementary output stage. Refer to Figure 10 which shows a block diagram of the Electrometer.

b. The Electrometer amplifier is connected as a unity-gain, voltage-to-current converter configuration. Refer to Figure 11 for a simplified diagram of the unity-gain amplifier in the Normal Mode. The Sensitivity selection circuitry is arranged such that a full-scale input voltage (e_i) results in a 1 milliampere output current through the Sensitivity resistor represented by R_S. The unity-gain voltage output (e_s) is determined as follows:

$$e_s = e_i \frac{K}{K+1} \qquad \text{Eq. 3}$$

where K is the amplifier loop gain.

3-3. AMPLIFIER CIRCUIT.

a. The amplifier input stage is a pair of insulated-gate field-effect transistors (IGFET) designated Q1201 and Q1202 connected in a differential configuration. The "gate" terminal of transistor Q1202 is connected to the unity-gain output.

b. The input stage is followed by a transistor differential amplifier composed of transistors Q1203 and Q1204. Transistors Q1207 and Q1212 make up a high gain stage which prevents "fold-over" and "lock-up" with positive input overloads. Diode D1214 between

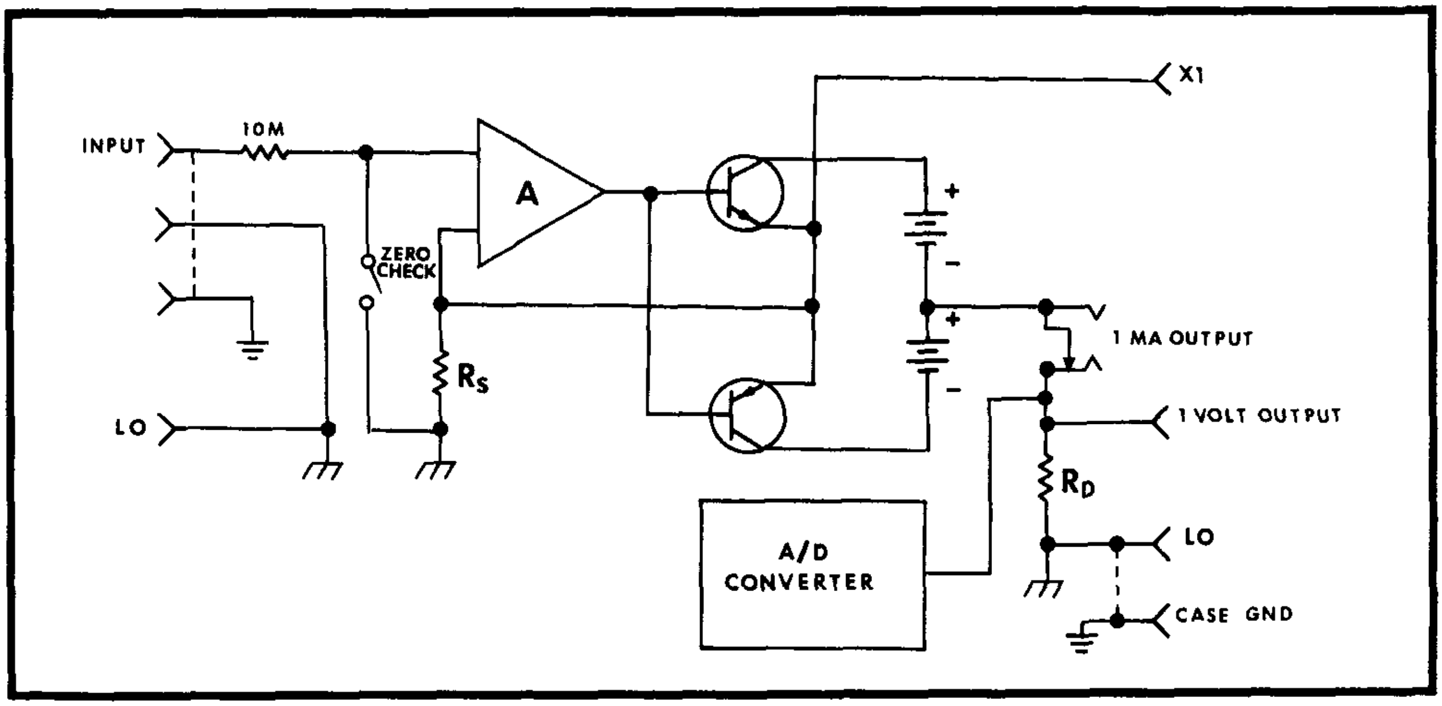


FIGURE 10. Voltmeter Normal Mode.

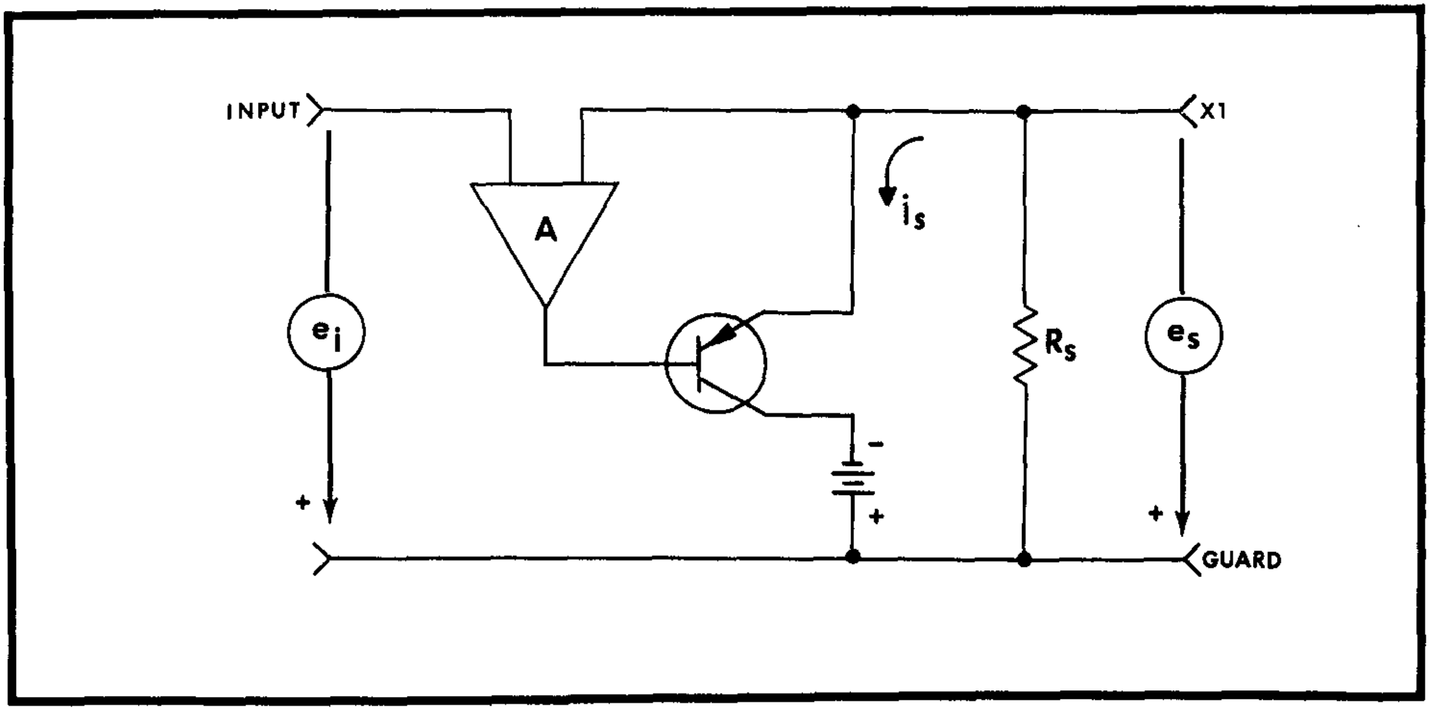


FIGURE 11. Unity-Gain Amplifier.

base and emitter of transistor Q1209 prevents "fold-over" and "lock-up" under negative input overloads.

NOTE

Amplifier "fold-over" is defined as a condition where the instrument erroneously indicates an on scale reading with a large overload. "Lock-up" is a condition where an amplifier stage saturates.

c. Frequency compensation is provided by capacitors C1213 and C1214, resistors R1240 and R1241, and capacitor C1215. The compensation networks provide a controlled frequency response characteristic to insure stability under all conditions of input and output capacitance loading.

d. The complementary-output stage composed of transistors Q1210 and Q1211 is connected to the unity-gain output to complete the unity-gain amplifier circuit.

e. The power supplies which provide ±120 volts dc for the output transistor stage are floating with respect to chassis ground. The ±9V power supplies for the amplifier gain stages are referred to the unity-gain output.

f. The SENSITIVITY Switch S1203 selects a resistor network (represented by resistor R_s) to provide full scale input ranges from 100 millivolts to 100 volts in four steps. The output voltage to current conversion is determined as follows:

$$i_s = \frac{e_s}{R_s} \qquad \text{Eq. 4}$$

where current i_s = 1 milliampere for full scale input.

g. The analog output signal for recorder outputs is derived from a resistor divider network represented by resistor R_D in Figure 10.

1. 1 VOLT OUTPUT (J1207). This output is derived from the 1 milliampere current (for full scale inputs) which flows through a resistor network of 1010.1 ohms. This output has been designed to provide a reference voltage for the analog-to-digital converter. The 1 VOLT OUTPUT Terminal may be used for monitoring purpose where loading can be 0.1 microampere maximum.

2. 1 MA OUTPUT (J1206). This output provides a one milliampere dc current for a full scale input voltage of 100 millivolts, 1 volt, 10 volts, or 100 volts depending on the SENSITIVITY Switch setting. The output connector used is a Switchcraft N113B female phono jack which connects the output in series with the reference voltage divider R_D.

3. X1 OUTPUT (J1203). This output is the unity-gain output as shown in Figure 11. The X1 Output provides a voltage e_s which is equal to the input according to the following ratio.

$$\frac{e_s}{e_i} = \frac{K}{K+1} \qquad \text{Eq. 5}$$

where K is the amplifier loop gain.

3-4. AMMETER OPERATION.

a. Normal Mode. With the FEEDBACK Switch in the

NORMAL position, an accurately known RANGE Switch resistor (CURRENT Range only) R1202 through R1212 is connected in shunt across the Electrometer amplifier input. Refer to Figure 10 for a block diagram of the Electrometer. The amplifier measures the voltage drop across the Range resistor to determine the input current. The digital readout display and analog outputs are calibrated to indicate the magnitude and polarity of the voltage. The actual current is obtained by multiplying the readout times the current range selected.

b. Fast Mode. With the FEEDBACK Switch in the FAST position, an accurately known RANGE Switch resistor (CURRENT Range only) R1202 through R1212 is connected across the amplifier feedback loop as shown in Figure 12. The unity-gain output (X1) is connected to Input LO. In this mode the GUARD and X1 Terminals may be used for monitoring purposes. The Fast Mode configuration minimizes the slowing effects of input capacitance. The input voltage drop is maintained at less than 100 microvolts.

3-5. OHMMETER OPERATION.

a. The Model 615 ohmmeter circuit provides a self-generated constant-current which is applied to the unknown input resistance. The constant-current source is represented by a voltage source E and series resistor R as shown in Figure 13. The Electrometer amplifier measures the voltage drop across the unknown resistance R_X to provide a digital display and analog output proportional to the unknown resistance.

b. The constant current source is composed of a +9 volt power supply and a resistor divider network selected by the OHMS Range Switch. The OHMS Range resistors are R1202 through R1212.

c. Normal Mode Operation. When the FEEDBACK Switch is in the NORMAL position, the unknown resistor is connected between the INPUT high and low as described in the OPERATION section of this manual. The actual resistance is determined by multiplying the digital readout display times the OHMS Range selected.

d. Fast Mode Operation (Guarded Method). When the FEEDBACK Switch is in the FAST position, the unknown resistor is connected between the INPUT High Terminal and the GUARD Terminal on the rear panel. In this mode the unknown resistor provides feedback around the Electrometer amplifier.

3-6. COULOMBMETER OPERATION.

a. With the FEEDBACK Switch in the FAST position, an accurately known RANGE Switch capacitor (COULOMBS Range only) is connected across the amplifier feedback loop as shown in Figure 14. The COULOMBS Range capacitors are C1203 through C1212. The Electrometer digital readout display indicates the stored charge proportional to the voltage across the capacitor. The actual charge in coulombs is determined by multiplying the digital readout times the COULOMBS Range Setting.

NOTE

The analog-to-digital converter circuit description can be found in paragraph 3-7. This circuitry is separate from the analog circuitry and is located on individual printed circuit boards.

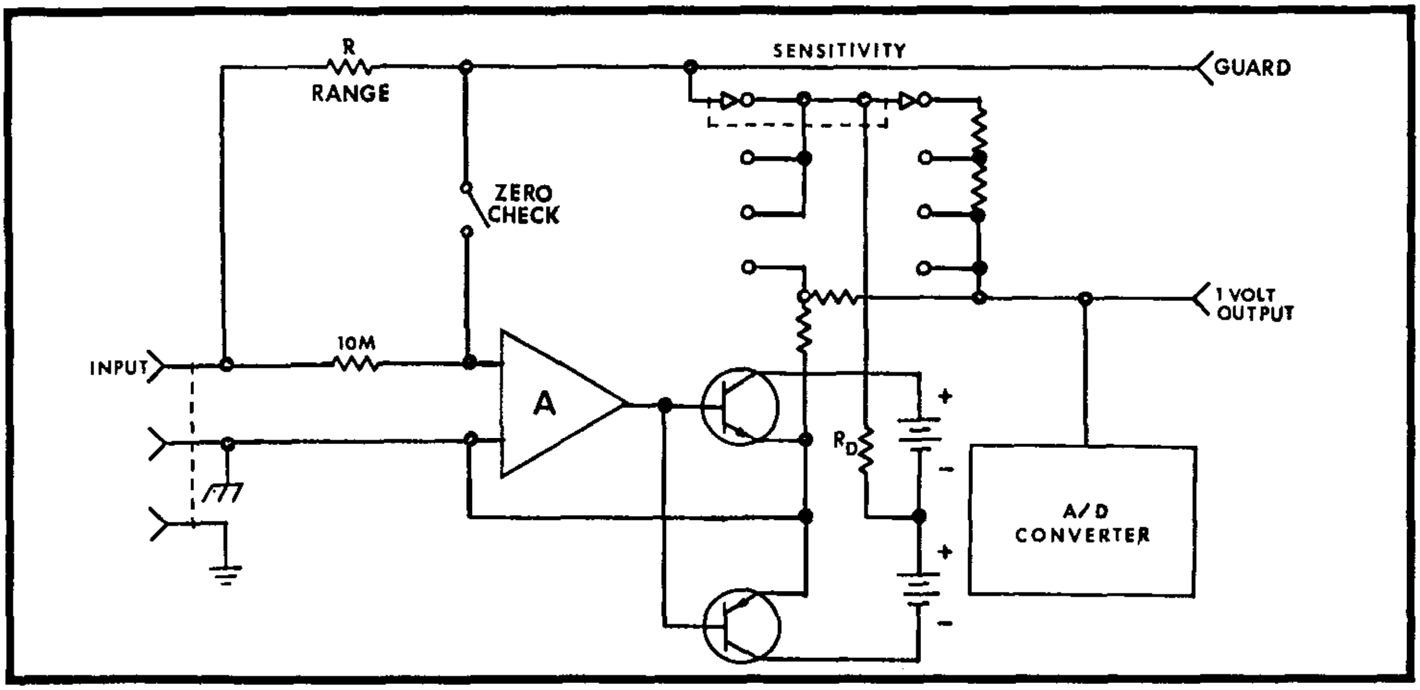


FIGURE 12. Ammeter-Coulombmeter Fast Mode.

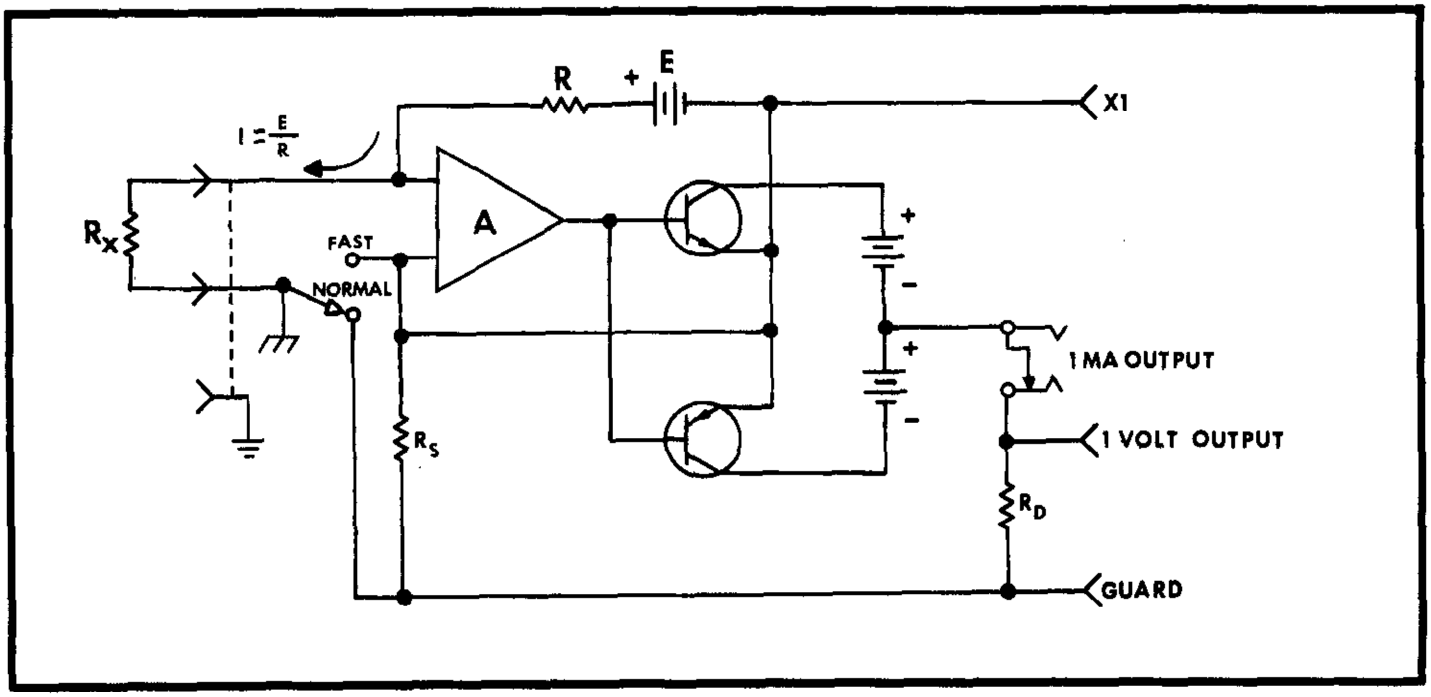


FIGURE 13. Ohmmeter Normal Mode.

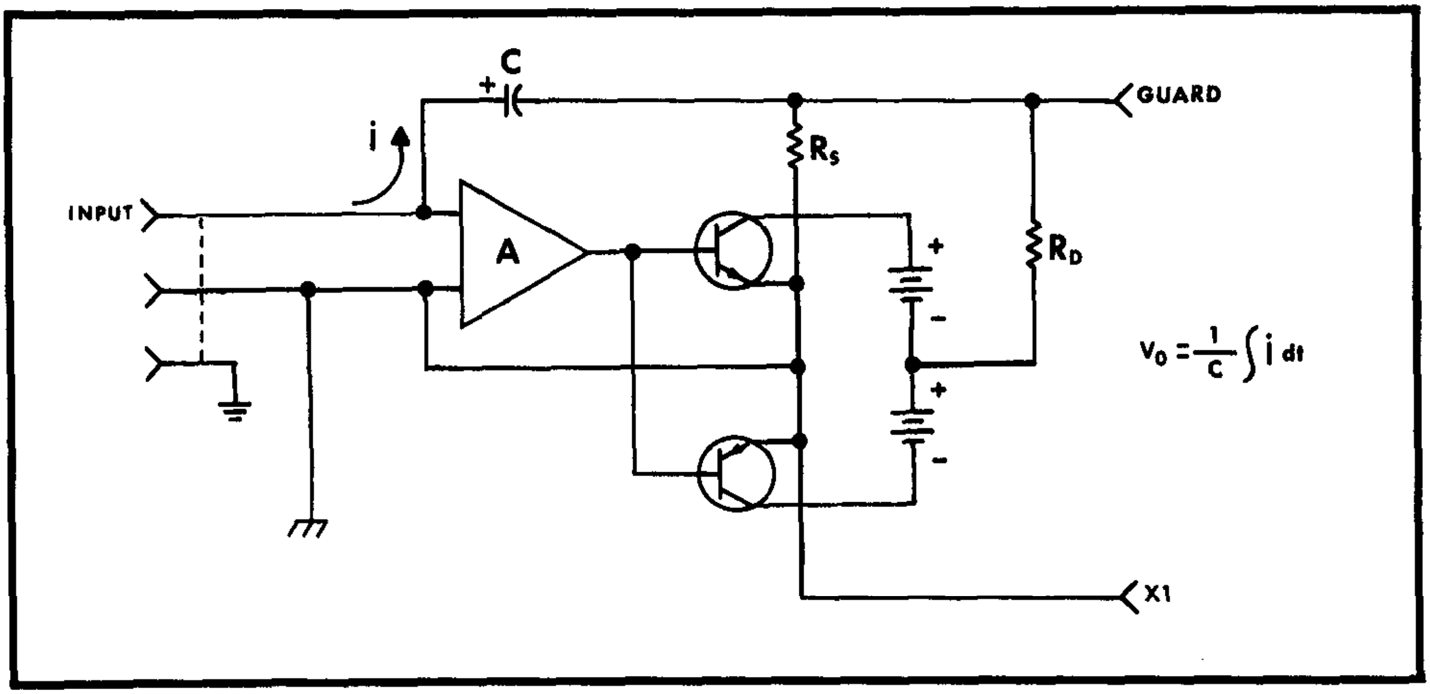


FIGURE 14. Coulombmeter Fast Mode.

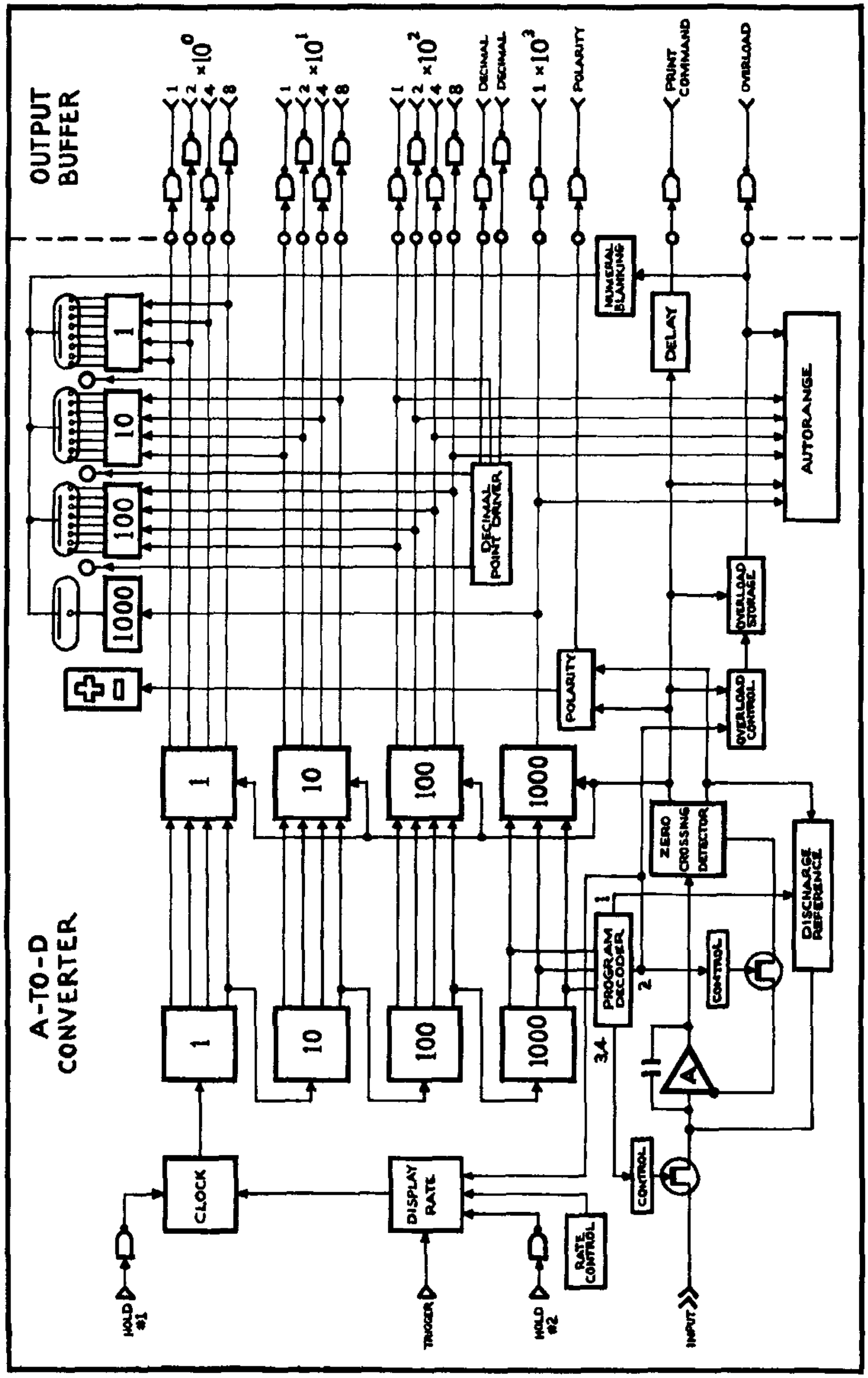


FIGURE 15. Block Diagram of A/D Converter.

3-7. ANALOG-TO-DIGITAL CONVERTER OPERATION.

a. General (refer to Figure 15 for a detailed block diagram of the A-to-D converter). The analog-to-digital converter operates using a dual slope integration technique which has inherent line frequency noise rejection. The analog signal is applied to the integrator for one complete line frequency cycle, therefore integrating the line frequency noise. The analog signal is then removed from the integrator input. The voltage on the integrator is then driven to zero to complete the voltage-to-time conversion. The time interval to reach a "Zero Crossing" is counted and displayed on the "Readout" in proportion to the original analog signal. The sequence is then repeated for a second reading. (Refer to the Timing Diagram shown in Figure 9).

b. The A-to-D Converter is composed of nine major circuits which perform the analog-to-digital conversions and provide various control commands.

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

c. Oscillator or Clock. The Oscillator produces pulses at a rate of 120 kilohertz for Electrometer using 60 Hz line power. (The 50 Hz units have a pulse rate of 100 kilohertz).

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

1. The "1", "10", and "100" counters have a capacity of ten counts each.

2. The "1000" counter has a capacity of five counts.

3. The total capacity of all four counters is 5000 counts.

e. Delay Hold. The Delay Hold circuit controls the DISPLAY RATE function and external Hold and Trigger commands (refer to Figure 16).

1. It determines the length of time between A-to-D conversions when the front panel DISPLAY RATE Control is set to any position other than MAX. The clock is stopped at the beginning of the ZERO (2) period for a time determined by the rotation of the DISPLAY RATE Control.

2. It ensures that when the Hold 2 is grounded the conversion in process will be completed and new data will be stored in the output storage register. Then the clock will be inhibited at the beginning of the ZERO period (2). The instrument will remain in this condition indefinitely until Hold 2 is released or until Trigger is shorted to ground. After conversion, the instrument will again be inhibited at the beginning of the period (2).

3. If both Switches S_1 and S_2 are closed, the conversion cycle works in the following manner.

a) After the previous conversion has been completed, the leading edge of the program command (2) resets the flip-flop. In this new condition $\overline{Q}$ is high and, therefore, the clock gives no output.

b) At that time, the unijunction timer begins its cycle and, after the appropriate time, produces a pulse that sets the flip-flop. This changes $\overline{Q}$ to a low state and a new conversion cycle begins. After the reading has been completed, the (2) command again resets the flip-flop and the timer again issues a new pulse to set the flip-flop.

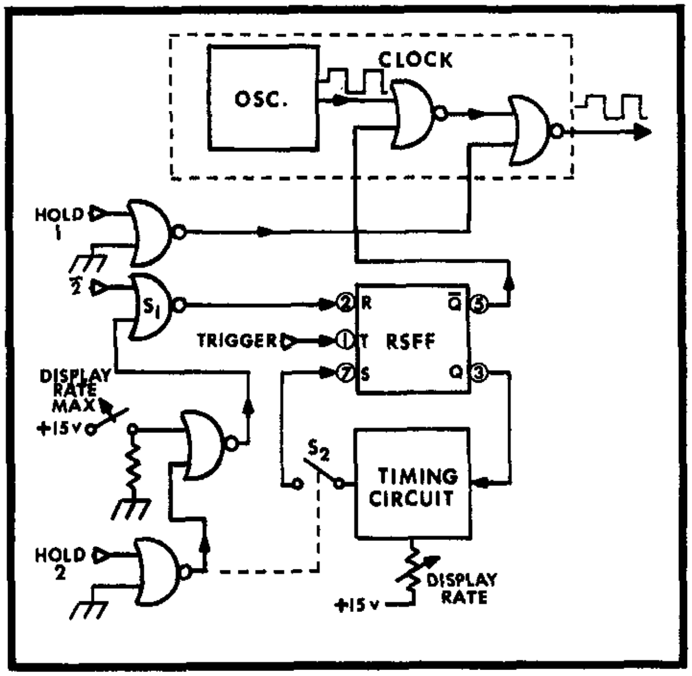


FIGURE 16. Block Diagram of Delay Hold Circuit.

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

g. Integrator. The Integrator circuit operation is composed of three periods (refer to Figure 9).

1. Zero Period. During this period the integrator amplifier is zeroed by the closure of switch S_b. Switches S_a, S_c, and S_d are open to prevent integrator charging (refer to Figure 17).

2. Integration Period. During this period, switch S_b, S_c, and S_d are open. Switch S_a is closed to permit charging by the analog voltage for a per-

iod of one line cycle.

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

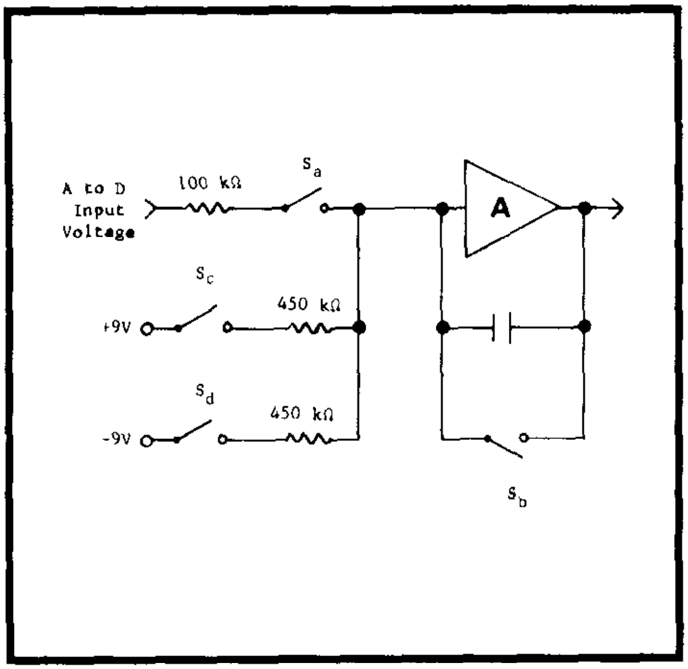


FIGURE 17. Integrator Block Diagram.

h. Zero Crossing Detector. The Zero Crossing Detector circuit provides a "High" or "Low" level output depending on the polarity of the detected input. Refer to Table 19 for a description of voltage outputs of the Zero Crossing Detector (refer to Figure 18).

TABLE 19.
Zero Crossing Detector Output Levels.

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

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

j. Decoder/Driver. The Decoder/Driver circuit de-

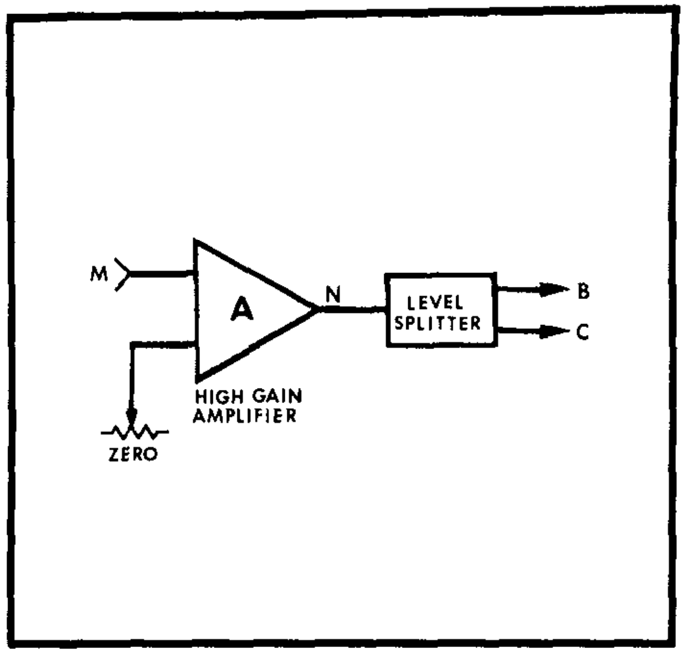


FIGURE 18. Zero Crossing Detector Block Diagram.

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

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

l. Summary of Operation. The operation of the A-to-D Converter can be described by considering a typical conversion cycle.

1. The Oscillator or Clock provides pulses at a rate of 120 kilohertz.

2. The Delay Hold circuit gates the output of the Oscillator depending on the state of the "RS flip-flop" and the "Hold 1" control line. A unijunction timing circuit provides a delay period before a conversion is initiated. The time delay is selected by the front panel DISPLAY RATE Control.

3. The BCD Counter serves as a master timing control for the A-to-D conversion cycle. The timing is accomplished by the "1000" counter which has five coded states, namely 0, 1, 2, 3, and 4.

4. The Program/Decoder controls the sequence of commands based on the coded states from the BCD Counter. The decoded commands are described as shown in Table 20. The "2" command initiates the integrator ZERO period which removes any residual charge on the integrator capacitor. The "3,4" command initiates the INTEGRATE period which permits an integration of the analog signal. At the end of the INTEGRATE period, the "0,1" command initiates the COUNT period.

TABLE 20.

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

5. When the "3,4" command is given, the integrator is charged by the analog signal for a period of 1 line cycle or 16.67 milliseconds.

6. When the "0,1" command is given, the analog signal is removed and the integrator output is driven to zero by a reference current. The Zero Crossing Detector senses a zero crossing of the Integrator output and removes the reference current. The Detector provides outputs as shown in Table 19. The +1.5 volt levels are provided for control of the Integrator and Polarity Storage Register. A pulse command is also produced to initiate a Buffer/Store and Print Command output.

7. When the Buffer/Store command is given, the Buffer/Storage Register copies the BCD Counterstates at that instant of time. The BCD coded information in the Register is then available for the Decoder/Driver and external printout.

8. The Decoder/Driver decodes the Buffer/Storage output and drives the Numerical Readout for a digital display.

9. The BCD Output information is available at the Model 4401 Buffer Card outputs in the form of positive (+10 volt) true logic (1-2-4-8 BCD Code).

10. The conversion cycle is completed when the BCD Counter reaches 2000 counts and the Program/Decoder provides a "2" command to initiate a new conversion cycle.

11. The Unijunction Timing Circuit will initiate the ZERO period after a preset time delay controlled by the front panel DISPLAY RATE Control.

3-8. ANALOG-TO-DIGITAL CONVERTER CIRCUITRY.

a. General. The circuits described in this section are located on the various Sub-Assemblies listed below and in Table 22 of Section 4.

1. Oscillator Board, PC-217.
2. Integrator Board, PC-246.
3. Display/Overload Board, PC-241
4. Readout Board, PC-229
5. Polarity Board, PC-207
6. Output Buffer Board, PC-218
7. Output Buffer Board, PC-209

b. Oscillator Board. The Oscillator Board contains portions of three circuits: the Oscillator (clock) circuit, the Delay/Hold circuit, and the Discharge-Voltage Current Source circuit.

1. Oscillator Circuit. Transistor Q501, crystal Y501, and phase shift capacitors C501, and C502 form a "Colpitts" type oscillator. Capacitors C503 and C504 are used for trimming the oscillator frequency. The output is taken from the collector of transistor Q510 which is a common emitter gain stage used for squaring the output. Transistor Q507 serves as an emitter-follower to reduce output impedance.

2. Delay/Hold Circuit. There are three major components in the Delay/Hold circuit: an "RS" type flip-flop circuit, a "Unijunction" timing circuit and a "Hold" gate circuit.

a) "RS" Type Flip-Flop Circuit. The flip-flop gates the output of the clock depending on the inputs at pins R and S. The RS flip-flop is constructed of gates QA501B and QA501C. The pins are identified as shown in Figure 16.

b) "Unijunction" Timing Circuit. The unijunction timing circuit determines the time delay between conversion cycles to obtain the desired conversion rate as determined by the front panel DISPLAY RATE Control. The circuit is composed of transistors Q513 and Q514, timing capacitor C507, and timing resistors R532 and R1269 (DISPLAY RATE Control potentiometer located on the front panel).

c) "HOLD" Gate Circuit. (Refer to Figure 16 for identification of switches S_1 and S_2). The "HOLD" gate circuit is composed of gates QA501A, QA501D, and QA502 (A, B, C, and D). Switch S_1 is gate QA501A and is controlled by either the "HOLD 2" external line or the "MAX" position on the DISPLAY RATE Control. Switch S_2 is transistor Q513 which is controlled by either the "Q" output of the flip-flop or the "HOLD 2" external line. The "HOLD 1" circuit is composed of gates QA502B and QA502C.

3. Discharge-Voltage Current Source Circuit. The positive current source composed of transistors Q502 and Q506 delivers a constant current of +7.5 milliamperes to drive a 9-volt zener diode D602 (located on the Integrator Board, PC-246) when +REF Terminal (Pin 13) is greater than +0.7 volt. The negative current source composed of transistors Q508 and Q509 delivers a constant current of -7.5 milliamperes to drive a 9-volt zener diode D601 (also located on the Integrator Board, PC-246).

c. Integrator Board. The Integrator Board consists of two major circuits: the Integrator circuit and the Zero Crossing Detector circuit.

1. Integrator Circuit. (Refer to Figure 17 for identification of switches S_a, S_b, S_c, and S_d). The operation of the Integrator is controlled by the positions of switches S_a, S_b, S_c, and S_d. Switch S_a is transistor Q605. Switch S_b is transistor Q606. Transistors Q601 through Q604 are control circuits arranged to turn off the proper FET switches depending on the signals at pins 11 and 12. The integrator amplifier consists of transistors Q607 and Q608 and integrated circuit QA601. The feedback capacitor is C603. Switches S_c and S_d (located on the Oscillator Board, PC-217) control the current for 9-volt zener diodes D601 and D602. Resistors R602

through R611 are full-scale calibration resistors.

2. Zero Crossing Detector Circuit. (Refer to Figure 18). The high gain amplifier is composed of cascaded amplifiers QA602 and QA603. The zero adjustment network consists of resistors R645, R646, R648, R649, and R650, and diodes D611 and D612. Transistor Q609 and other components form a 6-volt supply for QA603 and the zero circuit. The level-splitter circuit consists of diodes D613 and D614, resistors R651, R652, and R653 and gates QA604 (A, B,C).

d. Display/Overload Board. The Display/Overload Board contains a BCD Counter ("1000" counter), a Program Decoder circuit, and an Overload Control circuit.

1. The BCD Counter is composed of "J-K" flip-flop circuits QA301 and QA302.

2. The Program Decoder circuit is composed of gates QA303C and QA303D (3,4 Command) and QA304A, QA304B, QA304C, QA304D, QA305A, QA305B, QA305C, QA305D, QA303E, QA306A, QA306B, and QA306C (0,1, & 2 Commands).

3. The Overload Control circuit provides an overload signal if a zero crossing does not occur in the Discharge Period (0,1). It controls the Numerical Blanking circuit and provides an Overload Print signal.

e. Readout Board. The Readout Board contains Decade Counter circuits, Buffer Storage circuits, and Decoder Driver and Display circuits.

1. Decade Counter Circuits. Each decade counter is composed of four J-K flip-flops. Circuits QA401 through QA406 are Dual J-K Flip-Flop integrated circuits.

2. Buffer Storage Circuits. The Buffer Storage register is composed of Dual J-K Flip-Flop integrated circuits QA409 through QA414.

3. Decoder Driver Circuits. QA415, QA416, and QA417 are Decimal Decoder Driver integrated circuits.

4. Display Circuits. V401, V402, and V403 are Readout Tubes for Units, Tens, and Hundreds respectively.

f. Polarity Board. The Polarity Board contains various circuits which are controlled by signals "B" and "C" from the Zero Crossing Detector signal as shown in Figure 18.

1. Polarity Indicator Control Circuit. This circuit drives the Polarity Indicator DS201 to provide a Polarity display. QA201A and QA206A are J-K Flip-Flop circuits which control transistors Q201 and Q202.

2. Polarity Print Signal Circuit. The Polarity Print signal is determined by the $\overline{Q}$ output of J-K flip-flop QA206A.

3. Discharge Voltage Polarity Control Circuit. The +REF Control signal is determined by QA201A and gate QA204A. The -REF Control signal is determined by QA202A, QA203A, QA203B, QA202B, QA202C, QA203C, QA203D, and QA204B.

4. Buffer Store Command Circuit. The Buffer Store command is provided by J-K flip QA201B and gates QA204C and QA207A.

5. Overload Blanking Circuit. A portion of the Overload Blanking circuit QA204D, QA206B, and QA207B is located on the Polarity Board. The remainder of the circuit is located on the Display/Overload Board, PC-241.

g. Output Buffer Board, PC-218. This board contains 15 buffer circuits to provide BCD Data and Overload and Polarity Print signals. Buffer circuits "A" through "P" consist of transistor buffer stages as shown in Figure 19.

h. Output Buffer Board, PC-209. This board contains six buffer circuits and various gate circuits to provide Print Command and Range Signal Print signals.

1. Buffer Circuits. Buffer circuits "A" through "E" provide BCD Range information.

2. Print Command Circuits. Buffer circuits composed of transistors Q1101, Q1102, Q1104, Q1105, Q1106, and Q1107 provide Print Command signals as determined by gates QA1101 (A,B,C, and D) and QA1102 (A,B,C, and D).

3. Range Signal Circuit. Transistors Q1108, Q1109, and Q1110 comprise a Range Signal Buffer stage controlled by the Range Signal.

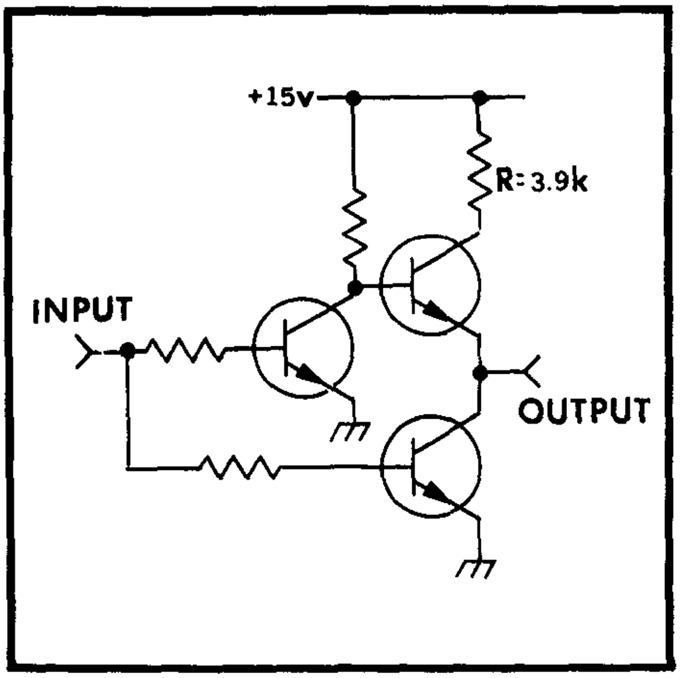


FIGURE 19. Model 4401 Buffer Stage.

4. Reference Voltages. A High and Low Reference voltage is provided by resistor divider R1114, R1115, and R1116. The voltages are +8 volts (High) and +2 volts (Low).

3-9. POWER SUPPLIES (refer to Schematic Diagram 24044E).

a. ±15 Volt Supply.

1. The ±15 volt supplies tap a-c power from a secondary of transformer T101. Diodes D103, D105, D107 and D108 and capacitors C104 and C105 compose a full-wave rectifier with filtering.

2. Transistors Q114 and Q115 form a differential amplifier which compares the voltage at R115 with the voltage of zener diode D110. The difference voltage is amplified by transistor Q109 and fed to Darlington transistor pair, Q106 and Q107, which series regulate the output voltage.

3. Transistors Q116 and Q117 form a differential amplifier which compares the voltage at R123 with respect to lo. The difference voltage is amplified by transistor Q113 and fed to Darlington transistor pair, Q110 and Q111, which series regulate the -15 volt output.

4. Transistors Q108 and Q112 limit the output current to about 200 milliamperes.

b. +3.6 Volt Supply.

1. The +3.6 volt supply taps a-c power from a secondary of transformer T101. Diodes D101 and D102 and capacitor C101 form a full-wave rectifier with filtering.

2. Transistor Q105 amplifies the difference between the +3.6 volt output and a reference voltage derived from the +15 volt supply and determined by resistors R103 and R104. The difference voltage is amplified by transistor Q104 which drives a Darlington transistor pair, Q101 and Q102. The Darlington pair series regulates the +3.6 volt output.

3. Transistor Q103 limits the output current to about 3 amperes.

c. +170 Volt Supply.

1. The +170V supply taps a-c power from a secondary of transformer T101. Diode D111 and capacitor C112 form a half-wave rectifier with filtering.

2. Transistor Q119 amplifies the voltage developed by the resistor divider R128 and R129. The output of Q119 controls the series regulator transistor Q118 to maintain the +170 volt output.

3. When the electrometer is overloaded, and overload signal drives transistor Q120 which in turn controls the voltage at the base of transistor Q119. The circuit composed of diode D112, transistor Q120, and resistors R130, R131 and R132 reduces the +170 volt output to +80 volts when overloading occurs. Grounding the overload input turns off transistor Q120 causing diode D112 to conduct and drive Q119.

4. The reduced +80 volt output causes blanking on all Numerical Readout Tubes connected to the +170 volt supply.

d. +210 volt output. The +210 volt supply is an unregulated voltage supply using the half-wave filtered voltage at diode D111 and capacitor C112.

e. ±9 Volt Supplies (shown on Schematic 24267E).

1. The ±9 volt supplies tap a-c power from a secondary of transformer T1201 or T101. Diodes D1201 to D1204 and capacitors C1216 and C1217 for a full-wave rectifier with filtering.

2. Zener diodes D1205 to D1208 provide regulated ±9 volt outputs.

f. ±120 Volt Supplies.

1. The ±120 volt supplies tap a-c power from a secondary of transformer T1201. Diodes D1211 and D1212 and capacitors C1218 and C1219 form a half-wave rectifier with filtering.

2. Zener diodes D1209 and D1210 provide regulated ±120 volt outputs.

SECTION 4. REPLACEABLE PARTS

4-1. REPLACEABLE PARTS LIST. This section contains a list of components used in the Model 615 Digital Electrometer for user reference. The Replaceable Parts List describes the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number), Manufacturer Part Number, and the Keithley Part Number. Also included is a Figure Reference Number where applicable. The complete name and address of the Manufacturers is listed in Table 24. (Refer also to Table 21 for Abbreviations and Symbols).

TABLE 21.
Abbreviations and Symbols

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

4-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as described in Section 3. Refer to Table 22 which identifies all schematic part numbers included.

4-3. HOW TO USE THE REPLACEABLE PARTS LIST. This Parts List is arranged such that the individual types of components are listed in alphabetical order. The parts for the instrument's Main Chassis are listed followed by printed circuit boards and other subassemblies. Refer to Table 23 for listing of circuit designation series assigned to each major sub-assembly.

4-4. HOW TO ORDER PARTS.

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

b. When ordering parts, include the following information.

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

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

TABLE 22.

Description	Circuit Designation	Schematic Part Number
Electrometer Board	Main Chassis, #2	24267E
Electrometer Board	Main Chassis, #1	24151E
Power Supply	Main Chassis, #3	24044E
Polarity Board	PC-207	23449D
0-1 Display/Overload Board	PC-241	24031D
Readout Board	PC-229	23451E
Oscillator Board	PC-217	23452D
Integrator Board	PC-246	24042E
Output Buffer Board	PC-218	23457D
Output Buffer Board	PC-209	23481E

TABLE 23.

Designation	Description	Series	Page Number
Power Supply	Power supply sub-assembly shown on Schematics 24267E and 24151E.	100	34
PC-207	Polarity P.C. Board. Plugs into connector J1214.	200	36
PC-241	0-1 Display/Overload P.C. Board. Plugs into connector J1215.	300	37
PC-229	Readout P.C. Board. Plugs into connectors J1216 and J1217.	400	38
PC-217	Oscillator P.C. Board. Plugs into connector J1218.	500	39
PC-246	Integrator P.C. Board. Plugs into connector J1219.	600	41
PC-218	Output Buffer P.C. Board. Plugs into connector J1212.	1000	43
PC-209	Output Buffer P.C. Board. Plugs into connector J1213.	1100	43

MAIN CHASSIS REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 24267E for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C1201	.01 μF	600V	CerD	72982	ED-.01	C22-.01M	22
C1202	150 pF	600V	CerD	72982	ED-150	C22-150P	21
C1203	5 pF	200V	Poly	00686	E1013-1	C31-5P	30
C1204	10 pF	500V	Poly	71590	CPR-22J	C138-10P	30
C1205	22 pF	500V	Poly	71590	CPR-22J	C138-22P	30
C1206	47 pF	500V	Poly	71590	CPR-47J	C138-47P	30
C1207	100 pF	200V	Poly	84171	2PJ-101G	C108-100P	30
C1208	.001 μF	200V	Poly	84171	2PJ-102G	C108-.001M	30
C1209	.1 μF	200V	Poly	84171	2PJ-104G	C108-.1M	30
C1210	.01 μF	200V	Poly	84171	2PJ-103G	C108-.01M	30
C1211	.001 μF	200V	Poly	84171	2PJ-102G	C108-.001M	30
C1212	100 pF	200V	Poly	84171	2PJ-101G	C108-100P	30
C1213	.033 μF	200V	My	13050	SM2A	C143-.033M	22
C1214	.033 μF	200V	My	13050	SM2A	C143-.033M	22
C1215	150 pF	600V	CerD	72982	ED-150	C22-150P	22
C1216	100 μF	50V	EAl	90201	MTV 100N 50 PDN	C186-100M	22
C1217	100 μF	50V	EAl	90201	MTV 100N 50 PDN	C186-100M	22
C1218	40 μF	350V	ETB	56289	TVA 1611	C23-40M	22
C1219	40 μF	350V	ETB	56289	TVA 1611	C23-40M	22
C1220	.01 μF	600V	CerD	72982	ED-.01	C22-.01M	22
C1221	.0047 μF	600V	CerD	72982	ED-.0047	C22-.0047M	22
C1222	.0047 μF	600V	CerD	72982	ED-.0047	C22-.0047M	22
C1223	.0047 μF	600V	CerD	72982	ED-.0047	C22-.0047M	22
C1224	.0047 μF	600V	CerD	72982	ED-.0047	C22-.0047M	22
C1225	5 pF	600V	CerD	72982	ED-5	C22-5P	22

CONNECTORS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
J1215	Receptacle, 15 Pin, Display/Overload Board	09922	PSC-4SS15-2	CS-175	22
J1216	Receptacle, 15 Pin, Readout Board	73690	02-015-113-6-200	CS-226	22
J1217	Receptacle, 6 Pin, Readout Board	73690	02-006-113-6-200	CS-225	22
J1218	Receptacle, 15 Pin, Oscillator Board	09922	PSC-4SS15-12	CS-175	22
J1219	Receptacle, 15 Pin, Integrator Board	09922	PSC-4SS15-12	CS-175	22
J1201	Receptacle, Printed Circuit	91662	02-005-113-6-200	CS-199	22
P1201	Contacts, Printed Circuit	91662	02-006-113-6-200	CS-200	22
J1202	Binding Post Terminal, Green (Case GND)	58474	DF21GC	BP-11 (Green)	2
J1203	Binding Post Terminal, Red (X1)	58474	DF21RC	BP-11 (Red)	2
J1204	Binding Post Terminal, Blue (Guard)	58474	DF21BC	BP-11 (Blue)	2
J1205	Binding Post Terminal, Black (LO)	58474	DF21BC	BP-11 (Black)	2
J1206	Receptacle, Phone Type	82389	N113B	CS-231	2
J1207	Receptacle, Microphone Type	02660	80-PC2F	CS-32	2
J1208	Not Used				
J1209	Receptacle, Triaxial, Input	95712	33050-2-NT34	CS-181	1
---	Plug, Triaxial Mate of J1209	95712	2743-1-NT34	CS-141	-
---	Cap, Input	02660	31-007	CAP-18	-
J1210	Binding Post Terminal, Black (LO)	58474	DF21BC	BP-11 (Black)	1
J1211	Receptacle, 50 Pin, Printer/Control	02660	47-40500-1	CS-221	2
---	Plug, 50 Pin, Mate of J1211	02660	57-30500-1	CS-220	-
J1212	Receptacle, 44 Pin, Output Buffer Card	09922	PSC4DD22-12	CS-205	22
J1213	Receptacle, 44 Pin, Output Buffer Card	09922	PSC4DD22-12	CS-205	22
J1214	Receptacle, 15 Pin, Polarity Board	09922	PSC4SS15-12	CS-175	22
---	Plug, Phone Type, Mates with J1206	82389	267	CS-244	-

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D1201*	Silicon	PD-10	83701	RF-36	22
D1202*					
D1203*	*(4-Diode Full-Wave Bridge Module)				
D1204*					
D1205	Zener	VR-20	84970	DZ-31	22
D1206	Zener	1N936	04713	DZ-5	22
D1207	Zener	VR-20	84970	DZ-31	22
D1208	Zener	1N936	04713	DZ-5	22
D1209	Zener	VR-120A	84970	DZ-32	22
D1210	Zener	VR-120A	84970	DZ-32	22
D1211	Silicon	1N3256	02735	RF-22	22
D1212	Silicon	1N3256	02735	RF-22	22
D1213	Silicon	1N645	01295	RF-14	22
D1214	Silicon	1N645	01295	RF-14	22

PRINTED CIRCUITS AND SUB-ASSEMBLIES

Circuit Desig.	Description	Schematic Part Number	Fig. Ref.
Power Supply	Mother Board	24044E	22
PC-207	Polarity P.C. Board.	23449D	23
PC-241	0-1 Display/Overload P.C. Board.	24031D	24
PC-229	Readout P.C. Board.	23451E	25
PC-217	Oscillator P.C. Board.	23452D	26
PC-246	Integrator P.C. Board.	24042E	27
PC-218	Model 4401 Output Buffer P.C. Board.	23457D	28
PC-209 -	Model 4401 Output Buffer P.C. Board.	23481E	29

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1201	10 MΩ	10%, 1/2 W	Comp	01121	EB	R1-10M	21
R1202	10 Ω	.25%, 10 W	WW	02985	TS-10	R163-10	30
R1203	100 Ω	.25%, 10 W	WW	02985	TS-10	R163-100	30
R1204	1 KΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-1K	30
R1205	10 KΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-10K	30
R1206	100 KΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-100K	30
R1207	1 MΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-1M	30
R1208	10 MΩ	1%, 1/2 W	DCb	91637	DCF-1/2	R12-10M	30
R1209	10^8 Ω	1%, 2 W	DCb	91637	DC-2	R14-10^8	30
R1210	10^9 Ω	+3 -0% 1/R W	GCb	63060	RX-1	R20-10^9	30
R1211	10^{10} Ω	+3 -0% 1/R W	GCb	63060	RX-1	R20-10^{10}	30
R1212	10^{11} Ω	+3 -0% 1/R W	GCb	63060	RX-1	R20-10^{11}	30
R1213	100 Ω	.5%, 1/2 W	MtF	07716	CBC	R61-100	22
R1214	900 Ω	.5%, 1/2 W	MtF	07716	CBC	R61-900	22
R1215	10 Ω	1%, 1/2 W	DCb	91637	DCF-1/2	R12-10	22
R1216	2 KΩ	20%, 2W	WW	71450	1NS-115	RP50-2K	22
R1217	7.15 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-7.15K	22
R1218	10 MΩ	1%, 1/2 W	DCb	91637	DCF-1/2	R12-10M	31
R1219	2.2 MΩ	1%, 1/2 W	DCb	91637	DCF-1/2	R12-2.2M	31
R1220	100 KΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	22
R1221	68 KΩ	1%, 1/8 W	MtF	07716	CEA	R88-68K	22
R1222	10 KΩ	5%	---	07716	8400	RP84-10K	22
R1223	68 KΩ	1%, 1/8 W	MtF	07716	CEA	R88-68K	22
R1224	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1225	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1226	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1227	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1228	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1229	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1230	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1231	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1232	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1233	226 Ω	1%, 1/2 W	MtF	07716	CEC	R94-226	32
R1234	34.8 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-34.8K	22
R1235	200 KΩ	1%, 1/2 W	DCb	91637	DCF-1/2	R12-200K	22

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1236	36.5 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-36.5K	22
R1237	36.5 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-36.5K	22
R1238	11.8 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-11.8K	22
R1239	200 KΩ	1%, 1/2 W	DCb	91637	DCF-1/2	R12-200K	22
R1240	2.2 KΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	22
R1241	2.2 KΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	22
R1242	28.7 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-28.7K	22
R1243	21.5 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-21.5K	22
R1244	7.15 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-7.15K	22
R1245	270 KΩ	10%, 1/2 W	Comp	01121	EB	R1-270K	22
R1246	100 KΩ	10%, 1/2 W	Comp	01121	EB	R1-100K	22
R1247	4.7 KΩ	10%, 1/2 W	Comp	01121	EB	R1-4.7K	22
R1248	15 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-15K	22
R1249	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	22
R1250	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	22
R1251	680 Ω	10%, 1/2 W	Comp	01121	EB	R1-680	22
R1252	1.8 KΩ	10%, 1/2 W	Comp	01121	EB	R1-1.8K	22
R1253	680 Ω	10%, 1/2 W	Comp	01121	EB	R1-680	22
R1254	1.8 KΩ	10%, 1/2 W	Comp	01121	EB	R1-1.8K	22
R1255	20 KΩ	5%, 5W	WW	91637	RS-5	R4A-20K	22
R1256	20 KΩ	5%, 5W	WW	91637	RS-5	R4A-20K	22
R1257	100 KΩ	1/2 W	MtF	07716	CBC	R61-100K	31
R1258	1.0101 KΩ	.01% .33W	WW	17870	1250	R166-1.0101K	22
R1259	90.000 KΩ	.05% .33W	WW	17870	1250	R165-90.000K	31
R1260	9.000 KΩ	.05% .33W	WW	17870	1250	R165-9.000K	31
R1261	909.09 Ω	.05% .33W	WW	17870	1250	R165-909.09	31
R1262	101.01 Ω	.05% .33W	WW	17870	1250	R165-101.01	31
R1263	10 KΩ	1%, 1/2 W	MtF	07716	CEC	R94-10K	31
R1264	Not Used						
R1265	Not Used						
R1266	Not Used						
R1267	Not Used						
R1268	2K Ω	2%, 2W	WW	71450	1NS 115	RP50-2K	22
R1269	500K Ω	±20%, 1/4W	CbVar	71450	GC45	RP75-500K	22
R1270	220 Ω	10%, 1/4 W	Comp	44655	RC07	R76-220	22
R1271	220 Ω	10%, 1/4 W	Comp	44655	RC07	R76-220	22
R1272	220 Ω	10%, 1/4 W	Comp	44655	RC07	R76-220	22
R1273	220 Ω	10%, 1/4 W	Comp	44655	RC07	R76-220	22

SWITCHES AND CONTROLS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
S1201	Rotary Switch less components, RANGE	80164	SW-287	1
---	Rotary Switch with components, Range Switch	80164	---	
---	Dial Assembly, Range Switch	80164	24026A	
S1202	Limit Switch, ZERO CHECK	04426	SW-94	1
---	Knob Assembly, Zero Check Switch	80164	15461A	
S1203	Rotary Switch less components, SENSITIVITY	80164	SW-307	1
---	Rotary Switch with components, Sensitivity Switch	80164	---	
---	Knob Assembly, Sensitivity Switch	80164	21384A	

SWITCHES AND CONTROLS (Cont'd.)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
S1204	Rotary Switch less components, FEEDBACK	80164	SW-308	1
---	Rotary Switch with components, Feedback Switch	80164	---	
---	Knob Assembly, Feedback Switch	80164	21384A	
S1205	Rotary Switch less components, COARSE ZERO	80164	SW-286	2
---	Rotary Switch with components, Coarse Zero Switch	80164	---	
---	Knob Assembly, Coarse Zero Switch	80164	16373A	
S1206	Rotary Switch, DISPLAY RATE (See also R1269)	71450	RP75-500K	1
---	Knob Assembly, Display Rate Control	80164	21384A	

TRANSISTORS

Circuit Desig.		Number	Mfg. Code	Keithley Part No.	Fig. Ref.
*Q1201	* These transistors should be replaced by ordering replacement FET Input Board No. 23733.				22
*Q1202					22
Q1203	NPN, Case TO-92	2N3903	04713	TG-49	22
Q1204	NPN, Case TO-92	2N3903	04713	TG-49	22
Q1205	NPN, Case TO-92	2N3903	04713	TG-49	22
Q1206	NPN, Case TO-92	2N3903	04713	TG-49	22
Q1207	NPN, Case TO-106	2N3565	07263	TG-39	22
Q1208	NPN, Case TO-92	2N3903	04713	TG-49	22
Q1209	PNP, Case TO-92	2N3905	04713	TG-53	22
Q1210	NPN, Case TO-39	MM3003	04713	TG-58	22
Q1211	PNP, Case TO-39	MM4003	04713	TG-59	22
Q1212	PNP, Case TO-92	2N3905	04713	TG-53	22

POWER SUPPLY PARTS LIST

(Refer to Schematic Diagram 24044E for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	2000 μF	15V	EAL	29309	36750200150	C93-2000M	22
C102	220 pF	1000V	CerD	71590	DD-221-10%	C22-220P	22
C103	150 pF	1000V	CerD	71590	DD-151-10%	C22-150P	22
C104	200 μF	35V	EAL	90201	MTV200N35PDN	C177-200M	22
C105	200 μF	35V	EAL	90201	MTV200N35PDN	C177-200M	22
C106	200 μF	35V	EAL	90201	MTV200N35PDN	C177-200M	22
C107	200 μF	35V	EAL	90201	MTV200N35PDN	C177-200M	22
C108	1.2 μF	20V	ETT	17554	TSD120125	C179-1.2M	22
C109	5 pF	1000V	CerD	71590	DD-050-10%	C22-5P	22
C110	125 μF	15V	ETB	73445	C426	C3-125M	22
C111	125 μF	15V	ETB	73445	C426	C3-125M	22
C112	15 μF	300V	EAL	90201	PTC015M300P3E	C173-15M	22
C113	Not Used						
C114	68 pF	500V	Mica	84171	DM15-680J	C21-68PF	22

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N4139	13327	RF-34	22
D102	Silicon	1N4139	13327	RF-34	22
D103	Silicon	1N645	01295	RF-14	22
D104	Silicon	1N645	01295	RF-14	22
D105	Silicon	1N645	01295	RF-14	22
D106	Silicon	1N645	01295	RF-14	22
D107	Silicon	1N645	01295	RF-14	22
D108	Silicon	1N645	01295	RF-14	22
D109	Silicon	1N645	01295	RF-14	22
D110	Zener	1N936	04713	DZ-5	22
D111	Silicon	1N3255	02735	RF-17	22
D112	Silicon	1N645	01295	RF-14	22

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
F101 (117V)	Fuse, slow blow, 3/4 A, 250V	71400	Type MDL	FU-19	2
F101 (234V)	Fuse, slow blow, 3/8 A, 250V	71400	Type MDL	FU-18	2
---	Fuse Holder	75915	342012	FH-3	2
P101	Cord Set, 6 feet	93656	4638-13	CO-5	2
S101	Slide Switch, 117-234V	80164	SW-151	SW-151	2
S102	Toggle Switch, POWER	80164	SW-265	SW-265	1
T101	Power Transformer	80164	TR-126	TR-126	2

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	6.8 kΩ	10%, 1/4 W	Comp	44655	CB-682	R76-6.8K	22
R102	0.2 Ω	±10%, 4.25 W	TCu	91637	CW-2	R151-0.2	22
R103	10 kΩ	1%, 1/8 W	MtF	07716	CEA-10KΩ	R88-10K	22
R104	1.1 kΩ	1%, 1/8 W	MtF	07716	CEA-1.1KΩ	R88-1.1K	22
R105	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1K	22
R106	100 Ω	1%, 1/8 W	MtF	07716	CEA-100Ω	R88-100	22
R107	150 Ω	1%, 1/8 W	MtF	07716	CEA-150Ω	R88-150	22
R108	33 kΩ	10%, 1/4 W	Comp	44655	CB-333	R76-33K	22
R109	3 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-3Ω	R12-3	22
R110	680 Ω	10%, 1/4 W	Comp	44655	CB-681	R76-680	22
R111	3.3 kΩ	10%, 1/4 W	Comp	44655	CB-332	R76-3.3K	22
R112	4.7 kΩ	10%, 1/4 W	Comp	44655	CB-472	R76-4.7K	22
R113	3.3 kΩ	10%, 1/4 W	Comp	44655	CB-332	R76-3.3K	22
R114	4.75 kΩ	1%, 1/8 W	MtF	07716	CEA-4.75KΩ	R88-4.75K	22
R115	2 kΩ	20%, 2 W	WWVar	71450	1NS 115-2KΩ	RP50-2K	22
R116	8.06 kΩ	1%, 1/8 W	MtF	07716	CEA-8.06KΩ	R88-8.06K	22
R117	18.2K	1%, 1/8 W	Comp	07716	CEA-18.2KΩ	R88-18.2K	22
R118	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA-7.5KΩ	R88-7.5K	22
R119	33 kΩ	10%, 1/4 W	Comp	44655	CB-333	R76-33K	22
R120	3 Ω	1%, 1/2 W	DCb	91637	DCF-1/2-3Ω	R12-3	22
R121	33 kΩ	10%, 1/4 W	Comp	44655	CB-333	R76-33K	22
R122	33 kΩ	10%, 1/4 W	Comp	44655	CB-333	R76-33K	22
R123	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA-7.5KΩ	R88-7.5K	22

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R124	82 Ω	10%, 1/2 W	Comp	01121	EB	R1-82	22
R125	1 MΩ	10%, 1/4 W	Comp	44655	RC07	R76-1M	22
R126	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	22
R127	56 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-56K	22
R128	80.6 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-80.6K	22
R129	7.32 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.32K	22
R130	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	22
R131	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	22
R132	12 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-12K	22
R133	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	22

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101	2N5183	02735	TG-68	22
Q102	ES-5321	71279	TG-54	22
Q103	2N3565	07263	TG-39	22
Q104	2N3565	07263	TG-39	22
Q105	S17638	07263	TG-33	22
Q106	2N3565	07263	TG-39	22
Q107	40317	02734	TG-43	22
Q108	2N3565	07263	TG-39	22
Q109	2N3565	07263	TG-39	22
Q110	S17638	07263	TG-33	22
Q111	40319	02734	TG-50	22
Q112	S17638	07263	TG-33	22
Q113	S17638	07263	TG-33	22
Q114	2N3565	07263	TG-39	22
Q115	2N3565	07263	TG-39	22
Q116	S17638	07263	TG-33	22
Q117	S17638	07263	TG-33	22
Q118	40346	02735	TG-44	22
Q119	40346	02735	TG-44	22
Q120	2N3565	07263	TG-39	22

POLARITY BOARD (P.C.-207) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 23449D for circuit designations).

CAPACITOR

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C201	150 pF	600V	CerD	72982	ED-150	C22-150P	23

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
QA201	Dual J-K Flip-Flop	04713	MC890P	IC-8
QA202	Quad 2 Input Gate	04713	MC824P	IC-5
QA203	Quad 2 Input Gate	04713	MC824P	IC-5

INTEGRATED CIRCUITS (Cont'd.)

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
QA204	Quad 2 Input Gate	04713	MC824P	IC-5
QA205	Quad 2 Input Gate	04713	MC824P	IC-5
QA206	Dual J-K Flip-Flop	04713	MC890P	IC-8
QA207	Dual 3 Input Buffer, non-inverting	04713	MC888P	IC-6

LAMP

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
DS201	‡Polarity Pilot Light	91802	2330 Series	PL-43	23

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R201	270 Ω	10%, 1/2 W	Comp	44655	RC07	R76-270	23
R202	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	23
R203	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	23
R204	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	23

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q201	2N5184	02735	TG-67	23
Q202	2N5184	02735	TG-67	23

0-1 DISPLAY/OVERLOAD BOARD (PC-241) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 24031D for circuit designations).

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
QA301	Dual J-K Flip-Flop	04713	MC890P	IC-8	24
QA302	Dual J-K Flip-Flop	04713	MC890P	IC-8	24
QA303	Hex Inverter	04713	MC889P	IC-7	24
QA304	Quad 2 Input Gate	04713	MC824P	IC-5	24
QA305	Quad 2 Input Gate	04713	MC824P	IC-5	24
QA306	Quad 2 Input Gate	04713	MC824P	IC-5	24

LAMP

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
DS301	Pilot Light, front panel thousands tube	80164	PL-42	PL-42	24

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R301	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	24
R302	10 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-10K	24

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R303	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	24
R304	820 Ω	10%, 1/4 W	Comp	44655	RC07	R76-820	24

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q301	2N5184	02735	TG-67	24
Q302	2N5184	02735	TG-67	24

READOUT BOARD (P.C.-229) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 23451E for circuit designations).

CONNECTORS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
P401	Plug, 6 pins, connects to J1206	73690	02-006-105-6-200	CS-223	25
P402	Plug, 22 pins, connects to J1207	73690	02-015-105-6-200	CS-222	25

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
QA401	Dual J-K Flip-Flop	04713	MC891P	IC-9	25
QA402	Dual J-K Flip-Flop	04713	MC891P	IC-9	25
QA403	Dual J-K Flip-Flop	04713	MC891P	IC-9	25
QA404	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA405	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA406	Dual J-K Flip-Flop	04713	MC891P	IC-8	25
QA407	Quad 2 Input Gate	04713	MC824P	IC-5	25
QA408	Quad 2 Input Gate	04713	MC824P	IC-5	25
QA409	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA410	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA411	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA412	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA413	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA414	Dual J-K Flip-Flop	04713	MC890P	IC-8	25
QA415	Decimal Decoder/Driver	07263	U6B996079X	IC-3	25
QA416	Decimal Decoder/Driver	07263	U6B996079X	IC-3	25
QA417	Decimal Decoder/Driver	07263	U6B996079X	IC-3	25

READOUT TUBES

Circuit Desig.		Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
V401	Units Readout Tube	83594	B5750	EV-5750	25
V402	Tens Readout Tube	83594	B5750	EV-5750	25
V403	Hundreds Readout Tube	83594	B5750	EV-5750	25

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R401	10 kΩ	5%, 1/2 W	Comp	01121	EB-10KΩ	R19-10K	25
R402	10 kΩ	5%, 1/2 W	Comp	01121	EB-10KΩ	R19-10K	25
R403	10 kΩ	5%, 1/2 W	Comp	01121	EB-10KΩ	R19-10K	25

OSCILLATOR BOARD (P.C.-217) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 23452D for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C501	.0022 μF	100V	Poly	13934	E3FR-222-1-C	C152-.0022M	26
C502	.001 μF	100V	Poly	13934	E3FR-222-1-C	C152-.001M	26
C503	4.5-25 pF	500V	Cer Trimmer	71590	802AZ	C76-4.5-25P	26
C504	22 pF	500V	Mica	84171	DM15-220J	C21-22P	26
C505	470 pF	600V	CerD	72982	ED-470	C22-470P	26
C506	220 pF	600V	CerD	72982	ED-220	C22-220P	26
C507	56 μF	15V	ETT	17554	CC201556610	C234-56M	26
C508	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	26

CRYSTAL

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
Y501	Crystal for 60 Hz operation	80164	CR-1	CR-1
	Crystal for 50 Hz operation	80164	CR-2	CR-2

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D501	Silicon	1N645	01295	RF-14	26
D502	Silicon	1N645	01295	RF-14	26
D503	Silicon	1N914	01295	RF-28	26

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
QA501	Quad 2 Input NOR Gate, 14-pin DIP	04713	MC824P	IC-5	26
QA502	Quad 2 Input NOR Gate, 14-pin DIP	04713	MC824P	IC-5	26

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R501	3.3 kΩ	10%, 1/4 W	Comp	44655	CB-332	R76-3.3K	26
R502	33 kΩ	10%, 1/4 W	Comp	44655	CB-333	R76-33K	26
R503	68.1 Ω	1%, 1/8 W	MtF	07716	CEA-68.1Ω	R88-68.1	26
R504	4.99 kΩ	1%, 1/8 W	MtF	07716	CEA-4.99KΩ	R88-4.99K	26
R505	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1K	26
R506	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1K	26
R507	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1KΩ	R88-1K	26
R508	470 Ω	10%, 1/4 W	Comp	44655	CB-471	R76-470	26

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R509	4.7 kΩ	10%, 1/4 W	Comp	44655	CB-472	R76-4.7K	26
R510	56 kΩ	10%, 1/4 W	Comp	44655	CB-563	R76-56K	26
R511	4.7 kΩ	10%, 1/4 W	Comp	44655	CB-472	R76-4.7K	26
R512	470 Ω	10%, 1/4 W	Comp	44655	CB-471	R76-470	26
R513	680 Ω	10%, 1/4 W	Comp	44655	CB-681	R76-680	26
R514	470 Ω	10%, 1/4 W	Comp	44655	CB-471	R76-470	26
R515	237 Ω	1%, 1/8 W	MtF	07716	CEA-237Ω	R88-237	26
R516	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1KΩ	R88-1K	26
R517	4.99 kΩ	1%, 1/8 W	MtF	07716	CEA-4.99KΩ	R88-4.99K	26
R518	56 kΩ	10%, 1/4 W	Comp	44655	CB-563	R76-56K	26
R519	237 Ω	1%, 1/8 W	MtF	07716	CEA-237Ω	R88-237	26
R520	3.3 kΩ	10%, 1/4 W	Comp	44655	CB-332	R76-3.3K	26
R521	Used on Model 445 only						
R522	Used on Model 445 only						
R523	Used on Model 445 only						
R524	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1K	26
R525	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10K	26
R526	1 kΩ	10%, 1/4 W	Comp	44655	CB-102	R76-1K	26
R527	3.9 kΩ	10%, 1/4 W	Comp	44655	CB-392	R76-3.9K	26
R528	3.9 kΩ	10%, 1/4 W	Comp	44655	CB-392	R76-3.9K	26
R529	330 Ω	10%, 1/4 W	Comp	44655	CB-331	R76-330	26
R530	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152	R76-1.5K	26
R531	5.6 kΩ	10%, 1/4 W	Comp	44655	CB-562	R76-5.6K	26
R532	10 kΩ	10%, 1/4 W	Comp	44655	CB-103	R76-10K	26
R533	10 Ω	10%, 1/4 W	Comp	44655	CB-100	R76-10	26
R534	1.5 kΩ	10%, 1/4 W	Comp	44655	CB-152	R76-1.5K	26
R535	1 kΩ	1%, 1/8 W	MtF	07716	CEA-1KΩ	R88-1K	26
R536	47 Ω	10%, 1/4 W	Comp	44655	CB-470	R76-47	26
R537	33 Ω	10%, 1/4 W	Comp	44655	CB-330	R76-33	26
R538	Not Used	---	--	--	--		26

TRANSISTORS

Circuit Desig.		Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q501	NPN, Case TO-106	2N5134	07263	TG-65	26
Q502	NPN, Case TO-106	2N5134	07263	TG-65	26
Q503	NPN, Case TO-106	2N5134	07263	TG-65	26
Q504	PNP, Case TO-106	2N5139	07263	TG-66	26
Q505	NPN, Case TO-106	2N5134	07263	TG-65	26
Q506	PNP, Case TO-106	2N5139	07263	TG-66	26
Q507	NPN, Case TO-106	2N5134	07263	TG-65	26
Q508	PNP, Case TO-106	2N5139	07263	TG-66	26
Q509	NPN, Case TO-106	2N5134	07263	TG-65	26
Q510	NPN, Case TO-106	2N5134	07263	TG-65	26
Q511		Used on Model 445 only			
Q512		Used on Model 445 only			
Q513	NPN, Case TO-106	2N5134	07263	TG-65	26
Q514	Unijunction, Case TO-72	2N2646	03508	TG-52	26

INTEGRATOR BOARD (P.C.-246) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 24042E for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C601	100 pF	600V	CerD	72982	ED-100	C22-100P	27
C602	10 pF	500V	Poly	71590	CPR-10J	C138-10P	27
C603	0.082 μF	100V	Poly	13934	E3FR-22-1-C	C152-.082M	27
C604	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	27
C605	1000 pF	600V	CerD	72982	ED-1000	C22-.001	27
C606	220 pF	600V	CerD	72982	ED-220	C22-220P	27
C607	.0047 μF	600V	CerD	72982	ED-.0047	C22-.0047M	27
C608	0.1 μF	250V		73445	C280AE/P100K	C178-.1M	27
C609	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	27
C610	390 pF	1000V	CerD	56289	5GAQ390	C72-390P	27
C611	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	27
C612	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	27
C613	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	27
C614	22 μF	10V	ETT	17554	TSD2-10-226	C180-22M	27
C615	1.5 pF	500V	CerD	00656	CC22	C77-1.5P	27
C616	10 pF	500V	CerD	72982	ED-10	C22-10P	27
C617	1 μF	25V	CerD	56289	5C13	C85-1M	27
C618	10 pF	500V	CerD	72982	ED-10	C22-10P	27

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D601	Zener	1N936	04713	DZ-5	27
D602	Zener	1N936	04713	DZ-5	27
D603	Silicon	2N3565	07263	TG-39	27
D604	Silicon	2N3565	07263	TG-39	27
D605	Silicon	1N645	01295	RF-14	27
D606	Silicon	1N645	01295	RF-14	27
D607	Silicon	1N914	01295	RF-28	27
D608	Silicon	1N914	01295	RF-28	27
D609	Silicon	1N645	01295	RF-14	27
D610	Silicon	1N645	01295	RF-14	27
D611	Silicon	1N645	01295	RF-14	27
D612	Silicon	1N645	01295	RF-14	27
D613	Silicon	1N914	01295	RF-28	27
D614	Silicon	1N914	01295	RF-28	27
D615	Silicon	1N645	01295	RF-14	27

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
QA601	Integrated Circuit	07263	U5B770939X	IC-1	27
QA602	Integrated Circuit	07263	U5B770939X	IC-1	27
QA603	High Speed Differential Comparator	07263	U5B771039X	IC-4	27
QA604	Quad 2 Input Gate	04713	MC824P	IC-5	27

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R601	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R602	*	1%, 1/8 W	MtF	91637	MFF-1/8	R177*	27

*NOTE: This part selected in final test.

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R603	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R604	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R605	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R606	10 kΩ	±20%, 3/4 W	Cermet	73138	77PR10K	RP64-10K	27
R607	*	1%, 1/8 W	MtF	91637	MFF-1/8	R177*	27
R608	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R609	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R610	7.5 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-7.5K	27
R611	10 kΩ	±20%, 3/4 W	Cermet	73138	77PR10K	RP64-10K	27
R612	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R613	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R614	Not Used						
R615	49.9 kΩ	1%, 1/8 W	MtF	91637	MMF-1/8	R177-49.9K	27
R616	680 Ω	10%, 1/4 W	Comp	44655	RC07	R76-680	27
R617	680 Ω	10%, 1/4 W	Comp	44655	RC07	R76-680	27
R618	33 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-33K	27
R619	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	27
R620	33 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-33K	27
R621	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	27
R622	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	27
R623	4.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-4.7K	27
R624	49.9 kΩ	1%, 1/8 W	MtF	91637	MMF-1/8	R177-49.9K	27
R625	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R626	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R627	301 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-301K	27
R628	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	27
R629	49.9 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-49.9K	27
R630	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R631	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	27
R632	15 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-15K	27
R633	301 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-301K	27
R634	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	27
R635	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	27
R636	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	27
R637	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	27
R638	47 Ω	10%, 1/4 W	Comp	44655	RC07	R76-47	27
R639	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	27
R640	1.5 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1.5K	27
R641	100 Ω	10%, 1/4 W	Comp	44655	RC07	R76-100	27
R642	10 Ω	10%, 1/4 W	Comp	44655	RC07	R76-10	27
R643	3.01 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-3.01K	27
R644	1 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-1K	27
R645	2.7 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.7K	27
R646	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	27
R647	10 Ω	10%, 1/4 W	Comp	44655	RC07	R76-10	27
R648	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R649	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	27
R650	100 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-100K	27
R651	3.3 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.3K	27
R652	820 Ω	10%, 1/4 W	Comp	44655	RC07	R76-820	27
R653	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	27
R654	220 Ω	10%, 1/4 W	Comp	44655	RC07	R76-220	27
R655	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	27

*NOTE: This part selected in final test.

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R656	6.98 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-6.98K	27
R657	6.04 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-6.04K	27
R658	Not Used	-	-	-	-	-	
R659	47 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-47K	27

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q601	2N5139	07263	TG-66	27
Q602	2N5139	07263	TG-66	27
Q603	2N5134	07263	TG-65	27
Q604	2N5134	07263	TG-65	27
Q605	2N4220	04713	TG-42	27
Q606	2N4220	04713	TG-42	27
Q607	T1570	01295	TG-71	27
Q608	T1570	01295	TG-71	27
Q609	S17638	07263	TG-33	27
Q610	2N4220	04713	TG-42	27
Q611	2N5139	07263	TG-66	27
Q612	2N4220	04713	TG-42	27

MODEL 4401 OUTPUT BUFFER BOARD (P.C.-218) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 23457D for circuit designations)

NOTE

On Schematic Diagram 23457D there are 15 buffers labeled 'A' through 'P' not including 'I'. Each buffer is composed of 4 resistors and 3 transistors. A sample buffer circuit is given in the lower lefthand corner of the Schematic. Following is a typical replaceable parts list for each buffer.

BUFFER RESISTORS (A thru P)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1001	180 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-180K	28
R1002	3.9 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.9K	28
R1003	120 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-120K	28
R1004	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	28

BUFFER TRANSISTORS (A thru P)

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q1001	2N3565	07263	TG-39	28
Q1002	2N3565	07263	TG-39	28
Q1003	2N3565	07263	TG-39	28

MODEL 4401 OUTPUT BUFFER BOARD (P.C.-209) REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 23481E for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C1101	.001 µF	600V	CerD	72982	ED-.001	C22-.001M	29
C1102	.0033 µF	600V	CerD	72982	ED-.0033	C22-.0033M	29
C1103	.001 µF	600V	CerD	72983	ED-.001	C22-.001M	29
C1104	0.1 µF	250V		73445	C280AE/P100K	C178-0.1M	29
C1105	100 pF	600V	CerD	72982	ED-100	C22-100P	29

CAPACITORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C1106	100 pF	600V	CerD	72982	ED-100	C22-100P	29
C1107	470 pF	600V	CerD	72982	ED-470	C22-470P	29
C1108	470 pF	600V	CerD	72982	ED-470	C22-470P	29
C1109	22 μF	10V	ETT	17554	TSD2-10-226	C180-22M	29
C1110	10 μF	20V	ETT	17554	TSD2-20-106	C179-10M	29

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
QA1101	Quad 2 Input Gate	04713	MC724P	IC-5	29
QA1102	Quad 2 Input Gate	04713	MC724P	IC-5	29

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1101	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	29
R1102	3.3 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.3K	29
R1103	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	29
R1104	3.3 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.3K	29
R1105	120 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-120K	29
R1106	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	29
R1107	180 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-180K	29
R1108	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	29
R1109	1 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-1K	29
R1110	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	29
R1111	120 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-120K	29
R1112	180 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-180K	29
R1113	2.2 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-2.2K	29
R1114	6.98 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-6.98K	29
R1115	6.04 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-6.04K	29
R1116	2 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-2K	29
R1117	120 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-120K	29
R1118	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	29
R1119	180 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-180K	29
R1120	3.9 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.9K	29

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q1101	2N3565	07263	TG-39	29
Q1102	2N3565	07263	TG-39	29
Q1103	Not Used			
Q1104	2N3565	07263	TG-39	29
Q1105	2N3565	07263	TG-39	29
Q1106	2N3565	07263	TG-39	29
Q1107	2N3565	07263	TG-39	29
Q1108	2N3565	07263	TG-39	29
Q1109	2N3565	07263	TG-39	29
Q1110	2N3565	07263	TG-39	29

NOTE

On Schematic Diagram 23481E there are 6 buffers labeled 'A' through 'F'. Each buffer is composed of 5 resistors and 3 transistors. A sample buffer circuit is given on the schematic. Following is a typical replaceable parts list for each buffer.

BUFFER RESISTORS (A thru F)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R1121	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	29
R1122	120 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-120K	29
R1123	10 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-10K	29
R1124	180 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-180K	29
R1125	3.9 kΩ	10%, 1/4 W	Comp	44655	RC07	R76-3.9K	29

BUFFER TRANSISTORS (A thru F)

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q1111	2N3565	07263	TG-39	29
Q1112	2N3565	07263	TG-39	29
Q1113	2N3565	07263	TG-39	29

TABLE 24.

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

01121	Allen-Bradley Corp. 1201 South 2nd Street Milwaukee, Wis. 53204
01295	Texas Instruments, Inc. Semiconductor-Components Div. 13500 N. Central Expressway Dallas, Texas 75231
01686	RCL Electronics, Inc. 195 McGregor Street Manchester, N.H. 03102
02660	Amphenol Electronics, Corp. 2801 South 25th Avenue Broadview, Ill. 60153
02734	Radio Corp. of America Defense Electronic Products Camden, New Jersey
02735	Radio Corp. of America Commercial Receiving Tube & Semiconductor Division Somerville, N.J.
03508	General Electric Company Semiconductor Products Dept. Electronics Park Syracuse, New York 13201
04713	Motorola Semiconductor Products, Inc. 5005 East McDowell Road Phoenix, Ariz. 85008
05397	Union Carbide Corp. Electronics Division 270 Park Avenue New York, New York 10017
07263	Fairchild Camera & Instrument Corp., Semiconductor Division 313 Frontage Road Mountain View, Calif.
07716	IRC, Inc. 2850 Mt. Pleasant Burlington, Iowa 52601
09922	Burndy Corp. Richards Avenue Norwalk, Conn. 06852
12040	National Semiconductor Corp. Commerce Drive Post Office Box 443 Danbury, Conn. 06813
13050	Potter Co. Highway 51 N. Wesson, Miss. 39191
13327	Solitron Devices, Inc. 256 Oak Tree Road Tappan, New York 10983
13934	Midwec Corp. 602 Main Oshkosh, Nebr. 69154
17554	Components, Inc. Smith Street Biddeford, Maine 04005
24655	General Radio Co. 22 Baker Avenue West Concord, Mass. 01781
27682	Hathaway Instruments, Inc. 5800 E. Jewell Avenue Denver, Colorado 80222
44655	Ohmite Mfg. Co. 3601 Howard Street Skokie, Illinois 60076
56289	Sprague Electric Co. North Adams, Mass.
58474	Superior Electric Co., The 383 Middle Street Bristol, Conn. 06012
71279	Cambridge Thermionic Corp. 430 Concord Avenue Cambridge, Mass.
71400	Bussmann Mfg. Div. of McGraw-Edison Co. 2538 W. University Street St. Louis, Mo.
71450	CTS Corp. 1142 W. Beardsley Avenue Elkhart, Ind.
71590	Centralab Division of Globe-Union, Inc. 932 E. Keefe Avenue Milwaukee, Wis. 53212
72982	Erie Technological Products, Inc. 644 W. 12th Street Erie, Pa. 16512
73138	Beckman Instruments, Inc. Helipot Division 2500 Harbor Blvd. Fullerton, Calif. 92634
73445	Amperex Electronic Co., Div. of North American Philips Co. Hicksville, N.Y.
73690	Elco Resistor Co. 1158 Broadway New York, New York
75915	Littlefuse, Inc. 800 E. Northwest Highway Des Plaines, Ill. 60016
80164	Keithley Instruments, Inc. 28775 Aurora Road Cleveland, Ohio 44139
83594	Burroughs Corp. Electronic Components Div. Post Office Box 1226 Plainfield, N.J. 07061
84171	Arco Electronics, Inc. Community Drive Great Neck, N.Y. 11022
84790	Dura Corp. Implement Div.-P.O. Box 231 Zanesville, Ohio 43702
90201	Mallory Capacitor 3029 West Washington Post Office Box 372 Indianapolis, Ind. 46206
91637	Dale Electronics, Inc. Post Office Box 609 Columbus, Nebr. 68601
91662	Elco Corp. Willow Grove, Pa.
91802	Industrial Devices, Inc. 982 River Road Edgewater, New Jersey 07020
93656	Electric Cord Co. 1275 Bloomfield Avenue Caldwell, N.J.
95712	Dage Electric Co., Inc. Hurricane Road Franklin, Indiana

SECTION 5. SERVICING

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

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

5-3. PARTS REPLACEMENT. Refer to the Replaceable Parts List, Section 4, for information regarding component specifications and part numbers. Replace components as indicated using replacement parts which meet the listed specifications.

5-4. TROUBLESHOOTING.

a. Test Equipment. Refer to Table 6-1 for recommended test equipment for servicing and calibrating this instrument.

b. Troubleshooting Guide. Refer to Table 5-1 for troubleshooting information and corrective action.

NOTE

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

TABLE 5-1.
Troubleshooting & Corrective Action

Difficulty	Probable Cause	Solution
No front panel display.	Power failure 210V Supply failure 120V Supply failure Line switch set at 234V with 117V line input	Check fuse. If blown, replace with rated size after checking for internal short. Check for voltage at capacitor C112 for 210V ±20V. Check for voltage at R128. Set switch to 117V.
Overload indication when input is shorted.	Analog amplifier is out of balance. FET Board faulty Supply voltage is missing Overload circuit malfunction.	Check analog output on rear panel. Check the Coarse zero switch for offset. If output is greater than 2 volts, replace input FET board and recheck output. Check ±9 volt supply; ±120 volt supply. If voltages are normal, check transistor Q120 for open collector malfunction.
Ohms ranges inaccurate.	Ohms reference faulty.	Check +9 volt reference voltage at D1206.
Current readings inaccurate on one range.	Shunt resistor out of tolerance.	Replace shunt resistor with accurate value.
Overrange "1" not lighted when it should indicate.	Transistor Q301. Readout tube V301.	Replace transistor if "open" from collector to emitter. Otherwise replace tube V301.
Polarity signs do not light.	Transistors Q201, Q202 Polarity display DS201.	Replace transistor if "open" from collector to emitter. Otherwise replace polarity display DS201.

SECTION 6. CALIBRATION

6-1. GENERAL. The following test and adjustment procedures, when completed, will ensure that the instrument is calibrated to published specifications. If any portion of the procedure cannot be performed due to malfunction of the circuitry, refer to the servicing section of the manual or contact a Keithley Sales Service representative.

6-2. TEST CONDITIONS. All measurements should be made in a laboratory environment at approx. 25°C and less than 50% relative humidity. Unless otherwise specified the instrument should be powered by 117 volts rms line at 60 Hz. (50 Hz for those instruments so designated.)

6-3. TEST EQUIPMENT. All measurements should be made using test equipment which meets or exceeds the minimum specifications given in Table 6-1.

6-4. PRELIMINARY PROCEDURE. Set the POWER switch to off before connecting the line cord. Place a shield cap (Keithley part no. CAP-18) on triaxial input. Connect the line cord to 117 volts, 60 Hz (use a variable transformer if necessary to obtain the proper voltage within ±1 volt). Make certain that the third ground plug on the line cord is connected to earth ground s that the instrument chassis is not at a live potent Turn the instrument on and allow to warm-up for one hour. (This will ensure that all thermal variations within the instrument have been stabilized.)

6-5. ADJUSTMENT PROCEDURE.

a. Zero Adjustment. Set the front panel controls as follows:

Zero Check Button — Lock
Sensitivity Switch — 0.0000
Range Switch — Volts
Feedback Switch — Normal

With the input capped, adjust the front panel zero co trol so that the polarity signs on the digital displa (±) light alternately with the same time interval fo each polarity (adjust so that ± flashing rate is maxi mum). If the front panel zero control does not permi sufficient zeroing capability, adjust the rear panel COARSE zero control (S1205) until a polarity change i noted.

TABLE 6-1.
Test Equipment

Code Letter	Instrument Type	Specification	Manufacturer and Model No.
A	Voltmeter, Digital	±0.1% of reading 1.000V to 1000 volts	Keithley Model 163
B	Recorder, Analog	1 volt full scale	Keithley Model 370
C	Voltmeter, Digital	±0.01% of reading 1.0000V to 1.9999V	Eldorado Model 1820A
D	Voltage Source	±0.02% 1V to 100V	Fluke Model 341A
E	High Megohm Resistors	10^8 to $10^{12}\Omega$ ±0.2%	Keithley Model 5155
F	Current Source	±0.2%, 10^{-8}A, 10^{-9}A ±0.4%, 10^{-10}A, 10^{-11}A	Keithley Model 261*
G	Current Source	±0.05%, 10^{-1}A to 10^{-7}A	Fluke 341A and GR1433

NOTE*

To verify the accuracy on the 10^{-8}A through 10^{-11}A ranges a specially calibrated Keithley Model 261 Picoampere source is required. The "three month" accuracy for the Model 261 is ±0.6% on 10^{-8}A to 10^{-11}A. However, a Model 261 may be calibrated to within ±0.4% when used with a Model 515A Megohm Bridge and a set of 5155 Megohm Standards (traceable to the N.B.S.). Since the resistors exhibit a temperature coefficient of approx. -0.1% per °C it may be necessary to compensate for temperature variations between the calibration area and the measurement area. To minimize the effects of drift in the value of the resistors it is important to recalibrate the Model 261 just prior to making a calibration check on the Model 615. Where it may not be necessary to verify the Model 615 current ranges to within ±4%, a standard Model 261 Picoampere source may be used. To verify the accuracy on the 10^{-1}A to 10^{-6}A ranges, a Model 341A should be used with precision resistors having ±0.03% accuracy.

b. DC Bias Adjustment. Set the front panel controls as above. To set the dc bias, monitor the voltage across resistor R1249 (test terminals D and E as shown in Figure 22). Adjust the dc bias control (R1268) for 25 mV ±3 mV using voltmeter (A).

c. Power Supply Check. Set the Sensitivity control (S1203) to the 100.0 volt range; the range switch to VOLTS; the Feedback switch to FAST. With the line voltage set to 117 volts measure the power supply voltages as follows:

TABLE 6-2.
Power Supply Voltages

+15V	±50 mV	(Adjust the +15V cal potentiometer R115 as shown in Figure 22.)
-15V	±0.4V	
+3.6V	±0.1V	
+170V	(170 to 180V)	
+120V	±12V	
-120V	±12V	
+9.1V	±0.9V	
-9.1V	±0.9V	

d. Ohms Calibration. Measure the voltage across resistors R1213 + R1214 (test terminals B and D as shown in Figure 22). Adjust the OHMS CAL potentiometer (R1216) for 1 volt ±1 mV using voltmeter (A).

e. Analog Range Calibration. (Check zero before each measurement.)

1. Voltage Range. Set the front panel controls as shown in Table 6-3. Apply an input voltage in decade steps from 1V to 100V ±0.02%. Measure the analog output at J1207 for full scale indication on each range. The 1 volt output should be within ±0.2%.

2. Amperes Range. Set the front panel controls as shown in Table 6-4. Apply an input current in decade steps from 10^{-1}A to 10^{-11}A. Measure the analog output at J1207 for full scale indication on each range. The 1 volt output should be within ±0.5% on 10^{-1}A to 10^{-6}A ranges; ±2% on 10^{-7}A and 10^{-8}A ranges; ±4% on 10^{-9}A to 10^{-11}A ranges.

3. Coulombs Range. Set the front panel controls as shown in Table 6-5. Apply an input current in decade steps from 10^{-8}A to 10^{-11}A ±0.4%. Measure the analog output at J1207 for full scale indication on each range. The output should integrate to 1 volt within a period of 10 seconds ±1/2 second (±5%).

4. Ohms Ranges. Set the front panel controls as shown in Table 6-6. Apply resistance values at the input in decade steps from $10^5\Omega$ to $10^{12}\Omega$. Measure the analog output at J1207 for full scale indication on each range. The 1 volt output should be within ±0.5% on $10^5\Omega$ to $10^6\Omega$ ranges; ±4% on $10^7\Omega$ to $10^{12}\Omega$ ranges.

f. Offset Current. Set the front panel controls as follows:

Zero Check Button	— Lock
Sensitivity Switch	— 0.0000
Range Switch	— 10^{-11} Amperes
Feedback Switch	— Fast

Place a cap on the input receptacle and adjust the zero control as necessary for a zero display. Unlock the zero check button. The digital display should indicate less than 0.0005 x 10^{-11} amperes (5 x 10^{-15}A).

g. Drift Check. Set the front panel controls as follows:

Zero Check Button	— Lock
Sensitivity Switch	— 0.0000
Range Switch	— 10^{-6} Amperes
Feedback Switch	— Fast

Connect recorder (B) to the analog output (J1207) and set for 1 V full scale sensitivity. Readjust the zero control as necessary. Connect a 10 kilohm resistor (1% tolerance; Keithley R88-10K) across the input. Unlock the zero check button. Monitor the 1 V output on the recorder for a 24 hour period at constant ambient temperature. The recorder output should not vary more than 10% of full scale during the 24 hour period.

h. Clock Frequency Adjust. Locate the CLOCK test point on the oscillator board PC-217 as shown in Figure 26. Connect a digital frequency counter between the CLOCK test point and low. Adjust trimming capacitor C503 so that the frequency reading is 120 kHz ±1 Hz for instruments operated at 60 Hz. (The crystal Y501 should be a Keithley CR-1 for 60 Hz; CR-2 for 50 Hz.) The frequency reading should be set to 100 kHz ±1 Hz for instruments operated at 50 Hz.

TABLE 6-3.
Voltage Ranges

Range Sensitivity Switch	Feedback Switch	Input Voltage	Full Scale Output
Volts 0.1000	Normal	0.1000 ±0.02%	1.000 ±0.2%
Volts 1.000	Normal	1.000 ±0.02%	1.000 ±0.2%
Volts 10.00	Normal	10.00 ±0.02%	1.000 ±0.2%
Volts 100.0	Normal	100.0 ±0.02%	1.000 ±0.2%

TABLE 6-4.
Current Ranges

Range Switch	Sensitivity Switch	Feedback	Input Current	Full Scale Output
10^{-1}A	1.000	Normal	10^{-1}A ±0.05%	1.000 ±0.5%
10^{-2}A	1.000	Normal	10^{-2}A ±0.05%	1.000 ±0.5%
10^{-3}A	1.000	Normal	10^{-3}A ±0.05%	1.000 ±0.5%
10^{-4}A	1.000	Normal	10^{-4}A ±0.05%	1.000 ±0.5%
10^{-5}A	1.000	Normal	10^{-5}A ±0.05%	1.000 ±0.5%
10^{-6}A	1.000	Fast	10^{-6}A ±0.05%	1.000 ±0.5%
10^{-6}A	0.100	Fast	10^{-7}A ±0.05%	1.000 ±0.5%
10^{-7}A	0.100	Fast	10^{-8}A ±0.2%	1.000 ±2%
10^{-8}A	0.100	Fast	10^{-9}A ±0.2%	1.000 ±2%
10^{-9}A	0.100	Fast	10^{-10}A ±0.4%	1.000 ±4%
10^{-10}A	0.100	Fast	10^{-11}A ±0.4%	1.000 ±4%
10^{-11}A	1.000	Fast	10^{-11}A ±0.4%	1.000 ±4%

TABLE 6-5.
Coulombs Ranges

Range Switch	Sensitivity Switch	Feedback	Input Current	Full Scale Output
10^{-7}Q	1.000	Fast	10^{-8}A ±0.5%	1.000*
10^{-8}Q	1.000	Fast	10^{-9}A ±0.5%	1.000*
10^{-9}Q	1.000	Fast	10^{-10}A ±0.5%	1.000*
10^{-10}Q	1.000	Fast	10^{-11}A ±0.5%	1.000*

*The time interval for integration to 1.000 volts should be 10 secs. ±5%.

TABLE 6-6.
Ohms Ranges

Range Switch	Sensitivity Switch	Feedback	Input Resistance	Full Scale Output
$10^{5}\Omega$	0.1000	Normal	$10^{4}\Omega$ ±0.05%	1.000 ±0.5%
$10^{6}\Omega$	0.1000	Normal	$10^{5}\Omega$ ±0.05%	1.000 ±0.5%
$10^{6}\Omega$	1.000	Normal	$10^{6}\Omega$ ±0.05%	1.000 ±0.5%
$10^{6}\Omega$	10.000	Normal	$10^{7}\Omega$ ±0.05%	1.000 ±0.5%
$10^{6}\Omega$	100.0	Normal	$10^{8}\Omega$ ±0.05%	1.000 ±0.5%
$10^{7}\Omega$	10.00	Normal	$10^{8}\Omega$ ±0.4%	1.000 ±4%
$10^{8}\Omega$	1.000	Normal	$10^{8}\Omega$ ±0.4%	1.000 ±4%
$10^{9}\Omega$	1.000	Normal	$10^{9}\Omega$ ±0.4%	1.000 ±4%
$10^{10}\Omega$	1.000	Normal	$10^{10}\Omega$ ±0.4%	1.000 ±4%
$10^{11}\Omega$	1.000	Normal	$10^{11}\Omega$ ±0.4%	1.000 ±4%
$10^{12}\Omega$	0.100	Normal	$10^{11}\Omega$ ±0.4%	1.000 ±4%

i. Overload Blanking Check. Set the sensitivity switch for 1.0000 (with the Range set to volts). Apply 1 volt at the input and increase until the reading blanks. Blanking should occur just beyond 1.999 volts. Set the Sensitivity switch to 100.0 volts. Apply 90 volts at the input and increase until the reading blanks. Blanking should occur just beyond 99.9 volts.

j. A-to-D Converter Calibration. Set the front panel controls as follows:

Zero Check Button	— Lock
Sensitivity Switch	— 1.000
Range Switch	— VOLTS
Feedback Switch	— Normal

Connect digital voltmeter (B) to the 1 volt analog output. Unlock the zero check button. Apply approx. +2 volts at input using Voltage Source (D). Adjust the input source so that the analog reading is +1.9995 volts. Adjust the +CAL potentiometer (R611) so that the display indicates between +1.999 volts and a blanked display (overload). (Display should alternate between readings.) After the +CAL is adjusted check the reading by reducing the input voltage until the digital display indicates between +0.999 volts and +1.000 volts. The analog output should read between 0.999 volts and 1.000 volts. Repeat the above steps using -1.9995 volts and adjust the -CAL potentiometer (R606).

SECTION 7. ACCESSORIES

7-1. GENERAL. The following Keithley accessories can be used with the Model 615 to provide additional convenience and versatility.

7-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 6101A Shielded Probe

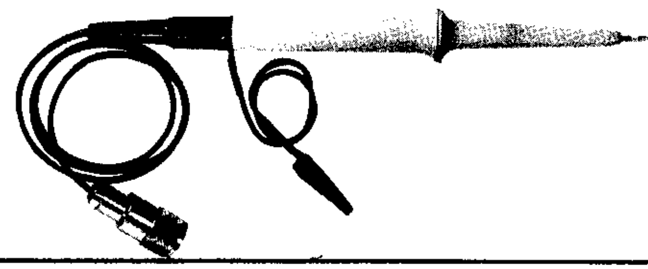
Description:

The Model 6101A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector.

Model 6101B Shielded Probe

Description:

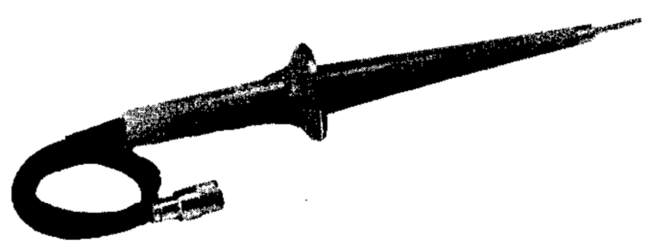
The Model 6101B is a shielded cable with a "gripping type" probe and 30 inches of low noise cable terminated by a UHF connector.



Model 6103A Divider Probe

Description:

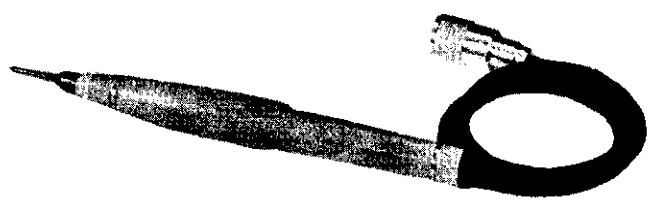
The Model 6103A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector. The probe includes a 1000:1 voltage divider with a $10^{12}\Omega$ input resistance. Accuracy is $\pm 6\%$ at 30 kilovolts.



Model 6102A Divider Probe

Description:

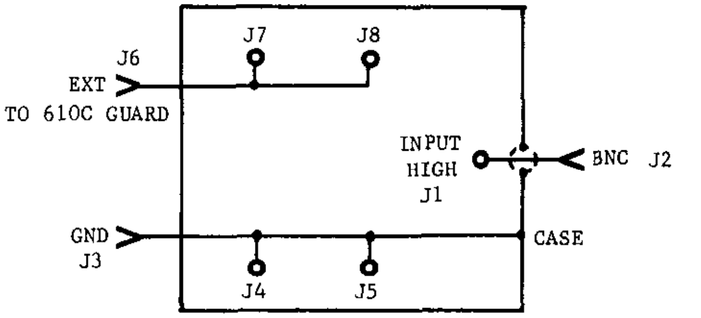
The Model 6102A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector. The probe includes a 10:1 voltage divider with $10^{10}\Omega$ input resistance. Accuracy is $\pm 4\%$ at 1000 volts.

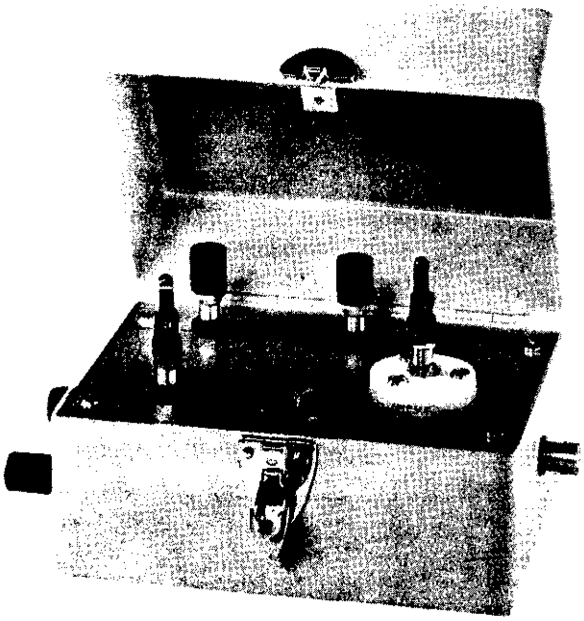


Model 6104 Test Shield

Description:

The Model 6104 is a shielded test box for two-terminal or three-terminal connections. The INPUT terminal is teflon insulated.





Applications:

1. Two Terminal Connections. Resistance measurements can be made conveniently using the INPUT and GROUND terminals on the Test Box. Connect the electrometer to the BNC output. Use the electrometer in NORMAL mode for ohms measurement.

2. Three Terminal Connections. The GUARD output on the Model 615 electrometer can be used for resistance measurements where the effects of cable capacitance may be significant. Connect the unknown between INPUT and EXT terminals. Connect the EXT terminal to the GUARD output on the electrometer. Use the electrometer in FAST mode for ohms measurement.

Model 6105 Resistivity Chamber

Description:

The Model 6105 is a guarded test fixture for measurement of surface and volume resistivities. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulating Materials, D257-66. The 6105 can be used in conjunction with an electrometer and voltage supply.

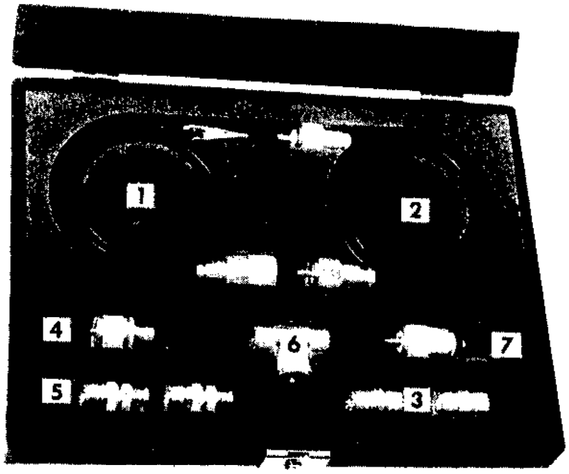
Applications:

Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The measurement can be made most conveniently when a set of electrodes are used which can be calibrated in terms of surface or volume resistivity. The Keithley Model 6105 Resistivity Adapter has been designed for use with a Keithley electrometer and an optional high voltage supply such as the Model 240A.

Model 6106 Electrometer Connection Kit

Description:

The Model 6106 contains a group of the most useful leads and adapters for low current measurements. All components are housed in a rugged carrying case with individual compartments.



Parts List:

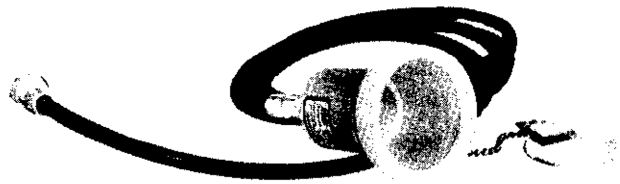
Description	Item No.	Keithley Part No.
Cable, 30", UHF to clips	1	19072C
Cable, 24", UHF to UHF	2	18265C
Connector, UHF to UHF	3	CS-5
Adaptor, UHF to BNC	4	CS-115
Adaptor, UHF to BNC	5	CS-172
Adaptor Tee, UHF to UHF	6	CS-171
Adaptor, Binding Post	7	19071B

The two cables (Items 1 and 2) are coaxial shielded leads useful for connections where low noise is essen- tial. The 24" cable (Item 2) can be used to intercon- nect two instruments having UHF receptacles. The 30" cable (Item 1) can be used to connect to the circuit under test through the use of clip leads. A binding post adapter gives easy access to the electrometer "high" terminal. Two UHF femal couplers (Item 3) permit cables to be connected together. The UHF "tee connector simplifies galvanometric current measuremen when using a current source and electrometer or pico- ammeter. Adapters (Items 4 and 5) are useful for co version from UHF to BNC terminations.

Models 2501, 2503 Static Detector Probes

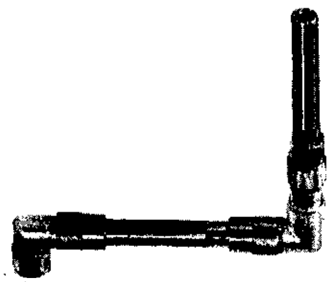
Description:

The Models 2501 and 2503 are specially designed detectors used to measure static charge on plane surfaces. Either probe must be used with an electrometer such as the 615.



Model 2501:

The 2501 is useful for measurements of charge on flat surfaces. The static head is 3 inches in diameter. Recommended spacing is 3/8" from the surface for 10,000:1 divider ratio. The 2501 is calibrated such that a 1 volt deflection on the electrometer corresponds to 10 kilovolts of static charge.



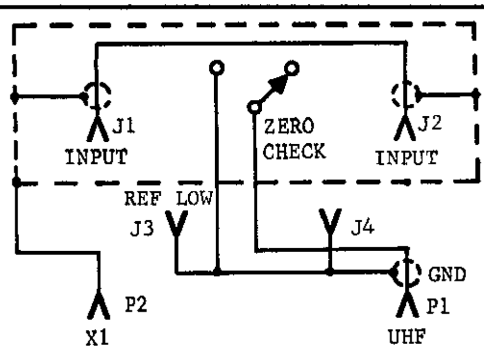
Model 2503:

The 2503 consists of a rigid probe 1/2 inches in diameter. Operation is similar to the use of the 2501 probe.

Model 6107 pH Electrode Adapter

Description:

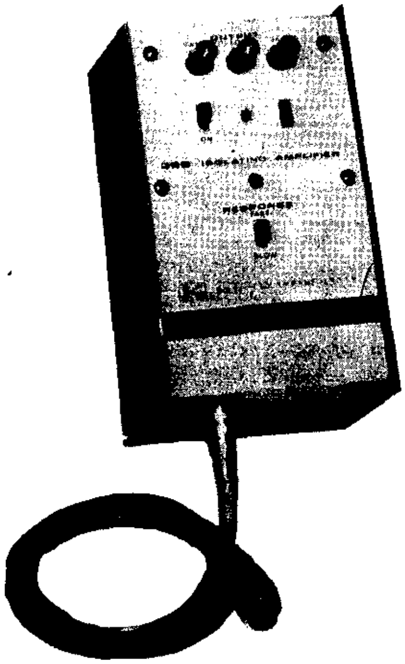
The Model 6107 is a test fixture which simplifies connections to the electrometer when making pH measurements. The adapter can be used with electrodes manufactured by Leeds & Northrup, Coleman and Beckman. The 6107 can be used for guarded measurements as shown in the diagram. A voltage-to-pH conversion chart is supplied with the 6107.



Model 399 Isolating Amplifier

Description: The Model 399 is a unity-gain amplifier that provides input isolation greater than 10^{12} ohms. It is useable for common mode input voltages up to 1500 volts peak, dc or ac.

Application: The 399 can be used for "FIFO" operation where both input and output must be floated. It can also be used to break ground loops within a system. The 399 output will drive recorders up to 1 mA. When used with the Model 615, the electrometer can be floated up to 100 volts while driving a Model 370 recorder up to 100 volts off ground.

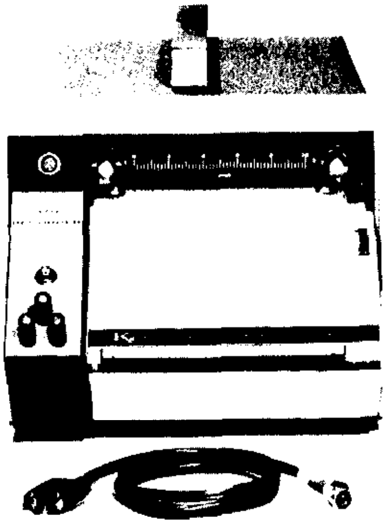


Specifications: (condensed)

GAIN: X1, adjustable ± 3%.
GAIN ACCURACY: ± 0.2% (as set at factory).
GAIN LINEARITY: Within 3 mV for signal levels below 1V.
FREQUENCY RESPONSE: Fast: dc to 100Hz; Slow: dc to 0.3Hz (-3 dB response).
INPUT RESISTANCE: 10^6 ohms.
FULL SCALE INPUT: ± 1 volt with 100% overrange.
MAXIMUM INPUT OVERLOAD: 100 volts.
INPUT ISOLATION: Greater than 10^{12} ohms at 50% relative humidity and 25 C shunted by less than 100 pF.
MAXIMUM COMMON MODE VOLTAGE: 1500 volts peak, dc or ac.
OUTPUT ISOLATION: Greater than 10^8 ohms shunted by less than 0.001 microfarad.
POWER: 105-125 or 210-250 volts (switch selected), 50-60 Hz, 5 watts.

Model 370

Description: The 370 is a compact, paper chart recorder which is compatible with most Keithley instruments having a 1 mA output.



Applications: The 370 can be used directly with the Model 615 up to 100 volts off ground. The Model 3701 cable supplied can be used for convenient connections to the instrument.

Model 3001 Bench Mounting Kit

Description:

The Model 3001 is a bench mounting kit for use with instruments 5-1/4" high x 17-1/2" wide x 10" deep. All parts are included for conversion of a rack mounted instrument to bench mounting complete with top cover, handle assembly, non-skid feet and tilt bail assembly.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Cover Assembly	1	17604B
2	Screw, Slotted 10-32x1/4	4	-
3	Bail Support, Right	1	19206B
4	Bail Support, Left	1	19205B
5	Foot, plastic	4	FE-5
6	Screw, Phillips, 8-32x3/8	4	-
7	Rubber Foot Insert	4	FE-6
8	Screw, Phillips, 6-32x1/4	2	-
9	Tilt Bail	1	14704B

Assembly:

1. Remove the rack angles attached to the rack mount instrument. The four 10-32 slotted screws suppli with the instrument should be used to install the bench-style top cover (item 1).

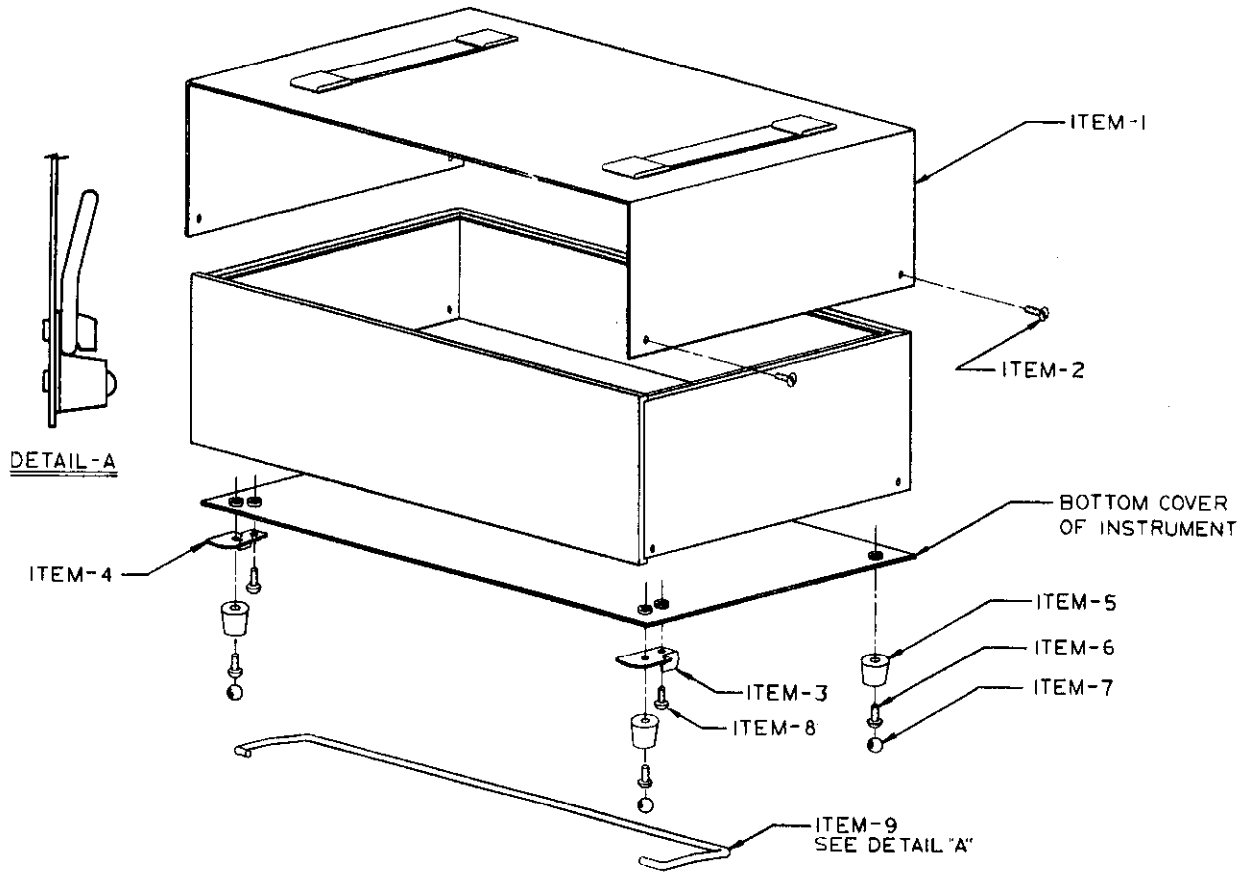
2. Remove the bottom cover to facilitate the mountin of the non-skid feet and tilt bail assembly. Use a screw driver to turn the pawl-type fasteners on the cover (about one-half turn clockwise).

3. Install the bail supports (items 3 and 4) using 6-32 screws (item 8).

4. Install the plastic feet (item 5) using 8-32 scre (item 6) in four places.

5. Install tilt bail (item 9) as shown.

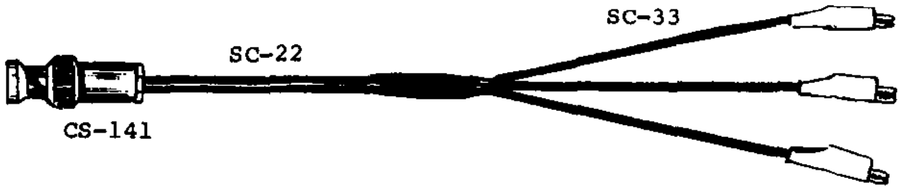
6. Install bottom cover using pawl-type fasteners.



Model 6011 Input Cable

Description: The 6011 is a low-noise triaxial cable, 30" long, terminated by three color-coded alligator clips. This cable mates directly with the triaxial input. The cable is fabricated using a Keithley part no. CS-141 connector and part no. SC-22 low-noise cable.

Application: The 6011 may be used for measurements which require a triaxial connection, especially when the input LO is floated above CASE ground. The cable permits full use of the Model 615 capabilities.



Model 6301 Guarded Probe

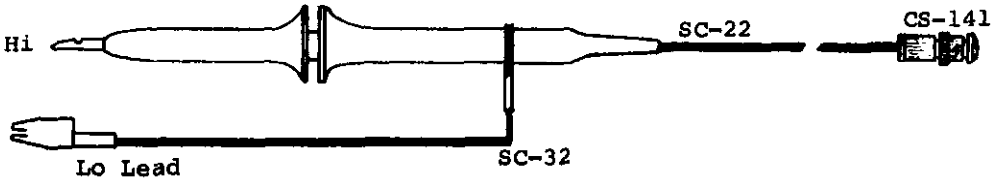
Description: The 6301 is a guarded triaxial cable, 3 ft. long, terminated by a probe for making point-to-point measurements.

Application: The 6301 may be used for measurements which require a triaxial cable with a guarded probe having an insulation resistance greater than 10^{14} ohms.

Model 1531 Gripping Probe

Description: The 1531 is a triaxial cable, 3 ft. long, terminated by a special gripping-type probe. The 1531 insulation resistance is greater than 10^{10} ohms. The probe is rated for off ground measurements up to 500 v

Applicarion: The 1531 may be used for measurements which require a triaxial cable. The probe permits convenient connections to the circuit under test due to the gripping feature.

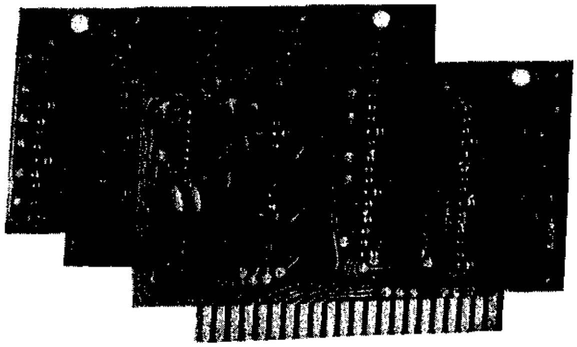


Model 6012 Triax-to-Coax Adapter

Description: The 6012 is an adapter for mating the triaxial input and UHF (coax) type connectors. This adapter can be used with Models 6101A, 6101B, 6103A, 6102A, etc.

Model 4401 Printer Output Cards

Description: The Model 4401 consists of two printer output cards which may be installed at the factory or in the field since no wiring is required. The output cards plug into prewired connectors on the chassis. BCD outputs are provided through the use of a 50-pin prewired output connector.



Model 4405 Terminal Box

Description: The Model 4405 consists of a 50-terminal box with convenient barrier-strip connections and a 3 ft. cable terminated with a CS-220 connector.

Model SC51 Fifty-Conductor Cable

Description: The Model SC51 cable is useful for fabricating a custom-length cable for use with the Model 4401 Printer Output cards. The cable is sold in custom lengths on special order.

Model 4406 Extender Cards

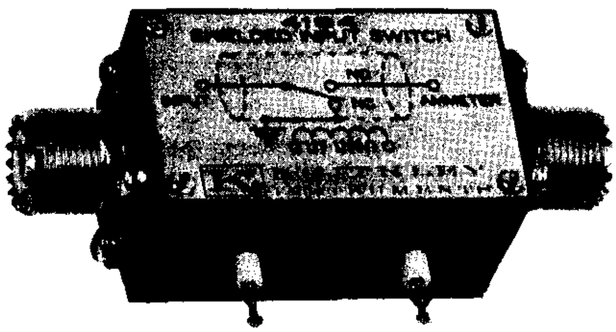
Description: The Model 4406 consists of two extender cards and one extractor for pulling pc cards. The extender cards permit access to test points and calibration controls on cards having either 15 or 22 pins.

Parts List:

Description	Keithley Part No.
PC Card Extractor	4195
PC Card Extender	(22 pins) PC-225
PC Card Extender	(15 pins) PC-224

Model 4194 Shielded Input Switch

Description: The Model 4194 is a remotely controlled reed switch that permits shorting of the input during sample changes, etc. The switch is useful in automated testing where it is important to keep the source input shorted when not being measured.



Mechanical Parts List.

Item No.	Description	Quantity Per Assembly	Keithley Part No.
1	Top Cover Assembly	-	17158C
-	Cover	1	17162C
-	Fastener	2	FA-54
2	Bottom Cover Assembly	-	17960C
-	Cover	1	17957C
-	Fastener	2	FA-54
3	Angle, Rack Assembly	2	14624B
4	Screw, Slotted, 10 - 32 x 1/4	4	-
5	Front Panel	1	23796D
6	Chassis	1	24181B

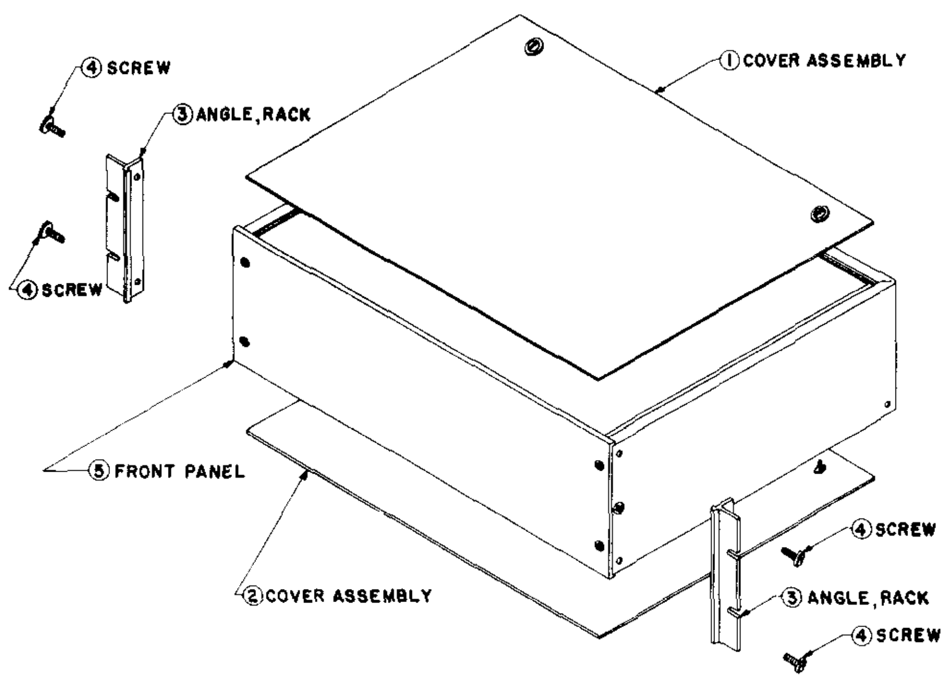


FIGURE 20. Mechanical Assembly.

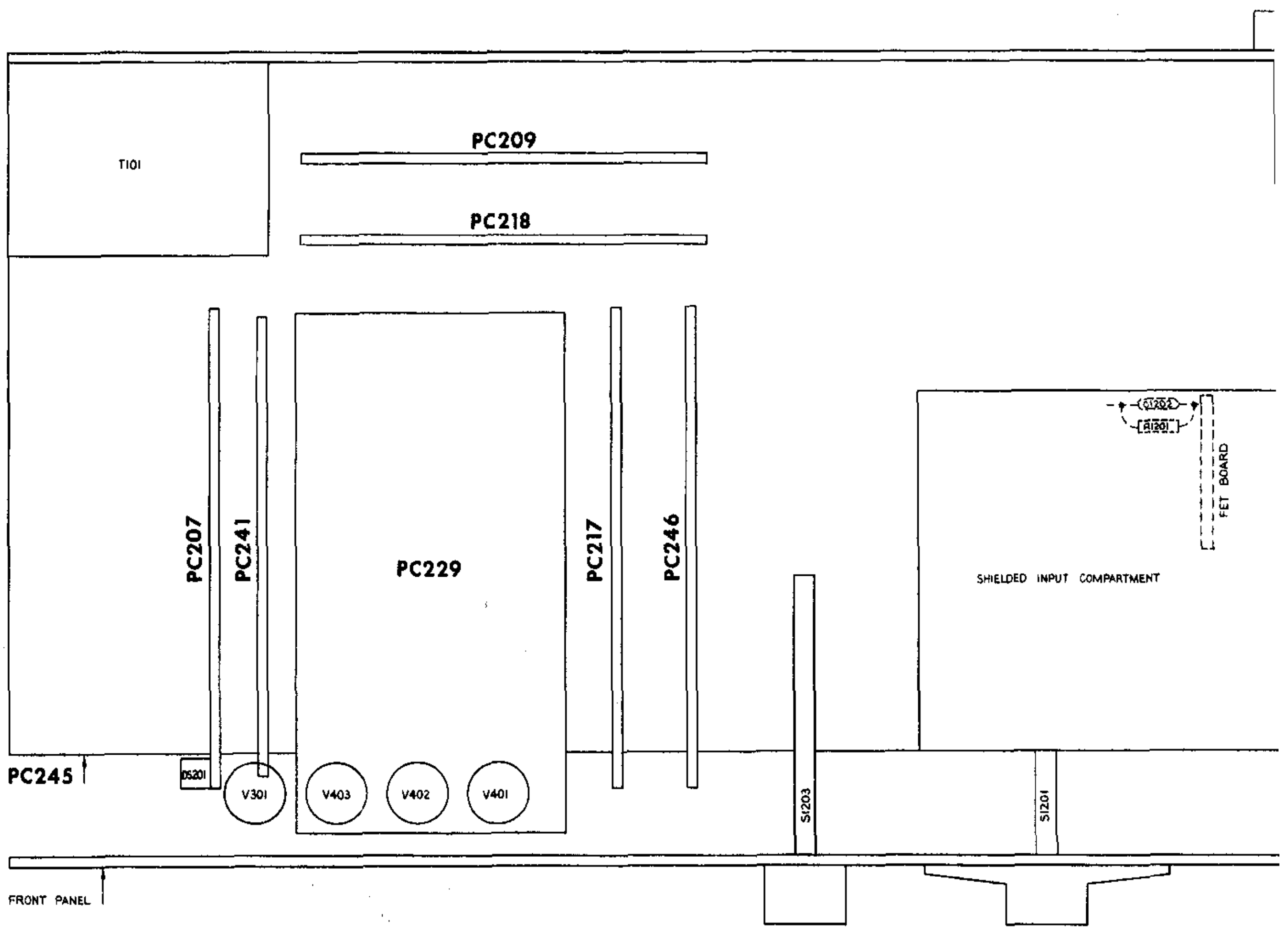
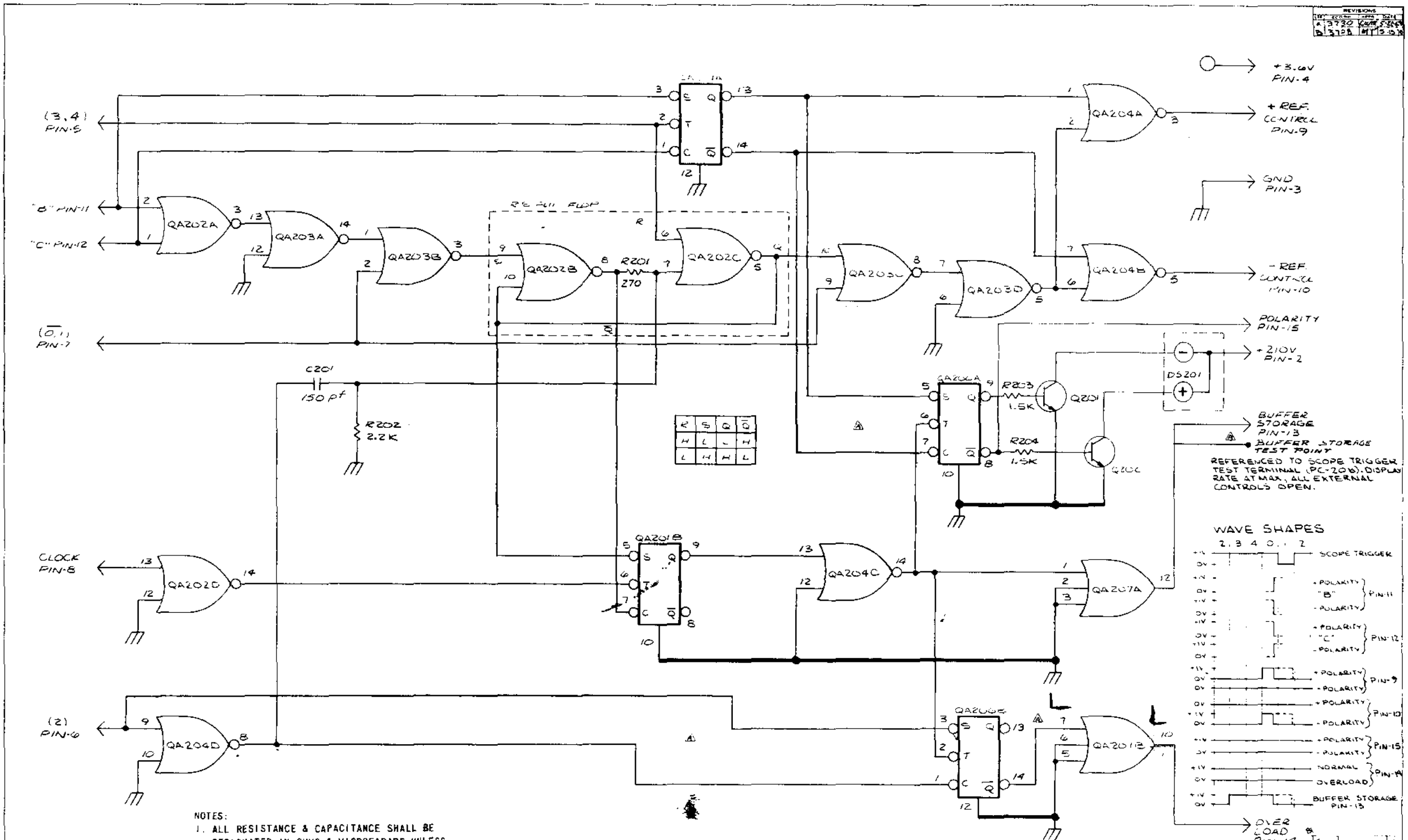


FIGURE 21. Chassis - Top View.



R	S	Q	Q̄
H	L	L	H
L	H	H	L

NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. K - 1000 OHMS   pf - PICOFARAD

HIGHEST REFERENCE DESIGNATIONS			
R204	C201	DS201	Q202
QA207			

REFERENCE DESIGNATIONS NOT USED			
QA205			

KEITHLEY INSTRUMENTS

TITLE SCHEMATIC, PC-207 POLARITY

DO NOT SCALE

PART NUMBER 23449D

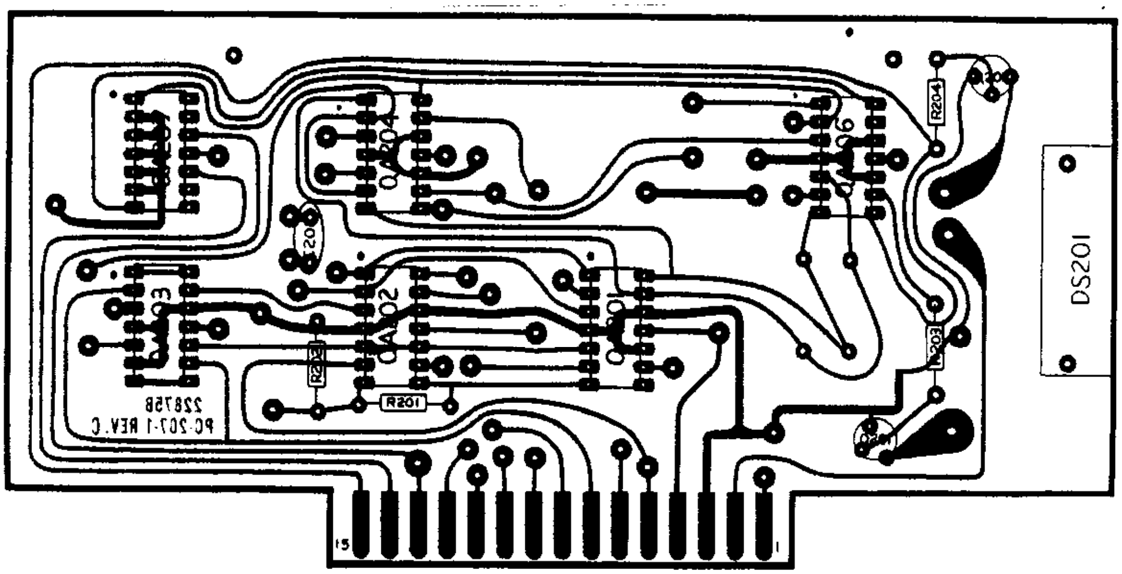


FIGURE 23. Component Layout, PC207.

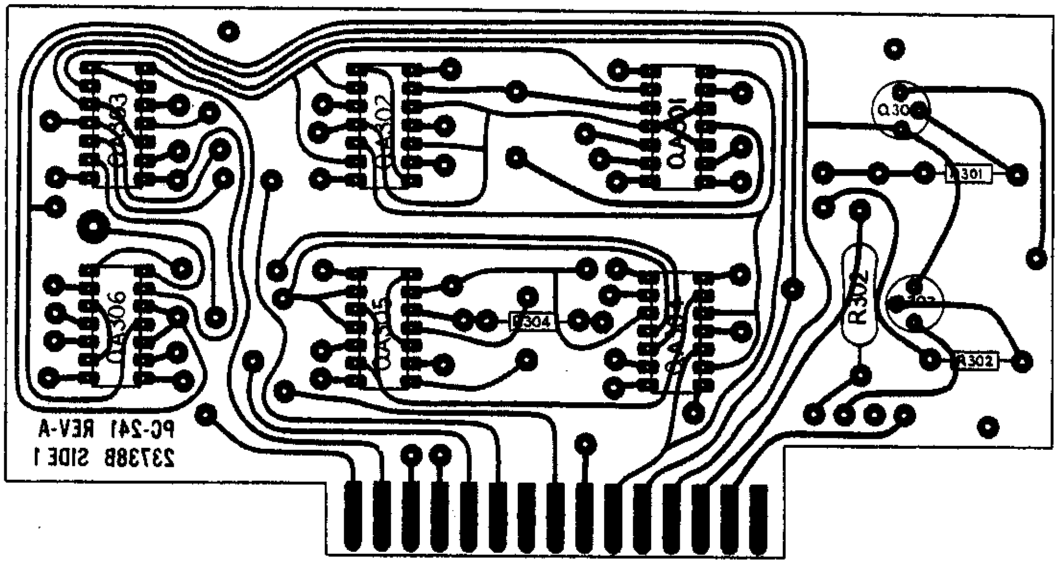
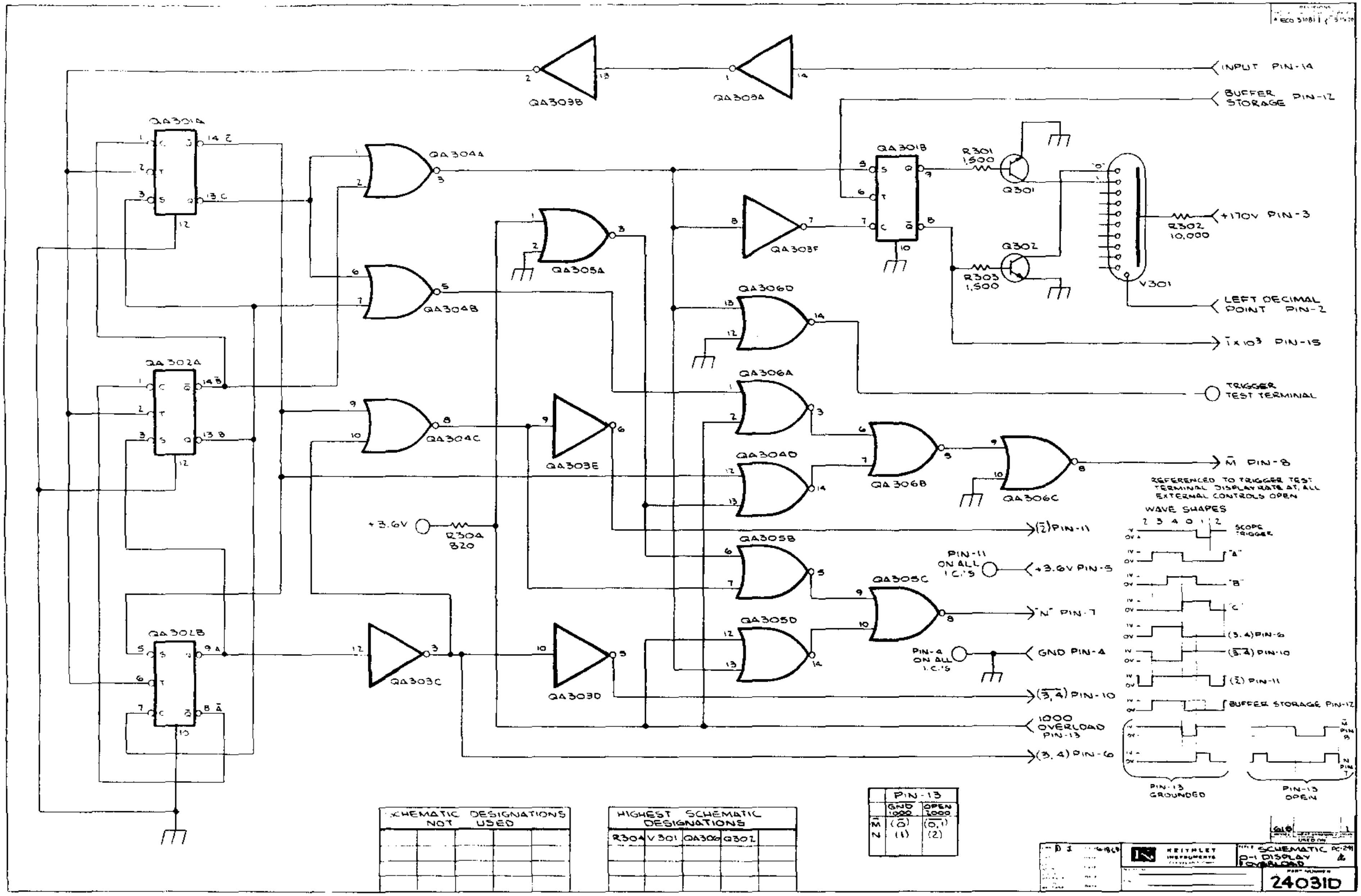
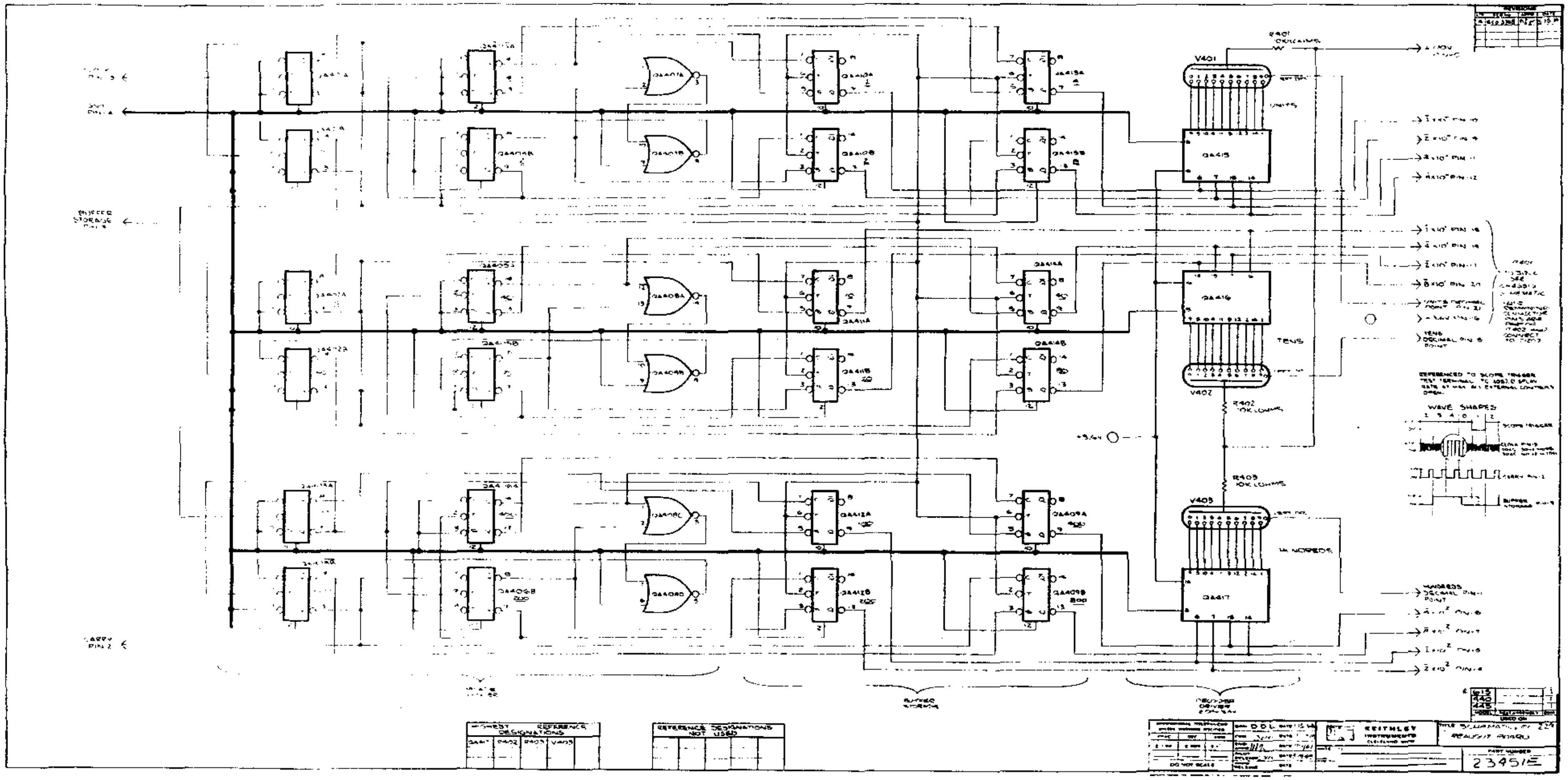


FIGURE 24. Component Layout, PC241.


INPUT PIN-14
BUFFER STORAGE PIN-12
QA303B
QA303A
QA301A
QA301B
QA302A
QA302B
QA304A
QA304B
QA304C
QA304D
QA305A
QA305B
QA305C
QA305D
QA306A
QA306B
QA306C
QA306D
QA303C
QA303D
QA303E
QA303F
R301 1,500
R303 1,500
R302 10,000
R304 820
Q301
Q302
V301
+170V PIN-3
LEFT DECIMAL POINT PIN-2
1x10³ PIN-15
TRIGGER TEST TERMINAL
M PIN-8
REFERENCED TO TRIGGER TEST TERMINAL DISPLAY RATE AT ALL EXTERNAL CONTROLS OPEN
WAVE SHAPES
SCOPE TRIGGER
+3.6V
(2) PIN-11
PIN-11 ON ALL I.C.'S
+3.6V PIN-5
"N" PIN-7
PIN-4 ON ALL I.C.'S
GND PIN-4
(3,4) PIN-10
1000 OVERLOAD PIN-13
(3,4) PIN-6
"A"
"B"
"C"
(3,4) PIN-6
(3,4) PIN-10
(2) PIN-11
BUFFER STORAGE PIN-12
PIN-13 GROUNDED
PIN-13 OPEN
SCHEMATIC DESIGNATIONS NOT USED
HIGHEST SCHEMATIC DESIGNATIONS
R304 | V301 | QA306 | Q302
PIN-13
GND 1000 | OPEN 2000
M (0) (0,1)
N (1) (2)
KEITHLEY INSTRUMENTS
SCHEMATIC PC-241
D-1 DISPLAY & OVERLOAD
24031D



V401
V402
V403
UNITS
TENS
HUNDREDS
R402 10K OHMS
R403 10K OHMS
WAVE SHAPES
BUFFER STORAGE
+5.6V
HIGHEST REFERENCE DESIGNATIONS
REFERENCE DESIGNATIONS NOT USED
KEITHLEY INSTRUMENTS
DO NOT SCALE
23451E

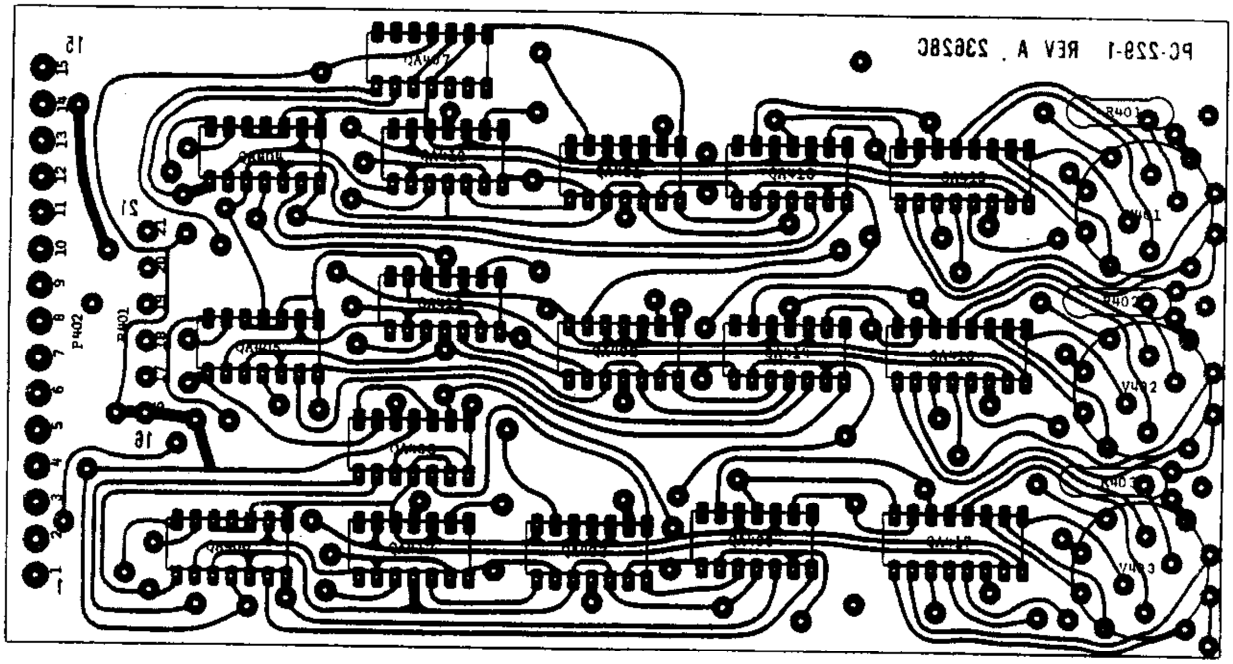


FIGURE 25. Component Layout, PC229.

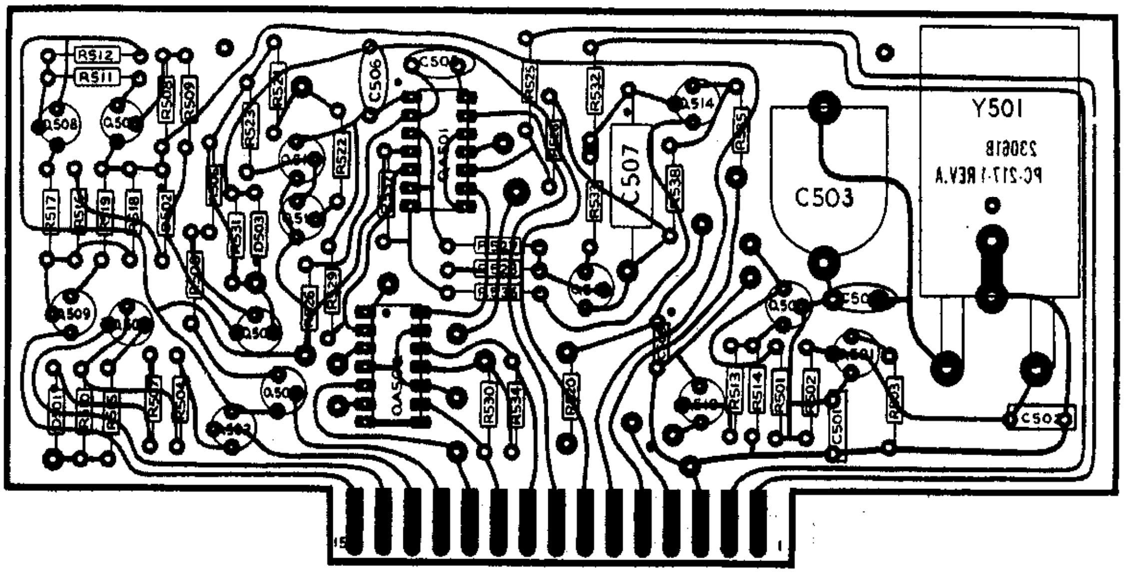
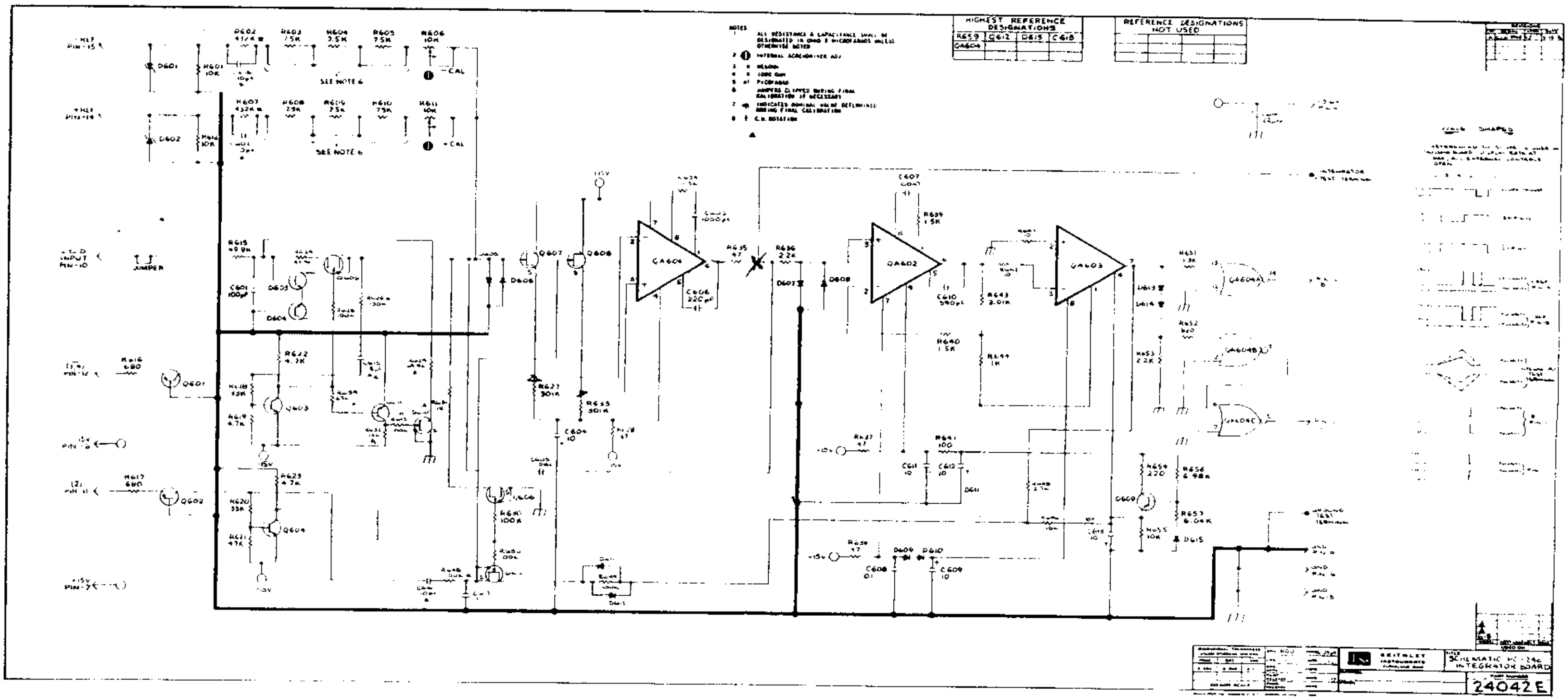
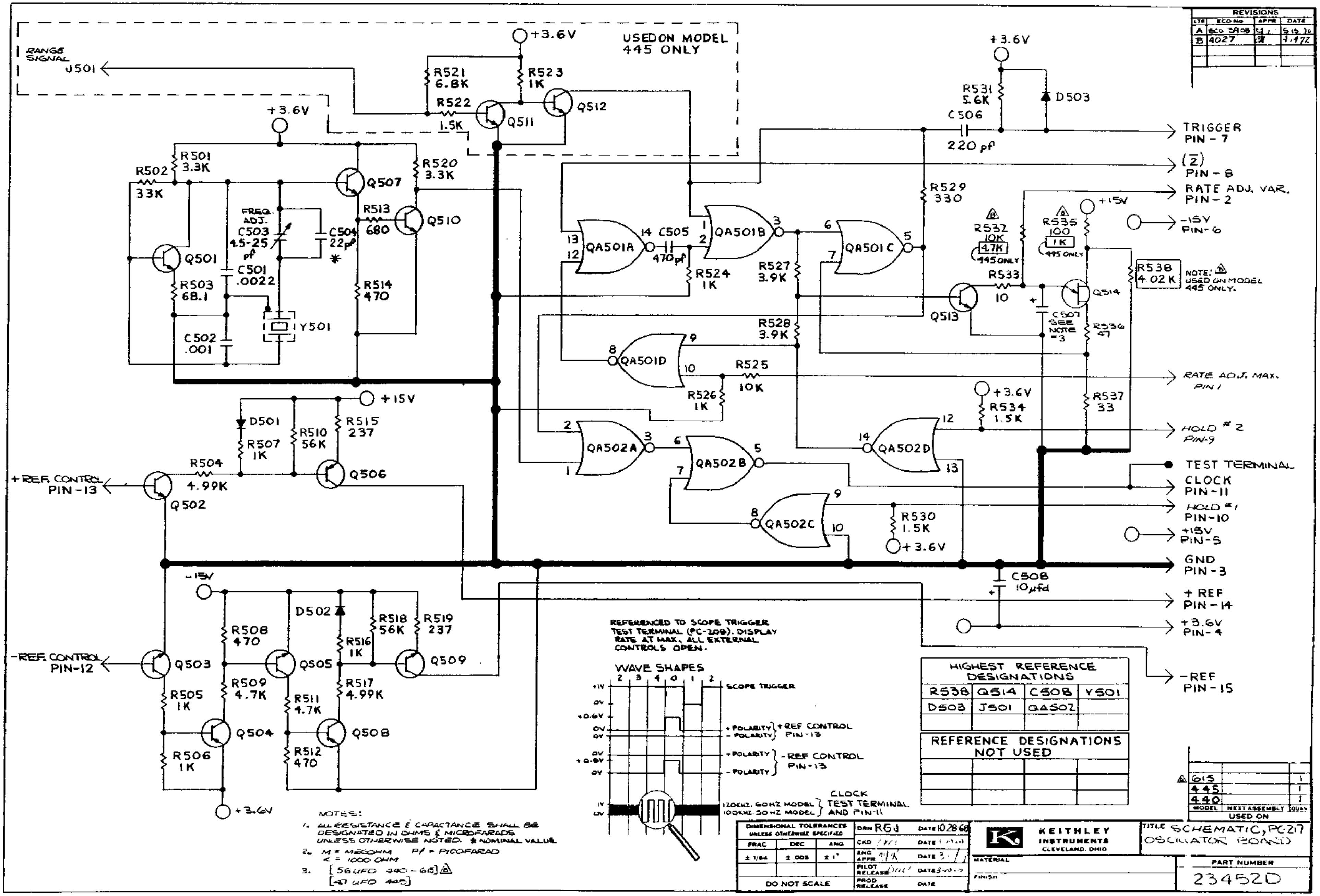


FIGURE 26. Component Layout, PC217.


HIGHEST REFERENCE DESIGNATIONS
R659
Q612
D615
C618
QA604
REFERENCE DESIGNATIONS NOT USED
SEE NOTE 6
QA604
QA602
QA603
Q601
Q602
Q603
Q604
Q607
Q608
Q609
JUMPER
SCHEMATIC MODEL 246 INTEGRATOR BOARD
KEITHLEY INSTRUMENTS
24042E



HIGHEST REFERENCE DESIGNATIONS			
R538	Q514	C508	Y501
D503	J501	QA502	

REFERENCE DESIGNATIONS NOT USED			

NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED. * NOMINAL VALUE
2. M = MEGOHM   Pf = PICOFARAD
   K = 1000 OHM
3. [56 UFD 440-615] [47 UFD 445]

REVISIONS			
LTR	ECO NO	APPR	DATE
A	ECO 3908		
B	4027		

MODEL	NEXT ASSEMBLY	QUAN
615		1
445		1
440		1

USED ON

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED — FRAC ± 1/64, DEC ± .005, ANG ± 1°. DO NOT SCALE

DRN RGJ DATE 10 28 68

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE SCHEMATIC, PC217 OSCILLATOR BOARD

PART NUMBER 23452D

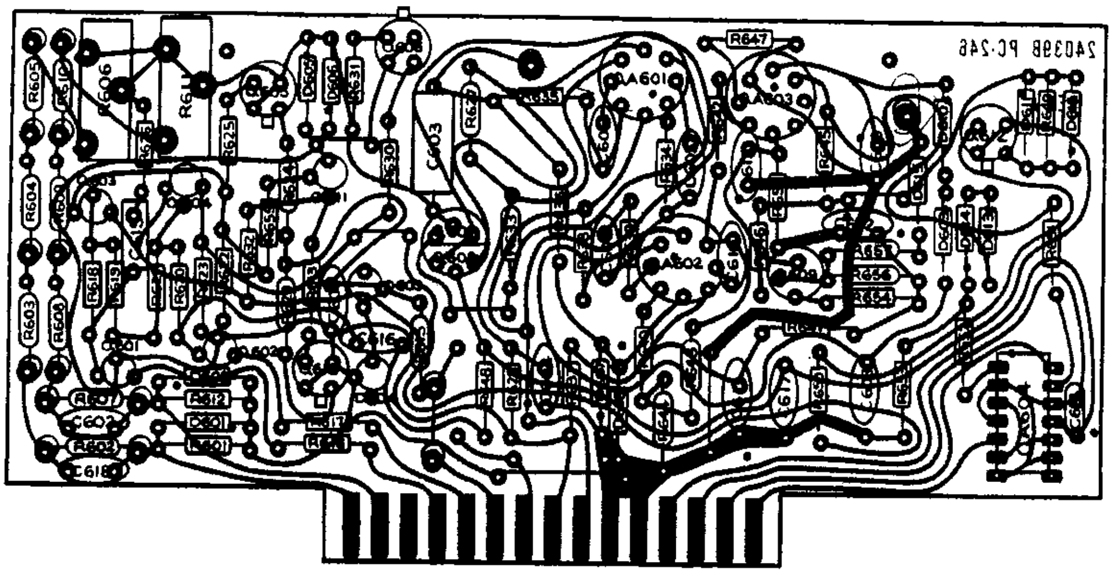


FIGURE 27. Component Layout, PC246.

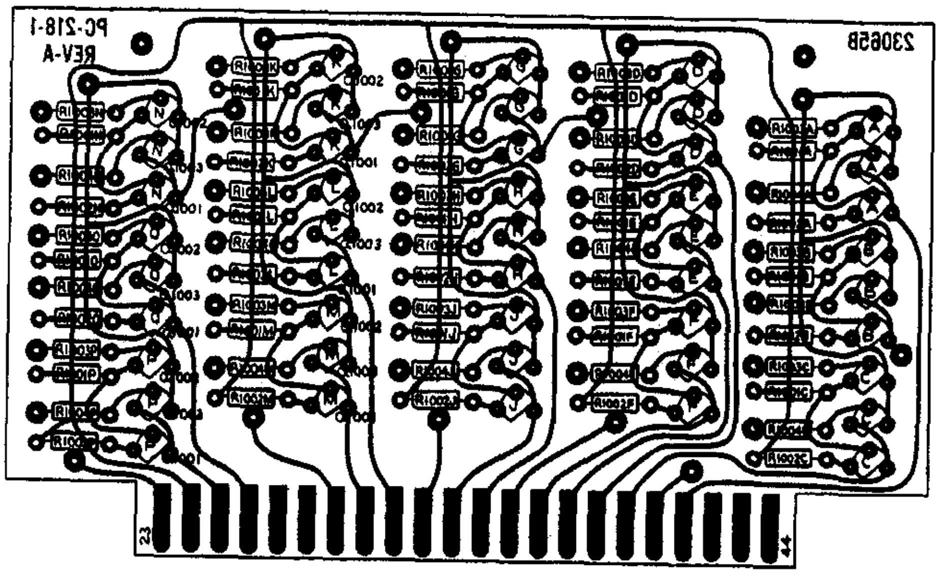
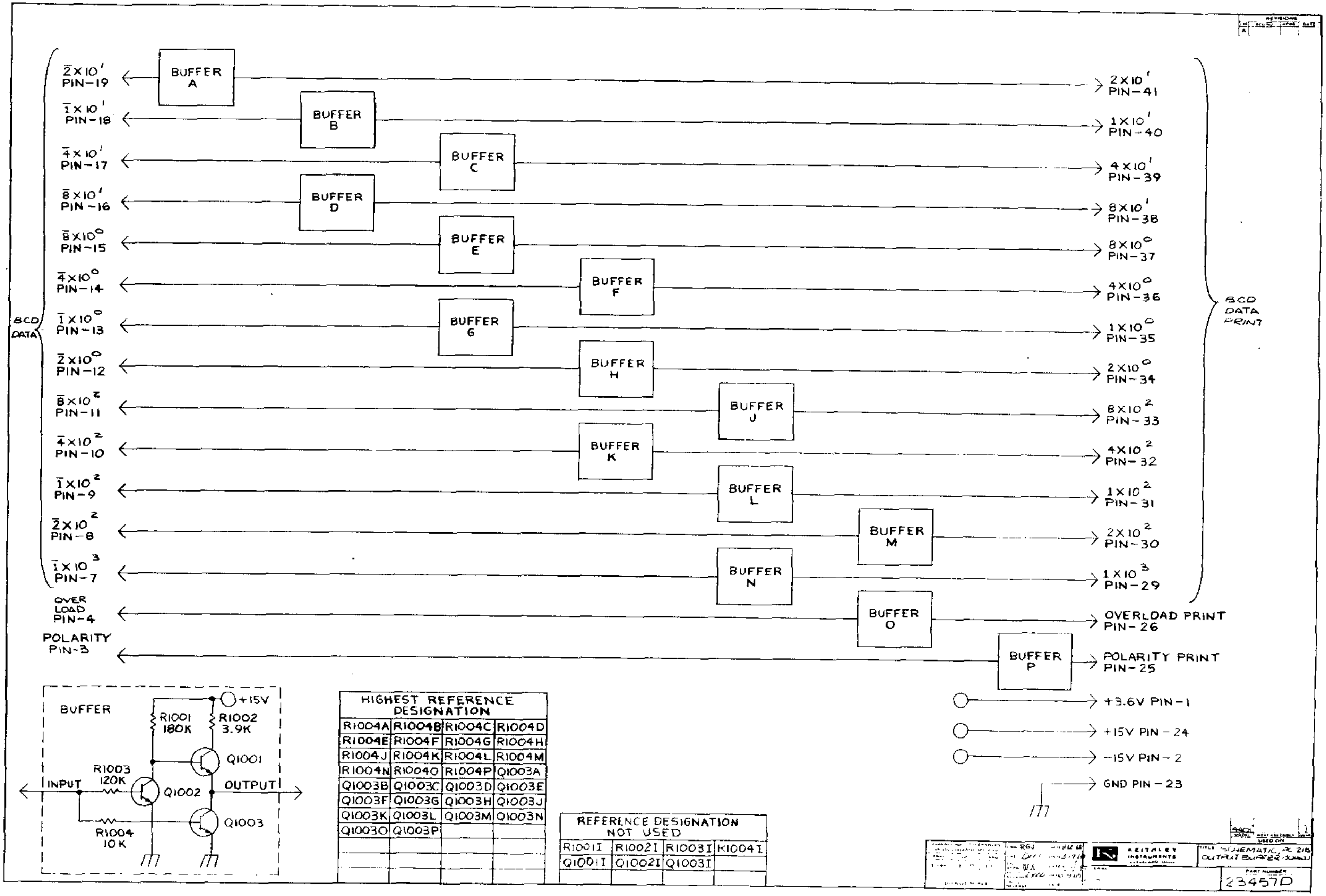
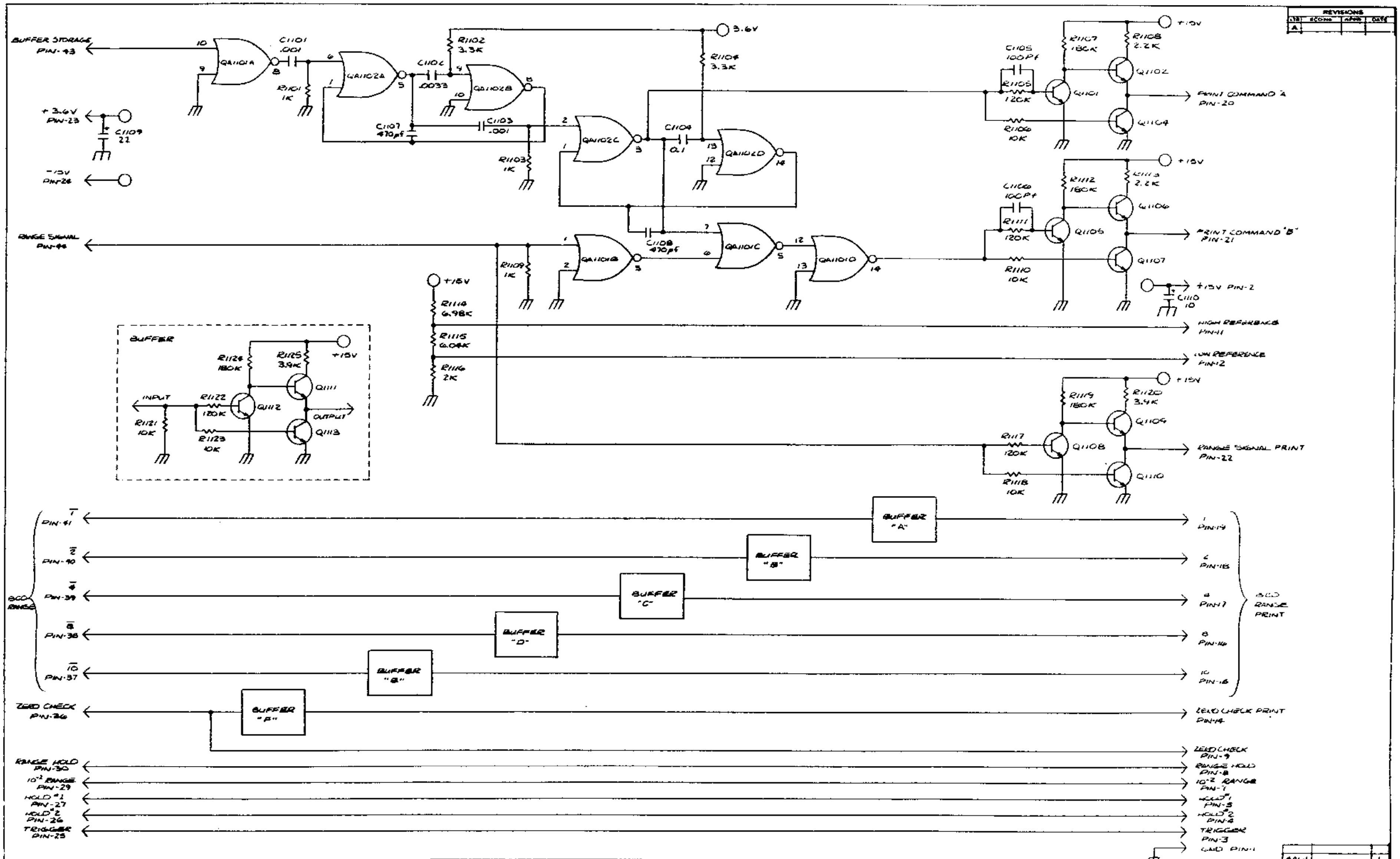


FIGURE 28. Component Layout, PC218.



HIGHEST REFERENCE DESIGNATION			
R1004A	R1004B	R1004C	R1004D
R1004E	R1004F	R1004G	R1004H
R1004J	R1004K	R1004L	R1004M
R1004N	R1004O	R1004P	Q1003A
Q1003B	Q1003C	Q1003D	Q1003E
Q1003F	Q1003G	Q1003H	Q1003J
Q1003K	Q1003L	Q1003M	Q1003N
Q1003O	Q1003P		

REFERENCE DESIGNATION NOT USED			
R1001I	R1002I	R1003I	R1004I
Q1001I	Q1002I	Q1003I	



NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATION IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. K = 1000 OHM
3. PF = PICOFARAD

HIGHEST REFERENCE DESIGNATIONS							
R1125A	R1125B	R1125C	R1125D	R1125E	R1125F		
Q1113A	Q1113B	Q1113C	Q1113D	Q1113E	Q1113F		
C1110	QA1102D						

REFERENCE DESIGNATIONS NOT USED

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FRAC	DEC	ANG
± 1/64	± .005	± 1°

DO NOT SCALE

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC, PC 209 OUTPUT BUFFER BOARD

MODEL 441 | NEXT ASSEMBLY | USED ON

PART NUMBER 23481E

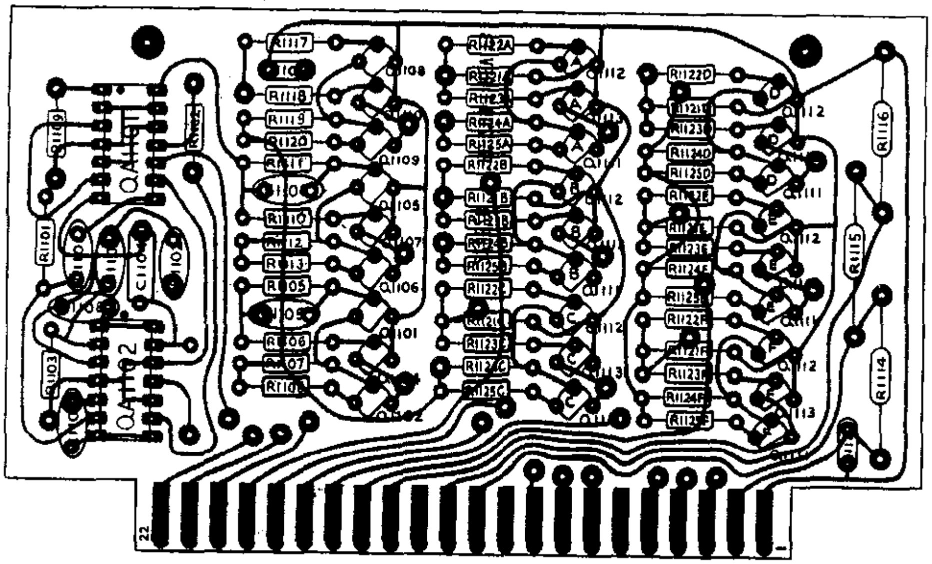


FIGURE 29. Component Layout, PC209.

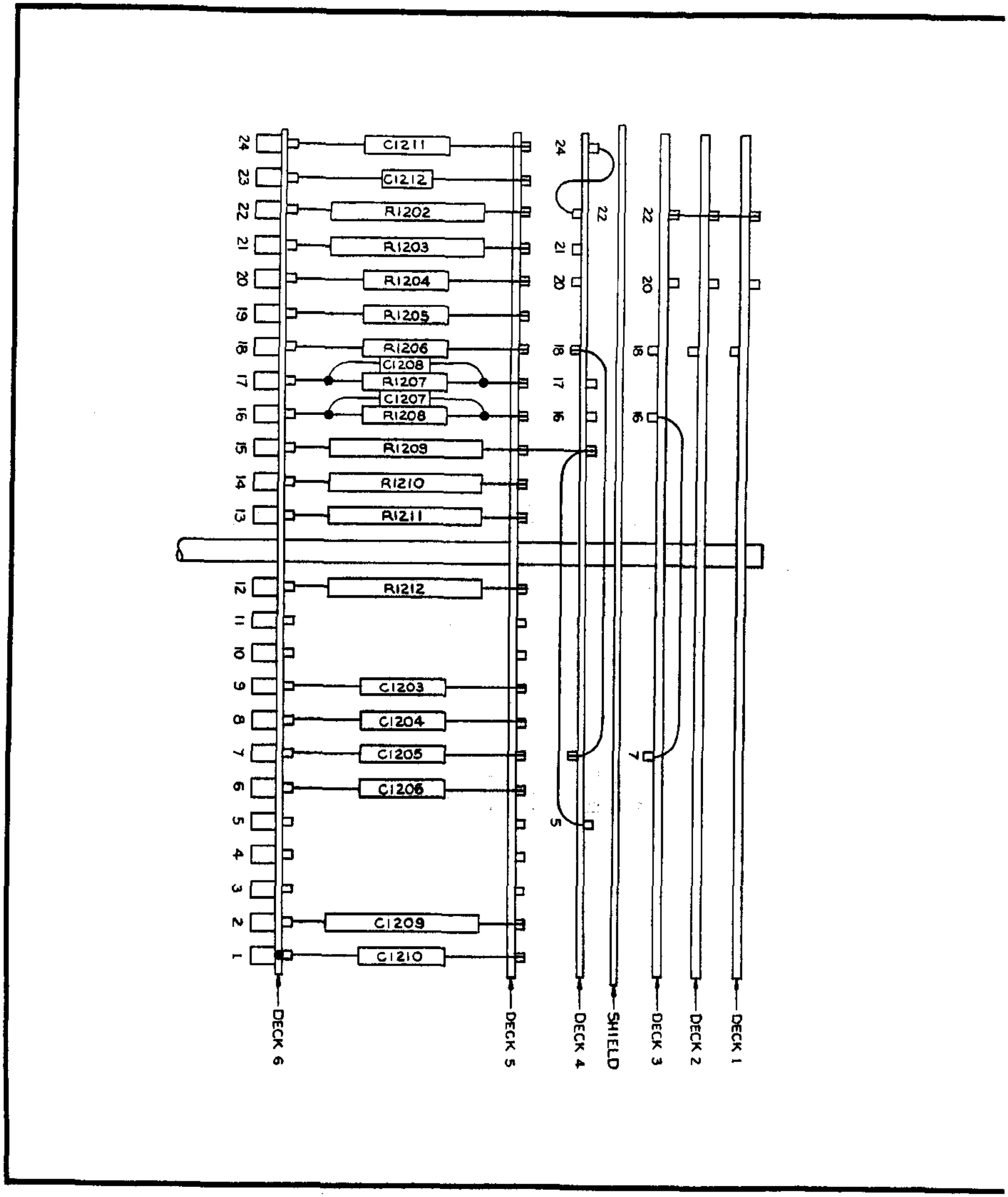
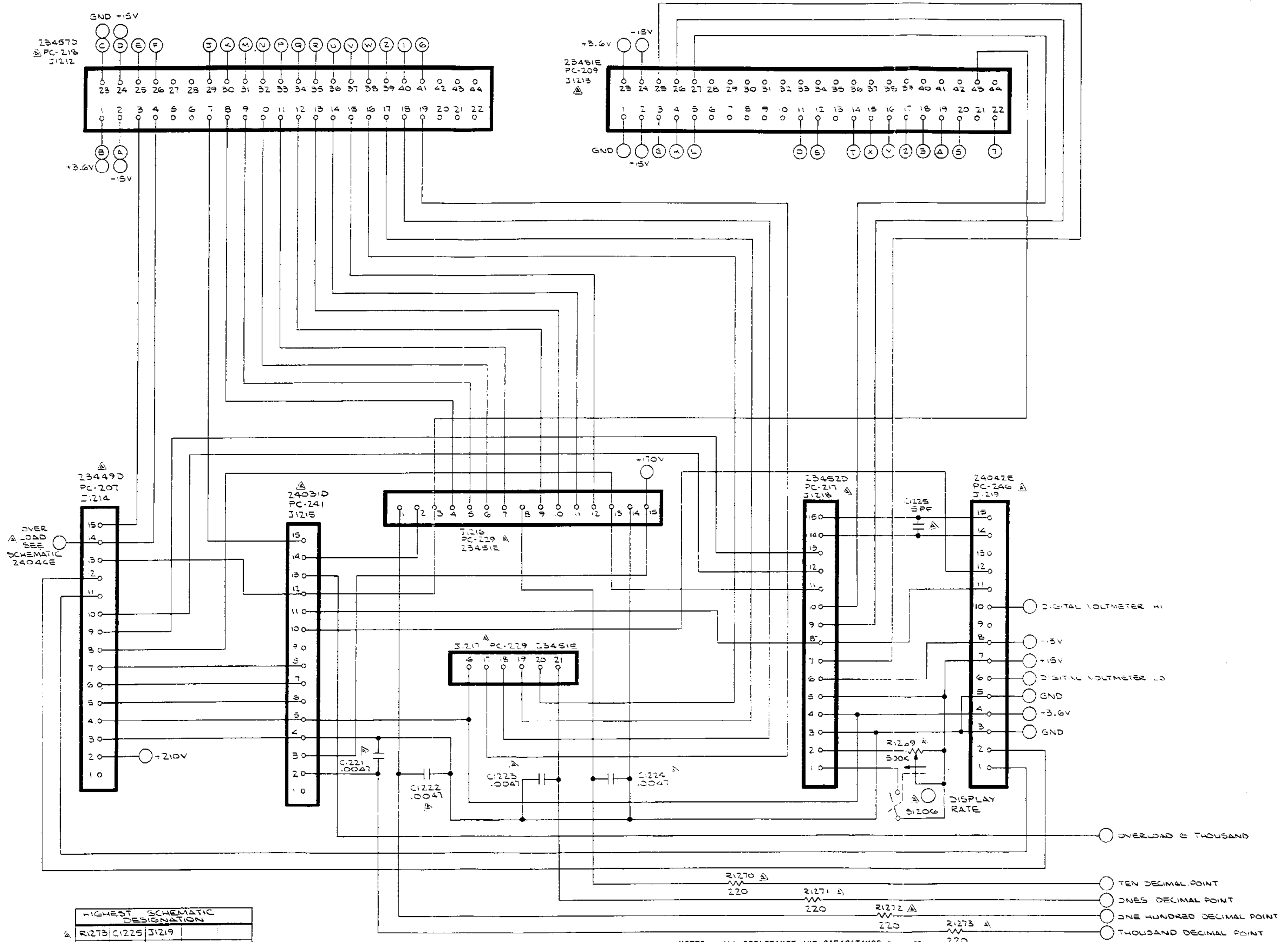
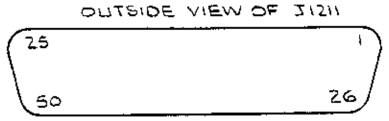


FIGURE 30. Switch S1201, RANGE.

J1211 P.N°	PC SYM	DESIGNATION
	R	1 x 10° DATA PRINT
2	Q	2 x 10° DATA PRINT
3	L	1 x 10¹ DATA PRINT
4	6	2 x 10¹ DATA PRINT
5	M	1 x 10² DATA PRINT
6	K	2 x 10² DATA PRINT
7	J	1 x 10³ DATA PRINT
8	C	GND
9	4	1 RANGE PRINT
10	3	2 RANGE PRINT
11	X	10 RANGE PRINT
12	C	GND
13	E	POLARITY PRINT
14	D	+15V
15	T	1 SENSITIVITY PRINT
16	7	2 SENSITIVITY PRINT
17	D	+15V
18	B	+3.6V
19		(NOT WIRED)
20		(NOT WIRED)
21		(NOT WIRED)
22		(NOT WIRED)
23	S	PRINT COMMAND
24	O	HI REFERENCE
25	S	LO REFERENCE
26	U	4 x 10° DATA PRINT
27	V	8 x 10° DATA PRINT
28	Z	4 x 10¹ DATA PRINT
29	W	8 x 10¹ DATA PRINT
30	N	4 x 10² DATA PRINT
31	P	8 x 10² DATA PRINT
32	C	GND
33	F	OVERLOAD PRINT
34	2	4 RANGE PRINT
35	Y	8 RANGE PRINT
36	C	GND
37	C	GND
38	C	GND
39	D	+15V
40	C	GND
41	C	GND
42	A	-15V
43	C	GND
44	L	HOLD #1
45	H	HOLD #2
46	G	TRIGGER
47		(NOT WIRED)
48		(NOT WIRED)
49		(NOT WIRED)
50		(NOT WIRED)



OUTSIDE VIEW OF J1211



HIGHEST SCHEMATIC DESIGNATION			
R1273	C1225	J1219	

SCHEMATIC DESIGNATION NOT USED

NOTES: 1. ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARAD UNLESS OTHERWISE NOTED.

2. ◯ FRONT PANEL CONTROL

3. K 1000 OHM

4. ⬇ CLOCKWISE ROTATION.

5. SEE DWG. 24261E FOR OTHER HALF OF MOTHER BOARD SCHEMATIC.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

DO NOT SCALE

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC, MOTHER BOARD PART 1

MODEL 615 | NEXT ASSEMBLY | USED ON

PART NUMBER 24151E

SEE NOTE #5

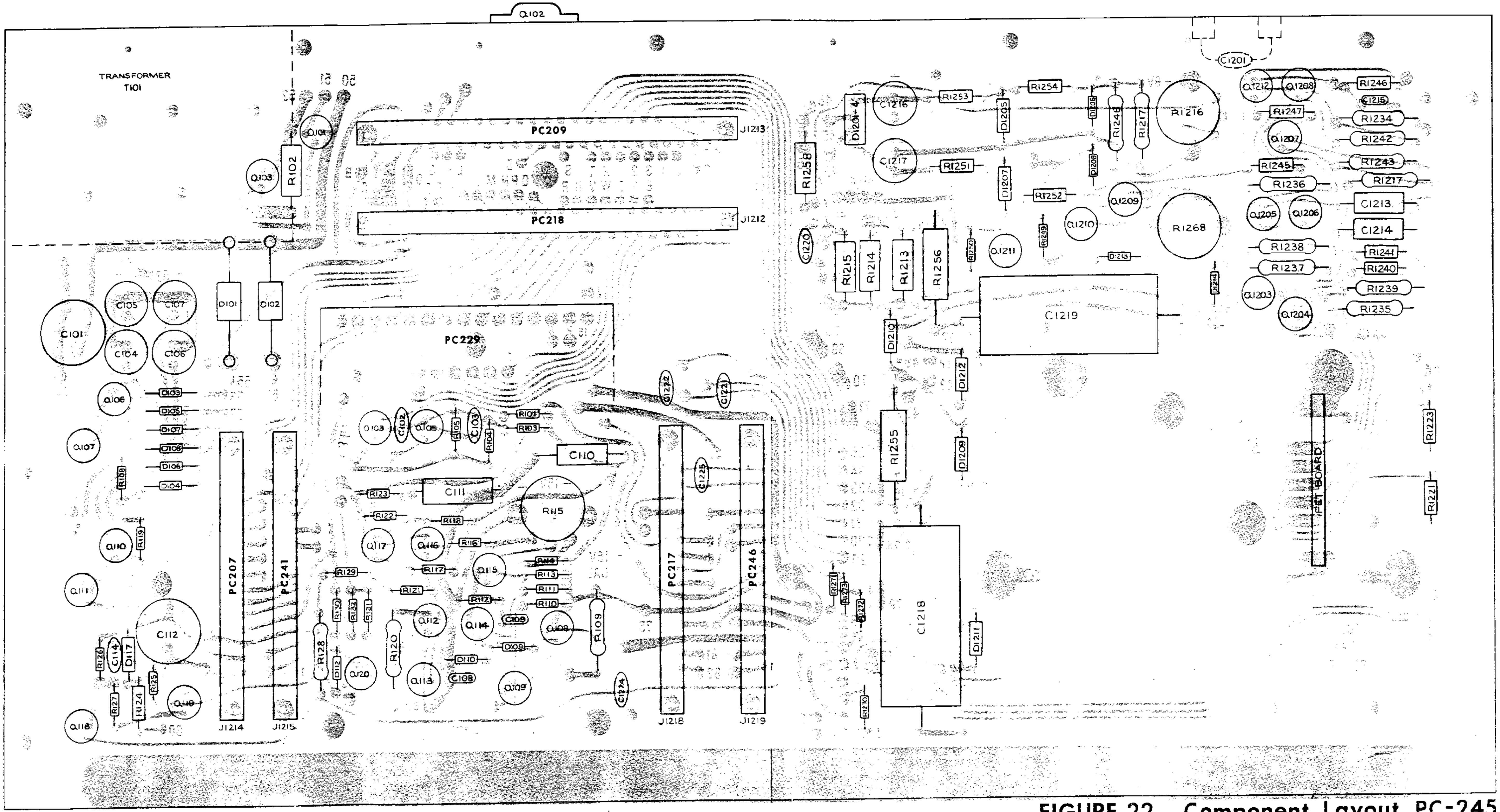
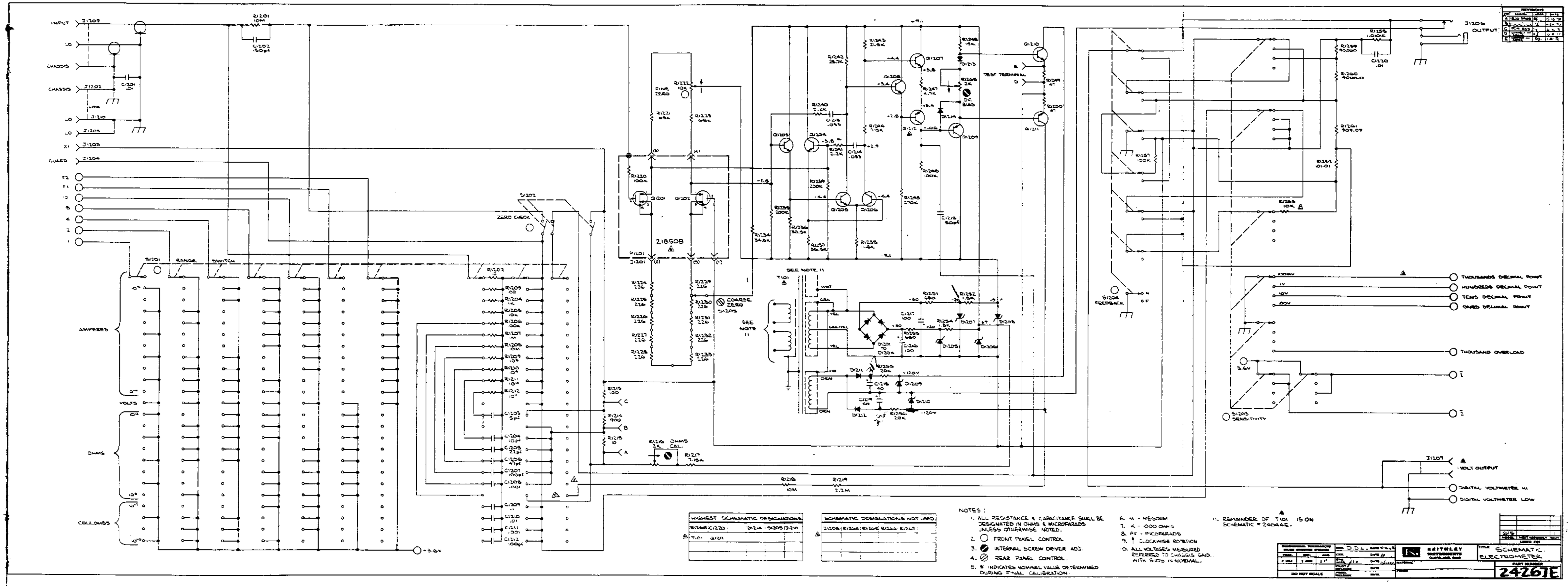
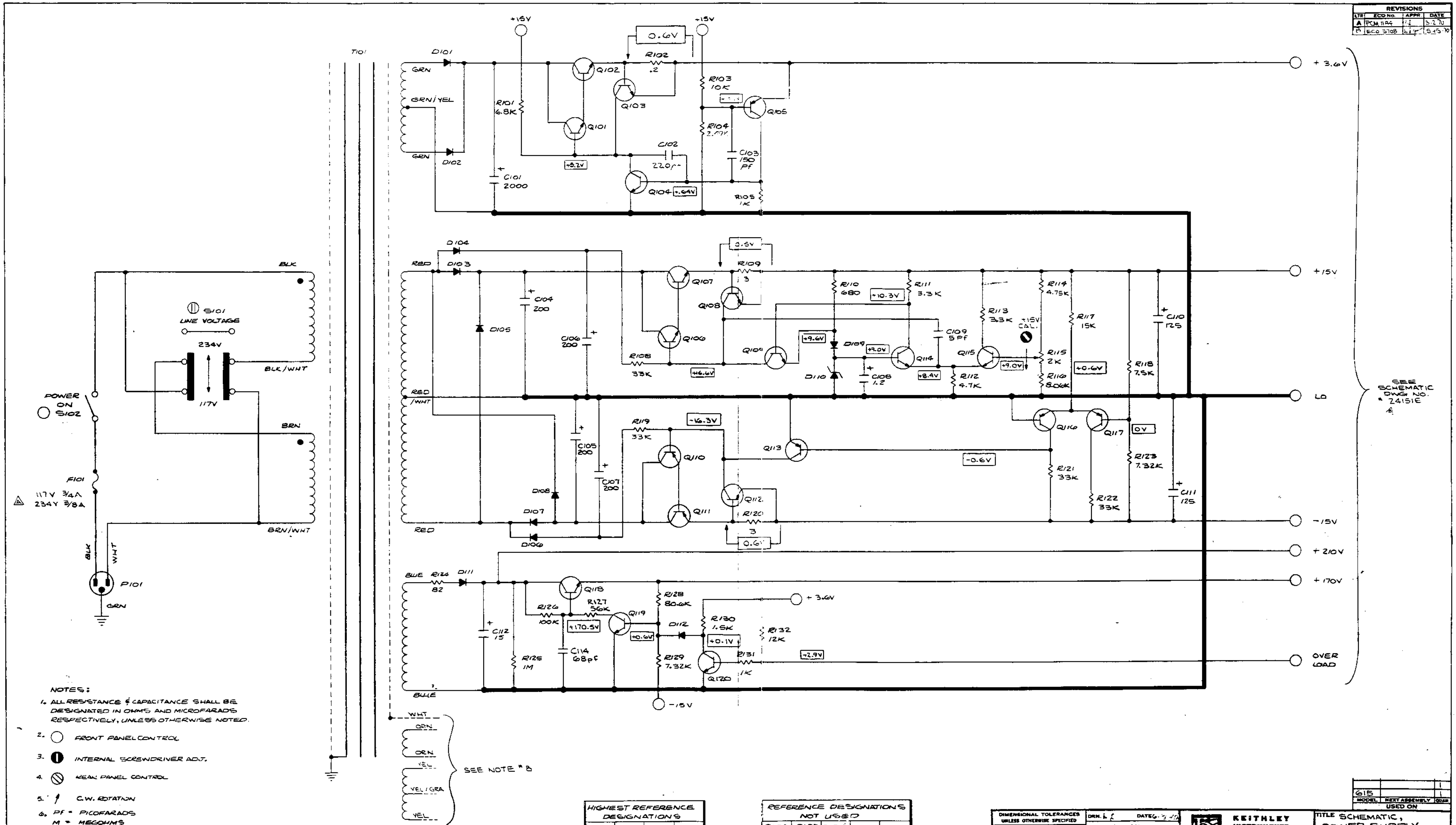


FIGURE 22. Component Layout, PC-245


INPUT
CHASSIS
GUARD
ZERO CHECK
AMPERES
VOLTS
OHMS
COULOMBS
FINE ZERO
COARSE ZERO
218508
SEE NOTE 11
TEST TERMINAL
DC BIAS
S1204 FEEDBACK
S1203 SENSITIVITY
J1206 OUTPUT
THOUSANDS DECIMAL POINT
HUNDREDS DECIMAL POINT
TENS DECIMAL POINT
ONES DECIMAL POINT
THOUSAND OVERLOAD
J1207
1 VOLT OUTPUT
DIGITAL VOLTMETER HI
DIGITAL VOLTMETER LOW
HIGHEST SCHEMATIC DESIGNATIONS
R1268 C1220 D1214 S1205 J1210
T101 Q1212
SCHEMATIC DESIGNATIONS NOT USED
J1208 R1264 R1265 R1266 R1267
NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. FRONT PANEL CONTROL
3. INTERNAL SCREW DRIVER ADJ.
4. REAR PANEL CONTROL.
5. * INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION.
6. M - MEGOHM
7. K - 1000 OHMS
8. PF - PICOFARADS
9. CLOCKWISE ROTATION
10. ALL VOLTAGES MEASURED REFERRED TO CHASSIS GND. WITH S105 IN NORMAL.
11. REMAINDER OF T101 IS ON SCHEMATIC # 24044E.
DO NOT SCALE
KEITHLEY INSTRUMENTS
TITLE SCHEMATIC ELECTROMETER
PART NUMBER
24261E



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICROFARADS RESPECTIVELY, UNLESS OTHERWISE NOTED.
2. ○ FRONT PANEL CONTROL
3. ● INTERNAL SCREWDRIVER ADJ.
4. ⊘ REAR PANEL CONTROL
5. ↑ C.W. ROTATION
6. PF = PICOFARADS
   M = MEGOHMS
   K = 1000 OHMS
7. TYPICAL VOLTAGES MEASURED WITH RESPECT TO LO WITH ... INSTRUMENT IN ZERO CHECK.

8. REMAINDER OF T101 ON SCHEMATIC 24267E.

HIGHEST REFERENCE DESIGNATIONS			
R132	C114	D112	Q120
F101	S102	T101	P101

REFERENCE DESIGNATIONS NOT USED			
R106	R107	C113/16	

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED		
FRAC.	DEC.	ANG.
± 1/64	± .005	± 1°
DO NOT SCALE		

DRN. | DATE
CKD. | DATE
ENG. APPR. | DATE
PILOT RELEASE | DATE
PROD. RELEASE | DATE

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

MATERIAL

FINISH

TITLE SCHEMATIC, POWER SUPPLY

MODEL	NEXT ASSEMBLY	QUAN
615		

USED ON

PART NUMBER 24044E