INSTRUCTION MANUAL

MODEL 165

DIGITAL MULTIMETER

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SPECIFICATIONS

calibrated at 25°C ±3°C

AS A DC VOLTMETER

RANGE	MAXIMUM READING	ACCURACY (6 months) ± (% of rdg + % of rng)	CMRR* dc,50, 60 Hz	NOMINAL** TEMP. COEFF. ± (% of rdg + % of rng)/°C
10 mV	19.99 mV	0.1% 0.2%	120 dB	0.01% 0.025%
100 mV	199.9 mV	0.1% 0.1%	120 dB	0.01% 0.01 %
1 V	1.999 V	0.1% 0.1%	120 dB	0.01% 0.01 %
10 V	19.99 V	0.1% 0.1%	80 dB	0.01% 0.01 %
100 V	199.9 V	0.1% 0.1%	70 dB	0.01% 0.01 %
1000 V	1000 V	0.2% 0.1%	60 dB	0.01% 0.01 %

*With at least 10% full-range dc applied

**Maximum temperature coefficient does not exceed twice nominal.

INPUT RESISTANCE: 10 megohms.

NORMAL MODE REJECTION RATIO: Greater than 60 dB above one digit for a voltage of line frequency or twice line frequency with at least 10% of full-range dc applied.

READING TIME: Typically 3 seconds to within 0.2% of final reading.

MAXIMUM ALLOWABLE INPUT: 1200 volts peak ac + dc on any range.

AS AN AC VOLTMETER

RANGE	MAXIMUM READING	ACCURACY* (6 months) @ 1000 Hz ± (% of rdg + % of rng)	ACCURACY* (6 months) @ 20 Hz & 20 kHz — (% of rdg + % of rng)
10 mV	19.99 mV	0.5% 0.4%	1% 1%
100 mV	199.9 mV	0.5% 0.22%	1% 1%
1 V	1.999 V	0.5% 0.2%	1% 1%
10 V	19.99 V	0.5% 0.2%	1% 1%
100 V	199.9 V	0.5% 0.2%	1% 1%
1000 V	500 V	0.5% 0.2%	1% 1%

*Average reading calibrated in rms of a sine wave

NOMINAL TEMPERATURE COEFFICIENT: ± (0.01% of reading + 0.01% of range)/°C. Maximum temperature coefficient does not exceed twice nominal.

INPUT IMPEDANCE: 1 megohm shunted by less than 75 picofarads.

READING TIME: Typically 3 seconds to within 0.2% of final reading.

MAXIMUM ALLOWABLE INPUT: 1200 volts peak ac + dc continuous except 250 volts rms maximum ac when manually operated on the 1-volt and lower ranges.

AS AN OHMMETER

RANGE	MAXIMUM READING	ACCURACY (6 months) ± (% of rdg + % of rng)	NOMINAL* TEMP. COEFF. ± (% of rdg + % of rng)/°C
100 Ω	199.9 Ω	0.3% 0.25%	0.03% 0.01%
1 kΩ	1.999 kΩ	0.3% 0.15%	0.03% 0.01%
10 kΩ	19.99 kΩ	0.3% 0.15%	0.03% 0.01%
100 kΩ	199.9 kΩ	0.3% 0.15%	0.03% 0.01%
1 MΩ	1.999 MΩ	0.5% 0.15%	0.034% 0.01%
10 MΩ	19.99 MΩ	2% 0.2 %	0.07% 0.01%
100 MΩ	199.9 mΩ	25% 0.2 %	0.43% 0.01%

*Maximum temperature coefficient does not exceed twice nominal.

VOLTAGE ACROSS UNKNOWN: 100 millivolts at full range, less than 1 volt into an open circuit.

MAXIMUM ALLOWABLE INPUT: 250 volts rms (400 volts peak) to 65 Hz on any range.

AS A CONTINUITY TESTER

On DC Voltmeter function, push-button nominal 1 mA current source provides 10 milliohms per digit (10 ohms full range) to 2 kilohms resistance range. Measures diode voltage to approximately 4 volts.

AS A DC AMMETER

RANGE	MAXIMUM READING	ACCURACY (6 months) ± (% of rdg + % of rng)	SHUNT RESIST.	MAX. FULL RANGE BURDEN
1 μA	1.999 μA	0.3% 0.3%	10 kΩ	10 mV
10 μA	19.99 μA	0.3% 0.3%	1 kΩ	10 mV
100 μA	199.9 μA	0.3% 0.3%	100 Ω	10 mV
1 mA	1.999 mA	0.3% 0.3%	10 Ω	10 mV
10 mA	19.99 mA	0.3% 0.3%	1 Ω	12 mV
100 mA	199.9 mA	0.3% 0.3%	0.1 Ω	30 mV
1000 mA	1999 mA	0.3% 0.3%	0.1 Ω	300 mV

NOMINAL TEMPERATURE COEFFICIENT: ± (0.02% of reading + 0.02% of range)/°C. Maximum temperature coefficient does not exceed twice nominal.

NORMAL MODE REJECTION RATIO: Greater than 60 dB above one digit for a current of line frequency or twice line frequency with at least 10% of full-range dc applied.

MAXIMUM ALLOWABLE INPUT: 3 amperes rms on any range.

AS AN AC AMMETER

RANGE	MAXIMUM READING	ACCURACY* (6 months) @ 1000 Hz ± (% of rdg + % of rng)	ACCURACY* (6 months) @ 20 Hz & 20 kHz ± (% of rdg + % of rng)	SHUNT RESIST.	MAX. FULL RANGE BURDEN
100 μA	199.9 μA	1% 0.4%	2% 1%	100 Ω	10 mV
1 mA	1.999 mA	1% 0.4%	2% 1%	10 Ω	10 mV
10 mA	19.99 mA	1% 0.4%	2% 1%	1 Ω	12 mV
100 mA	199.9 mA	1% 0.4%	2% 1%	0.1 Ω	30 mV
1000 mA	1999 mA	1% 0.4%	2% 1%	0.1 Ω	300 mV

*Average reading calibrated in rms of a sine wave.

NOMINAL TEMPERATURE COEFFICIENT: ± (0.02% of reading + 0.02% of range)/°C. Maximum temperature coefficient does not exceed twice nominal.

MAXIMUM ALLOWABLE INPUT: 3 amperes rms on any range.

GENERAL

ANALOG OUTPUTS: Nominal 1 volt.

POLARITY: Automatic.

RANGE SELECTION: Automatic and manual on each function.

WARMUP: Within 3-times rated accuracy at turn-on, two hours to complete stabilization.

DISPLAY: 3 digits plus 1 overrange digit, decimal position, polarity, function, range and overload indication; 5 readings per second.

ISOLATION: Circuit ground to chassis ground: greater than 1000 megohms shunted by 0.01 microfarad. Peak voltage between GND and either input terminal (CMV + NMV) must not exceed 1200 volts.

POWER: 90-110, 105-125, 195-235, 210-250 volts ac (switch selected), 50-60 Hz, 20 watts.

DIMENSIONS, WEIGHT: 4 in. high x 9-1/2 in. wide x 15 in. deep (100 x 240 x 380 mm). Net weight, 6 pounds (2.7 kg).

ENVIRONMENT: 15 to 50°C. 15 to 35°C with up to 70% RH.

CONNECTORS: Input HI, input LO, GND: Binding posts.

ACCESSORIES AVAILABLE:

Model 1653 Rack Mounting Kit: Adapts Model 165 for standard 3-1/2 in. x 19 in. rack mounting, 15 in. (300 mm) depth behind front panel.....

Model 1651 50 Ampere Shunt: External 0.001-ohm

SECTION 1. GENERAL DESCRIPTION

1-1. INTRODUCTION. The Model 165 Autoranging Multimeter (Figure 1) is a highly versatile 3-1/2 digit instrument capable of handling almost every measurement that will ever be encountered in most lab or production line facilities. The 165 measures 10 microvolts to 1000 volts dc, 10 microvolts to 500 volts rms ac, 10 milliohms to 200 megohms, 1 nanoampere to 2 amperes dc, and 0.1 microampere to 2 amperes rms ac. The specified ac frequency response of the ac volts and amps ranges is 20 Hz to 20kHz. Useable reading may be obtained typically from 10 Hz to 100-kHz. Thirty of the thirty-two ranges of the 165 are capable of 100% overranging, the two exceptions being the highest voltage ranges. This allows the user to accurately exceed a full-scale reading without having to immediately change range. The AUTO range mode of the 165 allows ranges to be changed automatically when an input signal exceeds 2000 counts or falls below 0179 counts on the display. A 1mA current source is built-in.

1-2. WARRANTY INFORMATION. The warranty is given on the inside front cover of this Manual. If there is a need to exercise the Warranty refer to Maintenance, Section 5-7a, "Repair Assistance".

1-3. CHANGE NOTICE. If there are any improvements or changes to the Model 165 that are not incorporated into this Manual, these will be explained on a yellow Change Notice attached to the inside back cover.

1-4. FEATURES.

a. Direct-Reading Display. The polarity decimal point, and engineering units of a reading are automatically shown on the bright, easy-to-read display panel.

b. Automatic or Manual Range Selection. The 165 provides for automatic or manual selection of all thirty-two ranges by rotating the RANGE switch (inner knob) to the appropriate setting.

c. Thirty-two Ranges. The 165 provides six ranges of dc voltage, six ranges of ac voltage, eight ranges of resistance (including the extra range provided by the 1mA current source), seven ranges of dc current, and five ranges of ac current.

d. Analog Outputs. The Model 165 has two nominal 1-volt analog outputs for monitoring purposes.

e. Built-in 1mA Current Source at up to 4 volts.

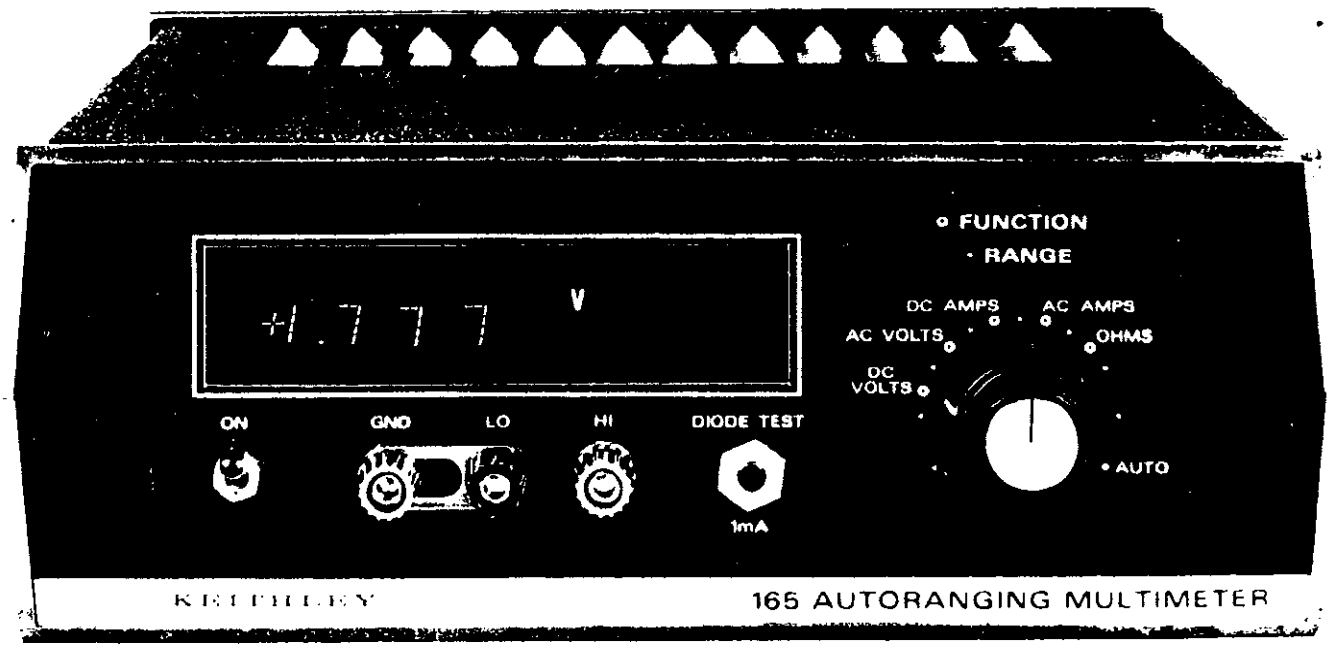


FIGURE 1. Model 165 Autoranging Multimeter.

TABLE 1-1.
Front Panel Controls and Terminals

Control	General Description	Paragraph
S301	ON; turns on instrument power.	2-2d, 2-4a
S401A	FUNCTION; sets instrument function (dc/ac volts, dc/ac amps, ohms).	2-4b
S401B	RANGE; sets instrument sensitivity.	2-4b
S402	1mA CURRENT SOURCE; injects +1mA into J401	2-9a,b
Terminal		
J401	HI; input high, red binding post	2-1c, 2-3a
J402	LO; input low, black binding post	2-1c, 2-3a
J403	GND; power-line ground, green binding post	2-1c, 2-3a

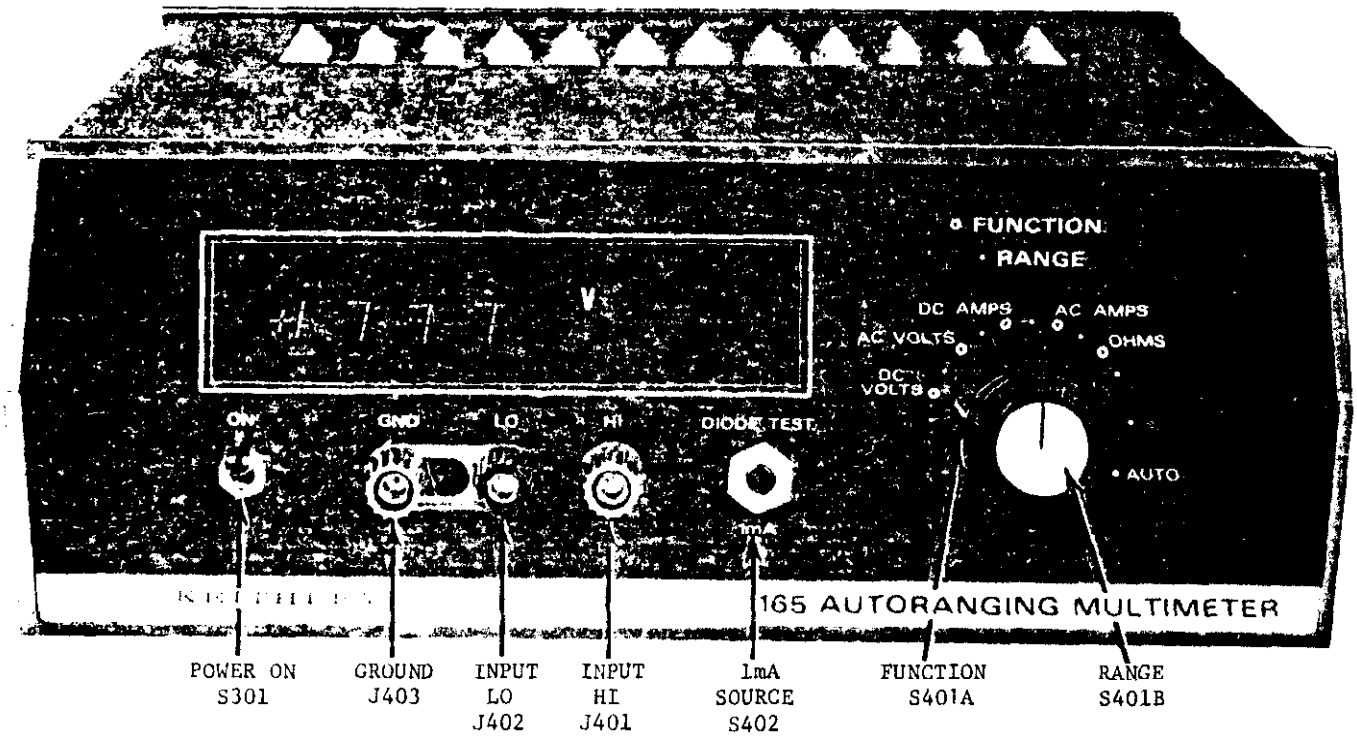


FIGURE 2. Front Panel Controls and Terminals.

TABLE 1-2.
Rear Panel Controls and Connectors

Control	General Description	Paragraph
Calibration	R424, R434, R201, R204, R211, R205, R402, R431	5-4
J201	NOMINAL 1-V ANALOG OUTPUT	2-3b
J202	NOMINAL 1-V ANALOG OUTPUT	2-3b
J203	COMMON, analog outputs	2-3b
S302	LINE SWITCH; set with S303	2-2b
S303	LINE SWITCH; set with S302	2-2b
F301	FUSE: 117V: 1/4 ampere 234V: 1/8 ampere	2-2a, 5-3b2
Connector		
P304	LINE (MAINS) INPUT	2-2, 5-3b1

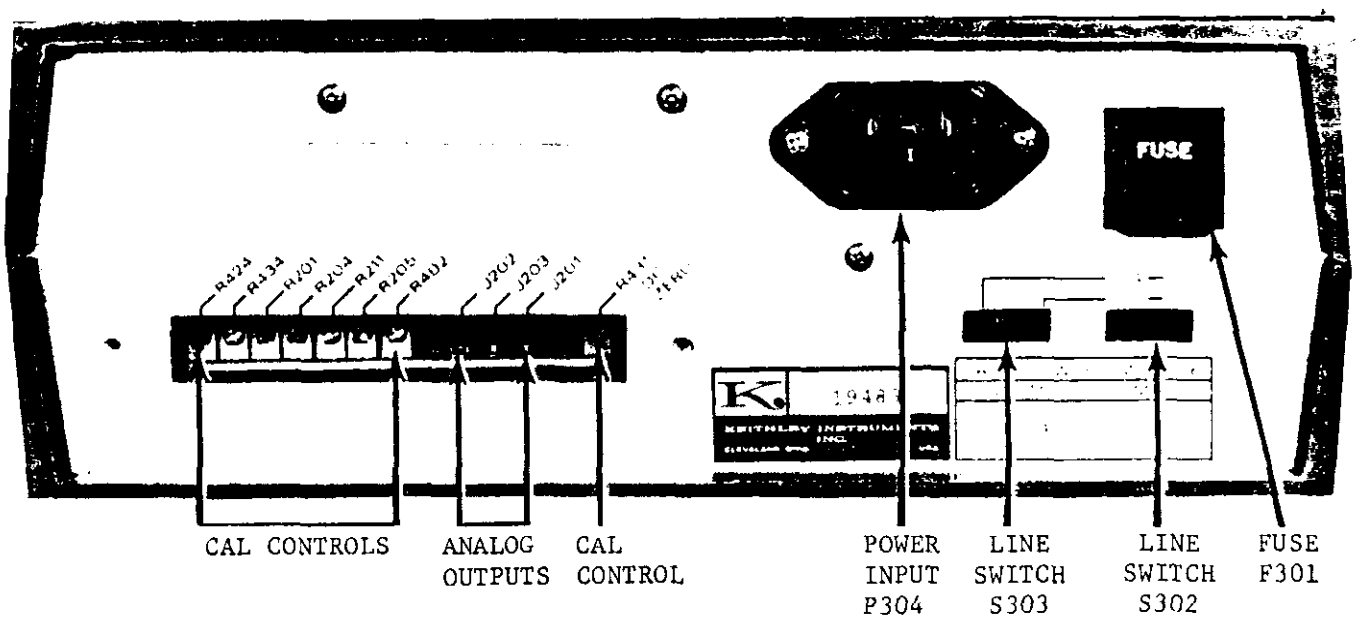


FIGURE 3. Rear Panel Controls and Connectors.

SECTION 2. OPERATION

2-1. GENERAL. This section describes the details of operating the Model 165 as a voltmeter, ammeter, ohmmeter, and current source. Included also are discussions of measurement considerations, power requirements, input and output connections, function and range selection, overload considerations, and a summary of operational procedures.

a. Measurement Considerations. Occasionally the situation may arise where noises of various types may be severe enough to interfer with a measurement, especially when measurements are made right near the lower limits of resolution of the 165. Most noise in a measuring circuit is usually generated by the source, by outside power sources, or in connections and cables to the source. Noise contributions by the 165 are minimal and considered in the specifications. Let's briefly discuss the common types of noise --- thermoelectric, ac power line, and magnetic --- with suggestions to minimize them.

1. Thermoelectric Noise. Potentials generated by thermal differences at the junction or junctions of two dissimilar metals are thermoelectric noises, more commonly called thermal EMFs. These potentials may be significant when making millivolt or microvolt measurements. To minimize thermal noise --- which may appear as a drift --- caused by thermal EMFs, use pure copper circuitry and terminations throughout the source and in all connections to the 165. The Keithley accessory Model 1483 Low Thermal Connection Kit contains all necessary materials for making very low-thermal copper connections for minimizing thermal EMFs.

2. AC Power Line Noise. The presence of electric fields generated by power lines or other power sources can have an effect on instrument operation. Also ac voltages present in the source which are very large with respect to the full-scale range sensitivity of the Model 165 could drive the analog amplifier into saturation, producing an erroneous digital display.

a). Shielding. Proper shielding of the source or cabling can minimize noise pickup when the instrument is in the presence of large ac fields or when very sensitive measurements are being made. Low-noise shielded cable, such as Keithley SC-9 cable, should do a sufficient job of shielding the input signal. Metal shields may be required to be installed around the source. The shields of the input cable and source should be connected together to ground at one point only, typically at the input of the Model 165. This one-point-ground method is a "tree" configuration, which minimizes ground loops in the measured circuitry. Ground loops are a secondary source of interfering noise which may also be considered in low-level measurements.

b). AC Rejection. The Model 165 provides attenuation of line frequency noise superimposed on a dc input signal. The ac rejection of the 165 is specified as follows:

NORMAL MODE REJECTION RATIO (NMRR): Greater than 60 dB above one digit for a voltage of line frequency or twice line frequency with at least 10% of full-range dc applied.

COMMON MODE REJECTION RATIO (CMRR): 120 dB on the 10 mV, 100 mV, and 1V ranges; 80 dB on the 10V range; 70 dB on the 100V range; and 60 dB on the 1000V range; for a dc, 50 Hz, or 60 Hz voltage with at least 10% of full-range dc applied.

3. Magnetic-field Noise. The presence of strong magnetic fields can be a possible source of objectionable ac noise. The Model 165 has been sufficiently shielded from typical magnetic interference; however, additional shielding may be required at the source or in the cabling to the 165. Magnetic flux lines which cut a conductor --- like an input cable --- can produce large ac noise, especially at power line frequencies. The voltage induced due to magnetic flux is proportional to the area enclosed by the circuit as well as the rate of change of magnetic flux. For example, the motion of a 3-inch diameter loop in the earth's magnetic field will induce a signal of several tenths of a microvolt. The ac rejection characteristics of the Model 165 will help minimize specific effects of magnetic fields. Magnetic pickup may be further minimized by arranging all source and input-cable wiring so that the loop area enclosed is as small as possible (such as by twisting input leads). Using conetic (magnetic) shielding in cables and around circuitry may further help in severe cases.

b. Effective Shielding. Here are general shielding rules to consider for measurements in the three function categories of the 165. Be sure that shielding is even needed before proceeding.

1. Voltmeter Measurements. Consider shielding input leads when source resistances are greater than 100 kilohm or when long input cables are used. Avoid even slight movements of input cabling or the source when making high source resistance measurements.

2. Current Measurements. On the mA and μA current ranges, generally no special shielding precautions need be taken. However, consider shielded input leads for measurements on the lowest ranges.

3. Resistance Measurements. Shielding of the input cabling and source may be necessary for measurements on the 10 megohm and 100 megohm ranges.

c. Floating Circuit Ground. The circuit ground-to-chassis-ground isolation of the input of the Model 165 is greater than 1000 Megohms shunted by 0.01 microfarad. Peak voltage between the green ground (GND) terminal and either the LO (black) or HI (red) input terminal (CMV + NMV) must not exceed 1200 volts. To use the Model 165 for floating measurements, disconnect the shorting link between the LO (input low) and GND (power-line ground) terminals on the front panel.

d. Source Impedance. The Model 165 has an input resistance of 10 megohms on all dc voltage ranges. For a source resistance (R_S), this creates a loading error of:

$$\text{Error} = -100[R_S/(10^7 + R_S)]\%$$

2-2. HOW TO APPLY POWER. Power should be supplied from a source of 50-60 Hz line voltages. Follow these steps before turning-on the 165:

a. Check for proper line-fuse (F301) value as follows:

117V: 1/4A 234V: 1/8A

b. Set line switches (S302 and S303) for the line-voltage being applied.

c. If 400 Hz line voltages are to be used, consult the factory applications department or your local Keithley representative for instructions.

d. Turn ON power switch S301.

2-3. CONNECTIONS. (refer to Figures 2 and 3).

a. Input. Three binding posts are provided on the front panel for input connections. The terminals are color-coded as follows: red = input high (HI) J401, black = input low (LO) J402, and green = power-line ground (GND) J403. These terminals mate with individual "banana" plugs similar to Keithley Part No. BG-5. The front panel terminals are spaced with 3/4-inch between centers to mate with a standard dual "banana" plug such as Keithley Part No. BG-7. Banana-plug-to-alligator-clip cables (available through any local electronics supply house), such as two Keithley Part No. 18762B cables, are ideal for fast connections to the 165 input. The shorting link provided at the input should be connected between LO and GND for grounded operation. It is preferable, to minimize the possible effects of ground loops (small currents flowing in the ground system), that there be only one ground point in the measuring system. If possible, connect all grounds together at one point, ideally at the GND input terminal of the 165. The input shorting link should be removed for floating operation.

b. Analog Outputs. The two analog outputs of the 165 are used as monitoring points to calibrate the instrument (see Section 5-4). These outputs may be used for monitoring purposes when the 165 is being used under normal operating conditions, although the max. levels are not specified. Note that these analog outputs, described in Table 2-1, are nominal values only. Output zero offsets and full-scale output levels are not calibrated and so accuracies are not guaranteed. Linearity of each output, however, is good. One analog output is available between the green tip jack J201 (HI) and the black tip jack J203 (LO) accessible from the rear panel. The other output is available between the red tip jack J202 (HI) and the black tip jack J203 (LO) also accessible from the rear panel. Use any common phone-tip plugs to mate with the tip jacks, such as Herman H. Smith, Inc. (Brooklyn, N. Y., U.S.A.) solder-type phone-tips part no. 108, 123, or 158.

TABLE 2-1.
Analog Outputs

Function Selected	Approximate Full-Range Voltage at: J201	J202
dc volts	± 0.9V dc	+ 0.9V dc
ac volts	1V rms ac	+ 0.9V dc
dc amps	± 0.9V dc	+ 0.9V dc
ac amps	1V rms ac	+ 0.9V dc
ohms	- 0.9V dc	+ 0.9V dc

2-4. CONTROLS. (refer to Figure 2).

a. Power Switch (S301). This front-panel toggle switch controls the line power to the instrument. When this switch is placed to ON, power is applied to the instrument.

b. Function Switch (S401A) and Range Switch (S401B). The Model 165 has a five-position rotary FUNCTION switch on the front-panel which sets the instrument to DC VOLTS, AC VOLTS, DC AMPS, AC AMPS, or OHMS by rotation of the outer knob. Range is selected either manually or automatically, using the inner knob.

1. Manual Range Selection. The RANGE switch on the front panel is the inner knob of the FUNCTION switch. The most sensitive full-range is located in the fully-counterclockwise switch position. As the RANGE switch is rotated, the decimal point, polarity, and engineering-units designator of a reading are automatically indicated on the display panel along with the digits. When initially making a measurement, the RANGE switch should be rotated clockwise to the least sensitive range. Then the switch may be rotated counterclockwise to obtain a suitable display.

2. Automatic Range Selection. To operate the 165 in the automatic ranging mode, turn the RANGE switch to the fully-clockwise (AUTO) position. In this AUTO mode, the 165 automatically changes its full-range sensitivity depending on the amplitude of the input signal.

2-5. DIGITAL DISPLAY. The digital display is composed of a 4-segment LED (light emitting diodes) polarity sign, three 7-segment LED digits, an over-range 4-segment LED "1" digit, an LED decimal point that is automatically positioned, and engineering-units designators, as shown in Figure 4. When dc volts or dc amps is selected, the polarity sign will automatically indicate "+" or "-", depending on the polarity of the dc input. When ac volts, ac amps, or

ohms is selected, the polarity sign blanks. A typical display reading, 1.234 mA rms ac, is shown in Figure 5.

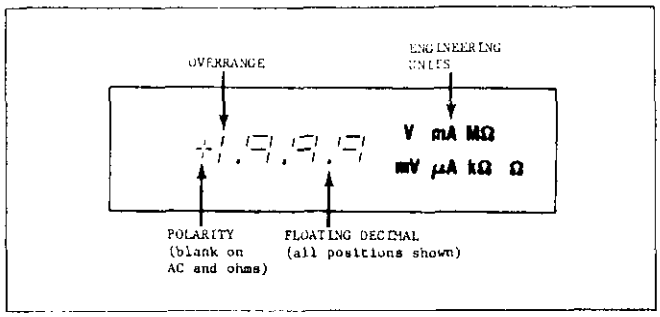


FIGURE 4. Complete Digital Display.

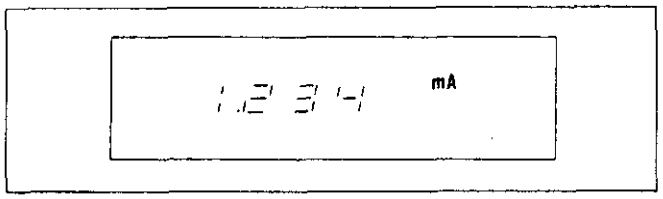


FIGURE 5. Typical Display Reading.

2-6. OPERATION AS A VOLTMETER. The Model 165 can be used to measure voltage from ±10 microvolts to ±1000 volts dc and 10 microvolts to 500 volts rms ac.

a. DC VOLTS Operation. The Model 165 provides six full-ranges of dc voltage operation from ±10 millivolts to ±1000 volts. Range selection can be accomplished either manually or automatically. Manual selection is accomplished by setting the RANGE switch S401B to any one of six positions, not including the two most counterclockwise positions. These two positions may be used but they just duplicate the operation of the ±10 millivolt dc voltage range, which is the third position from full counterclockwise. As the RANGE switch is rotated clockwise, the 165 dc voltage sensitivity is decreased. Automatic selection of range is accomplished by rotating the RANGE switch to the extreme clockwise position marked AUTO.

1. Measurement Procedure. Select the DC VOLTS function using the FUNCTION switch, set the RANGE switch, and make input connections to the front-panel terminals. The digital display indicates the proper polarity, decimal point location, and engineering units of the reading. If the display exceeds 1999 on the ±100-volt or lower ranges, the three right-hand digits will blank and the overrange "1" digit will remain lit. If the display exceeds 999 on the ±1000-volt range, in the AUTO or manual ranging mode, the display will blink but still read. Accuracy is specified to ±1000 volts. See Paragraph 2-6a5 for details of the maximum allowable input.

2. Input Resistance. The input resistance of the 165 on all dc voltage ranges is 10 megohms ±7%.

3. Accuracy. The accuracy (error limit) for DC VOLTS (and all other functions) is determined by the following equation:

$$E\% = \%\ RNG + (S/fs \times \%\ RDG)$$

Where E% = limit of error expressed as % of full range; % RNG = %-of-range specification; S = applied signal level; fs = selected full-range level; % RDG = %-of-reading specification. For example, for a signal of 12 volts on the 10-volt dc range:

$$E = 0.1\% + (12/10 \times 0.1\%)$$
$$E = 0.1\% + 0.12\%$$
$$E = 22\% \text{ of full range} = 22 \text{ millivolts}$$

Thus a reading of 12.00 volts dc indicates that input signal level is between 11.978 and 12.022 volts.

4. Half-digit Interpolation. Unlike dual-slope and other a-d converters, when the most right-hand digit of the 165 display is flashing between two adjacent numbers, the percentage of time spent on each is a half-digit interpolation of the incoming signal level. For example, 12.00 volts flashing in near-equal intervals to 12.01 volts would indicate a reading of 12.005 volts. Accuracy is determined as in Paragraph 2-6a3.

5. Maximum Allowable Input. The maximum continuous or intermittent input voltage which can be safely applied on any dc voltage range is 1200 volts peak ac + dc, using the manual or automatic ranging modes. On the 1000-volt range in either ranging mode, the Model 165 display will flash when the input exceeds ±999 volts, although a reading beyond this level is displayed.

b. AC VOLTS Operation. The Model 165 provides five and one-half decades (six ranges) of ac voltage operation from 10 millivolts to 500 volts rms ac. Range selection can be accomplished either manually or automatically. Manual selection is accomplished by setting the RANGE switch S401B to any one of six positions, not including the two most counterclockwise positions. These two positions may be used but they just duplicate the operation of the 10 millivolt rms ac range, which is the third position from full counterclockwise. As the RANGE switch is rotated clockwise, the 165 ac voltage sensitivity is decreased Automatic selection of range is accomplished by rotating the RANGE switch to the extreme clockwise position marked AUTO.

1. Measurement Procedure. Select the AC VOLTS function using the FUNCTION switch, set the RANGE switch, and make input connections to the front-panel terminals. The digital display indicates the decimal point location and engineering units of a reading. The polarity sign will not light when ac volts is selected. If the display exceeds 1999 on the 100-volt or lower ranges, the three right-hand digits will blank and the overrange "1" digit will remain lit. If the display exceeds 499 on the 1000-volt range, in the AUTO or manual ranging mode, the display will blink but still read. Accuracy is specified to 500 volts rms ac. See

Paragraph 2-6b5 for details of the maximum allowable input.

2. Input Resistance. The input resistance of the 165 on all ac voltage ranges is 1 megohm ±10% shunted by less than 75 picofarads of capacitance.

3. Accuracy. The Model 165 detects the average value of an applied input ac waveform. The display of the 165 is calibrated to indicate the rms value of an applied sinewave. The accuracy (error limit) calculations given in Paragraph 2-6a3 also apply for ac measurements, except that 20 Hz and 20kHz, the specified accuracy is asymmetical. Reference the specified ac-volts accuracy ranges at 20 Hz, 1kHz, and 20kHz. Typical accuracy bands at non-specified frequencies are shown in Figure 6.

4. Half-digit Interpolation. Same as for dc volts operation.

5. Maximum Allowable Input. The maximum continuous or intermittent input voltage which can be safely applied on manually selected 1-volt and lower ranges is 250 volts rms. When operating manually on the 10 volt to 500 volt rms ranges or in the autoranging mode on all ranges, the maximum continuous or intermittent input voltage which can be safely applied is 1200 volts peak ac + dc. On the 500-volt rms range (1000 volt range position) in either ranging mode, the 165 display will flash when the input exceeds 499 volts rms, although a reading beyond this level is displayed.

2-7. OPERATION AS AN AMMETER. The Model 165 can be used to measure current from ±1 nanoamp to ±2 amps dc and 100 nanoamps to 2 amps rms ac.

a. DC AMPS Operation. The Model 165 provides seven full-range decades of dc amps operation from ±1 microamp to ±1 amp (±1000 milliamps). Range selection can be accomplished either manually or automatically. Manual selection is accomplished by setting the RANGE switch S401B to any one of seven positions, not including the most counterclockwise position. This position may be used but it just duplicates the operation of the ± 1 microamp dc current range, which is the second position from full counterclockwise. As the RANGE switch is rotated clockwise, the 165 dc current sensitivity is decreased. Automatic selection of range is accomplished by rotating the RANGE switch to the extreme clockwise position marked AUTO.

1. Measurement Procedure. Select the DC AMPS function using the FUNCTION switch, set the RANGE switch, and make input connections to the front-panel terminals. The digital display indicates the proper polarity, decimal point location, and engineering units of a reading. If a reading exceeds ±1999 milliamps, in the AUTO or manual ranging mode, the display will blink but still read up to 2017 mA (the 2 is not shown). Accuracy is specified to ±2 amps. If the display exceeds 1999 on the ±100 milliamp or lower ranges, the three right-hand digits will blank and the overrange "1" digit will remain lit. See Paragraph 2-7a5 for details of the maximum allowable input.

2. Input Resistance. The amps ranges of the Model 165 have a voltage burden of 0.01 volt at full range except on the upper ranges, as indicated in Table 2-2. This table indicates the error due to voltage burden using a 10-volt source on all full-scale ranges of the 165.

TABLE 2-2.
Amps Ranges Voltage Burden Error

Full Range	Full Range Volt. Burden	Sensing Resistance	Volt. Burden Error*
1 µA	10 mV	10 kΩ	0.1 %
10 µA	10 mV	1 kΩ	0.1 %
100 µA	10 mV	100 Ω	0.1 %
1 mA	10 mV	10 Ω	0.1 %
10 mA	12 mV	1 Ω	0.12 %
100 mA	30 mV	0.1 Ω	0.3 %
1000 mA	300 mV	0.1 Ω	3 %

*Error due to voltage burden using a 10-volt source.

3. Accuracy. The dc-current accuracy of the 165 is ±(0.3% of reading + 0.3% of range). The error limit of a given measurement can be calculated using this specification (see Paragraph 2-6a3) and the voltage burden (see Paragraph 2-7a2).

4. Half-digit Interpolation. When the most right-hand digit of the 165 display is flashing between two adjacent numbers, the percentage of time spent on each is a half-digit interpolation of the incoming signal level. For example, 500 milliamps flashing in near-equal intervals to 501 milliamps would indicate a reading of 500.5 milliamps.

5. Maximum Allowable Input. An overload of 3 amps rms ac, dc, or in any combination may be applied continuously or intermittently on any current range without damage to the instrument or degradation of accuracy. The current-sensing range resistors are protected with diodes rated at 300 amps surge current. Voltage drop across these diodes is about 1.5 to 2 volts. These

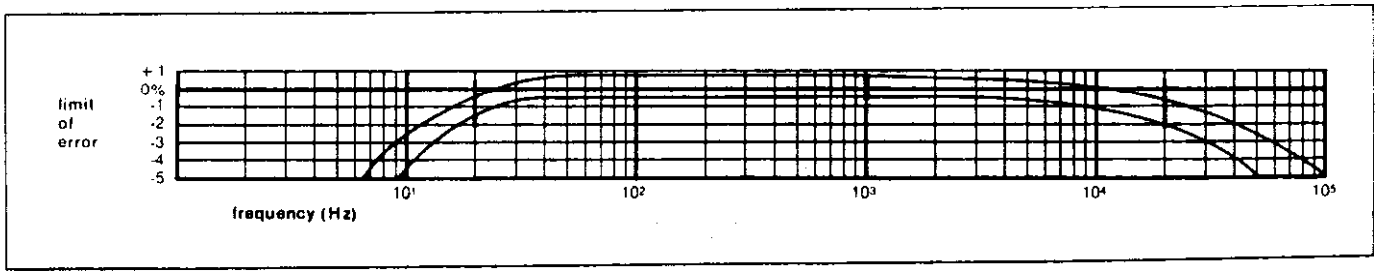


FIGURE 6. Typical AC Frequency Response of the Model 165.

diodes will protect the sensing resistors from currents up to levels which cause excessive heating or vaporization of pc-board tapes.

NOTICE

SEVERE DAMAGE TO CERTAIN CRITICAL COMPONENTS MAY OCCUR IF THE POWER LINES (MAINS) ARE CONNECTED TO THE INPUT TERMINALS ON DC OR AC AMPS FUNCTIONS, EVEN THOUGH THE LINES (MAINS) ARE FUSED (15 OR 20 AMPS) OR PROTECTED BY CIRCUIT BREAKERS.

b. AC AMPS Operation. The Model 165 provides five full-range decades of ac amps operation from 100 microamps to 1 amp (1000 milliamps) rms. Range selection can be accomplished either manually or automatically. Manual selection is accomplished by setting the RANGE switch S401B to any one of five positions, not including the three most counterclockwise positions. These three positions may be used but they just duplicate the operation of the 100 microamp rms ac current range, which is the fourth position from full counterclockwise. As the RANGE switch is rotated clockwise, the 165 ac current sensitivity is decreased. Automatic selection of range is accomplished by rotating the RANGE switch to the extreme clockwise position marked AUTO.

1. Measurement Procedure. Select the AC AMPS function using the FUNCTION switch, set the RANGE switch, and make input connections to the front-panel terminals. The digital display indicates the decimal point location and engineering units of a reading. The polarity sign will not light when ac amps is selected. If the display exceeds 1999 on the 100 milliamp or lower ranges, the three right-hand digits will blank and the overrange "1" digit will remain lit. See Paragraph 2-7a5 for details of the maximum allowable input.

2. Input Resistance. See Paragraph 2-7a2.

3. Accuracy. The ac-current accuracy specification of the 165 is used to calculate the error limit of a specific measurement (see Paragraph 2-6a3), except at 20 Hz and 20kHz where specified accuracy is asymmetrical. Reference the specified ac-amps accuracy ranges at 20 Hz, 1kHz, and 20kHz. Typical accuracy bands at non-specified frequencies are shown in Figure 6, although the 10-1000 mA range has somewhat flatter response at 20kHz than that shown. Voltage burden (see Paragraph 2-7b2) can also produce error, depending on the level of the source voltage.

4. Half-digit Interpolation. See Paragraph 2-7a4.

5. Maximum Allowable Input. See Paragraph 2-7a5.

2-8. OPERATION AS AN OHMMETER. The Model 165 can be used to measure resistance from 0.1 ohm to 200 megohms. The Model 165 provides seven full-range decades of resistance from 100 ohms to 100 megohms. Range selection can be accomplished either manually or automatically. Manual selection is accomplished by setting the RANGE switch S401B to any one of seven positions, not including the second position from full clockwise. This position may be used but it just duplicates the operation of the 100 megohm range, which is the third position from full clockwise. As the RANGE switch is rotated counterclockwise, the 165 resistance sensitivity is increased. Automatic selection of range is accomplished by rotating the RANGE switch to the extreme clockwise position marked AUTO.

a. Measurement Procedure. Select the OHMS function using the FUNCTION switch, set the RANGE switch, and make input connections to the front-panel terminals. The digital display indicates decimal point location and engineering units of a reading. The polarity sign will not light when ohms is selected. If the display exceeds 1999 on any range, the three right-hand digits will blank and the overrange "1" digit will remain lit. In the AUTO mode or manually on the outside 100-megohm position, an open-circuit input causes a flashing 01.7 MΩ display. With an open input, the inside 100-megohm range, the third position from full clockwise, may flash or blank depending on whether it was entered from the outside 100-megohm range or the 10-megohm range. Also, if the RANGE switch is rotated rapidly while in the AUTO mode, the display may blank. Neither condition just discussed represents a problem or malfunction.

b. Applied Test Current. The Model 165 applies a test current of 1 mA to 1 nA to the input terminals, as shown in Table 2-4. The HI input terminal J401 is negative with respect to the LO input terminal J402. The terminal voltage is 100 millivolts at full range (200 millivolts at maximum overrange reading). maximum open-circuit voltage is less than 1 volt.

TABLE 2-4.
Ohms Test Current

Full Range	Full-Range Terminal Voltage	Test Current
100 Ω	100 mV	1 mA
1 kΩ	100 mV	100 µA
10 kΩ	100 mV	10 µA
100 kΩ	100 mV	1 µA
1 MΩ	100 mV	100 nA
10 MΩ	100 mV	10 nA
100 MΩ	100 mV	1 nA

c. Accuracy. The accuracy for all ohms ranges is as specified. This specification applies for environmental conditions of 35°C at up to 70% relative humidity. Accuracy on the 1-megohm and higher ranges is typically two-times better than specifications. The error limit of a given measurement can be calculated using the specified accuracies as described in Paragraph 2-6a3.

d. Half-digit Interpolation. When the most right-hand digit of the 165 display is flashing between two adjacent numbers, the percentage of time spent on each is a half-digit interpolation of the incoming signal level. For example, 1.000 kilohms flashing in near-equal intervals to 1.001 kilohms would indicate a reading of 1.0005 kilohms.

e. Maximum Allowable Input. The maximum voltage which can be applied to the input in the OHMS function is 250 volts rms on any range. This voltage may be applied continuously or intermittently without damage or degradation of specifications.

2-9. OPERATION OF THE 1-mA SOURCE. The lmA front-panel pushbutton activates a current source of +1 mA ±10%. The current is internally injected into the HI input terminal J401. Voltage compliance is typically greater than 4 volts.

a. Resistance Measurements. If the DC VOLTS function is selected while using the 1 mA current source, the Model 165 becomes a direct-reading autoranging or manual ranging ohmmeter having 100% overranging on ranges from 10.00 ohms to 1.000 kilohms full-scale (corresponding respectively to 10.00 millivolt through 1.000 volt dc ranges). Useful measurements are available to 4.00 kilohms (corresponding to 4.00 volts on the 10.00 volt dc range). In any case, the voltage compliance limit is also the limit of resistance measurements using the lmA current source. Note that the engineering units on the display will still indicate volts, which is the voltage compliance at which measurements are being made. At the same time, the displayed numbers in the reading indicate the value of the resistance being measured. For example, a reading of 100.0 millivolts dc indicates the measured resistance is 100.0 ohms and a reading of 1.999 volts dc indicates 1.999 kilohms.

1. Measurement Procedure. The lmA current source feature of the Model 165 may be used to measure low resistances or to check continuity. An open circuit or resistance greater than the range limit is indicated by a display of the full compliance voltage. This voltage is easily determined by open-circuiting in the input terminals of the 165 and depressing the lmA pushbutton while operating in the DC VOLTS function either manually on the 10-volt range or in the AUTO range mode.

2. Compensating for Lead Resistance. A precise value of the lmA current source (I) can be obtained by open-circuiting the input terminals, selecting the DC AMPS function, and depressing the lmA pushbutton. The resistance of the test leads and internal connections (R_O) can be directly measured by shorting the test leads while in the DC VOLTS function and depressing the lmA pushbutton. Then the measured resistance (R) can be more accurately determined as follows:

$$R = \frac{V}{I} - R_O$$

where V is the observed voltage during the actual measurement of R.

b. Semiconductor Testing. In the DC VOLTS function and AUTO range mode, the lmA current source may be used to determine polarity of a semiconductor junction. The forward voltage drop of this junction at lmA is displayed on the Model 165 if the junction is connected between the input terminals in the forward polarity. Note that the lmA current source is internally injected into the HI input terminal J401. In the reverse polarity position, the display will indicate the compliance voltage limit of the current source, which can be measured as described in Paragraph 2-9a1.

NOTICE

DO NOT DEPRESS THE lmA PUSHBUTTON WHEN EXTERNAL VOLTAGE IS APPLIED TO THE INPUT TERMINALS.

2-10. OPERATIONS SUMMARY. Condensed operating instructions are found on the botton cover of the Model 165. They are repeated here with a little more detail. For complete details of operation, see 2-1 through 2-9.

a. Power. Set the rear-panel line switches S302 and S303 to the proper line voltage settings. Check the fuse F301 for proper rating. Connect the line cord CO-7 to 50 or 60 Hz power. Set the power switch S301 to ON.

b. Connections. Connect to the front-panel HI (red) J401 and LO (black) J402 binding post input terminals. Connect the ground link between GND (green) J403 and LO (black) for grounded operation, disconnecting the link for floating operation. Maximum allowed voltage between GND and HI or LO is 1200V peak.

c. Function Selection. Set the outer dial to the desired function: DC VOLTS, AC VOLTS, DC AMPS, AC AMPS, or OHMS. The digital LED display automatically indicates decimal point, polarity, and engineering units. Lack of polarity on the display on VOLTS or AMPS functions indicates ac readings.

d. Range Selection.

1. Manual. Set the inner dial to the appropriate sensitivity as indicated on the display. End range positions are duplicated on all functions.

2. Automatic. Set the inner dial to the fully-clockwise position (AUTO). In this position, the 165 automatically upranges at 2000 digits and downranges at 179 digits.

e. lmA Current Source. If the front-panel lmA pushbutton is depressed, approximately +1mA is injected into the HI input terminal at up to approximately 4 volts compliance. Set the RANGE switch to DC VOLTS. For semiconductor tests, forward voltage at lmA is read directly. For continuity or resistance measurements, resistance is read in ohms using millivolt dc ranges in kilohms using volts dc ranges (limited to compliance voltage level). With an open-circuited input actual compliance and current can be measured on DC VOLTS and DC AMPS respectively.

NOTE

DO NOT DEPRESS THE lmA PUSHBUTTON WHEN EXTERNAL VOLTAGE IS APPLLIED TO THE INPUT TERMINALS.

f. Zero. The DC ZERO potentiometer R431 on the rear panel may be adjusted for a ±0 display with the input shorted on the 10 millivolt dc range or with an open input on the 1 microamp dc range.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The block diagram of the Model 165 is shown in Schematic 25395D. The signal applied to the input terminals first goes through an input switching network and then is applied to a dc or ac preamplifier. A unipolar amplifier converts the signal to a positive dc signal which is then applied to an a-d converter. The a-d control and display logic is contained in the LSI circuits and on the display printed circuit boards. The numerical information corresponding to the input signal is displayed on LED digits. The logic properly positions the decimal point and indicates engineering units. The input switching network is controlled from the logic in the AUTO range mode or from the front panel manual range switch.

3-2. AC-VOLTS PREAMPLIFIER. (see Schematic 25392E). The signal applied at the input terminals is coupled through capacitor C401 to an ac-compensated attenuator consisting of RN403 and C402 through C405. This is shunted by an input resistance consisting of R401 and R437, and switching is accomplished by means of FUNCTION switch S401A Deck No. 2. Table 3-1 shows the attenuation and gain factors as well as relay states for each ac-volts range.

TABLE 3-1.
AC Volts: Gains and Relay States

RANGE	RN403 ATTENUATION	K401	K402	K403	AMP. GAIN	Q406	Q407	Q408
10mV	1 : 1	ON	OFF	OFF	x100	OFF	OFF	ON
100mV	1 : 1	ON	OFF	OFF	x 10	OFF	ON	OFF
1 V	1 : 1	ON	OFF	OFF	x 1	ON	OFF	OFF
10 V	100 : 1	OFF	ON	OFF	x 10	OFF	ON	OFF
100 V	1000 : 1	OFF	OFF	ON	x 10	OFF	ON	OFF
500 V	1000 : 1	OFF	OFF	ON	x 1	ON	OFF	OFF

a. On the 1 Volt Range. On the 1 volt range, K401 is closed, K402 and K403 are open, and the signal is applied through resistors R405 and R406 to the input of a xl amplifier QA403. The input to this amplifier is limited to the power supply levels by D419 and D420. Overload voltages applied at the input are dissipated in R405 and R406. Switching is accomplished through S401A Deck No. 6. On the 1 volt range Q406 is on, Q407 and Q408 are off. The output is coupled to the unipolar amplifier through C422 and switching is accomplished through S401A Deck Nos. 7 and 8.

b. On the 100 Millivolt Range. On the 100 millivolt range, the output of QA403 is applied to a x10 amplifier QA404. Q407 as on, Q406 and Q408 are off, therefore the input signal is amplified by a factor of 10 before being applied to the unipolar amplifier again through C422.

c. On the 10 Millivolt Range. On the 10 millivolt range, a second x 10 amplifier QA405 further amplifies the signal and it is applied through Q408 to the unipolar amplifier.

d. On the 10 Volt Range. On the 10 volt range, K401 and K403 are off, K402 is on. Thus, RN403 attenuates the signal by a factor of 100. The sign is then applied to the amplifier chain QA403 and QA404, with Q407 on, selecting the x10 gain for this chain. Thus, the signal is attenuated by 100 and amplified by 10 for a net attenuation of a factor of 10 before going to the unipolar amplifier.

e. On the 100 Volt Range. On the 100 volt range K403 is on, K402 and K401 are off, and the input signal is attenuated by a factor of 1000 before being applied to the x10 amplifier chain. Q407 remains on and the net attenuation is a factor of 100.

f. On the 500 Volt Range. On the 500 volt range, K403 remains on, and Q406 is on selecting the xl gain for the amplifier chain. Thus, the net attenuation is a factor of 1000. C402 and C403 are adjusted to ac-compensate the attenuator RN403.

3-3. DC-VOLTS PREAMPLIFIER. (see Schematic 25392E) The input signal is applied to the attenuator RN403 again through switch S401A Deck No. 2. The output of the attenuator, as selected by K401 through K403, is applied through S401A Deck No. 4 and limiting resistors R420 and R421 to the input of a dc amplifier at S401A Deck No. 5, "DC INPUT".

a. DC Amplifier. The dc amplifier consists of a FET modulator Q401A and Q401B, protected by D410 through D413, an ac amplifier QA403 through QA405 whose gain is controlled as in Paragraphs 3-2, a demodulator Q409, and a final dc amplifier consisting of QA406. The output of this amplifier "DC PREAMP OUTPUT" is fed back to the input by resistance elements in RN403, selected by K404 and K405. These relays select gains of 1, 10, or 100. Table 3-2 shows the attenuation gain factors as well as relay states for each dc-volts range.

TABLE 3-2.
DC Volts: Gains and Relay States

RANGE	RN403 ATTENUATION	K401	K402	K403	AMP. GAIN	K404	K40
10mV	1 : 1	ON	OFF	OFF	x100	OFF	OFF
100mV	1 : 1	ON	OFF	OFF	x 10	ON	OFF
1 V	1 : 1	ON	OFF	OFF	x 1	OFF	ON
10 V	100 : 1	OFF	ON	OFF	x 10	ON	OFF
100 V	1000 : 1	OFF	OFF	ON	x 10	ON	OFF
1000 V	1000 : 1	OFF	OFF	ON	x 1	OFF	ON

b. Modulator and Demodulator. The modulator and demodulator are operated at a frequency of 220 Hz. This is developed at the "+44" output of the LSI chip and appears in the middle of Schematic 25392E near the bottom. S401A Deck No. 1 disables the signal on ac functions. On dc functions, two phases

are developed by QA601, Q402, and Q410. They are coupled to the modulator gates by C417 and C418, and to the demodulator by C409. D421 and D422 clamp the gate drives to a reference level equal to the feedback voltage, developed by QA409, a x1 amplifier whose input is connected to the feedback point.

c. Input Zeroing. Input zeroing is accomplished by R431 which determines the current through R428 and R429. The voltage generated by this current across R428 is added to the feedback voltage developed across the 10-kilohm element of RN403 between pins 6 and 7. Use a pure copper wire and a dual banana plug for a shorting plug.

d. Input Offset Current. Input offset current is compensated for by adjusting R424 which develops a voltage referenced to the feedback point at the output of QA409. This voltage generates a compensating current through R423 which is applied to the common node of the FET modulators, Q401A and Q401B.

e. Offset Voltages. Offset voltages within the dc amplifier loop are compensated for by R434 which applies a voltage to the positive input terminal of QA406, the final dc amplifier. The controlling time constant within the loop is determined by C413 and R427 in the negative feedback loop of QA406.

3-4. OHMS CIRCUITRY. (see Schematic 25392E). On all ohms ranges, K404 and Q407 are on, fixing the dc voltage preamplifier at 100 millivolts full range. D416 near QA406 limits the output of this amplifier such that no more than 1 volt appears at the input under open-circuit conditions. The ohms circuit in the lower left corner of Schematic 25392E generates a reference current at the input terminals. This reference current is generated by a voltage at "Ω OUT" (S401A Deck No. 3) divided by a reference resistance selected by K409 through K415.

a. Reference Voltage. The reference voltage is the summation of 0.1 times the "DC PREAMP OUTPUT", and a fixed 100-millivolt reference. QA402 performs this summation. R462 and R463 provide an output of 0.08 times "DC PREAMP OUTPUT" at their junction. This voltage is applied to the positive input terminal of QA402 which has a non-inverting gain of 1.25 determined by R407 and R461. Q405 is on in normal operation. The 100-millivolt reference is developed from an attenuator across the 9-volt reference diode D408 consisting of R458, R402, and R465. The voltage at R465 is about -1.6 volts. This is amplified by -0.25 using QA401, and by another -0.25 with QA402.

b. Overload Conditions. Under negative overloads, D418 blocks current flow to Q405 or QA402 output, and D415 limits the input voltage at the negative terminal of QA402 to the supply voltage. Under positive overloads, D414 limits the negative input of QA402 to the positive voltage. This drives the output of QA402 negative until it is limited by D426. At that level, the current flow in the emitter of Q405 is determined by voltage across D426, the base-emitter drop in Q405, R454, and R408. These elements limit the collector current in Q405 to about 1.2 milliamps. This current is essentially independent of the voltage appearing at the collector of Q405, which is determined by the positive voltage at the HI terminal and the voltage drop of the 1.2 milliamps in the reference resistance. The reference resistance consists of R409, and R414 through R419. The specific value of the resistance is determined by the state of relays K409 through K415. The total resistance is equal to the full-range resistance. Note that this circuit applies a negative reference current through the unknown resistance.

3-5. 1mA CURRENT SOURCE. (see Schematic 25392E). The 1mA current is developed by Q404, R411 through R413 and D405. It is applied to the HI terminal by means of the front panel switch S402. R410 and D406 protect Q404 if S402 is accidentally depressed while the voltage is applied to the HI terminal.

3-6. DC-AMPS PREAMPLIFIER. (see Schematic 25392E). The input current passes through S401A Deck No. 2 to a reference resistance selected by K406 through K411. The voltage across this reference resistance is sensed by the dc amplifier in a 4-terminal method between terminal 1 of RN401 (at circuit LO) and junction of K411 and R415, which is applied to the input of the amplifier through S401A Deck No. 4, R420, and R421. On the 1-microamp through 100-milliamp ranges, the dc preamplifier is set to a gain of 100, corresponding to a full-range voltage of 10 millivolts. On these ranges, K406 through K411 select the reference resistance which covers a span from 0.1 ohm (in RN401) through 9 kilohms (R415). On the 1000-milliamp range, K406 selects the 0.1 ohm resistance in RN401, and the gain of the dc preamplifier is changed to 10, corresponding to 100 millivolts full range, as indicated in Paragraphs 3-3. D401 through D404 protects the relays and the sensing resistances from overcurrent.

3-7. AC-AMPS PREAMPLIFIER. (see Schematic 25392E). As in the case of dc amps, the ac input current is passed through S401A Deck No. 2 to a sensing resistance selected by relays. In this case, only relays K406 through K409 are used. The output voltage is sensed at S401A Deck No. 3 and coupled through C401, S401A Deck No. 2, and R455 to the AC Preamplifier chain. The ac preamplifier is set to a gain of 100 corresponding to 10 millivolts full range on the 100 microamp through 100 milliamp ranges, a gain of 10 corresponding to 100 millivolts full range on the 1000 milliamp ac amps range, selected as in Paragraphs 3-2. As in the case of dc amps, D401 through D404 protect the relays and sensing resistance from overcurrent. Note that since the capacitor-coupling through C401 occurs in the circuit following the sensing resistances, dc or ac overcurrents >3 A may have damaging effects on either DC AMPS or AC AMPS functions.

3-8. UNIPOLAR AMPLIFIER. (see Schematic 25393D). This circuit, consisting of QA202 and QA203, is shown in the left-half of Schematic 25393D. The preamplifier output is applied to J201, an analog output at the rear panel, and to R213. R213 and R404 (on Schematic 25392E, near S401A Deck No. 8) attenuate dc signals to the 0.91-volt level corresponding to 1 volt full range. Note that the positive terminals of QA202 and QA203 are essentially at LO, thus the feedback loops around each op-amp tend to constrain the negative inputs also to the LO level. Since terminals 3 and 16 of RN201 are connected to these negative inputs, we may consider the 10-kilohm elements connected to terminal 2 as a single 5-kilohm element to LO. The 5 kilohm element from terminal

1 to 2 of RN201 and this 5 kilohm equivalent element form a divider such that the voltage at terminal 2 of RN201 is half the voltage at terminal 1. For positive signals, the output of QA202 will go negative. D201 will be on, Q201 will be off. So if we define

V_{202} ≡ the output of QA202,
V_2 ≡ the voltage at terminal 2 of RN201,
V_{203} ≡ the output of QA203,
V_1 ≡ the voltage at terminal 1 of RN201 and also the preamplifier output;

then by superposition we may then write the following:

$$V_{203} = -2\ (V_{202}) - 2V_2$$
where $V_{202} = -2V_2$, therefore
$$V_{203} = +4V_2 - 2V_2 = +2V_2 = V_1$$

For negative signals, the output of QA202 will go positive. D201 will be off, Q201 will be on. In this case, the voltage at the output of QA203 is -2 times the voltage at terminal 2 of RN201. Thus,

$$V_{203} = -2V_2 = -V_1$$

From this, the unipolar output at J202 provides a positive signal equal in magnitude to the value of the preamplifier output J201, regardless of sign. For ac signals, QA202 acts as a full-wave rectifier, and QA203 as a filter using C203. The average value of the ac waveform appears at J202 as a positive dc signal. Note that Q201 is off for positive signals, on for negative signals. Thus the "polarity" line is HI for negative signals, LO for positive signals. This information is passed through two transistors of QA201 and R207, and presented to the logic on the F1 line on the right side of Schematic 25393D.

3-9. A-D CONVERTER. (see Schematic 25393D). The unipolar output J202 creates a non-negative current in the 1-kilohm resistors between terminals 1 and 8 of RN202. This current is always applied to the negative input terminal of integrator QA204. If the diode between terminals 1 and 3 of QA201 is off, this signal current is the only current applied to the integrator. If this diode is on, there is also a reference current at the input node of the integrator. This reference current is determined from the -9 volt reference, the emitter-follower between terminals 6 and 7 of QA201, the 9-kilohm resistance between terminals 5 and 3 of RN202, and the setting of R205. The state of the diode between terminals 1 to 3 of QA201 is determined by the state of the CS-line coming from the LSI logic. If CS is high, terminal 3 of QA201 will be high, and the diode from terminals 1 to 3 will be off. Figure 7 shows the pertinent logic internal to the LSI chip along with the circuitry shown on Schematic 25393D for the a-d converter. Note that CS will change state on the next clock pulse after TH has changed state. The state of TH is determined by a zero-crossing detector QA205 which follows the integrator QA204. For small inputs, the signal current makes the integrator slowly ramp negative, until the integrator output crosses zero (see Figure 8). During this time, the reference current is off (CS is HI) and TH is HI. When the integrator output crosses zero, TH goes LO, and on the next clock pluse CS will also go LO. This will turn on the negative reference current which will cause the integrator to ramp positive at a much faster rate (see Figure 9).

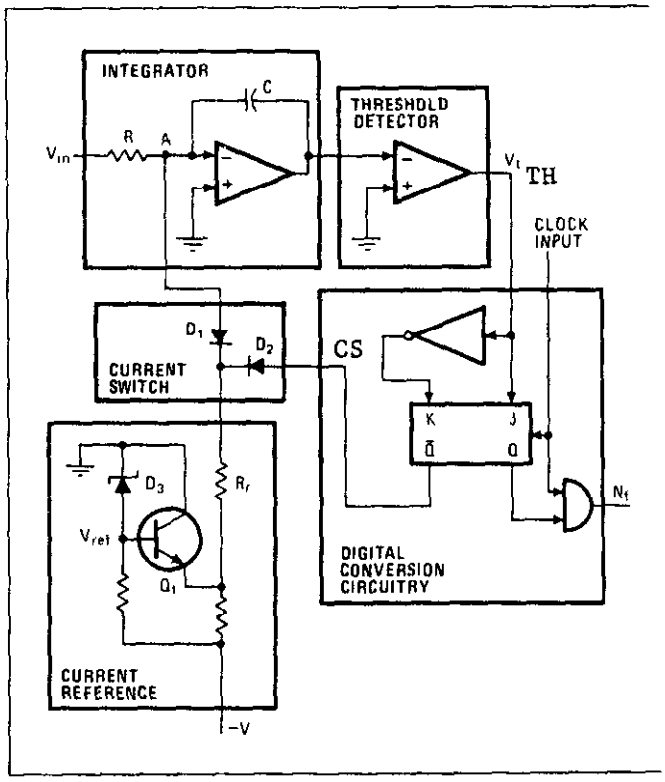
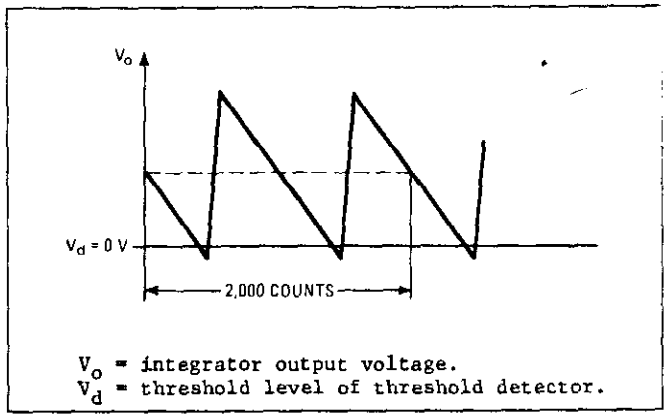


FIGURE 7. A-D Converter Logic Inside the LSI Chip.



V_o = integrator output voltage.
V_d = threshold level of threshold detector.

FIGURE 8. Integrator Characteristics for Small Input Signals.

If the input signal is very small, TH will go HI immediately after the reference current is turned on, and at the next clock pluse, the reference current will be turned off. For large signals approaching end scale (2000 counts), when the reference current is off, the signal current will cause the integrator to ramp at a faster rate in the negative direction (see Figure 10). When the reference current turns on after zero crossing and a clock pluse, the difference between the positive signal current and negative reference current will be very small since the

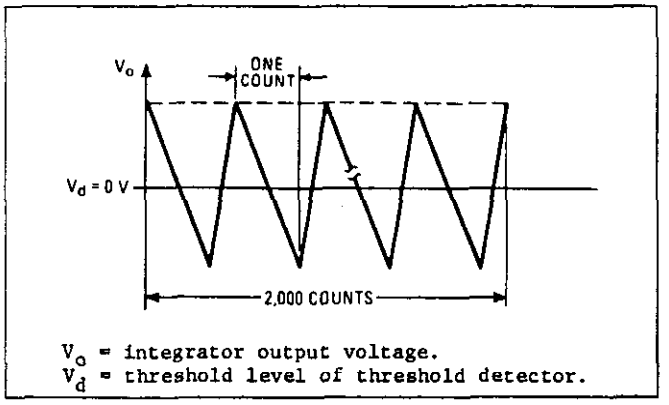


FIGURE 9. Integrator Characteristics for Full-Range Input Signals.

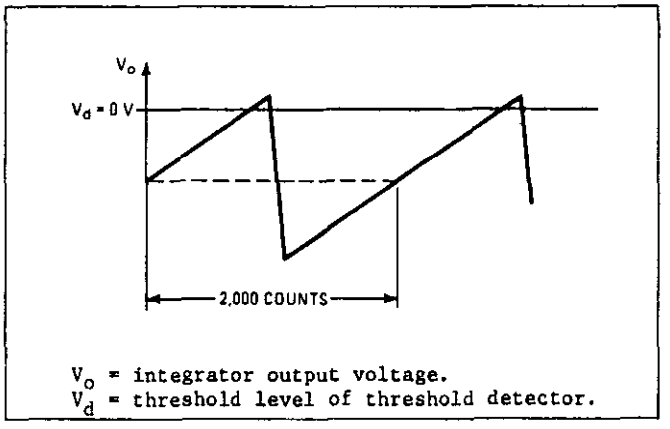


FIGURE 10. Integrator Characteristics for End-Scale (2000 counts) Input Signals.

reference current is set to be just greater than 2000 counts. Thus, the integrator will slowly ramp in the positive direction. In this case, the reference current is on most of the time; TH and CS are LO most of the time. Near full range, the reference current is on for 1 clock pluse and off for 1 clock pluse.

3-10. CLOCK. (see Schematic 25508D). The clock consists of QA503, QA602, R502 through R505, and C503, at the left edge of Schematic 25508D. This generates a low-duty-cycle 9,680 Hz clock for the LSI logic QA501.

3-11. LOGIC. (see Schematic 25508D). QA501 contains all logic for the a-d converter and autoranging circuitry. Range lines R1, R2, and R4 are controlled either by the autoranging circuitry on QA501 or by the range switch S401B Deck No. 10. On manual ranges, the MR line is connected to LO which inhibits the outputs to R1, R2, and R4 in the LSI chip. The function is selected by S401A Deck No. 1. Table 3-3 indicates the complete truth table for all functions and ranges of the Model 165. QA502 decodes this logic into control lines for various relays and analog switches shown on Schematic 25511D. Also see Schematic 25392E.

3-12. DISPLAY. (see Schematic 25394E). QA501 generates four multiplexing lines, T-0 to T-3, and each is high for an 800 microsecond time interval. During T-0 time, the function is indicated by DS101 through DS107, and the polarity and most significant 1 are displayed by LED DN103. During T-1, T-2, and T-3, DN104, DN105, and DN106 respectively display the numerical digits with decimal points.

3-13. POWER SUPPLY. (see Schematic 25391C). S302 and S303 select the appropriate primary combinations for the line voltages indicated. The output of D301 and C301 is a + 10 volt unregulated supply used for the display and for the +6 volt supply QA410 (see Schematic 25392E). QA301 generates a regulated +5 volt supply. This powers TTL, LSI, and some analog circuitry. QA302 regulates the output of D301 and D302 to -12 volts. J301 provides a means of disconnecting the power supplies so that they may be tested independently from the logic and analog circuitry.

TABLE 3-3.
Function/Range/Relay Decoder Truth Table

	Function Lines				Range Lines			Control Lines/Controlled Devices														
Function	F_4	F_2	F_1	Range	R_4	R_2	R_1	SW1/ K401	SW2/ K402	SW3/ K403	FGG/ Q408	SW4/ K404	SW5/ K405	SW6/ K406	SW7/ K407	SW8/ K408	SW9/ K409	SW10/ K410	SW11/ K411	SW13/ K413	SW14/ K414	SW15/ K415
+DCV	0	0	0	10mV	0	0	0	1	0	0	1	0	0	--	--	--	--	--	--	--	--	--
-DCV	0	0	1	10mV	0	0	1	1	0	0	1	0	0	--	--	--	--	--	--	--	--	--
ACV	0	1	0	10mV	0	1	0	1	0	0	1	0	0	--	--	--	--	--	--	--	--	--
				100mV	0	1	1	1	0	0	0	1	0	--	--	--	--	--	--	--	--	--
				1 V	1	0	0	1	0	0	0	0	1	--	--	--	--	--	--	--	--	--
				10 V	1	0	1	0	1	0	0	1	0	--	--	--	--	--	--	--	--	--
				100 V	1	1	0	0	0	1	0	1	0	--	--	--	--	--	--	--	--	--
				1KV	1	1	1	0	0	1	0	0	1	--	--	--	--	--	--	--	--	--
ACA	0	1	1	100µA	0	0	0	--	0	0	1	0	0	0	0	0	1	0	0	0	0	0
				100µA	0	0	1	--	0	0	1	0	0	0	0	0	1	0	0	0	0	0
				100µA	0	1	0	--	0	0	1	0	0	0	0	0	1	0	0	0	0	0
				100µA	0	1	1	--	0	0	1	0	0	0	0	0	1	0	0	0	0	0
				1mA	1	0	0	--	0	0	1	0	0	0	0	1	0	0	0	0	0	0
				10mA	1	0	1	--	0	0	1	0	0	0	1	0	0	0	0	0	0	0
				100mA	1	1	0	--	0	0	1	0	0	1	0	0	0	0	0	0	0	0
				1 A	1	1	1	--	0	0	0	1	0	1	0	0	0	0	0	0	0	0
+DCA	1	0	0	1µA	0	0	0	--	0	0	1	0	0	0	0	0	0	0	1	0	0	0
-DCA	1	0	1	1µA	0	0	1	--	0	0	1	0	0	0	0	0	0	0	1	0	0	0
				10µA	0	1	0	--	0	0	1	0	0	0	0	0	0	1	0	0	0	0
				100µA	0	1	1	--	0	0	1	0	0	0	0	0	1	0	0	0	0	0
				1mA	1	0	0	--	0	0	1	0	0	0	0	1	0	0	0	0	0	0
				10mA	1	0	1	--	0	0	1	0	0	0	1	0	0	0	0	0	0	0
				100mA	1	1	0	--	0	0	1	0	0	1	0	0	0	0	0	0	0	0
				1 A	1	1	1	--	0	0	0	1	0	1	0	0	0	0	0	0	0	0
OHMS	1	1	0	100 Ω	0	0	0	--	0	0	0	1	0	0	0	0	1	0	0	0	0	0
				1KΩ	0	0	1	--	0	0	0	1	0	0	0	0	0	1	0	0	0	0
				10KΩ	0	1	0	--	0	0	0	1	0	0	0	0	0	0	1	0	0	0
				100KΩ	0	1	1	--	0	0	0	1	0	0	0	0	0	0	0	1	0	0
				1MΩ	1	0	0	--	0	0	0	1	0	0	0	0	0	0	0	0	1	0
				10MΩ	1	0	1	--	0	0	0	1	0	0	0	0	0	0	0	0	0	1
				100MΩ	1	1	0	--	0	0	0	1	0	0	0	0	0	0	0	0	0	0
				100MΩ	1	1	1	--	0	0	0	1	0	0	0	0	0	0	0	0	0	0

SECTION 4. ACCESSORIES

4-1. GENERAL. The following Keithley accessories can be used with the Model 165 to provide additional convenience and versatility.

4-2. OPERATING INSTRUCTIONS. (includes assembly) A separate Instruction Sheet(s) is supplied with each accessory giving complete operating information.

4-3. MODEL 1651 50-AMPERE SHUNT. The Model 1651 pictured in Figure 11 is an optional accessory that expands the ac and dc current measuring capability of the 165 from 2 amps to 50 amps. The 1651 is a 4-terminal 0.001 ohm ±1% shunt that is connected externally to the 165 input terminals. The 165 is operated in the ac or dc volts mode manually on the 10 millivolt and 100 millivolt ranges or in the AUTO mode for the convenience of automatic ranging. The voltage drop across the 165 input, using the 1651 shunt is very low —— only 10 millivolts at 10 amps. The Model 1651 is approximately 6 inches long, 1-1/4 inches deep, and 1-3/8 inches high, and may be mounted to a hard surface using the 15/64-inch diameter mounting hole on either end of the shunt. A cable is provided to connect the input terminals of the Model 165 to the inner voltage-sensing terminals of the shunt. This cable is approximately 58 inches long. The outer current-sensing terminals of the shunt should be used to connect to the current source.

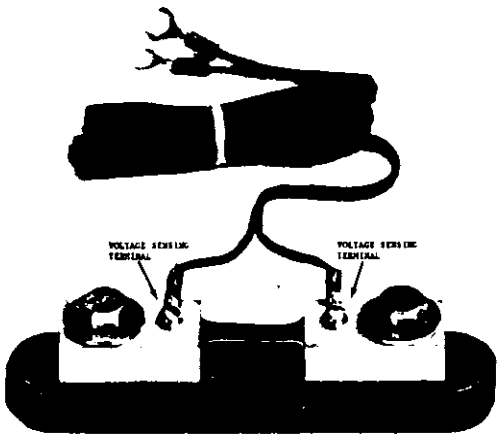


FIGURE 11. Model 1651 50-Ampere Shunt.

4-4. MODEL 1653 RACK MOUNTING KIT. The Model 1653 pictured in Figure 12 is a single rack mounting kit which converts the Model 165 from bench mounting to standard 3-1/2 inch x 19 inch rack mounting, with 15 inches (300 mm) depth behind the front panel.

a. Parts List. See Table 4-1.

TABLE 4-1.
Model 1653 Parts List

Item No.	Description	Quantity Required	Keithley Part No.
1	Rack Mounting Panel	2	25328B
2	Bottom Cover Bracket	1	25543B
3	Side Bracket	2	25330B
4	#6-32 x 1/4 LG PHIL PAN HD SCREW	2	--
5	#10-32 x 3/8 LG PHIL HD SCREW	4	--

b. Installation. Rack Mounting Panels and Side Brackets used in the 1653 are interchangeable. Using the four #10-32 screws provided, mount one Rack Mounting Panel to each Side Bracket as shown in Figure 12. Using the two #6-32 screws provided, mount the Bottom Cover Bracket between the two Side Brackets. Place the Model 165 inside the assembled rack kit, spreading the Side Brackets to fit around the instrument. The curved and cushioned back end of each Side Bracket fits around and into the rear-panel edges of the 165. The inside edges of the Rack Mounting Panels fit around the front-panel edges of the 165. Now mount the entire assembly of the 1653 and 165 in a 19-inch width rack.

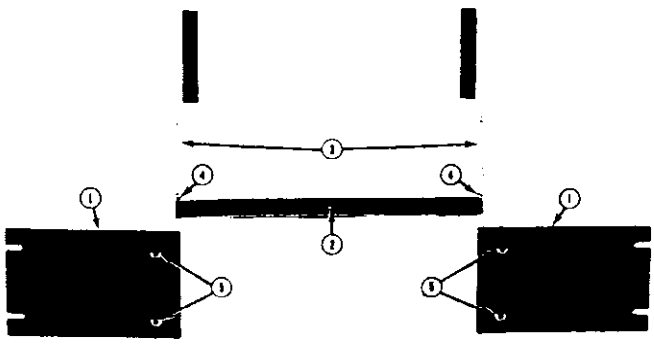


FIGURE 12. Model 1653 Single Rack Mounting Kit.

SECTION 5. MAINTENANCE

5-1. GENERAL. This section contains information necessary to maintain the instrument. Included are procedures for performance verification, calibration, and troubleshooting.

5-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for verifying performance and calibrating the Model 165 is given in Tables 5-1 and 5-8 respectively. Test equipment other than that recommended may be substituted if the specifications in the equipment tables are equalled or exceeded. These specifications are the minimum requirements.

5-3. PERFORMANCE VERIFICATION. The purpose of this procedure is to verify that the instrument is within specifications at the time and environmental conditions under which the procedure is executed. If verification is performed at a temperature other than the calibration temperature of 20 to 30°C, the specified temperature coefficient (correction factor) multiplied by the temperature difference must be added to the reading tolerance as indicated in Tables 5-2 through 5-7. Relative humidity should be less than 60%. If it is desired to insure that the Model 165 will stay within specifications for a period of six months, it is recommended that the calibration procedure of Paragraphs 5-4 be used.

a. Reading Tolerance and Interpolation. (see Tables 5-2 through 5-7). A specified reading tolerance with an integer number of digits allows a display reading with a steady indication or an occasional + and - one digit. For example, a ±2 digit tolerance on a display reading of 1.000 allows a steady reading of 1.002 (or 0.998) or a 1.002 with an occasional display of 1.001 and 1.003 (or 0.998 with an occasional display of 0.997 and 0.999). A specified reading tolerance with half digits allows a display reading with flashing between two adjacent digits. For example, a ±2.5 digit tolerance on a display reading of 1.000 allows a display that is flashing between 1.002 and 1.003 (or 0.997 and 0.998).

b. Preliminary Setup.

1. Set the rear panel line switches for the proper power line (mains) voltage that is available. Connect the power cord (CO-7) to the line.

2. Check the fuse on the rear panel for proper rating:

90-110,105-125 VAC: 1/4A, SLO-BLO, 3AG, Keithley FU-38
195-235,210-250 VAC: 1/8A, SLO-BLO, 3AG, Keithley FU-20

3. Connect the shorting link on the front panel between the LO and GND terminals. For maximum operator safety, make certain that the front and rear panels and internal chassis shield are connected to earth ground by way of the third-conductor on the power cord or by way of a separate clip lead from the GND terminal to earth ground.

4. Set the front-panel power switch to ON and allow the Model 165 to stabilize at ambient temperature for at least two hours.

c. Zero Verification. Table 5-2 shows the allowed tolerance of zero on all ranges. Manually select function and range on the 165 as indicated in the table.

d. DC Volts Verification. (see Table 5-3). The DC Voltage Source (A) is used directly for the 1 volt to 1000 volt ranges. For the 100mV and 10mV ranges, 1 volt from the DC Voltage Source (A) is divided by a ratio of 10:1 and 100:1 respectively using the Voltage Divider (B). For convenience, it is recommended that the tests of Table 5-3 be done in the autoranging mode. They may also be done in the manual range mode. Verification should be made for both positive and negative inputs. Table 5-3 indicates the allowed reading tolerance, equivalent settings, and temperature coefficient.

e. AC Volts Verification. (see Table 5-4). In this procedure, the AC Voltage Source (C) is used for the 10 millivolt through 500 volts ranges of the 165. Required source accuracy is given in Table 5-4. 20Hz verification is indicated only for the 1 volt range. This may be done on other ranges if desired, but it is not necessary in that the same circuit components are used on all ranges. Use the autoranging mode for convenience or use the manual range mode.

f. DC Amps Verification. (see Table 5-5). The DC Current Source (D) is used for the 100 microamp through 100 milliamp ranges. The 1000 milliamp range may be verified at the 100 milliamp level, since both the 100 and 1000 milliamp ranges use the same sensing resistance. For the 1 and 10 microamp ranges, DC Voltage Source (A) and DC Current Resistors (E) are used to develop the appropriate test currents. Settings for the DC Voltage Source (A) and the resistance box called DC Current Resistors (E) are given in Table 5-5. Both positive and negative currents should be verified. Autoranging is suggested for convenience, except on the 1000 milliamp range where it is necessary to use the manual range mode. The manual mode may be used on all range tests if desired.

g. AC Amps Verification. (see Table 5-6). It is not necessary to verify all ac amps ranges at all frequencies, since the same sensing resistors are also used on dc amps, and the frequency response has been already verified in Paragraph 5-3e. It is suggested that AC Current Resistors (F) be 0.1%-tolerance metal film resistors, used with AC Voltage Source (C) to develop the required ac currents. The resistors should be located right at the front-panel input terminals to the Model 165 so that cable capacity does not contribute to ac current errors. Ideally, the 10-kilohm and 100-kilohm resistance values should also be shielded. Depending upon the environment in which the test is made, this may not be necessary.

The combination of current ranges and frequencies given in Table 5-6 is suggested in order to verify at least one point on every range, and to minimize extraneous errors in the source current due to the effects mentioned above. Autoranging is suggested on all except the 1000 milliamp and 100 milliamp ranges, where the manual range mode must be used. The manual mode may be used on all range tests if desired.

h. Ohms Verification. (see Table 5-7). The Resistance Source (G) is used for all ohms ranges of the 165 through the 10-megohm range. A discrete 100-megohm resistor, Resistance Source (H) is used for the 100-megohm range. On this range, the sensitivity of the 165 is 1 pA per digit. Ideally, the 100-megohm resistor should be shielded to avoid electrostatic pickup. However, it is possible to verify this range without grounded metal shielding around the resistor, if care is used not to move anything around in the vicinity of the 100-megohm resistance, creating small electrostatic currents. Again, autoranging is suggested for convenience, although manual ranging may be used throughout.

i. 1mA Verification. The 1mA current source feature of the Model 165 may be verified using the following procedure:

1. open-circuit the input terminals on the front panel;

2. set the function switch to DC AMPS;

3. set the range switch to AUTO;

4. depress the 1mA pushbutton; the display reading should be between +0.9 and +1.1 milliamp;

5. set the function switch to DC VOLTS;

6. depress the 1mA pushbutton; the display reading should be between +3.80 and +5.00 volts.

j. Voltage Burden Verification as an Ammeter. The voltage burden for both ac and dc amps may be verified by using the following procedure on DC AMPS function:

1. connect the DC Current Source (D) to the input terminals of the 165;

2. set the function switch to DC AMPS;

3. set the range switch to AUTO;

4. connect the DC Digital Voltmeter (I) to the Model 165 input terminals in parallel with DC Current Source (D);

5. Apply ±100 milliamp dc from the DC Current Source (D). The DC Digital Voltmeter (I) should read less than 30 millivolts.

TABLE 5-1.
Performance Verification Test Equipment

Item	Description	Specification	Mfr.	Model
A	Voltage Source, DC	±0.005%	Fluke	3330B
B	Voltage Divider	±0.005%	ESI	SR1010
C	Voltage Source, AC (AC Calibrator/Amplifier)	see Table 5-4	Hewlett-Packard	745A/746A
D	Current Source, DC	±0.05%	Fluke	3330B
E	Current Resistors, DC	±0.01%	General Radio	1433Y
F	Current Resistors, AC	1kΩ, ± 0.1%, 1/4W 10kΩ, ± 0.1%, 1/8W 100kΩ, ± 0.1%, 1/8W	---	metal film
G	Resistance Source	±0.01%	General Radio	1433Y
H	Resistance Source	100MΩ, ± 1%, 2W	---	---
I	Digital Voltmeter, DC	100mV f.s. at ±(0.1% rdg + 0.1% rng)	Keithley	160, 163, or 165

TABLE 5-2.
Zero Verification

Input State	Function	165 Range	Display Reading	Reading Tolerance	Temperature Coefficient
shorted	DC Volts	10 mV	0.00	±2 digits	±0.25 digit/°C
		100 mV	00.0	±1	±0.1
		1 V	.000	±1	±0.1
		10 V	0.00	±1	±0.1
		100 V	00.0	±1	±0.1
		1 kV	000	±1	±0.1
shorted	AC Volts	10 mV	0.00	4 digits	±0.1 digit/°C
		100 mV	00.0	2.5	±0.1
		1 V	.000	2	±0.1
		10 V	0.00	2	±0.1
		100 V	00.0	2	±0.1
		500 V	000	2	±0.1
open	DC Amps	1 µA	.000	±3 digits	±0.2 digit/°C
		10 µA	0.00	±3	±0.2
		100 µA	00.0	±3	±0.2
		1 mA	.000	±3	±0.2
		10 mA	0.00	±3	±0.2
		100 mA	00.0	±3	±0.2
		1 A	000	±3	±0.2
open	AC Amps	100 µA	00.0	4 digits	±0.2 digit/°C
		1 mA	.000	4	±0.2
		10 mA	0.00	4	±0.2
		100 mA	00.0	4	±0.2
		1 A	000	4	±0.2
shorted	Ohms	100 Ω	00.0	2.5 digits	±0.1 digit/°C
		1 kΩ	.000	1.5	±0.1
		10 kΩ	0.00	1.5	±0.1
		100 kΩ	00.0	1.5	±0.1
		1 MΩ	.000	1.5	±0.1
		10 MΩ	0.00	2	±0.1
		100 MΩ	00.0	2	±0.1

TABLE 5-3.
DC-Volts Verification

DC Voltage Source (A)	Voltage Divider (B)	165 Range	Display Reading	Reading Tolerance	Temperature Coefficient
1 V	100:1	10 mV	10.00	±3 digits	±0.35 digit/°C
1 V	10:1	100 mV	100.0	±2	±0.2
1 V	--	1 V	1.000	±2	±0.2
10 V	--	10 V	10.00	±2	±0.2
100 V	--	100 V	100.0	±2	±0.2
1000 V	--	1000 V	1000	±3	±0.2

TABLE 5-4.
AC-Volts Verification

AC Voltage Source (C) Output	Frequency	Accuracy	165 Range	Display Reading	Reading Tolerance	Temperature Coefficient
10 mV	1kHz	±0.142%	10 mV	10.00	±7.5 digits	±0.2 digit/°C
100 mV	1kHz	±0.052	100 mV	100.0	±6.5	±0.2
1 V	1kHz	±0.052	1 V	1.000	±6.5	±0.2
10 V	1kHz	±0.052	10 V	10.00	±6.5	±0.2
100 V	1kHz	±0.052	100 V	100.0	±6.5	±0.2
500 V	1kHz	±0.032	500 V	500	±4	±0.15
10 mV	20kHz	±0.052%	10 mV	10.00	+7.5 digits -18.5	±0.2 digit/°C
100 mV	20kHz	±0.052	100 mV	100.0	+6.5 -19.5	±0.2
1 V	20kHz	±0.052	1 V	1.000	+6.5 -19.5	±0.2
10 V	20kHz	±0.052	10 V	10.00	+6.5 -19.5	±0.2
100 V	20kHz	±0.052	100 V	100.0	+6.5 -19.5	±0.2
500 V	20kHz	±0.032	500 V	500	+4 -14.5	±0.15
1 V	20 Hz	±0.15%	1 V	1.000	+5.5 digits -18.5	±0.2 digit/°C

TABLE 5-5.
DC-Amps Verification

DCV Source (A) DCA Source (D)	DC Current Resistors (E)	165 Range	Display Reading	Reading Tolerance	Temperature Coefficient
±10.01 V	10 MΩ	1 µA	±1.000	±6 digits	±0.4 digit/°C
±10.01 V	1 MΩ	10 µA	±10.00	±6	±0.4
±100 µA	----	100 µA	±100.0	±6	±0.4
±1 mA	----	1 mA	±1.000	±6	±0.4
±10 mA	----	10 mA	±10.00	±6	±0.4
±100 mA	----	100 mA	±100.0	±6	±0.4
±100 mA	----	1 A	±100	±3.5	±0.22

TABLE 5-6.
AC-Amps Verification

AC Voltage Source (C) Output	Frequency	AC Current Resistors (F)	Range	Display Reading	Reading Tolerance	Temperature Coefficient
10.01V	20 Hz	100 kΩ	100 µA	100.0	+13 digits -29	±0.4 digit/°C
10.01	1kHz	10 kΩ	1 mA	1.000	±13	±0.4
10.01	20kHz	1 kΩ	10 mA	10.00	+13 -29	±0.4
10.01	1kHz	1 kΩ	100 mA	10.0	±4.5	±0.22
10.01	1kHz	1 kΩ	1 A	10	±4	±0.2

TABLE 5-7.
Ohms Verification

Source Resistances (G&H)	165 Range	Display Reading	Reading Tolerance	Temperature Coefficient
100 Ω	100 Ω	100.0	±5.5 digits	±0.4 digit/°C
1 kΩ	1 kΩ	1.000	±4.5	±0.4
10 kΩ	10 kΩ	10.00	±4.5	±0.4
100 kΩ	100 kΩ	100.0	±4.5	±0.4
1 MΩ	1 MΩ	1.000	±6.5	±0.44
10 MΩ	10 MΩ	10.00	±22	±0.8
100 MΩ	100 MΩ	100.0	±252	±4.4

5-4. CALIBRATION. Recommended test equipment for calibrating the Model 165 is given in Table 5-8. Test equipment other than that recommended may be substituted if the specifications in the equipment table are equalled or exceeded. These specifications are the minimum requirements. Calibrated using the following procedure, the Model 165 will stay within specifications for a period of 6 months for relative humidities up to 70% at 35°C (see specifications). In order to allow for aging and humidity effects, the reading tolerance given in Tables 5-9 through 5-14 are the same or less than the tolerances given in Section 5-3 Performance Verification. If in verifying an instrument per Section 5-3, it is found that all readings are within the reading tolerances given in Tables 5-9 through 5-14, it is unnecessary to calibrate the instrument. Calibration should be performed at some temperature from 20 to 30°C at a relative humidity of less than 60%.

a. Reading Tolerance and Interpolation. (see Tables 5-9 through 5-14). A specified reading tolerance with an integer number of digits allows a display reading with a steady indication or an occasional + and - one digit. For example, a ±2 digit tolerance on a display reading of 1.000 allows a steady reading of 1.002 (or 0.998) or a 1.002 with an occasional display of 1.001 and 1.003 (or 0.998 with an occasional display of 0.997 and 0.999). A specified reading tolerance with half digits allows a display reading with flashing between two adjacent digits. For example, a ±2.5 digit tolerance on a display reading of 1.000 allows a display that is flashing between 1.002 and 1.003 (or 0.997 and 0.998).

b. Preliminary Setup. Calibration should be performed at some temperature from 20 to 30°C at relative humidity of less than 60%.

1. Set the rear panel line switches for the proper power line (mains) voltage that is available. Connect the power cord (CO-7) to the line.

2. Check the fuse on the rear panel for proper rating:

90-110, 105-125 VAC: 1/4A, SLO-BLO, 3AG, Keithley FU-38
195-235, 210-250 VAC: 1/8A, SLO-BLO, 3AG, Keithley FU-20

3. Connect the shorting link on the front panel between the LO and GND terminals. For maximum operator safety, make certain that the front and rear panels and internal chassis shield are connected to earth ground by way of the third-conductor on the power cord or by way of a separate clip lead from the GND terminal to earth ground.

4. Set the front-panel power switch to ON and allow the Model 165 to stabilize at ambient temperature for at least two hours.

c. DC Volts and Ohms Calibration.

1. Preamplifier Zero.

a). With the input shorting link between the LO and GND terminals, connect Resistance Source (G) to the HI and LO input terminals of the 165. Adjust Resistance Source (G) for 10 kilohms and set the 165 to OHMS function in the AUTO range mode.

b). Record the 165 display reading from step a).

c). Change the setting of Resistance Source (G) to 10 megohms.

d). Adjust calibration potentiometer R424 (see rear panel) so that the 165 display reading is within one digit of the reading from step b).

e). Set the 165 to the DC VOLTS function and manually select the 1-volt range. Remove Resistance Source (G) and connect Shorting Plug (J) to the HI and LO input terminals.

f). Adjust calibration potentiometer R434 (see rear panel) so that the display reading is 0 and the polarity sign flashes between + and -.

g). Manually select the 10 millivolt range of the 165.

h). Adjust calibration potentiometer R431 (see rear panel) so that the display reading is 0 and the polarity sign flashes between + and -.

i). Repeat steps a). through h). until all display readings are within the required tolerances.

2. Unipolar Amplifier and A-D Calibration.

a). Connect the DC Voltage Source (A) to the input of the 165. Set the DC Voltage Source (A) output to -0.001 volt, with the 165 manually set to the 1 volt range. Adjust calibration potentiometer R211 (see rear panel) so that the 165 display reading is -0.001 volt without flashing digits or with flashing equally between -0.000 and -0.002.

b). Adjust the DC Voltage Source (A) to supply a -0.011 volt output. Record this 165 display reading. Reverse the output polarity of the DC Voltage Source (A) and adjust calibration potentiometer R204 (see rear panel) such that the positive and negative inputs provide the same display reading on the 165.

c). Adjust the DC Voltage Source (A) to -1.911 volts output. Adjust calibration potentiometer R205 (see rear panel) so that the 165 display reading is within 0.5 digit of the input.

d). Reverse the output polarity of the DC Voltage Source (A) and adjust calibration potentiometer R201 (see rear panel) so that the 165 display reading is within 0.5 digit of the input.

d. Zero Calibration Verification. Table 5-9 shows the allowed tolerance of zero on all ranges. Manually select function and range on the 165 as indicated in the table. If zero cannot be verified, repeat Paragraphs 5-4c1. If zero still cannot be verified,

consult Troubleshooting Section 5-5.

e. DC Volts Calibration Verification. (see Table 5-10). The DC Voltage Source (A) is used directly for the 1 volt to 1000 volt ranges. For the 100 mV and 10 mV ranges, 1 volt from the DC Voltage Source (A) is divided by a ratio of 10:1 and 100:1 respectively using the Voltage Divider (B). For convenience, it is recommended that the tests of Table 5-10 be done in the autoranging mode. They may also be done in the manual range mode. Verification should be made for both positive and negative inputs. Table 5-10 indicates the allowed reading tolerance, equivalent settings, and temperature coefficient. If dc volts cannot be verified, repeat Paragraphs 5-4c. If dc volts still cannot be verified, consult Troubleshooting Section 5-5.

f. DC Amps Calibration Verification. (see Table 5-11). The DC Current Source (D) is used for the 100 microamp through 100 milliamp ranges. The 1000 milliamp range may be verified at the 100 milliamp level, since both the 100 and 1000 milliamp ranges use the same sensing resistance. For the 1 and 10 microamp ranges, DC Voltage Source (A) and DC Current Resistors (E) are used to develop the appropriate test currents. Settings for the DC Voltage Source (A) and the resistance box called DC Current Resistors (E) are given in Table 5-11. Both positive and negative currents should be verified. Autoranging is suggested for convenience, except on the 1000 milliamp range where it is necessary to use the manual range mode. The manual mode may be used on all range tests if desired. If dc amps cannot be verified, consult Troubleshooting Section 5-5.

g. Ohms Calibration Verification. (see Table 5-12). The Resistance Source (G) is used for all ohms ranges of the 165 through the 10-megohm range. A discreet 100-megohm resistor, Resistance Source (H) is used for the 100-megohm range. On this range, the sensitivity of the 165 is 1 pA per digit. Ideally, the 100-megohm resistor should be shielded to avoid electrostatic pick-up. However, it is possible to verify this range without grounded metal shielding around the resistor, if care is used not to move anything around in the vicinity of the 100-megohm resistance, creating small electrostatic currents. Again, autoranging is suggested for convenience, although manual ranging may be used throughout. If ohms cannot be verified, repeat Paragraphs 5-4c. If ohms still cannot be verified, consult Troubleshooting Section 5-5.

h. AC Calibration.

1. Set the 165 to the AC VOLTS function, manually selecting the 1-volt range. Connect the AC Voltage Source (C) to the input terminals of the 165. Set the AC Voltage Source (C) to 1 volt output at 20kHz. Record the 165 display reading.

2. Set the AC Voltage Source (C) to 100 volts output at 20kHz. Adjust calibration variable-capacitor C402 (sse Figure 13 and the bottom cover of the 165) so that the 165 displays the same digits as recorded in step 1. Tolerance on this adjustment is ±0.5 digit.

3. Set the AC Voltage Source (C) to 10 volts output at 20kHz and adjust calibration variable-capacitor C403 (see Figure 13 and the bottom cover of the 165) so that the 165 displays the same digits as recorded in step 1. Tolerance on this adjustment is ±0.5 digit.

i. AC Volts Calibration Verification. (see Table 5-13. In this procedure, the AC Voltage Source (C) is used for the 10 millivolt through 500 volts ranges of the 165. Required source accuracy is given in Table 5-13. 20 Hz verification is indicated only for the 1 volt range. This may be done on other ranges if desired, but it is not necessary in that the same circuit components are used on all ranges. Use the autoranging mode for convenience or use the manual range mode. If ac volts cannot be verified, repeat Paragraphs 5-4h. If ac volts still cannot be verified, consult Troubleshooting Section 5-5.

j. AC Amps Calibration Verification. (see Table 5-14). It is not necessary to verify all ac amps ranges at all frequencies, since the same sensing resistors are also used on dc amps, and the frequency response has been already verified. It is suggested that AC Current Resistors (F) be 0.1% tolerance metal film resistors, used with AC Voltage Source (C) to develop the required ac currents. The resistors should be located right at the front-panel input terminals to the Model 165 so that cable capacity does not contribute to ac current errors. Ideally, the 10-kilohm and 100-kilohm resistance values should also be shielded. Depending upon the environment in which the test is made, this may not be necessary. The combination of current ranges and frequencies given in Table 5-14 is suggested in order to verify at least one point on every range, and to minimize extraneous errors in the source current due to the effects mentioned above. Autoranging is suggested on all except the 1000 milliamp and 100 milliamp ranges, where the manual range mode must be used. The manual mode may be used on all range tests if desired.

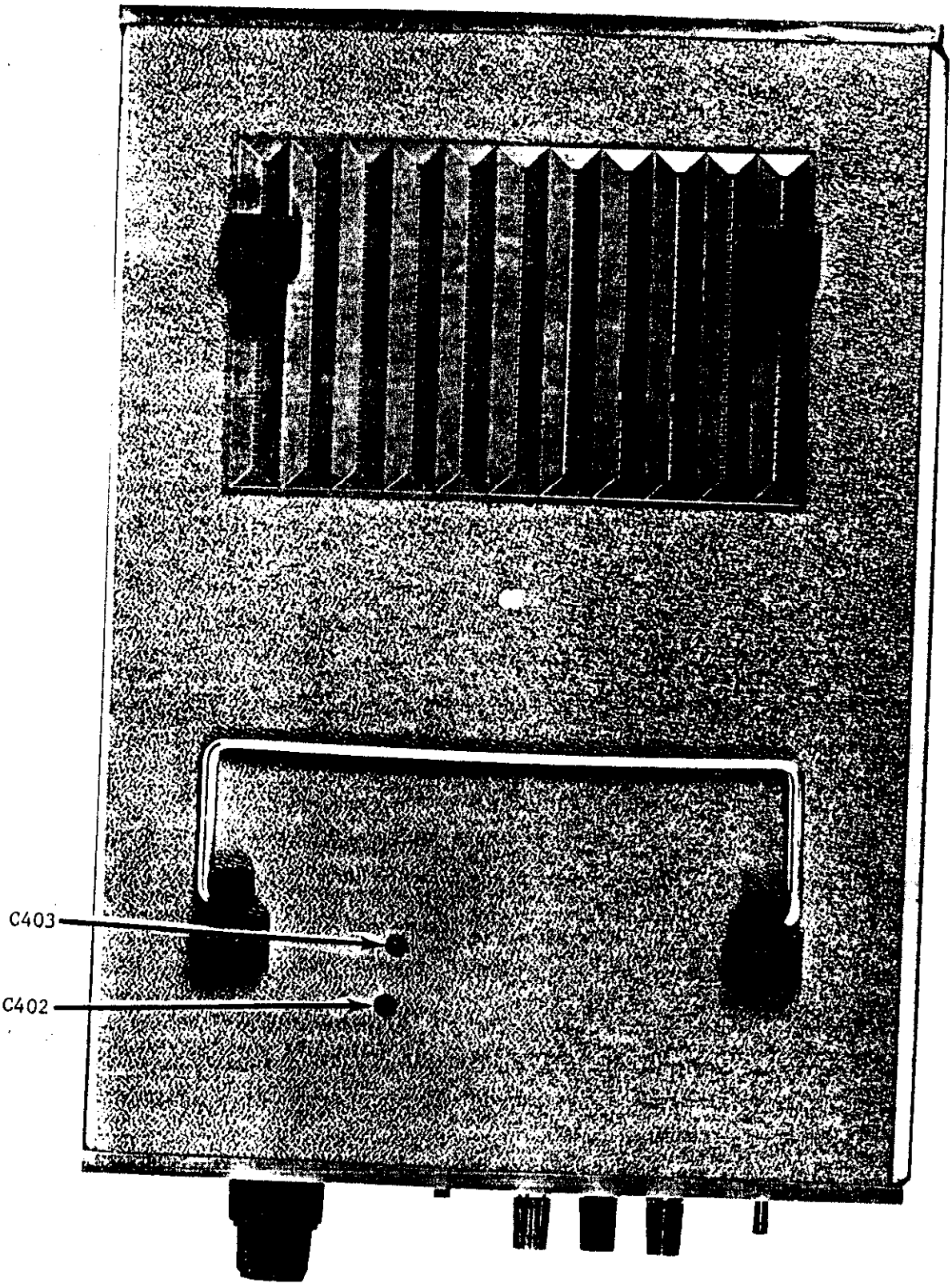


FIGURE 13. Calibration Adjustments through Bottom Cover.

TABLE 5-8.
Calibration Test Equipment

Item	Description	Specification	Mfr.	Model
A	Voltage Source, DC	±0.005%	Fluke	3330B
B	Voltage Divider	±0.005%	ESI	SR1010
C	Voltage Source, AC (AC Calibrator/Amplifier)	see Table 5-4	Hewlett-Packard	745A/746A
D	Current Source, DC	±0.05%	Fluke	3330B
E	Current Resistors, DC	±0.01%	General Radio	1433Y
F	Current Resistors, AC	1kΩ, ± 0.1%, 1/4W 10kΩ, ± 0.1%, 1/8W 100kΩ, ± 0.1%, 1/8W	---	metal film
G	Resistance Source	±0.01%	General Radio	1433Y
H	Resistance Source	100MΩ, ± 1%, 2W	---	---
I	Digital Voltmeter, DC	100mV f.s. at ±(0.1% rdg + 0.1% rng)	Keithley	160, 163, or 165
J	Shorting Plug	use pure copper solid wire and dual banana plug	Keithley	BG-7 (without copper short)

TABLE 5-9.
Zero Calibration Verification

Input State	Function	165 Range	Display Reading	Reading Tolerance* Min.	Max.
shorted	DC Volts	10 mV	0.00	-.00/1	+.00/1
		100 mV	00.0	-.0/1	+.0/1
		1 V	.000	-.000/1	+.000/1
		10 V	0.00	-.00/1	+.00/1
		100 V	00.0	-.0/1	+.0/1
		1 kV	000	-000/1	+000/1
shorted	AC Volts	10 mV	0.00	---	+.03/4
		100 mV	00.0	---	+.1/2
		1 V	.000	---	+.001/2
		10 V	0.00	---	+.01/2
		100 V	00.0	---	+.1/2
		500 V	000	---	+1/2
open	DC Amps	1 µA	.000	-.001/2	+.001/2
		10 µA	0.00	-.01/2	+.01/2
		100 µA	00.0	-.1/2	+.1/2
		1 mA	.000	-.001/2	+.001/2
		10 mA	0.00	-.01/2	+.01/2
		100 mA	00.0	-.1/2	+.1/2
		1 A	000	-1/2	+1/2
open	AC Amps	100 µA	00.0	---	+.3/4
		1 mA	.000	---	+.003/4
		10 mA	0.00	---	+.03/4
		100 mA	00.0	---	+.3/4
		1 A	000	---	+3/4
shorted	Ohms	100 Ω	00.0	---	+.1/2
		1 kΩ	.000	---	+.001
		10 kΩ	0.00	---	+.01
		100 kΩ	00.0	---	+.1
		1 MΩ	.000	---	+.001
		10 MΩ	0.00	---	+.01/2
		100 MΩ	00.0	---	+.1/2

TABLE 5-10.
DC-Volts Calibration Verification

DC Voltage Source (A)	Voltage Divider (B)	165 Range	Display Reading	Reading Tolerance* Min.	Max.
1 V	100:1	10 mV	10.00	-9.99	+10.01
1 V	10:1	100 mV	100.0	-99.8/9	+100.1/2
1 V	--	1 V	1.000	-.999	+1.001
10 V	--	10 V	10.00	-9.98/9	+10.01/2
100 V	--	100 V	100.0	-99.8/9	+100.1/2
1000 V	--	1000 V	1000	-998	+1002

*Reading tolerance can be minimum or maximum allowed, not both simultaneously. For example, a reading tolerance of -0.00/1 Min. to +0.00/1 Max. indicates that the reading tolerance allowed is -0.00 occasionally flashing -0.01 or +0.00 occasionally flashing +0.01.

TABLE 5-11.
DC-Amps Calibration Verification

DCV Source (A) DCA Source (D)	DC Current Resistors (E)	165 Range	Display Reading	Reading Tolerance* Min.	Max.
±10.01 V	10 MΩ	1 µA	±1.000	-.996	+1.004
±10.01 V	1 MΩ	10 µA	±10.00	-9.96	+10.04
±100 µA	----	100 µA	±100.0	-99.6	+100.4
±1 mA	----	1 mA	±1.000	-.996	+1.004
±10 mA	----	10 mA	±10.00	-9.96	+10.04
±100 mA	----	100 mA	±100.0	-99.6	+100.4
±100 mA	----	1 A	±100	-98/9	+101/2

TABLE 5-12.
Ohms Calibration Verification

Source Resistances (G&H)	165 Range	Display Reading	Reading Tolerance* Min.	Max.
100 Ω	100 Ω	100.0	99.6/7	100.3/4
1 kΩ	1 kΩ	1.000	.997	1.003
10 kΩ	10 kΩ	10.00	9.97	10.03
100 kΩ	100 kΩ	100.0	99.7	100.3
1 MΩ	1 MΩ	1.000	.997	1.003
10 MΩ	10 MΩ	10.00	9.92/3	10.07/8
100 MΩ	100 MΩ	100.0	83.0/1	116.9/117.0

TABLE 5-13.
AC-Volts Calibration Verification

AC Voltage Source (C) Output	Frequency	Accuracy	165 Range	Display Reading	Reading Tolerance* Min.	Max.
10 mV	1kHz	±0.142%	10 mV	10.00	9.94	10.06
100 mV	1kHz	±0.052	100 mV	100.0	99.4/5	100.5/6
1 V	1kHz	±0.052	1 V	1.000	.994/5	1.005/6
10 V	1kHz	±0.052	10 V	10.00	9.94/5	10.05/6
100 V	1kHz	±0.052	100 V	100.0	99.4/5	100.5/6
500 V	1kHz	±0.032	500 V	500	496/7	503/4
10 mV	20kHz	±0.052%	10 mV	10.00	9.82	10.07
100 mV	20kHz	±0.052	100 mV	100.0	98.1	100.5/6
1 V	20kHz	±0.052	1 V	1.000	.981	1.005/6
10 V	20kHz	±0.052	10 V	10.00	9.81	10.05/6
100 V	20kHz	±0.052	100 V	100.0	98.1	100.5/6
500 V	20kHz	±0.032	500 V	500	486	503/4
1 V	20 Hz	±0.15%	1 V	1.000	.982	1.005

*Reading tolerance can be minimum or maximum allowed, not both simultaneously. For example, a reading tolerance of -0.00/1 Min. to +0.00/1 Max. indicates that the reading tolerance allowed is -0.00 occasionally flashing -0.01 or +0.00 occasionally flashing +0.01.

TABLE 5-14.
AC-Amps Calibration Verification

AC Voltage Source (C) Output	Frequency	AC Current Resistors (F)	Range	Display Reading	Reading Tolerance* Min.	Max.
10.01V	20 Hz	100 kΩ	100 µA	100.0	97.7/8	100.7
10.01	1kHz	10 kΩ	1 mA	1.000	.986/7	1.013/4
10.01	20kHz	1 kΩ	10 mA	10.00	9.76/7	10.07/8
10.01	1kHz	1 kΩ	100 mA	10.0	9.6	10.4
10.01	1kHz	1 kΩ	1 A	10	6	14

*Reading tolerance can be minimum or maximum allowed, not both simultaneously. For example, a reading tolerance of -0.00/1 Min. to +0.00/1 Max, indicates that the reading tolerance allowed is -0.00 occasionally flashing -0.01 or +0.00 occasionally flashing ±0.01.

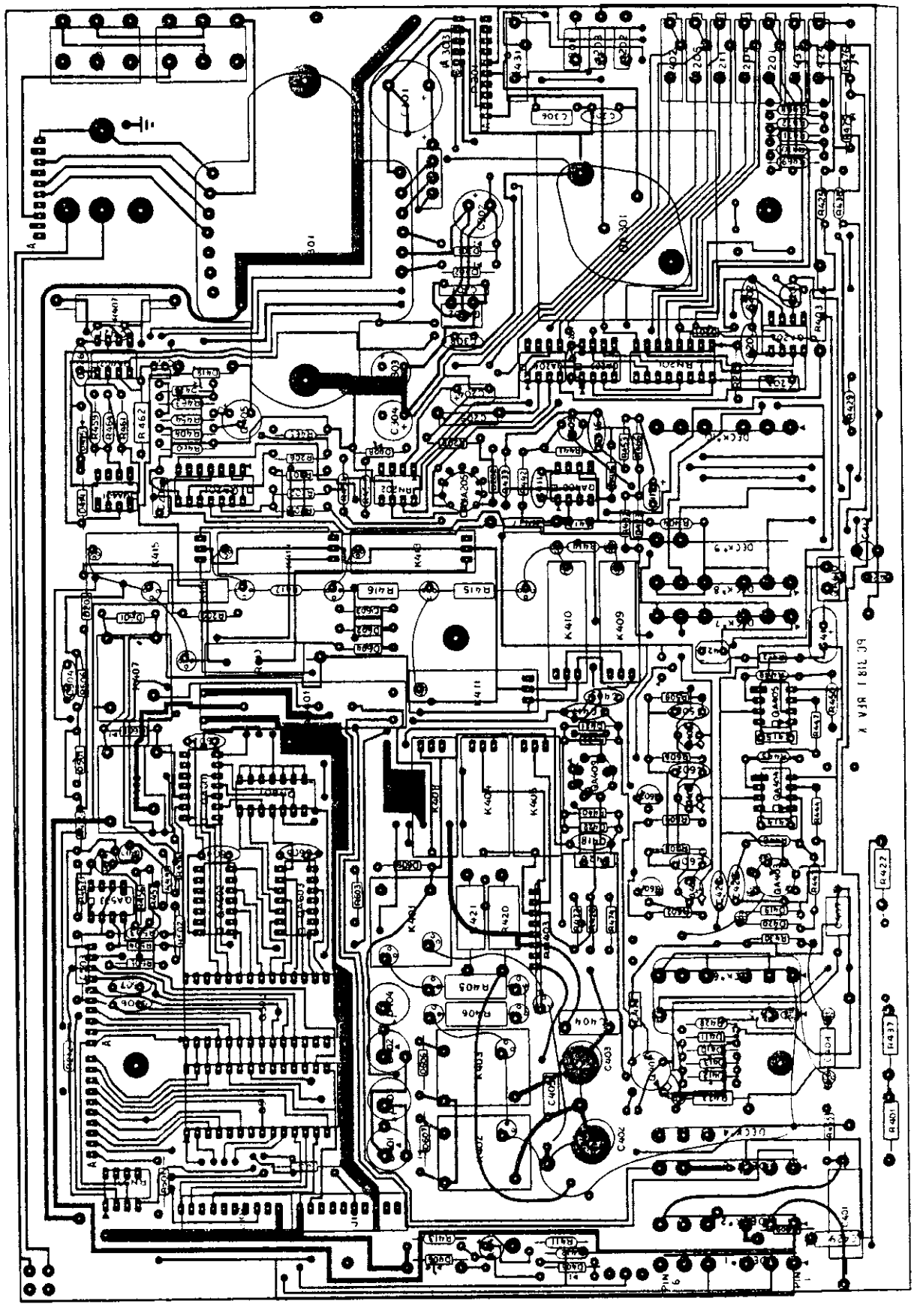


FIGURE 14. Component Layout, Mother Board, PC-318

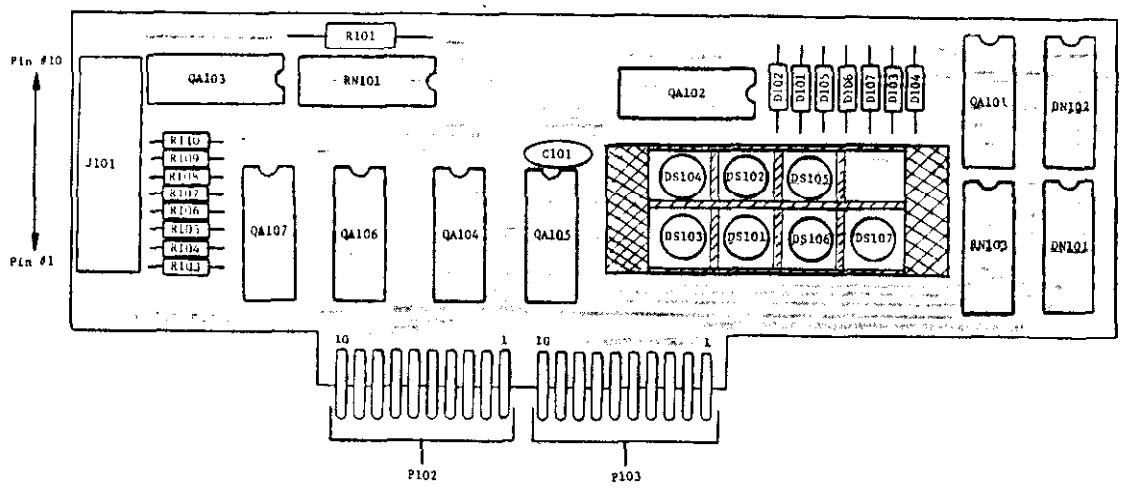


FIGURE 15. Component Layout, Logic Board, PC-313.

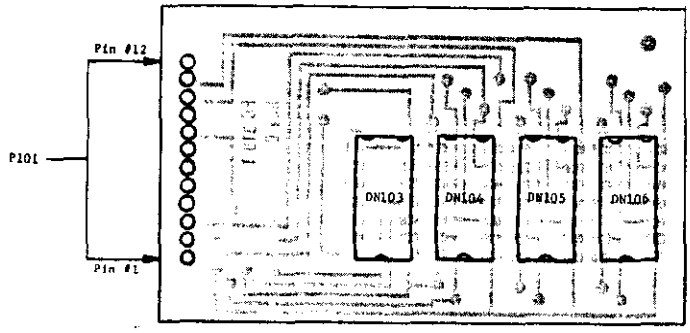
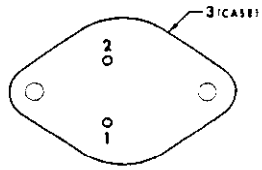


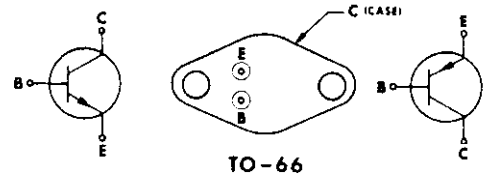
FIGURE 16. Component Layout, Readout Board, PC-319.

LEAD DESIG. TO-3



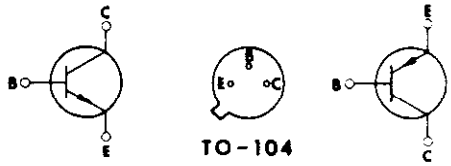
TO-3

LEAD DESIG. TO-66

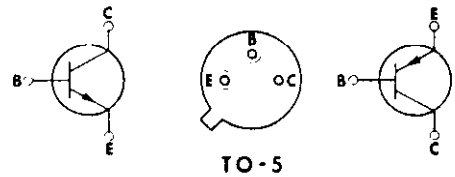


TO-66

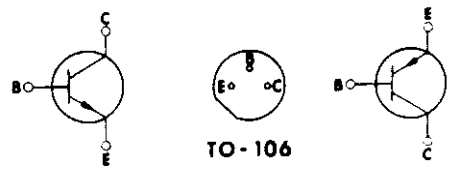
TO-92



TO-104



TO-5

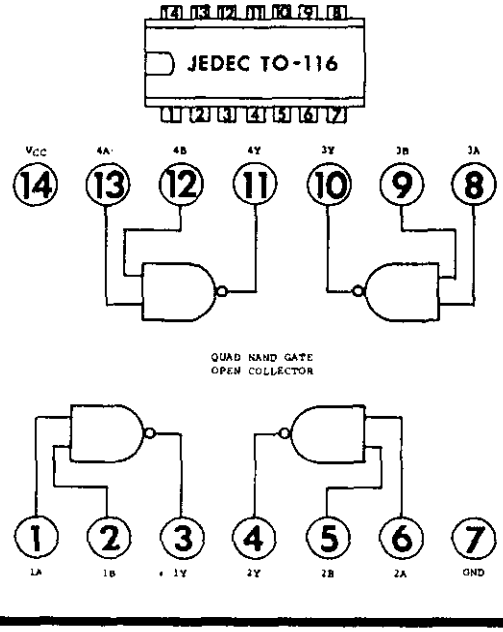


TO-106

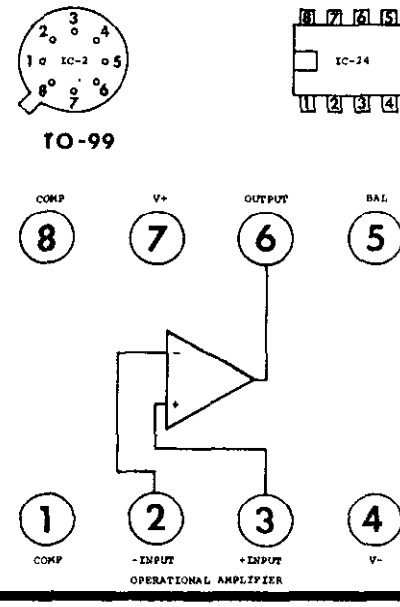
M

KEITHLEY PART NO. TG-41

KEITHLEY PART NO. IC-22



KEITHLEY PART NO. IC-2,24



5-7. TROUBLESHOOTING. If the 165 is out of tolerance for any specification, perform the calibration procedure given in Section 5-4. If during calibration an instrument malfunction is apparent, then proceed with the troubleshooting suggestions and hints given in Table 5-15, which describes the probable cause of various difficulties, and Table 5-16, which describes the probable damage caused by input overloads in excess of specifications. Note that all solutions to all possible problems cannot be tabularized, but Tables 5-15 and 5-16 do contain the most probable difficulties. Figure 17 illustrates how to assemble the pc boards of the Model 165.

a. Repair Assistance. Contact the Keithley Applications Engineering Department for any required additional assistance in repairing the Model 165. If the solutions listed in Tables 5-15 and 5-16 do not solve the problems or if the problems encountered are not listed, it is recommended that the 165 be returned to the Keithley repair facility in your country (U.S.A., Great Britain, W. Germany) or, if none exists, to your local Keithley sales representative. Completely fill out the Service Form at the end of this Model 165 Manual. Return this completed form and the malfunctioning instrument to:

(1) Sales Service Dept.
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
U.S.A.

(2) Keithley Instruments, Ltd.
1 Boulton Road
Reading, Berks., England

(3) Keithley Instruments, GmbH
Heiglhofstrasse 3A
D-8000 Munich 70
West Germany

If do not know who to contact regarding repairs or recalibration, write to:

Ke .A.
14;
P.C
CH tzerland

If you nere else in the world and do not know who to contact regarding repairs and recalibration, write to:

Keithley International Sales Corp.
28775 Aurora Road
Cleveland, Ohio 44139
U.S.A.

See the inside front cover of this Manual for more information regarding warranty repair and recalibration.

b. Rough Check of Functions. The built-in 1mA current source may be used to roughly check each function for operation. This procedure provides only an indication of performance and does not imply that every range is operating within all specifications. To do this procedure, set the range switch to AUTO and open-circuit the input. Now depress and release the 1mA pushbutton on the 165 front panel for each function and look for the following display readings:

DC VOLTS --- a display of +4 volts or greater;
AC VOLTS --- a transient followed by a display of a few millivolts;
DC AMPS --- a display of +0.9 to +1.1 mA;
AC AMPS --- a transient of approximately 100 microamps;
OHMS --- a blinking display of 1.7 Megohms that is not affected by depressing the 1mA button.

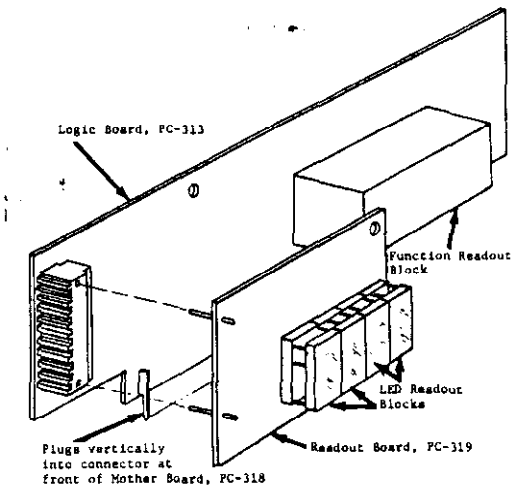


FIGURE 17. PC Board Assembly.

TABLE 5-15.
Troubleshooting: Various Difficulties

	Difficulty	Probable Cause	Solution
(a)	Blanked, blinking, or slowly increasing display on dc functions, all ranges; ac functions OK.	Shorted Chopper FET.	Replace Q401.
(b)	Lowest ohms ranges out of cal or all ohms ranges read zero.	(1) Defective R409. (2) Defective QA402 or Q405.	(1) Replace R409. (2) Replace QA402 or Q405. See Table 5-16 (d).
(c)	1mA current source not operational.	(1) Defective Q404. (2) Open R410. (3) Defective S402.	(1) Replace Q404. (2) Replace R410. (3) Replace S402.
(d)	All ac and dc-amps ranges not operational; out of cal.	(1) Defective RN401. (2) Open pc tape between D401 and D404. (3) High volts or amps input damaged S401A or K406, K407, K408, or K409.	(1) Replace RN401. (2) Replace with solid-wire jumper. (3) Replace or clean Deck No. 2 of S401A or replace damaged relay(s). See Table 5-16 (c).
(e)	Zero offset is high on many ac-volts ranges.	The a-d converter or unipolar amplifier.	Calibrate per Section 5-4. R204 and R211 are controlling adjustments.
(f)	High zero offset on 10mV ac and ac amps.	Wires near S401A Deck Nos. 2-5 have moved and/or RN403 is defective.	Position wires per Figure 14.
(g)	On 10-1000V ac ranges only, 20kHz spec is out of tolerance; 20 Hz spec is OK.	(1) C402, C403 out of adjustment. (2) Wires near S401A Deck Nos. 2-5 have moved and/or RN403 is defective.	(1) Recalibrate per Section 5-4. (2) Position wires per Figure 14.
(h)	Only one digit is lit and at high brightness.	(1) Clock circuit is inoperative. (2) Defective logic.	(1) Check for 5% duty cycle 9680 ±300 Hz waveform at pin 12, 13 of QA602. If not, replace QA503 or QA602. (2) 800 microsec. 25% duty cycle pulses should appear on T-0 through T-3 multiplexing lines. Replace QA501, QA104, and/or QA103.
(i)	All digits have identical segments either weakly lit or blank.	Defective segment logic.	Check segment line (A through G) for TTL level change at P102, QA106 and QA107, P101. Replace appropriate component.
(j)	One digit only has a weakly lit or blank segment.	Defective display.	Replace DN103, DN104, DN105, or DN106 as appropriate.
(k)	All power supplies are inoperative.	Fuse Blown.	Check for shorts in supplies; replace line fuse.
(l)	-12V and -6V supplies are inoperative; +10, +5, +6V supplies are OK.	(1) Short in -12V supply. (2) Defective QA302.	(1) Look for mechanical short and remove. With power turned off and J301 disconnected, check for 3 to 5 kilohms at Pin D of P301. Use 100mV f.s. ohmmeter (another Model 165) with circuit LO connected to input LO of defective 165. (2) Replace QA302.
(m)	+10, +5, +6V supplies are inoperative; -12V and -6V supplies are OK.	Short in +10V supply.	Look for mechanical short and remove. With power turned off and J301 disconnected, check for 100 to 200 kilohms at Pin E of P301. Use 100mV f.s. ohmmeter (another Model 165) with circuit LO connected to input LO of defective 165.

TABLE 5-16.
Troubleshooting: Excessive Overloads

Function	Overload	Probable Damage	Tests to Verify Damage
(a) DC VOLTS	Greater than 1200V dc or peak ac.	(1a) Q401.	(1a) Check waveform at a node of D421 and D422; it should not be a squarewave. Check for Difficulty (a) in Table 5-15.
		(1b) R420, R421.	(1b) Check R420 and R421 for darkening (heat damage) and/or cracking. If either is open, there will be no response to an input signal and high offset on the bottom ranges
(b) AC VOLTS	(1) Greater than 1200V dc.	(1a) C401. (1b) D419, D420.	(1a) Possibly shorted. (1b) Possibly leaky or shorted.
	(2) Greater than 1200V ac.	R405, R406.	Check R405 and R406 for darkening (heat damage) and/or cracking. If either is open, there will be no response to an input signal and high offset on the bottom ranges.
(c) DC AMPS and AC AMPS	Greater than 3 amps rms ac.	(1a) PC Board tapes near D401 through D404.	(1a) Inspect board for open or lifted tapes. Use jumper wire to bypass damaged tapes; jumper(s) should be in same physical location as pc tapes.
		(1b) RN401.	(1b) If pc tapes are damaged, check RN401 for 4-terminal resistance accuracy of ±0.2% at 100mV drop. Connect voltage sensor between terminals 1 and 7. Apply the appropriate constant current to terminals 2 and 3, 4, 5, or 6.
		(1c) S401A, Deck No. 2.	(1c) If function was changed during overload, inspect contacts for burn marks and damage. Replace or clean as needed.
(d) OHMS	(1) Greater than 200V rms ac, AUTO range mode.	(1a) Q405. (1b) QA402. (1c) D414, D415.	(1a) Shorted or open. (1b) Check for response to input. (1c) Check for clamping and leakage.
	(2) Greater than 250V rms or high voltage/ high frequency on lower ranges; manual range mode.	(2a) Range resistors. (2b) Relays. (2c) Ohms circuit	(2a) Check R409, R414 through R417 for 0.1% tolerance. (2b) Check operation of K409 through K414. (2c) Check Q405, QA402, D414, and D415.

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST: This section contains a list of components used in this instrument for user reference. The Replaceable Parts List described the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number), Manufacturer's Part Number, the Keithley Part Number, and Quantity required in entire instrument. The complete name and address of each Manufacturer is listed in the CODE-TO-NAME Listing following the parts list. Table 6-1 contains common abbreviations and symbols used throughout this manual.

TABLE 6-1.
Abbreviations and Symbols

A	ampere	Fig.	Figure	My	Mylar
		FET	Field Effect Transistor	MPC	Metal Polycarbonate
CbVar	Carbon Variable				
CerD	Ceramic Disc	GGb	Glass enclosed Carbon	No.	Number
CerTB	Ceramic Tubular			n	nano (10^{-9})
Cer Trimmer	Ceramic Trimmer	Hz	Hertz (cps)		
Comp	Composition			Ω	ohm
CerF	Ceramic Film	IC	integrated circuit		
				p	pico (10^{-12})
DCb	Deposited Carbon	k	kilo (10^{3})	PC	Printed Circuit
Desig.	Designation			Poly	Polystyrene
DM	Dipped Mica	LSI	large scale integration		
		LED	light emitting diode	RDG	Reading
EAL	Electrolytic, Aluminum			RNG	Range
ETB	Electrolytic, Tubular	m	milli (10^{-3})	Ref.	Reference
ETT	Electrolytic, Tantalum	MPoly	Metallized Polyester	RN	Resistor Network
EPoly	Epoxy-coated Polyester	μ	micro (10^{-6})		
		MMy	Metallized Mylar	TCu	Tinner Copperweld
f.s.	full scale	M	Meg (10^{6})	V	volt
F	farad	Mfr.	Manufacturer	W	watt
				WW	Wirewound
				WWVar	Wirewound Variable

6-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as discussed in Sections 3 and 5. Table 6-2 indentifies schematics with pc boards.

6-3. HOW TO USE THE REPLACEABLE PARTS LIST. This Parts List is arranged such that the individual types of components are listed in alphabetical order. Main Chassis parts are listed followed by printed circuit boards and other subassemblies.

6-4. HOW TO ORDER PARTS.

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

b. When ordering parts, include the following information.

1. Instrument Model 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 6-2.
Schematic Diagrams

Description	Assembly No.	Schematic Nos.
Logic Board	PC-313	25394E
Readout Board	PC-319	25394E
Mother Board	PC-318	25392E, 25391C, 25393D, 25508D, and 25511D
Block Diagram	--	25395D

6-5. CHASSIS PARTS LIST. (Reference Figure 18). Table 6-3 Chassis Parts List contains a comprehensive listing of every part of the basic mechanical chassis assembly of the Model 165 (excluding connectors, switches, and details of the front and rear panels). See Paragraph 6-7 Mechanical Parts List for parts not listed here.

TABLE 6-3.
Chassis Parts List

Item	Part Description	Quantity Required	Keithley Part No.
1	TOP COVER ASSEMBLY (with screen shield)	1	25534B
2	Spacers, Plastic	5	25355A
3	Spacers, Rubber	5	ST-115
4	BOTTOM COVER ASSEMBLY (with screen shield)	1	25880B
5	Tilt Bail	1	25520B
6	Feet, Plastic, Black	4	24322B
7	Ball, Rubber	4	FE-6
8	Screw, Slotted, Flat Hd., 6-32 x 2"	5	--
9	FRONT PANEL (less overlay)	1	25361B
10	REAR PANEL	1	25389B
11	Knob, Range	1	25503A
12	Knob, Function	1	25504A
13	Bushing, Insulator	1	25399A
	To remove PC-318 from Bottom Cover:		
14	Screw, Phillips, Pan Hd., 6-32 x 5/16"	2	—
	To remove PC-318 from rear panel:		
15	Screw, Phillips, Pan Hd., 6-32 x 5/16"	1	--
16	Kep Nut, 6-32	1	—

6-6. ELECTRICAL PARTS LIST. Table 6-4 Circuit Designation Series contains a list of the basic three-digit numbers of a series identifying location of electrical (and mechanical) parts to a particular printed-circuit assembly or assemblies. Reference is made to the manual pages (replaceable parts list) that contain all parts of a particular series. Following Table 6-4 is a complete electrical parts list for the Model 165. Reference Table 6-2 to identify the schematic(s) pertaining to a particular printed-circuit assembly number.

TABLE 6-4.
Circuit Designation Series

Series	Description	Assembly No.	Page No.
100	Logic Board	PC-313	37-38
	Readout Board	PC-319	
200	Mother Board	PC-318	39-40
300	Mother Board	PC-318	41
400	Mother Board	PC-318	42-46
500	Mother Board	PC-318	47
600	Mother Board	PC-318	48

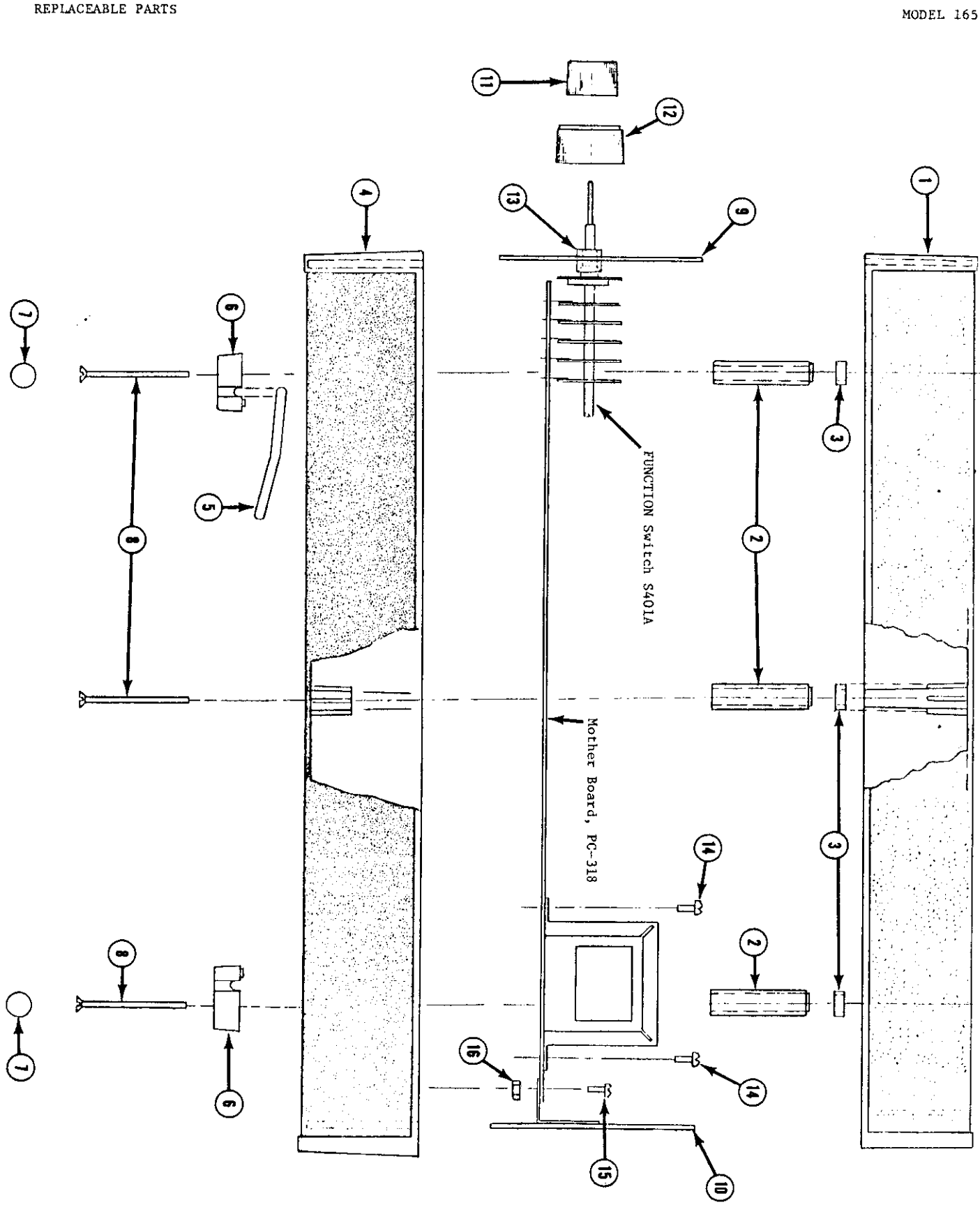


FIGURE 18. Chassis Assembly - Exploded View.

READOUT & LOGIC CIRCUITRY
"100" SERIES

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J101	Connector, 12 pins	02660	6-380949-2	CS-263	1
J102	Connector, 10 pins	02660	6-380949-0	CS-264	2
J103	Connector, 10 pins	02660	6-380949-0	CS-264	2
P101	Connector Pin, PC Board.	80164	------	24249A	29
P102	Connector Pin.	02660	1-380953-0	CS-265	20
P103	Connector Pin.	02660	1-380953-0	CS-265	20

CAPACITOR

Circuit Desig.	Description	Mfr. Code	Mfr. Desig	Keithley Part No.	Qty.
C101	100 µF, ±10%, 15V, ETT	06751	TSD515107A	C205-100M	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D101	Rectifier.	01295	1N645	RF-14	17
D102	Rectifier.	01295	1N645	RF-14	17
D103	Rectifier.	01295	1N645	RF-14	17
D104	Rectifier.	01295	1N645	RF-14	17
D105	Rectifier.	01295	1N645	RF-14	17
D106	Rectifier.	01295	1N645	RF-14	17
D107	Rectifier.	01295	1N645	RF-14	17

DIODE NETWORK

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DN101	Diode Network, 14-pin DIP.	07263	FSA2620M	DN-1	2
DN102	Diode Network, 14-pin DIP.	07263	FSA2620M	DN-1	2
DN103	Digital Display, Polarity/Overrange, 14-pin DIP.	H-P	HP5082-7732	DD-11*	1
DN104	Digital Display, 14-pin DIP, 7-segment	H-P	HP5082-7730	DD-9*	3
DN105	Digital Display, 14-pin DIP, 7-segment	H-P	HP5082-7730	DD-9*	3
DN106	Digital Display, 14-pin DIP, 7-segment	H-P	HP5082-7730	DD-9*	3

*Selected for Light Intensity, Codes "C", "D", or "E".

H-P = Hewlett-Packard

READOUT & LOGIC CIRCUITRY
"100" SERIES (cont'd)

INDICATORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS101	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS102	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS103	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS104	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS105	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS106	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7
DS107	Pilot Lamp, 6.3V, T-1-3/4.	05464	7381-AS25	PL-59	7

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA101	Transistor Array, 14-pin DIP	07263	FPQ3724	IC-63	1
QA102	Transistor Array, 14-pin DIP	07263	FPQ3467	IC-57	2
QA103	Transistor Array, 14-pin DIP	07263	FPQ3467	IC-57	2
QA104	Hex Inverter, 14-pin DIP	01295	SN7406	IC-62	3
QA105	Hex Inverter, 14-pin DIP	01295	SN7406	IC-62	3
QA106	Quad NAND, 14-pin DIP.	04713	MC858P	IC-22	1
QA107	Hex Inverter, 14-pin DIP	01295	SN7406	IC-62	3

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	18 Ω, 3%, 3W, WW	44655	4400-18Ω	R92-18	1
R102	Not Used	.....	.....	.....	--
R103	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R104	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R105	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R106	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R107	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R108	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R109	680Ω, 10%, 1/4W, Comp.	01121	CB-331-10%	R76-680	7
R110	1kΩ, 10%, 1/4W, Comp	01121	CB-561-10%	R76-1k	1

RESISTOR NETWORKS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN101	Thick Film Resistor Network.	80164	------	TF-11	1
RN102	Not Used	-----	------	--------	....
RN103	Thick Film Resistor Network.	80164	------	TF-9	1

UNIPOLAR AMPLIFIER & A/D CONVERTER
"200" SERIES

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J201	Test Jack, Black.	83330	430-103	TJ-7	3
J202	Test Jack, Black.	83330	430-103	TJ-7	2
J203	Test Jack, Black.	83330	430-103	TJ-7	3

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C201	150 pF, 1000V, CerD	71590	DD-151-10%	C64-150P	1
C202	5 pF, 1000V, CerD	71590	DD-050-10%	C64-5P	1
C203	1.0 µF, 50V, CerF	72982	8131050651-105M	C237-1M	3
C204	39 pF, 15V, Epoxy.	17554	TD4-015-396	C228-39P	1
C205	0.1 µF, 50V, My	84411	601PE-.1µF	C41-.1M	2
C206	0.1 µF, 50V, My	84411	601PE-.1µF	C41-.1M	2
C207	33 pF, 1000V, CerD	71590	DD-330-10%	C64-33P	2

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D201	Rectifier	01295	1N914	RF-28	8
D202	Zener, 3.5V	06751	1N703A	DZ-42	2
D203	Rectifier	01295	1N914	RF-28	8

TRANSISTOR

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q201	PNP, Case TO-92	04713	2N5087	TG-61	3

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA201	Transistor array, 14-pin DIP.	02735	CA3086	IC-53	1
QA202	Operational Amplifier, 8-pin DIP.	80164	IC-76	IC-76	4
QA203	Operational Amplifier, 8-pin DIP.	80164	IC-76	IC-76	4
QA204	Operational Amplifier, 8-pin DIP.	80164	IC-77	IC-77	1
QA205	Voltage Comparator, 10-pin, Case TO-100	07263	U5F7734393	IC-78	1

UNIPOLAR AMPLIFIER & A/D CONVERTER
"200" SERIES (cont'd)

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R201	1KΩ, 0.75W, Cermet.	73138	89P-1KΩ	RP89-1K	1
R202	120KΩ, 10%, 1/4W, Comp.	01121	CB-124-10%	R76-120K	2
R203	120KΩ, 10%, 1/4W, Comp.	01121	CB-124-10%	R76-120K	2
R204	500KΩ, 0.75W, Cermet.	73138	89P-500Ω	RP89-500	1
R205	2KΩ, 0.75W, Cermet.	73138	89P-2KΩ	RP89-2K	1
R206	150KΩ, 10%, 1/4W, Comp.	01121	CB-154-10%	R76-150K	1
R207	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	6
R208	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	6
R209	1MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	2
R210	Not Used.	.....	.....	.....	....
R211	10KΩ, 0.75W, Cermet	73138	89P-10KΩ	RP89-10K	4
R212	2.8KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-2.8KΩ	R88-2.8K	1
R213	6.04KΩ, 0.1%, 1/8W, MtF	91637	MFF-1/8-6.04K	R176-6.04K	1

RESISTOR NETWORK

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN201	Thick Film Resistor Network, 16-pin DIP	80164	TF-33	TF-33	1
RN202	Thick Film Resistor Network, 8-pin DIP.	80164	TF-10	TF-10	1

POWER SUPPLY CIRCUITRY
"300" SERIES

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
P301	Connector Pin, PC Board	80164	.....	24249A	29
P302	Not Used.	.....	.....	.....	....
P303	Connector Pin, PC Board	80164	.....	24249A	29
J301	Jumper Connector Assembly	80164	.....	25875A	1
S301	Switch, Power Toggle.	95146	MST205N	SW-271	1
S302	Switch, Slide, D.P.D.T.	79727	GG350PCDPDT	SW-324	2
S303	Switch, Slide, D.P.D.T.	79727	GG350PCDPDT	SW-324	2
T301	Transformer	80164	.....	TR-145	1
F301	Fuse, Slo-Blo 1/4A, 117V.	75915	313.250S	FU-38	1
....	Fuse, Slo-Blo 1/8A, 234V.	71400	MDL	FU-20	1
QA301	Integrated Circuit, Voltage Regulator, 5V, Case TO-3.	12040	LM309K	IC-34	1
QA302	Integrated Circuit, Voltage Regulator, 12V, Case TO-220	07263	UGH7812393	IC-60	1

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C301	2000µF, 15V, EAL.	29309	JCN2000158P	C210-2000M	1
C302	200 µF, 35V, EAL.	90201	MTV200N35PDN	C177-200M	1
C303	100 µF, 15V, EAL.	29309	JC6100158P	C210-100M	2
C304	100 µF, 15V, EAL.	29309	JC6100158P	C210-100M	2
C305	0.33µF, 50V, CerF	72982	8131050651-344M	C237-.33M	6
C306	0.1 µF, 16V, CerD	71590	UK16-104	C238-.1M	2
C307	0.1 µF, 16V, CerD	71590	UK16-104	C238-.1M	2
C308	0.33µF, 50V, CerF	72982	8131050651-334M	C237-.33M	6

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D301	Rectifier	01295	1N645	RF-14	17
D302	Rectifier	01295	1N645	RF-14	17
D303	Rectifier, Four-diode bridge.	83701	PD-10	RF-36	1

SWITCHING & AC/DC PREAMP CIRCUITRY
"400" SERIES

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J401	Binding Post, Red.	80164	.....	25537A	1
J402	Binding Post, Black.	80164	.....	25539A	1
J403	Binding Post, Green.	80164	.....	25538A	1
S401	Switch, Section A (Function) and Section B (Range)	80164	.....	SW-354	1
S402	Switch, Pushbutton, 1mA.	80164	.....	SW-223	1

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C401	0.068µF, 1200V	97419	M2WR-.068M	C181-.068M	1
C402	.8-8.5pF, 750V, Glass.	72982	562-013	C232-.8-8.5P	1
C403	1.0-30pF, 750V, Glass.	72982	568-013	C232-1.0-30P	1
C404	6800pF, 1%, 100V, Mica	14655	CD19FA682F03	C248-6800P	1
C405	60pF, 300V, Mica	14655	CD15FC641F03	C249-60P	1
C406	0.01µF, 1200V.	97419	M2WR-.0022M	C181-.01M	1
C407	0.015µF, 200V, MPCb.	14752	625B1C-153	C221-.015M	1
C408	0.0022µF, 200V, MPCb	14752	625B1C-222	C221-.0022M	1
C409	0.01µF, 1000V, CerD.	56289	10SS-S10	C22-.01M	6
C410	120µF, 10V, ETT.	17554	TSD210	C180-120M	1
C411	33pF, 1000V, CerD.	71590	DD-330-10%	C64-33P	2
C412	50µF, 15V, EAL,.	29309	JC650158N	C241-50M	1
C413	0.33µF, 50V, CerF.	72982	8131050651334M	C237-.33M	6*
C414	3.3pF, 600V, CerT.	71590	TCZ-3R3	C77-3.3P	2
C415	3.3pF, 600V, CerT.	71590	TCZ-3R3	C77-3.3P	2
C416	.001µF, 1000V, CerD.	72982	801000x5F0102K	C64-.001M	1
C417	0.022µF, 1000V, CerD	56289	10SS-S20	C152-.022M	2
C418	0.022µF, 1000V, CerD	56289	10SS-S20	C152-.022M	2
C419	1.2µF, 20V, ETT.	17554	TSD120125	C179-1.2M	1
C420	1.0µF, 50V, CerF	72982	8131050651105M	C237-1M	3
C421	0.01µF, 1000V, CerD.	56289	10SS-S10	C22-.01M	6
C422	33µF, 15V, Epoxy	17554	TD4015336-10	C228-33M	1
C423	1.0µF, 50V, CerF	72982	8121050651-104M	C237-1M	3
C424	0.1µF, 50V, CerF	72982	8131050651-105M	C237-.1M	1
C425	0.33µF, 50V, CerF.	72982	8131050651334M	C237-.33M	6
C426	330pF, 1000V, CerD	71590	DD331-10%	C64-330P	1
C427	0.1µF, 1000V, CerD	56289	10SS-S10	C258-.1M	2
C428	0.1µF, 1000V, CerD	56289	10SS-S10	C258-.1M	2
C429	0.0047 F, 400V, 20%, Mylar	80164	-----	C73-.0047M	1

SWITCHING & AC/DC PREAMP CIRCUITRY
"400" SERIES (cont'd)

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D401	Rectifier 3A, 200V.	04713	MR1032B	RF-40	4
D402	Rectifier 3A, 200V.	04713	MR1032B	RF-40	4
D403	Rectifier 3A, 200V.	04713	MR1032B	RF-40	4
D404	Rectifier 3A, 200V.	04713	MR1032B	RF-40	4
D405	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D406	Zener, 6V, 400mW.	12954	DZ701104A	DZ-47	2
D407	Not Used.	.....	.....	.....	....
D408	Zener, 9V	06751	1N937	DZ-41	1
D409	Not Used.	.....	.....	.....	....
D410	Zener, 11V, 1/4W.	12954	1N715	DZ-22	2
D411	Zener, 11V, 1/4W.	12954	1N715	DZ-22	2
D412	Rectifier	01295	1N3595	RF-43	4
D413	Rectifier	01295	1N3595	RF-43	4
D414	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D415	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D416	Rectifier, 75 mA, 75V	12954	DZ701104A	DZ-47	2
D417	Not Used.	.....	.....	.....	....
D418	Rectifier, 1A, 800V	04713	1N4006	RF-38	1
D419	Rectifier 125V, 1/2W.	07263	1N3595	RF-43	4
D420	Rectifier 125V, 1/2W.	07263	1N3595	RF-43	4
D421	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D422	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D423	Rectifier, 75 mA, 75V	01295	1N914	RF-28	8
D424	Not Used.	.....	.....	.....	....
D425	Not Used.	.....	.....	.....	....
D426	Zener, 3.5V	06751	1N703A	DZ-42	2

RELAYS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
K401	Single-Pole, N.O.	70309		RL-41	1
K402	Single-Pole, N.O.	70309		RL-39	4
K403	Single-Pole, N.O.	70309		RL-39	4
K404	Single-Pole, N.O.	95073	375-670	RL-40	9
K405	Single-Pole, N.O.	95073	375-670	RL-40	9
K406	Single-Pole, N.O.	70309		RL-39	4
K407	Single-Pole, N.O.	70390		RL-39	4
K408	Single-Pole, N.O.	95073	375-670	RL-40	9
K409	Single-Pole, N.O.	95073	375-670	RL-40	9
K410	Single-Pole, N.O.	95073	375-670	RL-40	9
K411	Single-Pole, N.O.	95073	375-670	RL-40	9
K412	Not Used.	.....	.....	.....	....
K413	Single-Pole, N.O.	95073	375-670	RL-40	9
K414	Single-Pole, N.O.	95073	375-670	RL-40	9
K415	Single-Pole, N.O.	95073	375-670	RL-40	9

SWITCHING & AC/DC PREAMP CIRCUITRY
"400" SERIES (cont'd)

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q401	P-Channel MOSFET (Dual)	72699	955-004	TG-94	1
Q402	PNP, Case TO-106.	07263	2N5910	TG-111	2
Q403	Not Used.	.....	.....	.....	....
Q404	PNP, Case TO-106.	07263	2N5139	TG-66	1
Q405	NPN, Case		2N3439	TG-93	1
Q406	P-Channel FET, Case TO-72	72699	575-011	TG-95	4
Q407	P-Channel FET, Case TO-72	72699	575-011	TG-95	4
Q408	P-Channel FET, Case TO-72	72699	575-011	TG-95	4
Q409	P-Channel FET, Case TO-72	72699	575-011	TG-95	4
Q410	PNP, Case TO-106.	07263	2N5910	TG-111	2

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA401	Operational Amplifier, 8-pin DIP.	12040	LM307N	IC-61	1
QA402	Operational Amplifier, 8-pin DIP.	07263	Special	IC-76	4
QA403	Operational Amplifier, 8-pin, Case TO-99.	12040	LM310H	IC-18	2
QA404	Amplifier, 8-pin DIP.	12040	LM301AN	IC-24	2
QA405	Amplifier, 8-pin DIP.	12040	LM301AN	IC-24	2
QA406	Operational Amplifier, 8-pin DIP.	07263	Special	IC-76	4
QA407	Not Used.	.....	.....	.....	....
QA408	Not Used.	.....	.....	.....	....
QA409	Operational Amplifier, 8-pin, Case TO-99.	12040	LM31011	IC-18	2
QA410	Voltage regulator, 6V, Cast TO-220.	07263	UGH7806393	IC-64	1

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R401	560KΩ, 5%, 1/2W, Comp	01121	EB-560KΩ	R19-560K	2
R402	5KΩ, 0.75W, Cermet.	73138	89P-5KΩ	RP89-5K	1
R403	1MΩ, 1%, 1/2W, DCb.	91637	DCF-1/2-1MΩ	R12-1M	1
R404	441Ω, 0.1%, 1/8W.	91637	MMF-1/8-441Ω	R176-441	1
R405	12.5KΩ, 5%, 3W, WW.	15909	DAS3-12.5KΩ	R208-12.5K	2
R406	12.5KΩ, 5%, 3W, WW.	15909	DAS3-12.5KΩ	R208-12.5K	2
R407	30.1KΩ, 0.1%, 3W, WW.	15909	DAS3-30.1KΩ	R207-30.1K	1
R408	1KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1KΩ	R88-1K	5
R409*	99.5Ω, 0.1%, 1/8W	91637	MMF-1/8-98.7Ω	R176-99.5	1
R410	1.2KΩ, 10%, 2W, Comp.	01121	HB-1.2KΩ	R3-1.2K	1
R411	1KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1KΩ	R88-1K	5
R412	1KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1KΩ	R88-1K	5
R413	3.01KΩ, 1%, 1/8W, MtF	07716	CEA-TO-1KΩ	R88-3.01K	1
R414	900Ω, 0.1%, 1/8W.	91637	MMF-1/8-900Ω	R176-900	1
R415	9KΩ, 0.1%, 1/2W, MtF.	91637	MFF-1/2-9KΩ	R205-9K	1

*Nominal value

SWITCHING & AC/DC PREAMP CIRCUITRY
"400" SERIES (cont'd)

RESISTORS (cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R416	90KΩ, 0.1%, 1/2W, MtF.	91637	MFF-1/2-90KΩ	R205-90K	1
R417	900KΩ, 0.1%, 1/4W, MtF	91637	MFF-1/4-900KΩ	R209-900K	1
R418	9MΩ, 0.1%, 1/2W.	14298	AME-70-9MΩ	R174-9M	1
R419	90MΩ, 1%, 1/4W	63060	MOX400	R216-90M	1
R420	180KΩ, 10%, 2W, Comp	01121	4B-180KΩ	R3-180K	2
R421	180KΩ, 10%, 2W, Comp	01121	4B-180KΩ	R3-180K	2
R422	330KΩ, 10%, 1/2W, Comp	01121	EB-330KΩ	R1-330K	1
R423	10^8Ω, 5%, 1/2W	07716	CBTY2-10^8	R180-10^8	2
R424	10KΩ, 0.75W, Cermet.	73138	89P-10KΩ	RP89-10K	4
R425	6.98KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-825Ω	R88-6.98K	2
R426	470Ω, 10%, 1/4W, Comp.	01121	CB-471-10%	R76-470	1
R427	10^8Ω, 5%, 1/2W	07716	CBTY2-10^8	R180-10^8	2
R428	100Ω, 10%, 1/4W, Comp.	01121	CB-101-10%	R176-100	1
R429	100KΩ, 1%, 1/8W, MtF	07716	CEA-100KΩ	R88-100K	1
R430	3.9MΩ, 10%, 1/4W, Comp	01121	CB-395-10%	R76-3.9M	1
R431	10KΩ, 0.75W, Cermet.	73138	89P-10KΩ	RP89-10K	4
R432	10MΩ, 10%, 1/4W, Comp.	01121	CB-106-10%	R76-10M	1
R433	10KΩ, 1%, 1/8W, MtF.	07716	CEA-10KΩ	R88-10K	2
R434	10KΩ, 0.75W, Cermet.	73138	89P-10KΩ	RP89-10K	4
R435	4.7KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	6
R436	4.7KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	6
R437	560KΩ, 5%, 1/2W, Comp.	01121	EB-560KΩ	R19-560K	2
R438	10KΩ, 1%, 1/8W, MtF.	07716	CEA-6.81KΩ	R88-10K	2
R439	2.2MΩ, 10%, 1/4W, Comp	01121	CB-225-10%	R76-2.2M	2
R440	2.2MΩ, 10%, 1/4W, Comp	01121	CB-225-10%	R76-2.2M	2
R441	2.7KΩ, 10%, 1/4W, Comp	01121	CB-272-10%	R76-2.7K	2
R442	10KΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	6
R443	1MΩ, 1%, 1/8W, MtF	07716	CEA-1MΩ	R88-1M	1
R444	1KΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	5
R445	9KΩ, 0.1%, 1/8W, MtF	91637	MFF-1/8-9KΩ	R168-9K	2
R446	1001Ω, 0.5%, 1/8W, MtF	91637	MFF-1/8-1001Ω	R168-1001	1
R447	1KΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	5
R448	1KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-1K	5
R449	9KΩ, 0.1%, 1/8W, MtF	91637	MFF-1/8-9KΩ	R168-9K	2
R450	1KΩ, 0.1%, 1/8W, MtF	91637	MFF-1/8-1KΩ	R168-1K	1
R451	348Ω, 1%, 1/8W, MtF.	07716	CEA-348Ω	R88-348	1
R452	47Ω, 10%, 1/4W, Comp	01121	CB-470-10%	R76-47	1
R453	2.7KΩ, 10%, 1/4W, Comp	01121	CB-272-10%	R76-2.7K	2
R454	2KΩ, 1%, 1/8W, MtF	07716	CEA-2KΩ	R88-2K	2
R455	10KΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	6
R456	4.7KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	6
R457	1KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-1K	5
R458	4.64KΩ, 1%, 1/8W, MtF.	91637	MFF-1/8-4.64KΩ	R206-4.64K	1
R459	121KΩ, 1%, 1/8W, MtF	91637	MFF-1/8-121KΩ	R206-121K	1
R460	24.3KΩ, 1%, 1/8W, MtF.	07716	CEA-24.3KΩ	R88-24.3K	1

SWITCHING & AC/DC PREAMP CIRCUITRY
"400" SERIES (cont'd)

RESISTORS (cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R461	120.4KΩ, 0.1%, 1/8W.	91637	MMF-1/8-120.4KΩ	R176-120.4K	1
R462	300.2KΩ, 0.1%, 1/8W.	91637	MMF-1/8-300.2KΩ	R176-300.2K	1
R463	26.1KΩ, 0.1%, 1/8W	91637	MMF-1/8-26.1KΩ	R176-26.1K	1
R464	30.1KΩ, 1%, 1/8W, MtF.	91637	MFF-1/8-30.1KΩ	R206-30.1K	1
R465	1.62KΩ, 1%, 1/8W, MtF.	91637	MFF-1/8-1.62KΩ	R206-1.62K	1
R466	10KΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	6
R467	4.7KΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	6
R468	6.98KΩ, 1%, 1/8W, MtF.	07716	CEA-6.98KΩ	R88-6.98K	2
R469	4.99KΩ, 1%, 1/8W, MtF.	07716	CEA-4.99KΩ	R88-4.99K	1
R470	1KΩ, 1%, 1/8W, MtF	07716	CEA-1KΩ	R88-1K	5
R471	1KΩ, 1%, 1/8W, MtF	07716	CEA-1KΩ	R88-1K	5
R472	11KΩ, 1%, 1/8W, MtF.	07716	CEA-11KΩ	R88-11K	1
R473	1MΩ, 10%, 1/4W, Comp	01121	CB-105-10%	R76-1M	2
R474	10KΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	6
R475	4.02KΩ, 1%, 1/8W, MtF.	07716	CEA-4.02KΩ	R88-4.02K	1
R476	2KΩ, 1%, 1/8W, MtF	07716	CEA-2KΩ	R88-2K	2

RESISTOR NETWORKS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN401	Thick Film Resistors	80164	.....	R202	1
RN402	Not Used	.....	.....	.....	....
RN403	Thick Film Resistors	80164	.....	TF-8	1

CLOCK & SWITCHING CIRCUITRY
"500" SERIES

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C501	Not Used	.....	.....	.....	....
C502	Not Used	.....	.....	.....	....
C503	0.01μF, 2%, 200V, Mylar.	14752	210B1C103-2%	C247-.01M	1
C504	0.01μF, 1000V, CerD.	56289	10SS-S10	C22-.01M	6
C505	Not Used	.....	.....	.....	....
C506	0.33μF, 1000V, CerD.	56289	10SS-S10	C237-.33M	6
C507	0.33μF, 1000V, CerD.	56289	10SS-S10	C237-.33M	6
C508	470 pF, 1000V, CerD.	71590	DD-471	C64-470P	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D501	Zener, 6.2V, 1/4W.	12954	1N709	DZ-21	1

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA501	Large Scale IC	80164	LSI-2	LSI-2	1
QA502	Large Scale IC	80164	LSI-3	LSI-3	1
QA503	Timing Logic, 8-pin DIP.	12954	1N709	IC-71	1

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R501	2.2KΩ, 10%, 1/4 W, Comp.	01121	CB-222-10%	R76-2.2K	1
R502	12.7KΩ, 1%, 1/8 W, MtF	07716	CEA-12.7KΩ	R88-12.7K	1
R503	1KΩ, 1%, 1/8 W, MtF	07716	CEA-1K	R88-1K	1
R504	4.7KΩ, 10%, 1/4 W, Comp.	01121	CB-472-10%	R76-4.7K	6
R505	4.7KΩ, 10%, 1/4 W, Comp.	01121	CB-472-10%	R76-4.7K	6
R506	1K Ω, 10%, 1/4 W, Comp	01121	CB-102-10%	R76-1K	5
R507	Not Used	.....	.....	.....	....
R508	47KΩ, 10%, 1/4 W, Comp	01121	CB-473-10%	R76-47K	1

RESISTOR NETWORK

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN501	Thick Film Resistors	80164	-------	TF-14	1

RELAY & DRIVER CIRCUITRY
"600" SERIES

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C601	470 pF, 1000 V, CerD	71590	DD-471	C64-470P	3
C602	470 pF, 1000 V, CerD	71590	DD-471	C64-470P	3
C603	0.01μF, 1000 V, CerD	56289	10SS-S10	C22-.01M	6
C604	0.01μF, 1000 V, CerD	56289	10SS-S10	C22-.01M	6
C605	0.01μF, 1000 V, CerD	56289	10SS-S10	C22-.01M	6

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D601	Rectifier.	01295	1N645	RF-14	17
D602	Rectifier.	01295	1N645	RF-14	17
D603	Rectifier.	01295	1N645	RF-14	17
D604	Rectifier.	01295	1N645	RF-14	17
D605	Rectifier.	01295	1N645	RF-14	17
D606	Rectifier.	01295	1N645	RF-14	17
D607	Rectifier.	01295	1N645	RF-14	17
D608	Rectifier.	01295	1N645	RF-14	17

DIODE NETWORK

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DN601	7-diodes, 14-pin DIP	07263	FSA2620M	DN-1	1

Transistors

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q601	PNP, Case TO-92.	04713	2N5087	TG-61	3
Q602	PNP, Case TO-92.	04713	2N5087	TG-61	3

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA601	Hex inverter, 14-pin DIP.	01295	SN7406	IC-62	3
QA602	Hex inverter, 14-pin DIP	01295	SN7406	IC-62	3
QA603	Hex inverter, 14-pin DIP	01295	SN7406	IC-62	3

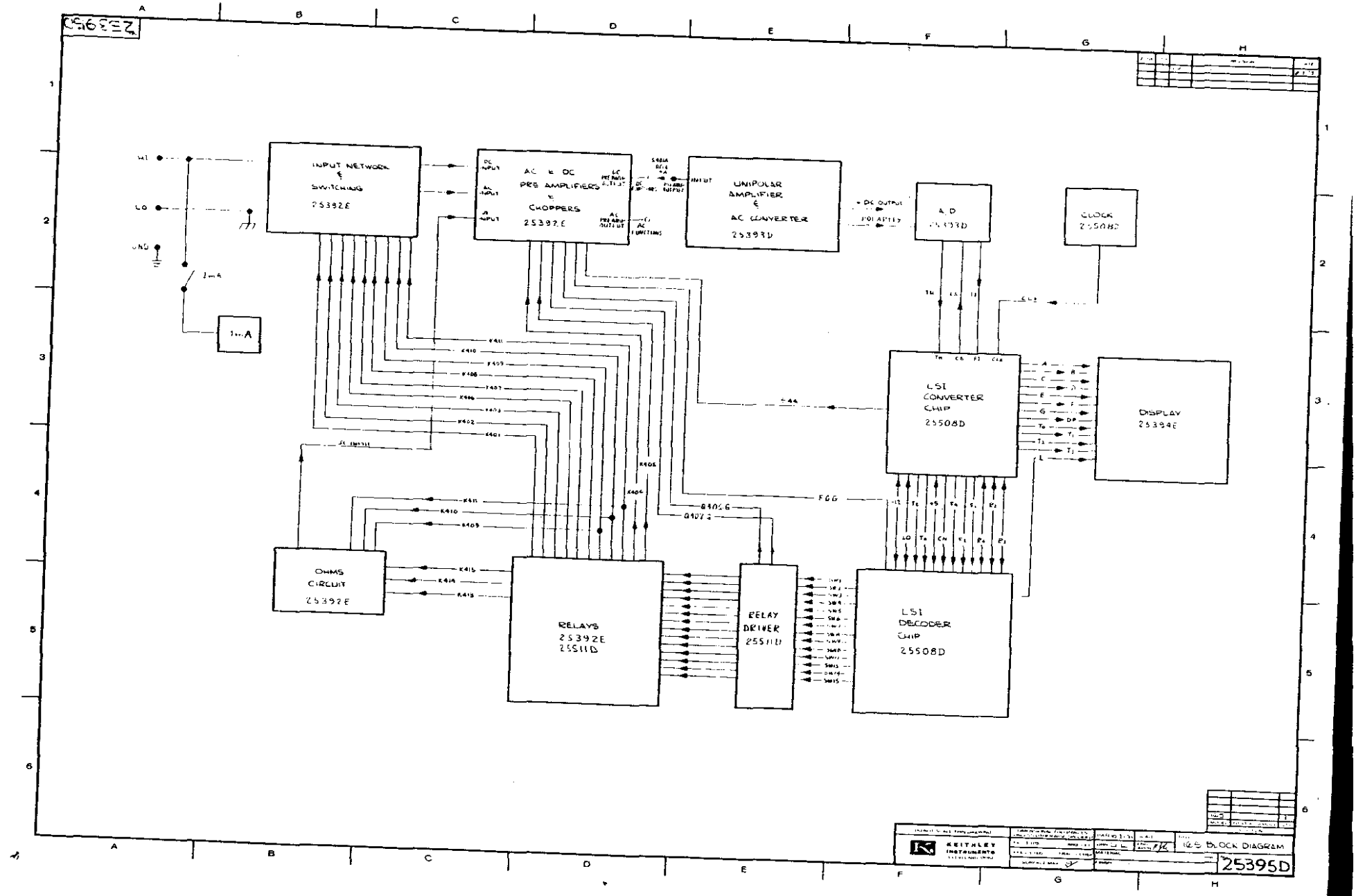
RESISTORS

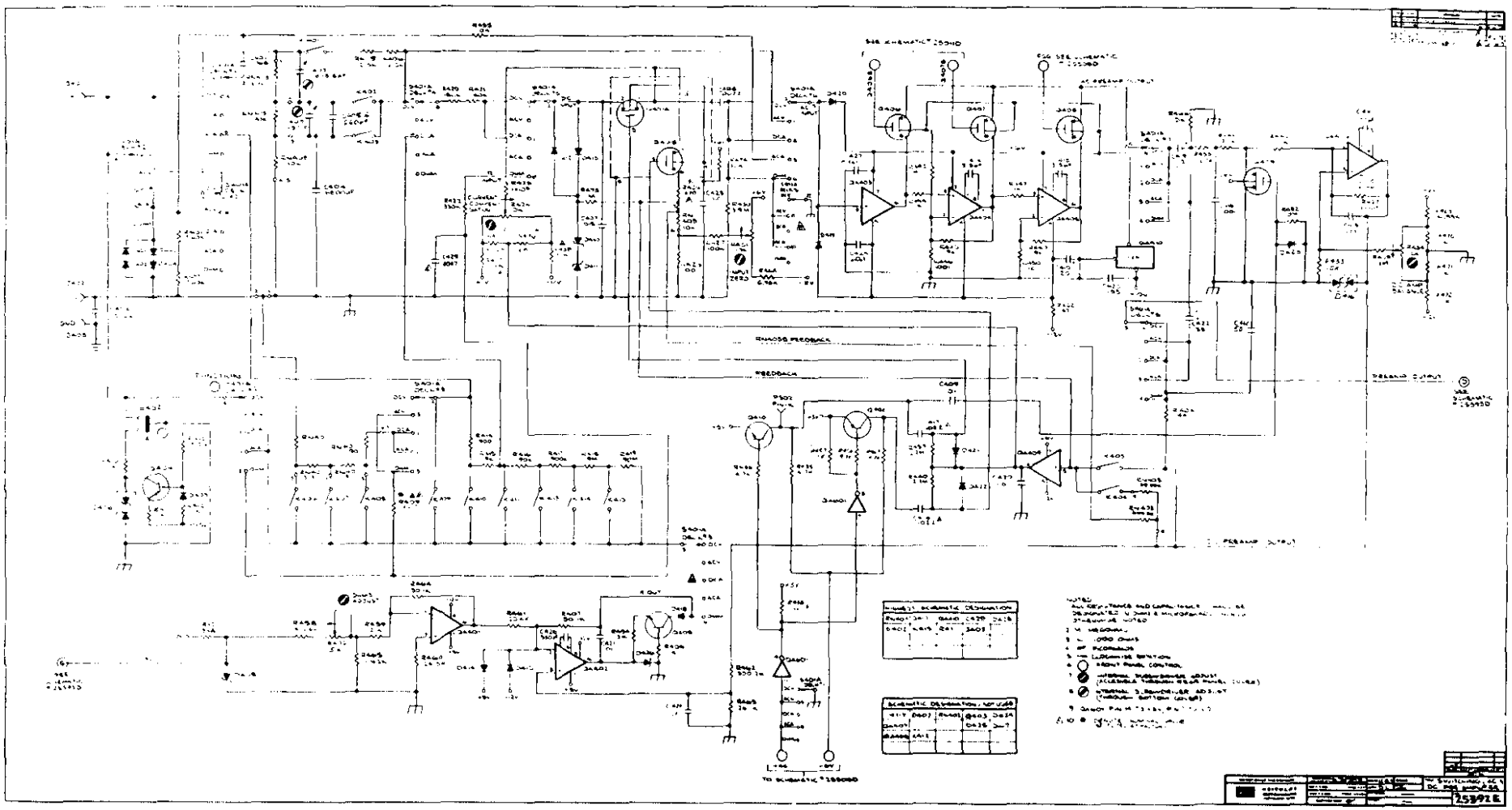
Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R601	Not Used	.....	.....	.....	....
R602	22KΩ, 10%, 1/4W, Comp.	01121	CB-223-10%	R76-22K	2
R603	470Ω, 10%, 1/4W, Comp.	01121	CB-471-10%	R76-470	1
R604	22KΩ, 10%, 1/4W, Comp.	01121	CB-223-10%	R76-22K	2
R605	18KΩ, 10%, 1/4W, Comp.	01121	CB-183-10%	R76-18K	2
R606	18KΩ, 10%, 1/4W, Comp.	01121	CB-183-10%	R76-18K	2

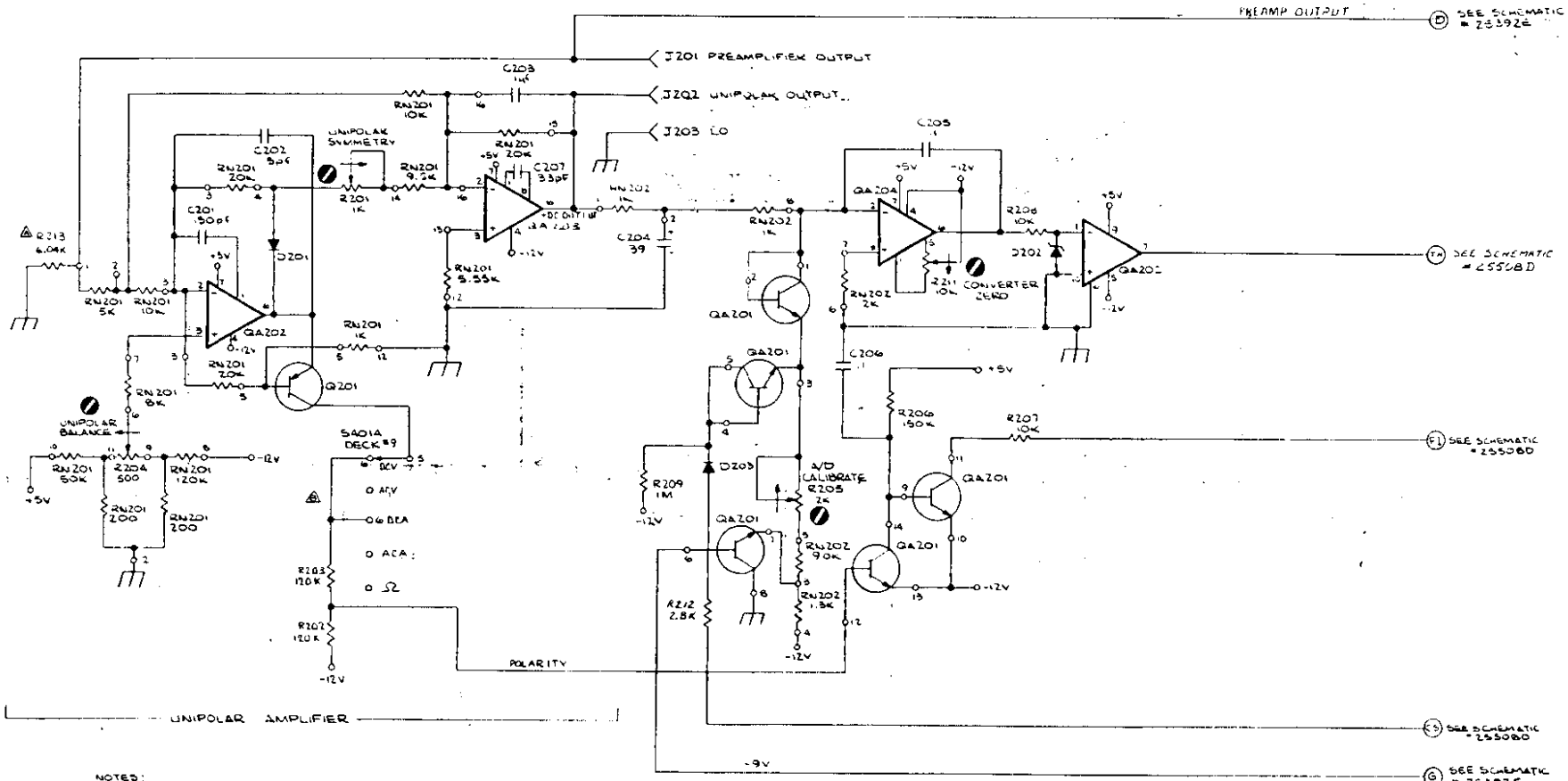
6-7. MECAHNICAL PARTS LIST. Table 6-5 is a list of replaceable mechanical parts for the Model 165 that are not listed elsewhere and include miscellaneous parts. It is recommended that items with Keithley part numbers be obtained from Keithley Instruments, Inc.

TABLE 6-5.
Mechanical Parts List

Description	Quantity Required	Keithley Part No.
Bracket, Rear Panel, holds PC-318	1	BR-18
Screw, Phillips, Pan Hd., 4-40 x 5/16"	1	-----
Kep Nut, 4-40	1	-----
Lug, Solder	1	LU-2
Connector, Male, Line (Mains)	1	CS-254
Screw, Phillips, Pan Hd., 4-40 x 5/16"	2	-----
Fuse Holder, for F301	1	FH-11
Hardware for PC-313, Logic Board:		
Screw, Phillips, Pan Hd., Self Tap, 2-56 x 1/4"	2	-----
Hardware for PC-319, Readout Board:		
Screw, Phillips, Pan Hd., 4-40 x 5/8"	1	-----
Heat Sink, for QA-301 Integrated Circuit	1	HS-11
Hole Plugs, Plastic, for Bottom-Cover access holes to C402 and C403	2	HP-18
Jumper, Dunny Resistor, for PC-318	1	J-3
Line (Mains) Power Cord Set	1	CO-7
Mounting Kit, for Q405 Transistor	1	MK-6
Mounting Nut, for S402	1	FA-59
Plate, Cover, Calibration Access	1	25348A
Screw, Slotted, Round Hd., 2-56 x 1/4"	2	-----
Plate, Cover (non-access)	1	25388A
Screw, Phillips, 4-40 x 1/4"	2	-----
Kep Nut, 4-40	2	-----
Readout Block, Film Overlay	1	25544A
Readout Block, Function (less overlay)	1	25338B
Readout Display, Window, Front Panel	1	25527A
Shorting Link, Input	1	BP-6
Socket, for DN103, DN104, DN105, DN106 LED Readout Dispalys	4	SO-70
Socket, 28-Pin, for QA501, QA502 Integrated Circuits	2	SO-69
Spacer, Front Panel and PC-Board	1	25358A
Washer, Brass, for J403	1	WA-58
Washer, for D401, D402, D403, D404 Rectifiers	4	WA-2
Washer, for S402	1	WA-65


INPUT NETWORK & SWITCHING 25392E
AC & DC PRE AMPLIFIERS & CHOPPERS 25392E
UNIPOLAR AMPLIFIER & AC CONVERTER 25393D
A/D 25393D
CLOCK 25508D
LSI CONVERTER CHIP 25508D
DISPLAY 25394E
OHMS CIRCUIT 25392E
RELAYS 25392E 25511D
RELAY DRIVER 25511D
LSI DECODER CHIP 25508D
HI
LO
GND
2mA
1mA
FOG
KEITHLEY INSTRUMENTS
25395D



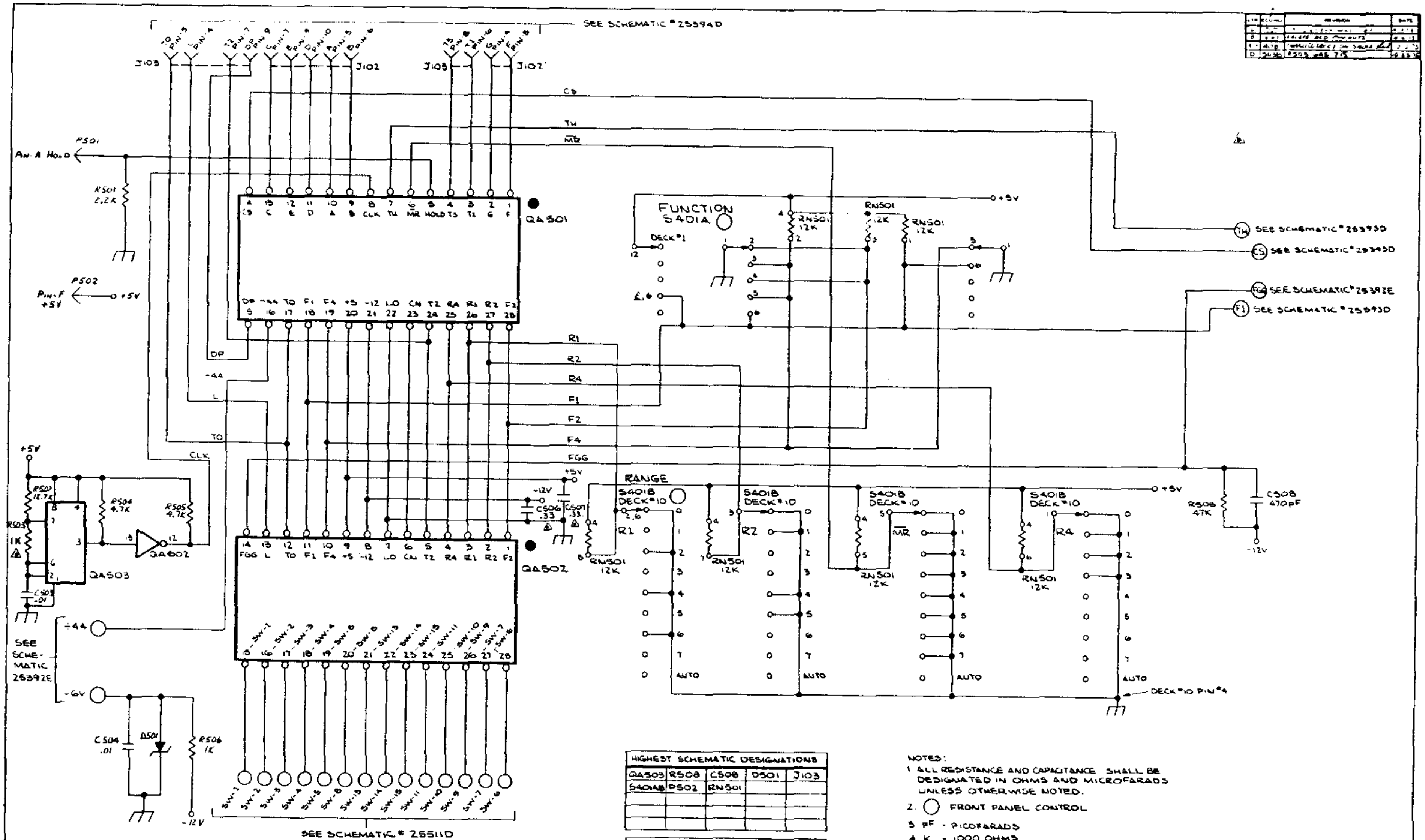


NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. INTERNAL SCREWDRIVER ADJ.
3. K - 1000 OHMS
4. pf - PICOFARADS
5. CLOCKWISE ROTATION

SCHEMATIC DESIGNATIONS NOT USED					
R210	Q202				

HIGHEST SCHEMATIC DESIGNATIONS					
J203	Q201	QA205	C206	D203	RN202
R213		5401			

UNIPOLAR AMPLIFIER
A-D CONVERTER
KEITHLEY INSTRUMENTS
25393D



NOTES:
1. ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICROFARADS UNLESS OTHERWISE NOTED.
2. ○ FRONT PANEL CONTROL
3. pF - PICOFARADS
4. K - 1000 OHMS

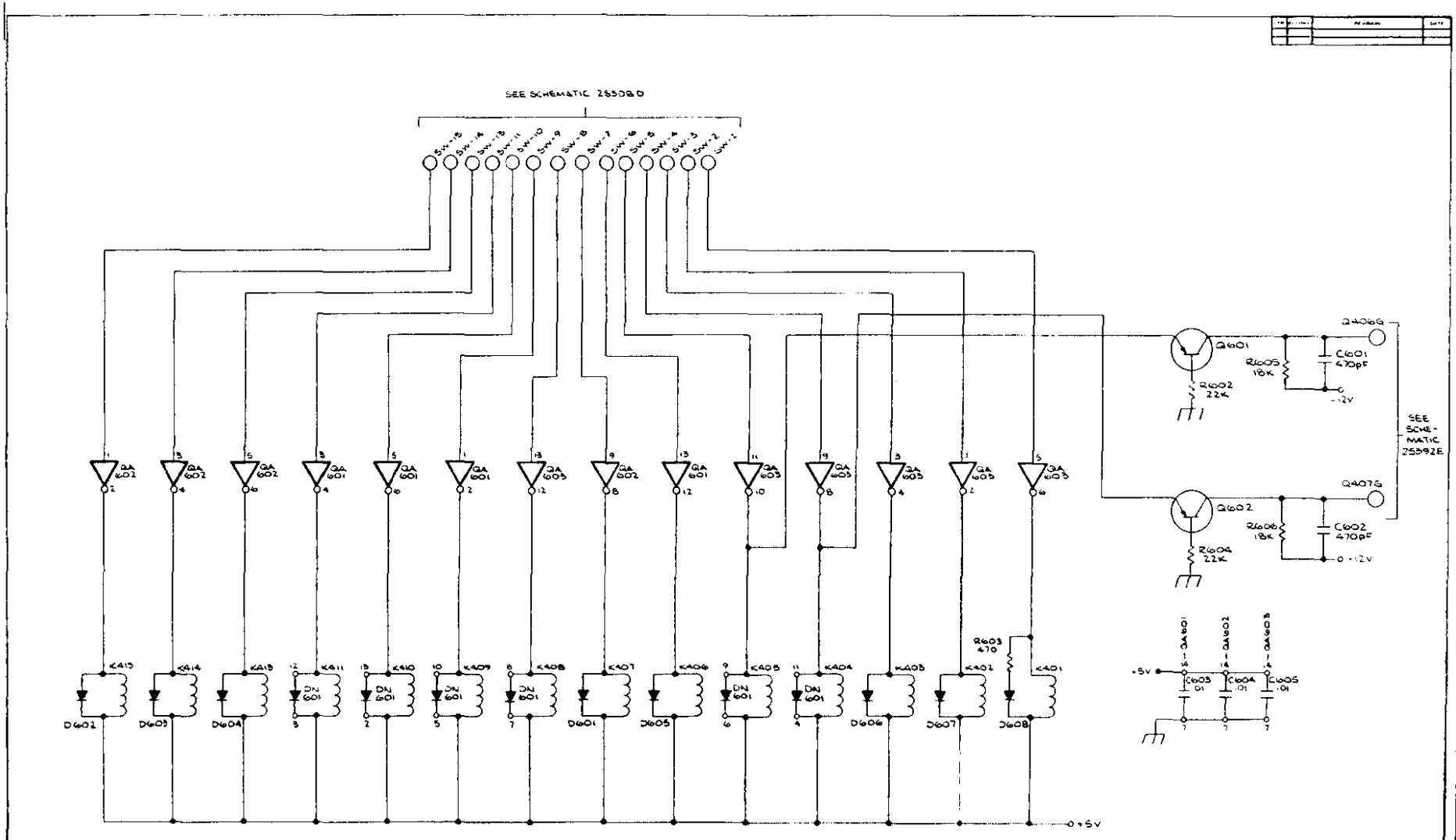
HIGHEST SCHEMATIC DESIGNATIONS				
QA503	R508	C508	D501	J103
S401A/B	P502	RN501		

SCHEMATIC DESIGNATIONS NOT USED				
C501	R507		C505	C502

KEITHLEY INSTRUMENTS

TITLE LOGIC, CLOCK AND SWITCHING SCH

25508D



HIGHEST SCHEMATIC DESIGNATIONS				
D608	DN601	K415	Q3A603	R606
Q602	C605			

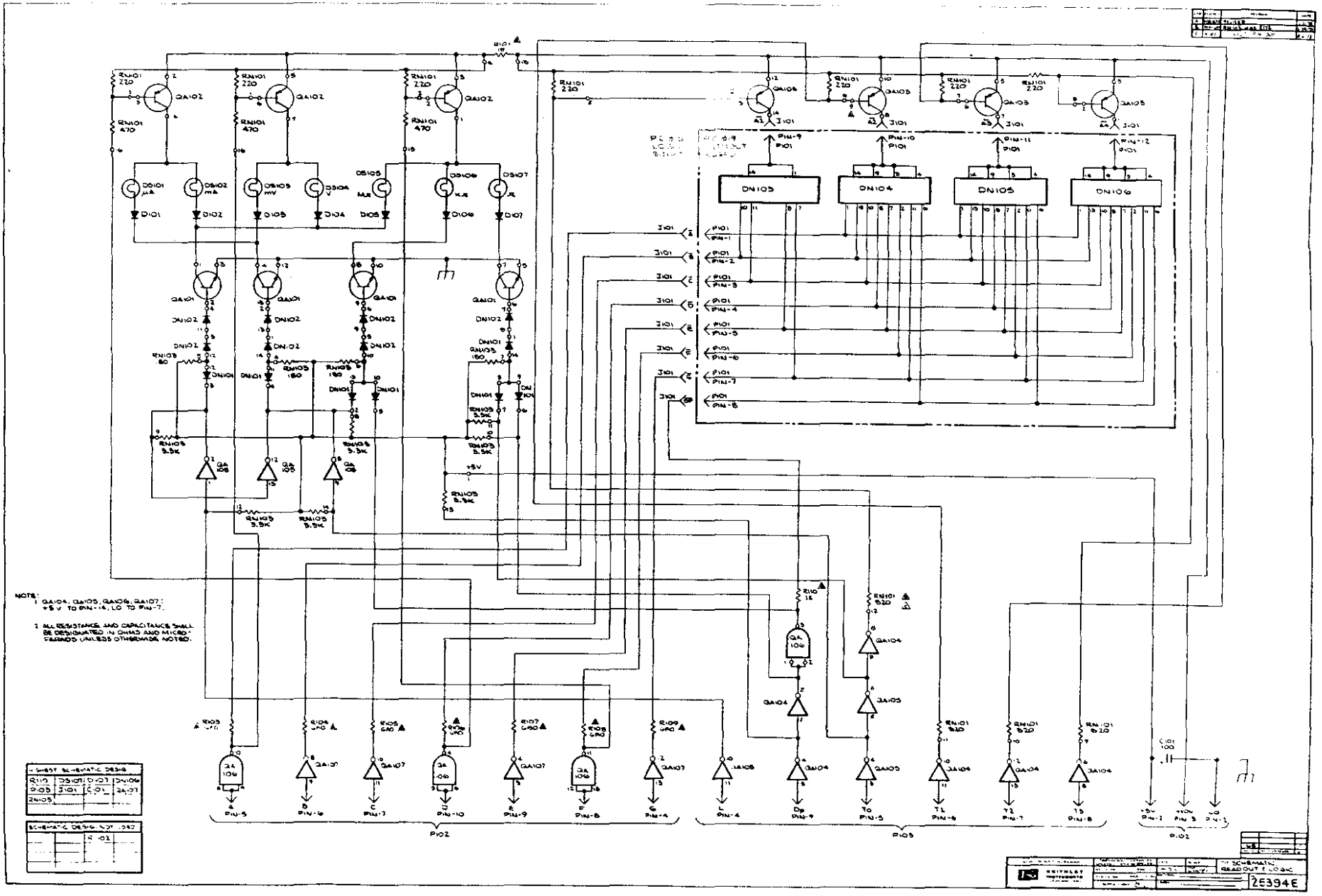
SCHEMATIC DESIGNATIONS NOT USED				
K412		R601		

NOTE:
- K - 1000 OHMS
- PF - PICOFARADS

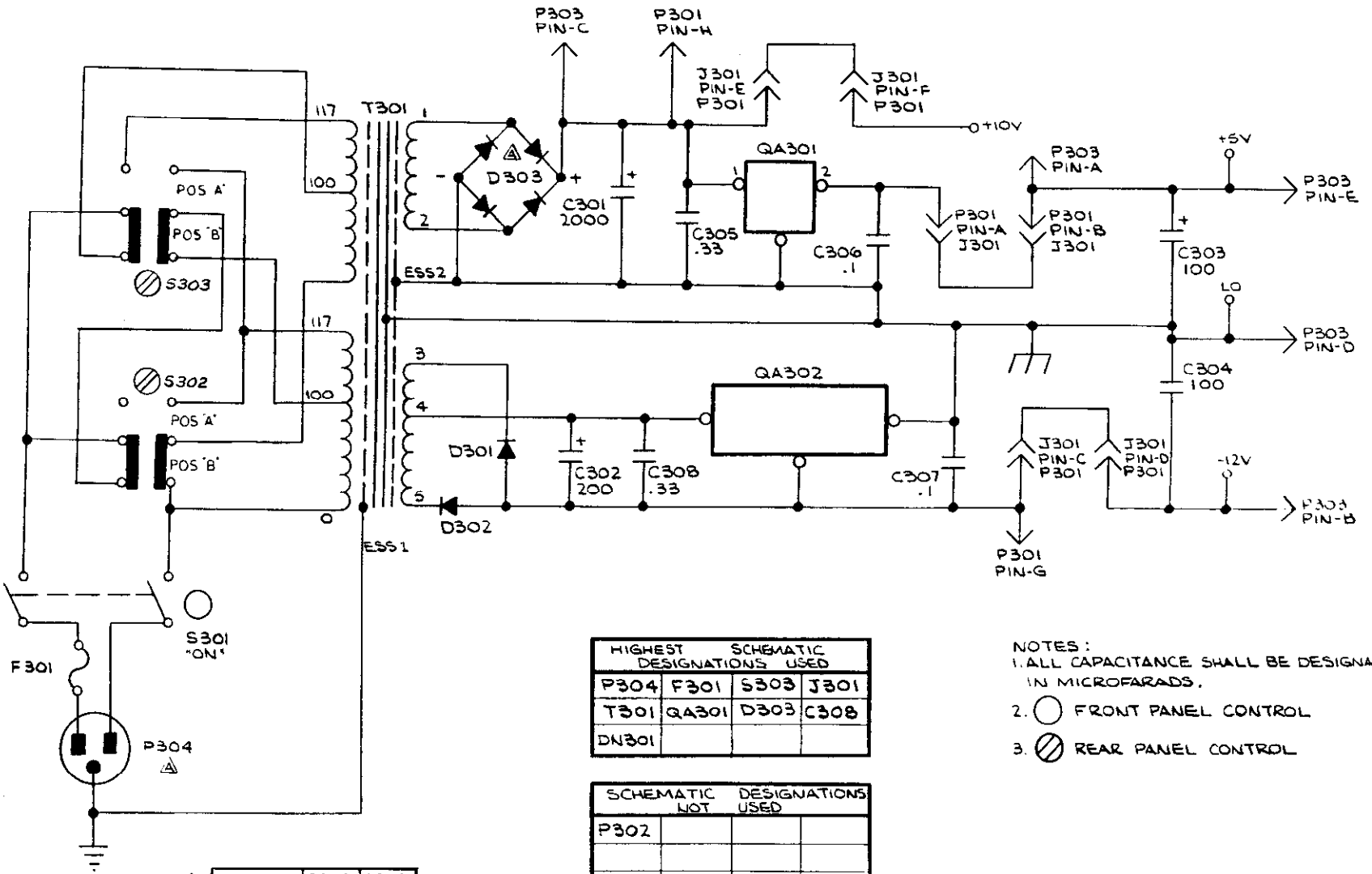
KEITHLEY INSTRUMENTS

RELAYS & DRIVERS

25511D


DN105
DN104
DN105
DN106
P101
P102
P103
+5V
GND
NOTE:
1 QA104, QA105, QA106, QA107: +5 V TO PIN-16, LG TO PIN-7.
2 ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICRO-FARADS UNLESS OTHERWISE NOTED.
SCHEMATIC DIAGRAM
SCHEMATIC DIAGRAM NOT USED
25394E

LTR	ECN #	REVISION	DATE
A	(MINI)	D303 AND D301 - P304 WAS P301	6-7-77
B	4141	SEE ECO	6-6-77



HIGHEST SCHEMATIC DESIGNATIONS USED			
P304	F301	S303	J301
T301	QA301	D303	C308
DN301			

SCHEMATIC DESIGNATIONS NOT USED			
P302			

NOTES:
1. ALL CAPACITANCE SHALL BE DESIGNATED IN MICROFARADS.
2. ○ FRONT PANEL CONTROL
3. ⊘ REAR PANEL CONTROL

⚠

VOLTS	S303 POS	S302 POS
90-110	B	B
105-125	A	B
195-235	B	A
210-250	A	A

MODEL	NEXT ASSEMBLY	QTY
163		
USED ON		

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .015 ANG = ± 1° XXX = ± .005 FRAC = ± 1/64 SURFACE MAX 63

DATE 7-5-77 DRN D.L. ENG APPR

SCALE

MATERIAL

FINISH

TITLE POWER SUPPLY

NO 25391C