INSTRUCTION MANUAL

MODEL 168

AUTORANGING DMM

KEITHLEY INSTRUMENTS, INC.

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ILLUSTRATIONS

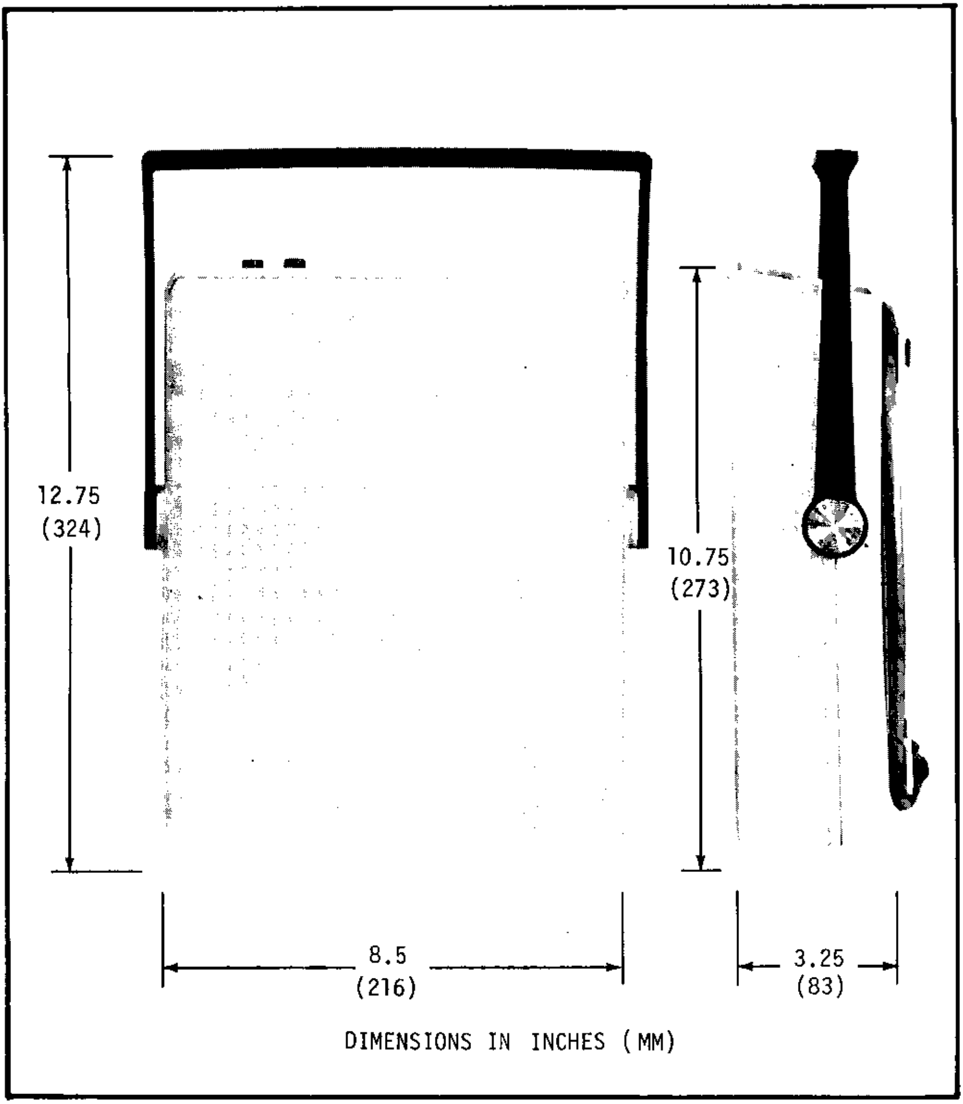


FIGURE 1. Dimensional Data.

SPECIFICATIONS

calibrated at 23° ±3°C.

AS AN AUTORANGING DC VOLTMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng)	
0.1V	.1999	0.1%	0.1%
1V	1.999	0.1%	0.1%
10V	19.99	0.1%	0.1%
100V	199.9	0.1%	0.1%
1000V	1000.	0.1%	0.1%

TEMPERATURE COEFFICIENT: ± (0.02% of reading + 0.01% of range) / °C.

INPUT RESISTANCE: 10 megohms.

NMRR: Greater than 75 dB over one digit 50 Hz to 20kHz, up to 300V p-p, with at least 1 mV dc applied.

CMRR (1kΩ unbalance): Greater than 140 dB at dc, 120 dB, 20 Hz to 20kHz (Lo driven).

AS AN AUTORANGING AC VOLTMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng)		FREQUENCY RANGE
0.1V	.1999	0.5%	0.3%	20Hz — 5KHz
1V	1.999	0.5%	0.3%	20Hz — 10kHz
10V	19.99	0.5%	0.3%	20Hz — 10kHz
100V	199.9	0.5%	0.3%	20Hz — 10kHz
1000V	500	2%	0.3%	20Hz — 5kHz

TEMPERATURE COEFFICIENT: ± (0.04% of reading + 0.01% of range) / °C.

INPUT IMPEDANCE: 9 megohms shunted by less than 90 picofarads.

CMRR (1kΩ unbalance): Greater than 100 dB dc to 65 Hz, 90 dB to 20kHz (Lo driven).

AS AN AUTORANGING OHMMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng) HI — mode — LO				VOLTAGE ACROSS UNKNOWN* @ 1100 digits HI — mode — LO		CURRENT IN UNKNOWN HI — mode — LO	
0.1kΩ	.1999	—	—	0.2%	0.2%	—	0.1V	—	1mA
1kΩ	1.999	0.2%	0.1%	0.2%	0.2%	1V	0.1V	1mA	100μA
10kΩ	19.99	0.2%	0.1%	0.2%	0.2%	1V	0.1V	100μA	10μA
100kΩ	199.9	0.2%	0.1%	0.2%	0.2%	1V	0.1V	10μA	1μA
1MΩ	1.999	0.2%	0.1%	0.2%	0.2%	1V	0.1V	1μA	0.1μA
10MΩ	19.99	0.2%	0.1%	—	—	1V	—	0.1μA	—

*6volts maximum in series with 9MΩ into an open circuit.

TEMPERATURE COEFFICIENT: ± (0.04% of reading + 0.01% of range) / °C.

AS AN AC AND DC AMMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng) DC — mode — AC*				SHUNT RESISTANCE	FUSE PROTECTION
0.1mA	.1999	0.3%	0.1%	1%	0.3%	1.2kΩ	10mA
1mA	1.999	0.3%	0.1%	1%	0.3%	1.2kΩ	10mA
0.1 A	.1999	0.3%	0.1%	1%	0.3%	1.1 Ω	2 A
1 A	1.000	0.3%	0.1%	1%	0.3%	1.1 Ω	2 A

*30 Hz to 5 kHz.

TEMPERATURE COEFFICIENT:

DC ± (0.03% of reading + 0.01% of range) / °C.
AC ± (0.05% of reading + 0.01% of range) / °C.

GENERAL

ZERO STABILITY: ± 0.05% of range / °C (adjustable to zero with front panel control).

READING TIME: 3 seconds to within 0.1% of final reading including range changing.

DISPLAY: 3½ digits, appropriate decimal position, function and polarity indication. Upranges at 2000, downranges at 0189; five readings per second.

ISOLATION: Input LO to power line ground, greater than 1000 megohms shunted by less than 300 picofarads. Maximum safe input between LO and power line ground, 1200 volts peak.

POLARITY: Automatic.

RANGING: Automatic on each span.

OVERLOAD INDICATION: Display blinks when beyond specified maximum except on current ranges.

MAXIMUM ALLOWABLE INPUT: Electronically protected to ± 1200 volts (dc plus peak ac) on voltage ranges, 250V rms sine wave or dc on ohms. Fuse protected on current ranges.

ENVIRONMENT:

Operating: 0°C to 50°C.
0% to 70% relative humidity up to 35°C.
Storage: −25°C to +65°C.

POWER: 90-110, 105-125, 195-235 or 210-250 volts (switch selected), 50-60 Hz; 6 watts. Optional rechargeable 6-hour battery pack.

CONNECTORS: Binding Posts.

DIMENSIONS, WEIGHT: 3½ in. high x 9¼ in. wide x 10¾ in. deep (85 x 235 x 275 mm). Net weight, exclusive of batteries, 3½ pounds (1,6 kg).

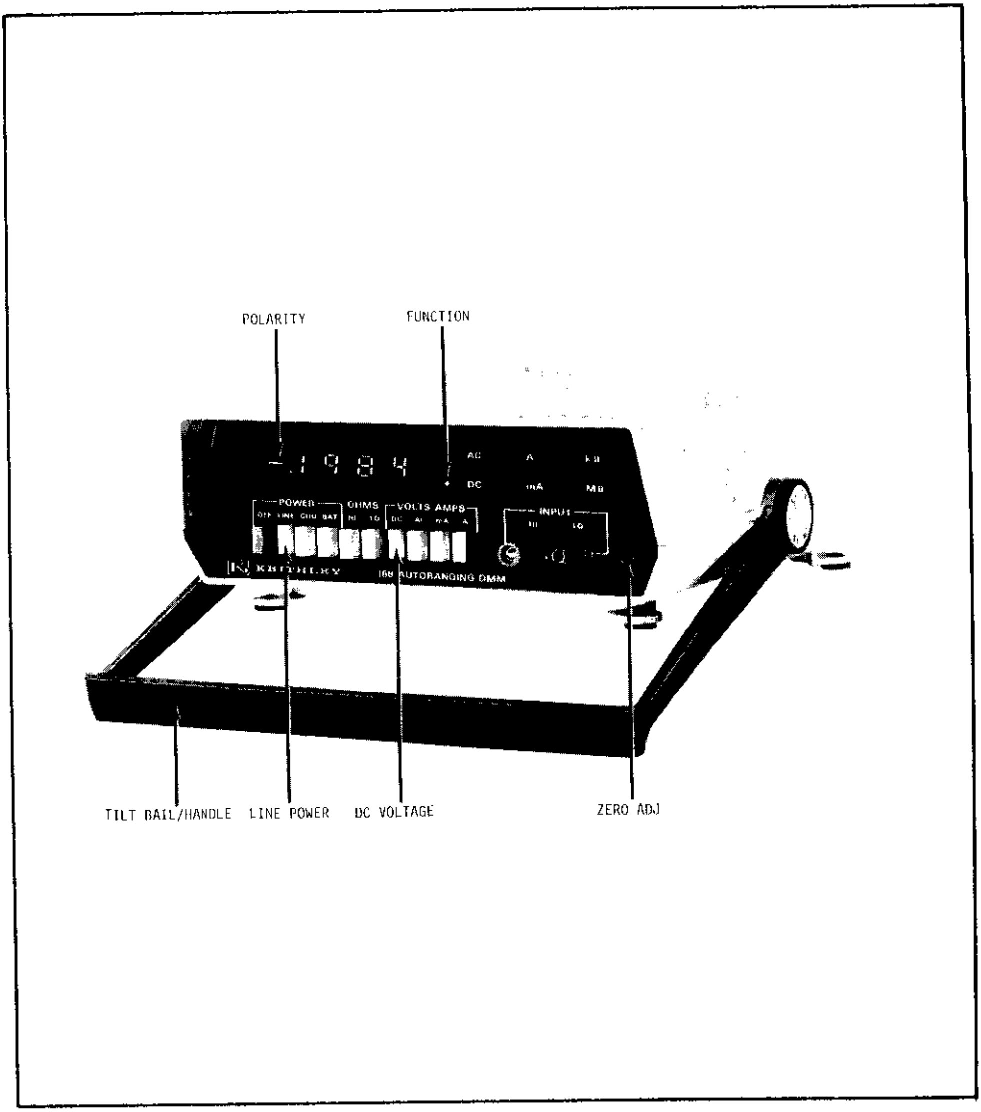


FIGURE 2. Front Panel

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 168 is a versatile autoranging digital multimeter useful for measurement of ac and dc voltage, ac and dc current, and resistance. Voltage measurements can be made from ±.0001 volt to ±1000 volts dc or .0001 volt to 500 volts ac. Current measurements can be made from .0001 milliampere to 1 ampere ac and dc in two spans. Resistance measurements can be made from 0.1 ohm to 20 megohms in two overlapping spans. Range and polarity is automatically selected. In addition to the display of digits, the 168 indicates decimal point, function (AC or DC), and measurement unit (mA, A, kΩ, MΩ).

1-2. WARRANTY INFORMATION. The Warranty is given on the inside front cover of this Instruction Manual. If there is a need to exercise the Warranty, contact the Keithley Representative in your area to determine the proper action to be taken. Keithley maintains service facilities in England, West Germany, as well as in the United States. Check the inside front cover of this Instruction Manual for addresses.

1-3. CHANGE NOTICES. Improvements or changes to the instrument which occur after printing of the Instruction Manual will be explained on a Change Notice sheet attached to the inside back cover.

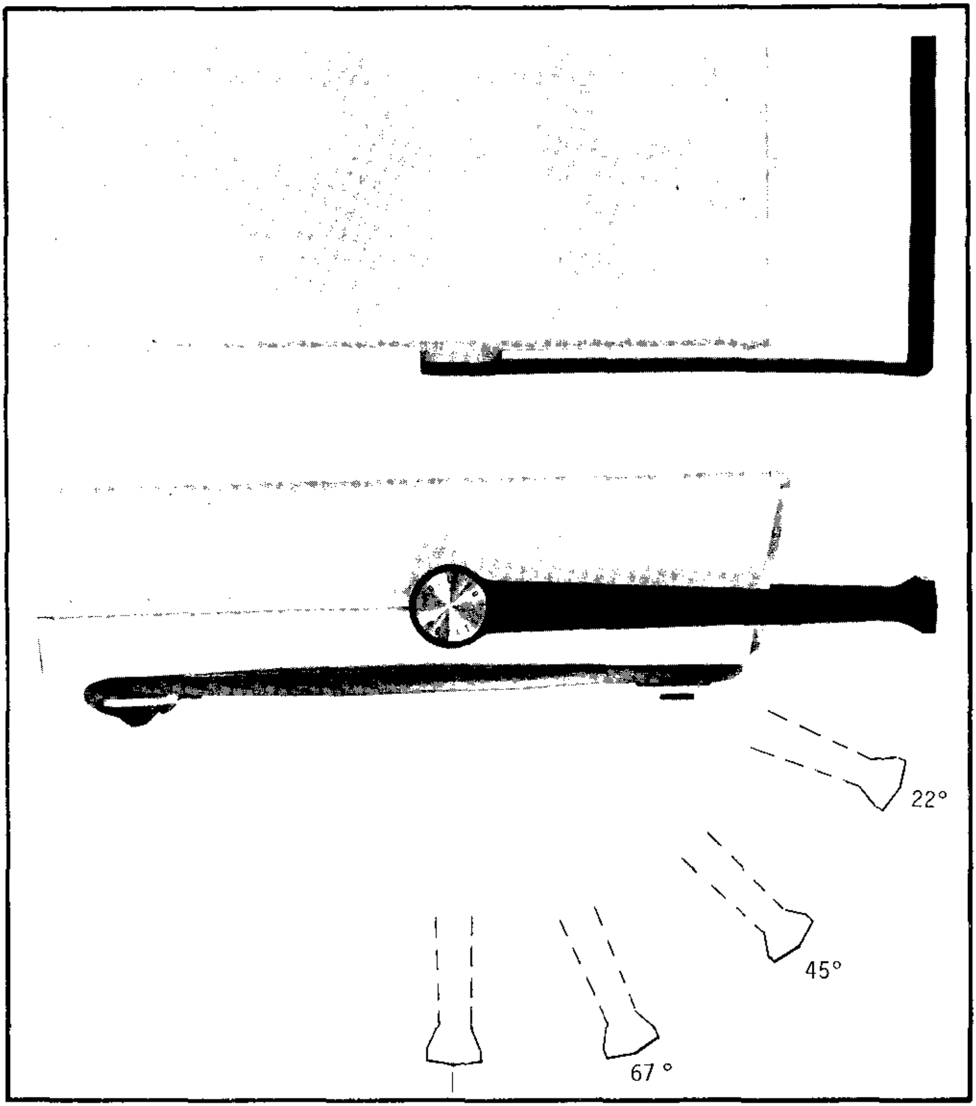


FIGURE 3. Tilt Bail Positions.

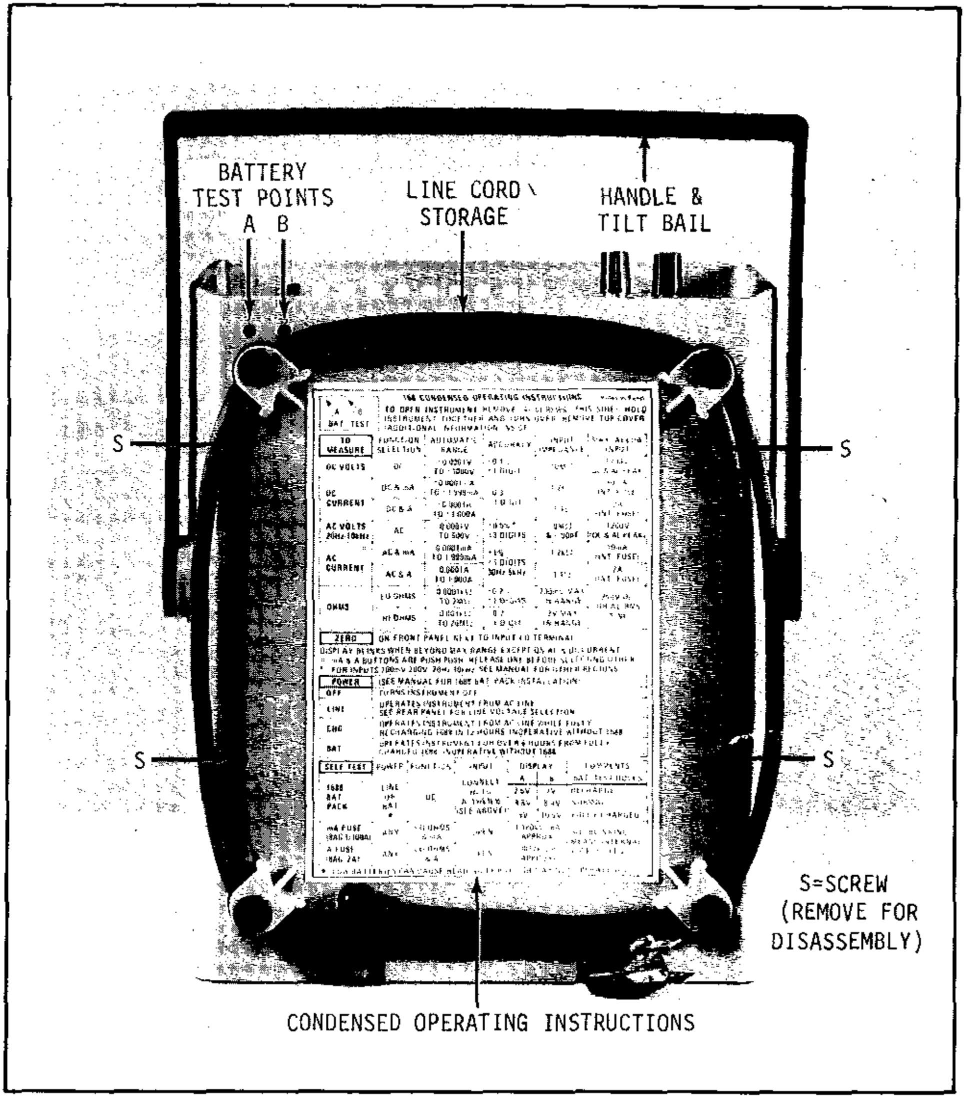
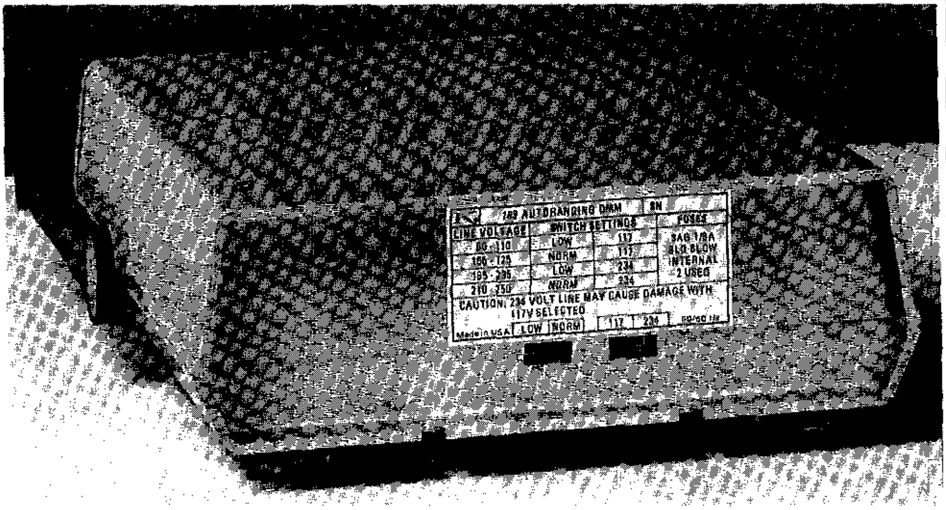


FIGURE 4. Bottom View Showing Line Cord.



K	168 AUTORANGING DMM		SN
LINE VOLTAGE	SWITCH SETTINGS		FUSES
90 - 110	LOW	117	3AG 1/8A SLO-BLOW INTERNAL 2 USED
105 - 125	NORM	117	
195 - 235	LOW	234	
210 - 250	NORM	234	
CAUTION: 234 VOLT LINE MAY CAUSE DAMAGE WITH 117V SELECTED.			
Made in USA LOW NORM	117 234		50/60 Hz

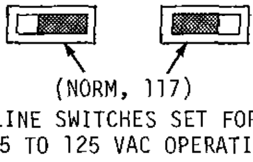


FIGURE 5. Rear View Showing Line Switches.

SECTION 2. INITIAL PREPARATION

2-1. GENERAL. This section provides information needed for incoming inspection and preparation for use.

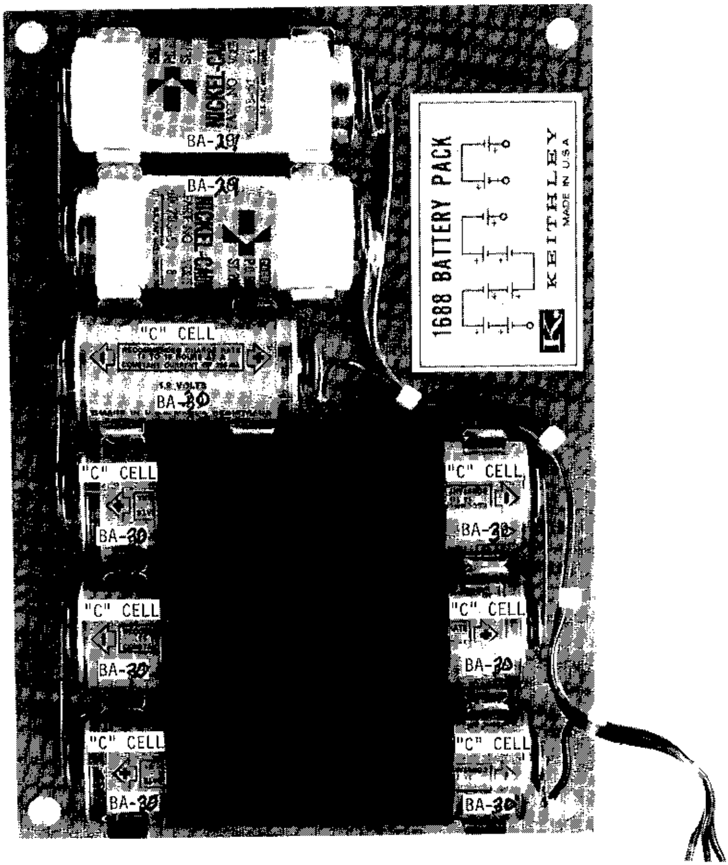
2-2. INSPECTION. The Model 168 was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures given in Section 5.

2-3. PREPARATION FOR USE. The Model 168 is shipped ready-to-use. The instrument may be powered from line voltage or from rechargeable nickel-cadmium batteries (when the optional Model 1688 Rechargeable Battery Set is installed).

a. How to Operate From Line Power. The Model 168 provides a three-wire line cord which mates with third-wire grounded receptacles. The permanently installed line cord is stored by wrapping the cord around the base of the instrument as shown in Figure 4.

1. How to Set Line Switches. The Model 168 has two rear panel line switches which are used to select line voltage ranges of 90-110V, 105-125V, 195-235V, or 210-250V. The line switches are identified as 117/234V (S102) and LOW/NORM (S101). Once the line voltage to be used has been determined, then the line voltage range should be selected from the four ranges available on the Model 168. For example, when the line voltage to be used is within the range from 105 to 125 volts, then the line switches should be set to "117V" and "NORM" positions. If the line voltage to be used is within either of two overlapping ranges, such as 107 volts, then either range may be selected (117V, LOW or 117V, NORM, for this particular example). Line voltages which are not covered by anyone of the four ranges are not useable. After the line voltage switches are set, connect the line cord and depress the LINE pushbutton to operate.

2. Line Fuse Requirements. The Model 168 requires two line fuses to protect the line-operated power supply. The fuse types are 1/8 ampere, 3AG slo-blo. Replacement instructions are given in Section 5.



J103

FIGURE 6. Model 1688 Rechargeable Battery Pack.

b. How to Operate From Battery Power. (Model 1688 Rechargeable Battery Set). The Model 168 may be operated from rechargeable nickel-cadmium batteries when the optional Model 1688 Rechargeable Battery Set is installed. The Model 1688 may be field installed at any time or may be ordered factory installed. The Rechargeable Battery Set includes a battery pack which mounts within the Model 168. Wiring is accomplished by a single plug-in connector. Battery operation from fully-charged NI-CAD batteries is typically 6 hours.

1. How to Install Model 1688 Rechargeable Battery Set. The batteries furnished with the Model 1688 come already installed in the battery pack. The battery pack includes 7 rechargeable "C" cells (1.2V, 2 AMP HR) and 2 rechargeable "button" cells (8.4V, .225 AMP HR). If batteries need to be replaced or re-installed, be certain to observe the proper polarity of individual cells as shown in Figure 6. To install the Model 1688 Battery Pack, turn the instrument over so that the bottom cover faces up. Remove four slotted screws on the bottom cover as shown in Figure 4. (A chisel-blade screwdriver is required to loosen the slotted screws.) Turn over the instrument with top cover facing up, taking care to hold the top and bottom covers together. Remove the top cover to gain access to the printed circuit board. Check to see that the four insulating standoffs are in position on the printed circuit board. Place the Model 1688 Battery Pack in position on the standoffs with the cable oriented as shown in Figure 8. Plug the 4-wire connector (J103) into the mating receptacle (P103) taking care to orient the connector as shown in Figure 8. After the Battery Pack is installed, replace the top cover. Turn over the instrument with bottom cover facing up and install the four slotted-head screws.

TABLE 2-1.
Summary of Batteries Used in Model 1688.

Description	Quantity	Keithley Part No.
Rechargeable "C" cell, 1.2V, 4 AMP-HR	7	BA-30
Rechargeable "Button" type battery, 8.4V, .225 AMP-HR (4 individual 1.2V cells)	2	BA-29

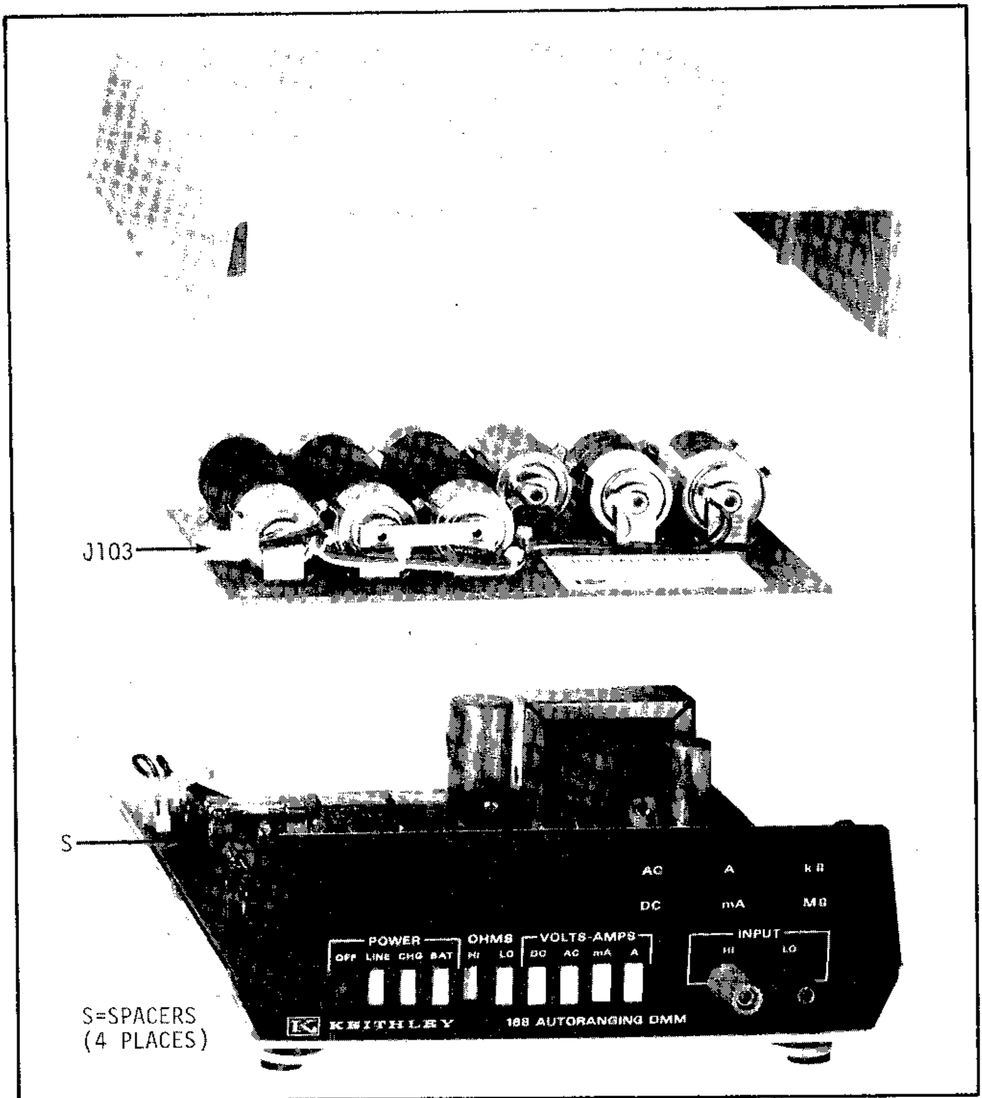


FIGURE 7. Exploded View of Model 168 with Model 1688.

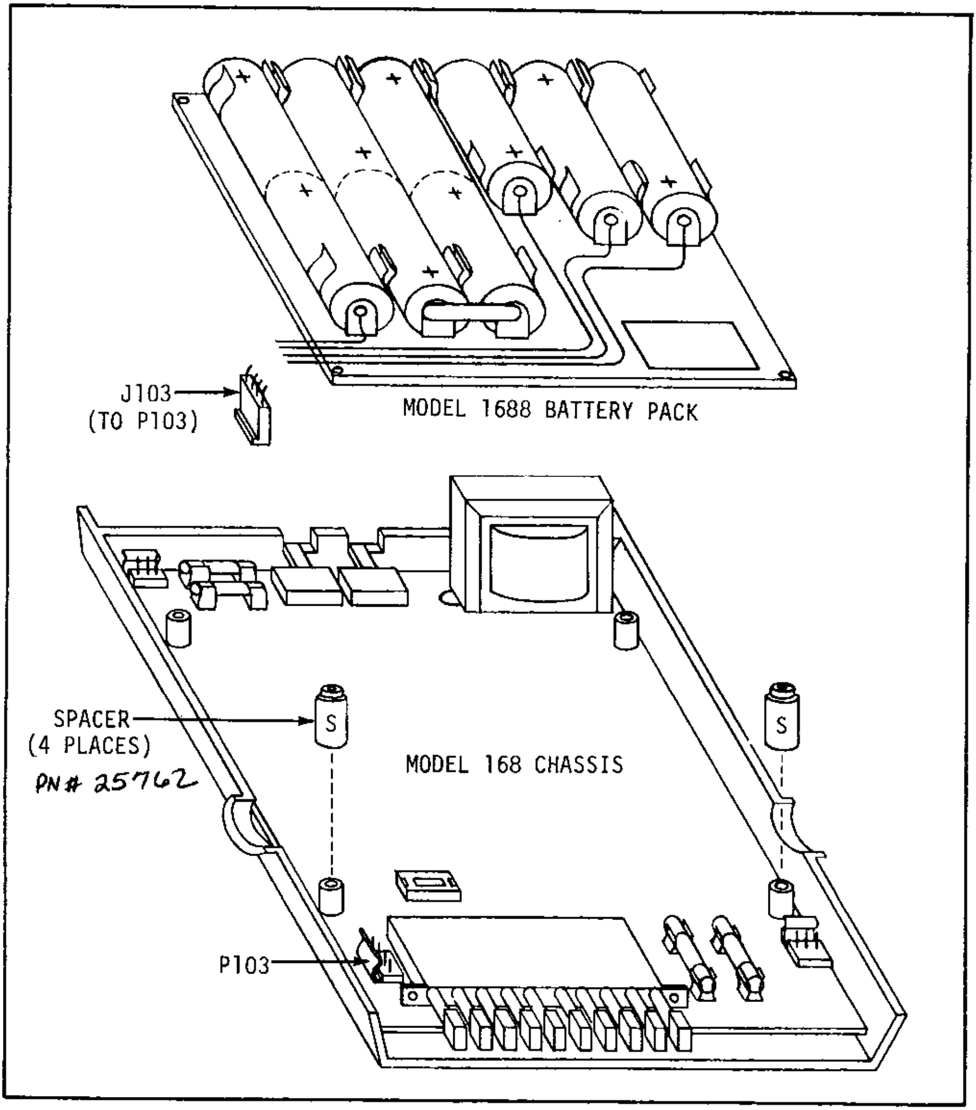


FIGURE 8. Installation of Battery Pack.

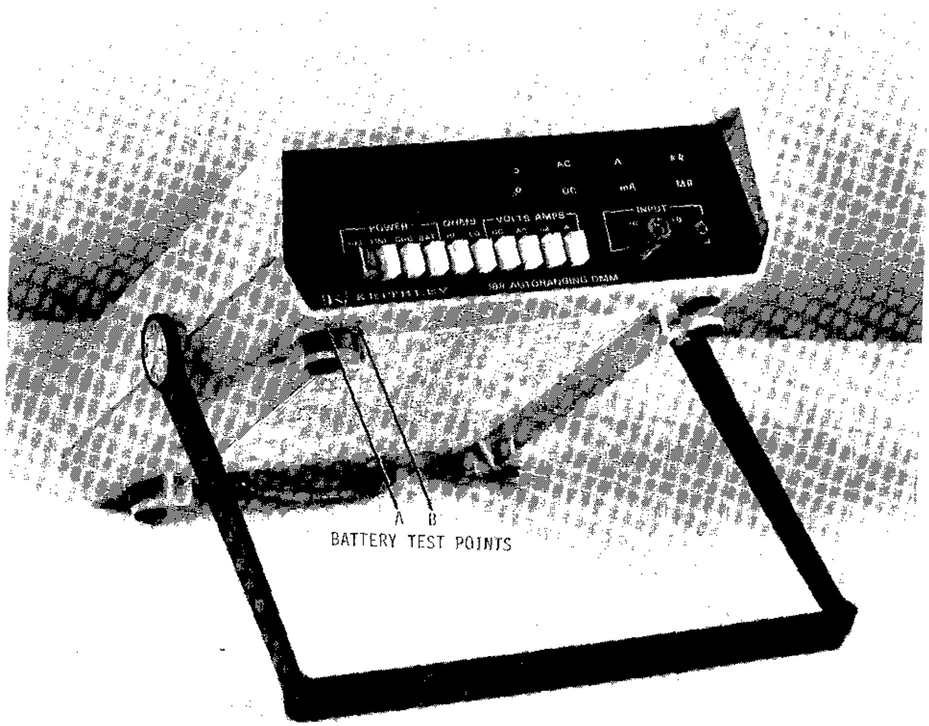


FIGURE 9. Battery Test Location.

2. How to Check Batteries. (Valid only in BAT mode). The Model 168 provides two test points (A and B) located on the bottom of the instrument as shown in Figure 9. These test points permit a convenient check of the condition of the internal Battery Pack without need to remove the Model 168 cover. The voltage at test points A or B may be measured using the Model 168 or any other comparable voltage measuring instrument. To check the voltages at test points A or B, select the BAT mode, connect the HI terminal of the Model 168 (for a self check) or other voltmeter to test points A or B and observe the measured voltage. (If a separate voltmeter is used, it is necessary to make a connection to the LO terminal of the Model 168 since both points A and B are to be referenced to circuit low.) Table 2-2 gives the battery voltages required at each test point.

IMPORTANT

The instrument must be operated in the BAT mode in order to obtain a valid battery condition at test points A and B. This will ensure that the batteries are supplying power to the instrument. If the voltages are measured when the Model 168 is operated in the LINE mode a different reading may be observed since the batteries are not connected and therefore do not supply power to the instrument.

TABLE 2-2.
Summary of Battery Voltage Levels (BAT mode)

Test Point	Acceptable Battery Levels Range	Normal	Recharge if below	Batteries Tested
A	2.5V - 9V	4.8V	2.5V	BA-29
B	7V - 10.5V	8.4V	7V	BA-30

3. How to Charge Batteries. The Model 168 provides built-in recharging circuitry for recharging the Model 1688 Battery Pack. To recharge the internal batteries, connect the Model 168 to line power and depress the CHG pushbutton. Recharging time is dependent on the condition of the batteries at the time of recharge. Typically, the recharge time is 1-1/2 hours per hour of discharge (or 9 hours of charging time for every 6 hours of operating time in the battery mode).

NOTE

The Model 168 may be operated while in the CHG mode. However, if the Battery Pack is not installed, the Model 168 will not be operable when the CHG mode is selected since the batteries are connected in series with the line power supply.

SECTION 3. OPERATING INSTRUCTIONS

3-1. GENERAL. This section provides information needed to operate the Model 168 for measurement of voltage, current, and resistance.

3-2. HOW TO SELECT POWER. The Model 168 may be powered from line voltage or rechargeable nickel-cadmium batteries (when the Model 1688 is installed). The Model 168 has a built-in line-voltage power supply and line cord. If the accessory Model 1688 Rechargeable Battery Set is ordered and installed, then the user has the option of selecting line or battery operation via the front panel pushbuttons labeled LINE and BAT.

NOTE

The accessory Model 1688 Rechargeable Battery Set may be ordered at the time of purchase of the Model 168 or may be purchased and field installed at a later time if so desired. The Model 1688 features plug-in wiring. As a result, no modifications need to be made to the Model 168 chassis.

a. How to Operate From Line Power. The Model 168 is operable over four ranges of line voltage from a minimum of 90 volts to a maximum of 250 volts, rms, 50-60 Hz. The line voltage ranges are 90-110V, 105-125V, 195-235V, and 210-250V.

TABLE 3-1.
Summary of Line Voltage Switch Settings

Rear Panel Line Switches	Line Voltage Ranges - Volts, rms, 50-60Hz			
	90-110	105-125	195-235	210-250
117/234V Switch (S102)	117	117	234	234
LOW/NORM Switch (S101)	LOW	NORM	LOW	NORM

b. How to Operate From Battery Power. The Model 168 may be used with the optional accessory Model 1688 Rechargeable Battery Set to provide portable operation in addition to line operation. To operate from battery power, depress the BAT pushbutton. Check the battery voltage at test points A and B to ensure that batteries are charged sufficiently.

Refer to Section 2-3b for instructions concerning installation of the Battery Pack, battery voltage checks, and recharging. Battery operation from fully charged NI-CAD batteries is 6 hours minimum. No fuses are required for operation in battery mode.

TABLE 3-2.
Summary of Battery Voltage Levels (BAT mode)

Test Point	Acceptable Battery Levels		Recharge if below	Batteries Tested
	Range	Normal		
A	2.5V - 9V	4.8V	2.5V	BA-29
B	7V - 10.5V	8.4V	7V	BA-30

TABLE 3-3.
Summary of Operation in LINE, CHG, and BAT Modes.

Pushbutton Depressed	Condition of Instrument: Line connected 1688 not installed	Line connected 1688 installed	Line not-connected 1688 installed
OFF	OFF	OFF	OFF
LINE	ON	ON	OFF
CHG	OFF	ON	OFF
BAT	OFF	ON	ON

NOTE

The instrument will be turned off if all power pushbuttons are released (all non-depressed). A lock-out feature prohibits selection of two or more pushbuttons at the same time.

3-3. HOW TO MAKE INPUT CONNECTIONS. The Model 168 has two front panel terminals identified as "HI" (red) and "LO" (black). These terminals accomodate banana plugs, alligator clips, spade lugs, bare wires, and other similar input connections. Leads may be fabricated using a good quality copper wire terminated by single banana plugs such as Keithley Part No. BG-5 or dual banana plug such as Keithley Part No. BG-7. Ready-made test leads are also available from Keithley. Accessory Model 1681 Clip-on Test Lead Set includes two 40 inch long leads terminated by a banana plug and spring-loaded clip which easily attaches to wires and terminals on pc boards, etc. Model 1683 Universal Test Lead Kit features interchangeable probe tips for various applications. The Kit includes regular probes, alligator clips, banana plugs, spade lugs, and phone tips.

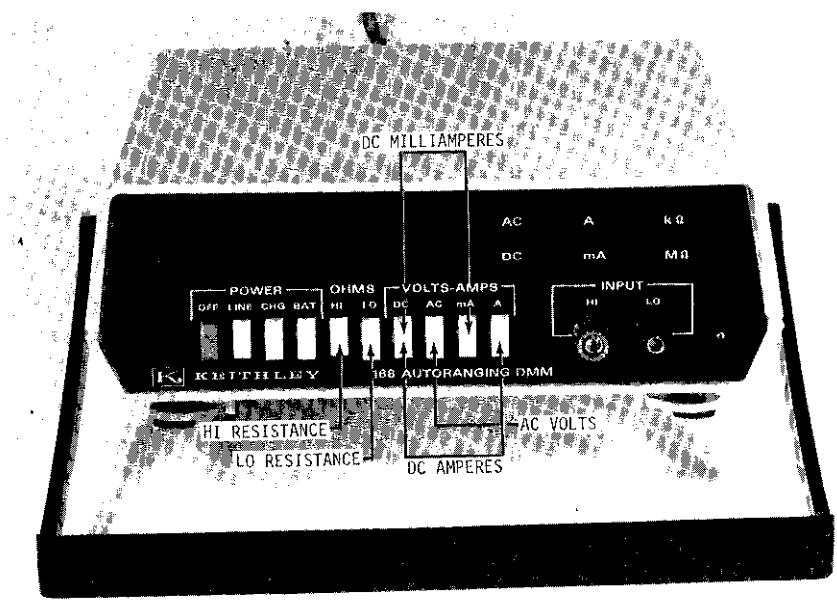


FIGURE 10. Front Panel Function Selection.

3-4. HOW TO SELECT FUNCTION. The front panel pushbuttons are arranged to permit selection of five functions including DC voltage, AC voltage, DC current, AC current, and resistance.

a. DC Voltage. To select DC voltage operation, depress the "DC" pushbutton. Voltage function is implied by the "DC" function indicator.

b. AC Voltage. To select AC voltage operation, depress the "AC" pushbutton. Voltage function is implied by the "AC" function indicator.

c. DC Current. To select DC current operation, depress the "DC" pushbutton. Then select either the "mA" or "A" pushbutton depending on the desired range. The "mA" and "A" pushbuttons are "push-push" type with lock-out, such that one pushbutton must be released before the other can be selected.

d. AC Current. To select AC current operation, depress the "AC" pushbutton. Then select either the "mA" or "A" pushbutton depending on the desired current range. The "mA" and "A" pushbuttons are "push-push" type with lock-out, such that one pushbutton must be released before the other can be selected.

e. Resistance. To select resistance operation, depress either the "LO OHMS" or "HI OHMS" pushbutton depending on the desired resistance range. Either "kΩ" or "MΩ" are displayed depending on range.

NOTE

If all function pushbuttons are released, the input to the Model 168 will be disconnected. A lock-out feature prohibits selection of inconsistent function pushbuttons at the same time.

TABLE 3-4.
Summary of Function Settings

Function Desired	Pushbuttons Depressed					
	Voltage & Current		Current		Resistance	
	DC	AC	mA	A	LO OHMS	HI OHMS
DC Voltage	X					
DC Milliamperes	X		X			
DC Amperes	X			X		
AC Voltage		X				
AC Milliamperes		X	X			
AC Amperes		X		X		
Resistance (LO)					X	
Resistance (HI)						X

3-5. HOW TO MEASURE VOLTAGE. The Model 168 measures ac and dc voltage in five ranges: 0.1V, 1V, 10V, 100V, and 1000V dc or 1000V ac (both ac and dc volts have a maximum input of 1200 volts peak ac + dc). The displayed voltage is direct-reading with decimal point located automatically.

a. DC Voltage. The Model 168 automatically displays voltage from ±.0001 volts dc to ±999 volts dc. Above 999 volts, the display reads properly and flashes to indicate an overrange condition. If the polarity at the HI terminal is negative, the Model 168 display indicates a (-) minus sign. If the minus sign is off, a positive voltage is implied. A lighted "DC" and decimal point are also displayed for all dc measurements.

1. How to Measure DC Voltage. Select the dc function by depressing the "DC" pushbutton. Connect the signal to be measured between HI and LO terminals. Observe the displayed digits, polarity sign, and decimal point location. The lighted "DC" indicates that the dc voltage function has been selected.

2. How to Select Range. The Model 168 automatically selects the appropriate range for all voltage measurements.

3. How to Determine Accuracy. The Model 168 accuracy is ±0.1% of reading ±1 digit. For example, a display reading of 1.000 volts dc will have an uncertainty of ±0.1% ±1 digit or ±.002 volts. The input resistance in the dc mode is 10 megohms. Measurements from relatively high source resistances could cause an additional reading error. The amount of error due to loading can be determined by the following relationship:

$$\%\ \text{error} = 100 \times R_S \div (R_S + 10^7)$$

where R_S = source resistance in ohms.

For example, a source resistance of 10,000 ohms will result in a loading error of approximately 0.1% of reading.

4. How to Determine Maximum Allowable Input. The maximum allowable voltage input is 1200 volts dc + peak ac. The Model 168 displays dc voltages to ±999 volts. Beyond 999 volts the display reads properly and blinks to indicate an overrange condition.

IMPORTANT

The Model 168 provides ac rejection of greater than 75 dB (NMRR). However, a large ac signal superimposed on a dc level could cause damage if the input exceeds 1200 volts dc + peak ac.

5. How to Zero the Display. The Model 168 has a front panel zero adjustment which may be used to zero the display to compensate for zero offset. Apply a short connection between the input terminals or select "A" function and adjust the zero control (screwdriver required) to obtain a .0000 display with the minus (-) polarity flashing on and off.

b. AC Voltage. The Model 168 automatically displays voltage from .0001 volts to 499 volts ac rms. Above 499 volts, the display reads properly and flashes to indicate an overrange condition. In the ac function, the Model 168 operates as an average-reading voltmeter, calibrated in terms of the root-mean-square (rms) of a sine wave. The ac-to-dc converter is a full-wave rectifier type, and as such the calibration is exact for sinusoidal waveforms. The input signal is ac coupled (capacitive) to the input amplifier so that dc is blocked. The input blocking capacitor effectively reduces the Model 168 low-frequency response to approximately 20 Hz.

1. How to Measure AC Voltage. Select the ac function by depressing the "AC" pushbutton. Connect the signal to be measured between HI and LO terminals. Observe the displayed digits, and decimal point location. The lighted "AC" indicates that the ac voltage function has been selected.

2. How to Select Range. The Model 168 automatically selects the appropriate range for a voltage measurement.

3. How to Determine Accuracy. The Model 168 accuracy is ±(0.5% of reading ±0.3% of range). For example, a display reading of 1.000 volts ac will have an uncertainty ±.008 volts over a frequency range from 20 Hz to 10kHz. An additional reading error may result if the source resistance is relatively high. The input impedance of the Model 168 is frequency dependent. For example, with an input resistance of 9 megohms and shunt capacitange of less than 90 picofarads, the effective input impedance at 60 Hz is approximately 8.23 megohms. The impedance at other frequencies may be determined by the following relationship.

$$Z_{in} = \frac{R_{in}}{\sqrt{1 + (2\pi f\, R_{in} C)^2}}$$

where Z_{in} = effective input impedance
R_{in} = 9×10^6 ohms
$C_{in} < 90 \times 10^{-6}$ farads
f = frequency in Hz

Source loading can be determined by the following relationship:

$$\% \text{ error} = 100 \times \frac{Z_s}{R_s + Z_{in}}$$

where Z_s = source impedance
Z_{in} = effective input impedance

4. How to Determine Maximum Allowable Input. The maximum allowable voltage input is 1200 volts dc + ac peak. The Model 168 displays ac voltages to 499 volts rms. Beyond 499 volts the display reads properly and blinks to indicate an overrange condition.

NOTE

The Model 168 blocks dc signals at the input as a result of the capacitive coupled input. However, a large dc signal superimposed on an ac level could cause damage if the input exceeds 1200 volts dc + peak ac.

c. Voltage Measurements using Model 1682. The Model 168 may be used with the accessory Model 1682 RF Probe to permit ac voltage measurements from 100 kHz to 100 MHz. The transfer accuracy of the 1682 is ±5%, calibrated in rms of a sine wave. Input impedance is 4 megohms shunted by 2pF. Maximum allowable input is 30V rms AC, 200V DC. To use the 1682 with the Model 168, connect the probe to HI and LO. Select DC voltage function. Voltage is direct reading in volts ac rms.

NOTE

The Model 1682 is designed for use with a voltmeter having an input resistance of 10 megohms ±10%.

3-6. HOW TO MEASURE CURRENT. The Model 168 measures ac and dc current in four ranges; 0.1mA, 1mA, 0.1A, and 1A. The displayed current is direct reading in terms of milliamperes (mA) or amperes (A) (depending on mode selected) with decimal point located automatically.

a. DC Current. The Model 168 measures dc current from .0001 mA to 2 mA and from .0001A to 1A. If the polarity at the HI terminal is negative, the Model 168 display indicates a (-) minus sign. If the minus sign is off, a positive current is implied. A lighted "DC" is displayed when the dc function is selected. Current may be selected for direct reading in terms of milliamperes (mA) or amperes (A) depending on the magnitude of current measured. When the amperes (A) mode is selected, the Model 168 measures current from 0.0001 ampere to 1 ampere. (The display will permit a reading up to 1.999 amperes or until the 2A fuse blows.) When the milliampere (mA) mode is selected, the Model 168 measures current from 0.001 milliampere to 2 milliamperes. (The display will permit a reading up to 9.99 mA or until the 10mA fuse blows.)

1. How to Measure DC Current. Select the dc function by depressing the "DC pushbutton. First select "A" mode. The "mA" and "A" pushbuttons are "push-push" type, such that one pushbutton must be released before the other can be selected. Connect the input signal between HI and LO terminals. Observe the displayed reading, the polarity sign (for negative inputs), and decimal point position. The lighted "DC" indicates that the dc function has been selected. The lighted "mA" or "A" indicates that the current mode has been selected.

2. How to Select Ranges. The Model 168 automatically determines the sensitivity for either "mA" or "A" modes. If the current to be measured is between 0.0001 mA and 2 mA, select the "mA" mode. If the current to be measured is between 0.0001 A and 1A, select the "A" mode. For either "mA" or "A" modes, the Model 168 has two sensitivities, 0.1000 and 1.000 full range. On the most sensitive range, the minimum reading is .0000 while the maximum reading is .1999. When the input exceeds .1999, the Model 168 automatically up-ranges to the higher range and decimal point location is changed appropriately. Down-ranging occurs when the input level is reduced, causing a displayed reading to be less than 1-9-0 on any range. For example, if an input signal is reduced from 0.190 to 0.189, the display will change from .190 to .1890. However, if the signal is increased from .1899 to .1900, the Model 168 will not uprange, but remain on the 0.1000 range.

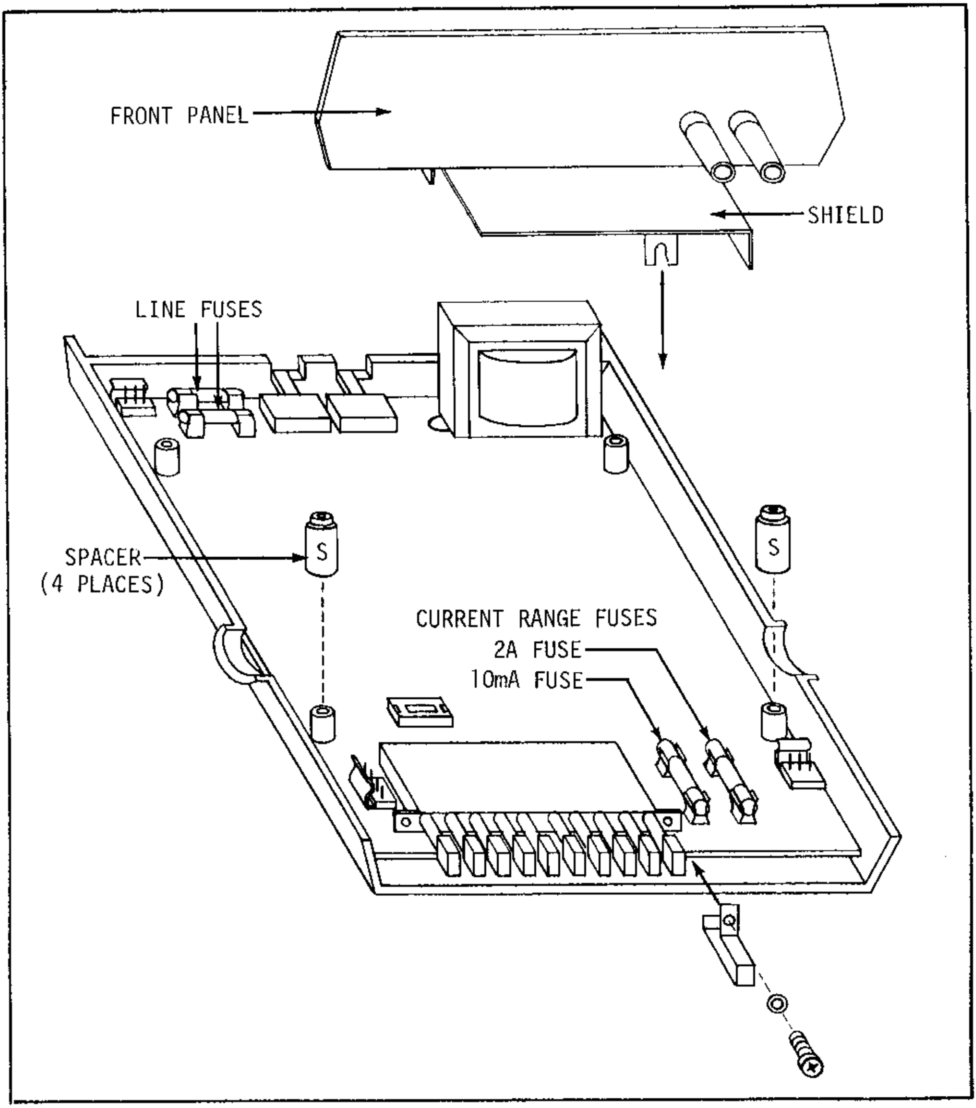


FIGURE 11. Location of Current Range Fuses.

3. How to Determine Accuracy. The accuracy of the Model 168 is ±(0.3% of reading + 0.1% of range). For example, a display of 1.000 ampere will have an uncertainty of ±.004 ampere. In the "mA" mode, the Model 168 uses a 1000 ohm shunt resistor. In the "A" mode, the Model 168 uses a 1 ohm shunt resistor. An additional reading error should be considered if the source resistance is not greater than 1000 times the shunt resistor. For example, in the "mA" mode, a source resistance of 100 kilohm would result in a loading error of approximately 0.1% of reading. Loading error for other source resistances can be determined by the following relationship:

$$\% \text{ error} = \frac{100 \times R_s}{R_s + 1000} \quad \text{(mA mode)}$$

where R_s = source resistance

$$\text{or } \% \text{ error} = \frac{100 \times R_s}{R_s + 1} \quad \text{(A mode)}$$

4. How to Determine Maximum Allowable Input. The Model 168 uses separate fuses for each current mode. The "mA" mode is protected by a 10 milliampere fuse. The "A" function is protected by a 2 ampere fuse.

a) How to Check the Current Range Fuses. To determine the condition of fuses for "mA" and "A" modes, select the "LO OHMS" resistance mode. Since the shunt resistors are connected between HI and LO terminals, the resistance including fuse can be measured directly on the Model 168. For the "mA" mode, select the "mA" pushbutton and observe the display. The display should read approximately 1.180 kΩ to indicate a "good fuse". A flashing display indicates a "blown" fuse. For the "A" mode, select the "A" pushbutton and observe the display. The display should read approximately .0012 kΩ to indicate a "good" fuse. A flashing display indicates a "blown" fuse.

b) How to Replace the Current Range Fuses. The current range fuses F103 and F104 are located on the printed circuit board. The fuses are accessible by removing the top cover and internal shield. To replace the fuses, turn the instrument over so that the bottom cover faces up. Use a screwdriver to remove the four slotted screws on the bottom cover as shown in Figure 4. After the screws are removed taking care to hold the top and bottom covers together, turn over the instrument so that the top cover faces up. Remove the top cover to gain access to the printed circuit board. If the Model 1688 Rechargeable Battery

Pack is installed, lift off the battery pack from the stand-offs and set to the left of the instrument. The fuses for current ranges are located on the printed circuit board near the front right side under the shield. The amplifier shield must be removed to gain access to the fuses. The shield is fastened to the circuit board by means of a single Phillips head screw. Before the screw can be removed, the front panel must be lifted out of the way. Gently lift the front panel and pull forward until panel is clear of pushbuttons. Locate and remove the Phillips head screw which holds the shield. The metal shield is held by clips to the printed circuit board and must be pried up. Replace fuses as necessary. Fuse types are as follows:

F103: 0.01A, 250V, type 8AG, fast acting ("mA" mode)
F104: 2A, 250V, type 8AG, fast acting ("A" mode)

After fuses are replaced, re-assemble shield, spring, washer, and Phillips screw as shown in Figure 11. Replace front panel. Replace Model 1688 battery pack on stand-offs. Replace top cover. Take care to hold top and bottom covers together and turn over instrument so that bottom cover faces up. Replace screws to complete re-assembly of chassis.

b. AC Current. The Model 168 measures ac current from .0001mA to 2mA and from .0001A to 1A. A lighted "AC" is displayed when the ac function is selected. Current may be selected for direct reading in terms of milliamperes (mA) or amperes (A) depending on the magnitude of current to be measured. When the amperes (A) mode is selected, the Model 168 measures current from .0001 ampere to 1 ampere. (The display will permit a reading up to 1.999 amperes or until the 2 ampere fuse blows.) When the milliampere (mA) mode is selected, the Model 168 measures current from .0001 milliampere to 2 milliamperes. (The display will permit a reading up to 9.99 mA or until the 10 mA fuse blows.)

1. How to Measure AC Current. Select the ac function by depressing the "AC" pushbutton. First select "A" mode. The "mA" and "A" pushbuttons are "push-push" type, such that one pushbutton must be released before the other can be selected. Connect the input signal between HI and LO terminals. Observe the displayed reading, and decimal point position. The lighted "AC" indicates that the ac function has been selected. The lighted "mA" or "A" indicates that the current mode has been selected.

2. How to Select Ranges. The Model 168 automatically determines the sensitivity for either "mA" or "A" modes. If the current to be measured is between 0.0001mA and 2mA, select the "mA" mode. If the current to be measured is between 0.0001A and 1A, select the "A" mode. For either "mA" or "A" modes, the Model 168 has two sensitivities, 0.1000 and 1.000 full range. On the most sensitive range, the minimum reading is .0000 while the maximum reading is .1999. When the input exceeds .1999, the Model 168 automatically up-ranges to the higher range and decimal point location is changed appropriately.

3. How to Determine Accuracy. The accuracy of the Model 168 is ±(1% of reading + 0.3% of range). For example, a display of 1.000 ampere will have an uncertainty of ±.013 amperes (over a frequency range from 30 Hz to 5kHz). In the "mA" mode, the Model 168 uses a 1000 ohm shunt resistor. An additional reading error should be considered if the source resistance is not greater than 1000 times the shunt resistor. For example, in the "mA" mode, a source resistance of 100 kilohm would result in a loading error of approximately 0.1% of reading. Loading error for other source resistances can be determined by the following relationship:

$$\%\ \text{error} = \frac{100 \times R_S}{R_S + 1000} \quad \text{(mA mode)}$$

where R_S = source resistance

4. How to Determine Maximum Allowable Input. The Model 168 uses separate fuses for each current mode. The "mA" mode is protected by a 10 milliampere fuse. The "A" function is protected by a 2 ampere fuse.

a) How to Check the Current Range Fuses. To determine the condition of fuses for "mA" and "A" modes, select the "LO OHMS" resistance mode. Since the shunt resistors are connected between HI and LO terminals, the resistance including fuse can be measured directly on the Model 168. For the "mA" mode, select the "mA" pushbutton and observe the display. The display should read approximately 1.180 kΩ to indicate a "good fuse". A flashing display indicates a "blown" fuse. For the "A" mode, select the "A" pushbutton and observe the display. The display should read approximately .0012 kΩ to indicate a "good" fuse. A flashing display indicates a "blown" fuse.

b) How to Replace the Current Range Fuses. The current range fuses F103 and F104 are located on the printed circuit board. The fuses are accessible by removing the top cover and internal shield. To replace the fuses, turn the instrument over so that the bottom cover faces up. Use a screwdriver to remove the four slotted screws on the bottom cover as shown in Figure 4. After the screws are removed taking care to hold the top and bottom covers together, turn over the instrument so that the top cover faces up. Remove the top cover to gain access to the printed circuit board.

TABLE 3-5.
Summary of Shunt Resistors in Current Modes

Range	Shunt Resistor	Voltage Drop across Shunt Resistor
0.1mA	1kΩ	0.1V
1mA	1kΩ	1V
0.1 A	1 Ω	0.1V
1 A	1 Ω	1V

*In series with fuses F103 (mA) or F104 (A).

c. Current Measurements to 50 Amperes. Current measurement capability of the Model 168 may be extended to 50 amperes through the use of accessory Model 1651 50-Ampere Shunt. The Model 1651 permits 4-terminal connections to minimize measurement error due to lead resistance.

1. DC Measurements. Select DC voltage function. Connect the voltage sensing leads of the Model 1651 to the Model 168 input terminals. Connect separate current leads (not furnished) between the source and the large hex-head bolts on the Model 1651. The current leads should be rated for currents up to 50 amperes (as well as connections to the 1651). The shunt resistance is 0.001 ohm which results in a voltage drop of 0.050 volts maximum at 50 amperes. Power dissipated in the shunt is 2.5 watts at 50 amperes.

2. AC Measurements. Select AC voltage function. Connect the voltage sensing leads of the Model 1651 to the Model 168 input terminals. Connect separate current leads (not furnished) between the source and the large hex-head bolts on the Model 1651. The current leads should be rated for currents up to 50 amperes (as well as connections to the 1651). The shunt resistance is 0.001 ohm which results in a voltage drop of 0.050 volts maximum at 50 amperes. Power dissipated in the shunt is 2.5 watts at 50 amperes.

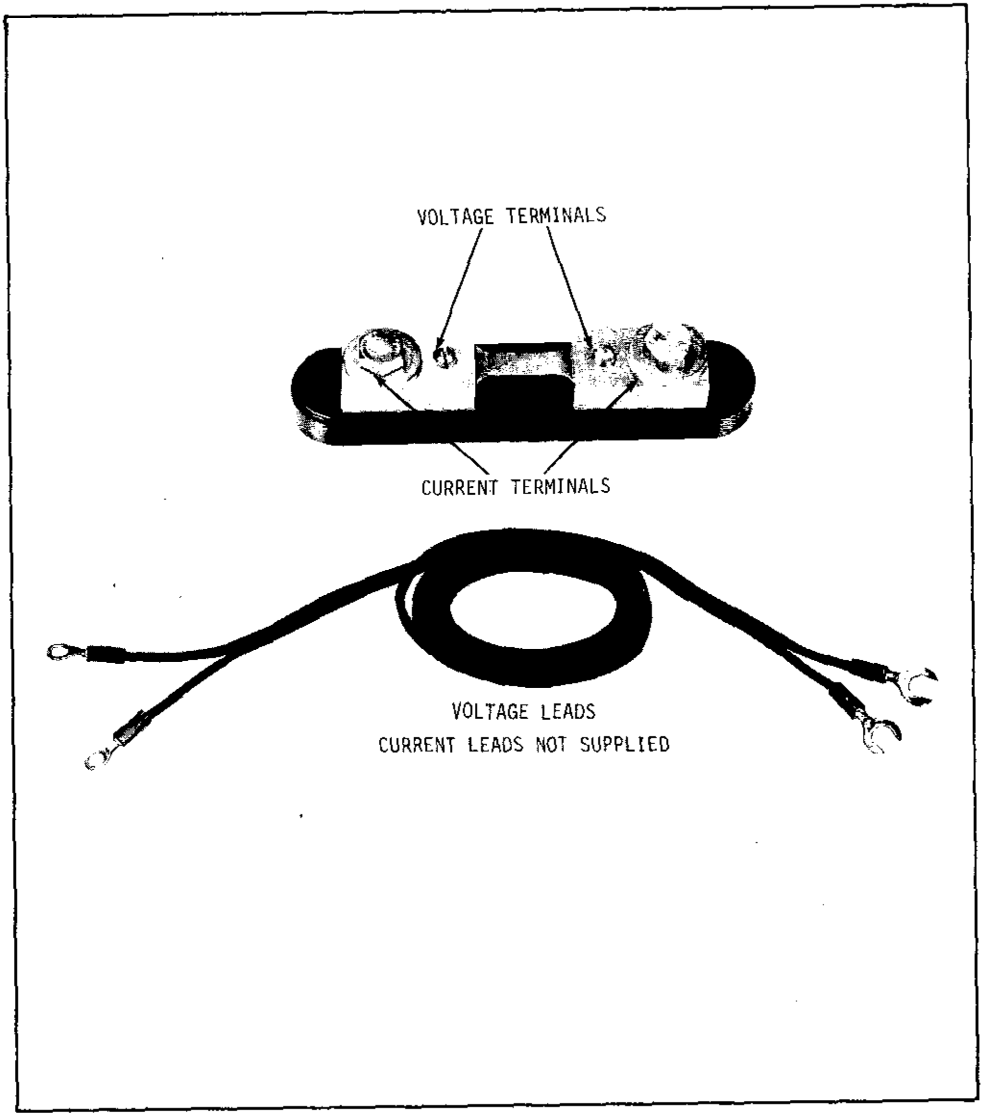


FIGURE 12. Current Measurements Using Model 1651.

3-7. HOW TO MEASURE RESISTANCE. The Model 168 measures resistance from 0.1Ω to 20 megohms in two over-lapping spans. The displayed resistance is direct reading in terms of kilohms (kΩ) or megohms (MΩ) with decimal point located automatically. The Model 168 offers two resistance modes, LO OHMS and HI OHMS. The LO OHMS mode may be used for measurements which require low power dissipation, and low voltage across the resistance. This mode has a distinct advantage when measuring in-circuit resistances where it is desirable to measure resistors without causing conduction of semiconductor junctions (such as in transistors and diodes). In the LO OHMS mode, the voltage drop at full range is 90 millivolts. The HI OHMS mode may be used for measurements which require a higher voltage across the resistance plus measuring capability to 20 megohms.

a. How to Use the LO OHMS Mode. In this mode, the Model 168 measures resistance from 0.1 ohm to 2 megohms. Five automatic ranges are provided: 0.1kΩ, 1kΩ, 10kΩ, 0.1MΩ, 1MΩ. To select the LO OHMS mode, depress the "LO OHMS" pushbutton. Connect the resistance between the HI and LO terminals. Observe the displayed reading and the decimal point position. The lighted "kΩ" or "MΩ" indicates the appropriate units of measurement.

b. How to Use the HI OHMS Mode. In this mode, the Model 168 measures resistance from 1 ohm to 20 megohms. Five automatic ranges are provided: 1kΩ, 10kΩ, 100kΩ, 1MΩ, and 10MΩ. To select the HI OHMS mode, depress the "HI OHMS" pushbutton. Connect the resistance between the HI and LO terminals. Observe the displayed reading including the decimal point position. The lighted "kΩ" or "MΩ" indicates the appropriate units of measurement.

c. How to Select Ranges. The Model 168 offers two spans of resistance measurement. In LO OHMS, the Model 168 has a span from 0.1 ohm to 2 megohms. In HI OHMS, the Model 168 has a span from 1 ohm to 20 megohms. In either the LO OHMS or HI OHMS mode, the Model 168 automatically selects the appropriate range and displays the proper decimal point location and measurement unit.

NOTE

The largest resistance displayed in the LO OHMS mode is 1.999 megohms. Beyond 1.999 megohms, the display flashes to indicate an overrange condition although the reading will be displayed up to 2.017 megohms. Above 2.017 megohms, the display will not change. In the HI OHMS mode, the maximum reading is 19.99 megohms. Beyond 19.99 megohms, the display flashes to indicate an overrange condition although the reading will be displayed up to 20.17 megohms. Above 20.17 megohms, the display will not change.

CAUTION

Care should be taken when making resistance measurements in circuits which may have voltages on capacitors etc. or where line voltage is present. Although the Model 168 is fully protected against accidental voltages up to 250V rms in OHMS, if higher voltages are applied damage may occur.

d. How to Determine Accuracy. The accuracy of the Model 168 is ±(0.2% of reading ± 0.1% of range) in HI OHMS. For example, a display reading of 1.000 kilohms will have an uncertainty of ±0.003 kilohms.

e. How to Determine the Current For Each Range. The voltage developed across the resistance is directly proportional to the current applied. For instance, a reading of 1.000 kilohms corresponds to a voltage developed of 0.900 volts in HI OHMS. The current applied by the Model 168 is determined by dividing the voltage by the resistance being measured. In the previous example, the current is equal to $0.900V \div 10^3\Omega = 0.9$ mA. The test current for each range is given in Tables 3-6 and 3-7.

TABLE 3-6.
Test Current in LO OHMS Mode

Range	Test Current
0.1kΩ	0.9mA
1kΩ	0.09mA
10kΩ	0.009mA
0.1MΩ	0.9nA
1MΩ	0.09nA

TABLE 3-7.
Test Current in HI OHMS Mode

Range	Test Current
1kΩ	0.9mA
10kΩ	0.09mA
100kΩ	0.009mA
1MΩ	0.9nA
10MΩ	0.09nA

f. How to Test Semiconductor Diodes and Transistors. The Model 168 can be used to test diodes and transistors to determine the condition of the device. For semiconductor diodes, the voltage applied must be sufficient to cause conduction in the forward direction. The "HI OHMS" mode of the Model 168 provides a voltage up to 2 volts at a current of 1 milliampere, which is sufficient to cause conduction. Since the "LO" terminal is positive with respect to the "HI" terminal for all resistance measurements, connections should be made as shown in Figure 13 to cause forward conduction of diodes.

NOTE

The silicon diode test should be performed using the lowest resistance range of HI OHMS, (2 kilohms maximum reading) since the current used on the higher ranges becomes small. When the input terminals of the Model 168 are open, the instrument automatically ranges to the highest range. To perform the diode test, a short must first be applied to the input terminals, causing the Model 168 to downrange to the lowest range. An easy way to accomplish this measurement is to depress the "A" pushbutton (which will cause the Model 168 to downrange to the lowest resistance). Then connect the diode and release the "A" pushbutton. Observe the displayed reading on the Model 168. A reading less than 1000 ohms (for silicon semiconductors) indicates that the diode is conducting. If the diode is faulty or connected in reverse, the display will flash 0.17MΩ which indicates that the resistance is greater than 20.17MΩ. The LO terminal is positive so that anode must be connected to LO.

To determine the semiconductor type (NPN or PNP) of a transistor, a measurement between base (B) and emitter(E) is required. First, identify the leads of the transistor by comparing the device to the appropriate transistor configuration as shown in manufacturer's data sheets.
Next, measure the resistance between base (B) and emitter(E). If the transistor is an NPN type, the "LO" terminal of the Model 168 should be connected to the base (B) to cause the base-emitter junction to conduct. A properly conducting junction will be less than 1000 ohms for an NPN transistor.

NOTE

To ensure that the Model 168 is on the lowest range, depress the "A" pushbutton, then release as described in the preceeding discussion of diode measurements.

If the transistor is PNP type, the "LO" terminals of the Model 168 should be connected to the emitter (E) to cause the base-emitter junction to conduct. A properly conducting junction will be less than 1000 ohms for a PNP transistor. To determine the condition of a transistor, a measurement of base-emitter and base-collector junctions is required. Table 3-8 describes the conditions which will determine if an NPN type transistor is faulty. Table 3-9 describes the conditions which will determine if a PNP transistor is faulty.

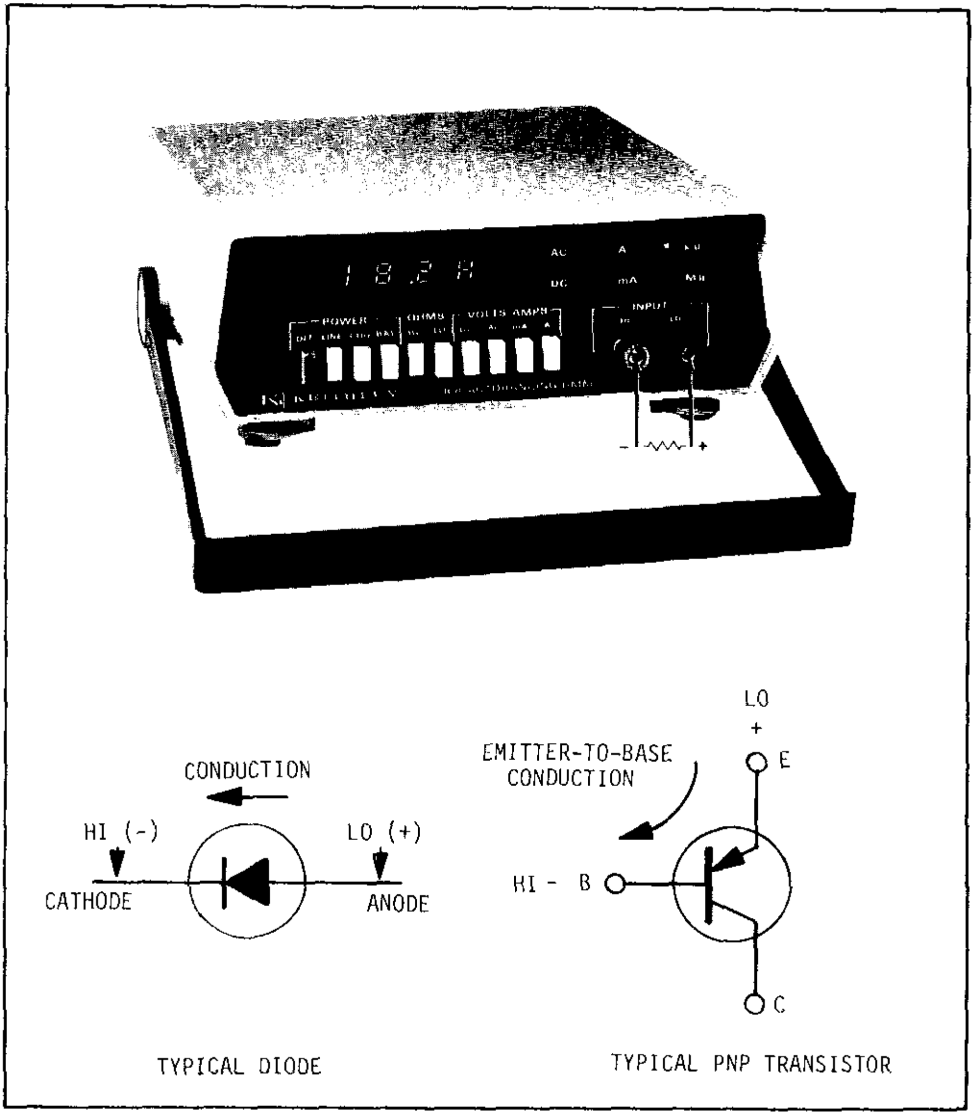


FIGURE 13. Diode and Semiconductor Testing.

TABLE 3-8.
Test Conditions for a Silicon NPN Type Transistor in HI OHMS.

Connection to LO Terminal	Connection to HI Terminal	(HI OHMS) Conditions Which Indicate A Normal or Faulty Transistor.
Base	Emitter	A reading of approx. 700 ohms indicates a normal junction. A reading greater than 1000 ohms indicates a faulty junction.
Emitter	Base	A reading greater than 20.17MΩ indicates a normal junction. A reading less than 20.17MΩ indicates a faulty junction.
Collector	Base	A reading greater than 20.17Ω indicates a normal junction. A reading less than 20.17MΩ indicates a faulty junction.
Base	Collector	A reading of approx. 700 ohms indicates a normal junction. A reading greater than 1000 ohms indicates a faulty junction.

TABLE 3-9.
Test Conditions for a Silicon PNP Type Transistor in HI OHMS.

Connection to LO Terminal	Connection to HI Terminal	(HI OHMS) Conditions Which Indicate A Normal or Faulty Transistor.
Emitter	Base	A reading of approx. 700 ohms indicates a normal junction. A reading greater than 1000 ohms indicates a faulty junction.
Base	Emitter	A reading greater than 20.17MΩ indicates a normal junction. A reading less than 20.17MΩ indicates a faulty junction.
Base	Collector	A reading greater than 20.17MΩ indicates a normal junction. A reading less than 20.17MΩ indicates a faulty junction.
Collector	Base	A reading of approx. 700 ohms indicates a normal junction. A reading greater than 1000 ohms indicates a faulty junction.

SECTION 4. THEORY OF OPERATION

4-1. GENERAL. This section contains information to describe the Model 168 circuit operation.

a. Glass-epoxy printed circuit boards are used for all circuitry. The analog and digital circuitry is located on mother board, PC-346. The digital display circuitry is located on display board, PC-347.

b. Compactness and high reliability are provided through the use of a digital LSI, a completely solid-state LED display, thick-film resistor networks, and linear integrated circuits.

NOTE

All circuit designations refer to components shown on schematics 26088E and 26089E located on pages 85 and 86.

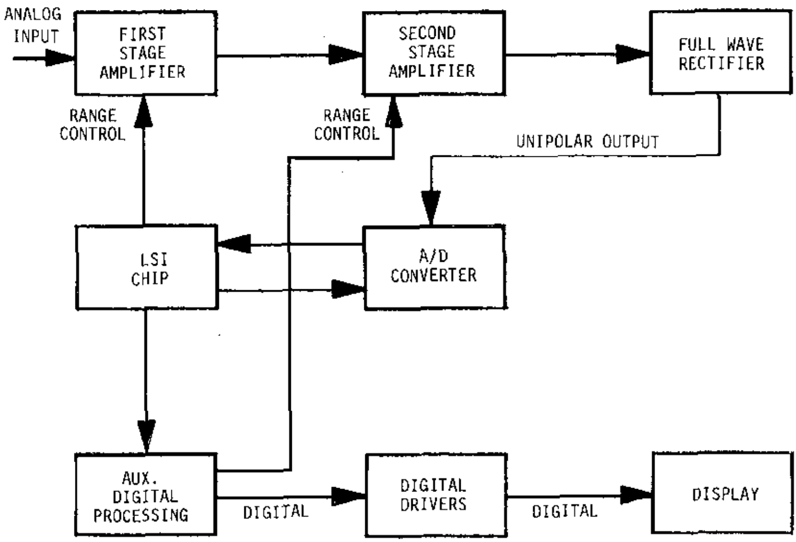
4-2. ANALOG CIRCUITRY

a. First Stage Amplifier. This amplifier is a FET input integrated circuit (QA103) connected as an inverting amplifier. Gain for the amplifier is set by automatically switching resistors with JFET's into the feedback of the amplifier. Potentiometer R135 is an input zero adjustment on the front panel.

b. Second Stage Amplifier. This amplifier provides additional gain for the most sensitive ranges. Integrated circuit QA104 is connected as an inverting amplifier with a gain of X1 or X10. Potentiometer R139 (-1V ADJ.) is a gain adjustment for X10 gain. Potentiometer R115 is a zero adjustment for X1 gain. Potentiometer R137 is a zero adjustment for X10 gain.

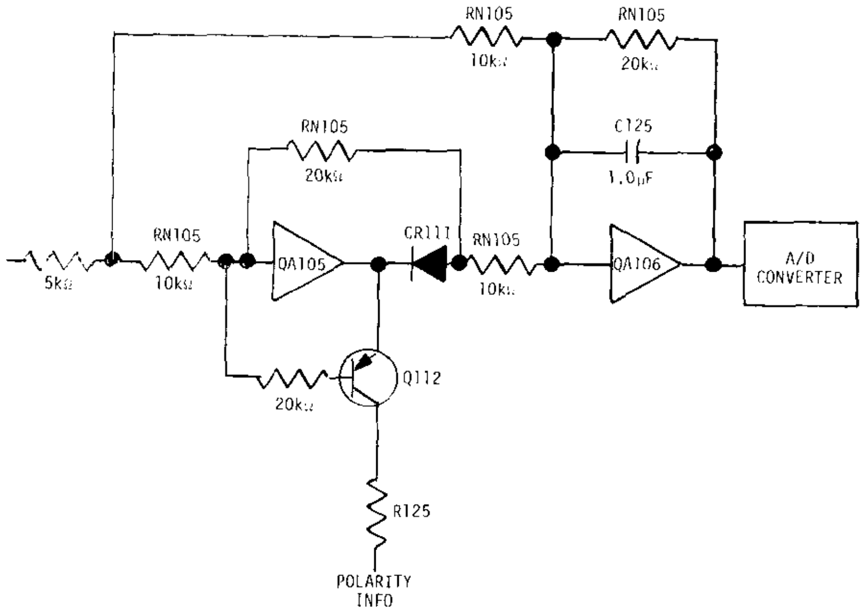
TABLE 4-1.
DC Gain Switching (UP-Ranging)

Range	First Stage Gain	Second Stage Gain	Overall Gain
0.1V	0.9	10	9.0
1V	0.09	10	0.9
10V	0.009	10	0.09
100V	0.009	1	0.009
1000V	0.0009	1	0.0009



Input amplifier (QA103) is controlled by LSI (QA212). Second-stage (QA104) is controlled by AUX. Digital Circuitry (QA205, QA206). First stage amplifier conditions input by Level Shifting (Gain) and Impedance Shifting. Second Stage provides additional Level Shifting. Full wave rectifier (FWR) provides unipolar output for ±DC volts and full-wave rectification for AC. A/D Converter converts unipolar analog signal to digital. LSI (QA212) performs majority of digital processing and decoding. AUX. Digital Processing circuitry (QA203, 204, 205, and 206) provides additional digital processing. Digital Drivers (QA209, 210, 211) condition digital information for display.

FIGURE 14. Overall Block Diagram.



Full-wave rectifier (FWR) circuitry provides unipolar output (0.9 volt full range). Polarity of dc voltage is detected by Q112. AC voltage is full-wave rectified by QA105 and QA106. C125 provides additional filtering.

FIGURE 15. Full Wave Rectifier.

TABLE 4-2.
DC Gain Switching (DOWN-Ranging)

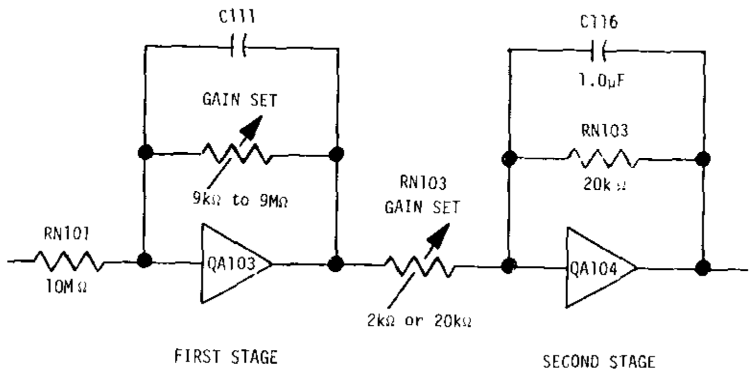
Range	First Stage Gain	Second Stage Gain	Overall Gain
1000V	0.0009	1	0.0009
100V	0.009	1	0.009
10V	0.09	1	0.09
1V	0.09	10	0.9
0.1V	0.9	10	9

c. Full Wave Rectifier (FWR). This circuit developes a positive dc output for all inputs, ac or dc. An ac signal is full-wave rectified and filtered by the FWR. Integrated circuit QA105 is used for signal transfer for one polarity only. If the input to the rectifier is negative, QA106 provides a gain of -1 so that the output is positive. When the input to the rectifier is positive, QA106 provides a gain of -1 (the same as for negative inputs) except the output of QA105 is summed to provide a net gain of +1. QA105 provides an inverting gain of -2 which is summed at the "Inverting input" of QA106. When the input to the rectifier is negative, the blocking action of diode CR111 disconnects QA105 from signal path. Transistor Q112 conducts to maintain feedback around QA105 and also provides polarity information in the "DCV" function.

4-3. DC VOLTAGE OPERATION.

a. Gain. In the dc mode, the first stage amplifier has a gain of X0.9 on the 0.1V volt range decreasing to X0.0009 on the 1000 volt range. The gain for each range is determined by the feedback resistors as shown in Table 4-3. The second stage gain is X1 or X10 depending on the range. The gain is determined by resistors RN103 (10,6) or RN103 (10,7), and RN103 (6,5) as shown in Table 4-4. The gains of these amplifiers QA103, QA104 are determined automatically by the digital circuitry. Since the input resistance is constant value (10MΩ), the source loading does not vary from range to range.

b. Filtering. In the dc mode, filtering is provided by capacitor C111 in the feedback of QA103 and C116 in feedback of QA104. Additional filtering is included in the FWR and a-d converter. The total filtering is greater than 75 dB at line frequencies with 1mV applied.



In DC voltage mode, analog amplifier (two stages) has an overall gain from X.0009 to X9 depending on range. Amplifier QA103 is a first stage, variable-gain amplifier with gain set in decade steps from X.0009 to X.9. Amplifier QA104 is a second-stage amplifier with a gain of X1 or X10. Gain is determined by the automatic ranging circuitry. Full range output of QA104 is 0.9V. Capacitors C111 and C116 provide filtering on DC.

FIGURE 16. DC Voltage Operation.

TABLE 4-3.
First Stage Gain in DC Mode.

Range	R_I	R_F	Gain
0.1V	10M	9M	0.90
1 or 10V	10M	900K	0.09
10 or 100V	10M	90K	0.009
1000V	10M	9K	0.0009

TABLE 4-4.
Second Stage Gain in DC Mode.

Range	R_I	R_F	Gain
0.1V	2K	20K	10
1V	2K	20K	10
10V	20K or 2K	20K	1 or 10
100V	20K	20K	1
1000V	20K	20K	1

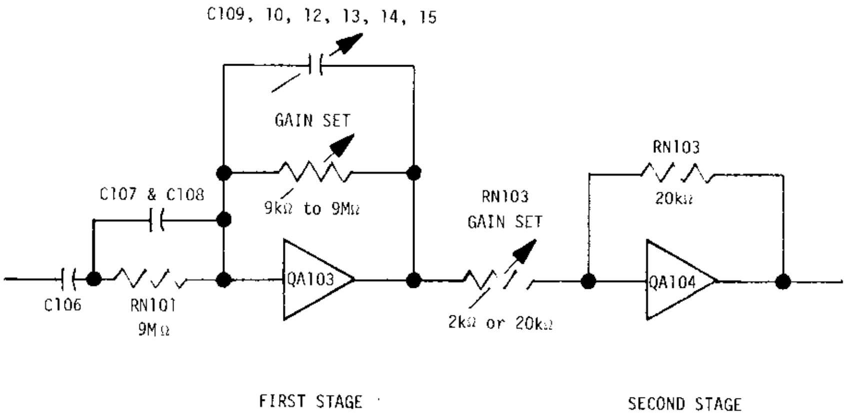
4-4. AC VOLTAGE OPERATION.

a. Gain. In the ac mode, the input amplifier has a unity gain on the 0.1 volt range decreasing to 0.001 on the 1000 volt range. The gain for each range is determined by the feedback components as shown in Table 4-5.

TABLE 4-5.
First Stage Gain in AC Mode.

Range	C_I	R_I	R_F	C_F	Gain
0.1V	55 pF	9M	9M	55 pF	1
1 or 10V	55 pF	9M	900K	550 pF	0.1
10 or 100V	55 pF	9M	90K	0.0055 μF	0.01
1000V	55 pF	9M	9K	0.055 μF	.001

b. Frequency Response. The frequency response is from 20Hz to 10kHz on 1, 10, and 100V ranges, 20Hz to 5kHz on .1V and 500V ranges. The ac ranges are calibrated through the use of three trimming capacitors C108, C110, and C113.



In AC voltage mode, analog amplifier (two stages) has an overall gain of X.001 to X10 depending on range. Amplifier QA103 is a first-stage, variable-gain amplifier with gain set in decade steps from X.001 to X1. Amplifier QA104 is a second-stage amplifier with gain of X1 or X10. Gain is determined by the automatic ranging circuitry. Full range output of QA104 is 1V rms.

FIGURE 17. AC Voltage Operation.

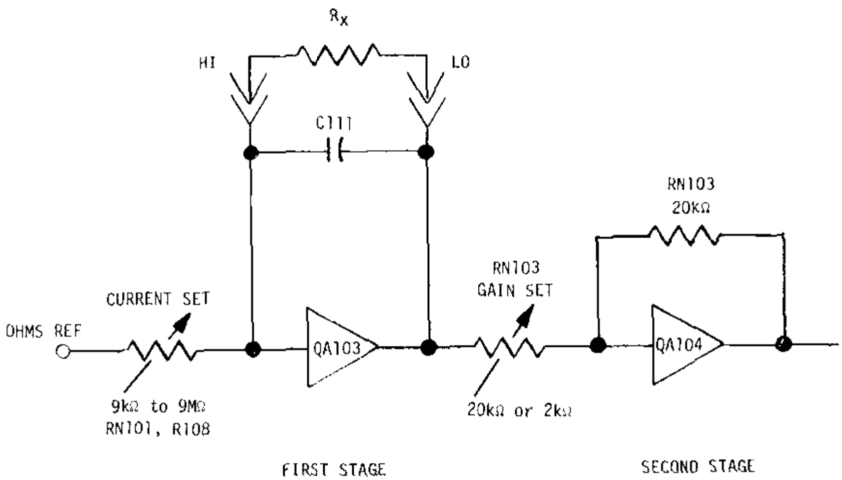
4-5. OHMS OPERATIQN. In the OHMS mode, the input terminals ("HI" and "LO") are connected in the feedback of QA103 so as to reduce the slowing effects of cable capacitances. When the OHMS mode is selected, constant current in decade steps is applied between the input terminals with the Lo terminal positive. The OHMS reference is composed of integrated circuit QA106 and range resistors RN101-3, -4, -5, and -6 which are also used on voltage modes. An additional resistor R105 is used on the 1kΩ range. The test current is generated by the -.81V reference voltage and the range resistor. The voltage developed across the terminals is proportional to the measured resistance. For example, when a 15 megohm resistor is connected, the voltage developed is .81V ÷ 9M x 15M = 1.35V. *Potentiometer R122 is the adjustment for the 100kΩ range. This control* sets the output of QA106 to approximately -.81 volts. Potentiometer R109 is the adjustment for the 1kΩ range. Adjustments made in high ohms mode only. Maximum open circuit voltage across the terminals is 6 volts in series with 9MΩ in either HI or LO OHMS.

TABLE 4-6.
Test Current in HI OHMS Mode

HI OHMS Range	Test Current	Range Resistance	Maximum Voltage Developed (at 1999 display)
1 kΩ	900 µA	.9K	1.8V
10 kΩ	90 µA	9K	1.8V
100 kΩ	9 µA	90K	1.8V
1 MΩ	0.9 µA	900K	1.8V
10 MΩ	0.09 µA	9M	1.8V

TABLE 4-7.
Test Current in LO OHMS Mode

LO OHMS Range	Test Current	Range Resistance	Maximum Voltage Developed (at 1999 display)
0.1 kΩ	900 µA	.9K	.18V
1 kΩ	90 µA	9K	.18V
10 kΩ	9 µA	90K	.18V
0.1 MΩ	0.9 µA	900K	.18V
1 MΩ	0.09 µA	9M	.18V



In HI OHMS, amplifier QA103 is a first-stage amplifier with full range output of 0.9 volts. The resistance to be measured is connected across the amplifier (in feedback) between HI and LO terminals. The current injected by the ohms reference is determined by the automatic ranging circuitry. Full range output of QA104 is 0.9V. The LO terminal is positive with respect to HI. Second stage gain is X1.

In LO OHMS, amplifier QA103 is a first-stage amplifier with a full range output of 0.09 volts. Full range output of QA104 is 0.9 volts. Second stage gain is X10.

FIGURE 18. Ohms Operation.

4-6. CURRENT OPERATION. In either CURRENT mode, the input is shunted by either a 1 ohm (R104) or a 1 kilohm (R101) resistor for direct reading in terms of amperes (A) or milliamperes (mA).

a. "A" ranges. When this function is selected, the Model 168 has two automatically selected sensitivities of 0.1mA and 1mA full range. An input shunt resistor of 1 ohm (R104) with F104 (2 ampere fuse) in series is placed across input; and voltage drop across R104 is read by voltmeter section.

b. "mA" ranges. When this function is selected, the Model 168 has two automatically selected sensitivities of 0.1 amp and 1 amp full range. An input shunt resistor of 1 kilohm (R101) with F103 (1/100 ampere fuse) in series is placed across input; and voltage drop across R103 is read by voltmeter section.

4-7. POWER SUPPLY. The Model 168 uses either line power or battery power (when the Model 1688 is installed).

a. Line Power. Transformer T101 has two tapped primary windings which are connected in series or in parallel depending on the position of line switches S101 and S102. Fuse F101 is in series with winding 4-5-6 for all settings. Fuse F102 is connected only when winding 1-2-3 is connected in parallel with winding 4-5-6. The secondary of T101 has two tapped windings. The lower taps (11 and 10; 8 and 7) are used in line mode. The upper taps (12 and 10; 9 and 7) are used in charge mode.

1. +5V Supply. In LINE operation, the ac voltage between transformer leads 10 and 11 is full-wave rectified by CR101. The filtered full-wave dc voltage (approx. 10V) is regulated by integrated circuit QA101. The output regulated voltage is 5V ±5%.

2. -12V Supply. In LINE operation, the voltage between transformer leads 7 and 8 is full-wave rectified by CR102. The filtered full-wave dc voltage (approx. 18V) is regulated by integrated circuit QA102. The regulated output voltage is -12V ±5%.

b. Battery Power. When BATTERY mode is selected, the Model 1688 Battery Pack is connected into the inputs of QA101 and QA102 while the line voltage is disconnected at the secondary. The 8.4V batteries provide input power for the +5V supply. The 16.8V batteries provide input power for the -12V supply. Battery test point A provides a measurement of the 16.8V battery supply with respect to power supply low. Therefore, the voltage measured is the difference between the battery supply and the -12 volt output which is approx. +4.8 volts. Battery test point B provides a measurement of the 8.4V battery supply.

4-8. DIGITAL CIRCUITRY.

a. A-to-D Converter. The a-to-d converter operates on a charge balancing principle. The circuit operates only with positive inputs. A block diagram of the converter is shown in Figure 20. The positive output of the rectifier tends to drive the integrator output negative (amplifier QA107). The rate of integration is a function of the input, resistor RN104 and capacitor C127. As the integrator goes negative, the threshold detector (amplifier QA108) output goes to a positive level. A positive level represents a "1" at the J input of the J-K flip-flop (the K input is a "0" due to the NAND gate). The charge and discharge periods for the integrator are determined by the state of the $\overline{Q}$ output on the J-K flip-flop. When the $\overline{Q}$ output is high, diode QA109-1,3 is back biased off the integrator can only be charged by the FWR output. When the Q output is low, diode QA109 is forward biased and discharge of the integrator is possible. Since Q and $\overline{Q}$ states can be changed only when a clock pluse is present, the charge/discharge periods are a function of the clock frequency as well. The a-to-d converter operates in a free running manner. The timing period is a total of 2016 counts. The reading is derived by counting the total number of clock pulses in the discharge period over a span of 2016 counts. This is accomplished by an AND gate as shown in Figure 20. For example, a 1 volt input would result in a total discharge period of 1000 counts. An input of 250 millivolts would represent 250 counts out of 2016. However, an input of 2.1 volts would cause the 168 to uprange since the total count would exceed 2000 which is the upranging level.

NOTE

One complete conversion cycle is 2048 counts. The BCD counter looks at the threshold for 2016 counts. The remaining 32 counts are used to stop the BCD counter, strobe and BCD counter information into latches, reset the BCD counter to zero, and initiate uprange or downrange or overrange if necessary. 2048 counts at a 10kHz rate is approx. 0.2 seconds per conversion, (or 5 readings per second).

b. Autoranging Circuit. This circuitry is located on the LSI module QA212 with exception of decoding diodes CR103 through CR108, and FET switches Q102 through Q105 which are located on the main circuit board. The threshold input (TH) and current switch (CS) signals are used to determine the proper range. The range information is coded by three outputs identified as R_1, R_2, and R_4 as shown in Tables 4-8 and 4-9. Ranging is bidirectional so that on a given range the 168 will either uprange or downrange to the adjacent range. When on the lowest range, the 168 is prohibited from downranging, and when on highest range, it is prohibited from upranging.

TABLE 4-8.
Ranging Logic for ACV and DCV

Range	R_1	R_2
.1V	0	0
1V & 10V	1	0
100V & 10V	0	1
1000V	1	1

TABLE 4-10.
Function Logic

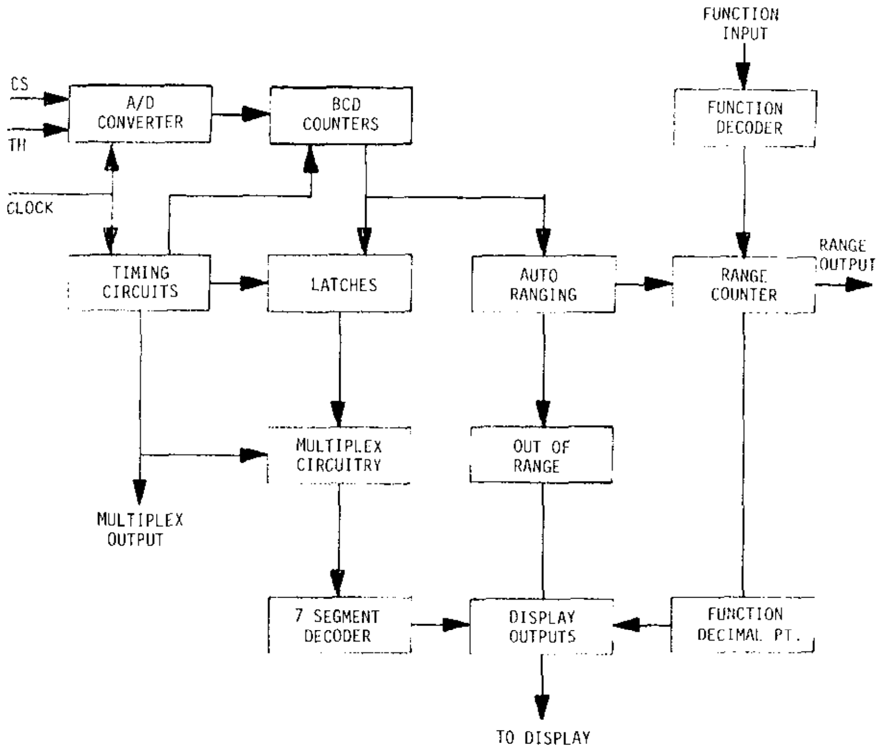
Function	Designation F_1	F_2
ACV & ACA	1	0
DCV+ & DCA+	1	1
DCV- & DCA-	0	1
OHMS	0	0

TABLE 4-9.
Ranging Logic for OHMS

HI OHMS	LO OHMS	R_1	R_2	R_4
1 K	.1 K	0	0	1
10 K	1 K	1	1	0
100 K	10 K	0	1	0
1 M	100 K	1	0	0
10 M	1 M	0	0	0

NOTE

With 3 range lines R_1, R_2, and R_4 there are 8 possible states of which four are used on ACV and DCV; five on OHMS. The remaining states may be established at instrument turn-on. The 168 logic is designed so that if these prohibited states occur at turn-on the logic circuitry will automatically shift into a defined state at end of first count cycle (0.2 seconds or less).



The LSI (QA212) contains the major circuitry required for a-to-d conversion and digital processing. The LSI provides digital logic and commands for a-to-d conversion, automatic ranging, overranging, decimal point location, multiplexing of display, and 7-segment decoding.

FIGURE 19. LSI Block Diagram.

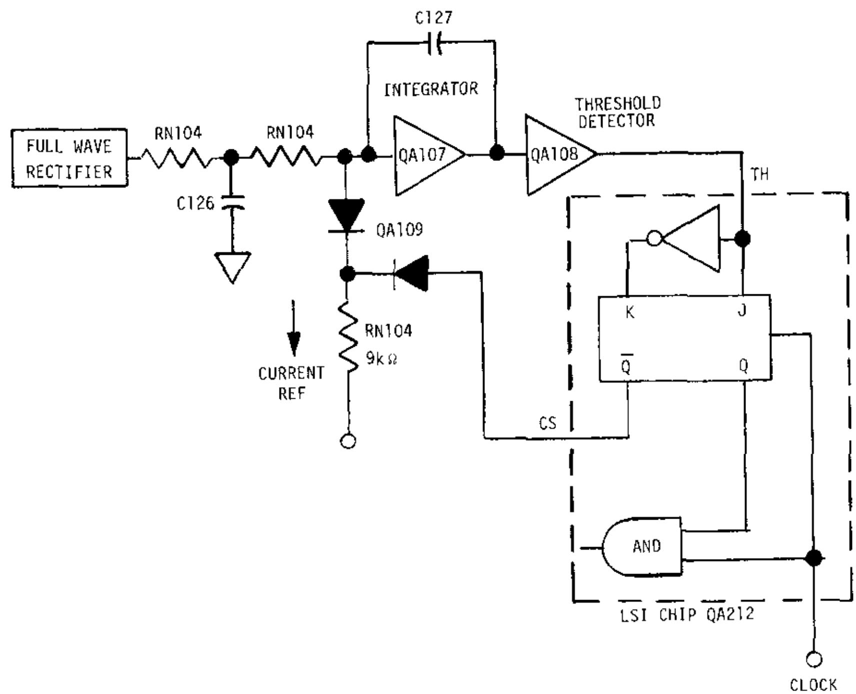


FIGURE 20. A/D Converter Simplified Diagram.

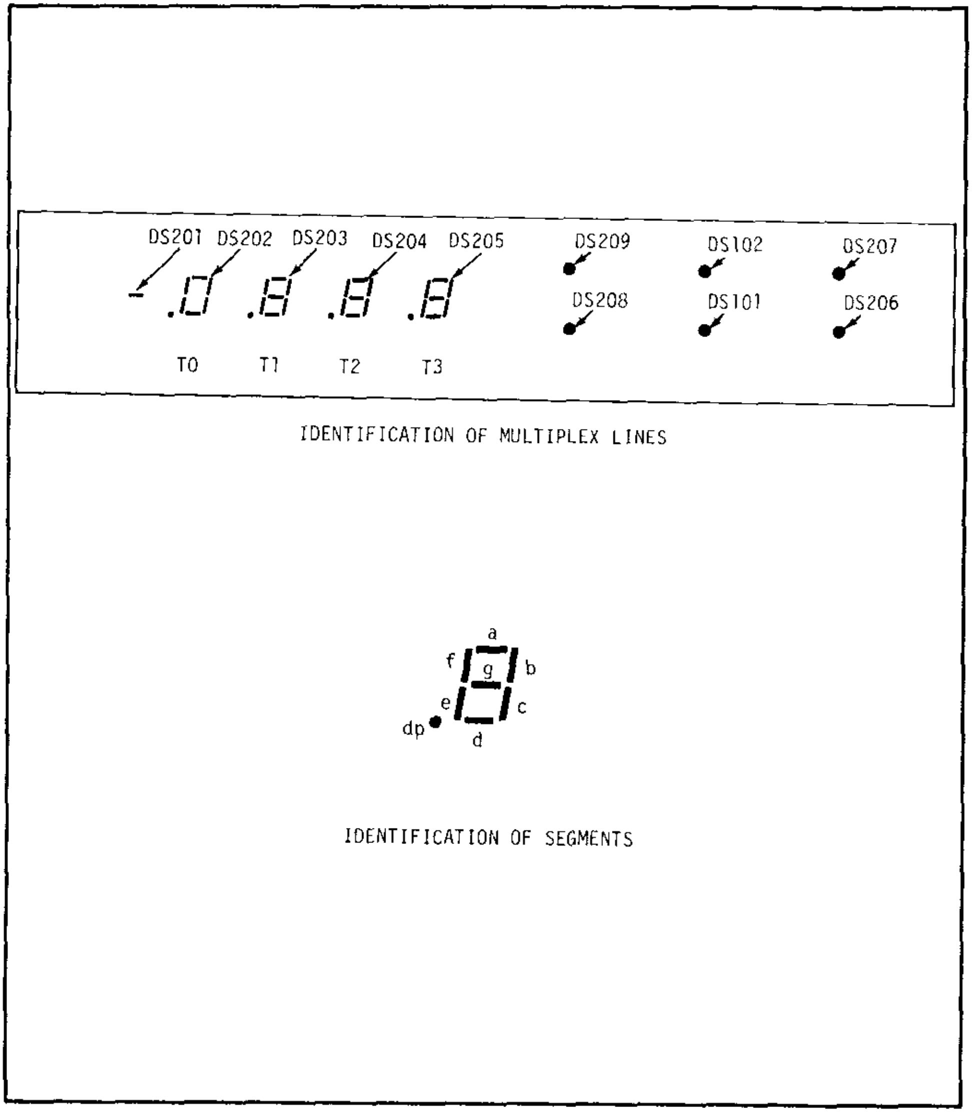


FIGURE 21. Identification of Segments -- Multiplex Lines.

c. Auxiliary Digital Circuits. Although the LSI circuit does most of the work in the digital section of the 168 (see LSI Block diagram), there is some additional work which needs to be done. This additional work is composed of the following:

1). Generating the clock signal which controls the overall digital function.

2). Additional decimal point manipulation.

3). Controlling the gain of the second stage amplifier (QA104).

4). Controlling the leading zero on 0.1V ac and dc voltage ranges, .1kΩ ranges, and .1mA and .1A ranges.

5). Conditioning the multiplexed output signals to properly drive the digital display.

d. Clock Generation. The clock is generated by two TTL inverters (part of QA201) which are cross coupled by 499 ohm resistors (part of RN201) and 0.15μf capacitors (C201 and C202). The clock frequency is approximately 9kHz ±20%. The clock frequency is not extremely stable with time and temperature, but it does not have to be with the charge balancing A-D convertor. The clock is buffered by a transistor (part of QA202), inverted by a TTL inverter (part of QA201) and level shifted by Q201 to drive the LSI circuit (QA212).

e. Decimal Point Selection. The clock and inverted clock are used to trigger the 2 sections of dual D flip-flop (QA203) so that the multiplexed decimal point information (dp) from the LSI circuit (QA212) is time shifted from the original multiplex time (T0 through T3) to the next multiplex time. This shifted dp is then ANDed (part of QA205) with T0 so that a decimal point in the T3 time slot will not be shifted to the next time slot (T0, the first one). This is done because no decimal point is wanted on the highest voltage range (1000V dc and 500V ac). The shifted dp is then ANDed (part of QA205) with $\overline{dp}$ to make sure that it can not occur when the original dp is present (correcting time delays through LSI circuit). The original dp and the shifted dp are then applied to separate NAND gates (part of QA204) and the proper one is selected to go to the display by an R-S flip-flop (part of QA206). This flip-flop is discussed in section 4-8f.

TABLE 4-11.
Pin Identification for LSI

Pin No.	Designation	Function	Voltage Levels
1	R2	Range	+5V = logic "1", -12V = logic "0"
2	R1	Range	+5V = logic "1", -12V = logic "0"
3	F2	Function	+5V = logic "1", -12V = logic "0"
4	F1	Function	+5V = logic "1", -12V = logic "0"
5	-12V	Power, -12V	-12V
6	Iz	No connection	No connection
7	CLK	Clock	Approx. 10kHz, +5V to -12V
8	TH	Threshold input	+5V or -12V
9	CS	Current Switch	+5V = integrate mode
10	T0	Multiplex line	+5V = ON, OV = OFF
11	T1	Multiplex line	+5V = ON, OV = OFF
12	T2	Multiplex line	+5V = ON, OV = OFF
13	T3	Multiplex line	+5V = ON, OV = OFF
14	a	Segment drive	+5V = ON, OV = OFF
15	b	Segment drive	+5V = ON, OV = OFF
16	c	Segment drive	+5V = ON, OV = OFF
17	d	Segment drive	+5V = ON, OV = OFF
18	e	Segment drive	+5V = ON, OV = OFF
19	f	Segment drive	+5V = ON, OV = OFF
20	g	Segment drive	+5V = ON, OV = OFF
21	dp	Decimal point	+5V = ON, OV = OFF
22	COM	Common or "LO"	OV
23	+5V	Power, +5V	+5V
24	R4	Range	+5V = Logic "1", -12V - logic "0"

f. Ranging Logic.

1). The LSI circuitry (QA212) was designed for a voltmeter having four voltage ranges. Since the 168 has 5 voltage ranges, additional digital circuitry was nesessary to generate this fifth range. The LSI circuit must be told there are only four ranges but the analog circuitry must have 5 ranges. This necessitated the decimal point manipulation and the second stage amplifier (QA104) in the analog section. This also made possible the HI and LO ohms mode.

2). The only way to determine what range the LSI is on is to examine what multiplex time that the dp is present. An RS flip-flop composed of 2 NOR gates (part of QA206) is used to select which decimal point is used and also to set the gain of the second stage amplifier (QA104). The state of this flip-flop is controlled by the location of the dp.

3). The state of the RS flip-flop is changed when dp occurs at T0 time. Its state is reversed when dp occurs at T3 time. These state changes are controlled through 2 NOR gates (part of QA206), two transistors (part of QA202) and two AND gates (part of QA205) in the voltage and current modes. In the ohms modes either one state or the other is forced and held by the ohms switches (part of S103). If the dp from the LSI (QA212) is used, the second stage gain (QA104) is X10. If the shifted dp is used, the gain of the second stage is X1.

g. Multiplexing of Display Lines. The LSI circuit (QA212) puts out polarity, function, leading 1, and decimal point information at T0 time. On the bottom range of DC, AC, mA, A, and Lo ohms, a leading zero is required. This information is needed at T0 time. Looking at Figure 21, if the count is less than 1000, the segments a, b, c, d, e, and f must light up. If the count if greater than 1000, then only b and c should light up. The LSI handles b and c for greater than 1000 counts by telling them to turn on. But below 1000 counts it does nothing. At T0 time, the LSI chip puts out function information as follows: "a" controls AC, "e" controls DC, "d" controls kΩ, and "f" controls MΩ. These lines are connected to the function indicator LED's. The a, d, e, and f segments of the leading zero are controlled by the auxiliary digital circuitry as follows: If the leading zero is needed, then dp must be present at T0 time. dp is ANDed with T0 (part of QA208 and QA201 invertor). If b is not present, then all segments of leading zero are turned on when dp occurs at T0 time. If b is is present at T0 time, then only b and c are energized. If dp is not present at T0 time segments a, d, e, and f do not light. b and c will light when they are present at T0 time on any other range.

h. Display

1). The display drivers will handle any common anode LED 7 segment display presently manufactured whether it is one or two LED diodes in series per segment. The common anodes of each digit are driven by PNP transistors (QA202, QA203, QA204, and QA205). The PNP transistors are each driven by buffered multiplex lines T0, T1, T2, and T3.

2). The display cathodes are all tied in parallel (a's to a's, b's to b's, ect.) for the hundreds, tens, and units digits (DS203, DS204, and DS205). There are seven display cathode drivers, each composed of an NPN transistor (parts of QA209, QA210, and QA202) and three resistors (RN203). Each cathode driver is a current source which delivers 15mA. This assures uniform drive current to each display segment. Since the display is multiplexed the average current per segment to the display is 1/4 of 15mA, or almost 4mA.

3). The thousands digit (DS202) has its b and c segments tied in parallel with the other digits b and c segments. The polarity signal occurs on the g segment at T0 time and thus g is connected to the negative sign (DS201), and the g cathodes of the hundreds, tens, and units digits. The a, d, e, and f cathodes of the thousands digit are connected to separate drivers (part of QA209 and QA210) which are driven from the circuitry discussed in Section 4-8f.

SECTION 5. MAINTENANCE

5-1. GENERAL. This section contains information necessary to maintain the instrument. Included are procedures for electrical Performance Checks, Calibration, Troubleshooting, Battery Replacement and Charging.

5-2. REQUIRED TEST EQUIPMENT. Recommended test equipment for checking and maintaining the instrument is given in Table 5-1. Test equipment other than recommended may be substituted if specifications equal or exceed the stated characteristics.

5-3. PERFORMANCE VERIFICATION. Use the following procedures to verify proper operation of the instrument. All measurements should be made at ambient temperature of approx. 23°C and relative humidity below 50%. If the instrument is out of specification at any point, perform a complete calibration as given in Paragraph 5-4. For each function that is checked, an additional uncertainty due to temperature coefficient should be considered if the ambient temperature is different from the absolute calibration temperature.

NOTE

> If it is necessary to recalibrate the instrument, the complete Calibration Procedure must be performed to ensure that all specifications are within tolerance.

TABLE 5-1.
Recommended Test Equipment for Performance Verification

Item	Description	Specification	Mfr.	Model
A	Digital Voltmeter	1mV to 1000V ± 0.1%	Keithley	160
B	Voltage Source	1V to 1000V ± 0.02%	Fluke	341A
C	Oscillator	20Hz to 20kHz	Hewlett Packard	202C
D	Resistance Source	1kΩ to 10MΩ ± 0.03%	General Radio	1433
E	Ohmmeter (Electrometer)	100 to $10^{14}\Omega$ ± 3%	Keithley	610C
F	Current Source (DC)	0.1, 1 mA; 0.1, 1 A ±0.04% accuracy	Fluke	382A
G	AC Calibrator	1mV to 1000V ±0.08% accuracy 20 Hz to 20 kHz	Hewlett Packard	745A/746A
H	Current Source (AC)	0.1, 1 mA; 0.1, 1 A ±0.13% accuracy	Hewlett Packard General Radio	745A/746A 1433

a. Battery Check. (With Model 1688 Battery Pack installed).

1. Check for proper installation of individual cells in the battery pack making note of polarity of cells as shown in Figure 6.

2. Depress "BAT" pushbutton.

3. Connect Voltmeter (A) between test point "A" and LO to verify the 8.4 volt supply or test point "B" to verify the 16.8 volt supply. Voltage reading in DC voltage mode should be within the range given in Table 3-2.

b. Input Resistance Check.

1. Depress "DC" pushbutton.

2. Measure input resistance using Electrometer (E).

3. Resistance should be 10.056 megohms ± 5%.

c. Voltage Accuracy Check.*

1. DCV Function. Use Voltage Source (B) or equivalent test equipment.

a). Select DC Function.

b). Set input zero using R135. (FRONT PANEL ZERO POT.)

c). Apply a dc voltage between "HI" and "LO" as given in Table 5-3.

d). For each voltage range, verify that the reading on the display is within the tolerance stated.

Since factory calibration is performed at 23°C ±3°C, an additional ±3°C of temperature uncertainty should be considered when accuracy is to be verified.

TABLE 5-3.
Accuracy Check for DC Voltage

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
0.1V	±.02%	.1000V	±2 digits
1.0V	±.02%	1.000V	±2 digits
10V	±.02%	10.00V	±2 digits
100V	±.02%	100.0V	±2 digits
1000V	±.02%	1000.V	±2 digits

**Temperature coefficient: ±(0.02% of rdg + 0.01% of rng)/°C.

2. ACV Function. Use AC Calibrator (G) or equivalent test equipment.

a). Select AC Function.

b). Apply an AC voltage between "HI" and "LO" as given in Table 5-4. Set AC Calibrator for 5kHz frequency.

c). For each voltage range, verify that the reading on the display is within the tolerance stated.

TABLE 5-4.
Accuracy Check for AC Voltage

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
0.1V	±.08%	.1000V	±8 digits
1.0V	±.08%	1.000V	±8 digits
10V	±.08%	10.00V	±8 digits
100V	±.08%	100.0V	±8 digits
500V	±.23	500. V	±23 digits

**Temperature coefficient: ±(0.04% of rdg + 0.01% of rng)/°C.

d. Resistance Accuracy Check.

1. LO OHMS Function. Use Resistance Source (D) or equivalent test equipment.

a). Select LO OHMS Function.

b). Apply a resistance between "HI" and "LO" as given in Table 5-5.

c). For each resistance range, verify that the reading on the display is within the tolerance stated.

TABLE 5-5.
Accuracy Check for LO OHMS

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
100 Ω	±.04%	.1000 kΩ	±4 digits
1 kΩ	±.04%	1.000 kΩ	±4 digits
10 kΩ	±.04%	10.00 kΩ	±4 digits
100 kΩ	±.04%	.1000 MΩ	±4 digits
1 MΩ	±.04%	1.000 MΩ	±4 digits

**Temperature coefficient: ±(0.04% of rdg + 0.01% of rng)/°C.

2. HI OHMS Function. Use Resistance Source (D) or equivalent test equipment.

a). Select HI OHMS function.

b). Apply a resistance between "HI" and "LO" as given in Table 5-6.

c). For each resistance range, verify that the reading on the display is within the tolerance stated.

TABLE 5-6.
Accuracy Check for HI OHMS

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
1 kΩ	±.03%	1.000 kΩ	±3 digits
10 kΩ	±.03%	10.00 kΩ	±3 digits
100 kΩ	±.03%	100.0 kΩ	±3 digits
1 MΩ	±.03%	1.000 MΩ	±3 digits
10 MΩ	±.03%	10.00 MΩ	±3 digits

**Temperature coefficient: ±(0.04% of rdg + 0.01% of rng)/°C.

e. Current Accuracy Check.

1. Fuse Protection.

a). Fuse Check for mA Ranges. Select "LO OHMS" and "mA" functions. Display should read approximately 1.180kΩ to indicate a "good" fuse. A blinking display of 0.17MΩ indicates a "blown" fuse.

b). Fuse Check for A Ranges. Select "LO OHMS" and "A" functions. Display should read approximately .0012kΩ to indicate a "good" fuse. A blinking display of 0.17MΩ indicates a "blown" fuse.

2. Accuracy Check for mA Ranges (DC). Use Current Source (F).

a). Select "DC" and "mA" functions.

b). Apply a current as given in Table 5-7.

c). Verify that the reading on the display is within the tolerance stated.

TABLE 5-7.
Accuracy Check for mA (DC).

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
0.1mA	0.04%	.1000 mA	±4 digits
1mA	0.04%	1.000 mA	±4 digits

**Temperature coefficient: ±(0.03% of rdg + 0.01% of rng)/°C.

3. Accuracy check for A Ranges (DC). Use Current Source (F).

a). Select "DC" and "A" functions.

b). Apply a current as given in Table 5-8.

c). Verify that the reading on the display is within the tolerance stated.

TABLE 5-8.
Accuracy Check for A (DC).

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
0.1A	0.04%	.1000 A	±4 digits
1A	0.04%	1.000 A	±4 digits

**Temperature coefficient: ±(0.05% of rdg + 0.01% of rng)/°C.

4. Accuracy Check for mA Ranges (AC). Use Current Source (H).

a). Select "AC" and "mA" functions.

b). Apply a current as given in Table 5-9.

c). Verify that the reading on the display is within the tolerance stated.

TABLE 5-9.
Accuracy Check for mA (AC).

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**	Frequency
0.1mA	0.13%	.1000 mA	±13 digits	5kHz
1mA	0.13%	1.000 mA	±13 digits	5kHz

**Temperature coefficient: ±(0.05% of rdg + 0.01% of rng)/°C.

5. Accuracy check for A Ranges (AC). Use Current Source (H).

a). Select "AC" and "A" functions.

b). Apply a current as given in Table 5-10.

c). Verify that the reading on the display is within the tolerance stated.

TABLE 5-10.
Accuracy Check for A (AC).

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**	Frequency
0.1A	0.13%	.1000 A	±13 digits	5kHz
1A	0.13%	1.000 A	±13 digits	5kHz

**Temperature coefficient: ±(0.05% of rdg + 0.01% of rng)/°C.

f. Frequency Response Check.

1. Select "AC" function.

2. Apply an ac signal using AC Calibrator (F) with an amplitude set for a reading of 1.000V at 10kHz.

3. Maintain a fixed amplitude at the input and checking readings for frequencies over the range from 20Hz to 10kHz.

4. Readings should not vary more than ±8 digits from 20Hz to 10kHz.

g. AC Rejection Check.

1. Select "DC function.

2. Connect a 1.5V battery.

3. Apply a 60Hz sine wave using Oscillator (C), in series with battery.

4. Set Oscillator output for 10V p-p.

NOTE

Reference oscillator should be transformer coupled so that no dc offset is introduced.

5. Reading on the Model 168 should not vary more than ±1 digit.

5-4. ADJUSTMENT/CALIBRATION PROCEDURE. The following adjustments should be performed when any specification has been determined to be out-of-tolerance. The Performance Check given in paragraph 5-3 should be performed prior to this Calibration Procedure. If any step in the Calibration Procedure cannot be performed properly, refer to the Troubleshooting Procedure (paragraph 5-5) or contact your Keithley representative or the factory.

a. Chassis Assembly. To gain access to the adjustments on the printed circuit board, remove the four slotted screws on the bottom panel as shown in Figure 20. Lift off the top cover and set aside.

CAUTION

Care should be taken to avoid contact with line voltages at various points on the pc board when the line voltage cord is connected. Operate the instrument from battery power (if the Model 1688 Rechargeable Battery Set is available) to minimize the possibility of electrical shock when troubleshooting the Model 168.

NOTE

The Model 1688 may be lifted off the spacers and set to one side to gain access to the pc board while operating the Model 168 in battery mode.

IMPORTANT

Follow the exact calibration sequence since the adjustments are interrelated and dependent on prior calibration steps. Shield over input section must be installed for proper calibration. See Figure 23.

TABLE 5-11.
Recommended Test Equipment For Calibration.

Item	Description	Specification	Mfr.	Model
I	Digital Voltmeter	1mV to 1000V ± 0.1%	Keithley	160
J	Voltage Source	0 - 1100V ± 0.02%	Fluke	341A
K	Resistance Source	1kΩ to 10MΩ ± 0.03%	General Radio	1433
L	AC Calibrator	1mV to 1000V ± 0.08% 20Hz to 20kHz	Hewlett Packard	745A/746A

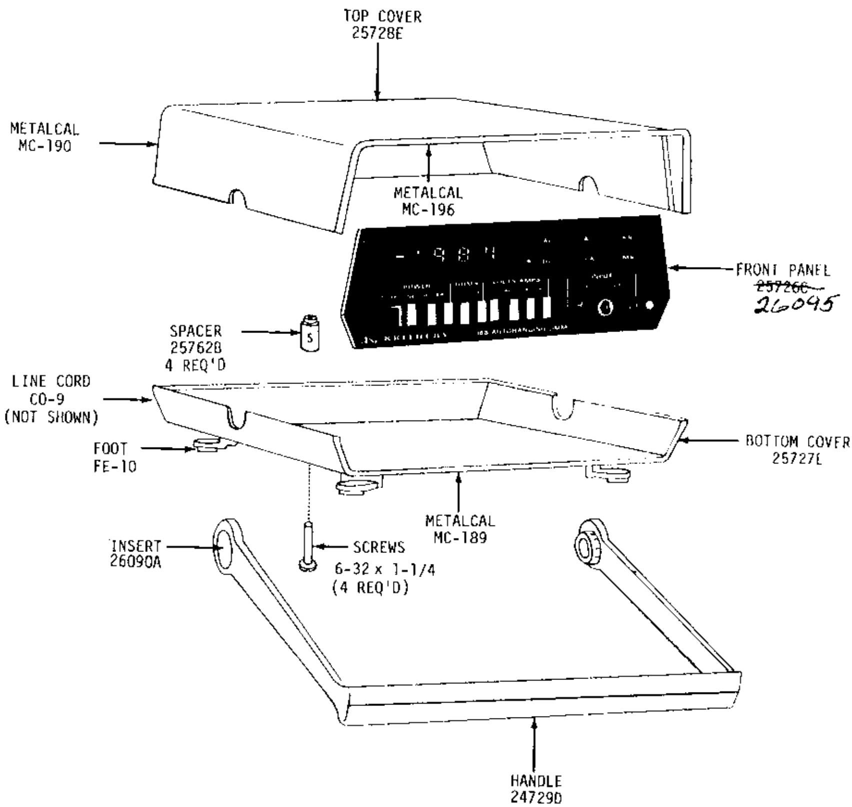


FIGURE 22. Top/Bottom Cover Assembly.

b. Power Supply Check. Measure dc voltages using Voltmeter (I) or equivalent test equipment.

1. Battery Check. If the calibration is to be performed using the BAT mode, then check the voltage of each supply directly across the battery terminals as shown in Figure 6.

2. Line Voltage Check.

a). Connect line cord to 117V ± 1V or 234V ± 2V, 50-60 Hz.

b). Set Line Switch to appropriate line voltage range.

c). Set power to LINE.

d). *Check fuses F101 and F102 if the display does not light up.*

3. +5V Regulated Supply. *Measure the voltage at +5V at resistor* R131 as shown in Figure 24. Use circuit low on switch hardware as common. The voltage should be within the range from +4.75V to +5.25V.

4. -12V Regulated Supply. Measure the voltage at -12V as shown in Figure 24. Use circuit low on switch hardware as common. The voltage should be within the range from -11.4V to -12.6 volts.

c. DC Voltage Calibration.

1. Zero Adjustment.

a). Select "DC" and "A" functions.

b). Connect Voltmeter (I) between Input LO and TP1 on the pc board. (Input terminals of the Model 168 must be open.)

c). Adjust the front panel zero control (R135) for a zero reading on Voltmeter (B) to within ±10 microvolts.

d). Connect Voltmeter (I) between Input LO and TP2 on the pc board.

e). Adjust potentiometer R137 (X10 ZERO) for a zero reading on Voltmeter (B) to within ±100 microvolts.

f). Connect a temporary jumper wire between -12 volts and transistor Q107 (gate lead).

g). Adjust potentiometer R115 (X1 ZERO) for a zero reading on Voltmeter (I) to within ±100 microvolts (as measured between LO and TP2).

h). Remove jumper previously installed in step 6.

i). Release "A" pushbutton.

j). Remove connections to Voltmeter (I).

2. Display Zero Adjust.

a). Apply a -1 millivolt dc signal to Model 168 input using Voltage Source (J).

b). Adjust potentiometer R129 (DISPLAY ZERO) for a display reading which flashes between -.0009 volts and -.0010 volts.

3. Rectifier Zero Adjust.

a). Apply a +1 millivolt dc signal to Model 168 input using Voltage Source (J).

b). Adjust potentiometer R126 (RECTIFIER ZERO) for a display reading which flashes between .0009 volts and .0010 volts. (Repeat steps 2 and 3 to achieve display conditions [so that no further adjustments are necessary].)

4. -100V Adjust.

a). Apply a -100 volt dc signal to Model 168 input using Voltage Source (J).

b). Adjust potentiometer R128 (-100V Adj.) for a display reading which flashes between -100.0 volts and -100.1 volts.

5. +100V Adjust.

a). Apply a +100 volt dc signal to Model 168 input using Voltage Source (J).

b). Adjust potentiometer R123 (+100V Adj.) for a display reading which flashes between +100.0 volts and +100.1 volts.

6. -1V Adjust.

a). Apply a -1 volt dc signal to Model 168 input using Voltage Source (J).

b). Adjust potentiometer R139 (-1V Adj.) for a display reading which flashes between -1.000 volts and -1.001 volts.

d. Ohms Calibration.

1. 100 Kilohm Adj.

a). Select "HI OHMS" function.

b). Apply 100 kilohm source (K) to Model 168 input.

c). Adjust potentiometer R122 (100kΩ Adj.) for a display reading which flashes between 100.0kΩ and 100.1kΩ.

2. 1 Kilohm Adj.

a). Apply 1 kilohm source (K) to Model 168 input.

b). Adjust potentiometer R109 (1kΩ Adj.) for a display reading which flashes between 1.000kΩ and 1.001kΩ.

e. AC Voltage Calibration.

1. 100 VAC Adj.

a). Select "AC" function.

b). Apply 100V ac rms at 5kHz frequency using AC Calibrator (L).

c). Adjust capacitor C108 (100 VAC Adj.) for a display reading which flashes between 100.0 and 100.1 volts ac.

2. 100mV AC Adj.

a). Apply 100mV ac rms at 3kHz frequency using AC Calibrator (L).

b). Adjust capacitor C110 (100mV AC Adj.) for a display reading which flashes between .1000 and .1001 volts ac.

3. 1V AC Adj.

a). Apply 1V ac rms at 5kHz frequency using AC Calibrator (L).

b). Adjust capacitor C113 (1V AC Adj.) for a display reading which flashes between 1.000 and 1.001 volts ac.

TABLE 5-12.
Summary of Calibration Adjustments.

Source Input	Source Accuracy	Display Reading	Adjustment Name	Adjustment Circuit Desig
Open	----	TP1 set to 0 ± 10μV	*Front panel zero*	R135
Open	----	TP2 set to 0 ± 100μV	X10 Zero Adj.	R137
Open	----	TP2 set to 0 ± 100μV (jumper installed)	X1 Zero Adj.	R115
-1mV dc	±.02%	-.0009 to -.0010V dc	Display Zero	R129
+1mV dc	±.02%	+.0009 to +.0010V dc	Rectifier Zero	R126
-100V dc	±.02%	-100.0 to -100.1V dc	-100V Adj.	R128
+100V dc	±.02%	+100.0 to +100.1V dc	+100V Adj.	R123
-1V dc	±.02%	-1.000 to -1.001V dc	-1V Adj.	R139
100kΩ	±.03%	100.0 to 100.1kΩ	100kΩ Adj.	R122
1kΩ	±.03%	1.000kΩ to 1.001kΩ	1kΩ Adj.	R109
100V ac rms @ 5kHz	±.08%	100.0 to 100.1V AC	100 VAC Adj.	C108
100mV ac rms @ 3kHz	±.08%	.1000 to .1001V AC	100mV AC Adj.	C110
1V ac rms @ 5kHz	±.08%	1.000 to 1.001V AC	1VAC Adj.	C113

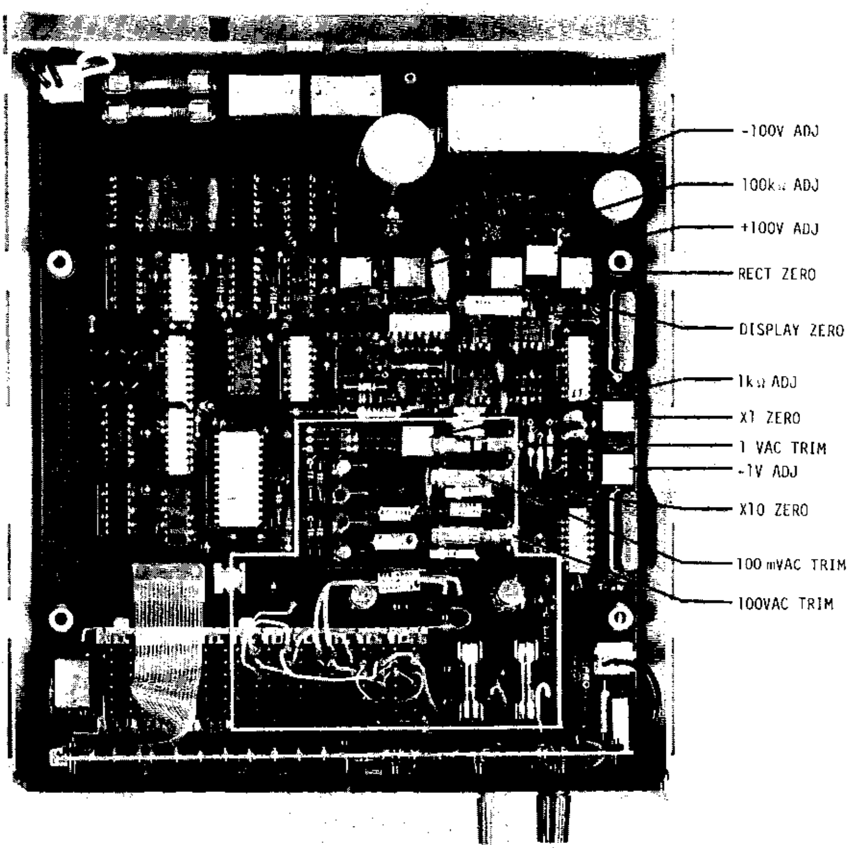


FIGURE 23. Location of Calibration Adjustments.

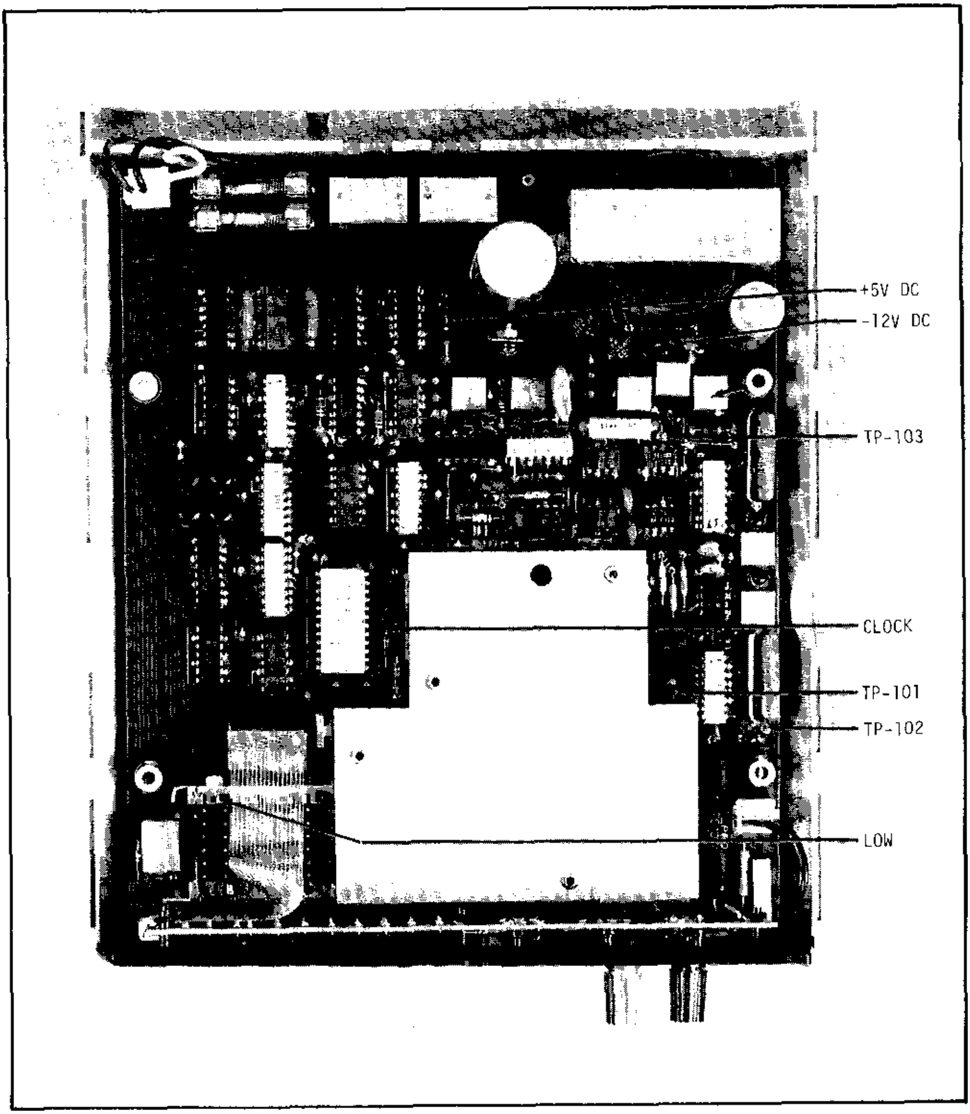


FIGURE 24. Location of Test Points.

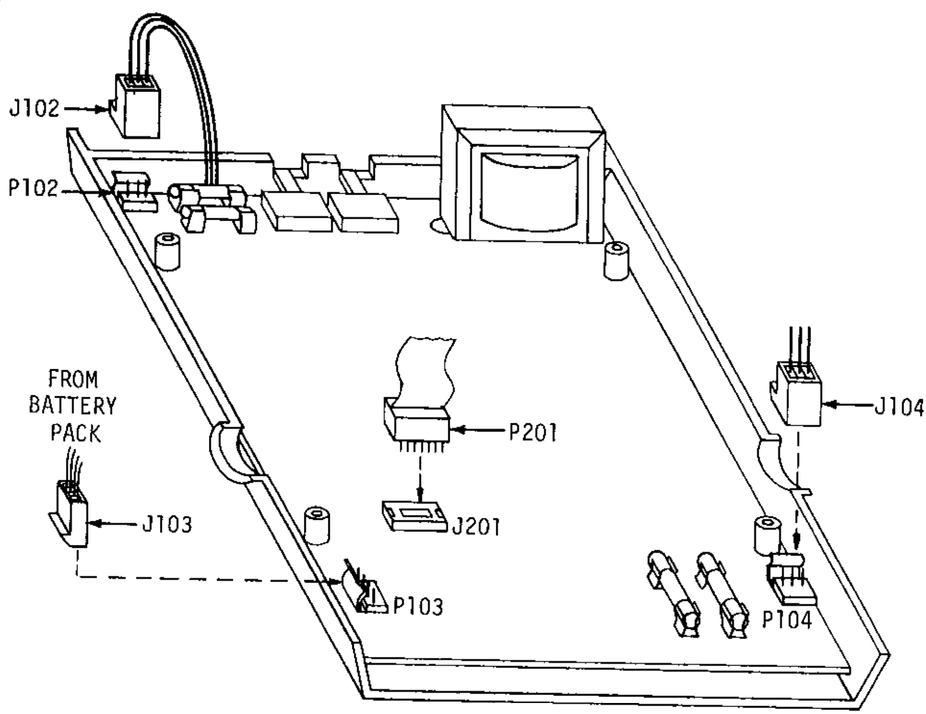


FIGURE 25. Location of Chassis Connections.

5-5. TROUBLESHOOTING. If the instrument is out-of-tolerance for any specification, perform the Calibration Procedure given in Paragraph 5-4. If during the calibration an instrument malfunction is apparent, then proceed with the troubleshooting steps as given in Table 5-14.

a. How to Replace Line Fuses. The Model 168 uses two line fuses in the primary windings of transformer T101. Fuse F101 (1/8A, 3AG) is connected in series with winding 4-5-6 for all positions of LINE Switches. Fuse F102 (1/8A, 3AG) is connected in series with winding 1-2-3 only when the Model 168 is set to 117V. The line fuses are located on the main printed circuit board PC-346 as shown in Figure 26. To gain access to the printed circuit board, turn the instrument over so that the bottom cover faces up. Remove four slotted screws on the bottom cover. Turn over the instrument with top cover facing up, taking care to hold the top and bottom covers together. Remove the top cover to gain access to the printed circuit board. Replace fuses as necessary. Replace top cover. Turn over the instrument with bottom cover facing up and install the four slotted-head screws.

b. How to Replace Batteries. (See Section 2-3 for installation of Model 1688 Rechargeable Battery Pack). If it should ever be necessary to replace the batteries in the Model 1688 Battery Pack, remove the top cover as in Section 5-5a (above). Then replace batteries with Keithley Part No. BA-29 and BA-30 as shown in Table 5-13.

TABLE 5-13.
Summary of Batteries Used in Model 1688.

Description	Quantity	Keithley Part No.
Rechargeable "C" cell, 1.2V, 4 AMP-HR	7	BA-30
Rechargeable "Button" type battery, 8.4V, .25 AMP-HR (4 individual 1.2V cells)	2	BA-29

c. Troubleshooting Procedure. The troubleshooting hints given in Table 5-14 are intended as an aid to locating and correcting circuit malfunctions. If difficulty is not corrected contact the factory or your Keithley representative for assistance (see inside front cover for addresses).

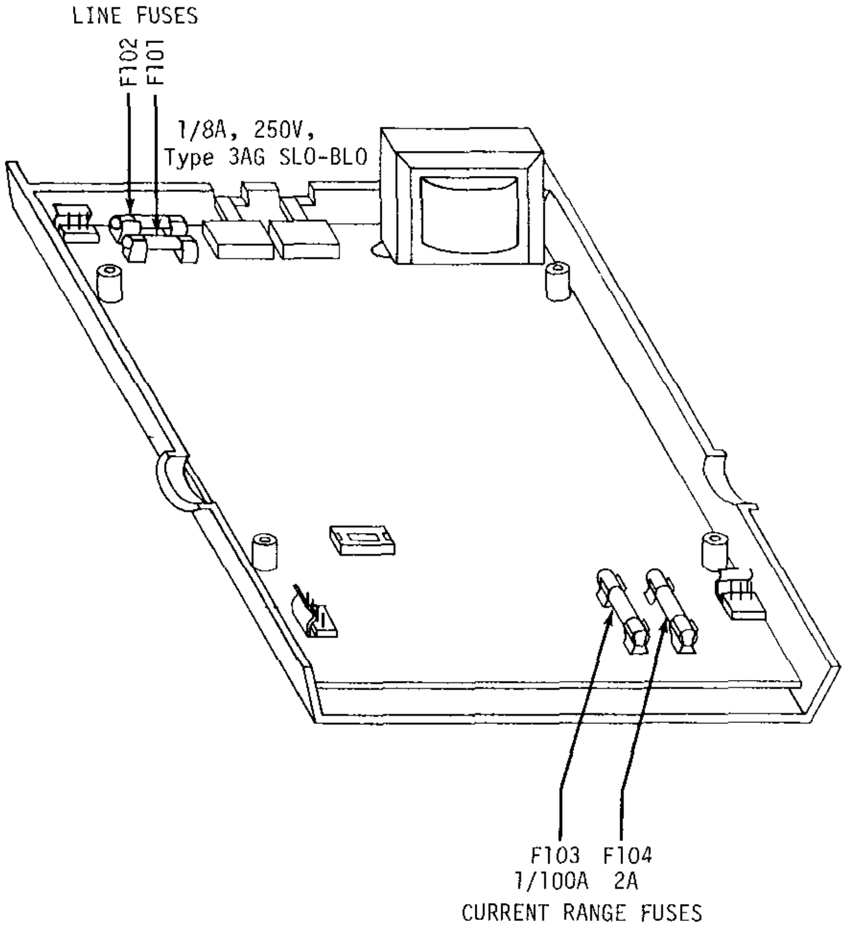


FIGURE 26. Location of Fuses.

TABLE 5-14.
Troubleshooting Procedure

Difficulty	Probable Cause	Corrective Action
(a) No Display (LINE mode only)	1) Line switches set incorrectly.	Check connection to line power. Check LINE switch settings to conform to line voltage available. See Section 2-3a.
	2) Fuses F101 and F201 are missing or open.	Check fuses F101 and F102. Replace with 3AG, 1/8A, 234V types. See Figure 26.
	3) Line voltage cable J102 improperly connected to pc board at P102.	Check connection to pc board at P102. See Figure 25.
(b) No Display (BAT mode).	1) Batteries need recharging.	Connect instrument to line power. Select CHG operation.
	2) Batteries improperly installed.	Check battery pack for proper polarity on all batteries. See Figure 6.
	3) Battery cable improperly installed.	Check battery cable J103 for proper connection to P103 on pc board. See Figure 8.
(c) No Display (CHG mode).	1) Batteries improperly installed.	Check battery pack for proper polarity on all batteries. See Figure 6.
	2) Battery cable improperly installed.	Check battery cable J103 for proper connection to P103 on pc board. See Figure 8.
(d) No Display (All modes).	1) Display cable P201 not connected to pc board at J201.	Check plug P201 and mating connector J201. Make certain all pins are making contact (pins should not be bent). White dot on connector indicates pin 1. See Figure 25.
	2) LSI module improperly installed.	Check QA212 for proper installation. Make certain all pins are making contact (pins should not be bent). Dot indicates pin 1. See Figure 24.
	3) Power Supply malfunction.	Check power supply voltages as described in Section 5-4b.
(e) Display is blank except for one digit. (All modes).	1) Clock waveform is missing.	Check pin 7 of LSI (QA212) for a clock waveform of approx. 9kHz, swinging between +5V and -12V. If waveform is present, LSI (QA212) is probably faulty. If waveform is not present, transistor Q201 is probably faulty.

TABLE 5-14 (Cont'd).
Troubleshooting Procedure

Difficulty	Probably Cause	Corrective Action
(f) One display bar missing on all digits	1) Faulty connection between P201 and J201	Check plug P201 and mating connector J201. Make certain all pins are making contact.
	2) Cathode driver circuitry faulty. See schematic 26088E.	"a" bar: Check QA210 pin 8 for signal. When "ON", voltage should be approx. +0.8V. "b" bar: Check QA210 pin 11 "c" bar: Check QA210 pin 14 "d" bar: Check QA209 pin 8 "e" bar: Check QA209 pin 11 "f" bar: Check QA209 pin 14 "g" bar: Check QA202 pin 11
(g) One digit missing.	1) Faulty connection between P201 and J201.	Check plug P201 and mating connector J201.
	2) Anode driver circuitry faulty. See schematic 26088E.	If units digit missing, check collector of Q202 for signal. When "ON", voltage should be approx. 4.8V. If tens digit missing, check collector of Q203. If hundreds digit missing, check collector Q204. If thousands digit, minus sign and function indicator missing, check collector Q205.
(h) Display flashes overload on volts function with input shorted.	1) Input amplifier malfunctioning. See schematic 26089E.	Check TP101 for zero. If at zero, problem is beyond this point. If near +5V or -12V, connect a jumper from pin 2 to pin 6 of QA103. If TP101 is now zero, probably one of switching FET's (Q102, Q103, Q104, Q105) is inoperative. If TP101 still is not near zero, QA103 is probably inoperative.
	2) Second stage amplifier malfunctioning	Check TP102 for zero. If zero, problem is beyond this point. If not zero, QA104 is probably inoperative.
	3) FWR circuitry malfunction.	Check TP103 for near zero. If near zero problem is either QA106 (Integrator) or QA107 (Threshold Detector). If TP103 is +2V or greater, problem is either QA105 or QA106.
(i) Display indicates zero when open on either HI or LO OHMS	1) Integrated circuit malfunction. QA110 (Ohms reference amp).	Check anode of Diode CR108 for approx. -.81V. If not present, replace QA110.

SECTION 6. REPLACEABLE PARTS

6-1. GENERAL. This section contains information for ordering replacement parts. The parts list is arranged in alphameric order of their Circuit Designations.

6-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of the manual for addresses. *When ordering, include the following information:*

a. Instrument Model Number
b. Instrument Serial Number
c. Part Description
d. Circuit Designation (if applicable)
e. Keithley Stock Part Number

TABLE 6-1.
Cross-reference of Manufacturers.

ABREV.	NAME AND ADDRESS	ABREV.	NAME AND ADDRESS
A-B	Allen-Bradley Corp. Milwaukee, WI. 53204	H-P	Hewlett Packard Palo Alto, CA. 94304
AMPRX	Amperex Elkgrove Village, IL. 60007	INTER	Intersil, Inc. Cupertino, CA. 95014
BECK	Beckman Instruments, Inc. Fullerton, CA. 92634	IRC	IRC Division Burlington, IA. 52601
BOURN	Bourns, Inc. Riverside, CA. 92507	KI	Keithley Instruments, Inc. Cleveland, OH. 44139
CAD	Caddock Riverside, CA. 92507	LITRO	Litronix Cupertino, CA. 95014
CENLB	Centralab Division Milwaukee, WI. 53201	LITFU	Littlefuse, Inc. Des Plaines, IL. 60016
COMPI	Components, Inc. Biddeford, ME. 04005	MOTOR	Motorola Semiconductor Products Inc. Phoenix, AZ. 85008
C-D	Cornell-Dubilier Electronics Div. Newark, NJ. 07105	MOLEX	Molex Downers Grove, IL. 60515
CTS	CTS Corporation Elkart, IN. 46514	NAT	National Semiconductor Corp. Santa Clara, CA. 95051
DICK	Dickson Electronics Corp. Scottsdale, AZ. 85052	RCA	RCA Corporation Somerville, NJ. 08876
ECI	Electrocube Inc. San Gabriel, CA. 91776	SCC	Standard Condenser Co. Chicago, IL. 60613
EDI	Electronic Devices Inc. Yonkers, NY. 10710	TEMPL	Temple Tecate, CA. 92080
ERIE	Erie Technological Products, Inc. Erie, PA. 16512	TEPRO	Tepro Clearwater, FL. 33517
FAIR	Fairchild Instrument Corp. Mountain View, CA. 94040	TEXAS	Texas Instruments, Inc. Dallas, TX. 75231

ANALOG CIRCUITRY
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CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C101	2000 µF, 25V, EAL	TEMPL	411-2000M	C255-2000M	1
C102	10 µF, 20V, ETT	COMPI	TD22010620	C179-10M	3
C103	10 µF, 20V, ETT	COMPI	TD22010620	C179-10M	..
C104	400 µF, 50V, EAL	TEMPL	411-400µF	C246-400M	1
C105	10 µF, 20V, ETT	COMPI	TD22010620	C179-10M	..
C106	.01 µF, 600V, MPCb	ECI	625B1F103	C224-.01M	1
C107	39 pF, 500V, Cer	ERIE	302000C0G0-390J	C226-39P	1
C108	.8-18 pF, 750V, Var.	ERIE	567-013	C225-.8-18P	3
C109	33 pF, 500V, Cer	ERIE	302000C0G0330J	C226-33P	1
C110	.8-18 pF, 750V, Var.	ERIE	567-013	C225-.8-18P	..
C111	.0047 µF, 200V, MPCb	ECI	625B1C472	C221-.0047M	1
C112	477 pF, 500V, Silver Mica	C-D	CD15FD477F03	C209-477P	1
C113	.8-18 pF, 750V, Var.	ERIE	567-013	C225-.8-18P	..
C114	.0055 µF, 200V, MPCb	ECI	625B1C552F	C222-.0055M	1
C115	.0495 µF, 200V, MPCb	ECI	625B1C495F	C222-.0495M	1
C116	1 µF, 250V, MPoly	AMPRX	C280AE/A1M	C256-1M	2
C117	5 pF, 1000V, CerD	CENLB	DD-050	C64-5P	2
C118	150 pF, 1000V, CerD	CENLB	DD-151	C64-150P	2
C119	100 pF, 1000V, CerD	CENLB	DD-101	C64-100P	1
C120	.02 µF, 500V, CerD	ERIE	811-Z5U0-203M	C22-.02M	1
C121	39 µF, 15V, Epoxy	COMPI	TD4015396-10	C228-39M	3
C122	39 µF, 15V, Epoxy	COMPI	TD4015396-10	C228-39M	..
C123	5 pF, 1000V, CerD	CENLB	DD-050	C64-5P	..
C124	150 pF, 1000V, CerD	CENLB	DD-151	C64-150P	..
C125	1 µF, 250V, MPoly	AMPRX	C280AE/A1M	C256-1M	..
C126	39 µF, 15V, Epoxy	COMPI	TD401539610	C228-39M	..
C127	0.1 µF, 200V, MPF	SCC	M2W-R-.033M	C143-.1M	1
C128	.001 µF, 500V, CerD	ERIE	808-000-Z5R0102K	C22-.001M	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR101	Full-wave rectifier (bridge), 1.5A, 400PRV	EDINC	PF-40	RF-46	2
CR102	Full-wave rectifier (bridge), 1.5A, 400PRV	EDINC	PF-40	RF-46	..
CR103		TEXAS	1N914	RF-28	8
CR104		TEXAS	1N914	RF-28	..
CR105		TEXAS	1N914	RF-28	..
CR106		TEXAS	1N914	RF-28	..
CR107		TEXAS	1N914	RF-28	..
CR108	Rectifier, 400 PIV	FAIR	1N4004	RF-44	1
CR109	Zener diode, 6.2V, 25 mA	DICK	1N709	DZ-21	1
CR110	Zener diode, 9V.	COMPI	1N937	DZ-41	1
CR111		TEXAS	1N914	RF-28	..
CR112		TEXAS	1N914	RF-28	..
CR113		TEXAS	1N914	RF-28	..

ANALOG CIRCUITRY (Cont'd)
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TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q101	NPN, Case TO-5 Selected TG-43*.	RCA	40317*	25505A	1
Q102	N-Chan J-FET, Case TO-18.	INTER	ITS3538	~~TG-88~~	4
Q103	N-Chan J-FET, Case TO-18.	INTER	ITS3538	TG-88 TG-128	..
Q104	N-Chan J-FET, Case TO-18.	INTER	ITS3538	~~TG-88~~	..
Q105	N-Chan J-FET, Case TO-18.	INTER	ITS3538	~~TG-88~~	..
Q106	N-Chan J-FET, Case R-110.	INTER	ITE4392	TG-77	3
Q107	N-Chan J-FET, Case R-110.	INTER	ITE4392	TG-77	..
Q108	N-Chan J-FET, Case R-110.	INTER	ITE4392	TG-77	..
Q109	NPN, Case TO-106.	FAIR	2N3565	TG-39	2
Q110	PNP, Case TO-106.	FAIR	2N5139	TG-66	1
Q111	NPN, Case TO-5.	FAIR	2N3439	TG-93	1
Q112	PNP, Case TO-92	MOTOR	2N5087	TG-61	1
Q113	NPN, Case TO-106.	FAIR	2N3565	TG-39	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA101	Voltage Regulator, 5V Case TO-220	FAIR	UGH7805393	IC-93	1
QA102	Voltage Regulator, 12V Case TO-220.	FAIR	UGH7812393	IC-60	1
QA103	Amplifier, Case TO-5.	NAT	LH0022CH	~~IC-92~~ IC-165	1
QA104	Amplifier, 8-pin DIP.	FAIR	Special	IC-76	3
QA105	Amplifier, 8-pin DIP.	FAIR	Special	IC-76	..
QA106	Amplifier, 8-pin DIP.	FAIR	Special	IC-77	1
QA107	Amplifier, 8-pin DIP.	FAIR	UGT7741393	IC-42	2
QA108	Amplifier, 8-pin DIP.	FAIR	UGT7741393	IC-42	..
QA109	Transistor Array, 14-pin DIP.	RCA	CA3086	IC-53	1
QA110	Amplifier, 8-pin DIP.	FAIR	Special	IC-76	..

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	1 kΩ, 0.1%, 1/2W, MtF	A-B	CB-102-10%	R169-1K	1
R102	680Ω, 10%, 1/4W, Comp	A-B	CB-681-10%	R76-680	2
R103	680Ω, 10%, 1/4W, Comp	A-B	CB-681-10%	R76-680	..
R104	1Ω, 0.1%, 10W, WW	TEPRO	TS-10W-1	R221-1	1
R105	56kΩ, 10%, 1/4W, Comp	A-B	CB-563-10%	R76-56K	1
R106	1MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R76-1M	5
R107	47Ω, 10%, 1/4W, Comp.	A-B	CB-470-10%	R76-47	1
R108	845Ω, 1%, 1/8W, MtF	IRC	CEA-TO-100Ω	R88-845	1
R109	200Ω, 0.5W, Var	BECK	72PMR-200	RP97-200	3
R110	1MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R76-1M	..
R111	1MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R76-1M	..
R112	1MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R76-1M	..
R113	1MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R76-1M	..
R114	1.8KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-1.8K	R88-1.8K	1
R115	10KΩ, 0.5W, Var	BECK	72PMR-10K	RP97-10K	2

ANALOG CIRCUITRY (Cont'd)
(Schematic 26089E)

RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R116	47kΩ, 10%, 1/4W, Comp	A-B	CB-473-10%	R76-47K	1
R117	1kΩ, 10%, 1/4W, Comp.	A-B	CB-102-10%	R76-1K	1
R118	2kΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-2K	R88-2K	1
R119	100kΩ, 10%, 1/2W, Comp.	A-B	EB-104-10%	R1-100K	1
R120	333kΩ, 1%, 1/2W, MtF.	IRC	CEC-333K	R94-333K	1
R121	333kΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-332k	R88-332K	1
R122	200Ω, 0.5W, Var	BECK	72PMR-200	RP97-200	..
R123	1kΩ, 0.5W, Var.	BECK	72PMR-1K	RP97-1K	1
R124	1kΩ, 10%, 1/4W, Comp.	A-B	CB-102-10%	R76-1K	1
R125	120kΩ, 10%, 1/4W, Comp.	A-B	CB-124-10%	R76-120K	1
R126	500Ω, 0.5W, Var	BECK	72PMR-500	RP97-500	1
R127	12kΩ, 10%, 1/4W, Comp	A-B	CB-123-10%	R76-12K	1
R128	2kΩ, 0.5W, Var.	BECK	72PMR-2K	RP97-2K	1
R129	10kΩ, 0.5W, Var	BECK	72PMR-10K	RP97-10K	..
R130	100kΩ, 10%, 1/4W, Comp.	A-B	CB-104-10%	R76-100K	1
R131	6.8kΩ, 10%, 1/4W, Comp.	A-B	CB-682-10%	R76-6.8K	1
R132	10kΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R76-10K	3
R133	10kΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R76-10K	..
R134	10kΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R76-10K	..
R135	1kΩ, 0.75W, Var	BECK	89P-1K	RP98-1K	1
R136	200Ω, 1%, 1/8W, MtF	IRC	CEA-TO-200	R88-200	2
R137	2kΩ, 0.5W, Var.	BOURN	3299W-1-202	RP104-2K	1
R138	200Ω, 1%, 1/8W, MtF	IRC	CEA-TO-200	R88-200	..
R139	200Ω, 0.5W, Var	BECK	72PMR-200	RP97-200	..
R140*	10^9Ω, 20%, 1/2W, Comp	IRC	GBT-10^9Ω	R37-10^9	1

*Selected in initial factory calibration.

RESISTOR NETWORKS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN101	7-pin	CAD	1718-33	TF-27	1
RN102	16-pin DIP	CTS	017-900-001	TF-5	1
RN103	16-pin DIP	CTS	900-12	TF-28	1
RN104	14-pin DIP	CTS	900-11	TF-29	1
RN105	16-pin DIP	CTS	017-900-002	TF-2	1

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS101	Display, mA Functions.	LITRO	RL-209 (RED)	PL-61	2
DS102	Display, A Function.	LITRO	RL-209 (RED)	PL-61	..
F101	Fuse, 1/8A, 250V, type 3AG slo-blo.	CTS	MDL-1/8A	FU-20	2
F102	Fuse, 1/8A, 250V, type 3AG slo-blo.	CTS	MDL-1/8A	FU-20	..
F103	Fuse, 1/100A, 250V, type 8AG Fast acting.	LITFU	361.010	FU-41	1
F104	Fuse, 2A, 250V, type 8AG fast acting.	LITFU	361002	FU-42	1
P101	Connector, line cord, 3-conductor, 6-ft. (18 AWG)	BELDN	17236B	CO-9	1
P102	Connector, 3-pin.	MOLEX	A-2391-3A	CS-288-3	2
P103	Connector, 4-pin.	MOLEX	A-2391-4A	CS-288-4	1
P104	Connector, 3-pin.	MOLEX	A-2391-3A	CS-288-3	..

ANALOG CIRCUITRY (Cont'd)
(Schematic 26089E)

MISCELLANEOUS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
S101	Switch, Slide type, DPDT, LOW/NORM	KI		SW-318	
S102	Switch, Slide type, DPDT, 117/234V	KI		SW-318	
S103	Switch, Pushbutton	KI		SW-371	
T101	Transformer	KI		TR-156	
TP101	Test Point.	KI		24249A	
TP102	Test Point.	KI		24249A	
TP103	Test Point.	KI		24249A	

DIGITAL CIRCUITRY
(Schematic 26088E)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C201	.15μF, 250V, MtF	AMPRX	C280AE	C178-.15M	2
C202	.15μF, 250V, MtF	AMPRX	C280AE	C178-.15M	..
C203	.001μF, 500V, CerD	ERIE	808-000-Z5R0102K	C22-.001M	1
C204	4.7μF, 20V, ETT.	COMPI	TSD120475	C179-4.7M	4
C205	4.7μF, 20V, ETT.	COMPI	TSD120475	C179-4.7M	..
C206	4.7μF, 20V, ETT.	COMPI	TSD120475	C179-4.7M	..
C207	4.7μF, 20V, ETT.	COMPI	TSD120475	C179-4.7M	..

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR201	Signal diode	TEXAS	1N914	RF-28	4
CR202	Signal diode	TEXAS	1N914	RF-28	..
CR203	Signal diode	TEXAS	1N914	RF-28	..
CR204	Signal diode	TEXAS	1N914	RF-28	..

INDICATORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS201	Digital Display, 7 segment, polarity	H-P	HP5082-7730	DD-10	1
DS202	Digital Display, 7 segment, Thousands Digit.	H-P	HP5082-7730	DD-9	4
DS203	Digital Display, 7 segment, Hundreds Digit	H-P	HP5082-7730	DD-9	..
DS204	Digital Display, 7 segment, Tens Digit	H-P	HP5082-7730	DD-9	..
DS205	Digital Display, 7 segment, Units Digit.	H-P	HP5082-7730	DD-9	..
DS206	Display, MΩ Function	LITRO	RL-209 (Red)	PL-61	4
DS207	Display, KΩ Function	LITRO	RL-209 (Red)	PL-61	..
DS208	Display, DC Function	LITRO	RL-209 (Red)	PL-61	..
DS209	Display, AC Function	LITRO	RL-209 (Red)	PL-61	..

DIGITAL CIRCUITRY (Cont'd)
(Schematic 26088E)

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q201	PNP, Case TO-106	FAIR	2N5139	TG-66	1
Q202	PNP, Case TO-106	FAIR	2N4355	TG-90	4
Q203	PNP, Case TO-106	FAIR	2N4355	TG-90	..
Q204	PNP, Case TO-106	FAIR	2N4355	TG-90	..
Q205	PNP, Case TO-106	FAIR	2N4355	TG-90	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA201	Hex Inverter, TTL, 14-pin DIP	TEXAS	SN7404N	IC-33	1
QA202	Transistor Array, 14-pin DIP	RCA	CA3086	IC-53	3
QA203	Dual Flip-Flop, 14-pin DIP	TEXAS	SN7474N	IC-31	1
QA204	Positive NAND Gates, Quad 2-Input, 14-pin DIP	TEXAS	SN7400N	IC-38	1
QA205	Quad 2-Input, Positive AND, 14-pin DIP	TEXAS	SN7408N	IC-94	1
QA206	Positive NOR Gates, 14-pin DIP	TEXAS	SN7402N	IC-32	1
QA207	Hex Inverters, 14-pin DIP	TEXAS	SN7405N	IC-45	2
QA208	Quad 2-Input, Positive NAND, 14-pin DIP	TEXAS	SN74L03N	IC-95	1
QA209	Transistor Array, 14-pin DIP	RCA	CA3086	IC-53	..
QA210	Transistor Array, 14-pin DIP	RCA	CA3086	IC-53	..
QA211	Hex Inverters, 14-pin DIP	TEXAS	SN7405N	IC-45	..
QA212	Large Scale Integrated Circuit, 24-pin DIP	KI	LSI-1	LSI-1	1

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R201	10 kΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R76-10K	1
R202	47 kΩ, 10%, 1/4W, Comp	A-B	CB-473-10%	R76-47K	2
R203	47 kΩ, 10%, 1/4W, Comp	A-B	CB-473-10%	R76-47K	..

RESISTOR NETWORKS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
RN201	16-pin DIP	CTS	900-8	TF-32	1
RN202	16-pin DIP	CTS	900-7	TF-31	1
RN203	16-pin DIP	CTS	900-6	TF-30	1

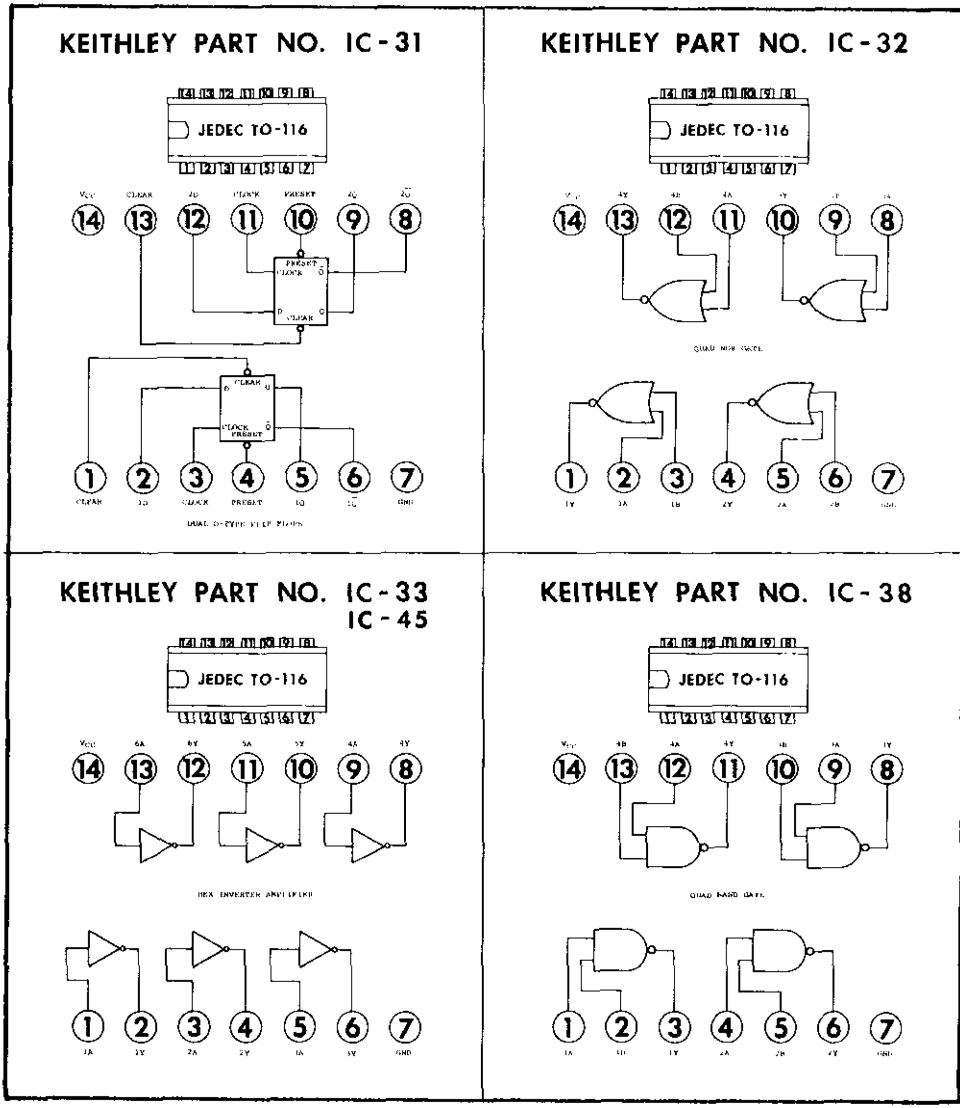


FIGURE 27. Case Outlines -- Integrated Circuits

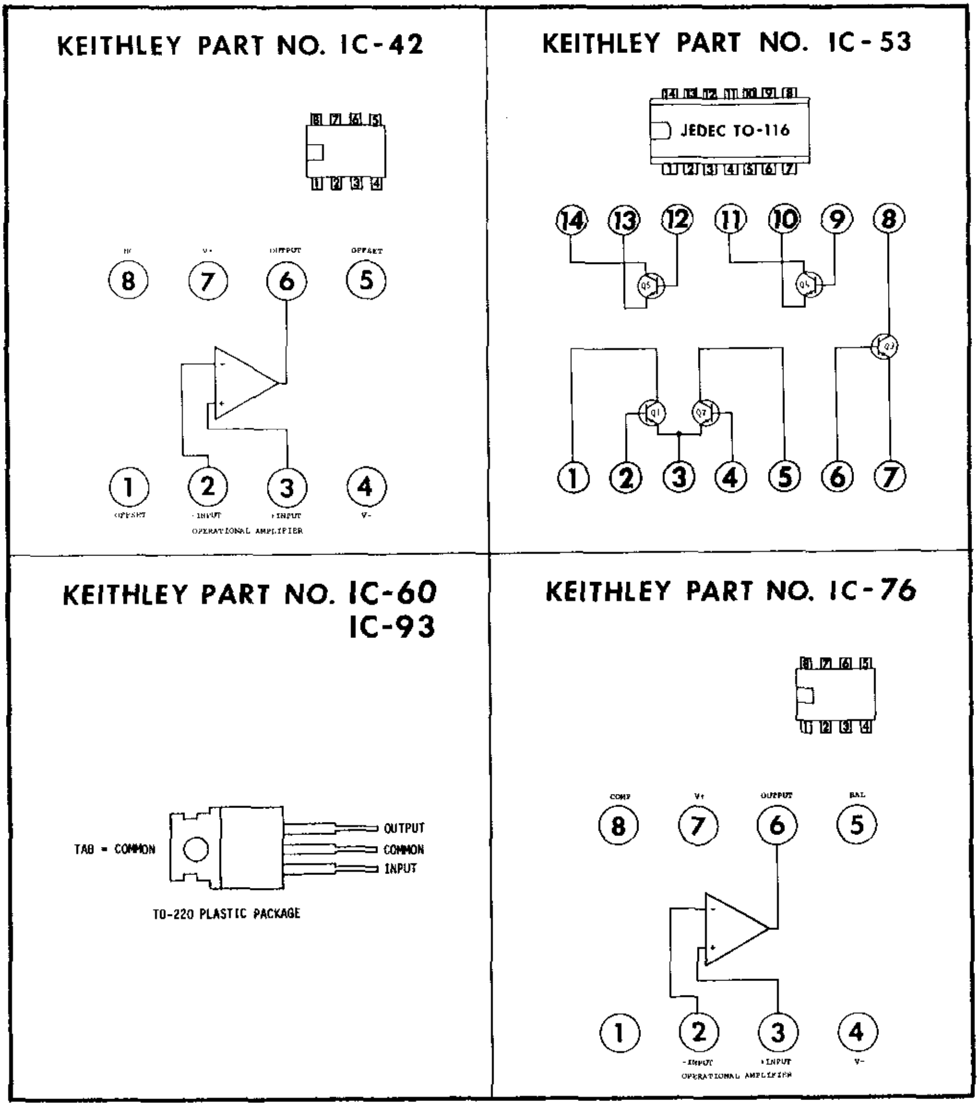


FIGURE 28. Case Outlines -- Integrated Circuits.

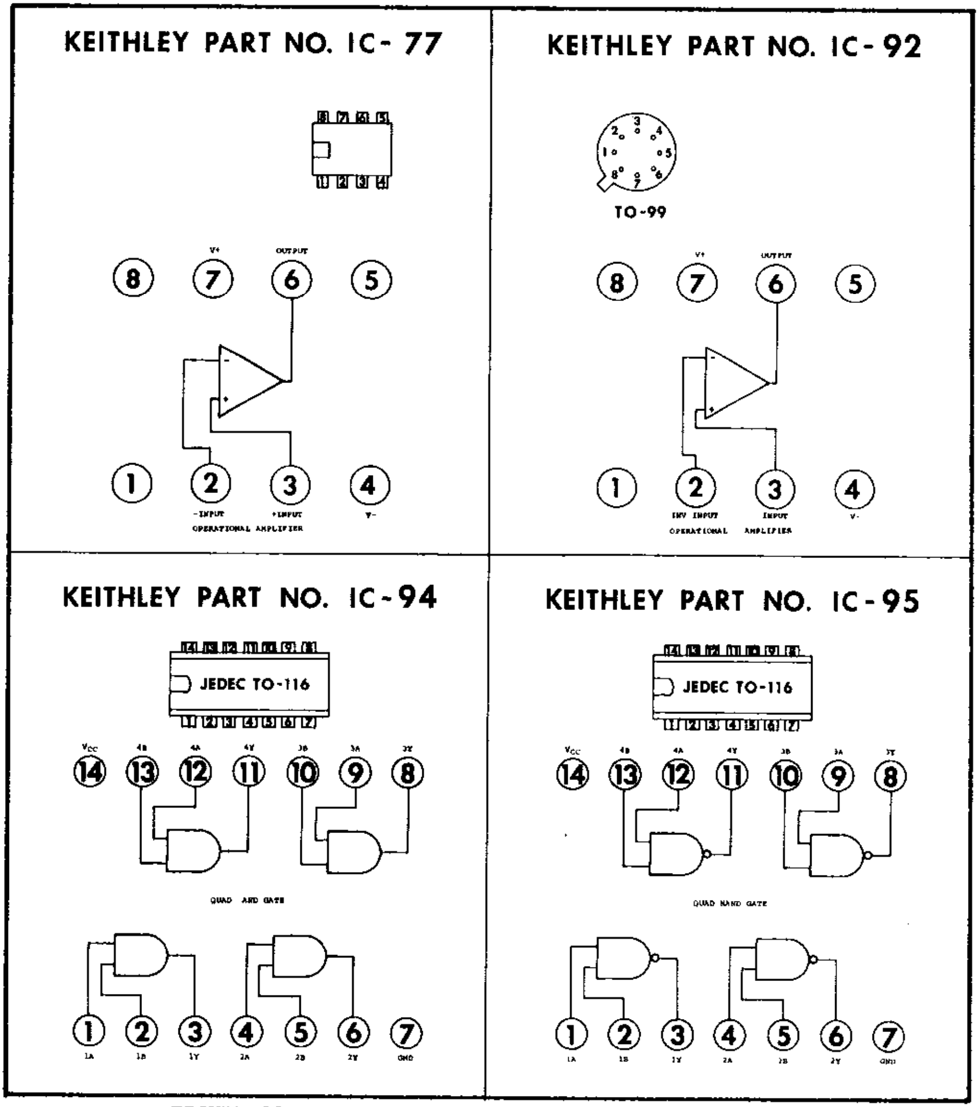


FIGURE 29. Case Outlines -- Integrated Circuits.

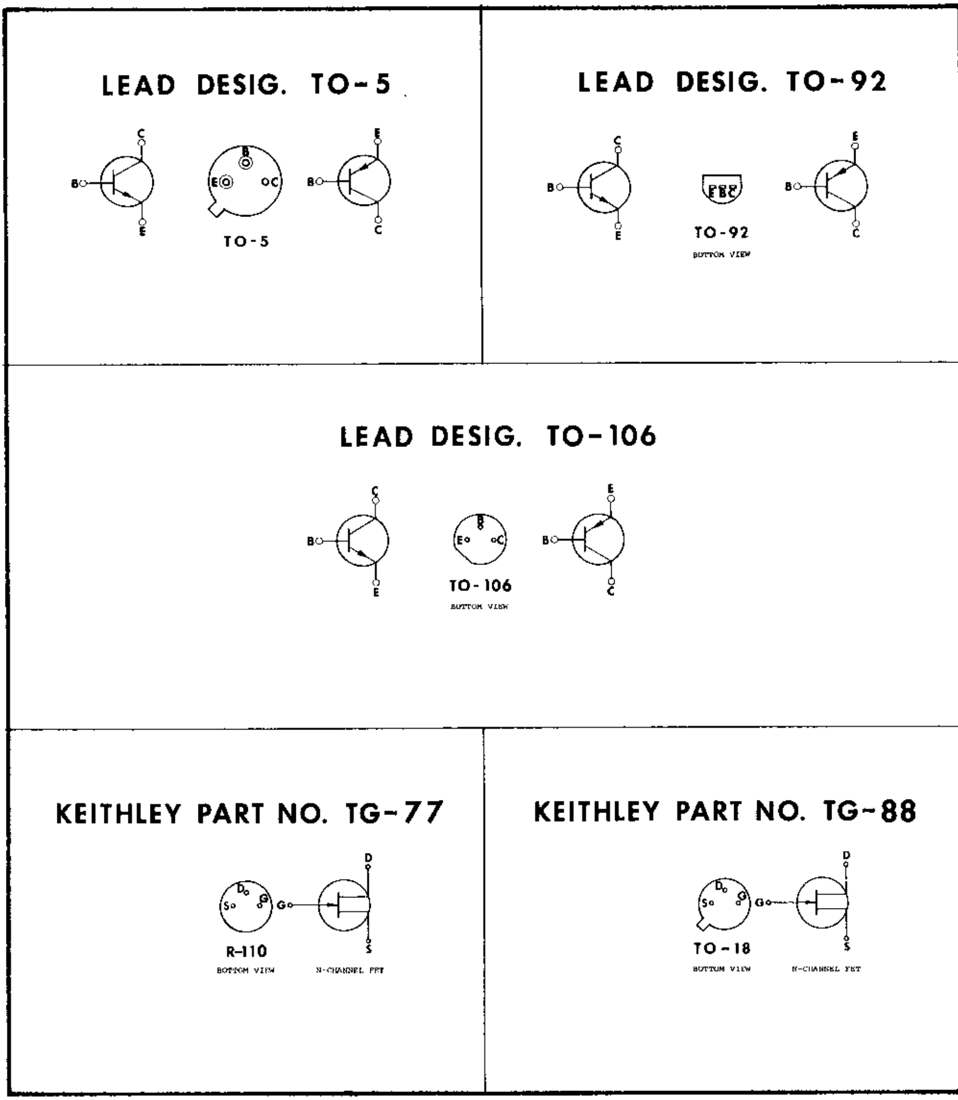


FIGURE 30. Case Outlines, Transistors.

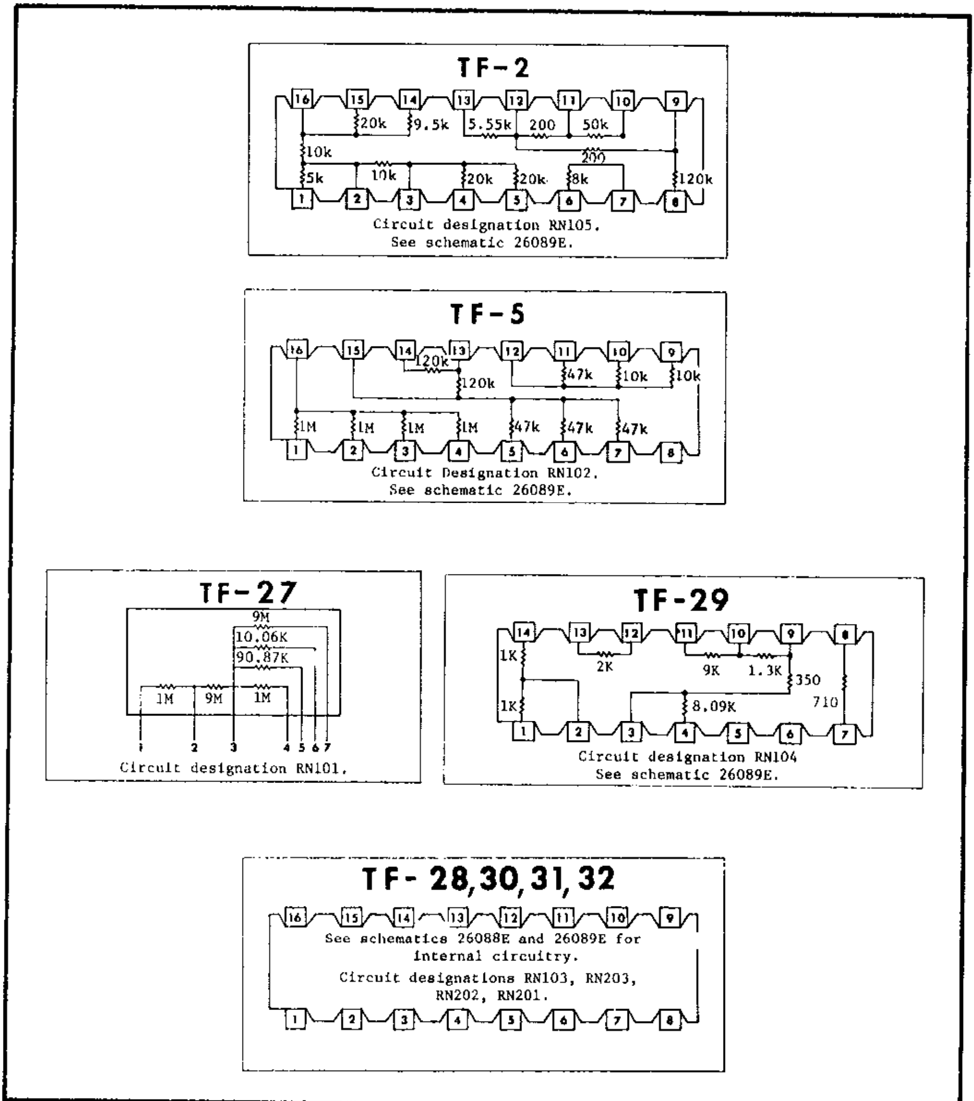


FIGURE 31. Case Outlines, Thick Film Networks.

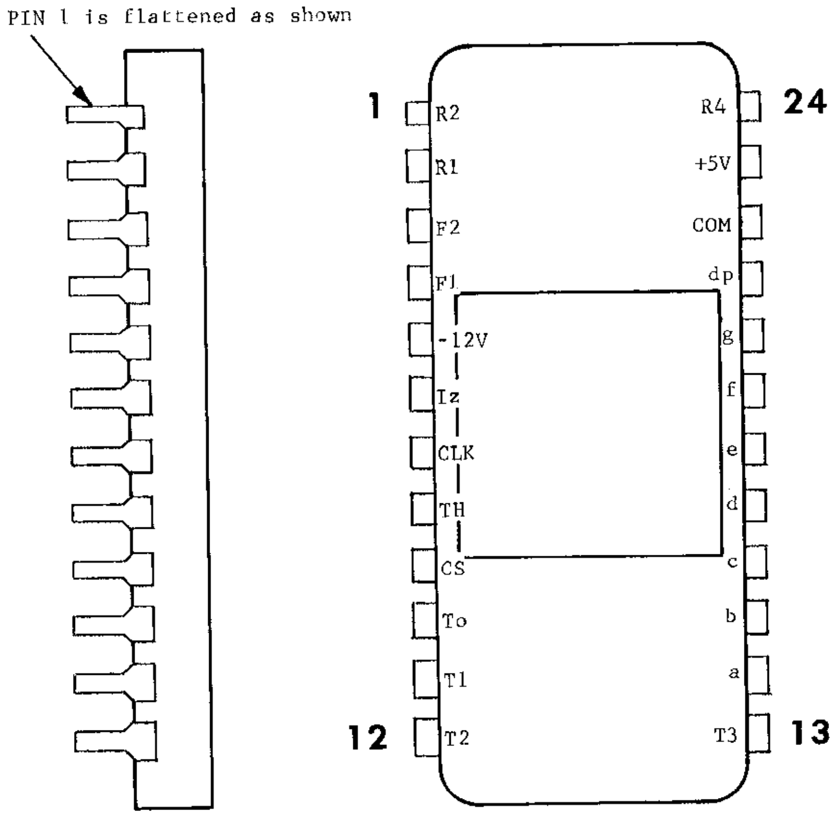
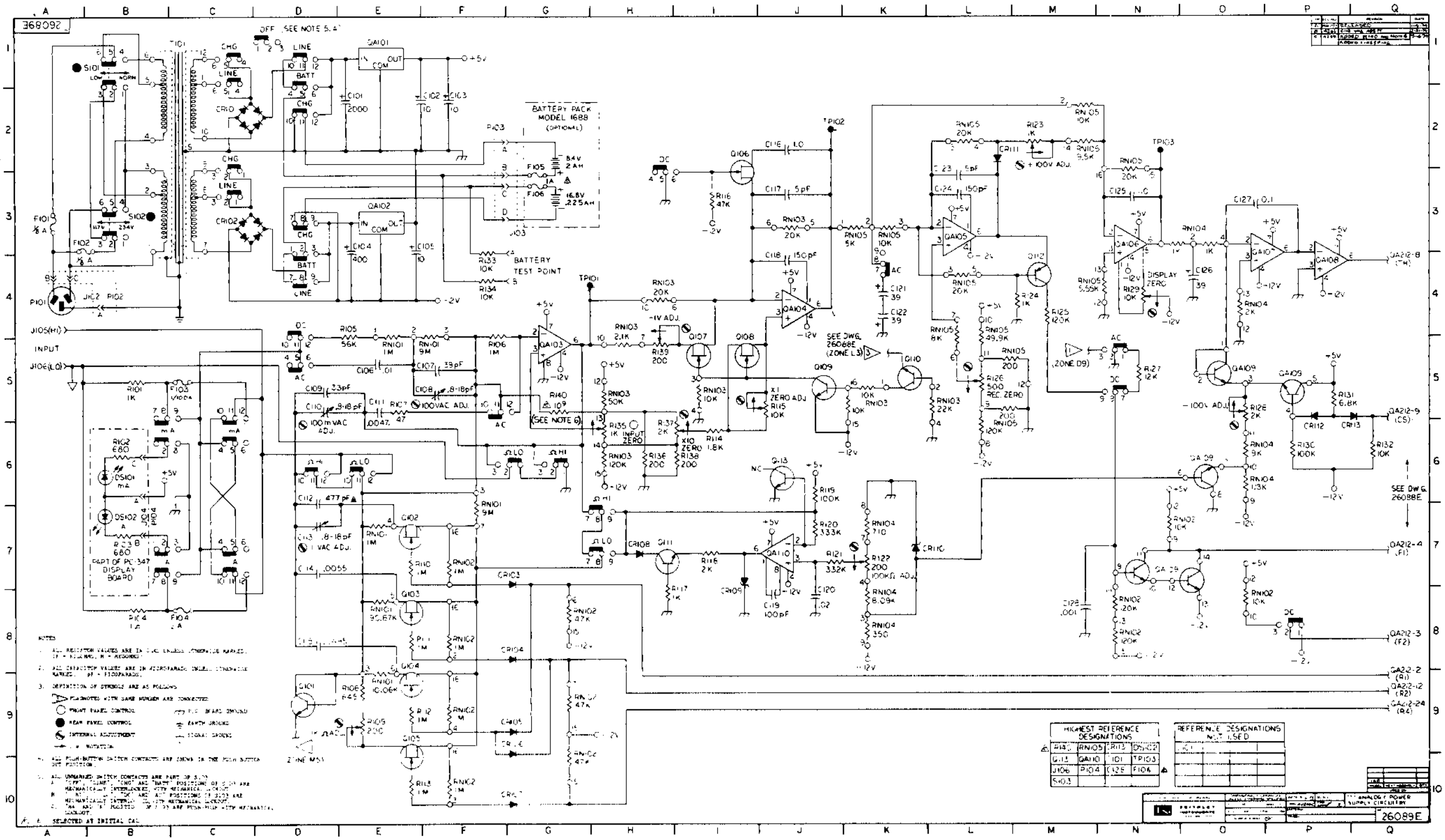
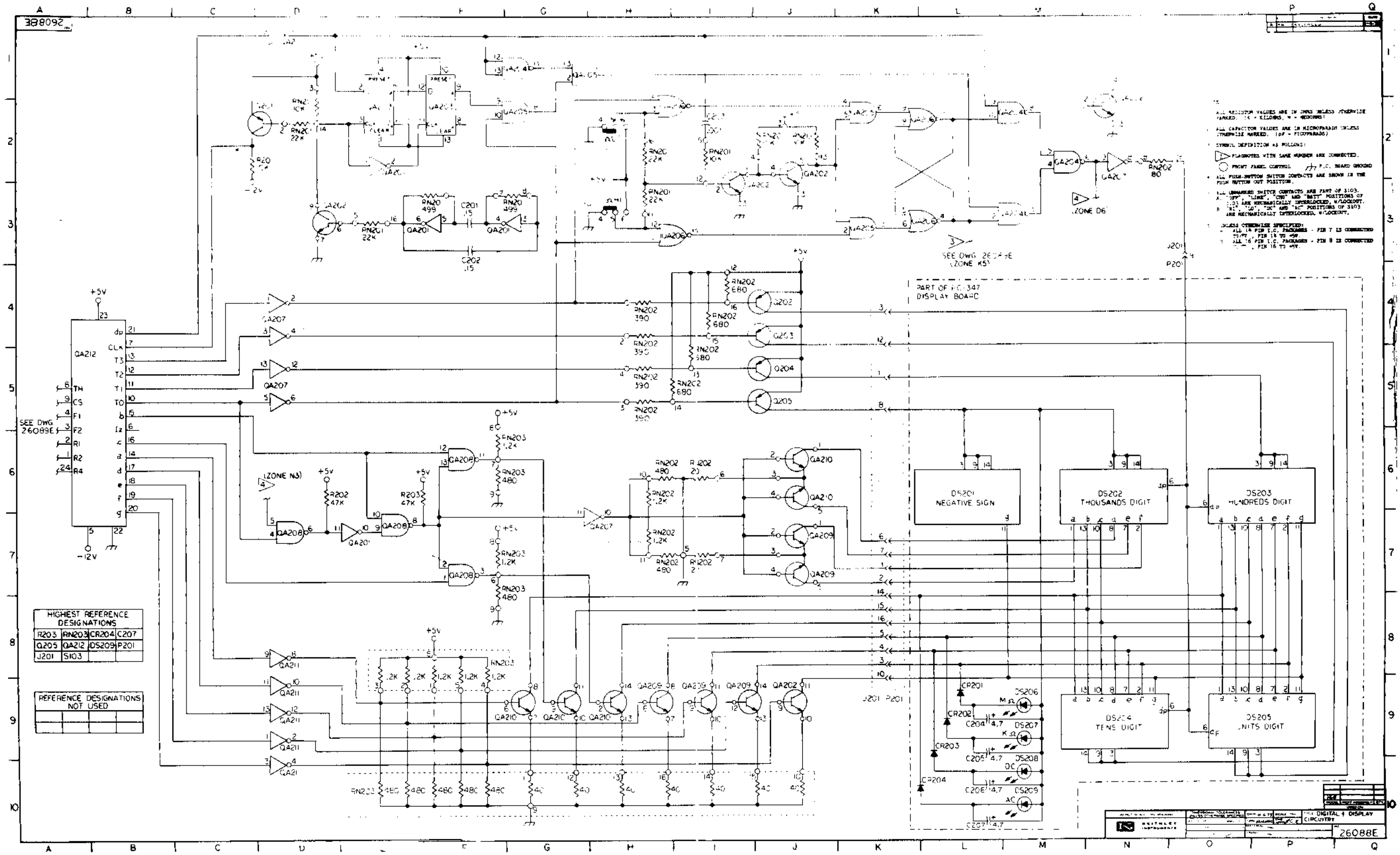


FIGURE 32. Case Outlines, LSI

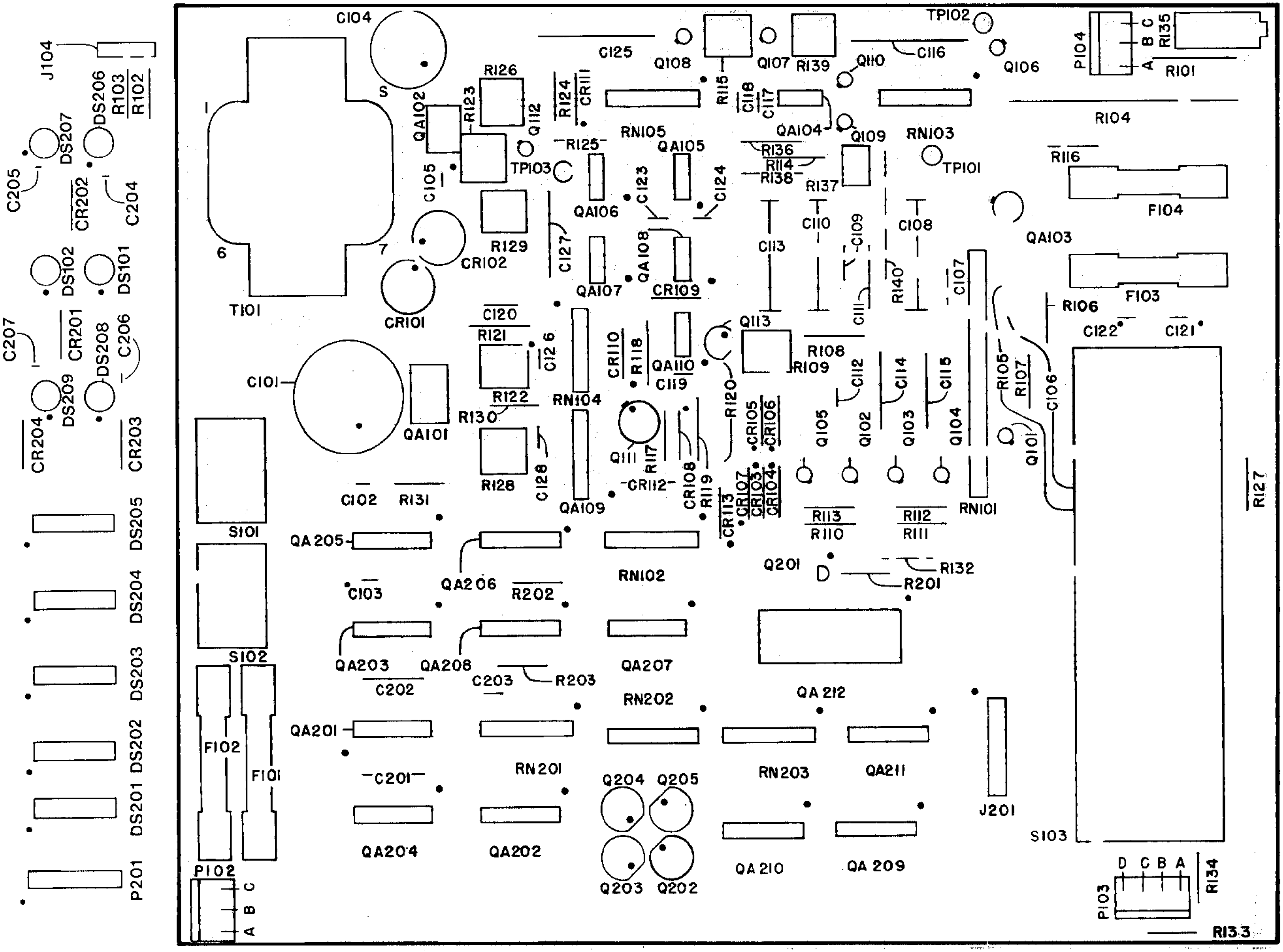


368092
BATTERY PACK MODEL 1688 (OPTIONAL)
BATTERY TEST POINT
INPUT
J105(HI)
J106(LO)
PART OF PC-347 DISPLAY BOARD
+100V ADJ.
DISPLAY ZERO
-1V ADJ.
X1 ZERO ADJ
X10 ZERO
1K INPUT ZERO
100mVAC ADJ.
100VAC ADJ.
1 VAC ADJ.
500 REC. ZERO
100KΩ ADJ.
-100V ADJ.
SEE DWG. 26088E (ZONE L3)
SEE DWG. 26088E
ZONE M5
NOTES
6. SELECTED AT INITIAL CAL
HIGHEST REFERENCE DESIGNATIONS
R140 | RN105 | CR113 | DS102
Q113 | QA110 | T101 | TP103
J106 | P104 | C128 | F106
S103
REFERENCE DESIGNATIONS NOT USED
ANALOG POWER SUPPLY CIRCUITRY
26089E



HIGHEST REFERENCE DESIGNATIONS			
R203	RN203	CR204	C207
Q205	QA212	DS209	P201
J201	S103		

REFERENCE DESIGNATIONS NOT USED			


J104
DS206
R103
R102
DS207
C205
CR202
C204
DS102
DS101
C207
CR201
DS208
C206
DS209
CR204
CR203
DS205
DS204
DS203
DS202
DS201
P201
C104
S
T101
1
6
7
R126
R123
QA102
Q112
R124
CR111
C125
Q108
R115
Q107
R139
Q110
C116
TP102
Q106
P104
A
B
C
R135
R101
C118
C117
QA104
Q109
RN105
RN103
R104
R125
QA105
R136
R114
R138
R137
TP103
TP101
R116
C105
QA106
C123
C124
F104
R129
CR102
C127
QA108
C110
C109
C108
QA103
C113
CR109
QA107
R140
C107
F103
C111
R106
CR101
C120
R121
C126
CR110
R118
Q113
R108
C122
C121
C101
QA101
R122
RN104
QA110
C119
R109
C112
C114
C115
R105
R107
C106
R130
Q111
R117
R120
CR105
CR106
Q105
Q102
Q103
Q104
Q101
R128
C128
CR112
CR108
R119
CR107
CR103
CR104
S101
C102
R131
QA109
CR113
R113
R110
R112
R111
RN101
R127
QA205
RN102
Q201
R132
R201
C103
QA206
R202
S102
QA203
QA208
QA207
C202
C203
R203
RN202
QA212
QA201
F102
F101
C201
RN201
Q204
Q205
RN203
QA211
J201
S103
QA204
QA202
Q203
Q202
QA210
QA209
D
C
B
A
R134
P103
P102
R133

APPENDIX

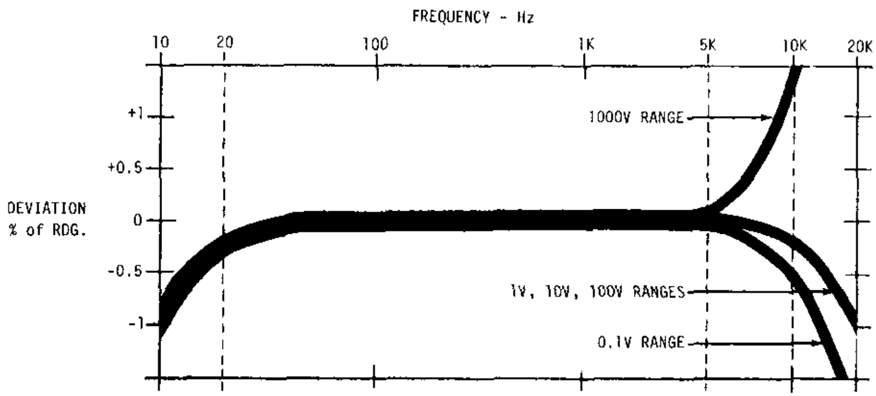


FIGURE A1. Typical Frequency Response Curves - AC Voltage Mode.

APPENDIX

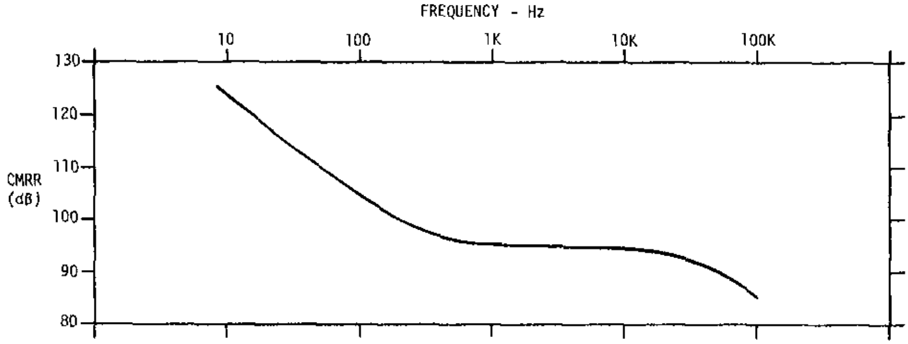


FIGURE A2. Typical CMRR (AC MODE) VS Frequency.
[With 1kΩ imbalance, LO driven, up to 2400V P-P CMV.]

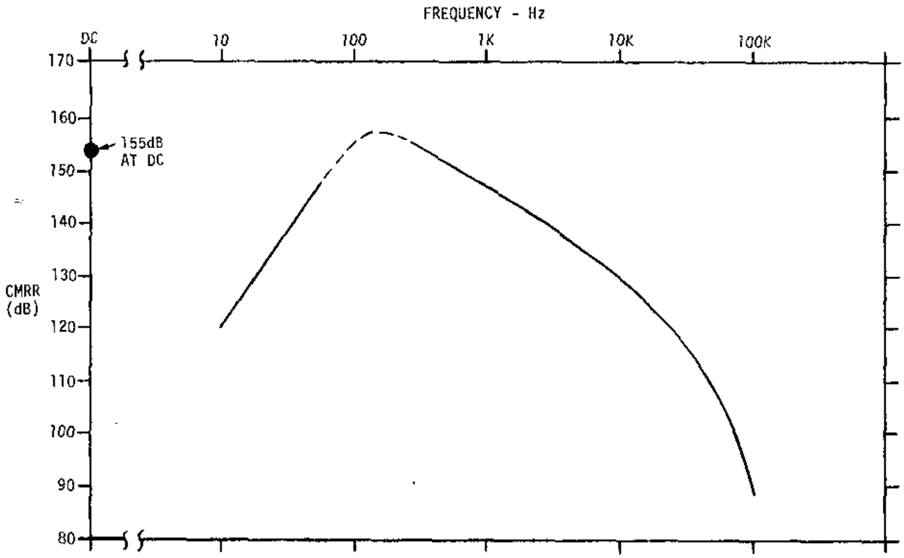


FIGURE A3. Typical CMRR (DC Mode) VS Frequency.
[With 1kΩ imbalance, LO driven, up to 2400V P-P CMV.]