INSTRUCTION MANUAL

Model 190

Digital Multimeter

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ILLUSTRATIONS

SPECIFICATIONS

AS A DC VOLTMETER

RANGE: ±10 microvolts per digit (1 volt full range) to ±1000 volts full range in four decade ranges. 100% overranging to 199999 on all ranges except on the 1000-volt range.

ACCURACY* (24 hours): ±(0.005% of reading + 0.005% of range). **(90 days);** ±(0.015% of reading + 0.005% of range). ± less than 0.00001% of reading per volt from full range.

TEMPERATURE COEFFICIENT: ±0.002% of reading/°C.

INPUT RESISTANCE: Greater than 1000 megohms on the 1-volt range. 10 megohms on the 10 to 1000-volt ranges.

SETTLING TIME*: Less than 5 seconds to within 0.01% of final reading.

NORMAL MODE REJECTION RATIO: Greater than 80 dB over one digit on the 1 and 10-volt ranges, decreasing to 60 dB on the 1000-volt range. 50 Hz to 180 Hz.

COMMON MODE REJECTION RATIO: Greater than 100 dB over one digit on the 1 and 10-volt ranges, decreasing to 80 dB on the 1000-volt range, dc to 180 Hz with 1 kilohm unbalance.

MAXIMUM ALLOWABLE INPUT: 1400 volts peak momentary, 1000 volts continuous dc + rms ac.

AS AN AC VOLTMETER

RANGE: 10 microvolts per digit (1 volt full range) to 1000 volts rms full range in four decade ranges. 100% overranging to 199999 on all ranges except the 1000-volt range.

ACCURACY (50 Hz to 10 kHz) (90 days): ±(0.3% of reading + 0.06% of range) to 400 volts. Application of greater than 400 volts ac + dc begins to cause temporary additional error up to ±0.3% of reading due to power heating effects. (Average reading calibrated in rms of a sine wave).

TEMPERATURE COEFFICIENT: ±(0.01% of reading + 0.005% of range)/°C.

INPUT IMPEDANCE: 1 megohm shunted by less than 40 picofarads.

SETTLING TIME: Less than 5 seconds to within 0.1% of final reading below 400 volts.

MAXIMUM ALLOWABLE INPUT: 1000 volts rms ac + dc, but not more than 600 volts dc on any range.

After application of greater than 500V for more than 1 minute, power heating effects begin to cause temporary additional error on all ranges of up to ±0.005% of reading.

AS AN OHMMETER

RANGE: 10 milliohms per digit (1 kilohm full range) to 10 megohms full range in five decade ranges. 100% overranging to 199999 on all ranges.

ACCURACY (90 days): ±(0.02% of reading + 0.01% of range + 0.2 ohm) except ±(0.08% of reading + 0.01% of range) on the 10-megohm range.

TEMPERATURE COEFFICIENT: ±(0.002% of reading + 0.001% of range)/ C except ±(0.01% of of reading + 0.001% of range) /°C on the 10-megohm range.

SETTLING TIME: Less than 3 seconds plus 1 second per megohm to within 0.01% of final reading.

CONFIGURATION: Two-terminal, constant current, HI terminal negative.

VOLTAGE ACROSS UNKNOWN: 5 volts for full range.

MAXIMUM ALLOWABLE INPUT: 20 volts on the 1-kilohm range, 60 volts on the 10-kilohm range, 250 volts on all other ranges, continuous rms ac + dc.

GENERAL

POLARITY: Automatic

ZERO STABILITY: 0.7 digit/°C.

WARMUP: 30 minutes to within twice specified accuracy, two hours for complete stabilization.

DISPLAY: 5 digits plus 1 overrange digit, decimal location; polarity and overload indication. Less than 1 second per reading, adjustable to 10 seconds per reading in 1-second steps.

ISOLATION: LO to CASE: greater than 100 megohms shunted by 0.01 microfarad. LO may be floated up to ±500 volts with respect to CASE.

OPERATING ENVIRONMENT: 15°C to 35°C up to 70% relative humidity.

POWER: 105-125 or 210-250 volts (switch-selected), 50-60 Hz, 20 watts.

CONNECTORS: HI, LO & CASE, Binding Posts; Digital Output, 18/36 card edge.

DIMENSIONS, WEIGHT: Overall bench size 4 in. high x 8-3/4 in. wide x 13-1/2 in. deep (100 x 220 x 345 mm). Net weight, 8 pounds (3,6 kg).

DIGITAL OUTPUT: BCD (8421; 0 = "0000") TTL-type lines represent each of five digits, overrange digit, overload ("1"), polarity (+ = "1"), decimal position and function (7 lines).

PRINT COMMAND: Logic "1" appears for 200 milliseconds after each display update.

HOLD CONTROL: Logic "0" retains last data in display and digital output.

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 190 is a precision digital multimeter offering measurement capability on dc voltage, ac voltage, resistance, and current when used with optional accessory shunts. The Model 190 has 5 full digits plus 100% overranging, 13 full ranges--4 ranges of ac and dc voltage (covering eight decades)--5 ranges of resistance (covering nine decades). Built-in BCD digital outputs are provided as standard.

1-2. WARRANTY INFORMATION. The warranty is stated on the inside front cover of the manual. If there is a need for service, contact your Keithley representative or authorized repair facility as given in our catalog. The Service Form supplied at the back of the manual should be used to provide the repair facility with adequate information concerning any difficulty.

1-3. CHANGE NOTICE. Improvements or changes to the instrument not incorporated into the manual will be explained on a change notice sheet attached to the inside back cover of the manual.

1-4. CURRENT ADAPTER OPTION. The Model 1901 Current Adapter provides current measuring capability when plugged into the front terminals of the Model 190. The Model 1901 offers five switched decade shunts of 0.1 ohm to 1 kilohm. The 190's resolution enables current measurements down to 1 microamp per digit.

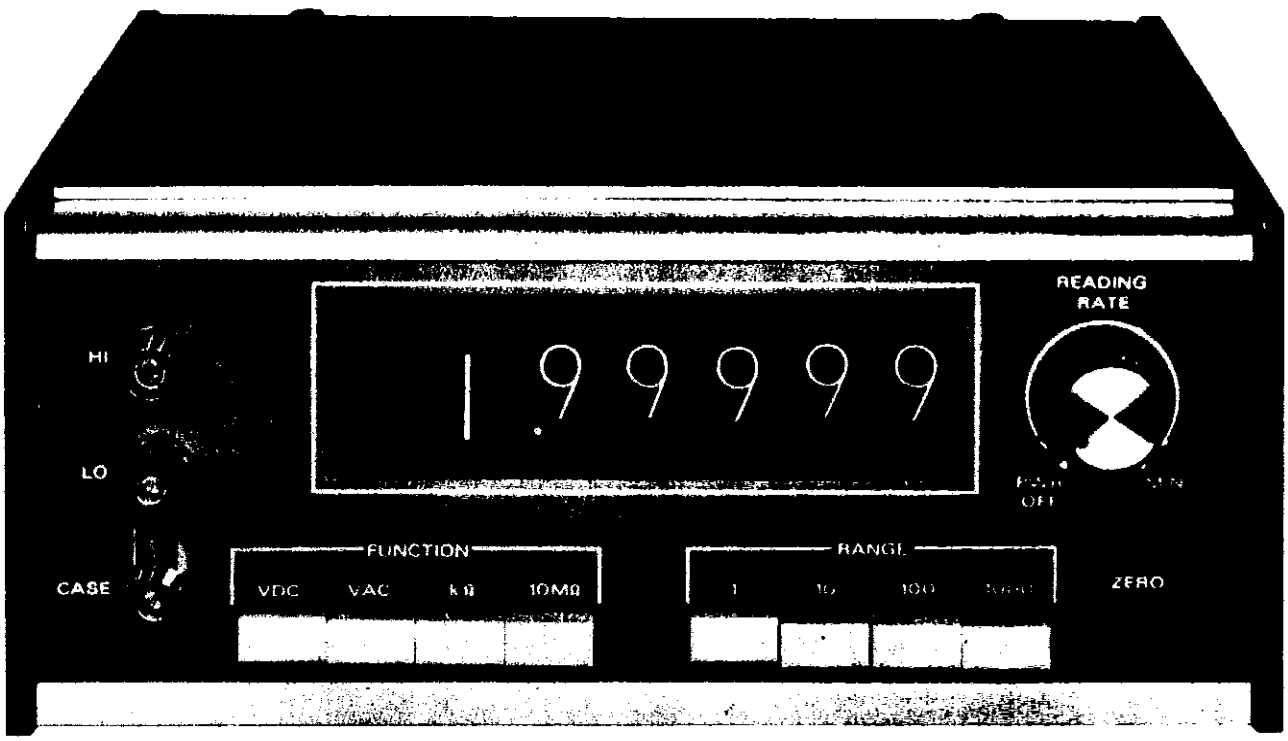

TABLE 1-1.
Front Panel Controls

Control	Functional Description	Paragraph
Power Off	Controls line power to instrument.	2-3d
Reading Rate	Sets reading rate and print rate at digital output. Variable control from 1 sec/reading (max) to 10 secs/reading (min).	3-3b
Input Terminals HI: LO: CASE:	 Connection to input high for all measurements. Connection to input low for all measurements. Connection to chassis ground. [Shorting link may be used between LO and CASE for grounded operation.]	3-3a
Function VDC: VAC: kΩ: 10MΩ:	Four pushbuttons select the desired input mode. Voltage mode, dc Voltage mode, ac rms Ohmmeter mode, kilohms Ohmmeter mode, ten megohms full range.	3-2
Range	Four pushbuttons select full ranges for VDC, VAC, and kΩ functions only. When 10MΩ function is selected all range buttons are released. Range Multiplier: 1: 1.99999 10: 19.9999 Decimal 100: 199.999 Position 1000: 999.99	----
Zero	Permits adjustment of zero offset.	----

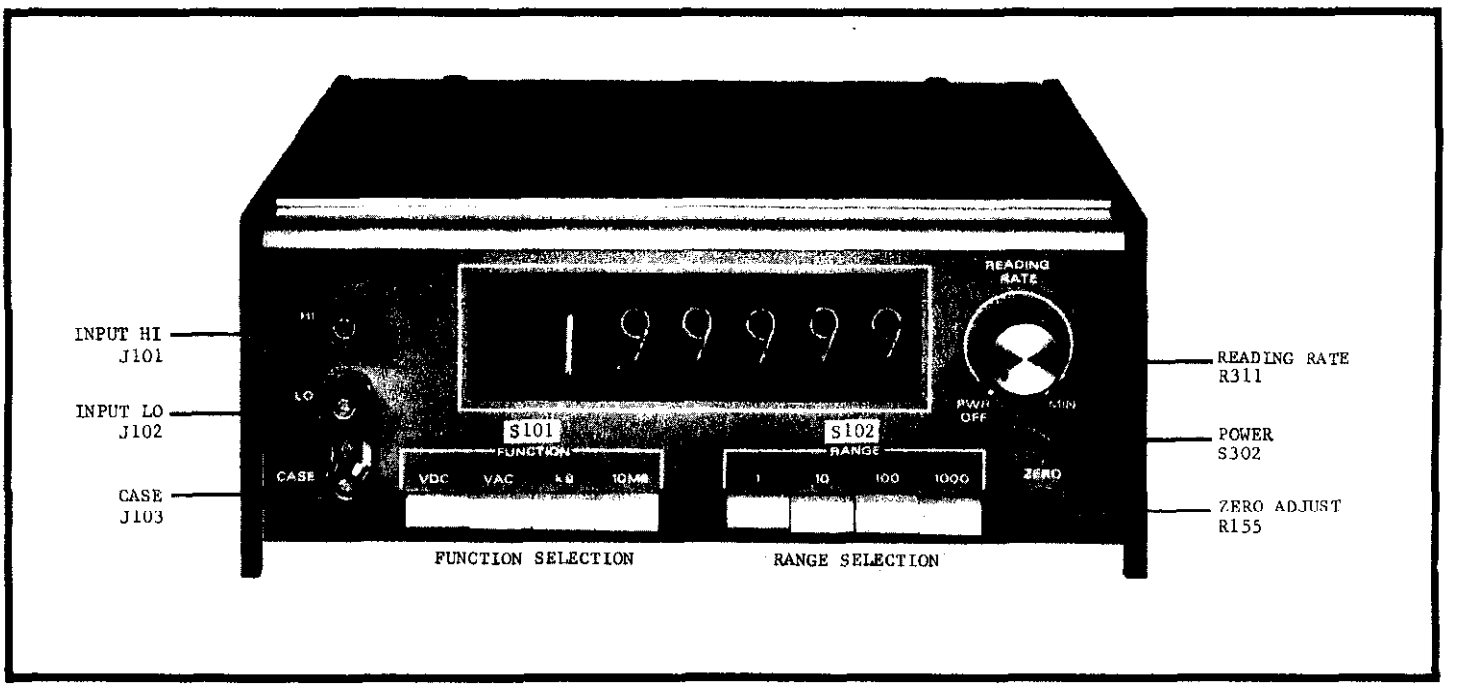

FIGURE 2. Front Panel Controls.

TABLE 1-2.
Rear Panel Controls

Control	Functional Description	Paragraph
Line Switch	Sets instrument for nominal 117V or 234V.	2-3a
Line Receptacle	Mates with 3-wire line cord.	2-3c
Fuse	117V: 1/4 A 234V: 1/8 A	2-3b
Digital Output	Card edge connector.	3-6
+10V Ref. Adjust	Calibration control.	---
-10V Ref. Adjust	Calibration control.	---

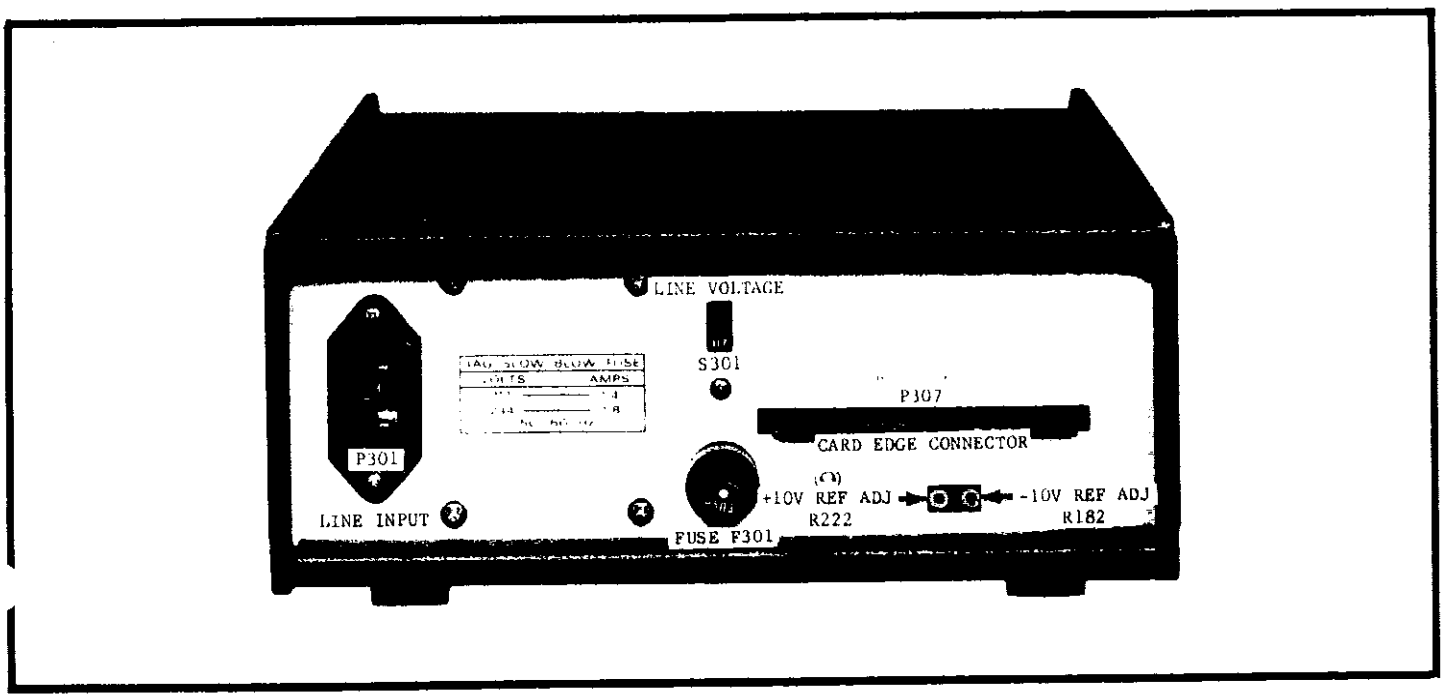

FIGURE 3. Rear Panel Controls.

SECTION 2. INITIAL PREPARATION

2-1. GENERAL. This section describes procedures for incoming inspection and preparation for use.

2-2. INSPECTION. The Model 190 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.

2-3. PREPARATION FOR USE.

a. Line Voltage. Before power is applied, check the position of the LINE switch (S301) on the rear panel. Select the 117V position for operation from 50-60 Hz line voltages over the range 105 to 125V rms. Select the 234V position for operation from 50-60 Hz line voltages over the range 210-250V rms.

b. Fuse Installation. After the line voltage range is selected, check for the proper fuse type and rating as follows:

117V:	1/4A	(FU-17)
234V:	1/8A	(FU-20)

c. Line Connection. This instrument requires a three-wire line cord (Keithley part no. CO-7) which provides connections to line power (high, common, and chassis). For operator safety, the chassis ground pin should be connected to earth ground.

CAUTION

If the instrument input LO is to be floated above chassis ground, make certain that the "link" between LO and CASE on the front panel is removed.

d. Warm-up. Complete stabilization to rated accuracy requires a warm-up time (with power on) of two hours. This time is required to ensure that the internal circuitry has reached a temperature equilibrium. Ambient temperature variations after stabilization must be considered using the appropriate temperature coefficients for each function.

e. Zero Adjustment. To achieve rated accuracy on voltage measurements, check the zero reading on the 1-volt range by connecting a low-thermal short across the input terminals. Adjust the front panel zero control to obtain a zero reading such that the "minus" polarity sign flashes on and off.

SECTION 3. OPERATING INSTRUCTIONS

3-1. GENERAL. This section describes the procedures for operating the Model 190 as an ac voltmeter, dc voltmeter, and ohmmeter.

3-2. FUNCTION SELECTION. The Model 190 provides four pushbuttons for selection of the desired input mode. The buttons are identified as VDC, VAC, kΩ, and 10MΩ respectively.

a. VDC. When this button is depressed, the 190 operates as a dc voltmeter.

b. VAC. When this button is depressed, the 190 operates as an ac voltmeter. In this mode, the 190 is an average-reading voltmeter calibrated in rms of a sine wave.

c. kΩ. When this button is depressed, the 190 operates as an ohmmeter having a 1000 kilohm maximum range.

d. 10MΩ. When this button is depressed, the 190 operates as an ohmmeter having a single 10 megohm full range. Depression of the 10MΩ function interlocks the kΩ button. Both buttons will be depressed for proper 10M operation. All range pushbuttons are automatically released when the 10MΩ function is selected. To select any other function, simply depress the desired range button.

TABLE 3-1.
DC Voltage Ranges

Range	Full Range Display	Overrange Display
1	1.00000 V	1.99999 V
10	10.0000 V	19.9999 V
100	100.000 V	199.999 V
1000	1000.00 V	1000.00 V*

*Maximum allowable input: 1400 v peak momentary

3-3. DC VOLTAGE MEASUREMENTS. The Model 190 provides four ranges from 1V to 1000V full range. Overrange capability is 100% on 1V through 100V ranges

a. Connections. Make connections to the input HI and LO terminals. For grounded applications, make certain that the shorting link is connected between LO and CASE. For floating applications, the shorting link must be removed.

b. Control Settings. To select the dc voltage mode, depress the VDC pushbutton. To select the full range sensitivity, depress the appropriate range pushbutton, 1, 10, 100, or 1000. Adjust the Reading Rate to achieve the desired display rate.

c. Maximum Allowable Input. 1400 volts peak momentary, 1000 volts continuous dc or rms ac. An overload condition is indicated by a flashing O/R display when on 1V, 10V, and 100V full ranges.

d. Input Resistance. Greater than 1000 megohms on the 1-volt range, but reduced to 10 megohms on the 10-to-1000 volt ranges. On the 10-to-1000 volt ranges, a resistive divider network is used to divide down the input signal.

e. Polarity Indication. A lighted "minus" sign is automatically displayed for a negative voltage applied to the HI terminal. A positive polarity is implied when the "minus" sign is turned off.

TABLE 3-2.
AC Voltage Ranges

Range	Full Range Display	Overrange Display
1	1.00000 V	1.99999 V
10	10.0000 V	19.9999 V
100	100.000 V	199.999 V
1000	1000.00 V	1000.00 V*

*Maximum allowable input: 1000 volts rms + dc

3-4. AC VOLTAGE MEASUREMENTS. The Model 190 provides four ranges from 1V to 1000V rms full range. Overrange capability is 100% on 1V to 100V ranges. In this mode, the Model 190 is an average-reading voltmeter calibrated in rms of a sine wave.

a. Connections. Make connections to the input HI and LO terminals. For grounded applications, make certain that the shorting link is connected between LO and CASE. For floating applications, the shorting link must be removed.

b. Control Settings. To select the ac voltage mode, depress the VAC pushbutton. To select the full range sensitivity, depress the appropriate range pushbutton, 1, 10, 100, or 1000. Adjust the Reading Rate to achieve the desired display rate.

c. Maximum Allowable Input. 1000 volts rms ac + dc, but no more than 600 volts dc on any range. An overload condition is indicated by a flashing O/R display when on 1V, 10V, and 100V full ranges.

d. Input Impedance. 1 megohm shunted by less than 40 picofarads. Effective impedance will be determined by the frequency of the ac signals to be measured, where $Zin = \frac{Rin.}{\sqrt{1 + (2\pi f R_{in} C)^2}}$

3-5. RESISTANCE MEASUREMENTS. The Model 190 provides five ranges from 1 kilohm to 10 megohms full range. Overrange capability is 100% on all ranges.

TABLE 3-3.
Resistance Ranges

Function	Range	Full Range Display	Overrange Display
KΩ	1	1.00000 KΩ	1.99999 KΩ
KΩ	10	10.0000 KΩ	19.9999 KΩ
KΩ	100	100.000 KΩ	199.999 KΩ
KΩ	1000	1000.00 KΩ	1999.99 KΩ
10MΩ	NONE	10.0000 MΩ	19.9999 MΩ

a. Connections. Make connections to the input HI and LO terminals. When measuring semiconductors and other polarity sensitive devices it is important to consider the polarity of the voltage developed across the input terminals. The HI terminal is negative with respect to the LO terminal. For grounded applications, make certain that the shorting link is connected between LO and CASE. For floating applications, the shorting link must be removed.

b. Voltage Across the Unknown. Full range voltage is 5 volts. At 100% overrange, the voltage across the unknown is 10 volts. See Theory of Operation for a complete explanation of open-circuit voltage condition. Test current for each range is given in Table 3-4.

TABLE 3-4.
Test Current for Resistance Modes

Full Range	Test Current	Full Range Voltage
1 kΩ	5 mA	5 V
10 kΩ	500 µA	5 V
100 kΩ	50 µA	5 V
1000 kΩ	5 µA	5 V
10 MΩ	500 nA	5 V

c. Control Settings. Five ranges are available on the Model 190. Two functions can be selected, kΩ and 10 MΩ.

1. Kilohm Function. For measurements over the range from 0.01 ohms to 2000 kilohms, depress the kΩ function pushbutton. Then depress the appropriate range pushbutton, 1, 10, 100, or 1000.

2. Ten Megohm Function. For measurements from 100 ohms to 20 megohms depress the 10 MΩ function pushbutton.

NOTE
Both the kΩ and 10 MΩ pushbuttons should be depressed to operate in the 10 MΩ mode. The Range pushbutton switches are released when the 10 MΩ pushbutton is depressed to prevent an ambiguous mode of operation. To select either VDC, VAC, or kΩ modes while in 10 MΩ mode, simply depress any one of the Range pushbuttons and then select the desired Function.

d. Maximum Overload. 20 volts dc or rms ac on the 1-kilohm range, 60 volts on the 10-kilohm range 250 volts on all other ranges.

NOTE
The Model 190 should not be subjected to a voltage input while in kΩ or 10 MΩ ranges even though protection is provided in case of accidental overloads.

e. Residual Resistance. Since the Model 190 uses a two-wire configuration, an inherent offset of a few digits may be noticed on the 1 kilohm range. This offset reading should be recorded and subtracted from all readings on the 1 kΩ range. Lead resistance will also add to the resistance offset and should be considered as well.

3-6. DIGITAL OUTPUT.

a. General. The Model 190 provides BCD TTL-type lines which represent each of five digits, an overrange digit ("1"), overload, polarity, decimal position, and function. The lines are 8421 configuration where 0 = 0000. In addition to data outputs the 190 provides a Print Command and Hold Control. Refer to Table 3-6 for digital output pin identification.

b. Data Outputs. All outputs except Function 1 and 2 and Hold are Series 7400 TTL circuits (see manufacturers literature for specifications). Polarit (pin 10) and overload (pin 1) outputs are not buffered. Function 1 and 2 outputs consist of 4.7 kΩ pull up resistors connected to the internal +5 V supply. Refer to Table 3-5 for function line coding.

c. Print Command. Logic "1" appears for 200 milliseconds after each display update. Refer to Figure 4 for a graphic description of the A/D converter timing.

d. Hold Control. Logic "0" retains last data in display and digital output. To enable the Hold control, an equivalent of 4 TTL gates current sinking capability is necessary.

e. Common. Pin 18 should be used for all common connections to the digital output.

f. Connections. Use of Model 1902 Digital Output connector (optional) is recommended for connections to the 18/36 card edge connector.

TABLE 3-5.
Function Coding

Function Selected	Function Line 1	2	3
VDC	1	1	0
VAC	0	1	1
KΩ	1	1	1
10MΩ	1	0	1
Where	Logic 0 = low state Logic 1 = high state		

TABLE 3-6.
Digital Output Pin Identification.

Pin No.	Description	Pin No.	Description
1	Overrange = Logic 1	19	HOLD
2	Not Used	20	Print Command
3	Not Used	21	1×10^4
4	DP-3 = Logic 1 (1×10^3 Digit)	22	2×10^4
5	DP-2 = Logic 1 (1×10^2 Digit)	23	8×10^4
6	DP-1 = Logic 1 (1×10^1 Digit)	24	4×10^4
7	Not Used	25	2×10^2
8	Function 3 (See Table 3-5)	26	1×10^2
9	DP-4 = Logic 1 (1×10^4 Digit)	27	8×10^2
10	Polarity (Minus = Logic 0)	28	4×10^2
11	1×10^5	29	1×10^3
12	2×10^0	30	2×10^3
13	1×10^0	31	8×10^3
14	8×10^0	32	4×10^3
15	4×10^0	33	2×10^1
16	Function 1 (See Table 3-5)	34	1×10^1
17	Function 2 (See Table 3-5)	35	8×10^1
18	Common	36	4×10^1

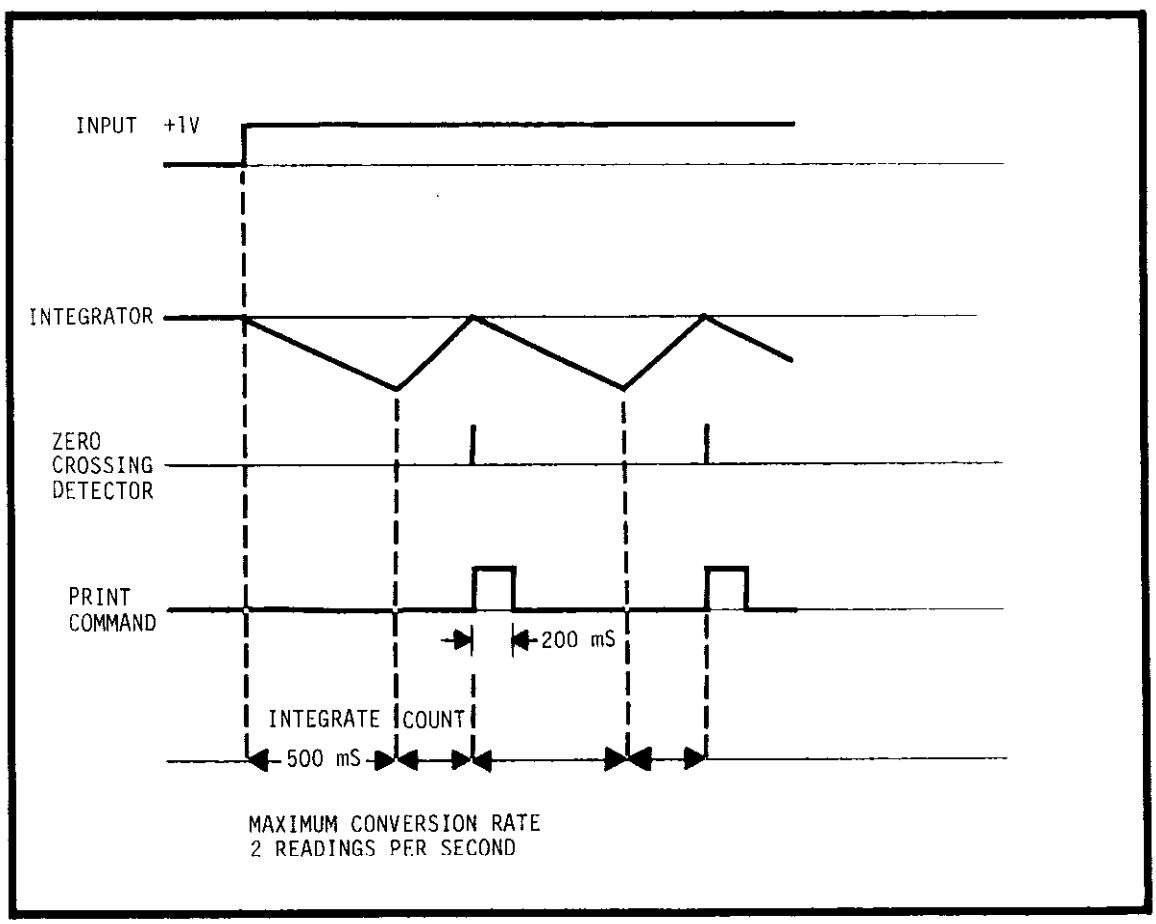

FIGURE 4. Timing Diagram.

3-7. MEASUREMENT CONSIDERATIONS.

a. Connections. Use of shielded input leads is recommended when source resistances are greater than 1 kilohm or when using the 10MΩ mode. Care should be exercised so as not to degrade the insulation characteristics of the binding posts. In the resistance modes, accuracy may be degraded if the terminals and/or leads become contaminated. Care should also be taken to minimize effects of thermoelectric potentials which may be generated as a result of temperature differences between junctions of dissimilar metals.

b. Accuracy. All specifications are based on a calibration temperative of 25°C ± 1°C. Thus it may be necessary to utilize the temperature coefficients as a correction factor if the operating ambient temperature is not the same as the actual calibration temperature.

1. DC Voltage. The dc voltage accuracy is specified in terms of a percent of reading and a percent of range. An additional factor of .00001% of reading, per volt from full range reflects an uncertainty due to voltage coefficients for measurements made at other than full range. Short term accuracy is valid for a period of 24 hours after complete calibration. Long term accuracy (90 days) includes an additional .01% of reading uncertainty due to aging of precision components. In addition, the effects of power dissipated in the input resistors should be considered whenever more than 500 volts is continuously applied (for 1 minute or longer). Heating may cause an additional uncertainty due to the temperature coefficients of individual circuit elements.

2. DC Current. When the Model 1901 Current Adapter is used an additional ±0.3% of reading uncertainty must be considered. As in any current measurement the input drop should also be considered. For example, a full range drop of 200mV across the shunt results in an error of 1% if the source is 20 volts.

3. AC Voltage. The ac voltage accuracy is specified in terms of a percent of reading and a percent of range. In addition, the effects of power dissipated in the input resistors should be considered whenever more than 400 volts is applied.

4. Resistance. Accuracy on resistance ranges is specified in terms of a percent of reading and a percent of range. An additional uncertainty due to residual resistance should also be considered.

NOTE

When making resistance measurements, it is important to make certain that the 190 is properly zeroed in VDC function. For example an additional error of .0001% of reading can occur per digit of voltage offset on the 1kΩ - 100kΩ ranges; .001% and .01% of reading per digit offset on 1000kΩ and 10MΩ ranges respectively.

c. Normal Mode Rejection. The Model 190 provides ac rejection of greater than 80 dB over one digit on the 1 and 10 volt ranges, 50 Hz to 180 Hz. Typically the NMRR for the Model 190 is greater than 90 dB on 1 and 10 volt ranges; 80 dB on the 100 volt ranges; 70 dB on the 1000 volt range.

d. Common Mode Rejection. The Model 190 provides common mode ac rejection of greater than 100 dB over one digit on the 1 and 10-volt ranges, dc to 180 Hz with 1 kilohm unbalance. Typically, the CMRR for the Model 190 is greater than 90 dB on the 100 volt range; 80 dB on the 1000 volt range.

SECTION 4. THEORY OF OPERATION

4-1. GENERAL DESCRIPTION. The Model 190 Digital Multimeter utilizes a modified integrating technqiue for A/D conversion. The latest linear and digital integrated circuits are utilized for greater reliability and servicing. The circuitry is broken down into two major areas and assemblies; the Analog Assembly and Digital and Power Supply Assembly. The Analog section provides input signal conditioning, attenuation, filtering, buffering comparing, and initiates the main control signal for the entire system. The Digital section provides logic control, counting, decoding and display. Also located on the Digital assembly are the power supplies for the entire system. The Analog assembly is connected to the Digital assembly through J301 and J302.

To follow through a block diagram description it will be necessary to make several assumptions; assume the display is reading 0.0000, the counters have been reset to zero, the analog switch, S1 (Q117) has just turned on allowing the integrator to sample the voltage at the input terminals. A voltage of +10 VDC is applied to the input terminals. The 10 volt signal is routed to the DC attenuator and divided to 1 VDC which passes through the filter section to bypass any AC component to common. The output of the filter section is applied to the input amplifier section which provides signal isolation and a fixed gain of 5. The amplifier signal, now at 5 VDC, is applied to the Integrator section via S1 (Q117), Analog Switch. The Analog Switch has been turned on by a control level provided by circuitry, (the primary control flip-flop), in the Digital Assembly. Application of the +5V signal causes the integrating capacitor, C141, to charge for a fixed period of time, (approximately 500 milliseconds), or 200,000 counts. The final count pulse clears the counters to 0.0000. At the end of this period of time, a combination of a logic level at the zero detector amplifier, and the resetting of the primary control flip-flop, causes S1 (Q117) Analog Switch, to turn off and S3 (Q116), minus Reference Switch, to turn on. The counter starts counting towards 200,000 again. With a minus input from the reference now applied to the Integrating Amplifier, C141, begins to discharge towards zero. Upon reaching zero volts, the zero detector Amplifier creates a logic pulse that stops the counter which due to the relationship of the Integrator and clock has counted to 100,000. This pulse becomes a primary control for the logic, it is gated to form a strobe for the storage section. Information present in storage is now made available to the decoder section which furnishes levels that light the display with the counted number 100,000. A delayed strobe pulse follows within 1.0 microsecond which resets the counters to zero, and resets the primary control flip-flop. This causes S3, (Q116) minus Reference Switch, to turn off, and S1 (Q117) Analog Switch, to turn on.

4-2. ANALOG ASSEMBLY. The following paragraphs describe individual Analog circuits in detail. These circuits are divided according to their primary function in the system. (Refer to Schematic 25864E).

a. DC Attenuator. A 10 megohm divider using R111-R118, and parts of S102 and S101, provides attenuation for input signals above 2 VDC (100% overrange on the 1 V range). S102-3D is used to short out the high impedance for better input matching on the lowest dc range.

b. Input Filter. This section provides attenuation of ac components and noise present on dc input signals.

c. Input Amplifier. Comprised of three active components, this circuit provides input isolation and signal conditioning. Q119 is a low leakage matched FET providing high input impedance and matched voltage and temperature tracking. A bipolar device, outputs from this FET are applied directly at QA101, an operational amplfier. R146, (Coarse Zero) a 100 Ω variable resistor, is used for initial balancing of input FET pair while Q106 provides a constant current source. Q119 and QA101, an IC Operational Amplifier, provide the gain required by the Input DC Amplifier The maximum output swing at the Input Amplifier, TP1, is ±10 VDC. This output is fed directly to Q117, the Analog Switch. Potentiometer R155, front panel zero, is used for fine zero adjustment.

d. Signal Switches (See Figure 5). Comprised of Q110, Q116, and Q117, these solid state switches provide high speed, low leakage paths for signals applied to the Integrating Amplifier. These switches are driven by logic levels from the Digital Assembly with Q109 and Q111 through Q115 supplying buffering.

e. Integrating Amplifier. Also a bipolar circuit this Amplifier integrates dc levels from signals applied through S1 (Q117), S2 (Q110), and S3 (Q116). A unity dc Gain Amplifier, the precision ramps created by the time constants of R201 and C141 are directly proportional to the clock speed in the Digital Section. Using a modified dual slope principal, the charge time of C141 is fixed at approximately 500 ms, while the discharge time is a function of the input voltage. The maximum swing at the output of this amplifier, TP4, is approximately ±12 V peak. The output is fed directly to the comparator.

f. Zero Detector - Comparator. This circuit creates the main control pulse and logic level necessary for proper digital and analog functions. QA106, an IC Operational Amplifier, provides a dc gain for signals less than +100 μV. The level at the output of QA107, is determined by the polarity of the unknown

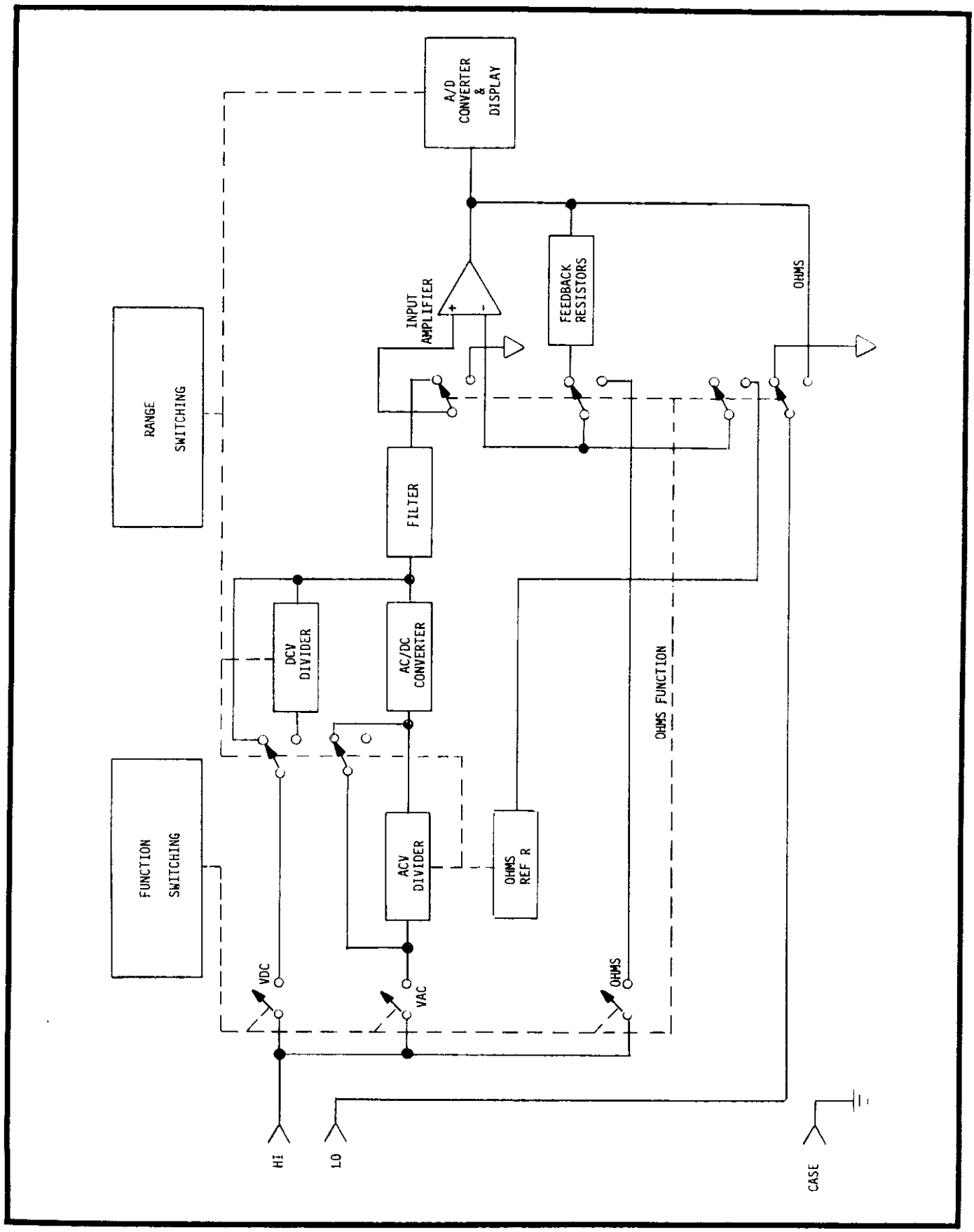

FIGURE 5. Block Diagram of Function and Range Switching.

ut signal. A plus input signal will create a low ic level 0 V, while a minus unknown will create a high, +5V. A pulse, whose width is determined by the resetting of the main control flip-flop, will be present when the Integrating Amplifier crosses zero. The output level is used to determine polarity, while the pulse at zero detection creates strobe and reset commands for the Digital Section. Q118 provides buffering between the Analog and Digital Sections.

g. AC Converter. AC voltage measurements applied to the input terminals are converted to dc levels via this converter amplifier. Input signals are attenuated and applied to Q101, the input FET. This three stage, high input impedance, ac amplifier converts ac rms signals to dc voltages directly proportional. The maximum output swing is plus 2 VDC, (100% overrange). DC signals at the output TP6, are fed directly to the Input Amplifier via the Input Filter.

h. Ohms Converter. A Feedback ohms measuring technique is used, utilizing the Input Amplifier and a precision constant current source. The voltage drop across the unknown resistor is measured as a dc voltage. Scale factor resistors are switched via the front panel. Maximum output at TP1 is +10 VDC. The current source is composed of a voltage source V_O and a scale factor resistor R_O. The current developed I_O is given in Table 4-1.

TABLE 4-1.
Current Source in Resistance Modes

Range	V_O	R_O	I_O
1 kΩ	10 V	2 k	5 mA
10 kΩ	10 V	20 k	500 µA
100 kΩ	10 V	200 k	50 µA
1000 kΩ	1 V	200 k	5 µA
10 MΩ	0.1 V	200 k	500 nA

NOTE

Input Amplifier must be properly zeroed in VDC function in order to avoid additional errors in Ohms function. For 1 kΩ-100 kΩ ranges an additional error of .0001% of reading per digit offset can occur. For 1000 kΩ & 10 MΩ an additional error of .001% and .01% of reading per digit offset respectively can occur.

IMPORTANT

Since the 190 uses a feedback amplifier method of resistance measurement, an out-of-range resistance (or open-circuit across input terminals) may cause the amplifier to be driven beyond 10 volts (up to 25 volts can occur between HI and LO).

4-3. DIGITAL SECTION. The following paragraphs describe individual circuits located on The Digital Assembly in detail, according to their primary function in the system. (Refer to Schematic 25865E).

a. System Power Supplies. Four basic DC Power Supplies are created on this assembly for use in the ire system. A step-down dual primary transformer plies ac power to three separate rectifiers. Raw dc supplies are then applied to the individual regulator circuits, creating well regulated current limiting dc voltages. The +5V supply is used as VCC for all digital IC's. The +15V and -15V supplies are provided as operating voltages for all linear IC's. The +170V unregulated supply is the voltage used to drive the readout tubes.

b. Master Clock. A free running multivibrator, this circuit creates clock pulses used by the Counters. A single dual power inverter, a crystal oscillator, and two capacitors create these pulses with C312 for repetition rate, and C313 for pulse width. The frequency of this clock is approximately 400 kHz.

c. The Counters. These 1248 Binary Counters create logic information necessary for lighting the numbers in the individual decades. Starting at the least significant decade, clock pulses set the counters in sequence. Each Counter divides the clock by a factor of 10. The final output flip-flop, QA325 (5, 6), is running at 2 times per second or a 500 ms rate. This rate in turn is fed into another divide by 2 flip-flop, the primary switch control flip-flop QA315 (5, 6), which determines the basic digitizing rate of the DMM. These Counters are reset to zero via an output at QA312 (8).

d. Storage and Decoding. Outputs from the Counters are stored in the bi-stable latches QA318, 320, 322, 324, 333 and flip-flop QA325. This stored information is transferred to the inputs of the decoders upon receipt of the strobe pulse created by the zero detector through QA315, 311, 331, 309, 319, 310. The Decoders decode the 1248 Binary information to decimal, creating the logic common necessary to light the neon indicators.

e. Polarity and Out-of-Range. QA316 (8, 9) used as a storage flip-flop is set by the strobe pulse for polarity information. An edge created by the zero detector level through QA314 (3, 6) sets QA316 (5, 6). The set and reset outputs of QA316 (5, 6) "anded" with the primary switch control flip-flop determines which reference switch will be turned on. The true state for this control, whose outputs are at QA314 pins 11 and 8, is common. These outputs control Q110 and Q116 polarity switches, while the output of QA315 (5, 6) controls Q117 Analog Switch. The Out-of-Range Indicator will turn off and turn on at the Counter rate when the Counter has counted to full scale and a strobe pulse has not been received.

f. Timing.

1. Integrate Period. During the "INTEGRATE" period, the analog signal is applied to the integrating amplifier. The ramp waveform of the integrator could have a positive or negative slope, depending on the polarity of the input signal.

2. Count Period. During the "COUNT" period, the integrating amplifier is driven to zero by a discharge voltage, with the analog signal removed from the amplifier. The "COUNT INTERVAL" represents the actual count time for the integrating amplifier to reach a zero crossing from the original level of the applied signal. Thus, this interval is proportional to the analog signal and may be from 0 to 500 milliseconds in duration. For a 100% overrange signal, this interval would then be at its maximum value of 500 milliseconds.

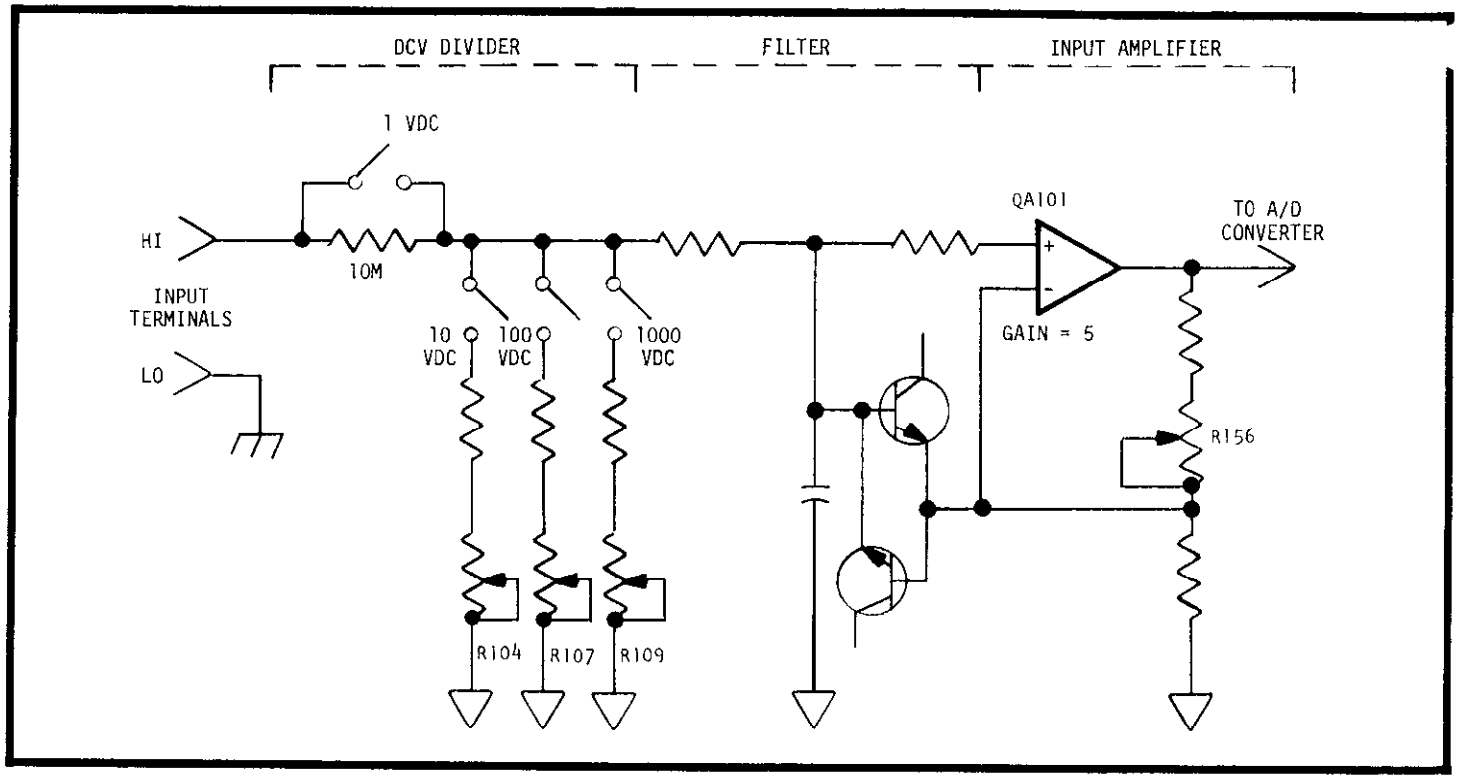

FIGURE 6. Simplified Diagram of DC Voltage Mode.

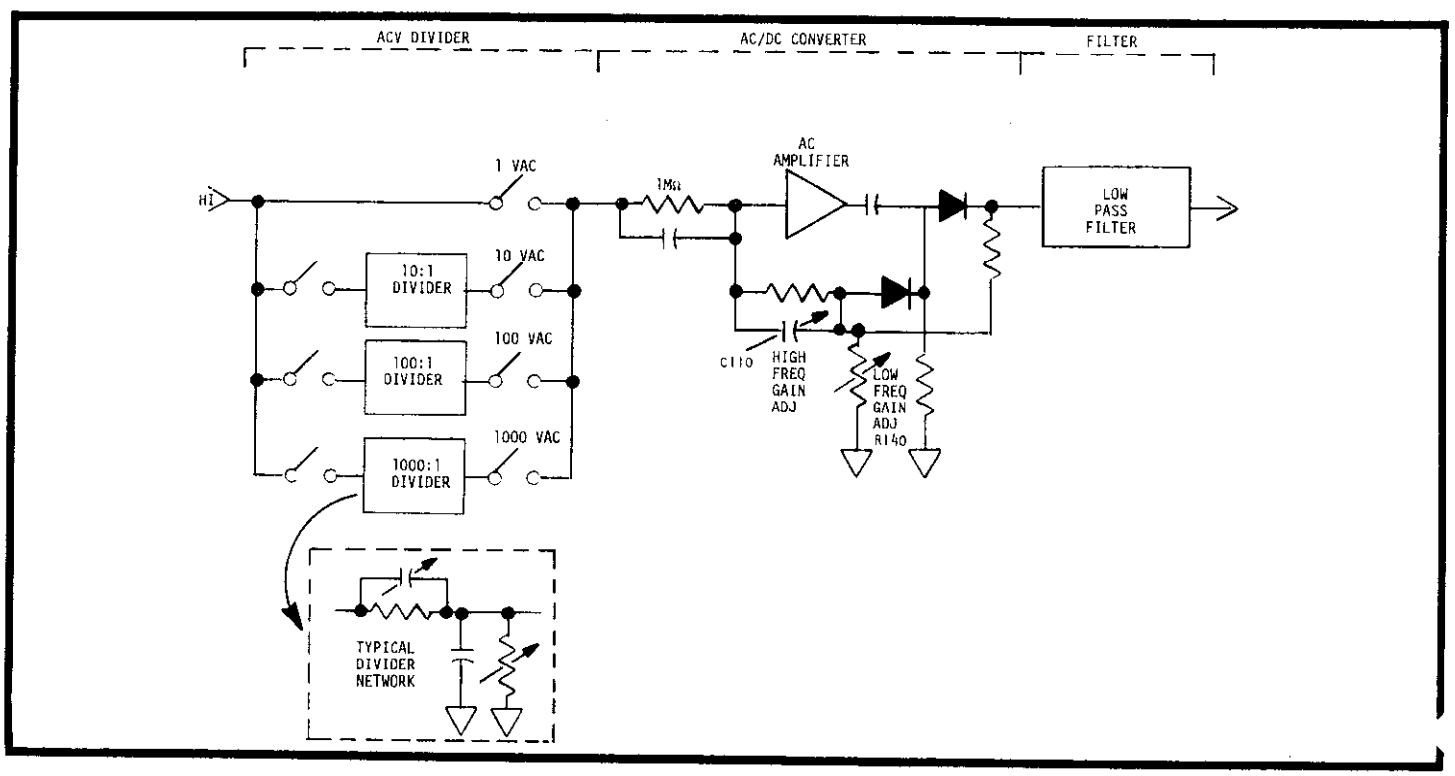

FIGURE 7. Simplified Diagram of AC Voltage Mode.

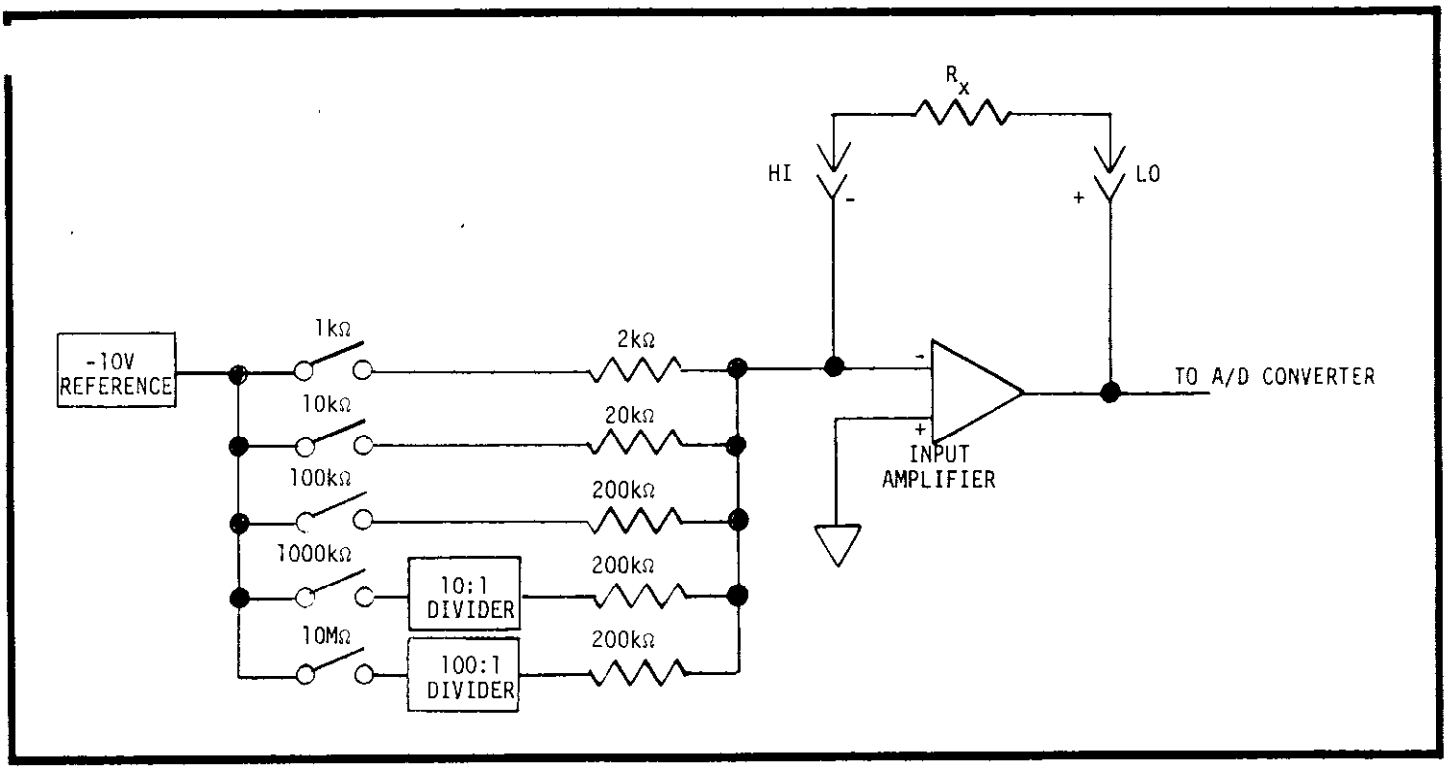

FIGURE 8. Simplified Diagram of Resistance Mode.

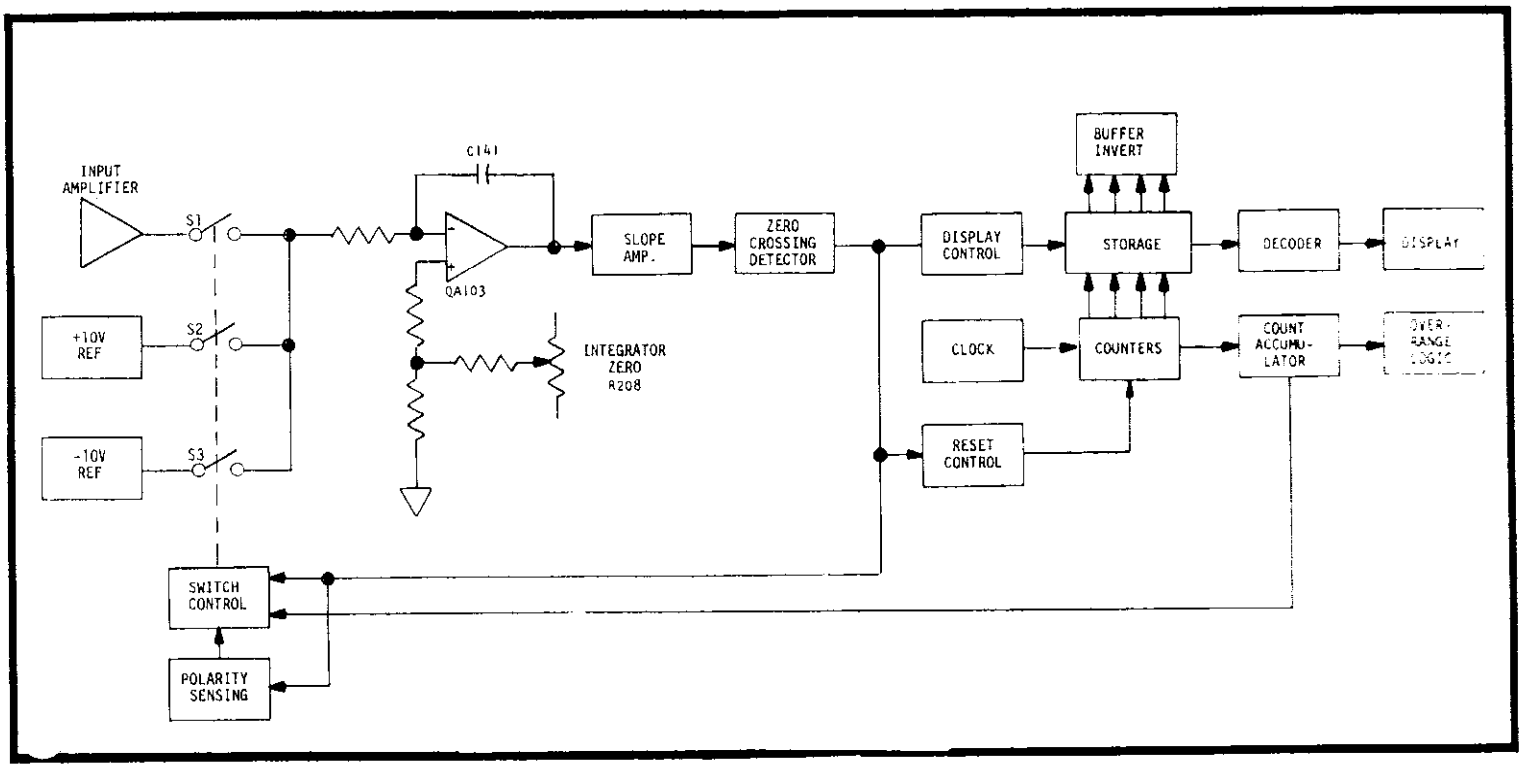

FIGURE 9. Simplified Diagram of A/D Converter.

SECTION 5. ACCESSORIES

5-1. GENERAL. The following Keithley accessories can be used with the Model 190 to provide additional convenience and versatility.

5-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 1901 Current Adapter

Description:

Five switched decade shunts of 0.1 ohm to 1 kilohm ±0.3%. Maximum continuous voltage drop is 200 mV. Shunt resistors are connected so as to eliminate contact resistance errors.

Application:

The Model 1901 may be used on ac and dc voltage ranges of the 190 to measure currents up to 200 mA. Adapter plugs into input terminals.

Model 1902 Output Connector

Description:

Mating card-edge connector for digital output (18/36 pins). Connector plugs into card edge at rear panel of the 190.

Application:

Provides access to all 36 pins at digital outputs. Enables custom wiring to digital printers or other digital acquisition equipment.

Model 1903 Calibration Cover

Description:

Provides access to all internal calibration controls while maintaining thermal equilibrium of instrument after warm-up.

Application:

Used whenever calibration adjustments are necessary. Controls are identified by circuit designation as shown on schematics.

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST: This section contains a list of components used in this instrument for user reference. The Replaceable Parts List describes the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number), Manufacturer's Part Number, and the Keithley Part Number. Also included is a quantity per assembly total where applicable. The complete name and address of each Manufacturer is listed in the Federal Supply Code for Manufacturers, Cataloging Handbook, H 4-2.

TABLE 6-1.
Abbreviations and Symbols

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

6-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as discussed in Section 4. Table 6-2 identifies all schematic part numbers included.

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

6-4. HOW TO ORDER PARTS.

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

b. When ordering parts, include the following information.

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

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

TABLE 6-2.
Schematics

Description	Assembly No.	Schematic No.
Analog Section	PC-327	25864E
Digital Section	PC-328	25865E

TABLE 6-3.
Mechanical Parts List

Item No.	Description	Qty. Per Assembly	Keithley Part No.
--	Chassis Assembly	--	--
1	Side Panel, Left	1	25859A
2	Side Panel, Right	1	25832C
3	Rear Panel	1	25840B
4	Front Panel	1	25830C
5	Overlay	1	25860B
--	Window	1	25843A
6	Top Cover	1	25836C
7	Bottom Cover Assembly	1	25846B
--	Bottom Cover	1	25835C
--	Tilt Bail	1	24879B
--	Feet, Molded	4	24322B
--	Rubber Ball	4	FE-6
8	Screw, Flat Phil. Hd.	4	#6-32 x 5/16"
9	Knob Assembly	1	25151A
10	Buttons, white	8	--

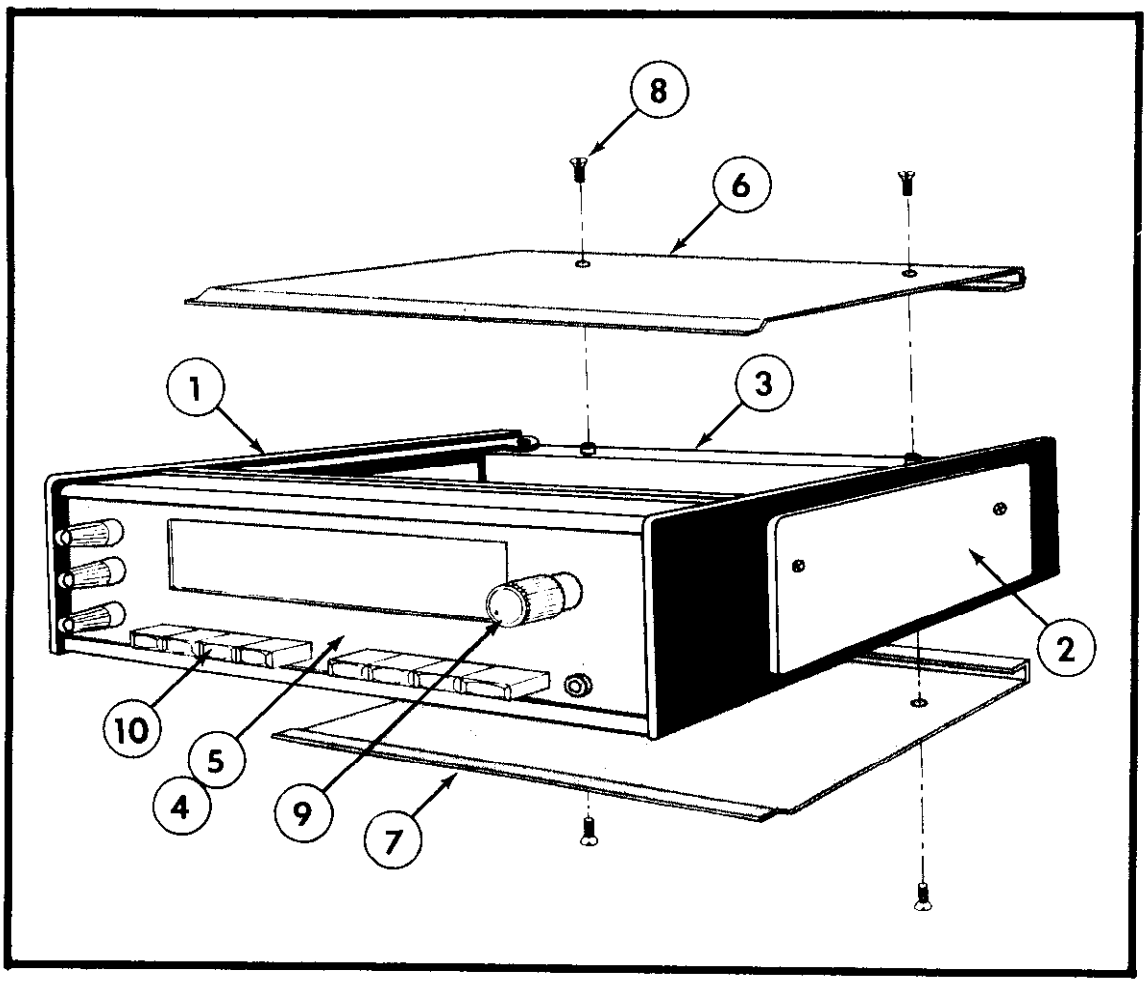

FIGURE 10. Exploded View of Chassis.

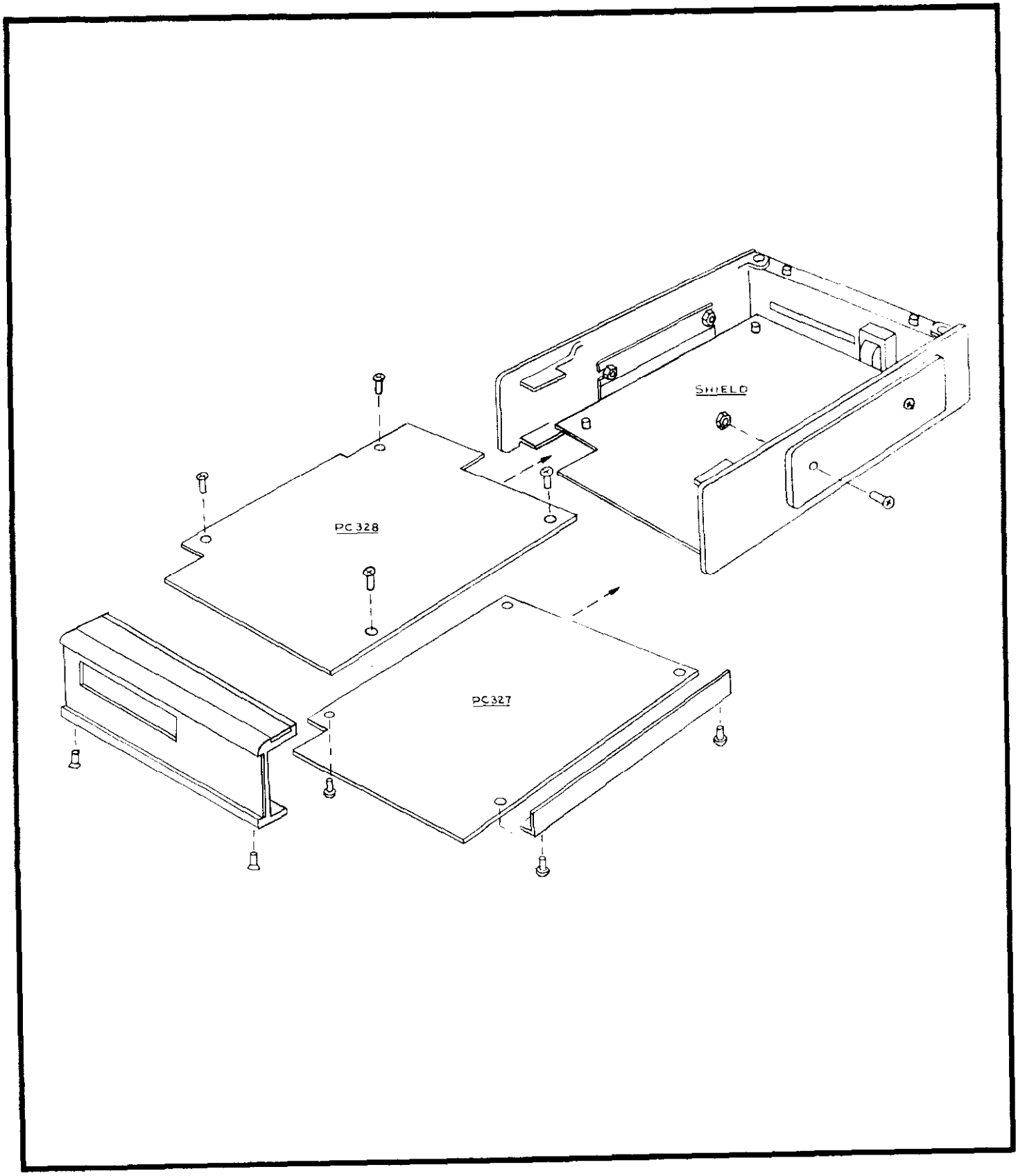

FIGURE 11. Assembly of Printed Circuit Boards.

ANALOG SECTION
(Schematic 25864E)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C101	.8-12 pF, VAR	73899	5C154Y	C253-.8-12P	3
C102	33 pF, 500V, Mica	14655	CD10ED330J03	C236-33P	1
C103	.8-12 pF, VAR	73899	5C154Y	C253-.8-12P	-
C104	390 pF, 500V, Mica.	14655	CD19ED391J03	C236-390P	1
C105	.8-12 pF, VAR	73899	5C154Y	C253-.8-12P	-
C106	4700 pF, 500V, Mica	14655	CD19ED471J03	C236-4700P	1
C107	.01 µF, 600V, PolyF	97419	M2WF-0.1µF	C220-0.1M	1
C108	2 pF, 500V, Mica.	14655	CD10CD020D03	C231-2P	2
C109	2 pF, 500V, Mica.	14655	CD10CD020D03	C231-2P	-
C110	.8-18 pF, 750V, VAR	72982	567-013	C225-.8-18P	1
C111	4.7 µF, 20V, ETT.	17554	TSD1-20	C179-4.7M	3
C112	4.7 µF, 20V, ETT.	17554	TSD1-20	C179-4.7M	-
C113	56 µF, 20V, ETT	17554	TSD1-20	C179-56M	1
C114	100 pF, 500V, Mica.	14655	CD10ED101J03	C236-100P	1
C115	20 pF, 500V, Mica	14655	CD10ED200J03	C236-20P	4
C116	100 µF, 15V, Epoxy.	17554	TD5-015-107-10	C228-100M	1
C117	2.0 µF, 50V, MPC.	14752	625B1A	C201-2.0M	1
C118	0.1 µF, 250V, MtF	73445	C280AE	C178-.1M	12
C119	1.0 µF, 50V, MtF.	14752	625B1A105	C215-1.0M	1
C120	0.22 µF, 250V, MtF.	73445	C280AE	C178-.22M	1
C121	0.1 µF, 250V, MtF	73445	C280AE	C178-.1M	-
C122	.047 µF, 200V, MPCb	14752	625B1C473	C221-.047M	3
C123	.047 µF, 200V, MPCb	14752	625B1C473	C221-.047M	-
C124	0.01 µF, 500V, CerD	72982	871-Z5U0103M	C22-.01M	3
C125	0.1 µF, 250V, MtF	73445	C280AE	C178-.1M	-
C126	.01 µF, 500V, CerD.	72982	871-Z5U0103M	C22-.01M	-
C127	.047 µF, 200V, MPCb	14752	625B1C473	C221-.047M	-
C128	.01 µF, 500V, CerD.	72982	871-Z5U0103M	C22-.01M	-
C129	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C130	Not Used.	.....	.....	.....	-
C131	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C132	4.7 µF, 20V, ETT.	17554	TSD1-20	C179-4.7M	-
C133	33 pF, 1000V, CerD.	71590	DD-330	C64-33P	3
C134	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C135	33 pF, 1000V, CerD.	71590	DD-330	C64-33P	-
C136	.0022 µF, 1000V, CerD	56289	10SS-D22	C64-.0022M	3
C137	.0022 µF, 1000V, CerD	56289	10SS-D22	C64-.0022M	-
C138	20 pF, 500V, Mica	14655	CD10ED200J03	C236-20P	-
C139	20 pF, 500V, Mica	14655	CD10ED200J03	C236-20P	-
C140	20 pF, 500V, Mica	14655	CD10ED200J03	C236-20P	-
C141	1.0 µF, 100V, Poly.	97419	PYW-R (1.0)	C142-1.0M	1
C142	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C143	33 pF, 1000V, CerD.	71590	DD-330	C64-33P	-
C144	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C145	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C146	Not Used.	.....	.....	.....	-
C147	Not Used.	.....	.....	.....	-
C148	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C149	5 pF, 1000V, CerD	71590	DD-050	C64-5P	1
C150	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-

ANALOG SECTION (Cont'd)
(Schematic 25864E)

CAPACITORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C151	0.1 µF, 250V, MtF	73445	C280AE	C178-0.1M	-
C152	.0022 µF, 1000V, CerD	56289	10SS-D22	C64-.0022M	-
C153	.0068 µF, 500V, CerD.	72982	851-Z5U0-682M	C22-.0068M	1
C154	150 pF, 1000V, CerD	71590	DD-151	C64-150P	-
C155	150 pF, 1000V, CerD	71590	DD-151	C64-150P	-
C156	5 pF, 1000V, CerD	71590	DD-050	C64-5P	

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D101	Transistor, NPN, Case TO-106.	07263	2N3565	TG-39	1
D102	Transistor, NPN, Case TO-106.	07263	2N3565	TG-39	-
D103	75V PIV, 75 mA.	01295	1N914	RF-28	1
D104	75V PIV, 75 mA.	01295	1N914	RF-28	-
D105	75V PIV, 75 mA.	01295	1N914	RF-28	-
D106	Zener, 6.3V, 1/4W	M-C	1N827A*	28619A	1
D107	75V PIV, 75 mA.	01295	1N914	RF-28	-
D108	75V PIV, 75 mA.	01295	1N914	RF-28	-
D109	75V PIV, 75 mA.	01295	1N914	RF-28	-
D110	75V PIV, 75 mA.	01295	1N914	RF-28	-
D111	75V PIV, 75 mA.	01295	1N914	RF-28	-
D112	75V PIV, 75 mA.	01295	1N914	RF-28	-
D113	75V PIV, 75 mA.	01295	1N914	RF-28	-
D114	75V PIV, 75 mA.	01295	1N914	RF-28	-
D115	75V PIV, 75 mA.	01295	1N914	RF-28	-
D116	Zener, 5.8V	12954	1N706	DZ-1	1
D117	Not Used.	.....	.....	.....	-
D118	Zener, 3.5V	06751	1N703A	DZ-42	2
D119	Zener, 3.5V	06751	1N703A	DZ-42	-
D120	75V PIV, 75 mA.	01295	1N914	RF-28	-
D121	75V PIV, 75 mA.	01295	1N914	RF-28	-

*Selected

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Location
J101	Binding Post (Red) HI	.....	820-65	BP-19R	Front Panel
J102	Binding Post (Blk) LO	.....	820-45	BP-19Blk	Front Panel
J103	Binding Post (Grn) CASE	.....	820-95	BP-19Grn	Front Panel

M-C = MICROSEMICONDUCTOR

ANALOG SECTION (Cont'd)
(Schematic 25864E)

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q101	N-Chan FET, Case TO-72.	04713	2N4220	TG-42	1
Q102	NPN, Case TO-92	04713	2N5089	TG-62	2
Q103	NPN, Case TO-92	04713	2N5089	TG-62	-
Q104	NPN, Case TO-92	04713	2N3903	TG-49	7
Q105	NPN, Case TO-92	04713	2N3903	TG-49	-
Q106	NPN, Case TO-92	04713	2N3903	TG-49	-
Q107	PNP, Case TO-92	04713	2N3905	TG-53	5
Q108	NPN, Case TO-92	04713	2N3903	TG-49	-
Q109	NPN, Case TO-92	04713	2N3903	TG-49	-
Q110	N-Chan, J-FET, Case TO-18	32293	ITS3538	TG-88	-
Q111	PNP, Case TO-92	04713	2N3905	TG-53	-
Q112	NPN, Case TO-92	04713	2N3903	TG-49	-
Q113	PNP, Case TO-92	04713	2N3905	TG-53	-
Q114	NPN, Case TO-92	04713	2N3903	TG-49	-
Q115	PNP, Case TO-92	04713	2N3905	TG-53	-
Q116	N-Chan J-FET, Case TO-18.	32293	ITS3538	TG-88	-
Q117	N-Chan J-FET, Case TO-18.	32293	ITS3538	TG-88	-
Q118	PNP, Case TO-92	04713	2N3905	TG-53	-
Q119	Dual N-Chan J-FET, Case TO-71	32293	ITS30092	TG-98	1

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA101	Operational Amplifier, 8-pin, Case TO-99.	24355	AD741*	IC-97	1
QA102	Not Used.	.....	.....	.....	
QA103	Operational Amplifier, 8-pin, Case TO-99.	12040	LM308H	IC-67	1
QA104	Operational Amplifier, 8-pin DIP.	32293	ITS6214	IC-74	2
QA105	Operational Amplifier, 8-pin DIP.	32293	ITS6214	IC-74	-
QA106	Amplifier, 8-pin, DIP	12040	LM301AN	IC-24	2
QA107	Amplifier, 8-pin, DIP	12040	LM301AN	IC-24	-

*Selected, order by Keithley Part No. IC-97.

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Location
S101	Switch, Function.	80164		SW-370	Front Panel
S102	Switch, Range	80164		SW-369	Front Panel

ANALOG SECTION (cont'd)
(Schematic 25864E)

RESISTORS

Circuit Desig.	Descrpption	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	470 KΩ, 10%, 1/4W, Comp	01121	CB-474-10%	R76-470K	-
R102	1 MΩ, 0.5%, 2W.	03888	PME75 (1M)	R210-1M	-
R103	121 KΩ, 0.1%, 1/2W, MtF	91637	MFF-121K	R169-121K	1
R104	2 KΩ, 0.5W, VAR	73138	72PMR-2K	RP97-2K	1
R105	1 MΩ, 0.5%, 2W.	03888	PME75 (1M)	R210-1M	-
R106	10 KΩ, 0.1%, 1/2W, MtF.	91637	MFF-10K	R169-10K	-
R107	200 Ω, 0.5W, VAR.	73138	72PMR-200	RP97-200	1
R108	1 MΩ, 0.5%, 2W.	03888	PME75 (1M)	R210-1M	-
R109	992 Ω, 0.1%, 1/2W, MtF.	91637	MFF-992	R169-992	1
R110	20 Ω, 0.5W, VAR	73138	72PMR-20	RP97-20	-
R111	10 MΩ, 2W	03888	PME80 (10M)	R224-10M*	1
R112	1.11 MΩ, 1/4W	03888	PME60 (1.11M)	R224-1.11M*	1
R113	100.91KΩ, 1/4W.	03888	PME60 (100.91K)	R224-100.91K*	1
R114	931 KΩ, 1%, 1/8W, MtF	07716	CEA-TO-931K	R88-931K	1
R115	10.11 KΩ, 1/4W.	03888	PME60-(10.11K)	R224-10.11K*	1
*Matched set, order only as a group of 4 resistors.					
R116	2 KΩ, 0.5W, VAR	80294	3299W-1-202	RP104-2K	1
R117	200 Ω, 0.5W, VAR.	80294	3299W-1-201	RP104-200	1
R118	200 KΩ, 0.5W, VAR	80294	3299W-1-204	RP104-200K	1
R119	470 KΩ, 10%, 1W, Comp	01121	GB-470K	R2-470K	1
R120	470 KΩ, 10%, 1/2W, Comp	01121	EB-470K-10%	R1-470K	1
R121	470 KΩ, 10%, 1W, Comp	01121	GB-470K-10%	R2-470K	-
R122	1 MΩ, 0.5%, 2W.	03888	PME75 (1M)	R210-1M	-
R123	121 KΩ, 0.1%, 1/2W, MtF	91637	MFF-121K	R169-121K	-
R124	49.9 KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-49.9K	R88-49.9K	1
R125	100 KΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	-
R126	60.4 KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-60.4K	R88-60.4K	1
R127	2.2 KΩ, 10%, 1/4W, Comp	01121	CB-222-10%	R76-2.2K	1
R128	150 KΩ, 10%, 1/4W, Comp	01121	CB-154-10%	R76-150K	1
R129	680 Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	5
R130	10 KΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	7
R131	150 KΩ, 10%, 1/4W, Comp	01121	CB-154-10%	R76-150K	-
R132	1.8 KΩ, 10%, 1/4W, Comp	01121	CB-182-10%	R76-1.8K	1
R133	680 Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	-
R134	680 Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	-
R135	3.9 KΩ, 10%, 1/4W, Comp	01121	CB-392-10%	R76-3.9K	1
R136	232 KΩ, 1%, 1/8W, MtF	07716	CEA-TO-232K	R88-232K	1
R137	180 KΩ, 10%, 1/4W, Comp	01121	CB-184-10%	R76-180K	1
R138	20 KΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-20K	R168-20K	1
R139	1.15 KΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-1.15K	R168-1.15K	1
R140	20 Ω, 0.5W, VAR	73138	72PMR-20	RP97-20	1
R141	Selected Value*, 1%, 1/8W, MtF.	07716	CEA-TO-*	R88-*	1
R142	270 KΩ, 10%, 1/4W, Comp	01121	CB-274-10%	R76-270K	1
R143	470 KΩ, 10%, 1/4W, Comp	01121	CB-474-10%	R76-470K	1
R144	14 KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-14K	R88-14K	1
R145	10 KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-10K	R88-10K	1
R146	100 Ω, 0.5W, VAR.	73138	72PMR-100	RP97-100	1
R147	30 KΩ, .02%, .3W.	18612	V53-1-30K	R183-30K	1
R148	100 KΩ, 1%, 1/8W, MtF	07716	CEA-TO-100K	R88-100K	1
R149	30 KΩ, .02%, .3W.	18612	V53-1-30K	R183-30K	-
R150	39.2 KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-39.2K	R88-39.2K	1

ANALOG SECTION (Cont'd)
(Schematic 25864E)

RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig	Keithley Part No.	Qty.
R151	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	2
R152	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	-
R153	9.997KΩ, 0.02%, 0.3W.	18612	V53-1-9.997K-.02%	R183-9.997K	1
R154	Not Used.	.....	.....	.....	
R155	1KΩ, 0.75W, VAR	73138	89P (1KΩ)	RP96-1K	1
R156	10Ω, 0.5W, VAR.	73138	72PMR-10	RP97-10	2
R157	Not Used.	.....	.....	.....	
R158	2.5KΩ, 0.02%, 0.3W.	18612	V53-1-2.5K-.02%	R183-2.5K	1
R159	47KΩ, 10%, 1/2W, Comp	01121	EB-473-10%	R1-47K	1
R160	2KΩ, 0.01%, 0.5W, MtF	18612	V53-5-2K	R214-2K	1
R161	20KΩ, 0.01%, 0.3W	18612	V53-1-20K-.01%	R184-20K	1
R162	200KΩ, 0.01%, 0.75W, MtF	18612	V53-6-200K	R215-200K	1
R163	20KΩ, 0.02%, 0.3W	18612	V53-1-20K-.02%	R183-20K	1
R164	202.7Ω, 0.02%, 0.3W	18612	V53-1-202.7-.02%	R183-202.7	1
R165	30.1KΩ, 1%, 1/8W, MtF	07716	CEA-TO-30.1K	R88-30.1K	1
R166	200KΩ, 0.5W, VAR.	73138	72PMR-200K	RP97-200K	1
R167	2.242KΩ, 0.02% 0.3W	18612	V53-1-2.242K-.02%	R183-2.242K	1
R168	10Ω, 0.5W, VAR.	73138	72PMR-10	RP97-10	-
R169	Not Used.	.....	.....	.....	
R170	Not Used.	.....	.....	.....	
R171	Not Used.	.....	.....	.....	
R172	Not Used.	.....	.....	.....	
R173	Not Used.	.....	.....	.....	
R174	Not Used.	.....	.....	.....	
R175	Not Used.	.....	.....	.....	
R176	4.7KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	3
R177	Not Used.	.....	.....	.....	
R178	1KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1K	R88-1K	1
R179	Selected Value, 0.1%, 1/8W.	91637	MFF-1/8	R168-*	3
R180	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	-
R181	1.2KΩ, 10%, 1/4W, Comp.	01121	CB-122-10%	R76-1.2K	2
R182	100KΩ, .75W, VAR.	73138	89P-100K	RP89-100K	2
R183	1MΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1M	R88-1M	2
R184	2KΩ, 0.02%, 0.3W.	18612	V53-1-2K-.02%	R183-2K	3
R185	2KΩ, 0.02%, 0.3W.	18612	V53-1-2K-.02%	R183-2K	-
R186	Selected Value, 0.1%, 1/8W.	91637	MFF-1/8	R168-*	-
R187	1.2KΩ, 10%, 1/4W, Comp.	01121	CB-122-10%	R76-1.2K	-
R188	1.11KΩ, 0.02%, 0.3W	18612	V53-1-1.11K-.02%	R183-1.11K	1
R189	2KΩ, 0.02%, 0.3W.	18612	V53-1-2K-.02%	R183-2K	-
R190	1MΩ, 1%, 1/8W, MtF.	07716	CEA-TO-1M	R88-1M	-
R191	100KΩ, 10%, 1/4W, Comp.	01121	CB-104-10%	R76-100K	-
R192	5.6KΩ, 10%, 1/4W, Comp.	01121	CB-562-10%	R76-5.6K	4
R193	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R194	1KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	5
R195	100KΩ, 10%, 1/4W, Comp.	01121	CB-104-10%	R76-100K	-

ANALOG SECTION (Cont'd)
(Schematic 25864E)

RESISTORS (cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R196	5.6KΩ, 10%, 1/4W, Comp.	01121	CB-562-10%	R76-5.6K	-
R197	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R198	1KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R199	5.6KΩ, 10%, 1/4W, Comp.	01121	CB-562-10%	R76-5.6K	-
R200	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R201	392KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-392K	R88-392K	1
R202	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R203	1KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R204	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	-
R205	392KΩ, 1%, 1/8W, MtF.	07716	CEA-TO-392K	R88-392K	-
R206	5.6KΩ, 10%, 1/4W, Comp.	01121	CB-562-10%	R76-5.6K	-
R207	10MΩ, 10%, 1/4W, Comp	01121	CB-562-10%	R76-10M	1
R208	10KΩ, 0.5W, VAR	80294	3299W-1-103	RP104-10K	1
R209	Not Used.	.....	.....	.....	
R210	Not Used.	.....	.....	.....	
R211	1KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R212	1MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	1
R213	1KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R214	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	1
R215	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R216	10KΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	-
R217	1MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	-
R218	4.7KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	-
R219	4.7KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	-
R220	100KΩ, 10%, 1/4W, Comp.	01121	CB-104-10%	R76-100K	-
R221	Selected Value*, 0.1%, 1/8W, MtF.	91637	MFF-1/8-*	R168-*	-
R222	100KΩ, .75W, VAR.	73138	89P-100K	RP89-100K	-
R223	Selected Value*, 10%, 1/4W, Comp.	01121	CB-*	R76-*	-

DIGITAL SECTION
(Schematic 25865E)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C301	1000 µF, 25V, EMC.	73445	ET102X025A03	C160-1000M	1
C302	200 µF, 35V, EAL	90201	MTV200N35PDN	C177-200M	2
C303	.047 µF, 250V, MtF	73445	C280AE	C178-.047M	2
C304	.047 µF, 250V, MtF	73445	C280AE	C178-.047M	-
C305	200 µF, 35V, EAL	90201	MTV200N35PDN	C177-200M	-
C306	0.33µF, 50V, Ceramic Film.	72982	8131050651-334M	C237-.33M	
C307	22 µF, 10V, ETT.	17554	TSD210	C180-22M	1
C308	4.7 µF, 20V, ETT	17554	TSD1-20	C179-4.7M	2
C309	4.7 µF, 20V, ETT	17554	TSD1-20	C179-4.7M	-
C310	22 µF, 15V, ETT.	17554	CC-Z-015-226-10	C234-22M	1
C311	470 pF, 1000V, CerD.	71590	DD-471	C64-470P	3
C312	470 pF, 500V, Mica	14655	CD19ED471J03	C236-470P	1
C313	390 pF, 500V, Mica	14655	CD19ED391J03	C236-390P	1
C314	470 pF, 1000V, CerD.	71590	DD-471	C64-470P	-
C315	470 pF, 1000V, CerD.	71590	DD-471	C64-470P	-
C316	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	12
C317	470 pF, 1000V, CerD.	71580	DD-471	C22-470P	1
C318	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C319	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C320	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C321	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C322	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C323	.01 µF, 500V, CerD..	72982	871-Z5U0-103M	C22-.01M	-
C324	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C325	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C326	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C327	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-
C328	0.1 µF, 250V, MtF.	73445	C280AE	C178-.1M	1
C329	.0047 µF, 500V, CerD	72982	801-Z5U0-472M	C22-.0047M	1
C330	.01 µF, 500V, CerD	72982	871-Z5U0-103M	C22-.01M	-

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D301	Rectifier, 3A, 50V PIV	13327	1N4139	RF-34	2
D302	Rectifier, 3A, 50V PIV	13327	1N4139	RF-34	-
D303	Bridge Rectifier, 100V, 2A	.....	PD10	RF-36	1
D304	Not Used	.....	.....	.....	
D305	Not Used	.....	.....	.....	
D306	Not Used	.....	.....	.....	
D307	75V PIV, 75 mA	01295	1N914	RF-28	12
D308	75V PIV, 75 mA	01295	1N914	RF-28	-
D309	Zener, 15V, 1/4W	12954	1N718	DZ-18	2
D310	75V PIV, 75 mA	01295	1N914	RF-28	-
D311	75V PIV, 75 mA	01295	1N914	RF-28	-
D312	Zener, 15V, 1/4W	12954	1N718	DZ-18	-
D313	75V PIV, 75 mA	01295	1N914	RF-28	-
D314	75V PIV, 75 mA	01295	1N914	RF-28	-

DIGITAL SECTION (Cont'd)
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DIODES (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D315	75V PIV, 75 mA	01295	1N914	RF-28	-
D316	75V PIV, 75 mA	01295	1N914	RF-28	-
D317	75V PIV, 75 mA	01295	1N914	RF-28	-
D318	75V PIV, 75 mA	01295	1N914	RF-28	-
D319	75V PIV, 75 mA	01295	1N914	RF-28	-
D320	75V PIV, 75 mA	01295	1N914	RF-28	-
D321	800V PIV, 1 A.	04713	1N4006	RF-38	1

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS301	Lamp, "1".	74276	A261	PL-42	1
DS302	Lamp, Polarity & Overrange	.....	2330	PL-60	1
F301	Fuse 117V : 1/4A	75915	313.250	FU-17	1
	234V : 1/8A	71400	MDL	FU-20	1
S301	Switch, Line Voltage	80164	.....	SW-151	1
S302	Switch, POWER (See also R311).	10582	GC-45	RP107-500K	-
T301	Transformer.	80164	.....	TR-156	1
V301	Readout.	80164	.....	EV-NL5853S	5
V302	Readout.	80164	.....	EV-NL5853S	-
V303	Readout.	80164	.....	EV-NL5853S	-
V304	Readout.	80164	.....	EV-NL5853S	-
V305	Readout.	80164	.....	EV-NL5853S	-
P301	Receptacle, Line Power	82389	EAC301	CS-254	1
Y301	Crystal.	80164	.....	CR-5	1

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q301	NPN, Case TO-5	02734	40317	TG-43	1
Q302	NPN, Case TO-92.	04713	2N3903	TG-49	2
Q303	PNP, Case TO-92.	04713	2N3905	TG-53	1
Q304	PNP, Case TO-5	02734	40319	TG-50	1
Q305	Unijunction.	03508	2N2647	TG-112	1
Q306	NPN, Case TO-92.	04713	2N3903	TG-49	-
Q307	NPN, Case TO-92.	04713	2N5551	TG-67	7
Q308	NPN, Case TO-92.	04713	2N5551	TG-67	-
Q309	NPN, Case TO-92.	04713	2N5551	TG-67	-
Q310	NPN, Case TO-92.	04713	2N5551	TG-67	-
Q311	NPN, Case TO-92.	04713	2N5551	TG-67	-
Q312	NPN, Case TO-92.	04713	2N5551	TG-67	-
Q313	NPN, Case TO-92.	04713	2N5551	TG-67	-

DIGITAL SECTION (Cont'd)
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INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA301	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	10
QA302	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA303	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA304	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA305	Hex Inverter, 14-pin DIP	01295	SN7404N	IC-33	2
QA306	Hex Inverter, 14-pin DIP	01295	SN7404N	IC-33	-
QA307	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA308	Dual 4-Input NAND, 14-pin DIP.	01295	SN15832N	IC-73	1
QA309	Positive NAND, Triple 3-input, 14-pin DIP.	01295	SN7410N	IC-43	1
QA310	Dual 4-Input NAND, 14-pin DIP.	01295	SN7440N	IC-72	1
QA311	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA312	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA313	Positive NOR Gates, 14-pin DIP	01295	SN7402N	IC-32	1
QA314	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA315	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	3
QA316	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	-
QA317	Decade Counters, 14-pin DIP.	01295	SN7490N	IC-37	5
QA318	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	5
QA319	Decade Counters, 14-pin DIP.	01295	SN7490N	IC-37	-
QA320	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	-
QA321	Decade Counters, 14-pin DIP.	01295	SN7490N	IC-37	-
QA322	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	-
QA323	Decade Counters, 14-pin DIP.	01295	SN7490N	IC-37	-
QA324	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	-
QA325	Dual Flip-Flop, 14-pin DIP	01295	SN7474N	IC-31	-
QA326	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	5
QA327	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	-
QA328	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	-
QA329	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	-
QA330	Regulator, 5V Case TO-3.	12040	LM309K	IC-34	1
QA331	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-
QA332	Decade Counters, 14-pin DIP.	01295	SN7490N	IC-37	-
QA333	Bistable Latches, 16-pin DIP	01295	SN7475N	IC-36	-
QA334	Decoder/Driver, 16-pin DIP	01295	SN7441AN	IC-35	-
QA335	Quad 2-Input NAND, 14-pin DIP.	01295	SN7400N	IC-38	-

DIGITAL SECTION (Cont'd)
(Schematic 25865E)

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R301	2.2 KΩ, 10%, 1/4W, Comp.	01121	CB-222-10%	R76-2.2K	3
R302	4.7 Ω, 5%, 1/2W, Comp.	01121	EB-4.7-5%	R19-4.7	2
R303	47 Ω, 10%, 1/2W, Comp.	01121	EB-47-10%	R1-47	2
R304	47 Ω, 10%, 1/2W, Comp.	01121	EB-47-10%	R1-47	-
R305	2.2 KΩ, 10%, 1/4W, Comp.	01121	CB-222-10%	R76-2.2K	-
R306	4.7 Ω, 5%, 1/2W, Comp.	01121	EB-4.7-5%	R19-4.7	-
R307	4.7 KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	4
R308	4.7 KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	-
R309	4.7 KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	-
R310	4.7 KΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	-
R311	500 KΩ, Var.. (potentiometer with SPST switch)	10582	GC-45	RP107-500K	1
R312	8.87 KΩ, 1%, 1/8W, MtF	07716	CEA-TO-8.87K	R88-8.87K	1
R313	100 Ω, 1%, 1/8W, MtF	07716	CEA-TO-100	R88-100	1
R314	470 Ω, 10%, 1/4W, Comp	01121	CB-471-10%	R76-470	2
R315	51.1 Ω, 1%, 1/8W, MtF.	07716	CEA-TO-51.1	R88-51.1	1
R316	2.2 KΩ, 10%, 1/4W, Comp.	01121	CB-222-10%	R76-2.2K	-
R317	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	7
R318	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R319	470 Ω, 10%, 1/4W, Comp	01121	CB-471-10%	R76-470	-
320	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R321	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R322	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	6
R323	Not Used	.....	.....	.....	
R324	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R325	10 KΩ, 10%, 1/2W, Comp	01121	EB-10K-10%	R1-10K	5
R326	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R327	10 KΩ, 10%, 1/2W, Comp	01121	EB-10K-10%	R1-10K	-
R328	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R329	10 KΩ, 10%, 1/2W, Comp	01121	EB-10K-10%	R1-10K	-
R330	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R331	10 KΩ, 10%, 1/2W, Comp	01121	EB-10K-10%	R1-10K	-
R332	1 KΩ, 10%, 1/4W, Comp.	01121	CB-102-10%	R76-1K	-
R333	1 MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	1
R334	3.9 KΩ, 10%, 1/4W, Comp.	01121	CB-392-10%	R76-3.9K	3
R335	1 MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	-
R336	3.9 KΩ, 10%, 1/4W, Comp.	01121	CB-392-10%	R76-3.9K	-
R337	3.9 KΩ, 10%, 1/4W, Comp.	01121	CB-392-10%	R76-3.9K	-
R338	1 MΩ, 10%, 1/4W, Comp.	01121	CB-105-10%	R76-1M	-
R339	47 KΩ, 10%, 1/2W, Comp	01121	EB-47K-10%	R1-47K	1
R340	390 Ω, 10%, 1/4W, Comp	01121	CB-391-10%	R76-390	1
R341	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R342	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R343	2.21 KΩ, 10%, 1/2W, MtF.	07716	CEA-TO-2.21K	R88-2.21K	1
R344	220 Ω, 10%, 1/4W, Comp	01121	CB-221-10%	R76-220	-
R345	10 KΩ, 10%, 1/4W, Comp	01121	EB-10K-10%	R1-10K	-

SECTION 7. CALIBRATION

7-1. GENERAL. This section contains information necessary to maintain the instrument to published specifications.

7-2. REQUIRED TEST EQUIPMENT. Minimum requirements for test equipment are given in Table 7-1.

7-3. PERFORMANCE CHECKS. Use the following procedure to verify proper operation of the instrument. Performance of the instrument is based on an operating temperature between 15°C and 35°C and relative humidity less than 70%. For each function that is checked, an additional uncertainty due to temperature coefficient factor should be considered if the ambient temperature is different from the absolute calibration temperature.

NOTE

Since factory calibration is performed at 25°C ±1°C, an additional ±1°C of temperature uncertainty should be considered.

a. Preliminary Set-up.

1. Set Line switch to appropriate line voltage.

2. Fuse check: 117V:1/4 Amp Slo-Blo, Keithley FU-17; 234V: 1/8 Amp Slo-Blo, Keithley FU-20.

3. Connect power cord to a variable transformer which has been set to 117 V ±1 V or 234 V ±2 V depending on the line voltage selected.

4. Connect shorting link on the front panel between LO and CASE. For maximum operator safety, make certain that the chassis is connected to earth ground by way of the third conductor on the line cord or by way of a separate clip lead from CASE to earth ground.

5. Turn the power on and allow the instrument to stabilize at ambient temperature for at least two hours. Record the temperature so that temperature coefficients can be utilized as necessary.

b. Accuracy Check.

1. VDC Function.

a) Select the dc voltage function by depressing the appropriate front panel FUNCTION pushbutton.

b) Select the appropriate RANGE pushbutton for 1 VDC range.

c) Apply a short circuit between the HI and LO input terminals. The display should indicate .00000. If necessary, adjust the front panel ZERO control to obtain a zero reading with the polarity indicator flashing.

d) Remove the short circuit and apply dc voltages to the input of the 190 with the appropriate RANGE switch setting as given in TABLE 7-2.

e) Verify that the readings on the display are within the tolerances stated.

TABLE 7-1.
Calibration Equipment

Item	Description	Specification	Mfr. & Model
A	Voltage Source	10V @ 5 ppm accuracy	--
B	Voltage Divider	10:1, 100:1 @ 5 ppm accuracy	--
C	Null Detector	1μV, 10μV, 100μV	Keithley, Model 155
D	Voltage Source	1V, 10V, 100V, 1000V with 0.1 ppm of setting resolution	Fluke, 3330B, 343B
E	Voltage Source, AC Calibrator	1V-1000V, accuracy to ±(.025% of setting +.002% of range)	HP 745A/746A
F	Resistance Source	1KΩ-1MΩ @ .002% accuracy 10MΩ @ .010% accuracy	--
G	Calibration Cover	--	Keithley, Model 1903
H	Digital Voltmeter	5-1/2 digit, 0.02% accuracy	Keithley, Model 190

TABLE 7-2.
Accuracy Check for VDC

Source Input	Source Accuracy	Range Setting	Display Reading	Reading Tolerance*
1 V	±.001%	1	1.00000	±20 digits
10 V	±.001%	10	10.0000	±20 digits
100 V	±.001%	100	100.000	±20 digits
1000 V	±.001%	1000	1000.00	±20 digits

*± two digits/°C away from Absolute Calibration Temperature.

2. Ohms Function.

a) Select the ohms function by depressing the appropriate front panel FUNCTION pushbutton.

b) Apply resistance values to the input of the 190 with the appropriate RANGE Switch setting as given in Table 7-3 using Resistance Source (G).

c) Verify that the readings on the display are within the tolerances stated.

NOTE

Resistance Source should be calibrated to compensate for lead resistance between Source and input terminals of the Model 190.

3. VAC Function.

a) Select the ac voltage function by depressing the appropriate front panel FUNCTION pushbutton.

b) Select the appropriate RANGE pushbutton for 1 VAC range.

c) Apply a short circuit between the HI and LO input terminals. The display should indicate .00000 ±5 digits.

d) Remove the short circuit and apply ac voltages to the input of the 190 with appropriate RANGE switch setting as given in Table 7-4 using AC Calibrator (F).

e) Verify that the readings on the display are within the tolerance stated.

TABLE 7-3.
Accuracy Check for Resistance

Source Input	Source Accuracy	Range Setting	Display Reading	Reading Tolerance (+.2 Ω)
1 kΩ	.002%	1	1.00000	±30 digits *
10 kΩ	.002%	10	10.0000	±30 digits *
100 kΩ	.002%	100	100.000	±30 digits *
1000 kΩ	.002%	1000	1000.00	±30 digits *
10 MΩ	.010%	10MΩ***	10.0000	±90 digits **

* ±3 digits/°C away from Absolute Calibration Temperature.
** ±11 digits/°C away from Absolute Calibration Temperature.
***Depress both kΩ and 10 MΩ pushbuttons.

TABLE 7-4.
Accuracy Check for VAC

Source Input*	Source Accuracy	Frequency Range	Range Switch Setting	Display Reading	Reading Tolerance
1 V	.027%	50 Hz-10 kHz	1	1.00000	±360 digits **
10 V	.027%	50 Hz-10 kHz	10	10.0000	±360 digits **
100 V	.027%	50 Hz-10 kHz	100	100.000	±360 digits **
400 V	.037%	50 Hz-10 kHz	1000	400.00	±180 digits ***

* rms sine wave
**±15 digits/°C away from Absolute Calibration Temperature.
***±9 digits/°C away from Absolute Calibration Temperature.

7-4. ADJUSTMENT AND CALIBRATION. This procedure should be used whenever it is necessary to calibrate the instrument to ensure that it meets all published specifications. Calibration may be accomplished every ninety-days to ensure accuracy over long-term use or more frequently if 24 hour accuracy is desired.

a. Test Equipment. The test equipment recommended in Table 7-2 should be used to ensure proper results. Other equipment may be substituted if specifications meet or exceed those given.

b. Environment. The calibration should be performed in a controlled environment. The factory calibration is performed at a 25°C ±1°C temperature and less than 50% relative humidity. Recommended temperature range for calibration is 22°C to 26°C.

c. Preliminary Set-up.

1. Check rear panel Line Switch for proper setting.

2. Check the fuse for proper rating.

3. Connect the power cord to a source of ac voltage set to either 117V ±1V or 234V ±2V. Use a variable transformer and ac meter to set voltage.

4. Connect the shorting link between front panel LO and CASE terminals.

5. Set the Power Switch to "ON".

d. Power Supply Calibration. Remove the top cover of the Model 190.

1. +5 Volt Supply. Measure the supply voltage between TP-7 and TP-9 using Voltmeter (H). Reading should be +5V ±200mV. No adjustment control is required.

2. +15 Volt Supply. Measure the supply voltage between TP-8 and TP-9 using Voltmeter (H). Reading should be between +14.5V and +16.5V. No adjustment control is required.

3. -15 Volt Supply. Measure the supply voltage between TP-10 and TP-9 using Voltmeter (H). Reading should be between -14.5V and -16.5V. No adjustment control is required.

e. 10V Reference Calibration.

1. +10 Volt Reference. Measure the reference voltage between TP-2 and LO using Voltmeter (H). Reading should be +10.0000V ±0.0005V. Potentiometer R222 (accessible from rear panel) should be used to adjust the +10V Reference as needed.

2. -10 Volt Reference. Measure the reference voltage between TP-3 and LO using Voltmeter (H). Reading should be -10.0000V ±0.0005V. Potentiometer R182 (accessible from rear panel) should be used to adjust the -10V Reference as needed.

f. Stabilization. Install calibration cover (C). Allow the instrument to reach complete stabilization in a controlled environment for a minimum of two hours.

g. DC Voltage Mode Calibration. Select the dc voltage function by depressing the front panel VDC pushbutton.

1. Zero Adjustments.

a). Input Amplifier Zero.

1) Select the 1 VDC range.

2) Connect a low-thermal short between input HI and LO.

3) Check the voltage between TP-1 and LO using Null Detector (C). Reading should be within ±20 microvolts of zero. Potentiometer R155 (on front panel) should be used to adjust for the zero offset as needed.

b). Integrator Zero.

1) Select the 1 VDC range.

2) Set up test equipment as in Figure 12.

3) Set the divider for 1mV output. To change polarity of input reverse the leads at the input to the divider.

4) Apply ±1mV to the input terminals of the 190.

5) Adjust potentiometer R208 (Integrator Zero) such that readings for both plus and minus inputs are equal.

2. 1 Volt Range.

a) Set up test equipment as in Figure 12.

b) Apply -1.00000V to the input terminals of the 190.

c) Reading on the 190 should be -1.00001 ±2 digits.

d) Potentiometer R156 (Analog Gain) should be used for adjustment to within ±2 digits.

e) Potentiometer R222 (+10V Reference Adj.) should be used to adjust the reading of -1.00001 ±1/2 digit. (Display should hold at 1.00001 with no more than 1 digit momentary change.)

f) Reverse leads at the input to the divider and apply +1.00000V to the input terminals of the 190.

g) Reading on the 190 should be +1.00001 ±1/2 digit. (Display should hold at 1.00001 with no more than 1 digit momentary change.)

h) Potentiometer R182 (-10V Reference Adj.) should be used to adjust the reading as required.

3. 10 Volt Range.

a) Set up test equipment as in Figure 12.

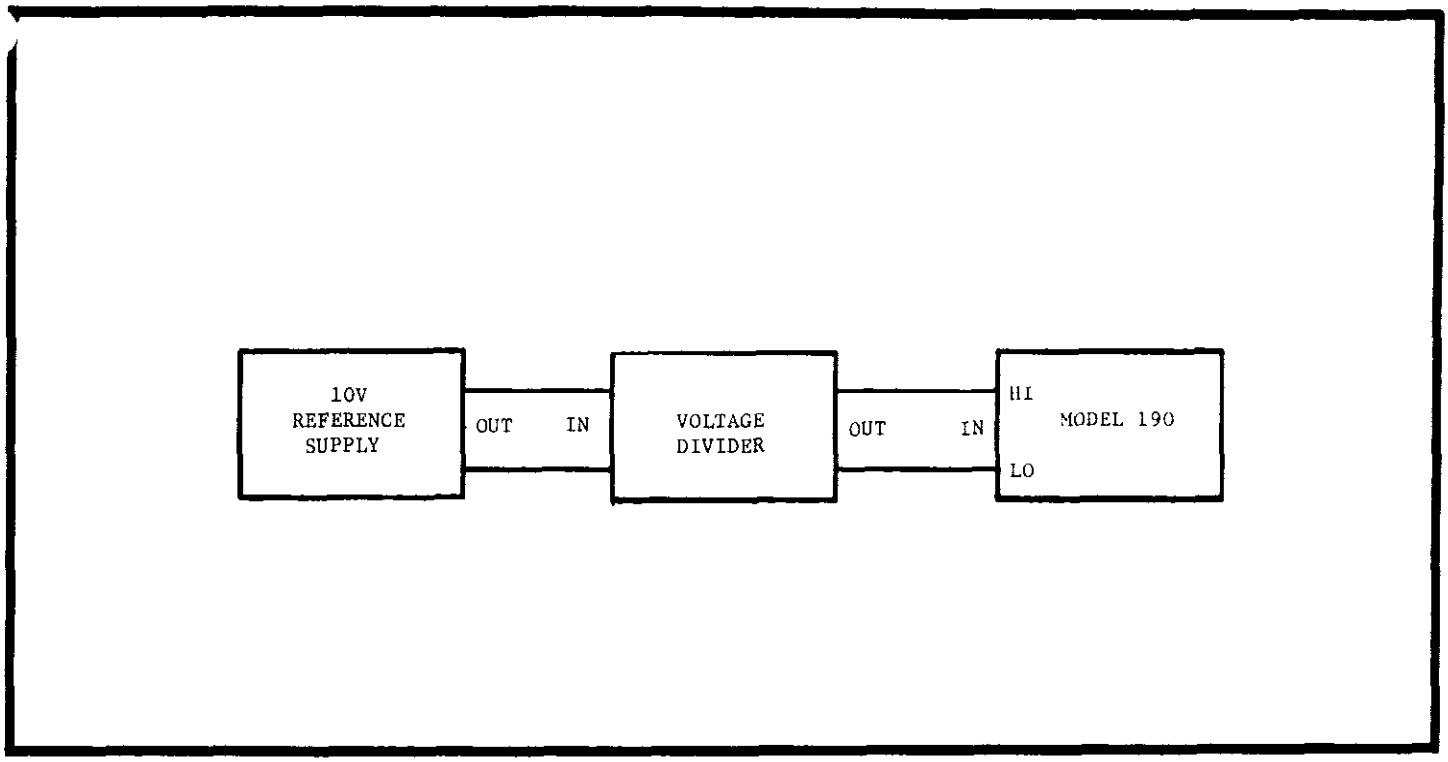


FIGURE 12. 1 VDC Voltage Calibration.

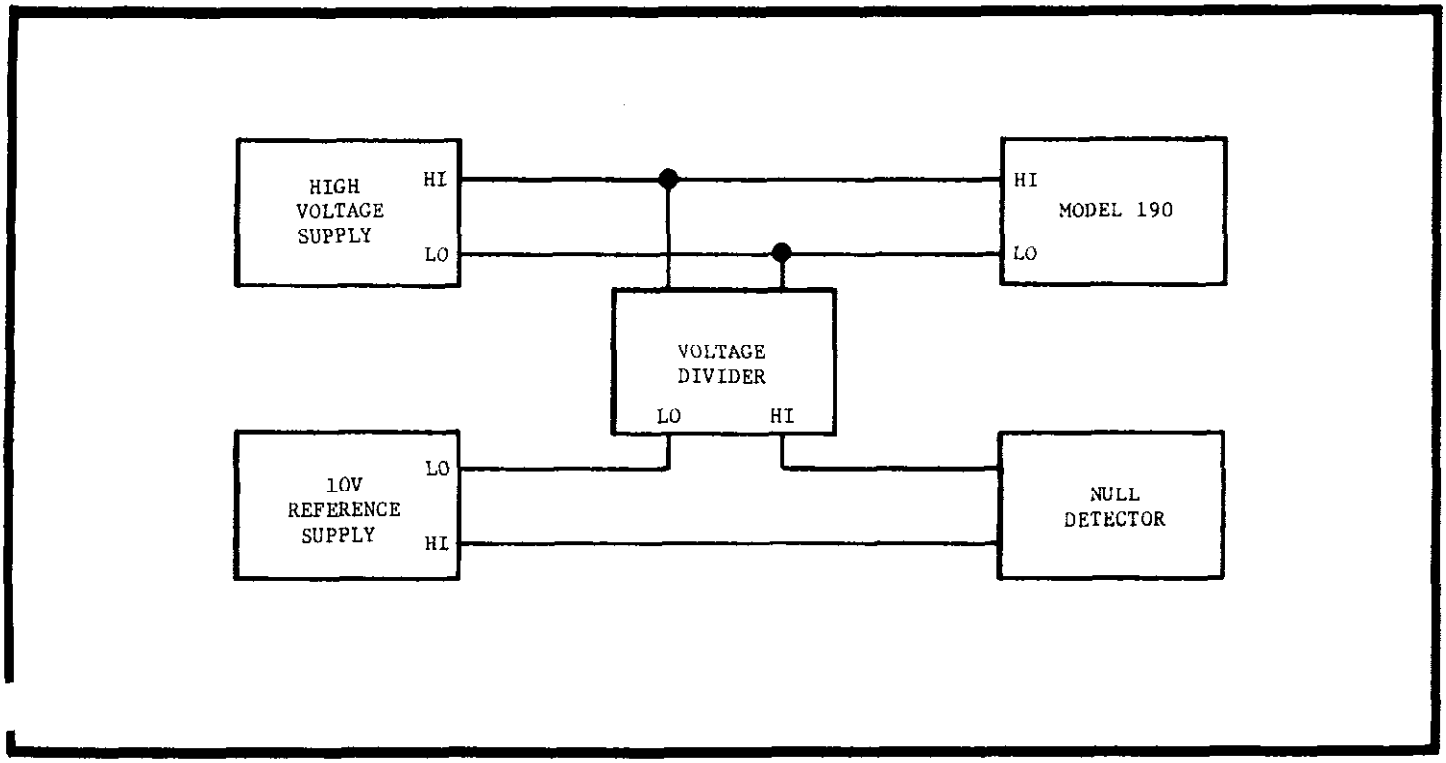


FIGURE 13. 100 VDC Voltage Calibration.

b) Apply -10.0000V to the input terminals of the 190.

c) Reading on the 190 should be -10.0001V ±1/2 digit. (Display should hold at 10.0001 with no more than 1 digit momentary change.)

d) Potentiometer R116 should be used to adjust the reading as required.

e) Reverse leads at the input to the divider and apply +10.0000V to the input terminals of the 190.

f) Reading on the 190 should be +10.0000 ±5 digits. No calibration control is required.

4. 100 Volt Range.

a) Set up test equipment as in Figure 13.

b) Voltage Source (D) should be adjusted to obtain a null reading on Null Detector (C) to within ±1 microvolt. Voltage Divider (B) should be set to 1:10.

c) Apply -100.000V to the input terminals of the 190.

d) Reading on the 190 should be -100.001V ±1/2 digit. (Display should hold at 100.001 with no more than 1 digit momentary change.)

e) Potentiometer R117 should be used to adjust the reading as required.

f) Reverse leads at input to Model 190 and apply +100.000V.

g) Reading on the 190 should be +100.000V ±5 digits.

h) No calibration control is required.

5. 1000 Volt Range.

a) Set up test equipment as in Figure 13.

b) Voltage Source (D) should be adjusted to obtain a null reading on Null Detector (C) to within ±1 microvolt. Voltage Divider (B) should be set to 1:100.

c) Apply -1000.00V to the input terminals of the 190.

d) Reading on the 190 should be -1000.00V ±1/2 digit. (Display should hold at 1000.00 with no more than 1 digit momentary change.)

e) Potentiometer R118 should be used to adjust the reading as required.

f) Reverse leads at input to Model 190 and apply +1000.00V.

g) Reading on the 190 should be +1000.00V ±5 digits.

h. Resistance Mode Calibration (kΩ).

1. Select the kΩ function.

2. Perform dc voltage zero and calibration procedure prior to calibration of resistance modes.

3. Connect Resistance Source (F) to input terminals of Model 190. Resistance enclosure (shield) should be connected to the CASE terminal.

NOTE

Accuracy of the 190 is specified at the terminals. A residual resistance due to connections internal to the 190 may contribute an offset up to .00020 kilohm. External lead resistance may contribute an additional offset unless compensated for by the resistance source. Check the offset reading on 1 kΩ with the 190 terminals shorted. Reading should be between -.00010 kΩ and +.00030 kΩ.

4. Select 1 kilohm (1 kΩ) range.

5. Set Resistance Source (F) for 1000Ω.

6. Reading on the 190 should be 1.00000 kΩ ±0.00025 kΩ (includes % of reading and % of range accuracy, but not the residual resistance of up to 0.00020 kΩ). No calibration adjustment is required.

7. Repeat steps 3 through 5 using Table 7-7 as a guide as to input and reading required. Adjust potentiometer R168 as required to obtain reading on 1000 MΩ range.

i. Resistance Mode Calibration (10 MΩ).

1. Select the 10 MΩ function.

2. Connect Resistance Source (F) to input terminals of 190.

3. Set Resistance Source (F) for 10 MΩ.

4. Reading on the 190 should be 10.0000 MΩ ±0.0005 MΩ. Potentiometer R166 should be used to adjust 10 MΩ range as required.

j. AC Voltage Calibration.

1. Select the ac voltage function by depressing the front panel VAC pushbutton.

2. Connect AC Voltage Source (E) to input of Model 190.

3. Adjust the 190 and AC Voltage Source as specified in Table 7-8.

4. Perform the calibration in the exact sequence given.

5. Make calibration adjustments for each range and frequency to obtain readings within the tolerances given in Table 7-8.

TABLE 7-5.
Preliminary Calibration

Voltage	Test Point	Tolerance	Adjustment
+5 V	TP-7	±200 mV	None
+15 V	TP-8	+14.5 V to +16.5 V	None
-15 V	TP-10	-14.5 V to -16.5 V	None
+10 V	TP-2	±0.0005 V	R222
-10 V	TP-3	±0.0005 V	R182

TABLE 7-6.
DC Voltage Calibration

Range	Input	Reading	Adjustment
1 V	-1.00000 V	-1.00001 ± 1/2 d	R156, R222
1 V	+1.00000 V	+1.00001 ± 1/2 d	R182
10 V	-10.0000 V	-10.0001 ± 1/2 d	R116
10 V	+10.0000 V	+10.0000 ± 5 d	NONE
100 V	-100.000 V	-100.001 ± 1/2 d	R117
100 V	+100.000 V	+100.000 ± 5 d	NONE
1000 V	-1000.00 V	-1000.00 ± 1/2 d	R118
1000 V	+1000.00 V	+1000.00 ± 5 d	NONE

TABLE 7-7.
Resistance Calibration (kΩ)

Range	Reading	Tolerance*	Adjustment
1 kΩ	1.00000 kΩ	±.00025 kΩ	None
10 kΩ	10.0000 kΩ	±.0024 kΩ	None
100 kΩ	100.000 kΩ	±.024 kΩ	None
1000 kΩ	1000.00 kΩ	±.05 kΩ	R168

*Does not include residual offset up to .00020 kΩ.

TABLE 7-8.
AC Voltage Calibration

Range	Input	Frequency	Reading	Tolerance	Adj.
1 V	1.0 V	400 Hz	1.00000	±0.00010 V	R140
1 V	1.0 V	10 kHz	1.00000	±0.00010 V	C110
10 V	10.0 V	400 Hz	10.0000	±0.0010 V	R104
10 V	10.0 V	10 kHz	10.0000	±0.0010 V	C101
100 V	100.0 V	400 Hz	100.000	±0.010 V	R107
100 V	100.0 V	10 kHz	100.000	±0.010 V	C103
1000 V	400.0 V	400 Hz	400.00	±0.10 V	R110
1000 V	400.0 V	10 kHz	400.00	±0.10 V	C105

KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD
CLEVELAND, OHIO 44139

SERVICE FORM

MODEL NO._____ SERIAL NO._____ P.O. NO._____ DATE_____ R-

NAME _____ PHONE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____ ZIP_____

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) _____

_____

_____ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. _____

_____

4. Describe input signal source levels, frequencies, etc. _____

_____

_____

5. List and describe all cables used in the experiment (length, shielding, etc.).

_____

_____

6. List and describe all other equipment used in the experiment. Give control settings for each. _____

_____

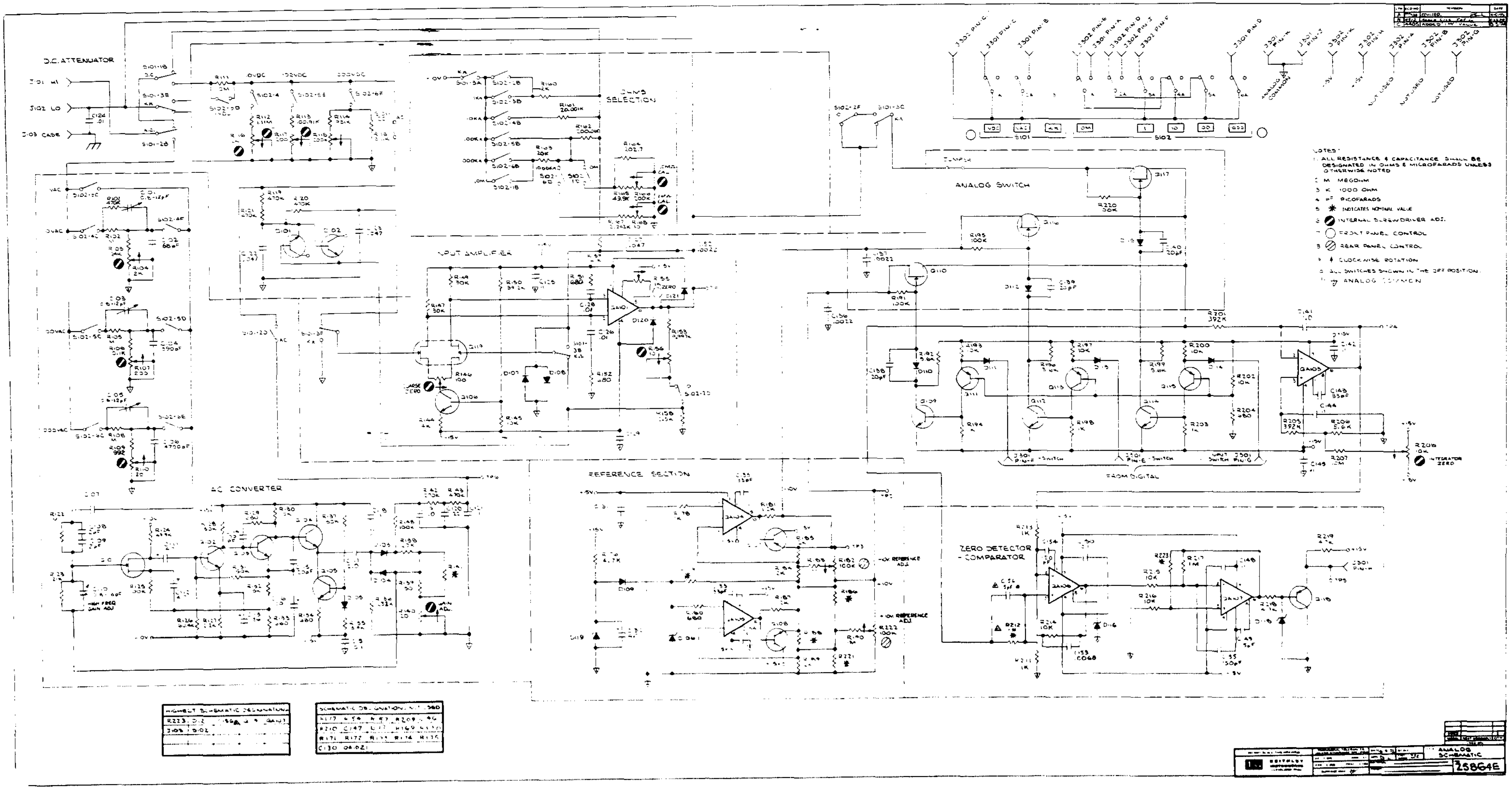
_____

7. Environment:
   Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) _____
   What power line voltage is used? _____ Variation? _____ Frequency? _____
   Ambient temperature? _____°F. Variation? ____°F. Rel. Humidity? _____
   Other _____

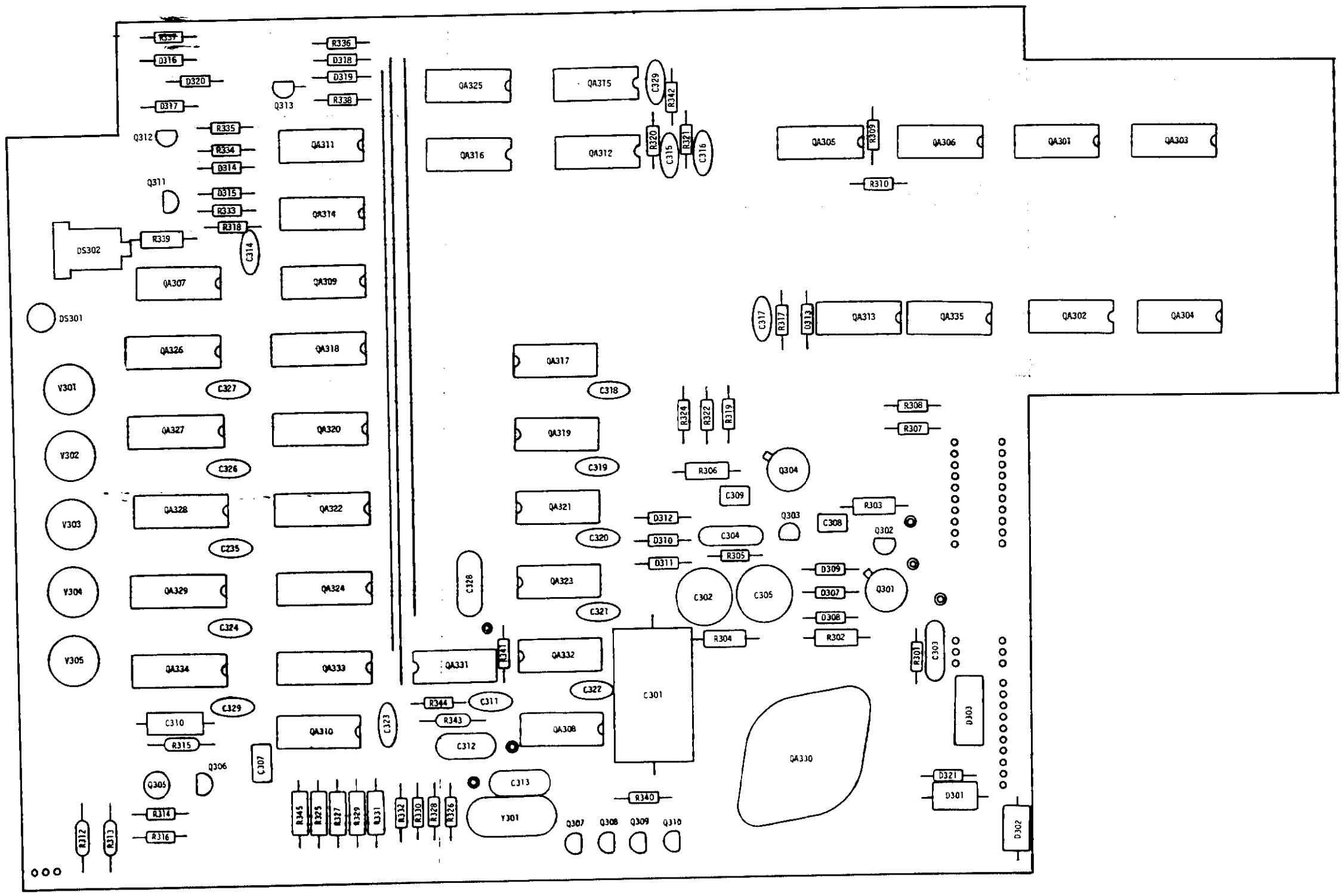
8. Additional Information. (If special modifications have been made by the user, please describe below.) _____

_____

_____ REV 0774



D.C. ATTENUATOR
OHMS SELECTION
ANALOG SWITCH
INPUT AMPLIFIER
AC CONVERTER
REFERENCE SECTION
ZERO DETECTOR - COMPARATOR
FROM DIGITAL
NOTES:
ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED
M MEGOHM
K 1000 OHM
PF PICOFARADS
INDICATES NOMINAL VALUE
INTERNAL SCREWDRIVER ADJ.
FRONT PANEL CONTROL
REAR PANEL CONTROL
CLOCKWISE ROTATION
ALL SWITCHES SHOWN IN THE OFF POSITION.
ANALOG COMMON
HIGHEST SCHEMATIC DESIGNATIONS
SCHEMATIC DESIGNATIONS NOT USED
ANALOG SCHEMATIC
KEITHLEY
25864E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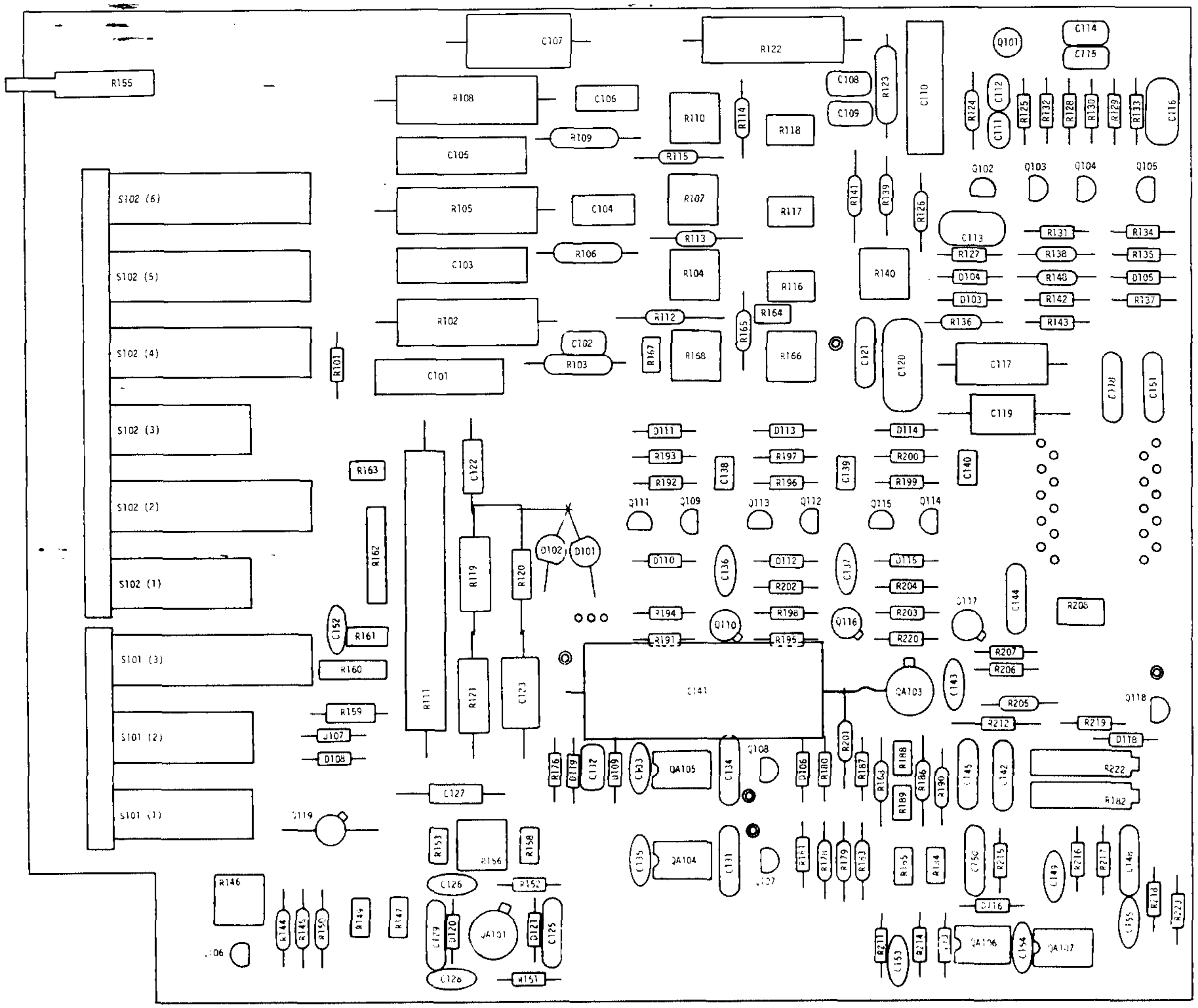

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D109
C133
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Q108
D106
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C145
C142
R222
R184
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R190
R182
C127
R189
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R156
R158
C135
QA104
C131
R185
C150
R215
R216
R217
C146
C149
R146
C126
R152
D116
R144
R145
R150
R149
R147
C129
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C125
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C154
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C153
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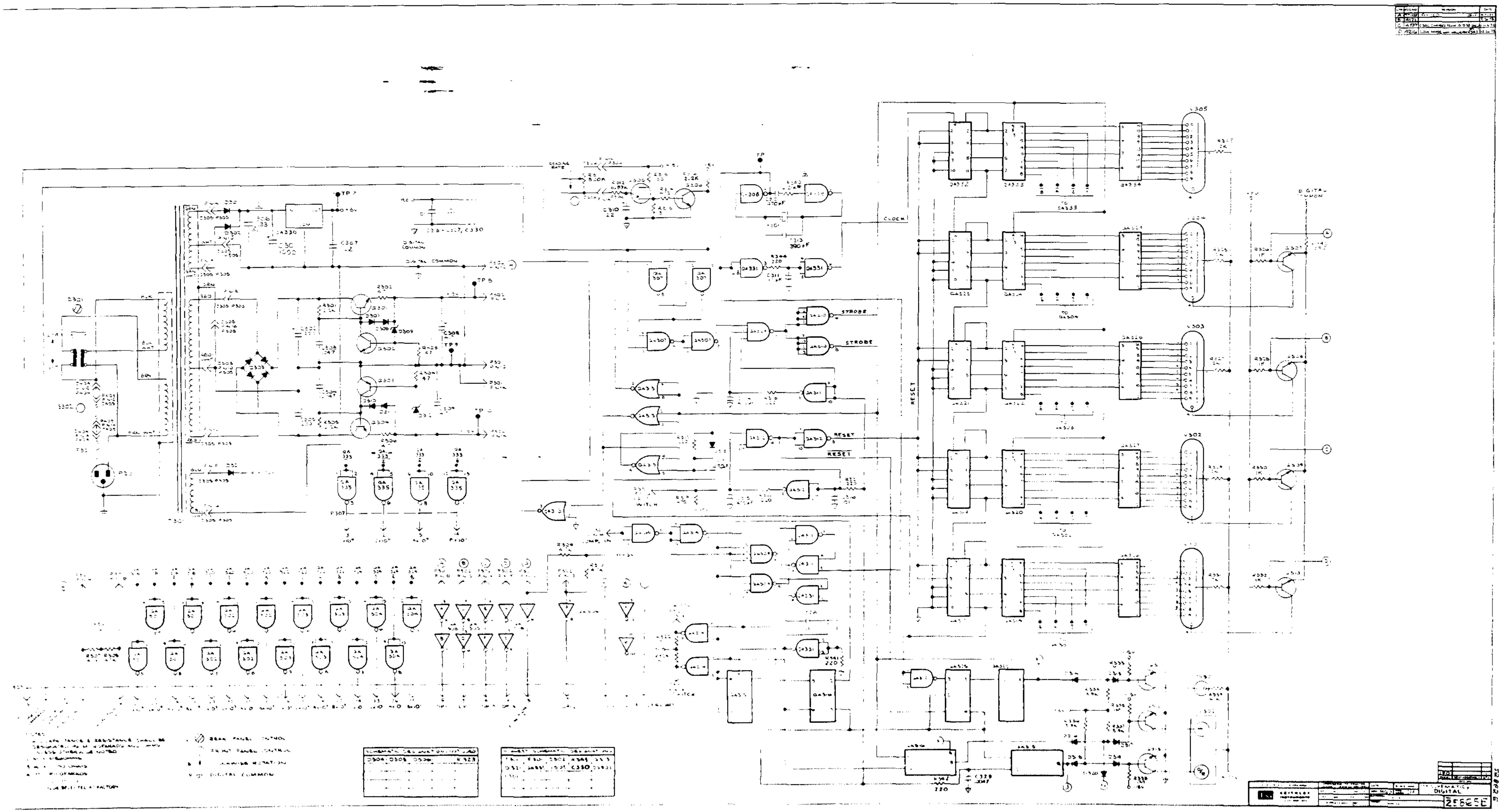
R223
R151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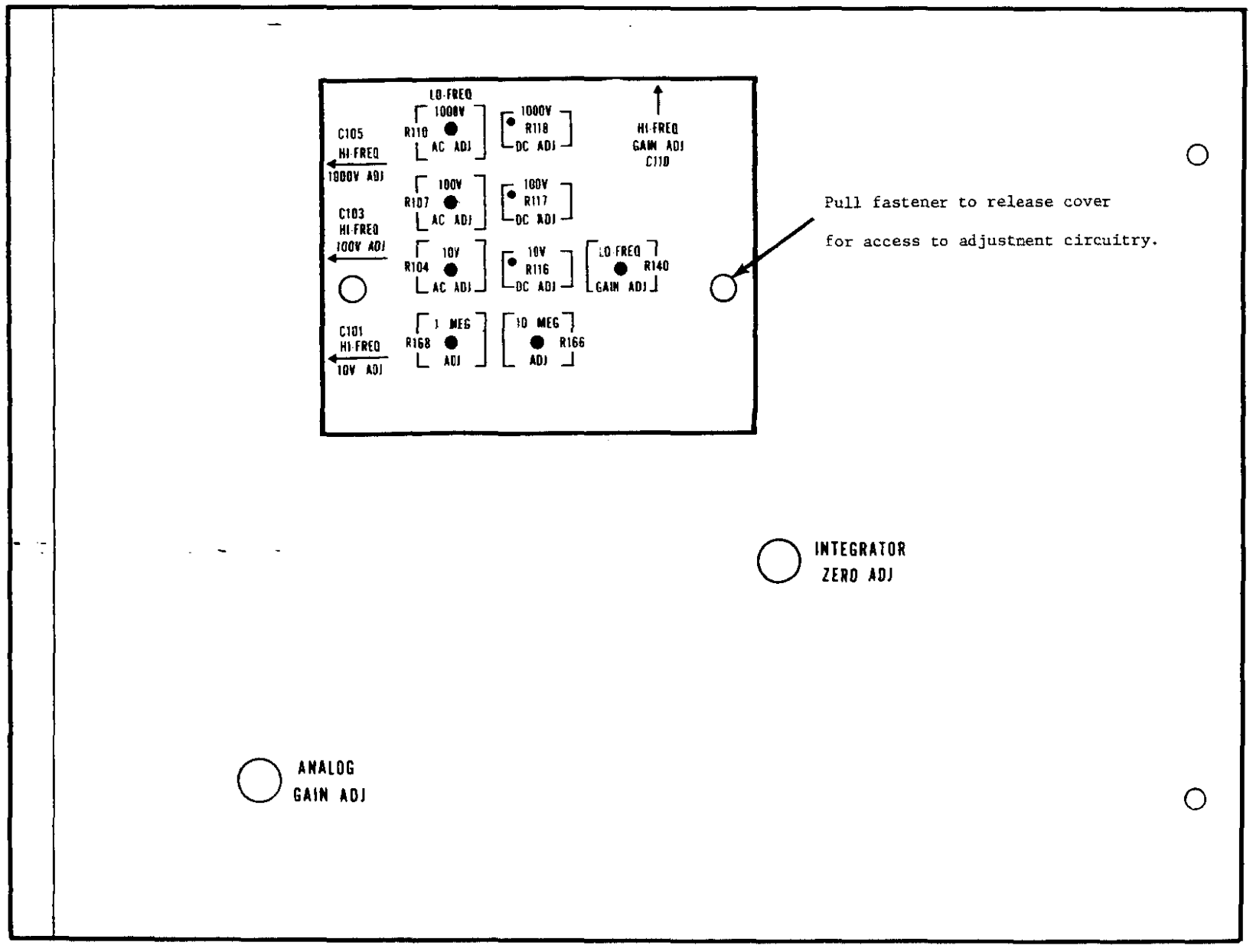

FIGURE 16. Calibration Cover.