Instruction Manual
Model 191
Digital Multimeter

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ILLUSTRATIONS.

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The Keithley Model 191 is a 5-1/2 digit, 200,000-count, manual-ranging bench digital multimeter with dc volts and ohms ranges standard. It provides highly accurate, stable, low noise and fast-responding readings from 1μV to 1200 volts dc on 5 voltage ranges, and 2 and 4 terminal measurements from 1 milliohm to 20 megohms on 6 resistance ranges. The 191 is capable of 0.0005% resolution and 1μV/1mΩ sensitivity. In addition, if you purchased the Model 1910 AC Voltage Option, your DMM will provide readings from 10μV to 1000 volts ac on 4 ranges. This option may also be purchased later, and field installed.

1-3. Your DMM also has features and advantages that might not be readily apparent. Some of these are:

- 5-1/2 digit LED display with appropriate decimal point - 0.5 inch digits permit monitoring measurements from across the room.
- Pushbutton NULL - eliminates potentiometer zeroing, corrects for lead resistance in 2-wire ohms, bucks out thermal EMF's in low level dc measurements and permits you to measure deviations from a set value. The NULL light indicates that the function is active for operator safety and to lessen the chance of measurement error.

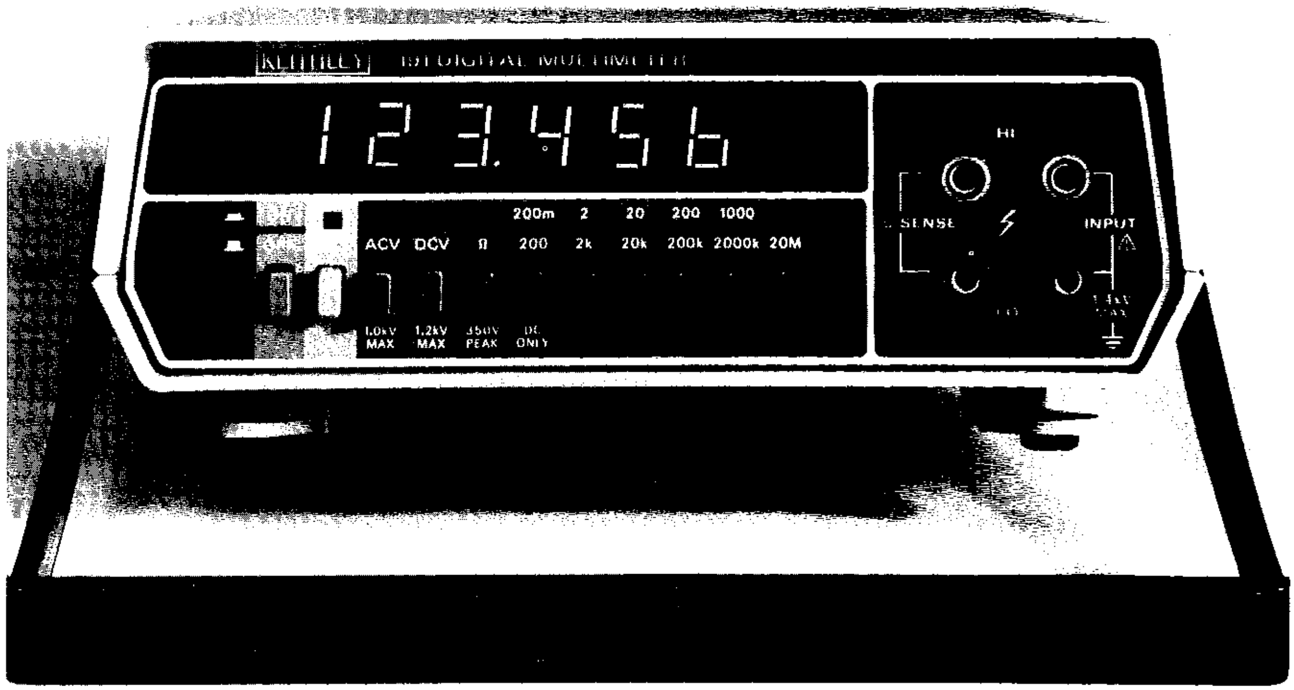


FIGURE 1-1. Model 191 Digital Multimeter

1-3. Continued.

- A Micro-processor based design that provides:

  A Combination of single slope and charge balance AD conversion - for faster response and better linearity.

  Automatic non-linear digital filtering - for faster response and reduced noise on the display.

  A reduction in the number of parts while maintaining high accuracy and speed of measurement - simplifies high accuracy measurements and calibration of the instrument and provides higher mean time between failures.

- -IEEEEE error message indicates improper uses of the instrument - prevents erroneous readings and reduces possibility of injury to the user or damage to the instrument.

- Each range has:

  Automatic polarity operation - minus sign displayed, positive implied.

  Effective input overload protection.

  Overrange indication - polarity and overrange digit displayed.

  Decimal point positioned by range pushbutton.

- Automatic 2/4 wire ohms operation - saves time and simplifies 2-wire or 4-wire ohms measurements.

- A full line of optional accessories that extend the measurement capability of your Model 191. Some of these accessory models are:

  1600 High voltage Probe allows your DMM to measure from 1200V to 40kV dc.

  1901 Plug-In Current Adapter allows your DMM to read dc current from 1nA/digit to 2000mA. With the AC Voltage option, it reads from 10nA/digit to 2000mA ac.

  1682 High Frequency (RF) Probe allows your DMM to measure from 0.25V to 30V rms ac over a frequency range of 100kHz to 100MHz. It can be used without the AC Voltage Option.

  1685 Clamp-On AC Current Probe (when used with AC Voltage Option) allows your DMM to measure from zero to 200A rms ac.

  1651 50-Ampere Current shunt allows your DMM to measure from 0-50A dc, and with AC Voltage Option from 10A to 50A rms ac.

NOTE

Refer to Section 4 for more detailed information on these accessories.

1-4. WARRANTY INFORMATION.

1-5. 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 the United Kingdom and West Germany, as well as in the United States. Check the inside front cover of this Manual for addresses.

1-6. CHANGE NOTICES.

1-7. 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.

1-8. SAFETY SYMBOLS.

1-9. Safety symbols used in this manual are as follows:

IMPORTANT

The ⚠ symbol can be found in various places in this Manual. Carefully read the associated CAUTION statements with regard to proper use and handling of the instrument. Damage to the instrument may occur if these precautions are ignored.

This ⚡ symbol can be found in various places in this Manual. This symbol indicates those areas on the instrument which are potential shock hazards. Carefully read the associated WARNING statements with regard to proper use and handling of the instrument. Serious personal injury may result if these precautions are ignored.

1-10. SPECIFICATIONS

1-11. Detailed specifications for the Model 191 are given in Table 1-1.

TABLE 1-1
SPECIFICATIONS

DC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY ± (% rdg + digits) 24 Hr 22-24°C	ACCURACY ± (% rdg + digits) 1 yr 18-28°C	TEMPERATURE COEF. ± (% rdg + digits)/°C 0-18°C & 28-50°C	INPUT RESISTANCE	MAXIMUM ALLOWABLE INPUT	SETTLING TIME[3]
200mV	199.999	.005 + 2d[1]	.007 + 3d[1]	.0007 + 1.6d	>1000Mohm	1200V[2]	0.5 sec[4]
2 V	1.99999	.004 + 1.5d	.007 + 2d	.0007 + 0.2d	>1000Mohm	1200V[2]	0.5 sec
20 V	19.9999	.004 + 1.5d	.010 + 2d	.0008 + 0.2d	10Mohm	1200V	0.5 sec
200 V	199.999	.004 + 1.5d	.010 + 2d	.0008 + 0.2d	10Mohm	1200V	0.5 sec
1200 V	1200.00	.005 + 1.5d	.010 + 2d	.0012 + 0.2d	10Mohm	1200V	0.5 sec

NMRR: >60dB at 50 & 60 Hz.
CMRR: >120dB at DC, 50 & 60 Hz (with 1kohm in either lead).

[1]With zero set by Null function
[2]1 minute max., 700 volts continuous
[3]To within 5 digits of final reading
[4]1.6 sec for input changes < 15 microvolts

RESISTANCE

RANGE	MAXIMUM READING	ACCURACY ± (% rdg + digits) 24 Hr 22-24°C	ACCURACY ± (% rdg + digits) 1 Yr 18-28°C	TEMPERATURE COEF. ± (% rdg + digits)/°C 0-18°C & 28-50°C	MAXIMUM OUTPUTS I short	MAXIMUM OUTPUTS V open	SETTLING TIME[2]	4-TERMINAL LEAD RESISTANCE[4]
200 ohm	199.999	.006 + 2d[1]	.012 + 3d[1]	.0015 + 2d	4mA	400mV	1 sec[3]	5ohm
2kohm	1.99999	.006 + 1.5d	.012 + 2d	.0015 + 0.2d	4mA	4 V	1 sec	22ohm
20kohm	19.9999	.006 + 1.5d	.012 + 2d	.0015 + 0.2d	400μA	4 V	1 sec	50ohm
200kohm	199.999	.006 + 1.5d	.012 + 2d	.0015 + 0.2d	40 μA	4 V	1 sec	220ohm
2000kohm	1999.99	.01 + 1.5d	.03 + 2d	.002 + 0.2d	4 μA	4 V	1 sec	500ohm
20Mohm	19.9999	.04 + 1.5d	.08 + 2d	.006 + 0.2d	1 μA	4 V	2 sec	2200ohm

CONFIGURATION: 4 terminal or 2-terminal.
MAXIMUM ALLLOWABLE INPUT: 360V peak, 250V rms.

[1]With zero set by Null function
[2]To within 5 digits of final reading
[3]3 sec for input changes < 15 milliohms.
[4]Maximum resistance per lead for additional 1 digit error

AC VOLTAGE (Option 1910)

RANGE	MAXIMUM READING	ACCURACY ± (% rdg + digits) (Above 1000 Counts)[1] 1 Year 18-28°C 50Hz-20kHz	ACCURACY 20-50Hz & 20k-100kHz	TEMPERATURE COEFFICIENT ± (% rdg + digits)/°C 0-18°C & 28-50°C 50Hz-20kHz	TEMPERATURE COEFFICIENT 20-50Hz & 20k-100kHz
2V	1.99999	0.10 + 10d	1.0 + 20d	0.015 + 0.5d	0.05 + 0.5d
20V	19.9999	0.10 + 10d	1.0 + 20d	0.015 + 0.5d	0.05 + 0.5d
200V	199.999	0.10 + 10d	1.0 + 20d	0.015 + 0.5d	0.25 + 0.5d
1000V	1000.00	0.15 + 10d[2]	1.0 + 20d[3]	0.020 + 0.5d	0.05 + 0.5d

RESPONSE: Average, calibrated in rms of a sinewave.
MAXIMUM ALLOWABLE INPUT: 1000V rms sine or DC, 2 x 10^7V • Hz.
SETTLING TIME: < 1.3 seconds to within 0.05% of final reading for zero to full-scale step input.
CMRR: >60dB at DC, 50 & 60 Hz (1kohm in either lead)
INPUT IMPEDANCE: 2Mohm shunted by less than 50pf

[1]With input shorted, display reads approximately 20 digits
[2]50Hz-10kHz.
[3]20Hz-50Hz & 10kHz-20kHz

GENERAL

NULL: Pushbutton allows zeroing of on scale readings. Front panel annunciator indicates null mode.
DISPLAY: Six 0.5 inch LED digits with appropriate decimal point.
CONVERSION SPEED: 4 readings/second on DC volts.
3 readings/second on ohms.
2 readings/second on AC volts.
POLARITY: Automatic, minus indicated, plus implied.
RANGING: Manual.
OVERLOAD INDICATION: Display indicates polarity and overrange digit only.
INVALID RANGE/FUNCTION SELECTION: Display reads −EEEEE.
ISOLATION: Input LO to power line ground, greater than 1000 megohms shunted by approximately 300 picofarads. Maximum input between LO and power line ground, 1400 volts peak, 5 x 10^5V • Hz.
WARMUP: 1 hour to rated accuracy.
ENVIRONMENTAL LIMITS:
Operating: 0°C to 50°C, 0% to 80% relative humidity up to 35°C.
Storage: -25°C to 65°C.
POWER: 105-125 or 210-250V (internal switch selected), 90-110V available; 50-60Hz, 25V•A maximum.

INPUT CONNECTORS: 5-way binding posts
DIMENSIONS, WEIGHT: 85mm high x 235mm wide x 275mm deep (3½ in. x 9¼ in. x 10¾ in.) Net weight 2.3kg (5 lbs)
ACCESSORIES SUPPLIED: Instruction Manual.

AVAILABLE ACCESSORIES:
- Model 1010 Single Rack Mounting Kit
- Model 1017 Dual Rack Mounting Kit
- Model 1600 High Voltage Probe
- Model 1641 Kelvin Test Lead Set
- Model 1651 50 Ampere Shunt
- Model 1681 Clip-On Test Lead Set
- Model 1682 RF Probe
- Model 1683 Universal Test Lead Set
- Model 1684 Carrying Case
- Model 1685 Clamp-On Current Probe
- Model 1901 Current Adapter
- Model 1910 AC Volts Option
- Model 1913 Calibration Cover

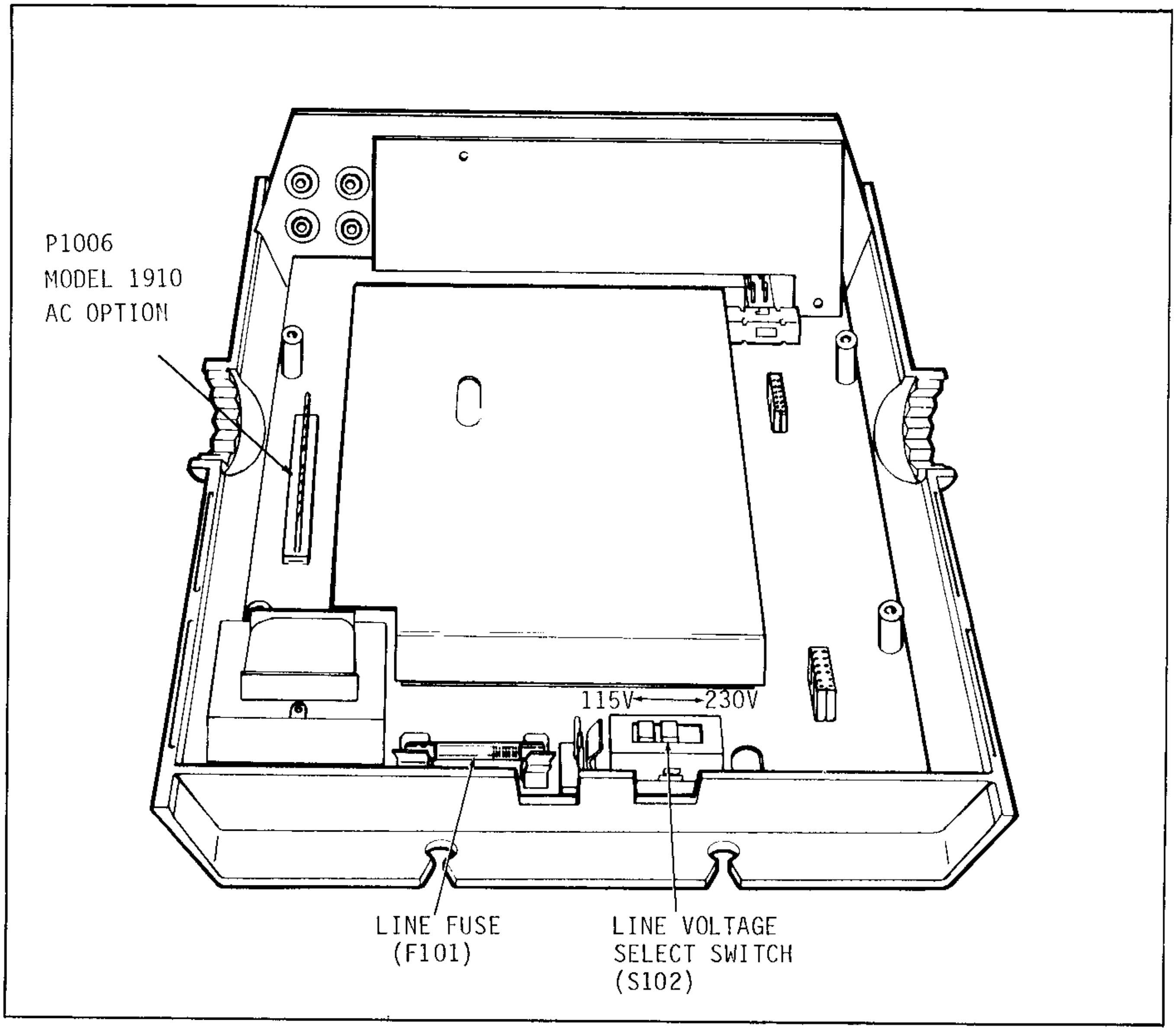


FIGURE 2-1. Location of Line Fuse and Line Voltage Select Switch.

SECTION 2. OPERATION.

2-1. INTRODUCTION.

2-2. This section provides information needed for incoming inspection, preparation for use, and operation of the Model 191 and its accessories.

2-3. UNPACKING AND INSPECTION.

2-4. The Model 191 was carefully inspected, both mechanically and electrically before shipment. Upon receiving the Model 191, unpack all items from the shipping container and check for any obvious damage which may have occured during transit. Report any damages to the shipping agent. Retain and use the original packaging materials if reshipment is required. The following items are shipped with all Model 191 orders:

a. Model 191 DMM.
b. A Copy of this Manual.
c. Installed or separate optional accessories, as ordered.

2-5. PREPARATION FOR USE.

2-6. The Model 191 is shipped ready-for-use on the line voltage marked on its rear panel. Instructions on how to connect the Model 191 to your available ac line power are contained in Paragraph 2-7 Line Power.

2-7. LINE POWER

2-8. The Model 191 is provided with a 3-wire line cord which mates with a 3rd wire earth grounded receptacle. The instrument will operate on 3 voltage ranges of 60 or 50 Hertz ac power. Standard voltage ranges are 105 to 125 volts and 210 to 250 volts. Either of these ranges may be selected by positioning an internal slide switch and installing the appropriate fuse for that range. An optional line voltage range of 90 to 110 volts is available by special order. Instruments with this range use a different transformer. Connect the Model 191 to your available ac power inaccordance with the following procedures:

NOTE

The line voltage setting of the instrument is marked on the rear panel. The following procedure can be used to either confirm the factory setting, or to set up the instrument for operation on another voltage range. If the line voltage range is changed, the box next to the selected line voltage should be appropriately marked as an external reminder of the setting. Use a water soluable marking pen.

2-9. Line Voltage Selection.

2-10. Set up the Model 191 to operate on your available ac line voltage as follows:

a. Turn the DMM bottom side up and loosen the four screws in the bottom cover. These screws are held captive by rubber O-rings.

b. Hold the top and bottom cover together to prevent their separation and turn the DMM over to normal position. Remove the top cover.

c. Set switch S102 and install the proper rated line fuse, as indicated in Table 2-1, for your available input line voltage. These items are shown in Figure 2-1.

d. Reinstall the top cover.

TABLE 2-1.
Line Voltage Selection.

INPUT VOLTAGE	SWITCH S102	FUSE F101
90-110V*	115V	1/4A
105-125V	115V	1/4A
210-250V	230V	1/8A

*Requires special factory installed transformer.

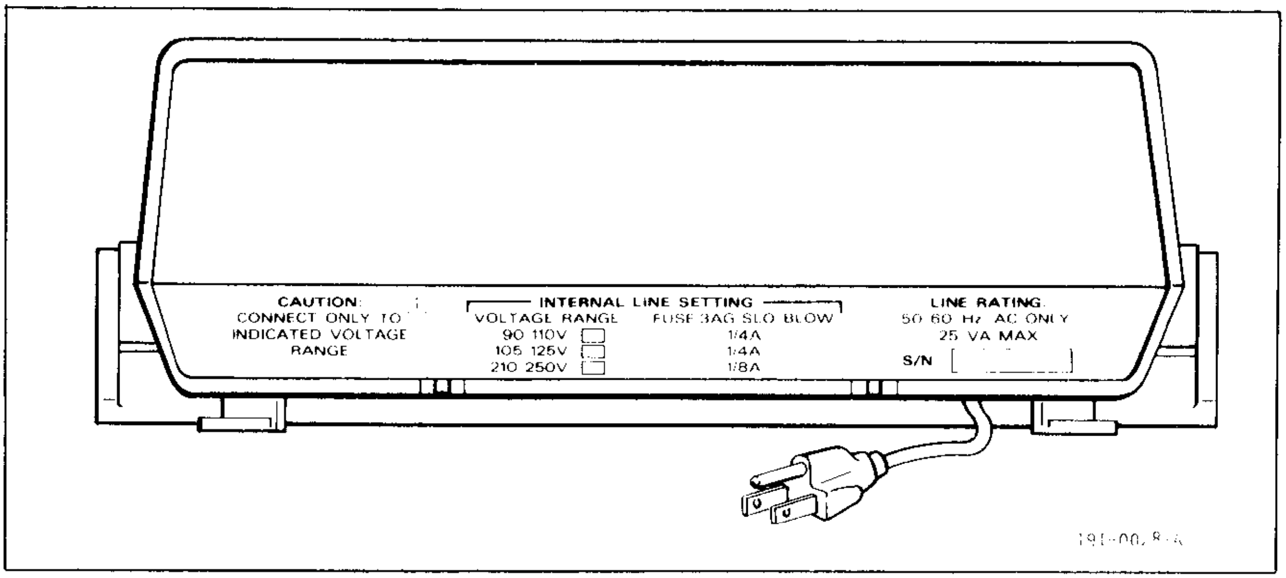


FIGURE 2-2. Rear View Showing Line Cord.

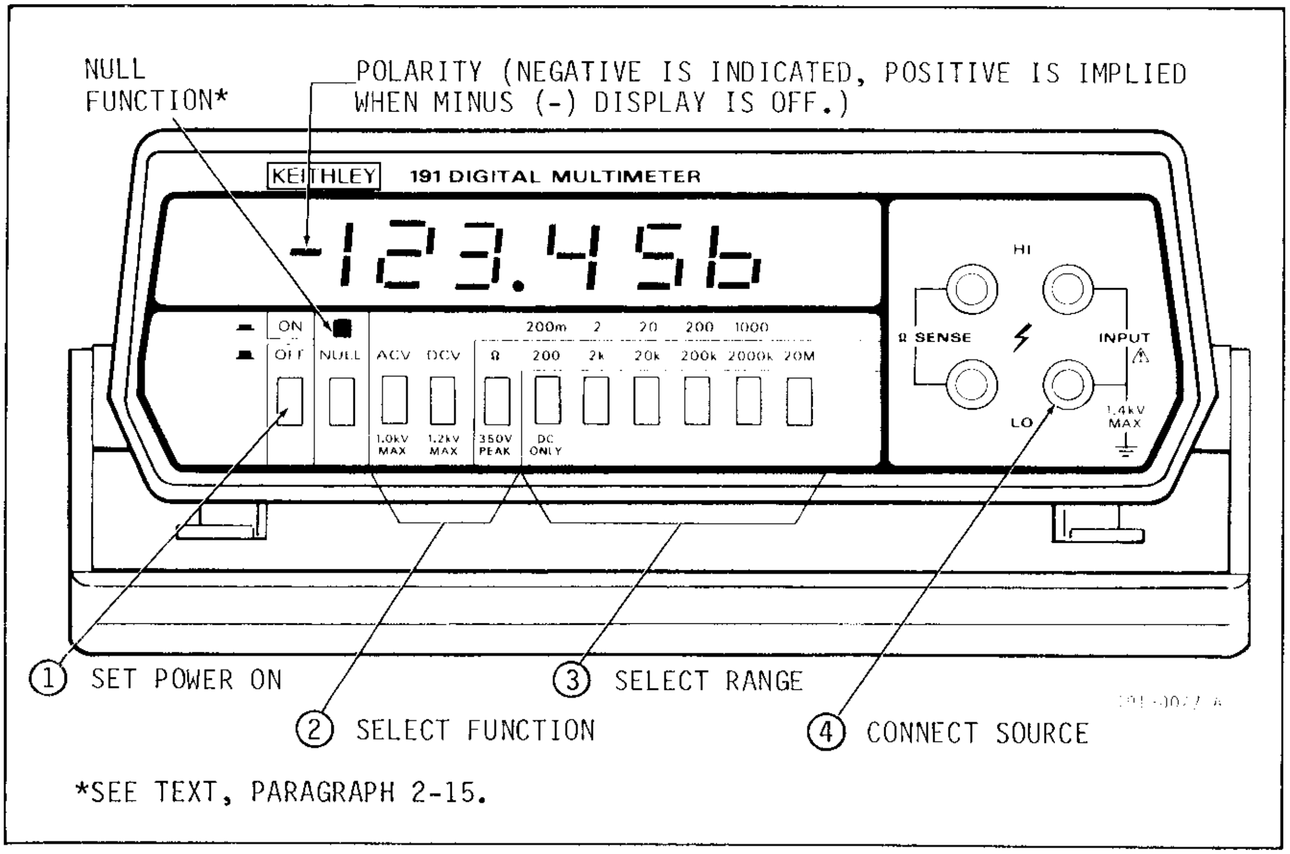


FIGURE 2-3. Operating Controls.

2-11. Connecting Line Power.

2-12. The Model 191 is provided with a 3-wire line cord, shown in Figure 2-2, which mates with third-wire grounded receptacles. Connect the instrument to ac line power as follows:

WARNING

Ground the instrument through a properly earth-grounded receptacle before operation. Failure to ground the instrument can result in severe injury or death in the event of short circuit or malfunction. In addition, connect only to the line voltage selected. Application of incorrect voltage can damage the instrument.

a. Plug the power cord into a properly grounded outlet of a source having the selected line voltage.

b. Operate the Model 191 as described in Paragraph 2-13.

2-13. OPERATING INSTRUCTIONS

2-14. The basic operating instructions for the Model 191 DMM are outlined below, and Condensed Operating instructions are provided on the bottom cover of the instrument. These instructions should only be used after becoming completely familiar with the operation of the Model 191 through day-to-day use. Until this familiarity has been achieved, best performance and safest operation will be obtained by using the individual instructions provided in this section which describe how to make specific function measurements. Refer to Figure 2-3 and operate the DMM as follows:

CAUTION

Do not exceed the Maximum Inputs limits given in Table 2-2.

a. Turn on the power by depressing the ON/OFF pushbutton. If the instrument is within 18-28°C, it is useable immediately, but a 1 hour warmup is required to obtain rated accuracy. Up to 1 additional hour may be required from temperature extremes.

b. Select the function with the ACV, DCV or Ω pushbuttons.

c. Select the range by depressing the appropriate pushbutton.

d. Connect the source to the INPUT terminals and make the measurement. Accessories described in Section 4 should be used as required.

TABLE 2-2
Summary of Maximum Inputs.

FUNCTION	RANGE	MAXIMUM INPUT
DCV	200mV, 2V	700V Continuous; 1200V for 1 minute maximum.
	20V-1200V	1200V Continuous
Ω(ohms)	ALL	250V rms; 360V peak
ACV (Option)	ALL	1000V rms sine or dc; 2×10^7 V ·Hz

2-15. NULL FUNCTION.

2-16. The NULL function is operable on all ranges and functions. It is a switch selectable software based function. The annunciator is lighted when the function is selected. When the NULL pushbutton is depressed with an on-scale reading on the display, that reading is subtracted from all subsequent readings. The nulling process is merely a subtraction of two numbers, and has nothing to do with the range or function selected. For this reason, although primarily designed to provide convenient pushbutton compensation for test lead resistance and thermal emf's generated in circuits connected to the DMM INPUT terminals, the null function can also be used to measure variations above or below a set value. For example, +1.00000 VDC input could be used to null the display, and variations above 10.0000MΩ could be made by switching to the 20MΩ range and Ω function. This is possible because the number being subtracted is 100,000 (counts) in both instances, and the minus sign is active for Ω (and ACV) in the NULL mode.

2-17. It is important to note that the use of NULL reduces the dynamic range of measurement. For instance, if +1.00000 VDC is the nulled value, input voltages greater than 2V would still overload the A/D converter (200,000 counts), even though overrange would occur at ≈100,000 counts displayed, and readings less than -1V would cause overrange (2V less than +1V) because of the maximum display reading of -199,999 counts. This reduction in the dynamic range of the measurement is illustrated in Figure 2-4. In DCV function, both the Display Dynamic Range and the input dynamic range can be exceeded and thus, both can limit the dynamic range of the measurement. In ACV and Ω, only the input dynamic range can be exceeded.

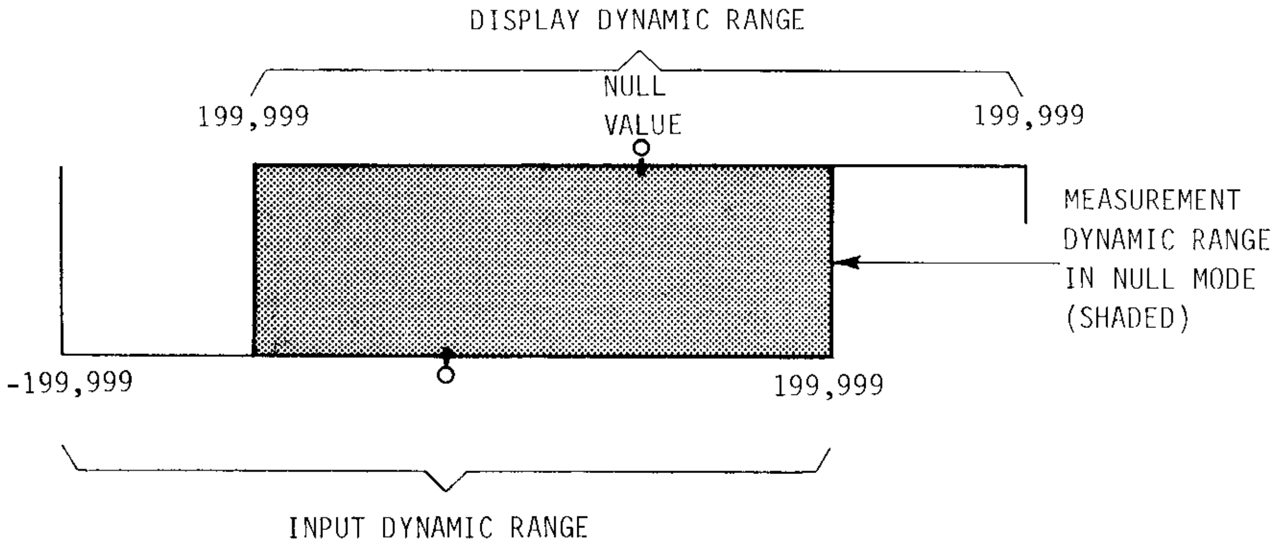


FIGURE 2-4. Effect of NULL function on Dynamic Range of DCV Measurement.

2-18. The Use of NULL as pushbutton "zero" is described in DC Voltage and Ω Measurement Procedures.

2-19. OVERRANGE INDICATION.

2-20. Overrange is indicated by the minus sign along with the overrange digit and the appropriate decimal point. All of the remaining less significant digits are blanked. Example: (-1--.---). Overrange is indicated whenever the dynamic range of DCV measurement is exceeded. With the NULL function off, this occurs above ±199,999 counts. As described in Paragraph 2-17, the dynamic range of the measurement is reduced by an amount determined by the size and polarity of the nulled signal when the instrument is in the null mode.

2-21. ERROR INDICATION.

2-22. -IEEEEE is displayed when an improper range - function is selected. These selections are:

ACV function - when AC option is not installed.

20MΩ range - with ACV or DCV function selected.

ACV function - with 200Ω, 200mV range selected.

2-23. DC VOLTAGE MEASUREMENT.

2-24. The Model 191 reads dc voltages from 1 microvolt/digit to 1200 volts. The maximum displayed reading is 199999. Overrange is indicated by (-)1-----, except on 1200 volt range. On the 1200 volt range, the display can read beyond the maximum allowable input voltage. Maximum allowable input: 1200V for 1 minute maximum, 700 volts continuous on the 200mV and 2V ranges; 1200 volts continuous on the 20V-1200 volt ranges. Use the Model 191 to measure dc voltage as follows:

⚠ CAUTION

Do not exceed the maximum allowable input voltage limits. Instrument damage may occur.

a. Turn on power with the ON/OFF pushbutton and depress the DCV pushbutton.

b. Select the desired range from the five ranges available. The decimal point is positioned by the range pushbutton. The 1200 VDC range is selected by the 1000 pushbutton.

c. Ensure that the NULL pushbutton is out (light off) unless measurements are to be made as deviations from a preset value.

d. Connect the signal to be measured between the INPUT HI and LO binding posts. The binding posts accept wires, spade lugs or banana plugs for ease of connecting the circuit to be measured. Low thermal cabling and connections are recommended for measurements on the 200mV range.

e. For the top four ranges, merely observe the displayed digits, polarity sign and decimal point locations. The top four ranges are direct-reading in volts.

f. For the 200mV range, ZERO must set with the NULL function to obtain rated accuracy. Zeroing is necessary to compensate for thermal EMF's generated by the connections to the circuit to be measured. These voltages may be only a few microvolts or several tens of microvolts. Set zero as follows:

1) Set Model 191 to 200mV range.
2) Disconnect the test leads at the circuit to be measured and short them.
3) Depress the NULL pushbutton.
4) Reconnect the test lead and make the measurement by applying the signal and reading millivolts on the display.

g. The optional Model 1600 High voltage Probe can be used with the Model 191 to measure dc voltages up to 40 Kilovolts, at reduced accuracy. Refer to Paragraph 2-30.

2-25. RESISTANCE (Ω) MEASUREMENT

2-26. The Model 191 DMM measures resistance from 1 milliohm/digit to 20 megohms. See Table 2-3 for ranges. The Model 191 provides automatic 2-wire or 4-wire ohms operation. This means that if the ohms sense leads are connected, the measurement is automatically done 4-terminal. If the sense leads are not connected, the measurement is done 2-terminal. For 4-terminal measurements rated accuracy (+1 digit) can be obtained on the top five ranges as long as the maximum lead resistances given in Table 2-3 are not exceeded. For 2-terminal or 4-terminal measurements on the 200Ω range, zero must be set by the NULL function to obtain rated accuracy. Use the Model 191 to measure resistance as follows:

⚠ CAUTION

MAXIMUM ALLOWABLE INPUT VOLTAGE (all ranges): 360V peak, 250V rms. Do not exceed maximum voltage. Instrument damage may occur.

a. Turn on power and depress Ω pushbutton.

b. Connect the circuit to be measured to the INPUT terminals and select the desired range from the six ranges available. The decimal point is positioned by the range pushbutton.

TABLE 2-3
Resistance Ranges

RANGE SETTING	MAXIMUM READING	MAXIMUM OUTPUTS* I(Shorted)	MAXIMUM OUTPUTS* V(Open)	4-WIRE Max. Ω**
200 Ω***	199.999	-4mA	-400mV	7Ω
2k Ω	1.99999	-4mA	-4V	22Ω
20k Ω	19.9999	-400µA	-4V	70Ω
200k Ω	199.999	-40µA	-4V	220Ω
2000k Ω	1999.99	-4µA	-4V	700Ω
20M Ω	19.9999	-.4µA	-4V	2200Ω
		ALL RANGES		
		OVERRANGE: -1-----	MAXIMUM ALLOWABLE INPUT: 360Vpeak, 250Vrms	

* HI binding post (red) is negative.
** Maximum resistance per lead for additional 1 digit error.
*** Zero must be set by NULL to obtain rated accuracy.

c. For 4-terminal measurement connect the sense leads to the circuit to be measured and to the Ω SENSE terminals on the 191. This arrangement eliminates the error due to the voltage drop across the current-carrying leads.

d. Ensure that the NULL pushbutton is out (light off) unless measurements are to be made as deviations from a preset value.

e. For the top five ranges of 2-wire or 4-wire measurements, merely observe the displayed digits and decimal point to make the measurement.

f. For a 2-wire or 4-wire ohms measurement on the 200Ω range, ZERO must be set with the NULL function to obtain rated accuracy. Zeroing is necessary to compensate for test lead resistance On 2-wire & Thermal Emfs on 2 & 4-wire. Set zero as follows:

1) Disconnect the test leads at the circuit to be measured, and short them.

2) Depress NULL pushbutton.

3) Reconnect the test leads and make the measurement.

g. Diode Test. The 2KΩ range is recommended for diode testing. On this range the forward on resistance of a silicon diode will read approximately 190Ω. (High Terminal is Negative)

2-27. AC VOLTAGE MEASUREMENT (WITH 1910 AC OPTION).

2-28. With the Model 1910 option, the Model 191 reads ac voltages from 10 microvolts/digit to 1000 volts. The instrument is average responding and displays the root mean square value of a sine wave with a frequency of 50Hz to 100kHz. Accuracy is specified for 1000 counts and above. The maximum reading is 199999. Overrange is indicated by (-) 1-----, except on 1000 volt range. On the 1000 volt range, the display can read beyond the maximum allowable input voltage. Maximum allowable input: 1000V rms or dc; 2 x 10^7V·Hz. Use the Model 191 to measure ac voltage as follows:

⚠ CAUTION

Do not exceed maximum allowable input voltage. Instrument damage may occur.

a. Turn on power with ON/OFF pushbutton and depress the ACV pushbutton.

b. Select the desired range from the 4 ranges available. The decimal point is positioned by the range pushbutton.

c. Ensure that the NULL pushbutton is out (light off) unless measurements are to be made as deviations from a preset value.

NOTE

Do not use NULL to zero the range. A small residual zero reading is normal (approx. 200μV) If NULL is used to zero this offset, readings in specified accuracy range will be low by the offset amount.

d. Connect the signal to be measured between the INPUT HI and LO binding posts. The binding posts accept wires, spade lugs or banana plugs for ease of connecting the circuit to be measured. Observe the displayed digits and decimal point.

e. The Model 1682 RF Probe can be used with the Model 191 to measure 0.25V to 30V rms ac signals with a frequency 100kHz to 100MHz (and above at reduced accuracy). Refer to Paragraph 2-36.

SECTION 3 PERFORMANCE VERIFICATION.

3-1. GENERAL.

3-2. Performance verification may be performed upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of the instrument's accuracy, and following calibration, if desired.

NOTE

For instruments that are still under warranty (Less than 12 months since date of shipment), if the instrument's performance falls outside specifications at any point, contact your Keithley representative or the factory immediately.

3-3. RECOMMENDED TEST EQUIPMENT.

3-4. Recommended test equipment for performance verification is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy of the alternate test equipment is not at least 3 times better than the instrument specifications, additional allowance must be made in the readings obtained. Some of the equipment listed in Table 3-1 is not 3 times better than the 191 specifications because such equipment is not readily available. In these instances, the verification procedures indicate the equipment manufacturer's specified uncertainty, and include the uncertainty in determining the allowable reading for the Model 191.

3-5. ENVIRONMENTAL CONDITIONS.

3-6. All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F), and a relative humidity of less than 80%.

3-7. PERFORMANCE VERIFICATION PROCEDURE.

3-8. Use the following procedures to verify the basic accuracy of the Model 191 DMM for dc voltage, resistance and ac voltage (with Model 1910 AC Voltage Option installed) measurements. If the instrument is out of specification at any point, perform a complete calibration as described in Section 6, unless the instrument is still under warranty, as noted above.

NOTE

Performance verification should be performed by qualified personnel using accurate and reliable test equipment.

3-9. Initial Conditions.

3-10. Before beginning the verification procedure the instrument must meet the following conditions:

a. If the instrument has been subjected to extremes of temperature, allow sufficient time for internal temperatures to reach environmental conditions specified in Paragraph 3-5. Typically, it takes one hour to stabilize a unit that is 10°C (18°F) out of the specified temperature range.

TABLE 3-1.
Recommended Test Equipment For Performance Verification.

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	10V, 100V, 1000V ±0.002% or 20μV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	High Voltage Amplifier (Used with Model 745A)	1000V ±0.04%	H-P	746A
D	Decade Resistor	190Ω, 1.9kΩ,19kΩ, 190kΩ,1.9MΩ, 10MΩ, ±0.01%	ESI	RS725
E	Kelvin-Varley Voltage Divider (Used with Model 343A)	.19V, 1.9V with .2ppm Terminal Linearity	Fluke	720A

b. Turn on the Model 191 and allow it to warm up for one hour.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

3-11. DC Voltage Accuracy Check (20V to 1200V Ranges).

a. Select dc voltage function.

b. Connect the DC calibrator (Item A, Table 3-1) to the instrument.

c. Select the 20V range, and apply positive 10V dc to the DMM. The reading must be within the limits specified in Table 3-2.

d. Select each remaining range and apply required voltage specified in Table 3-2. Verify that the reading is within specifications.

e. Repeat all checks with negative voltage.

TABLE 3-2.
DC Voltage Performance Check (20V to 1200V Range).

Range	Applied Voltage	Allowable Readings at 18° to 28°C
20V	10.000V	9.9986 to 10.0014
200V	100.000V	99.986 to 100.014
1200V	1000.00V	999.86 to 1000.14

3-12. DC Voltage Accuracy Check (200mV and 2V Ranges).

a. Select DCV and 200mV range.

b. Disconnect test leads at the DC calibrator (A) and short them. Depress the Model 191 NULL button. Verify a display indication of 00.000mV ±0.001mV flashing.

c. Connect the DC calibrator (A), Kelvin-Varley Voltage Divider (E) and Model 191 as shown in Figure 3-1. Set the voltage divider (E) for .0190000 output.

d. Temporarily disconnect the test leads from the DC calibrator (A) and short them. Depress Model 191 NULL button for a display indication of 00.000 ±00.001mV flashing.

e. Reconnect the DC calibrator (A) and set to an output of +10.00000V.

f. Verify that the Model 191 reading is between +189.978 to +190.022mV. Note that the allowable reading includes a 6 digit allowance for the uncertainty of the DC calibrator (A) and Voltage Divider (E).

g. Repeat step d thru f with negative voltage.

h. Select the 2V range and release the NULL button. Set the Kelvin-Varley Voltage Divider (E) to .190000 output.

i. Verify that the Model 191 reading is between +1.89981 and +1.90019V. Note that the allowable reading includes ±4 digits for DC calibrator (A) uncertainty.

j. Repeat step i with negative voltage.

3-13. AC Voltage Accuracy Check (With Model 1910 AC Voltage Option Installed).

a. Select ac voltage function.

b. Connect the AC calibrator (Item B, Table 3-1) to the DMM. Set the calibrator frequency to 1kHz.

c. Set the DMM to the 2V range and apply 1V ac to the DMM. The reading must be within the limits specified in Table 3-3.

d. Select the 20 and 200 volt ranges and apply the required voltages as specified in Table 3-3. Verify that the readings are within specifications.

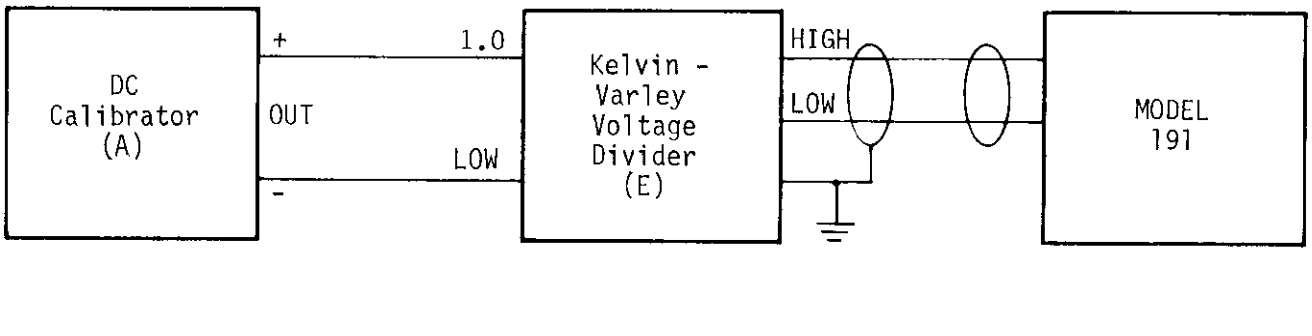


FIGURE 3-1. Test Circuit For 200mV And 2V Accuracy Check.

e. *To check the 1000 volt range, connect the* High Voltage Amplifier (Item C, Table 3-1) to the output of the AC calibrator per the manufacturer's instructions. Connect the amplifier output to the Model 191 INPUT terminals. Set the AC calibrator for amplifier output of 1000.00 volts at 1kHz. Verify that the DMM reading is within the specified limits in Table 3-3.

TABLE 3-3.
AC Voltage Accuracy Check

Range	Applied Voltage	Allowable Readings at 18° to 28°C
	at 1kHz	
2V	1.000V	.99868 to 1.00132V
20V	10.000V	9.9868 to 10.0132V
200V	100.00V	99.868 to 100.132V
1000V	1000.0V	998.00 to 1002.00V
	at 50Hz	
20V	10.000V	9.9868 to 10.0132V
	at 20kHz	
20V	10.000V	9.9868 to 10.0132V
	at 100kHz	
20V	10.000V	9.90 to 10.10

f. *To check accuracy at 50Hz, 20kHz, and 100kHz,* select the 20 volt range, apply the voltage specified in Table 3-3 at 50Hz, then repeat at 20kHz and 100kHz. Verify that the DMM readings are within the specified limits.

3-14. Resistance (Ω) Accuracy Check.

a. Select resistance function by depressing the Ω pushbutton.

b. Select 200Ω range.

c. Connect the decade resistor (Item D, Table 3-1) to the DMM.

d. Set the decade resistor to zero and compensate for lead resistance by depressing the NULL for a display indication of 00.000 ± 00.001 flashing.

e. Set the decade resistor to 190Ω. Verify that the reading for the 200Ω range is within the limits specified in Table 3-4.

f. Select the 2kΩ range.

g. Set the decade resistor to zero and reset the NULL.

h. Set the decade resistor to 1.900kΩ. Verify that the reading is within the limits specified *in Table 3-4.*

i. Continue by using the NULL to eliminate lead resistance on each range and measure the next resistance as specified in Table 3-4. Test each item in the table and verify that each reading is within specifications.

TABLE 3-4.
Resistance Accuracy Check.

RANGE	RESISTANCE	ALLOWABLE READING AT 18° to 28°C	*
200Ω	190Ω	189.955 to 190.045Ω	±19 digits
2kΩ	1.900 kΩ	1.89956 to 1.90044 kΩ	±19 digits
20kΩ	19.00 kΩ	18.9956 to 19.0044 kΩ	±19 digits
200kΩ	190.00 kΩ	189.956 to 190.044 kΩ	±19 digits
2000kΩ	1900.0 kΩ	1899.22 to 1900.78 kΩ	±19 digits
20MΩ	10.000 MΩ	9.9908 to 10.0092 MΩ	±10 digits

* *Manufacturer's specified uncertainty of the decade resistor (D) in digits.* This uncertainty has been added to the specified accuracy of the Model 191 to obtain the allowable reading.

SECTION 4. ACCESSORIES

4-1. GENERAL.

4-2. This section describes the various accessories and options available for use with the Model 191 DMM.

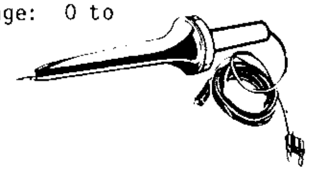
4-3. LINE POWER OPTION.

4-4. The Model 191 can be powered by a line voltage of 90 - 110V, 50 - 60Hz with the special factory installed transformer option. This option is available by ordering a Model 191 DMM (90 - 110V, 50 - 60Hz).

4-5. MODEL 1600 HIGH VOLTAGE PROBE.

4-6. The Model 1600 extends the DMM to 40kV. It has a 1000:1 division ratio which means that 1 volt on the DMM corresponds to 1 kilovolt.

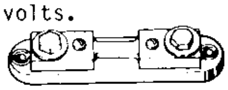
To Operate: Set the DMM to DCV and 200 Volt range. Connect the banana plug on the Model 1600 to the **INPUT** terminals. Connect the alligator clip on the Model 1600 to source low. Connect the probe tip to source high.



Specifications: Voltage Range: 0 to 40,000 volts DC.
Input Resistance: 1000 megohms.
Division Ratio: 1000:1.
Ratio Accuracy
±1.5% at 25kV, decreasing to
±2.0% at 20kV and 30kV
±3.0% at 10kV and 40kV, and
±4.0% at 1kV.
Ratio Stability: ±0.01% per °C; ±0.1% per year.
Heating Effects: Self-heating due to application of high voltage for period in excess of 1 minute will cause a maximum of 0.2% additional error at 40kV (error is less at lower voltage).

4-7. MODEL 1651 50-AMPERE SHUNT

4-8. The Model 1651 allows current measurements to be made from 0 to 50 amperes DC and from 10 to 50 amperes AC with AC Voltage option. It is a 0.001ohm ±1% 4 terminal shunt. A fifty ampere current will correspond to 50 millivolts.



To operate: Connect separate current leads (not furnished) between the source and the Model 1651 hex-head bolts. Use leads that are rated up to 50 ampere capacity. Connect the voltage leads (furnished) between the Model 1651 screw terminals and the DMM **INPUT** terminals. Set the DMM to ACV and 2V range or DCV and 200 millivolt range. Use NULL to zero on DC 200mV.

4-9. MODEL 1681 CLIP-ON TEST LEAD SET.

4-10. The Model 1681 contains two leads 1.2m (48 inches) long, terminated with banana plug and spring-action clip-on probe.

4-11. MODEL 1682 RF PROBE.

4-12. The Model 1682 extends the AC voltage response of the Model 191 from 100kHz to 100MHz.

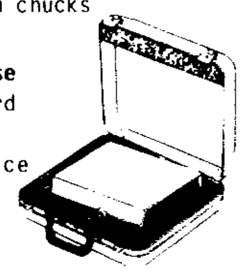
To Operate: Set the DMM to **DCV** and 200 Volt range. Connect the Model 1682 to the DMM **INPUT** terminals.

Specifications:
Voltage Range: 0.25 to 30 volts rms.
Transfer Accuracy: ±0.5dB, 100kHz to 100MHz peak responding calibrated in rms of a sinewave.
Input Impedance: 4 megohm shunted by 3pF.
Maximum Allowable Input: 30V rms AC, 200V DC.
Accessories Supplied: straight tip, hook tip, ground clip, hi adapter, banana plug adapter.

4-13. MODEL 1683 UNIVERSAL TEST LEAD KIT.

4-14. Two test leads, 1.2m (48 inches) long with 12 screw-in tips - 2 banana plugs, 2 spade lugs, 2 alligator clips with boots, 2 needle tips with chucks and 4 heavy duty tip plugs.

4-15. Model 1684 Carrying Case



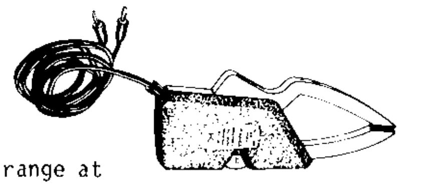
4-16. The Model 1684 is a hard vinyl case with a fitted foam insert with room for the Service Manual and small accessories.

4-17. MODEL 1685 CLAMP-ON AC CURRENT PROBE.

4-18. The Model 1685 measures AC current by clamping onto a single conductor. Interruption of the current path is unnecessary. The Model 1685 detects current by sensing magnetic field produced by current.

To Operate: Set the DMM to **ACV** and 20 volt range. Connect the Model 1685 to the DMM

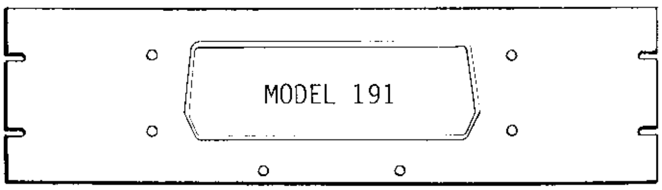
INPUT terminals. The DMM will display 0.1 volts per ampere.



Specifications:
Range: 2, 20 and 200 amperes rms.
Accuracy: ±4% of range at 60Hz. ±6% of range at 50Hz.
Temperature Coefficient: ±0.05%/°C on the 20 and 200 ampere range. ±0.3%/°C on the 2 ampere range.
Maximum Allowable Current: 300 amperes rms.
Maximum Conductor Voltage: 600 volts rms.
Conversion Ratio: 0.1 volt rms per ampere.

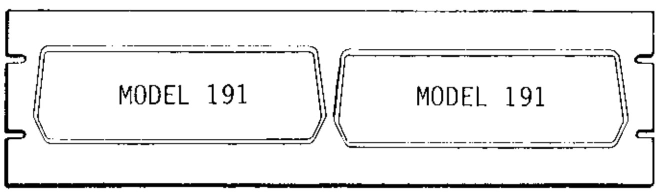
4-19. MODEL 1010 SINGLE RACK MOUNTING KIT.

4-20. The Model 1010 is a single rack mounting kit with overall dimensions 5-1/4 inches (133mm) high and 19 inches (483mm) wide.



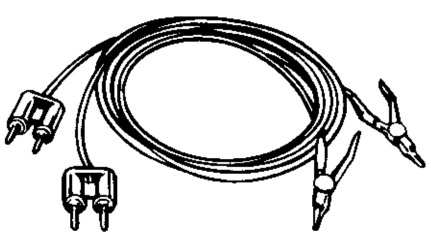
4-21. MODEL 1017 DUAL RACK MOUNTING KIT.

4-22. The Model 1017 is a single/dual mounting kit with overall dimensions 5-1/4 inches (133mm) high and 19 inches (483mm) wide.



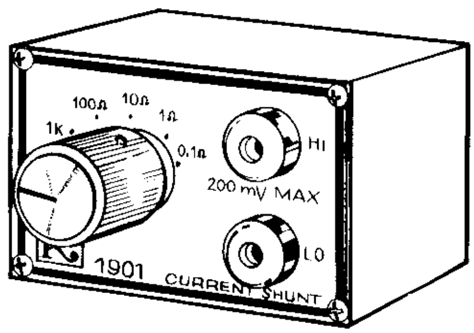
4-23. MODEL 1641 KELVIN TEST LEAD SET.

4-24. The Model 1641 test leads are for use in making 4-terminal measurements. The test leads (1 pair) are 1.2m (48 inches) long twin-lead cables. Each cable is terminated by a twin-banana plug and a spring-clip Kelvin contact. Plug twin banana plug into DMM horizontally (HI to HI and LO to LO).



4-25. MODEL 1901 CURRENT ADAPTER.

4-26. The Model 1901 allows your DMM to read dc current from 1nA/digit to 2000mA. With the 1910 AC Voltage Option it reads from 10nA/digit to 2000mA. The Model 1901 plugs into the INPUT terminals of the 191. Maximum allowable continuous voltage drop (full scale input voltage burden) is 200mV. Shunt resistors are connected so as to eliminate contact resistance errors. Use the Model 191 200mV dc range and 2V ac range, for dc current and ac current respectively. Input voltage burden can be reduced by selecting the lowest shunt that provides the necessary resolution.



4-27. MODEL 1910 AC VOLTAGE OPTION.

4-28. The Model 1910 (not shown) is a factory or field installable option which allows your DMM to read ac volts from 10µV/digit to 1000V. The Model 1910 is internally installed in the Model 191. It is important to note that field installation or removal/replacement of the Model 1910 requires recalibration of ac voltage. Specifications for the 1910 are given in Table 1-1 and ac voltage measurements are described in Paragraph 2-27.

4-29. MODEL 1913 CALIBRATION COVER KIT.

4-30. The 1913 (not shown) contains a calibration cover and an Instruction/Service Manual for the Model 191 DMM. The calibration cover is installed in place of the normal 191 top cover during calibration. It allows the 191 to reach normal internal operating temperature and has openings that are marked to facilitate making the calibration adjustment.

SECTION 5. THEORY OF OPERATION

5-1. GENERAL

5-2. This section contains circuit descriptions for the Model 191 DMM and the Model 1910 AC Voltage option. The information is arranged to provide a description of overall instrument operation, followed by descriptions of individual functional circuit blocks. To facilitate understanding, the descriptions are keyed to accompanying simplified block and schematic diagrams. Detailed schematics of the Model 191 and Model 1910 are provided in Section 7.

5-3. OVERALL FUNCTIONAL DESCRIPTION

5-4. The Model 191 is a 5-1/2 digit, ±200,000 count, bench DMM with 5 dc voltage and 6 resistance ranges standard. It has 1μV and 1mΩ sensitivity, and 0.0005% resolution. When the Model 1910 plug-in option is installed, ac voltage from 10μV/digit to 1000 volts can be measured. The most unique feature of the Model 191 is its hybrid Analog-to-Digital converter which uses both charge balance and single slope conversion techniques, and operates under the control of the microcomputer. Very high accuracy, high conversion speeds and quick settling times are some of the major benefits provided by this feature. Other benefits and functions which can be attributed to the use of the microcomputer are: a reduction in the number of component parts; non-linear digital filtering; pushbutton nulling of any on-scale input signal; and automatic 2/4 terminal ohms. These items will be described in more detail later in this section.

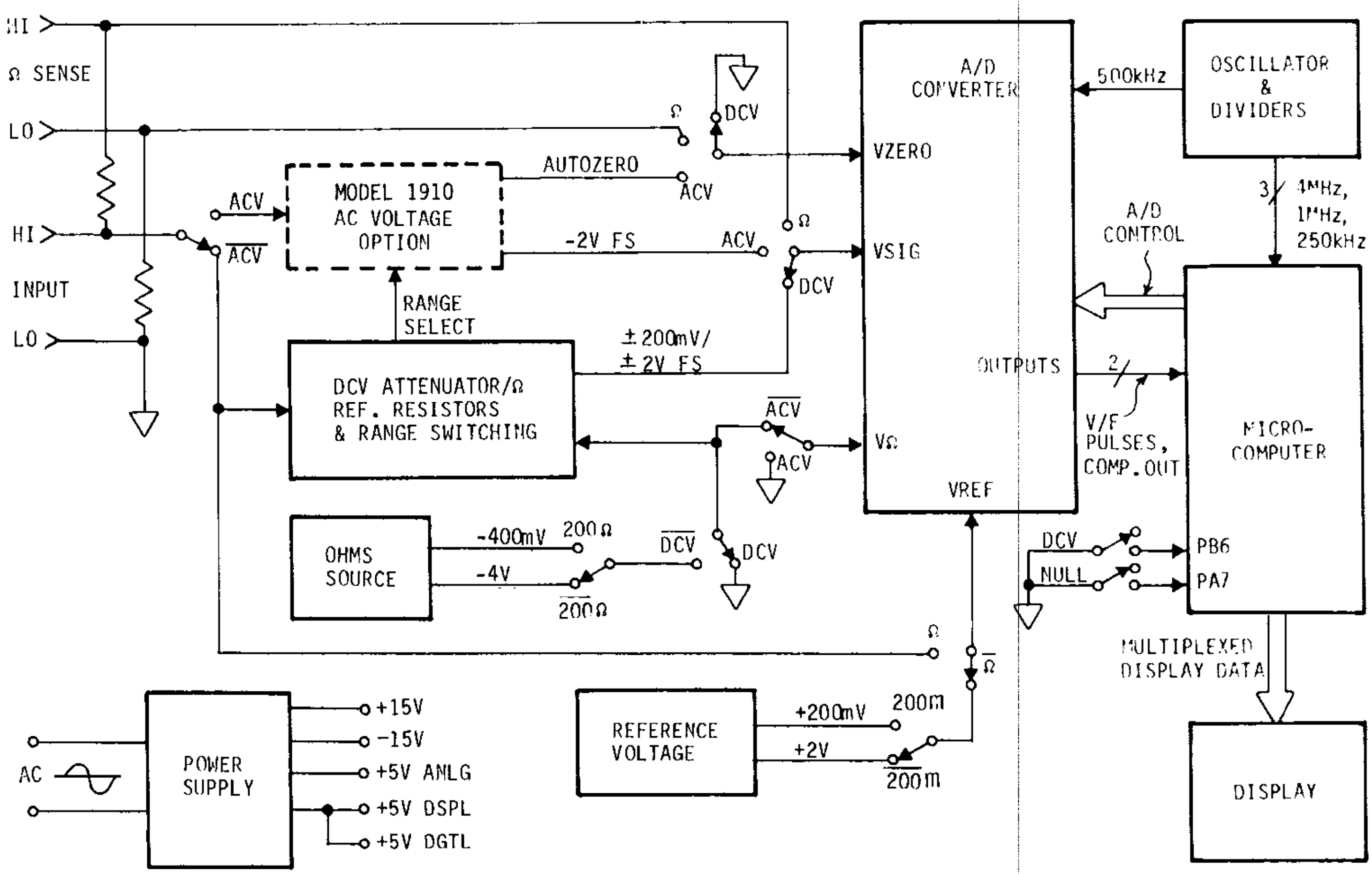


FIGURE 5-1. Simplified Signal Flow Block Diagram, Model 191 DMM.

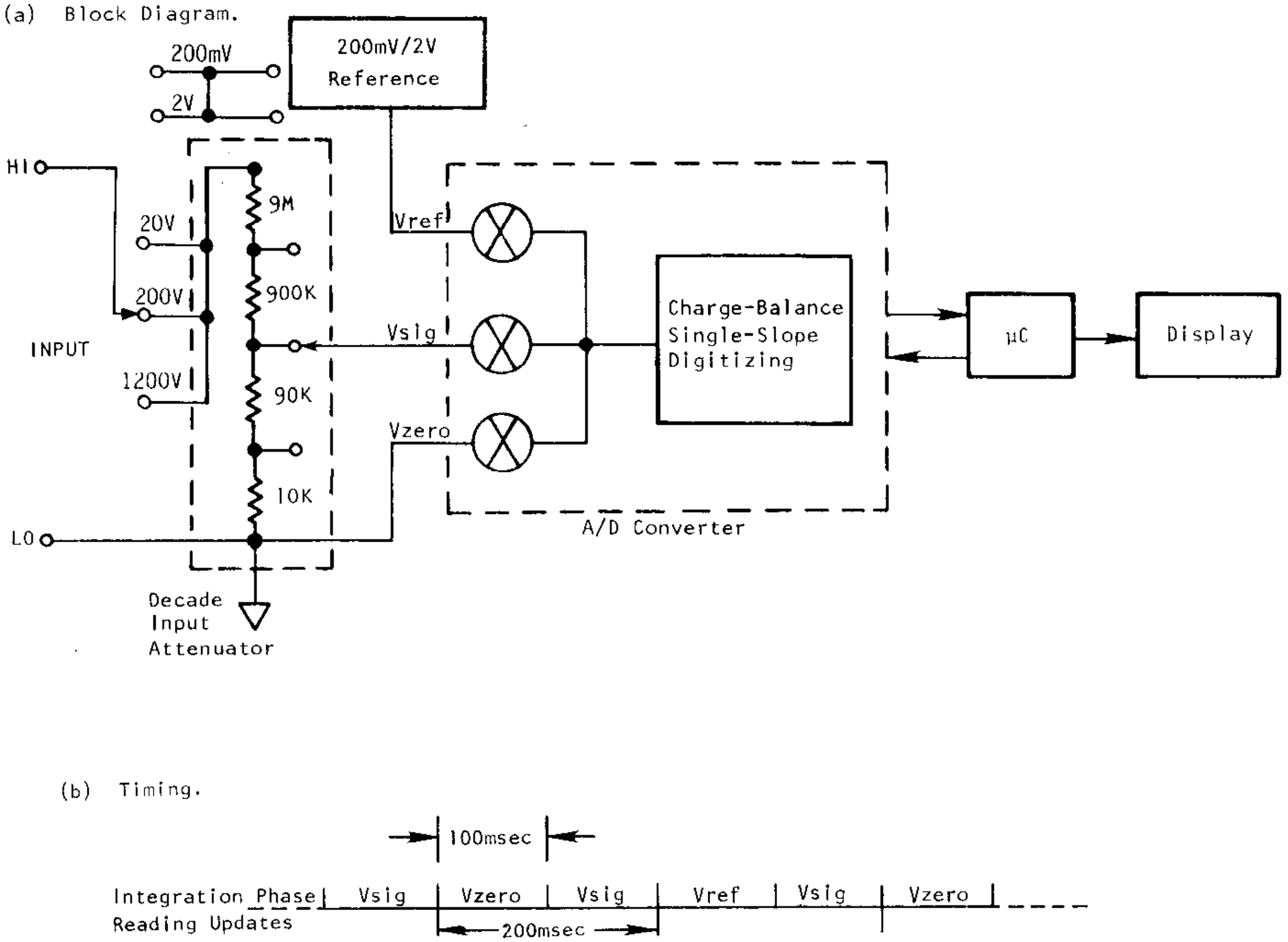


FIGURE 5-2. Block Diagram of DC Voltage Measurements.

5-5. Figure 5-1 provides a simplified signal flow block diagram of the Model 191. As previusly mentioned, operation of the Model 191 is centered around the A/D converter, operating under the control of the microcomputer. The A/D converter is designed to handle input signals up to +2 Vdc, and up to four separate signals (i.e., VZERO, VSIG, VΩ and VREF). It can be seen from the diagram that the function switches control which of the signals that can be applied to the A/D converter, as well as the signal conditioning path of the input signal applied to the input terminals. The microcomputer, through the A/D Control lines, controls the sequence and timing of signals applied to the A/D converter. Timing includes a precise 100 millisecond integration period for the charge balance phase of conversion, up to 1 millisecond for single slope conversion and the necessary delays to allow an input signal to settle and to perform mathematical calculations and housekeeping chores. The microcomputer also provides the automatic zero and automatic calibration corrections to eliminate zero and gain errors from the signal to be displayed. This is done mathematically and requires that more than just VSIG be converted. Three signals are required for dc voltage mesurements, and four signals for ohms and ac volts. Each signal required for the measurement is applied to the A/D converter and the resulting digitized value is stored in memory. The microcomputer uses the stored values to calculate the reading and sends it to the display. In this way, the microcomputer corrects for zero and gain errors, and the displayed reading is the digitized value of the input signal within the specified accuracy of the instrument.

5-6. DC Voltage Measurement.

5-7. In dc volts operation, as shown in Figure 5-2, the input signal either goes directly to the A/D or is connected across a decade attenuator with a total resistance of 10 megohms. The attenuation of the dc input signal is determined by the range selected. As previously mentioned, three input signals to the A/D converter are required for dc volts operation (i.e., VSIG, VZERO and VREF). Each signal is presented to the A/D input and measured for 100 milliseconds (See A/D Converter discussion). Each digitized value is stored in memory and then used to calculate a reading by the formula:

$$V_{DISP} = 2\left(\frac{VSIG-VZERO}{VREF-VZERO}\right)$$

It can be seen that the the zero error is subtracted from both the signal and the reference, and then the ratio is taken. Multiplication by 2 is needed because the reference is 2 volts (or 200 millivolts on the lowest DC range).

5-8. As shown in the timing portion of the diagram, VSIG is measured every other time and VZERO and VREF are alternated in in the other time slots. This permits the display to be updated after every two integration (charge balance) phases. Considering that up to an additional 70 milliseconds may be required (to complete single slope conversions, counting of the remainder in counters and mathematical computations), a new display update can be made approximately every 270 milliseconds, or approximately 4 readings/second can be obtained.

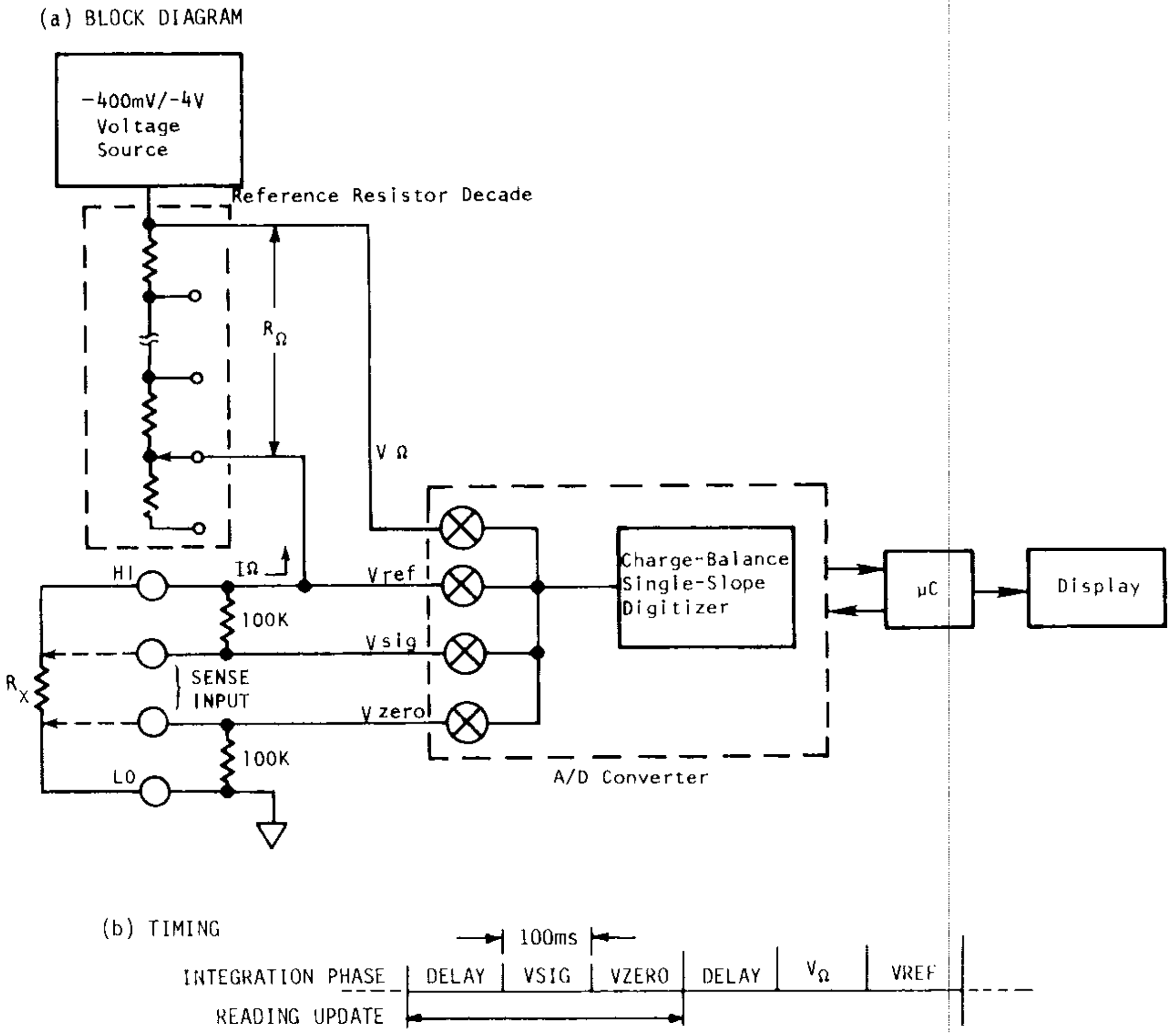


FIGURE 5-3. Block Diagram of Resistance Measurement.

5-9. Resistance Measurement.

5-10. In ohms operation, as shown in Figure 5-3, the ohms voltage source is connected as an input to the A/D converter and to one end of the reference resistor decade. The resistance reference resistors are the same resistors that are use for dc volts attenuation, but unlike dc volts, where only the ratios affect accuracy, the absolute characteristics of the resistors determine accuracy of the ohms measurement. The value of the ohms reference resistor (R_Ω) is determined by the range selected. An ohms source voltage of -400 millivolts is used on the 200Ω range, and -4V is used for all other Ω ranges. For resistance measurements, four input signals to the A/D converter are required. Each signal is measured for 100 milliseconds and its digitized value is stored in memory. The microcomputer then calculates a reading using the formula:

$$\Omega DISP = \frac{VSIG - VZERO}{V\Omega - VREF}$$

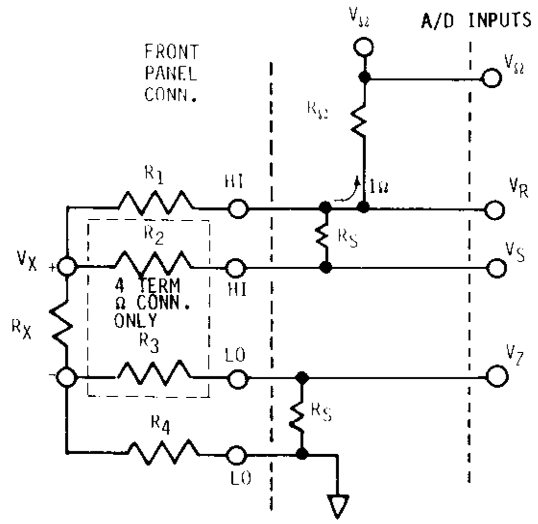
It can be seen that VΩ - VREF is the voltage across RΩ ($I_\Omega \times R_\Omega$) and that VSIG - VZERO is the voltage across R_X ($I_\Omega \times R_X$). therefore:

$$V_X = \frac{I_\Omega R_X}{I_\Omega R_\Omega} = \frac{R_X}{R_\Omega}$$

Thus, the ohms reading depends only on the value of the ohms reference resistor (R_Ω).

5-11. As shown on the timing portion of the diagram, there are two 100 millisecond delays and four 100 millisecond integration periods needed to gather the information for calculating a reading with the above formula. When the additional delay times, as described for DC Measurements, are considered it might appear that approximately 2 seconds would be necessary for three readings. However, in actual operation, approximately three valid readings per second can be obtained by calculating a new reading after each 300 milliseconds, using the new data and the stored data from the previous 300 milliseconds.

5-12. Up to this point in the discussion, the effect of lead resistance on the resistance measurement has not been considered. As shown in Figure 5-4, lead resistance can affect the displayed ohms reading in both 2-terminal or 4-terminal measurements. For this explanation, resistances of the test leads have been designated as R_1 - R_4. If Ω SENSE HI and LO terminals are not connected to R_X, the sensing occurs at the HI LO INPUT terminals through resistors R_S and the displayed reading includes the resistance of R_1 and R_4 added to the unkown (R_X). For 4-terminal measurements, the Ω SENSE leads are connected to R_X and the effect of lead resistance can be calculated as shown. It can be readily seen from this discussion why the stated accuracy for the 200 Ω range requires that the effect of lead resistance be cancelled with the NULL pushbutton for both 2-terminal and 4-terminal measurements.



In 2-terminal: $\Omega = R_1 + R_4 + R_X$.

In 4-terminal: $\Omega = R_X + \frac{R_1 R_2}{R_1+R_2+R_s} + \frac{R_3 R_4}{R_3+R_4+R_s}$

If $R_1 = R_2 = R_3 = R_4$, and $R_1 \ll R_s$,

$$\Omega \; R_X + \frac{2R_1^2}{R_s}$$

Example: $R_1 = 10\Omega = R_2 = R_3 = R_4$, $R_s = 100k\Omega$

$$\therefore \Omega = R_X + \frac{2(10)^2}{10^5} = R_X + 2m\Omega$$

FIGURE 5-4. Affect of Lead Resistance in Ohms Measurements.

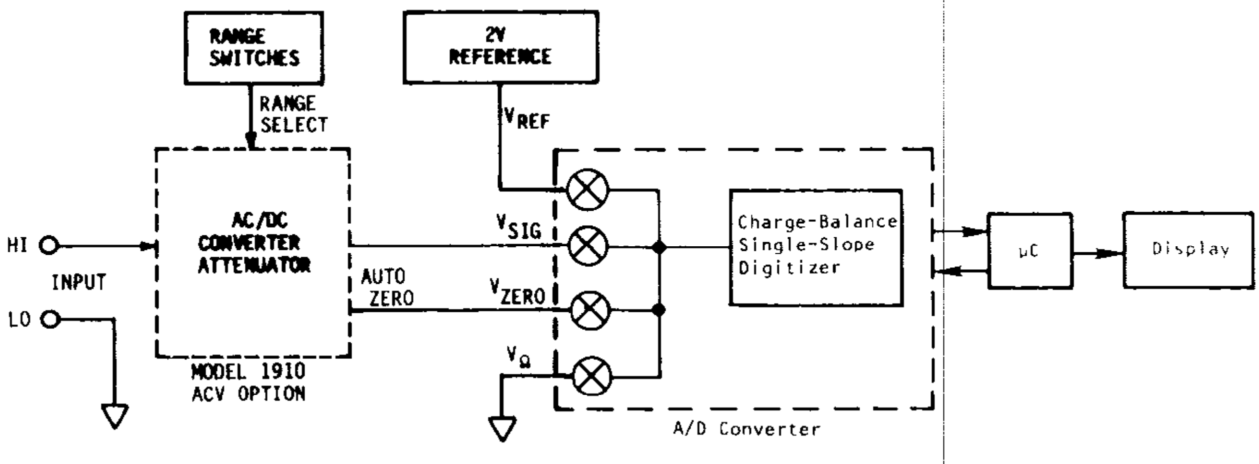


FIGURE 5-5. Block Diagram of AC Voltage Measurements.

5-13. AC Voltage Measurement.

5-14. In ac volts operation, as shown in Figure 5-5, the Model 1910 AC Voltage Option is placed between the input and the A/D converter. The 1910 converts the ac input voltage to a dc voltage between zero and -2 volts. On other than the 2V range, the input signal is divided by 10, 100, or 1000 - depending on the range selected. For ac voltage measurements, four input signals to the A/D converter are required. Each signal is measured for 100 milliseconds and its digitized value is stored in memory. The microcomputer then calculates a reading using the formula:

$$V_{ac} = \frac{2\ (VSIG - VZERO)}{(VREF - V\Omega)}$$

Where VSIG is the 1910 output, VZERO (AUTOZERO line) is its dc offset, VREF is the 2V reference and VΩ is signal ground. The 2 is required because of the 2V reference. Since ac volts is a four phase measurement, with the input signal measured only once during the measurement, the maximum conversion rate for ac volts is two valid readings/second.

5-15. A/D Converter.

5-16. A simplified schematic of the A/D converter is given in Figure 5-6, and its waveform is shown in Figure 5-7. In operation, the microcomputer provides time division multiplexing of the input signals by controlling switches S_1 through S_4. The sequence and timing of the switches is dependent on the function selected (DC Volts, Ohms, or AC Volts). Copper leaded JFETs are used for the input MUX switches to achieve the necessary high off resistance, low leakage current and low thermal characteristics. The Input Buffer is a non-inverting, high Z amplifier that looks at each input signal with either a x1 or x10 gain. A gain of x10 is used on the 200mVDC and 200Ω ranges, all other ranges use x1. The output of the input buffer is applied to the Transconductance Amplifier. This amplifier provides two functions. It converts the input voltage to a current, which goes to the integrator when requested, and provides an offset current so that its bipolar input voltages are converted to unipolar output currents.

5-17. The A/D converter, as shown in Figure 5-7, operates first in a charge balance (CB) phase, and then in a single slope (SS) phase. A 100 millisecond interval was selected to look at each input as the best compromise to achieve good line rejection (50 and 60Hz) and relatively fast conversion speed. A CB phase is begun when INPUT DISABLE goes low. This occurs at the completion of a delay period that allows the signal to settle after turning on the appropriate input MUX switch. The delay is software generated and is dependent on the function selected, as given is Table 5-1. When INPUT DISABLE is released, I_{in} is connected to the integrator, and V_o ramps positive. The D flip flops then act as a comparator, providing timing and control. After V_o exceeds the D threshold of U106A, Q_1 goes high at the next positive going clock edge. At the next clock edge (negative going), Q_2 goes high and connects I_{CB} to the integrator. I_{CB} is greater than $2I_{in}$ maximum, and thus, V_o immediately ramps negative.

$\overline{Q_2}$ is also low at this time which sets and holds Q_1 low. At the next negative clock edge (1 cycle later), I_{CB} is turned off and D_1 is enabled by Q_2 going low again. What has happened to this point is that I_{CB} was turned on for one clock

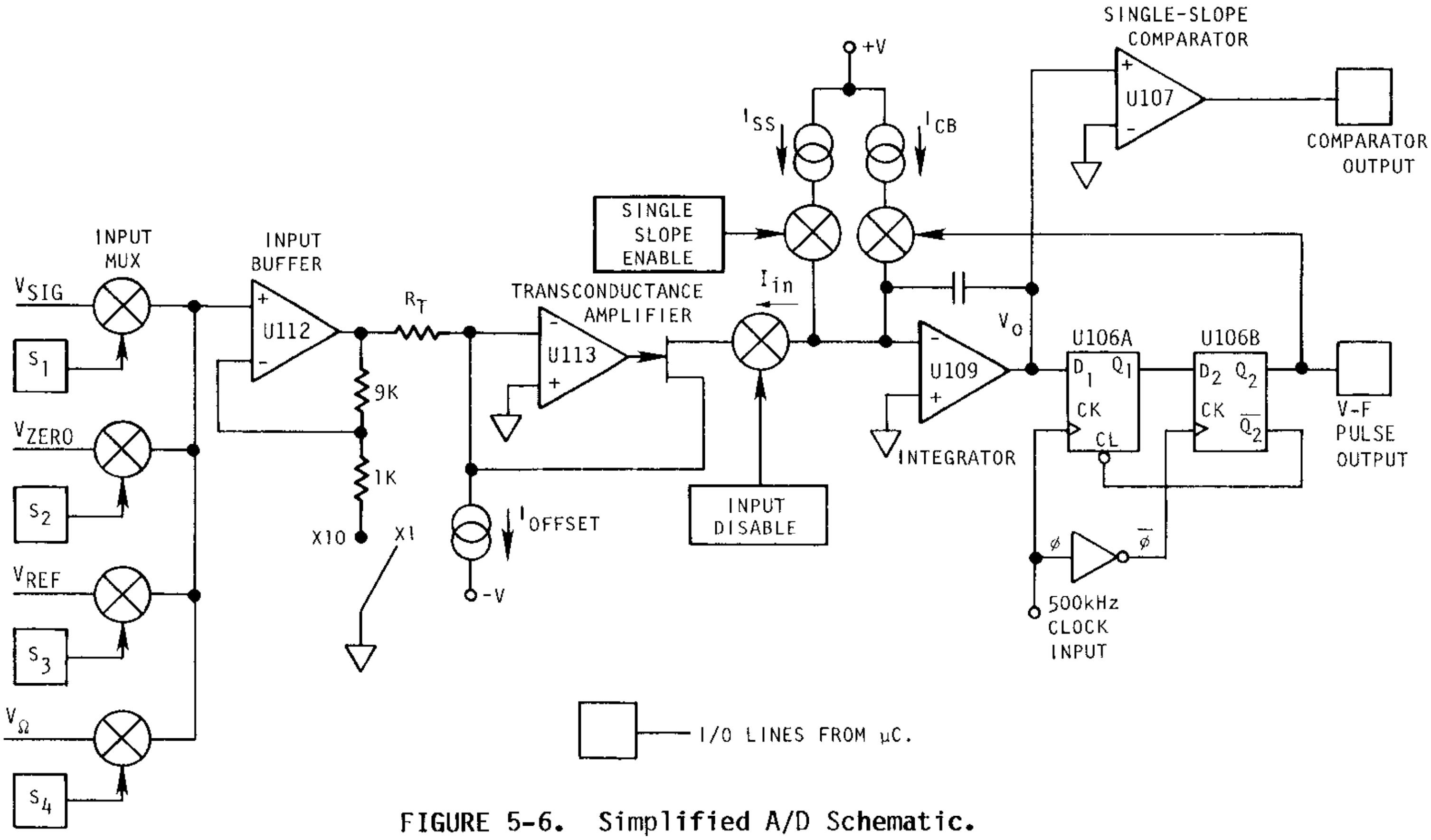


FIGURE 5-6. Simplified A/D Schematic.

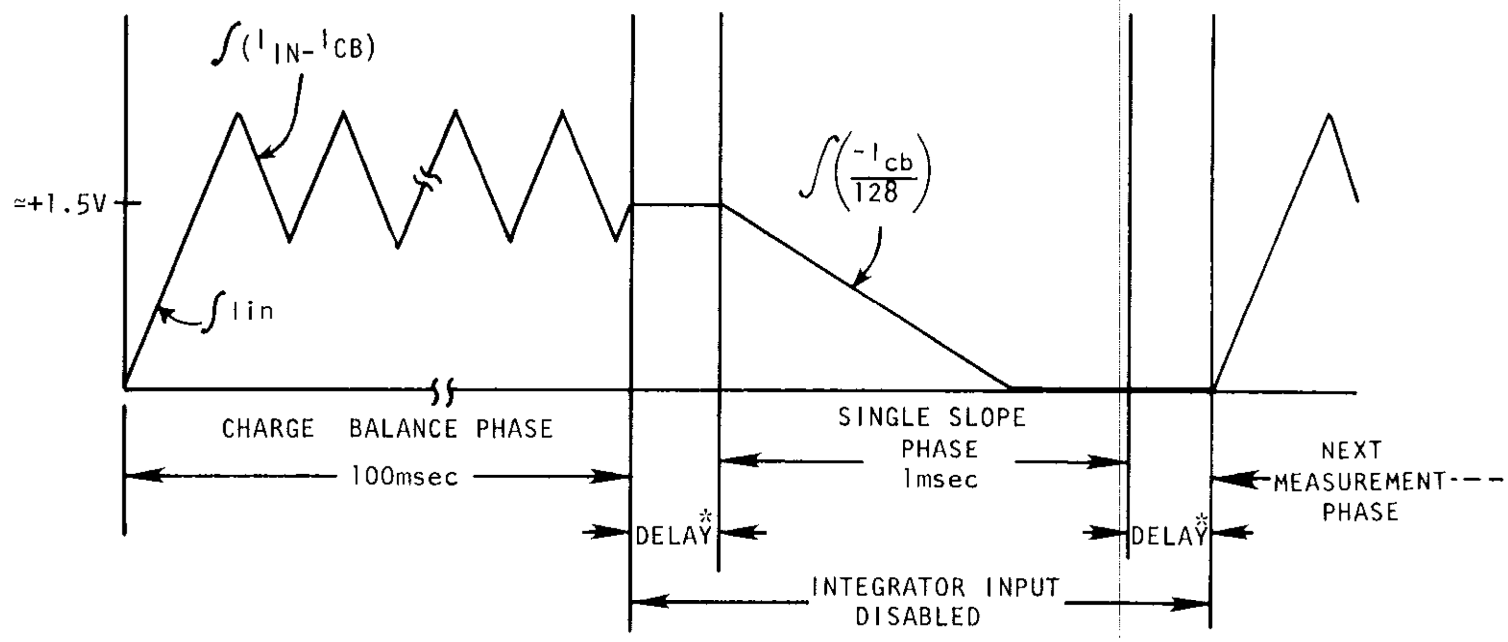
cycle (2 microseconds) and then turned off. The earliest it can be turned on again is one clock cycle later. Each time I_{CB} is turned on, a counter is incremented by an inverted V-F PULSE from Q_2. It can be seen that the flip flops divide the clock frequency by two, limiting the maximum number of charge balance integrations and output counts to one half of the clock frequency. And, since 50,000 clock cycles occur in the precise 100 millisecond charge balance period, the maximum number of times that Q_2 can go high and be counted is 25,000.

5-18. At the end of the charge balance phase, the output of the integrator is resting at some positive voltage. The single-slope comparator output is also positive and it will not switch until the integrator output crosses zero. The comparator output is ANDed with a one millisecond pulse in the digital section to produce SINGLE SLOPE ENABLE. This allows I_{SS} to flow into the integrator. A 1MHz clock is counted from the time SINGLE SLOPE ENABLE went high until the single-slope comparator changes state (V_o crosses zero). When this occurs, I_{SS} is shut off and the counting is stopped. The amount of charge delivered by I_{SS} in one microsecond (1MHz period) is equal to 1/256 of the charge delivered by I_{CB} in two microseconds. The microcomputer multiplies the CB counts by 256 and adds the SS counts to it to obtain the composite count ($\leq$6.4 million maximum).

TABLE 5-1

Settling Delays, $S^{(n)}$ on to Turn On of Integrator.

JFET SWITCH	Delays (msecs) DCV	ACV	Ω
S1	30	30	100
S2	1	1	1
S3	1	1	100
S4	X	1	1



*FOR READOUT OF µP PRE-SCALE COUNTER

FIGURE 5-7. 191 A/D Waveform.

5-19. DIGITAL CONTROL and DISPLAY CIRCUITS.

5-20. A functional block diagram of the digital control and display circuitry is given in Figure 5-8. This diagram also shows location of the circuits by printed circuit board.

5-21. Microcomputer.

5-22. The microcomputer and its associated logic circuitry provide timing and control of both the display and the A/D converter. Additional functions provided by the microcomputer include the NULL function and digital filtering. The Null function is described in Paragraph 2-15 and digital filtering is described later in this section. Count prescaling, and recovery from a transient or lost program are additional functions provided by the logic circuitry.

5-23. The microcomputer is a MicroBus® based system that is comprised of a 6802 microprocessor (U302), a 6821 peripheral interface adapter (PIA, U303), and 1024 x 8 bytes of read only memory which provides the control program and is contained on either U305 (ROM) or U304 and U305 (PROMs). The microprocessor contains a set of 72 variable length instructions, and 128 x 8 bytes of random access memory (RAM) for temporary storage. The PIA contains four bytes of memory and provides the Input/Output (I/O) control lines for interfacing the microcomputer to the other circuits in the 191. The microcomputer uses partial memory decoding. When A15 is a logic "0", either the 128 bytes of RAM or bytes 129 through 132 in the PIA are selected. A7 then determines which is selected (A7 = logic "0" RAM, logic "1" PIA). When A15 is a logic "1" (high), read only memory is selected (ROM/PROMs), and A9 determines whether the lower 512 bytes or the upper 512 bytes are selected. When A9 is high, the upper 512 bytes are selected.

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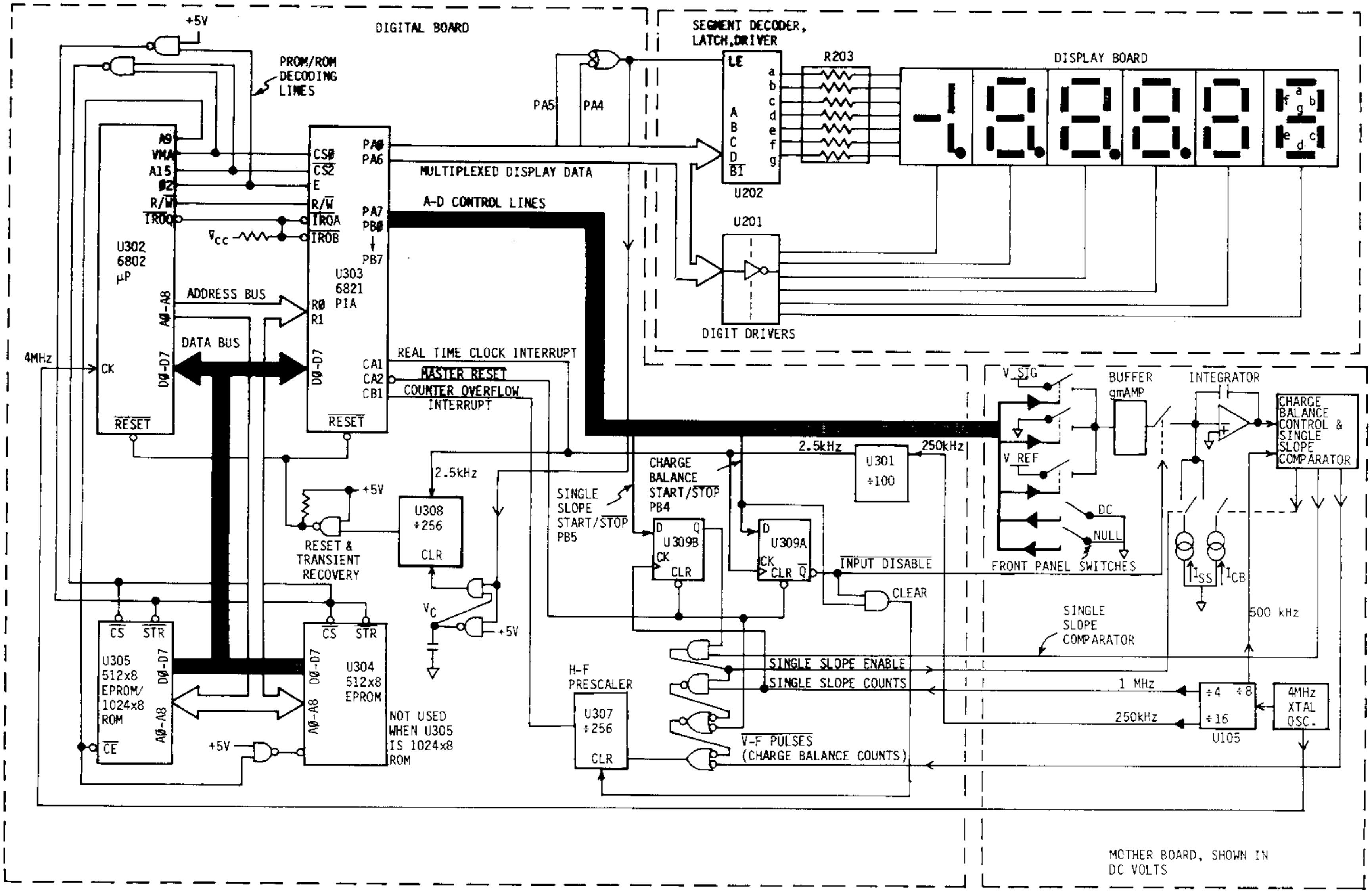


FIGURE 5-8. Functional Block Diagram of Digital Control and Display Circuit.

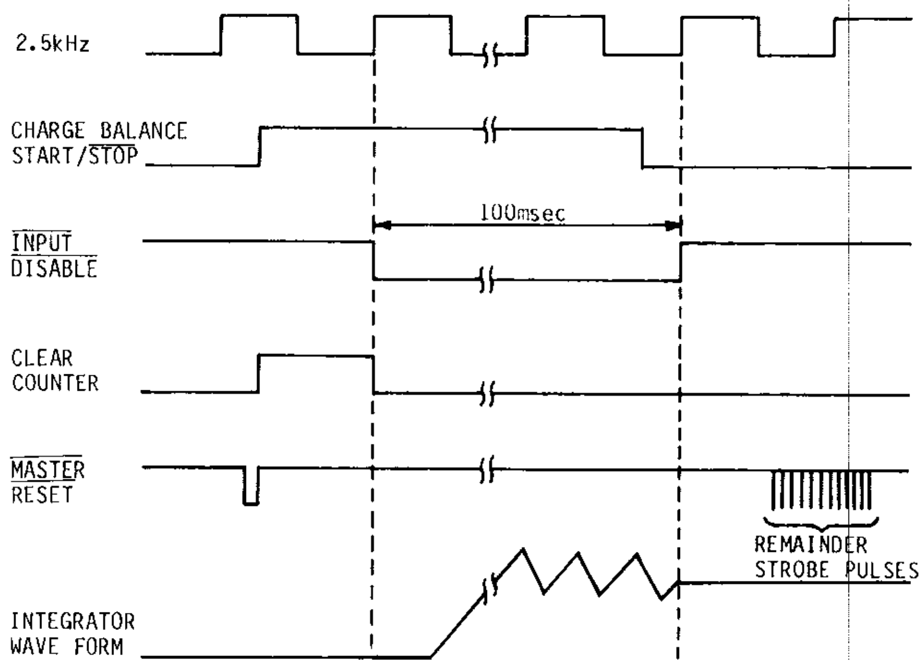


FIGURE 5-9. Charge Balance Timing.

5-24. A/D Converter Control.

5-25. Looking at the A/D Controls Lines on Figure 5-8, a logic "0" on PA7 indicates that the NULL function is selected and a logic "1" on PB7 indicates that the instrument is in DC volts. These signals are from the front panel NULL and DCV push-buttons, respectively. If not in DC volts mode, the processor determines whether AC volts or Ohms has been selected by looking at the value of the reference voltage after it has been digitized.

5-26. Refer to Figure 5-8 and the timing diagram in Figure 5-9 for the following discussion. A Charge-Balance phase begins with the MASTER RESET line pulsing low, clearing U309A and B flip flops. As described in the A/D converter discussion, the appropriate signal to its input amplifiers is then enabled by S1, S2, S3 or S4 going to a logic "1". After the completion of the appropriate delay period given in Table 5-1, the "D" input to U309A is made a "1". This same signal is ANDed at this time to clear the H-F PRescaling counter U307. The next rising edge of the 2.5kHz clock sets the Q output of U309A low, enabling the input signal to the integrator of the A/D. The processor now counts 250 interrupts from the 25kHz clock, and then sets the "D" input to U309A to a "0". The next rising edge of the clock sets INPUT DISABLE high again, disabling the input to the integrator, and ending the exact 100 millisecond integration period.

5-27. During the integration period above, V-F PULSES are fed into counter U307. Each time the counter overflows (after 256 counts) an interrupt is generated which the processor counts in an internal register. These interrupt counts become the 8 most significant bits of the result.

5-28. At the end of the charge-balance phase, 8 bits of data are left on counter U307. This data is obtained by pulsing the MASTER RESET line into the counter, and waiting for the counter to overflow. The number left on the counter is equal to 256 minus the the number of MASTER RESET pulses. This data becomes the middle 8 bits of the 24 bit result.

5-29. At the completion of remainder counting, the Single-Slope phase is begun by the SINGLE SLOPE

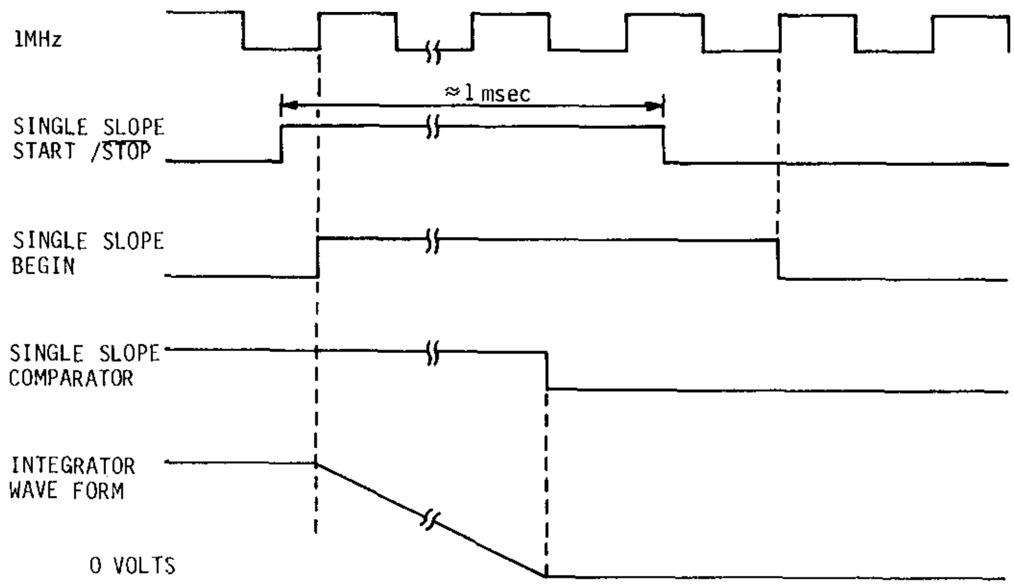


FIGURE 5-10. Single Slope Timing.

START/$\overline{STOP}$ signal going high, setting the "D" input of U309B to a "1". On the next rising edge of the 1MHz clock, the SINGLE SLOPE BEGIN signal from Q of U309B goes high, and is ANDed with the COMPARATOR OUTPUT signal to enable single-slope counting. The 1MHz clock is now fed to U307, and counted similar to the charge balance phase. The single-slope phase ends when COMPARATOR OUTPUT goes low, and gates off the 1MHz clock to the counter. The remainder left in the counter is again read, as in the charge-balance phase. This result is added to the charge-balance counts to generate the 24 bit (22 bit maximum) result. Timing for the single-slope phase is shown in Figure 5-10.

5-30. Display.

5-31. The display circuits, as shown in Figure 5-8, consist of the LED digits, and the necessary decoding and driver circuits. These operate under the control of the microcomputer. The diagram shows the possible location of the decimal points, but they are controlled by the range switching which is not shown.

5-32. Display information is fed out on lines PAØ through PA6 of the PIA I/O bus. It is updated at a 2.5kHz rate, with each digit on for approximately 400 microseconds. Since the display is fully multiplexed, 6 updates are required to turn each of the six digits of the display on once. This means that the entire display is updated 416 times a second. An update begins by blanking the display and disab-

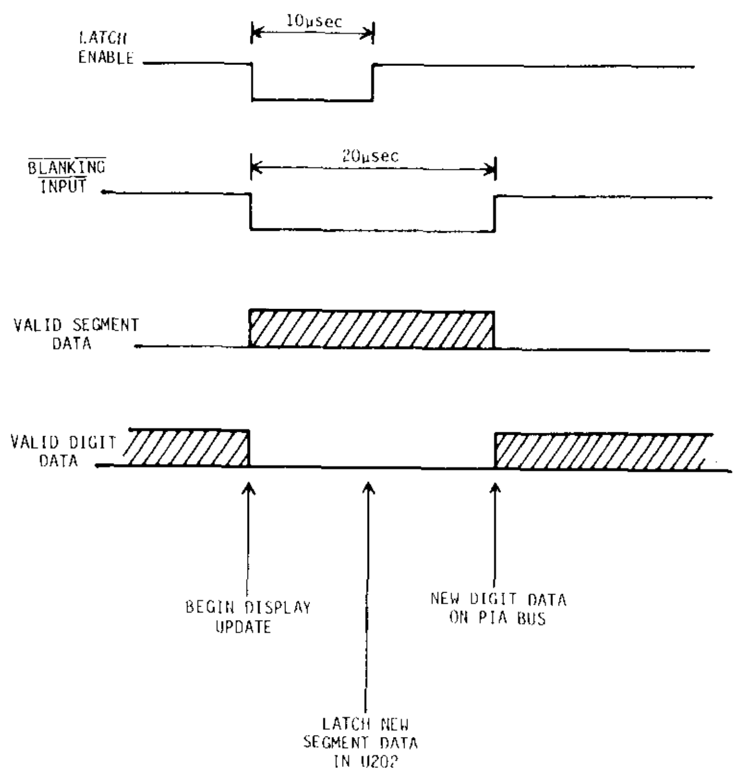


FIGURE 5-11. Display Timing.

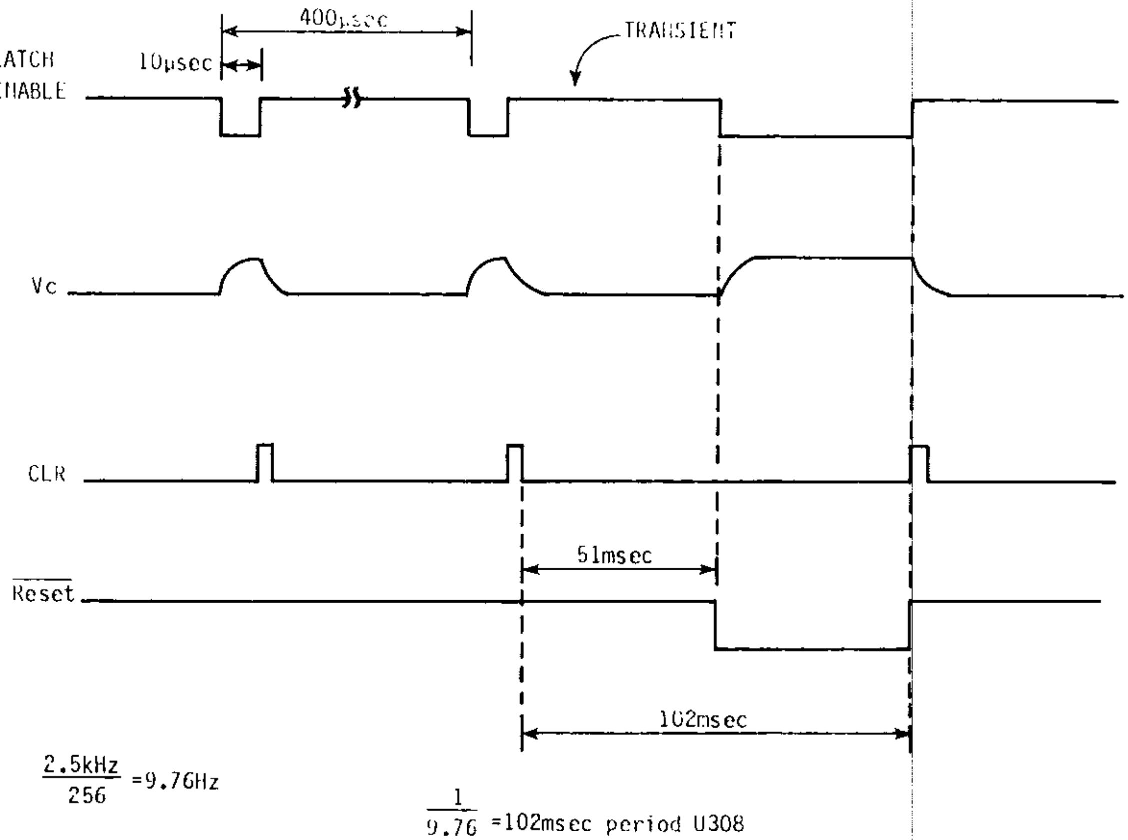


FIGURE 5-12. Reset and Transient Recovery Circuit Timing.

ling the latch of U202. The display is blanked by PA6 pulsing to a logic "0" for 20 microseconds, and the latch is disabled by pulsing PA4 and PA5 to a "1" for 10 microseconds. New segment data is now presented on lines PAØ through PA3, and this data is latched into U202 when PA4 and PA5 return low after the 10 microsecond period. At the completion of the 20 microsecond period, the display is unblanked, while new digit information is on the PIA bus. This results in the correct digit for the latched segment data being turned on until the beginning of the next update. Display timing is shown in Figure 5-11.

5-33. Reset and Transient Recovery Circuit.

5-34. The reset and transient recovery circuit is shown below the PIA on Figure 5-8. It consists of two NAND gates, an AND gate, a 6800pF capacitor and counter U308 which divides by 256. Its function is to restart the system by resetting the Microprocessor and PIA whenever either the program is lost or a long duration transient occurs.

5-35. Timing of this circuit is shown in Figure 5-12. The circuit has two input signals, the 2.5kHz clock and LATCH ENABLE. The 2.5kHz clock is counted by U308 and LATCH ENABLE is used to clear U308. In normal operation, LATCH ENABLE pulses low for 10 microseconds every 400 microseconds (2.5kHz rate), as described in the Display discussion. While LATCH ENABLE is low, the voltage on the capacitor (Vc) rises exponentially. When LATCH ENABLE returns high, and while Vc is above the threshold of the AND gate, a clear pulse is applied to U308. Thus, normally U308 accumulates one count and is then cleared. A transient can mask the LATCH ENABLE pulses or a lost program can prevent their appearance at all. If no pulses appear for 51 milliseconds, 128 counts from the 2.5kHz clock will accumulate in U308 and its output will go high. This high is NANDed with +5 volts to clear the microprocessor and PIA. Coincidently, LATCH ENABLE is forced low and Vc begins to rise to its maximum. U308 continues to count the 2.5kHz clock and when it overflows after 256 counts, its ouput returns low. This removes the RESET and allows the microprocessor to return to the proper location in the control program. This completes the recovery process.

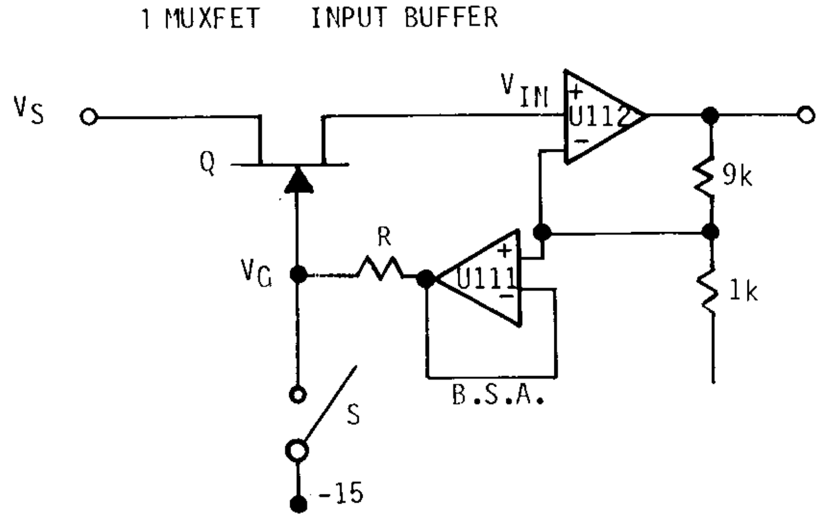


FIGURE 5-13. Turning on JFET Switches.

5-36. Digital Filtering.

5-37. When the 200mV or 200 Ohm range is selected, a logic "0" is applied to PB7 of the PIA, which tells the microprocessor to filter by averaging the last 8 readings. For this condition, the last 8 readings are averaged together and displayed, as long as the latest conversion is within digits of the previous diplay. If the new conversion is more than + digits away from the previous reading, the new reading is displayed. Thus, speed is attained for large signal changes, but random noise is reduced by a factor of 8. For all other ranges, the microprocessor uses a threshold of ±5 digits and averages the last 4 readings. Thus, smaller signal changes are responded to, while random noise is reduced by a factor of 4.

5-38. Oscillator and Clock Divider.

5-39. These circuits are shown in block diagram form in the lower right corner of Figure 5-8, and the complete circuits are shown on page 2 of Schematic 30162D. Basically, the 4MHz crystal control oscillator is a Pierce type oscillator. Its 4MHz output is fed direct to the clock divider (U105), and it is buffered by a CMOS inverter before application to the microprocessor (U302). U105 provides three outputs by dividing 4MHz by 4, 8 and 16. Its outputs are buffered by CMOS inverters to provide zero to +4 volt square waves. The 1MHz output is used for Single-Slope counting, 500kHz is used in the A/D converter for Charge-Balance timing, and 250kHz is divided by 100 in U301 to produce the 2.5kHz clock.

5-40. A/D CONVERTER CIRCUITS

5-41. The A/D converter must have a high input impedance and be linear to within a few parts per million over the + 2 volt operating range. To meet this critera, several innovative circuits had to be designed. These circuits are described in the following paragraphs.

5-42. Input Buffer.

5-43. The input buffer is a non-inverting, high input impedance amplifier which looks at each input with either x10 or x1 gain. Its input signals are multiplexed by switches S1 through S4 under the control of the microcomputer. One of the first problems encountered was the high transients that appear as the multiplexing switches are turned on. The effects of these transients were eliminated by the use of software generated delays. It was, however, necessary to drive the gate of the appropriate JFET with the input signal voltage to turn it on. This was accomplished with a bootstrap amplifier (BSA) connected to the inverting terminal of the input buffer (see Figure 5-13). When switch S is opened, the gate of Q rises to the output of BSA which equals the input voltage (V_{IN}). This turns Q on, which means that $V_{IN} = V_S = V_G$. Note that this technique works regardless of input buffer gain.

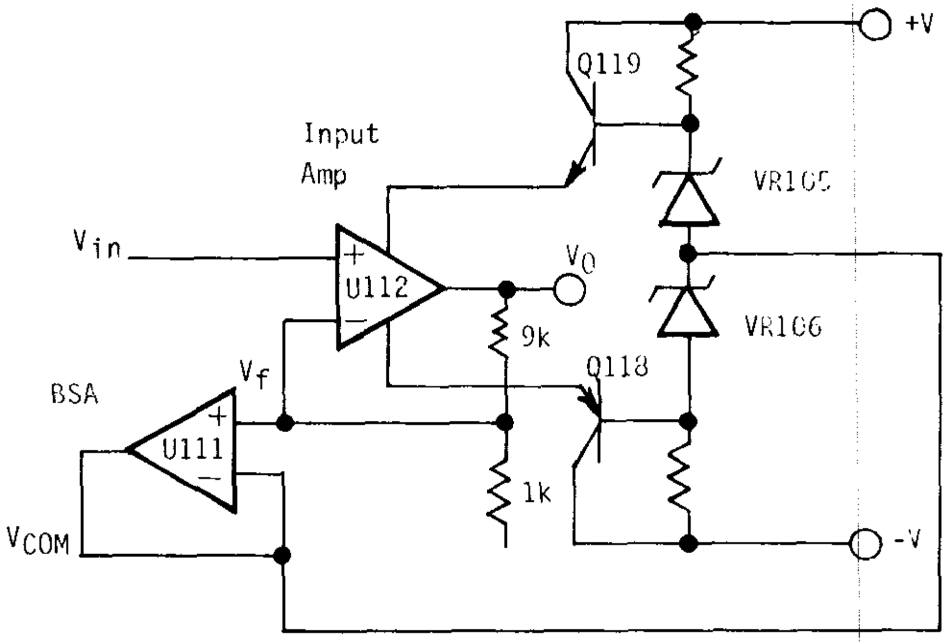
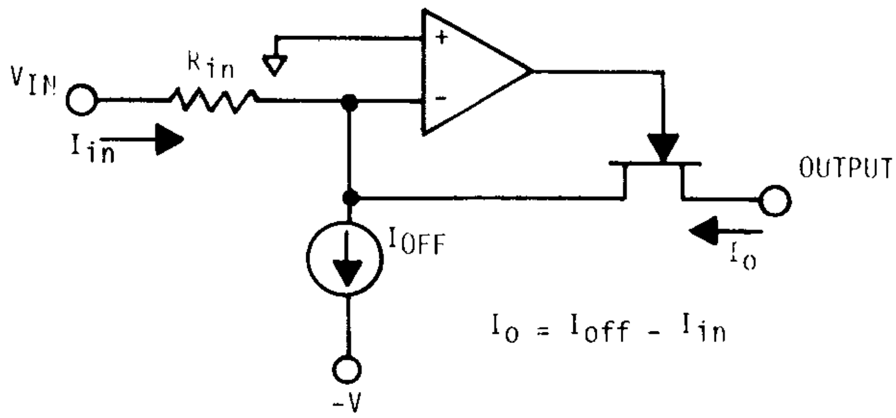


FIGURE 5-14. Power Supply Common Bootstrapped to Input Voltage.

5-44. As previously mentioned, the A/D converter was designed for linearity. This means that the input buffer must be linear over the full measurement range of ±2V to no more than a few parts per million. Since it also must be non-inverting, with very high input impedance, its gain linearity would normally be determined by common mode non-linearity. Most amplifiers specify 80 dB CMRR, and since CM non-linearity would typically be a factor of 10 or better, one could expect 10 ppm non-linearity from CM effects. Since this would be far too much error, it was required that the common mode errors be reduced. Common mode errors can be overcome either by improving CMRR through critical selection of devices, or by eliminating the common mode (CM) voltage. The latter method was chosen, as shown in Figure 5-14. First consider that, for non-inverting operational amplifiers, the common mode voltage (V_{CM}) is equal to V_{IN} - V_{COM} (power supply common). Thus, it can be seen that if V_{IN} - V_{COM} could be made equal to zero, common mode errors would be zero because V_{CM} = 0. To achieve this, it was necessary to bootstrap the power supply common for the input amplifier at the input voltage. This was accomplished by adding 2 zeners, 2 transistors, and a few resistors. The power supply common is seen to be the junction of VR105 and VR106 (the output of BSA), which is equal to V_{IN}. Thus, $V_{CM} = V_{IN} - V_{COM} \approx 0$, and the common mode error is eliminated. Note that this technique also raises input impedance because:

$$Z_{IN} = \frac{\Delta V_{IN}}{\Delta I_{IN}}$$

And, since there is no bias change on the input FETs of the input amplifier, $I_{IN} \approx 0$ and $Z_{IN} \approx \infty$. With the common mode error eliminated, the only gain error is open loop gain nonlinearity divided by loop gain. For closed loop unity gain, non-linearity is 0.5 ppm since open loop gain non-linearity is 10% and open loop gain is 200,000. For x10 gain, nonlinearity is 5 ppm.



$$I_{off} \text{ is made } \approx \frac{V_{in} \text{ Max.}}{R_{in}}$$

Thus when $V_{in} = V_{in}$ max, $I_o \sim 0$ (pos. full scale)

$V_{in} = 0$, $I_o = I_{off}$ (zero)

$$V_{in} = -V_{in} \text{ max. } I_o = I_{off} + \frac{V_{in} \text{ max}}{R_{in}} \approx 2\, I_{off} \text{ (minus f.s.)}$$

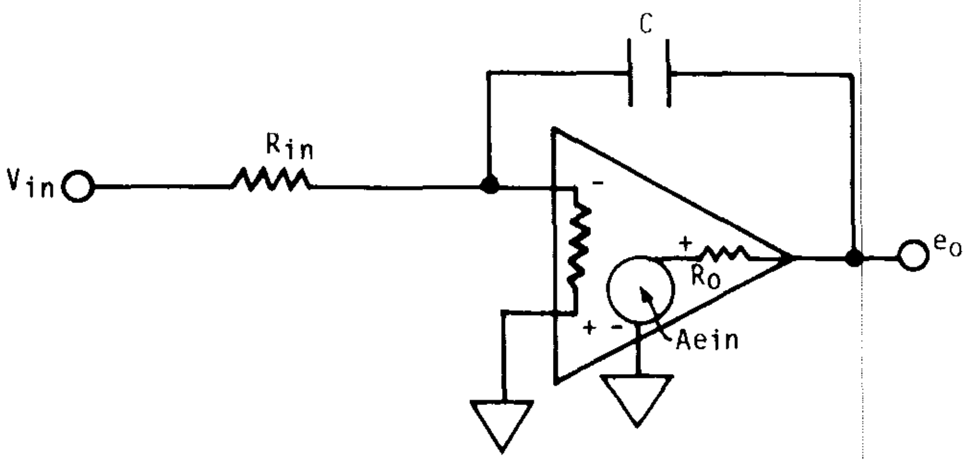
FIGURE 5-15. Transconductance Amplifier Operation.

5-45. Transconductance Amplifier.

5-46. This amplifier performs two functions. It converts the input voltage to an output current that is sent to the integrator on request. It also provides an offset current so that its bipolar input voltages are converted to unipolar output currents. Because of the current mode of operation, its linearity is excellent. Figure 5-15 shows how the circuit operates.

5-47. Integrator.

5-48. The integrator has been designed to guard against the most common problems associated with high speed integrator operation. Active integrators have two major problems which limit their high speed performance. One is the GAINBANDWIDTH of the integrator amplifier, and the other is the output resistance of the same amplifier. These effects can be seen by looking at the integrator model in Figure 5-16. If a voltage step appears at V_{in}, the amplifier will not respond immediately, and C will initially be a short circuit. As shown in the equation, the effect is that the wrong current will be applied to the capacitor until the amplifier recovers. It can also be seen that if a bipolar input amplifier was used for the integrator, charge could be conducted away from the capacitor and cause significant errors. To guard against these problems, the 191 uses an emitter follower on the integrator output to keep R_0 small into the MHz region, and all inputs to the integrator are current sources. Also, FET input operational amplifier is used, which would allow a few volts to appear on the summing junction with no loss in charge.



For step voltage inputs: $e \sim e_o = V_{in} \dfrac{R_o}{R_o + R_{in}}$

FIGURE 5-16. Integrator Problems at High Speed.

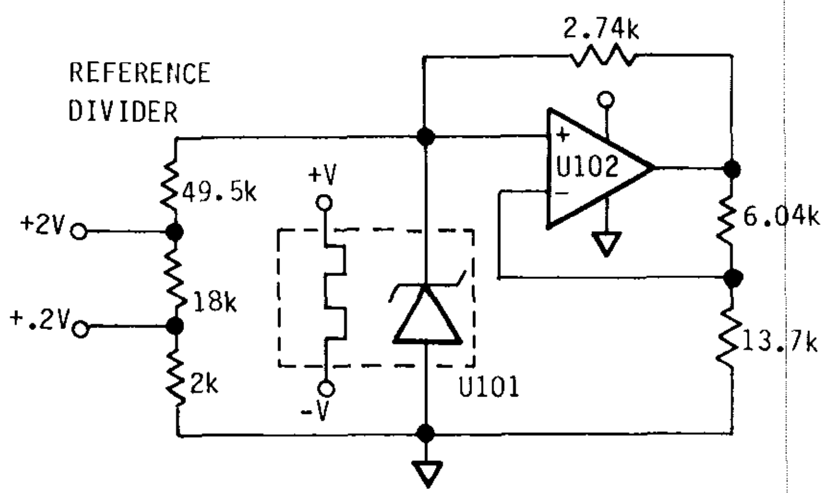


FIGURE 5-17. Simplified Schematic of Reference Supply.

5-49. REFERENCE SUPPLY.

5-50. The reference supply is shown in Figure 5-17. As previously mentioned, the A/D converter was designed for linearity and low noise. This means that stability and accuracy must be provided by the reference. The heart of the reference circuit is a buried layer zener diode, with an on-board heater, which was selected because of its stability, low noise, low temperature coefficient and low dynamic resistance. It is driven by a constant current (nominally 1mA) developed by amplifier U102. Since the zener current is well regulated, it is immune to power supply variations. For example: a 1 volt change in +V would only cause a zener current change of about 150 nanoamperes. And, since the dynamic resistance of the zener is 0.5 ohms, the zener voltage would only change 7.5 nanovolts. Super stable tracking resistors are used in the reference divider to provide very stable 2 volt and 0.2 volt reference voltages. The input resistors of the divider are specially selected (depending on the zener voltage) to provide a nominal 100 microamperes of current to the divider. For example: the values of resistance shown in the diagram would be for a zener voltage of 6.95 volts.

5-51. POWER SUPPLY.

5-52. Page 4 of Schematic 30162D contains the voltage regulators, line transformer, line voltage switching and full-wave rectifiers which make up the power supply for the Model 191. There are three integrated circuit regulators and one discrete component regulator used. The plus and minus 15 volts dc is provided by VR101 and VR102, respectively. These are 3-terminal regulators with ± 10% accuracy. They receive approximately +18 and -18 volts dc from T101 and CR102 when the minimum selected line voltage is supplied to the instrument. Input voltages are filtered by C111 and C114 and input currents are limited by R158 and R159. Output voltages are filtered by C110 and C113. VR104 provides the +5 volts used in the analog (ANLG) circuitry. It is a 3-terminal regulator with ± 5% accuracy. Its input voltage is supplied from T101 and CR101, and is approximately 8 volts (±0.5V) with minimum selected line voltage applied. Input filtering is provided by C115, and output filtering by C116. Q126 and Q127 comprise a series regulator which provides +5 volts for the Digital and Display circuitry. It is slaved to VR104, and thus, has the same output accuracy. It receives approximately 6.5 volts (±0.5V) from T101 and CR103 when minmum selected line voltage is applied. Input filtering is provided by C109, and CR106 prevents thermal runaway in the event of a circuit fault.

The allowable zener voltage is between 6.6 and 7.3 volts, with the resistors matched accordingly.

5-53. MODEL 1910 AC VOLTAGE OPTION.

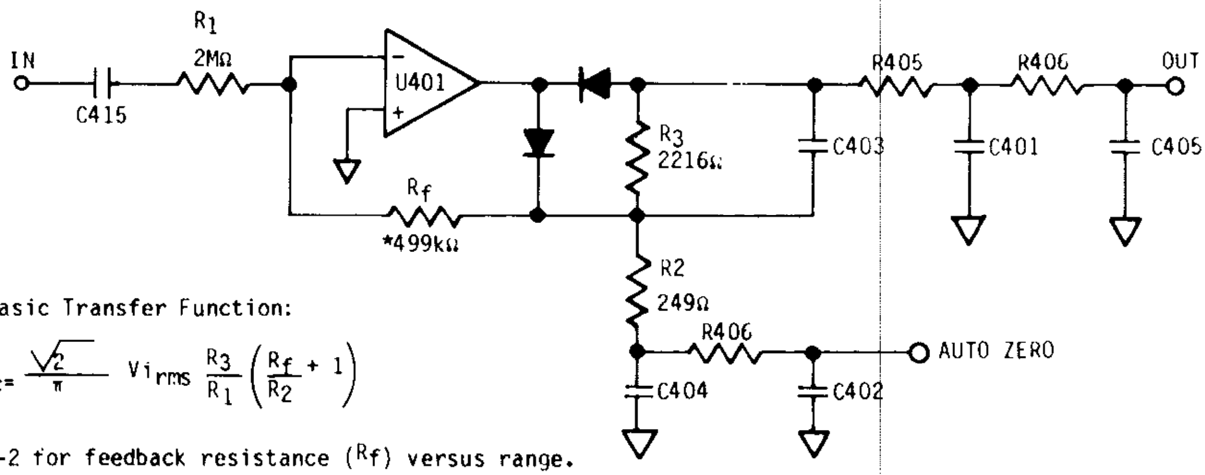
5-54. The Model 1910 is basically a plug-in ac/dc converter with variable gain that conditions the ac input voltage for application to the A/D converter. The basic transfer function of the ac/dc converter is shown on the simplified schematic (Figure 5-18). The resistor values were selected so that 1 Vac rms_{IN} = -1 Vdc_{OUT}. For ac input voltages above 2 volts, the feedback resistance (R_f) is reduced (by selection of a higher range) to keep the output always less than -2Vdc. The dc output is a half-wave rectified sine wave, and the converter is average responding, calibrated to the rms value of a sine wave. Capacitor C415 blocks dc inputs, and the dc offset voltage of the amplifier is autozeroed out. Output filtering is provided by the combination of resistors R404-R406 and capacitors C401-C405.

5-55. In actual circuit operation (as shown in schematic 29960D, Section 7) the feedback resistance of U401 is controlled by K401, K402 and K403. With all three relays de-energized as shown, the overall gain of the ac/dc converter is unity (i.e., 1 Vac rms_{IN} = -1 Vdc_{OUT}). With both K401 and K402 energized, gain is ÷ 1000. Gain is ÷ 10 when K403 is energized with K401 and K402 de-energized. The relays are controlled by the front panel range pushbuttons via the range select lines, as shown on sheet 1 of schematic 30162D. See Table 5-2 for gain chart of the ac voltage ranges.

Table 5-2
Gain Chart for AC Voltage

Range	Attenuation	U401 FDBK Resistance (R_f)*	Energized Relays
2V	÷ 1	499 kΩ	None
20V	÷ 10	49.7 kΩ	K403
200V	÷ 100	4.7 kΩ	K402
1000V	÷ 1000	250.2 Ω	K402,401

*See Figure 5-18.



Basic Transfer Function:

$$-VO_{dc} = \frac{\sqrt{2}}{\pi} \; Vi_{rms} \; \frac{R_3}{R_1}\left(\frac{R_f}{R_2} + 1\right)$$

*See Table 5-2 for feedback resistance (R_f) versus range.

FIGURE 5-18. Simplified Schematic of Model 1910.

SECTION 6. MAINTENANCE

6-1. GENERAL

6-2. This section contains information necessary to maintain the Model 191 DMM and the Model 1910 AC Volts Option. Adjustment/calibration, troubleshooting, and fuse replacement procedures are provided. Calibration should be performed yearly (every 12 months) or whenever performance verification (see Section 3) indicates that the Model 191 is out of specifications. If any step in the calibration procedure cannot be performed properly, refer to troubleshooting information in this section or contact your Keithley representative or the factory.

NOTE

Calibration should be performed by qualified personnel using accurate and reliable equipment

6-3. RECOMMENDED TEST EQUIPMENT.

6-4. Recommended test equipment for calibration is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 3 times better than the Model 191 specifications, or equal to Table 6-1 specifications.

6-5. ENVIRONMENTAL CONDITIONS.

6-6. Calibration should be performed under laboratory conditions having an ambient temperature of 23 ±1°C, and a relative humidity of less than 70%. If the instrument has been subjected to temperatures outside of this range, or to higher humidity, allow one hour minimum for the instrument to stabilize at the specified environmental conditions before beginning the calibration procedure.

6-7. CALIBRATION PROCEDURE.

6-8. Perform the following procedures and make the adjustments indicated to calibrate the Model 191 DMM.

6-9. Installation of the Model 1913 calibration cover.

6-10. Calibration should be performed using the Model 1913 calibration cover. This cover permits access to the Model 191 adjustments, while allowing the instrument to reach normal internal operating temperature. Install the cover as follows:

WARNING

Disconnect the line cord before removing the cover. To discharge voltage on capacitors, depress the OFF/ON pushbutton after disconnecting the line cord.

TABLE 6-1.
Recommended Test Equipment For Calibration.

Item	Description	Specification	Mfr.	Model
A	DC Calibrator	19V,190V, 1000V ±0.002% or 20µV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	High Voltage Amplifier (Used with Model 745A)	1000 V ±0.04%	H-P	746A
D	Decade Resistor	190Ω, 1.9KΩ 190KΩ Certified to 50 ppm	ESI	RS725
E	Kelvin-Varley Voltage Divider(Used with Model 343A)	.19V, 1.9V With 2 ppm Terminal Linearity	Fluke	720A

a. Turn off power and disconnect the line cord.

b. Turn the instrument over so that the bottom cover is facing up, loosen the four screws in the bottom panel. These screws are held captive by rubber O-rings.

c. Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

d. Carefully lift off the top cover.

e. Position the calibration cover in place on the Model 191 and tighten the bottom panel screws.

6-11. Warm Up.

6-12. Connect the line cord and depress OFF/ON pushbutton to ON position. Allow a one hour warm-up time before beginning the calibration adjustments.

6-13. Calibration Adjustments.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. Use an insulated tool when making adjustments.

a. Refer to Table 6-2 and perform the listed adjustments in the sequence indicated. Note that the step sequence is also indicated on the Model 1913 Calibration cover by box numerals. The sequence must be followed exactly because the adjustments are interrelated and dependent on the preceeding steps. Perform steps 1 through 8 to calibrate the basic Model 191. If the Model 1910 AC Volts Option is installed, also perform steps 9 through 15.

b. Following calibration, to insure that all functions and ranges are operating properly, utilize the Performance Verification procedure in Section 3.

c. If calibration cannot be accomplished or the Performance Verification procedure indicates a problem, proceed to Troubleshooting information in this section.

6-14. TROUBLESHOOTING.

6-15. The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital electronic principles and components used in a precision electronic test instrument. Instructions have been written to assist in isolating the defective circuit or subcircuit. Isolation of the specific defective component has been left to the technician.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), If the instrument's performance is outside of specifications at any point, contact your Keithley representative or the factory before attempting troubleshooting or repair, other than fuse replacement.

6-16. TROUBLESHOOTING PROCEDURE.

6-17. This section contains tables listing step-by step checks of the major DMM circuits descibed in Section 5, Theory of Operation. The following steps outline the use of these tables and provide instruction for preparing the DMM for toubleshooting. Read all of these steps carefully before troubleshooting the instrument.

6-18. It may be necessary to remove the shields on the mother board and the Model 1910 AC voltage Option (if installed) to gain access to test points and circuit components for troubleshooting.

NOTE

Recalibration of the Model 1910 AC Voltage Option may be necessary if any of the following occurs.

1) Removal/Replacement of Model 1910.

2) Disturbing position of Model 1910 in the connector.

3) Removal/Replacement of shields on the Model 1910.

Refer to Section 3-13 to check AC Voltage accuracy. If calibration is necessary perform steps 9 through 15 in Table 6-2

6-19. Shield Removal/Replacement.

6-20. Perform the following procedures to remove/replace shields on mother board and Model 1910 AC Voltage Option.

WARNING

Disconnect the line cord before removing the case cover.

a. Turn off power and disconnect the line cord. Remove four screws from the bottom of the case and separate the top cover from the bottom cover.

b. Remove mother board shield by carefully lifting shield from the retaining clips. To reinstall, position shield on the four retaining clips so that the small bent tab on side of shield is positioned against the grounded retaining clip (See Figure 6-2). This tab prevents the shield from moving too far towards the rear of the mother board. Press firmly on top of shield to engage fully into retaining clips.

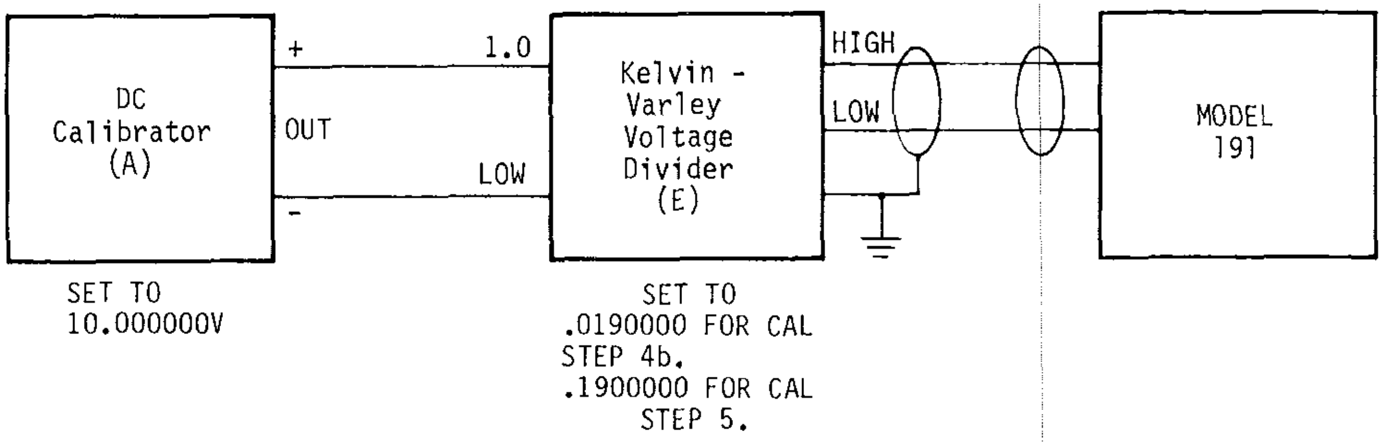


FIGURE 6-1. Test Circuit For 200mVDC And 2VDC Calibration.

c. To gain access to shields on the Model 1910 AC Voltage Option disconnect the brown and blue wires at the pushbutton switch and completely remove the Model 1910 from connector P1006. Detach shields from PC board by removing the two retaining screws. Refrain from any unnecessary touching of circuit components. Handle the board by its edges. Reverse the procedure to reinstall the Model 1910. The wiring instructions for the Model 1910 are located on the mother board shield.

6-21. Special Handling of Static Sensitive Devices.

6-22. CMOS devices are designed to function at very high impedance levels for low power consumption. For this reason, a normal static charge build up on your person or clothing can be sufficient to destroy these devices. The following steps list the static sensitive devices in your Model 191 and provide instruction on how to avoid damaging them when they must be removed/replaced.

a. Static sensitive devices:

Keithley Part Number	Reference Designation
LSI-8	U303
LSI-18	U302
IC-168	U202

b. The above integrated circuits should be handled and transported only in protective containers. Typically they will be received in metal tubes or static protective foam. Keep the devices in their original containers until ready for use.

c. Remove the devices from their protective containers only at a properly gounded work bench or table, and only after grounding yourself by using a wrist strap.

d. Handle the devices only by the body. Do not touch the pins.

e. Any printed circuit board into which a device is to be inserted must also be grounded to the bench or table.

f. Use only anti-static type solder suckers.

g. Use only grounded tip soldering irons.

h. After soldering the device into the board, or properly inserting it into the mating receptacle, the device is adequately protected and normal handling can be resumed.

6-23. Line Power.

6-24. In general, start troubleshooting with Table 6-3, Line Power Checks to verify that the power supplies are providing the correct voltages to the electronic components.

6-25. A/D Converter and Display.

6-26. Proper operation of the A/D converter and display should be verified before troubleshooting the signal conditioning circuits. Check the A/D converter and display per Tables 6-4 and 6-5 respectively.

6-27. AC Converter.

6-28. Problems with ac voltage may involve the Model 1910 AC Voltage Option. Check this circuit per Table 6-6.

TABLE 6-2.
Calibration Adjustments.

Step	Function	Range	Applied* Input	Adjustment Point**	Desired Reading	Test Equipment
1a	Ω	200Ω	Dial "0" Ohms, depress NULL		00.000	Decade Resistor (D)
1b	Ω	200Ω	190	R122	190.000	Decade Resistor
2a	Ω	2KΩ	Dial "0" Ohms, reset NULL		.00000	Decade Resistor
2b	Ω	2KΩ	1.9KΩ	R123	1.90000	Decade Resistor
3	Ω	200KΩ	Release NULL, 190KΩ	R124	190.000	Decade Resistor
4a	DC V	200 mV	Disconnect DC Calibrator, Short Input depress NULL		00.000	See Figure 6-1
4b	DC V	200 mV	+190 mV	R125	190.000	See Figure 6-1
5	DC V	2 V	Release NULL, +1.9 V	R126	1.90000	See Figure 6-1
6	DC V	200 V	+190 V	R132	190.000	DC Calibrator (A)
7	DC V	20 V	+19V	R131	19.0000	DC Calibrator
8	DC V	1000 V	+1000 V	R130	1000.00	DC Calibrator
9	AC V	1000 V	1000V at 1k Hz	R401	1000.00	AC Calibrator (B) and High Voltage Amplifier (C)
10	AC V	2 V	1V at 1k Hz	R410	1.00000	AC Calibrator
11	AC V	20 V	10V at 1k Hz	R411	10.0000	AC Calibrator
12	AC V	200 V	100V at 1k Hz	R409	100.000	AC Calibrator
13	AC V	200 V	100V at 50kHz	C412	100.000	AC Calibrator
14	AC V	2 V	1V at 50 kHz	C411	1.00000	AC Calibrator
15	AC V	20 V	10V at 50kHz	C408	10.0000	AC Calibrator

* Connect to INPUT HI and LO terminals. SENSE terminals should not be used during calibration.

** Refer To Figures 6-2 and 6-3 for location of Adjustment Points.

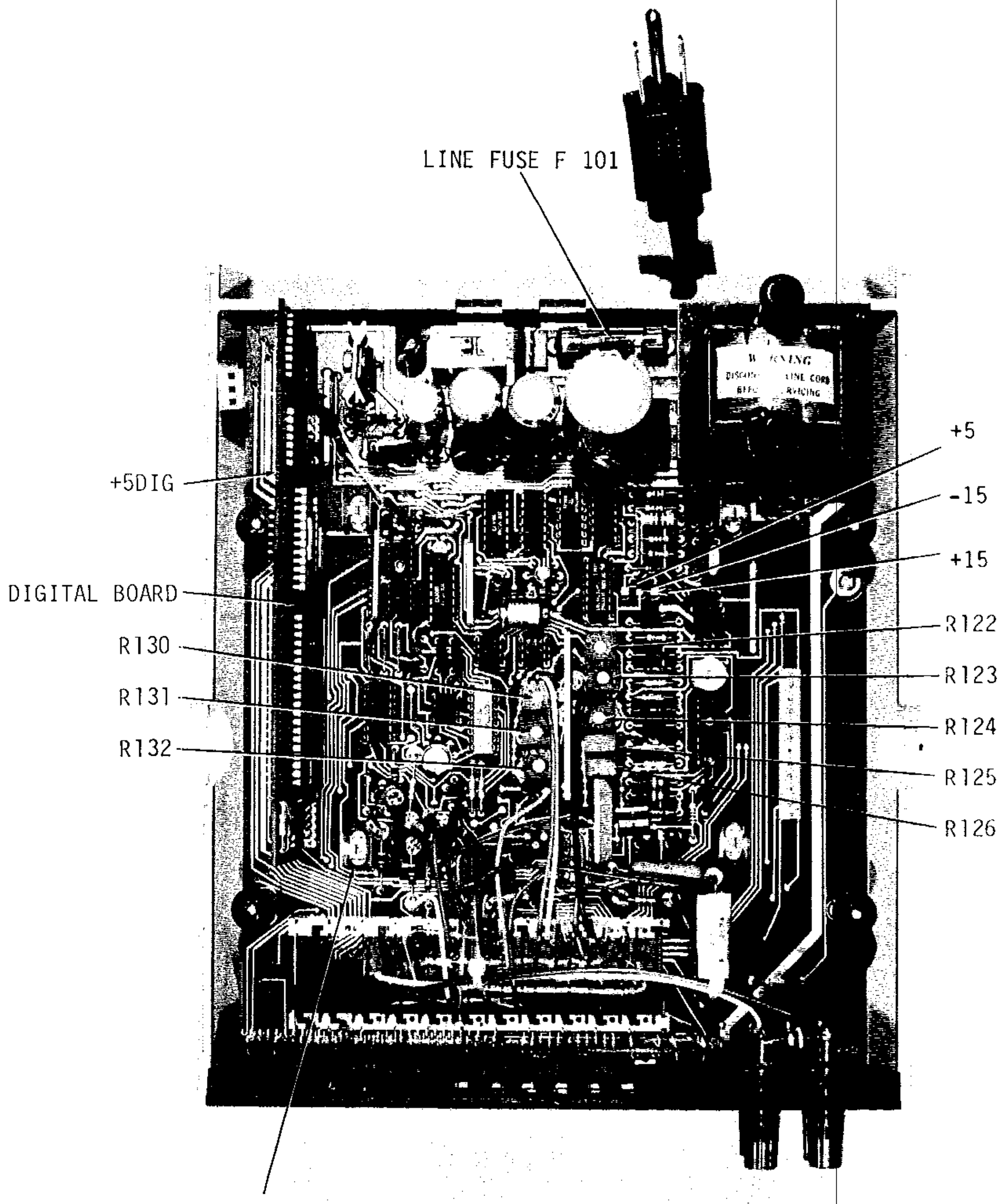


FIGURE 6-2. Model 191 (Shield Removed)

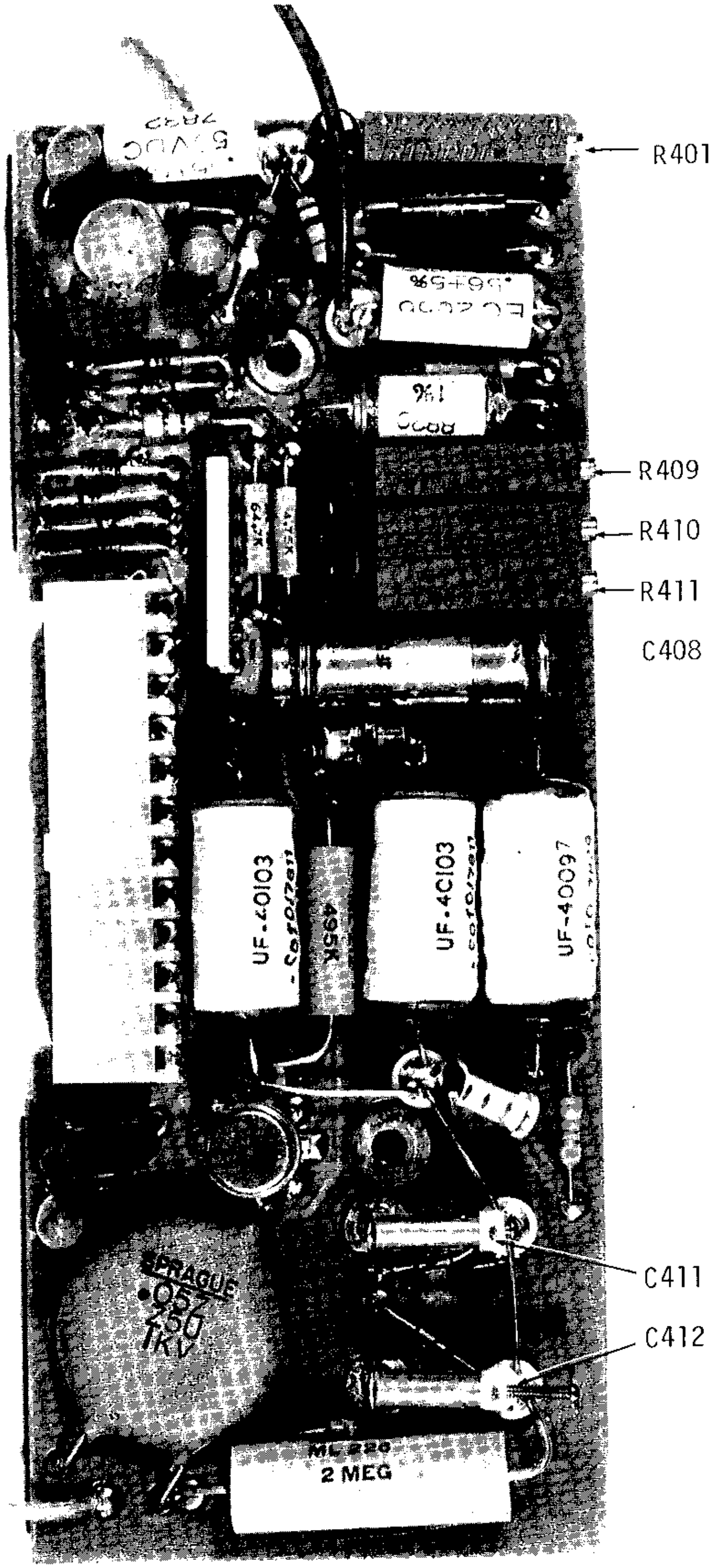


FIGURE 6-3. Model 1910 AC Voltage Option (Shields Removed)

6-29. DC Attenuator and Ohms Source and Resistors.

6-30. Problems with dc voltage or resistance ranges may involve these signal conditioning circuits. Check these circuits per Tables 6-7 and 6-8.

NOTE

Dust, flux or other contamination will degrade performance on resistance and dc voltage ranges.

6-31. Digital Board.

6-32. Problems may exist with the microprocessor or associated circuitry. Check out per Table 6-9.

6-33. All measurements are referenced to analog common (INPUT LO terminal), unless otherwise noted in the tables.

6-34. If a gross failure exists that indicates a possible blown fuse (line power) refer to Paragraph 6-35 for fuse replacement instructions.

WARNING

Some procedures in the following tables require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. The mother board shield is at INPUT LO Potential. An input voltage floating high enough will create a shock hazard between the shield and earth ground.

TABLE 6-3.
Line Power Checks.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1	S102 line Switch	Must be set to 115V or 230V as appropriate.**	
2	F101 line fuse	Continuity	
3	P1014 line cord	Plugged into live receptacle	
4		Turn on power	
5	+5V pad*, Analog	+5 volts, ±5%	Output of VR104
6	VR104, IN.	+7.4 volts minimum	Input to VR104
7	+5V pad*, Digital	+5 volts, ±5%	Collector of Q126
8	Emitter of Q126	+6 volts minimum	Unregulated input
9	+15V pad*	+15 volts, ±10%	Output of VR101
10	VR101 IN.	+17.9 volts minimum	Input to VR101
11	-15 pad*	-15 volts, ±10%	Output of VR102
12	VR102 IN.	-17.9 volts minimum	Input to VR102
			NOTE: Hot regulator may indicate shorted load.

* On main printed circuit board (see Figure 6-2).
**On optional line voltage units set to 115V.

TABLE 6-4.
A/D Converter.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 1000 VDC.	NOTE: Some tests here could fail because of Digital Board problems and vice versa.
2	Display	000.00 ±2 Digits	
3*	U104,pin 10	0 to +4 volt square wave at 4 MHz	4 MHz clock (P1005, pin 2).
4*	U104,pin 8	0 to +4 volt square wave at 1 MHz.	1 MHz Clock (P1005, pin 7).
5*	U104,pin 12	0 to +4 volt square wave at 250 kHz	250 kHz clock (P1005 pin 3).
6	U106,pin 3	0 to +4 volt square wave at 500 kHz.	500 kHz clock
7	U106,pin 11	0 to +4 volt square wave at 500kHz	500 kHz clock
8	R138	+2 volts for 100 milliseconds, 0 volts for 400 milliseconds	Input Buffer output
9	U113,pin 2	-2.5 volts, ±7% (175mVolts)	Transconductance Amp bias.
10	U114,pin 2	+5 volts, ±7% (350mVolts)	Charge Dispenser bias
11	C112	0 volts ±15 millivolts	Integrator input
12	C112	See waveform per Figure 5-7	Integrator output
13		Select 2 V DC Range	
14	External voltage source	Apply +1.90000 volts	Calibrated point
15	Display	1.90000 ±10 digits	If different, check 2 volt reference (pin 7, 200mV switch).
16		Select 200mV DC range	
17	External voltage source	Apply .000000 volts	Calibrated point
18		Depress NULL	
19	Display	00.000 ±1 digit	Input offset nulled
20	External voltage Source	Apply +190 millivolts	Calibration point
21	Display	190.000 ±10 digits	If different, check 0.2 volt reference (pin 9, 200mV switch) or X10 gain of Input Buffer.

* Skip these steps, if steps 1 through 4 on Digital Board (Table 6-9) have been performed.

TABLE 6-5.
Display.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 1000 V DC range.	
2	+5V Digital Pad* or P1002, pin 4	+5 volts ±5%	If low, check per Table 6-3.
3	U201, pin 1,2,6, 7,9 and 13	Digit drive. Low=enabled	LED cathode
4	U202, pin 9,10, 11,12,13,14 and 15	HI=enabled	7 Segment outputs
5	U202, pin 4 and 5	Negative - going pulse (+5V to 0V) occurring every 400 sec. (2.5kHz).	
6	J1002, pins 2,5,7 and 8	Appropriate DP line high (on).	Depress RANGE pushbuttons to checkall DP's.

* On main printed circuit board. See Figure (6-2.)

TABLE 6-6.
AC Converter. (Model 1910)

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 2V DC range.	NOTE: Full scale input on all ranges should produce approximately -2V DC at output. (pin 7, DC VOLTS switch).
2		Short input	NOTE: Do not perform unless A/D tests are completed.
3	Display	.00020 ±10 digits	Normal zero offset range.
4	Pin 7, DCV Switch	10 millivolts	Impedance meter to measure ($\geq 10^9 \Omega$). Output resistance is 300 kΩ
5	Pin 12, ACV switch	Same as step 4, plus reading at step 3.	ACV Auto zero.
6	External voltage source	Apply 1.00000 volts rms at 1kHz	Calibration point.
7	Display	1.00000 ±100 digits	
8	Pin 7, DCV switch	-1 volt, plus reading at step 4	DC output
9	Pin 12, ACV switch	Same as step 5	Auto zero
		NOTE: If any of above checks fail, proceed to bias checks, step 18.	
10		Select 20 VAC range	
11	External voltage source	Apply 10.0000 volts rms at 1kHz	Calibration point
12	Display	10.0000 ±100 digits	Calibration point
13	External voltage source	Select 200 VAC range and apply 100.000 volts rms.	
14	Display	100.000 ±100 digits	

TABLE 6-6. (Continued)
AC Converter. (Model 1910)

STEPS	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
15		Select 1000 VAC range	
16	External voltage source	Apply 1000.00 volts rms	Calibration point
17	Display	1000.00 ±100 digits	
18		TURN OFF POWER. Remove Model 1910 AC Voltage Option from Model 191. Remove shields and re-install Model 1910 in Model 191. Select 2VAC range and short INPUT. Turn on power.	NOTE: with shields removed, display will be noisy and read many millivolts of AC pickup. Display will also change with operator movement.
19	Pin 2, U401	0 volts ±10 millivolts.	Summing junction, AC amplifier.
20	R405, CR401	0 volts ±10 millivolts	DC output before filter.
21	R402, R406	0 volts ±10 millivolts	Feedback circuit
22	Q404, base	-7.5 volts ±10%	Base voltage
23	Q403, emitter	+5.7 volts ±10%	5 milliamp current source.
24	Q401, base	-3.6 volts ±10%	Bias for C404 protection circuit.

NOTE: Model 1910 must be recalibrated if step 18 was performed.

TABLE 6-7.
DC Attenuator.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 200V DC range.	NOTE: These checks should not be made if a problem exists on the 200mV DC or 2VDC ranges.
2	External voltage	Apply +190.000 volts	Calibration point
3	Display	190.00 ±10 digits	100:1 Attenuator (R129A,B,C,D, R124 wiper).
4		Select 20V DC range	
5	External voltage source	Apply +19.0000 volts	Calibration point.
6	Display	19.0000 ±10 digits	10:1 Attenuator (R129A,B,C,D, R131 wiper).
7		Select 1000 VDC range	
8	External voltage source	Apply +1000.00 volts	Calibration point.
9	Display	1000.00 ±5 digits	1000:1 Attenuator (R129A,B,C,D, R130 wiper).

TABLE 6-8.
Ohms Source and Resistors.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Select 200 range and short INPUT with 18 gage (or lower) copper wire. (tin plated OK).	NOTE: Do not perform unless A/D converter and DC attenuator tests are completed.
2	Display	Less than 00.010	Two wire offset, including thermals.
3	Pin 5, ACV switch	-0.4 volts ±9%	Ohms reference voltage
4	Pin 3, U103	-0.4 volts ±7%	Ohms reference divider.
5		Select 2KΩ range	
6	Display	.00000 ±2 digits	
7	Pin 5, ACV	-4 volts ±7%	Ohms reference voltage.
8	Pin 3, U103	-4 volts ±7%	Ohms reference divider.
9	1.00000 k Ω	Apply to input (4-wire connection)	Calibrated resistance
10	Display	1.00000 ±10 digits	Range resistors : R107, R109. Q105 and Q106 are protection transistors.
11	Pin 5, ACV	-4 volts ±7%	Ohms reference voltage.
12	INPUT HI	-2 volts ±7% (half of step 11)	Voltage across unknown.
13	10.0000k Ω	Apply to INPUT and select 20kΩ range	Calibrated resistance
14	Display	10.0000 ±10 digits	Range resistors: R107, R109, R129D, R130.
15		Repeat Steps 11 and 12	
16	100.000k Ω resistor	Apply to INPUT and select 200kΩ range.	Calibrated resistance

TABLE 6-8 (Continued)
Ohms Source and Resistors.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
17	Display	100.000 ±10 digits	Range resistors: R107, R109, R129D. R130, R129C, R124.
18		Repeat Steps 11 and 12	Use meter with high input impedance ($\geq 10^9 \Omega$).
19	1.0000M Ω resistor	Apply to INPUT and select 2000kΩ range.	Calibrated resistance
20	Display	1.00000 ±30 digits	Range resistors: R107, R109, R129D, R130,, R129C, R124, R129B, R131.
21		Repeat Step 18	Use meter with high input impedance ($\geq 10^9 \Omega$).
22	10.000 MΩ resistor	Apply to INPUT and select 20MΩ range	Calibrated resistance.
23	Display	10.0000 ±100 digits	Range resistors: R107, R109, R129D, R130, R129C, R124, R129B, R131, R132, R129A, R119.
24		Repeat Step 18	

TABLE 6-9
Digital Board

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 1000 VAC range*	NOTE: Some tests here could fail because of A/D Converter problems and vice versa.
2	U302,**	0 to +4 volt square wave at 4 MHz	4 MHz clock.
3	U302, pin 37	0 to +4 volt square wave at 1 MHz	1 MHz clock.
4	U309, pin 11	0 to +4 volt square wave at 1 MHz	1 MHz clock.
5	U308, pin 4	0 to +4 volt square wave at 250 kHz	250 kHz clock.
6	U308, pin 13	0 to +4 volt square wave at 2.5 kHz	2.5 kHz clock.
7	U302, pin 40	+5 volts ±5%	Reset line.
8	J1004, pin 4	Negative going pulse (+5V to 0V) occurring every 400 µsec.	Latch enable for Display Board.
9	J1004, pin 9	Negative going pulse (+5V to 0V) occurring every 400 µsec.	Blanking input for Display Board
10	J1004, pin 8	Rectangular wave, +5V for 140 to 170 msec and 0V for 370 to 400 msec.	S1 line for input signal multiplex.
11	J1004, pin 7	Rectangular wave, +5V for 130 to 150 msec and 0V for 390 to 420 msec	S2 line for input signal multiplex.
12	J1004, pin 6	Rectangular wave, +5V for 110 to 140 msec and 0V for 400 to 430 msec.	S3 line for input signal multiplex.
13	J1004, pin 5	Rectangular wave, +5V for 110 to 140 msec and 0V for 420 to 450 msec.	S4 line for input signal multiplex.

* If Model 1910 AC Option is not installed, display should read—IEEE.EE.

** Pin 38 for Revision A and B Digital Board,
Pin 39 for Revision C and above Digital Board.

6-35. LINE POWER FUSE (F101) REPLACEMENT.

6-36. Fuse is located internally in the Model 191. To replace fuse, proceed as follows:

WARNING
Disconnect the line cord before removing the case cover.

a. Turn off power and disconnect the line cord.

b. Turn the DMM bottom side up and loosen the four screws in the bottom cover. These screws are held captive by rubber O-rings.

c. Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

d. Lift off the top cover.

CAUTION
Do not install fuse with higher rating than specified. Instrument damage may occur.

e. F101 is now accessible without removing any other components.

f. Remove F101, shown in Figure 6-2, and replace per Table 6-10.

TABLE 6-10.
Fuse Replacement.

LINE VOLTAGE	FUSE F101	KEITHLEY PART NO.
90-110V*	1/4A,250V,3AG	FU-17
105-125V	1/4A,250V,3AG	FU-17
210-250V	1/8A,250V,3AG	FU-20

* Optional line voltage range.

g. Replace the top cover.

SECTION 7. REPLACEABLE PARTS.

7-1. GENERAL.

7-2. This section contains information for ordering replacement parts. Panel and covers are shown separately on Figure 7-1. The Replaceable Parts List is arranged in alphabetical order of the Circuit Designations of the components. A cross-reference list of manufacturers, containing their addresses, is given in Table 7-1.

7-3. ORDERING INFORMATION.

7-4. To place an order or to obtain information concerning replacement parts contact your Keithley representative or the factory. See the inside front cover 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 Part Number.

7-5. FACTORY SERVICE.

7-6. If the instrument is to be returned to the factory for service, please complete the Service Form which follows this section, and return it with the instrument.

7-7. SCHEMATICS.

7-8. The Model 191 schematic (30162D) is comprised of four pages:

a. Page 1 of 30162D - Signal Conditioning, Pg. 7-19.
b. Page 2 of 30162D - A/D Converter, Pg. 7-20.
c. Page 3 of 30162D - Digital and Display, Pg. 7-21.
d. Page 4 of 30162D - Power Supply, Pg. 7-22.

7-9. Model 1910 AC Voltage Option (AC Converter): Schematic No. 29960D, Pg. 7-27.

7-10. COMPONENT LAYOUTS.

7-11. Model 191 Mother Board, PC-489, Component Layout No. 29675D, Pgs. 7-23, 24.

7-12. Model 191 Display Board, PC-486, Component Layout No. 29667C, Pg. 7-25.

7-13. Model 191 Digital Board, PC 490, Component Layout No. 29679C, Pg. 7-26.

7-14. Model 1910 AC Voltage Option, PC-496, Component Layout No. 29955C, Pg. 7-28.

7-15. MODEL 1919 SPARE PARTS KIT.

7-16. A spare parts kit is available that contains a complement of spare parts that can maintain up to five Model 191/1910's for approximately one year. A list of the spare parts is given in Table 7-2.

TABLE 7-1
Cross Reference of Manufacturers

MFG. CODE	NAME AND ADDRESS	FED SUPPLY CODE
A-B	Allen-Bradley Corp. Milwaukee, WI 53204	01121
A-D	Analog Devices, Inc. Norwood, MA 02026	24355
A-P	A-P Products Painsville, OH	
ACI	American Conponents, Inc. Conshohochen, PA 19428	14298
AMI	American Microsystems, Inc. Santa Clara, CA 95051	31471
AMP	Amphenol Broadview, IL 60153	02660
BRG	Berg Electronic, Inc. NC	
BRN	Bourns, Inc. Riverside,CA 92507	80294
C-D	Cornell-Dubilier Newark, NJ 07101	14655
C-W	Continental-Wirt Electronic Corp. Warminster, PA 18974	79727
CAD	Caddock Riverside, CA 92507	19647
CLB	Centralab Division Milwaukee, WI 53201	71590
COT	Coto-Coil Co., Inc. Providence, RI	71707
DTN	Dielettron (Consolidated) New York City, NY 10013	

TABLE 7-1 (CON'T)
Cross Reference of Manufacturers

MFG. CODE	NAME AND ADDESS	FED SUPPLY CODE
ECI	Electro Cube, Inc. San Gabriel, CA 91776	14752
EFJ	E. F. Johnson Co. Waseca, MN 56093	74970
ERI	Erie Technological Products Erie, PA 16512	72982
F-I	Fairchild Instrument Corp. Mountain View, CA 94043	07263
G-I	General Instrument Corp. Newark, NJ 07104	72699
HHS	H. H. Smith Brooklyn, NY 11207	83330
INT	Intersil, Inc. Cupertino, CA 95014	32293
K-I	Keithley Instruments, Inc. Cleveland, Ohio 44139	80164
L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
MEP	Mepco, Inc. Morristown, NJ	80031
MOL	Molex Downers Grove, IL 60515	27264
MOT	Motorola Semi Products, Inc. Phoenix, AZ 85008	04713
NAT	National Semi. Corp. Santa Clara, CA 95051	27014
NCG	Nytronics Components Group, Inc. Darlington, SC 29532	83125
NIC	Nichicon Corp Chicago, IL 60645	
PRP	Precision Resistive Products Mediapolis, IA 53237	
SIE	Siemens Corp. Iselin, NJ 08830	25088
SPG	Sprague Electric Co. Visalia, CA 93278	14659
STD	Standard Condensor Chicago, IL	97419
T-I	Texas Instruments, Inc. Dallas, TX 75231	01295
UCC	United Chemi-Con, Inc. Rosemont, IL 60018	

TABLE 7-2
MODEL 1919 SPARE PARTS KIT

QTY.	KEITHLEY PART NO.	SCHEMATIC DESIGNATION
2	DD-16	DS202 thru DS206
1	DD-17	DS201
2	FU-17	F101
1	IC-53	U108,U110
1	IC-93	VR104
1	IC-96	VR101
1	IC-152	U401
1	IC-174	VR102
1	LSI-8*	U303
1	LSI-18*	U302
2	RF-28	CR401 thru CR408
1	RL-57	(K401***), K402,K403
1	TG-47	Q107 thru Q110, Q119, Q404
1	TG-61	Q117, Q123, Q402, Q403
1	TG-62	Q127, Q401
1	TG-84	Q118, Q405, Q128
2	TG-128	Q111 thru Q116, Q120 thru Q122, (Q101)
1	TG-136	Q126
1	TG-137	Q103
1	28234	Q102, Q105, Q106, Q124, Q125
1	30163	U113, (U102, U103, U109, U111, U114)**
1	30167	U112

* Anti-Static protection and handling required.
** Better Replacement Part.
*** Cut off extra pin to use.

REPLACEABLE PARTS LIST

CAPACITORS (C)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C101	.1μF,16VDC, CerD	2/D5	5/B2	CLB	UK16 104	C-238-.1
C102	.1μF,16VDC, CerD	2/E5	6/B2	CLB	UK16 104	C-238-.1
C103	68pF,1000V, CerD	2/D5	7/B2	CLB	DD-680	C-64-68p
C104	.1μF,16VDC, CerD	2/E5	8/C2	CLB	UK16 104	C-238-.1
C105	.1uF,16VDC, CerD	2/G5	9/C2	CLB	UK16 104	C-238-.1
C106	.1μF,16VDC, CerD	2/H5	10/C2	CLB	UK16 104	C-238-.1
C107	.1μF,16VDC, CerD	2/H5	11/C2	CLB	UK16 104	C-238-.1
C108	.01μF,1200V, Poly	1/C2	12/E2	STD	PYW-R.01	C-286-.01
C109	10,000μF,10V, ETT	4/C4	13/B3	NIC	10ULA 10000	C-304-10,000
C110	10μF,20V, ETT	4/E2	14/B3	ITT	TAPA 10μFK20	C-179-10
C111	470μF,50V, ETT	4/D2	15/B4	UCC	50VBSL 470	C-276-470
C112	3600pF,500VDC, Poly	2/E3	16/C4	CLB	CPR-3600J	C-138-3600p
C113	10μF,20V, ETT	4/E3	17/B4	ITT	TAPA 10μFK20	C-179-10
C114	470μF,50V, ETT	4/D3	18/B4	UCC	50VBSL 470	C-276-470
C115	1000μF,10V, ETT	4/D5	19/B4	NIC	10ULA 1000	C-304-1000
C116	10μF,20V, ETT	4/E4	20/B4	ITT	TAPA 10μFK20	C-179-10
C117	.1μF,16VDC, CerD	2/C5	21/C4	CLB	UK-104	C-238-.1
C118	.1μF,16VDC, CerD	2/C5	22/C4	CLB	UK-104	C-238-.1

CAPACITORS (C) (CON'T)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C119	8.2pF,50V, TubCer	2/A3	23/D4	CLB	C40C8 R2K	C-282-~~8.2p~~ C-372-10P ECO 10830 8-7-85
C120	.1μF,16VDC, CerD	1/E2	24/D2	CLB	UK-104	C-238-.1
C121	47pF,1000V, CerD	2/E6	25/C3	CLB	DD-470	C-64-47p
C122	.1μF,16VDC, CerD	1/F3	26/D3	CLB	UK-104	C-238-.1
C123	150pF,1000V, CerD	1/G5	27/G2	CLB	DD-151	C-64-150p

"200" Series (Sch. 30162D - Pgs. 7-19, 20,21, 22)
(PC-Board 486 - Pg. 7-23, 25)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C201	4.7μF,35V, EAL	3/E2	3/E3	ITT	TAPA 4.7μFK20	C-179-4.7

"300" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 490 - Pg. 7-26)

Circuit Desig.	Description	Sch. Pg/ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C301	4.7μF,35V, EAL	3/B6	4/B2	ITT	TAPA75 4.7FK20	C-179-4.7
C302	6800pF,500V, CerD	3/C6	5/E2	ERI	851-Z5V0 682M	C-22-6800p
C303	.1μF,16VDC, CerD	3/F5	6/E2	CLB	UK16-104	C-238-.1
C304	.1μF,16VDC, CerD	3/F5	7/E3	CLB	UK16-104	C-238-.1

Model 1910 AC Voltage Option
"400" Series (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No. Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C401	.56μF,50V, MPF	F3	5/B2	ECI	625B1A 564J	C-201-.56
C402	10μF,20V, ETT	F4	6/B3	ITT	TAPA 10μFK20	C-179-10
C403	3.3μF,20V, ETT	F3	7/B3	ITT	TAPA 3.3μFK20	C-179-3.3
C404	680μF,3V, Tant	E4	8/B3	SPG	199D687 X0003FA2	C-297-680

CAPACITORS (C) (CON'T)
Model 1910 AC Voltage Option
"400" Series (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No. Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
C405	.56µF,50V, MPF	G3	9/B2	ECI	625B1A 564J	C-201-.56
C406	8820pF,63V, Poly	D6	10/B2	DTN	8820pF, 63V,1%	C-299-8820p
C407	418pF,500VDC, Mica	D5	11/C2	G-I	RDM 15FD	C-278-418p
C408	Adjustable Capacitor .8-18pF	D5	12/C2	ERI	567-013	C-225
C409	30pF,500V, Mica	D4	13/C2	C-D	CD10ED3 00J03	C-236-30p
C410	1.5pF,50VDC, TubCer	C4	14/D2	ERI	301-000C0 H015ac	C-282-1.5p
C411	.25-1.5pF,2000V, Trimmer	D4	15/D2	EFJ	273-00.1-002	C-216
C412	.25-1.5pF,2000V, Trimmer	B1	16/E2	EFJ	273-0001-002	C-216
C413	.1µF,16VDC, CerD	C1	17/D3	CLB	UK-104	C-238-.1
C414	10µF,20V, ETT	C2	18/D3	ITT	TAPA 10 FK20	C-179-10
C415	.05µF,1000V, CerD	B2	19/E2	SPG	41C16 9AB	C-298-.05

DIODES (CR)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg/ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
CR101	Rectifier, Silicon	4/C4	29/B2	G-I	W04M	RF-46
CR102	Rectifier, Silicon	4/C2	30/B2	G-I	W04M	RF-46
CR103	Rectifier	4/C3	31/B3	G-I	KBP02	RF-36
CR104	Rectifier	1/G5	32/D3	MOT	1N4006	RF-38
CR105	Diode	4/D3	33/B5	F-I	1N4607	RF-41
CR106	Rectifier	4/E3	34/B5	MOT	1N4006	RF-38

DIODES (CR) (CON'T)
"200 Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 486 - Pg. 7-25)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
CR201	Diode,Diffused, Silicon	3/E2	5/E2	T-I	1N915	RF-28
CR202	Diode,Diffused, Silicon	3/E2	6/E2	T-I	1N915	RF-28

Model 1910 AC Voltage Option
"400" Series (Sch. 29960D - Pg. 7-25)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
CR401	Diode,Diffused, Silicon	F2	24/B3	T-I	1N915	RF-28
CR402	Diode,Diffused, Silicon	E2	25/B3	T-I	1N915	RF-28
CR403	Diode,Diffused, Silicon	D2	26/B3	T-I	1N915	RF-28
CR404	Diode,Diffused, Silicon	F5	27/B3	T-I	1N915	RF-28
CR405	Diode,Diffused, Silicon	E5	28/B3	T-I	1N915	RF-28
CR406	Diode,Diffused, Silicon	E5	29/B3	T-I	1N915	RF-28
CR407	Diode,Diffused, Silicon	B2	30/D2	T-I	1N915	RF-28
CR408	Diode,Diffused, Silicon	B2	31/E2	T-I	1N915	RF-28

DISPLAYS (DS)
"200" Series (Sch 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 486 - Pg. 7-25)

Circuit Desig.	Description	Sch. Pg/ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
DS201	Digital Display ±1	3/D2	8/B2	F-I	FND 561	DD-21
DS202	Digital Display	3/D2	9/C2	F-I	FND 560	DD-20
DS203	Digital Display	3/D2	10/C2	F-I	FND 560	DD-20
DS204	Digital Display	3/D2	11/D2	F-I	FND 560	DD-20
DS205	Digital Display	3/E2	12/D2	F-I	FND 560	DD-20
DS206	Digital Display	3/E2	13/E2	F-I	FND 560	DD-20

DISPLAYS (DS) (CON'T)
"200" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 486 - Pg. 7-25)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
DS207	Pilot Light, LED	3/D2	14/B3	H-P	5082-4494	PL-63

FUSES (F)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
F101	Fuse,SLO-BLO, 1/4A/250V/3AG	4/A5	36/A3	L-F	313. 250	FU-17
F101	Fuse,SLO-BLO, 1/8A/250V/3AG	4/A5	37/A3	L-F	313. 125	FU-20

CONNECTORS (J)
"1000" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
J1001	Connector,Female, 8 Contacts	Several	39/F5	A-P	929853-04	CS-356-4
J1002	Connector,Female, 8 Contacts	Several	40/F2	A-P	929853-04	CS-356-4
J1003	Connector, 3 pins, For line cord	4/Several		MOL	2139-3	CS-287-3
J1004	Connector,Female, 12 Contacts	Several	42/D5	A-P	929853-06	CS-356-6
J1005	Connector,Female, 12 Contacts	Several	43/B5	A-P	929853-06	CS-356-6
J1006*	Connector,Female, 12 Contacts	Several*	34/C3*	MOL	09-62-3121	CS-337-12
J1007*	Lug,Receptacle	B2*	35/F1*	AMP	42428-2	LU-90
J1008*	Lug, Receptacle	G2*	36/A3*	AMP	42428-2	LU-90
J1009	Connector,Female, Mini-PV	1/F1		BRG	75691-5	CS-236
J1010	Binding Post, Red	1/A2	46/G4	HHS	1517 Red	BP-11-2
J1011	Binding Post, Black	1/A2	47/G5	HHS	1517 Black	BP-11-0
J1012	Binding Post, Red	1/A1	48/H4	HHS	1517 Red	BP-11-2
J1013	Binding Post, Black	1/A1	49/H5	HHS	1517 Black	BP-11-0

*Located on Model 1910 AC Voltage Option (PC-496, Schematic 29960D).

RELAYS (K)
Model 1910 AC Voltage Option
"400" Series (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
K401	Relay, Reed Type	C6	40/C2	COT	UF-400 97	RL-56
K402	Relay, Reed Type	C5	41/C2	COT	UF-401 03	RL-57
K403	Relay, Reed Type	C4	42/C2	COT	UF-401 03	RL-57

CHOKES (L)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
L101	Choke,2.5MHz	2/E5	51/B3	NCC	SWD 100	CH-14

CONNECTORS (P)
"1000" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
P1001	Connector, Male, 8 Contacts	3/C3,4	PC-486 17/A3	A-P	929838-01-04	CS-355-4
P1002	Connector, Male, 8 Contacts	3/Several	PC-486 18/F3	A-P	929838-01-04	CS-355-4
P1003	Connector, Male, 3 Contacts	4/Several	PC-489 54/A4	MOL	A-2391-3A	CS-288-3
P1004	Connector, Male, 8 Contacts	3/C3,4	PC-490 12/B3	A-P	929838-01-06	CS-355-6
P1005	Connector, Male, 8 Contacts	3/Several	PC-490 13/E3	A-P	929838-01-06	CS-355-6
P1006	Connector, Male, Modified CS-338-12	1/Several	PC-489 55/D2	K-I		29995
P1007	Not Used					
P1008	Not Used					
P1009	Pin, 1 Contact	1/F1	PC-489 56/E3	K-I		24249

TRANSISTORS (Q)
"100" Series (Sch. 30162D-Pgs. 7-19, 20, 21, 22)
(PC-Board 489-Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg/ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
Q101	N-Chan,JFET	2/E6	60/C2	INT	ITE 4392	TG-77
Q102	Transistor,NPN, Case TO-106	1/G5	61/D2	K-I		28234
Q103	NPN,Silicon	1/H5	62/D2	T-I	TIP-49	TG-137
Q104*	Transistor,PNP Case TO-92	2/G3	63/C3	A-D	AD-820	TG-84
Q105	Transistor,NPN, Case TO-106	1/C4	64/D4	K-I		28234
Q106	Transistor,NPN, Case TO-106	1/C4	65/D4	K-I		28234
Q107	NPN,Switch	2/A5	66/D4	MOT	2N3904	TG-47
Q108	NPN,Switch	3/F3	67/E3	MOT	2N3904	TG-47
Q109	NPN,Switch	2/F3	68/C4	MOT	2N3904	TG-47
Q110	NPN,Switch	2/C3	69/D4	MOT	2N3904	TG-47
Q111	N-Chan,JFET Selected	1/G2	70/D4	K-I		TG-128
Q112	N-Chan,JFET Selected	1/G2	71/D4	K-I		TG-128
Q113	N-Chan,JFET Selected	2/D3	72/C4	K-I		TG-128
Q114	N-Chan,JFET Selected	2/B3	73/D4	K-I		TG-128
Q115	N-Chan,JFET Selected	2/B4	74/D4	K-I		TG-128
Q116	N-Chan,JFET Selected	1/E3	75/D4	K-I		TG-128
Q117	PNP,Silicon, Case TO-92	2/E1	76/B5	MOT	2N5087	TG-61
Q118	PNP,Silicon	2/C6	77/C5	MOT	2N3906	TG-84
Q119	NPN,Switch	2/C5	78/C5	MOT	2N3904	TG-47
Q120	N-Chan,JFET	2/B4	79/D5	K-I		TG-128
Q121	N-Chan,JFET	2/B3	80/D5	K-I		TG-128
Q122	N-Chan,JFET	1/E4	81/D5	K-I		TG-128
Q123	PNP,Silicon, Case TO-92	2/E2	82/B5	MOT	2N5087	TG-61
Q124	Transistor,NPN, Case TO-106	1/H4	83/D5	K-I		28234

TRANSISTORS (Q) (Con't)
"100" Series (Sch. 30162D-Pgs. 7-19, 20, 21, 22)
(PC-Board 489 -Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
Q125	Transistor,NPN, Case TO-106	1/H3	84/D5	K-I		28234
Q126	PNP,Silcon	4/D3	85/B5	T-I	TIP-32	TG-136
Q127	NPN,Case TO-92	4/D4	86/B5	MOT	2N5089	TG-62
Q128*	Transistor,PNP Case TO-92	2/G3	87/C4	MOT	2N3906	TG-84

*In earlier units Q104 is a dual transistor (TG-121) and Q128 is not used.

Model 1910 AC Voltage Option
"400" Series (Sch 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location.	Mfg. Code	Mfg. Desig.	Keithley Part No.
Q401	Transistor,NPN, Silcon, Case TO-92	E4	45/A2	MOT	2N5089	TG-62
Q402	Transistor,PNP, Silcon, Case TO-92	E4	46/B2	T-I	2N5087	TG-61
Q403	Transistor, PNP, Silcon, Case TO-92	F2	47/B3	T-I	2N5087	TG-61
Q404	Transistor,PNP Silcon, Case TO-92	D2	48/B3	T-I	2N3904	TG-47
Q405	Transistor,PNP, Silicon, Case TO-92	C2	49/C2	MOT	2N3906	TG-84

RESISTORS (R)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23,24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Code	Desig.	Keithley Part No.
R101	NOT USED					
R102	22Ω, 5%, 1/4W,CarbF	2/D5	93/B3	MEP	CR25*	R-76-22
R103	22Ω, 5%, 1/4W,CarbF	2/E5	94/B3	MEP	CR25*	R-76-22
R104	4.7kΩ, 5%, 1/4W,CarbF	2/E6	95/B3	MEP	CR25*	R-76-4.7K
R105	4.7KΩ, 5%, 1/4W,CarbF	2/E6	96/C3	MEP	CR25*	R-76-4.7K
R106	10MΩ, 10%, 1/4W,CarbF	2/D6	97/C3	MEP	CR25*	R-76-10M

RESISTOR (R) (Con't)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Design.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithly Part No.
R107	910Ω, .1%, 1/10W,MtF	1/C5	98/C3	ACI	VAR-.1% C6-910	R-263-910
R108	73.2kΩ, 1%, 1/8W,MtF	1/C5	99/C3	PRP	**	R-88-73.2K
R109	101.15Ω, .1%, 1/10W,MtF	1/C6	100/C3	ACI	VAR-.1% C6-101.15	R-263-101.15
R110	8.06kΩ, 1%, 1/8W,MtF	1/C6	101/C3	PRP	**	R-88-8.06K
R111	13.7kΩ, 1%, 1/8W,MtF	1/F3	102/C3	PRP	**	R-88-13.7K
R112	6.04kΩ, 1%, 1/8W,MtF	1/F3	103/C3	PRP	**	R-88-6.04K
R113	2.74kΩ, 1%, 1/8W,MtF	1/F2	104/C3	PRP	**	R-88-2.74K
R114	Selected-Part of matched set	1/E2	105/D3	K-I		29996
R115	Selected-Part of matched set	1/E2	106/D3	K-I		29996
R116	162kΩ, 1%, 1/8W,MtF	1/E3	107/D3	PRP	**	R-88-162K
R117	220kΩ, 10%, 1/2W,Comp	1/G5	108/D3	A-B	EB-224-10%	R-1-220K
R118	220kΩ, 10%, 1/2W,Comp	1/G5	109/D3	A-B	EB-224-10%	R-1-220K
R119	200kΩ, 1%, 8W	1/C2	110/E3	CAD	MS-281 200K	R-247-200K
R120	910kΩ, 5%, 1/4W,CarbF	1/G1	111/E3	MEP	CR25*	R-76-910K
R121	100Ω, 5%, 1/4W,CarbF	1/E2	112/D3	MEP	CR25*	R-76-100
R122	2kΩ, 10%, Cermet Trimmer	1/C6	113/C3	BRN	3386F-1-202	RP-97-2K
R123	20kΩ, 10%, Cermet Trimmer	1/C5	114/C3	BRN	3386F-1-203	RP-97-20K
R124	200Ω, 10%, Cermet Trimmer	1/C4	115/C3	BRN	3386F-1-201	RP-97-200
R125	100kΩ, 10%, Cermet Trimmer	1/E3	116/D3	BRN	3299W-1-104	RP-104-100k
R126	100Ω, 10%, Cermet Trimmer	1/E2	117/D3	BRN	3299W-1-101	RP-104-100
R127	Thick Film	1/E2,E3	118/D3	K-I		TF-84

RESISTORS (R) (CON'T)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No/ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
R128	Thick Film	1/H5	119/D3	K-I		TF-88
R129	Thick Film	1/Several	120/D3	K-I		TF-83
R130	20Ω, 10%,	1/C4	121/D3	BRN	3386F-1-200	RP-97-20
R131	2kΩ, 10%, Cermet Trimmer	1/C3	122/D3	BRN	3386F-1-202	RP-97-2k
R132	20kΩ, 10%, Cermet Trimmer	1/C3	123/D3	BRN	3386F-1-203	RP-97-20k
R133	Thick Film	2/Several	124/D4	K-I		TF-87
R134	9.09kΩ, 1%, 1/8W,MtF	2/C3	125/D4	PRP	**	R-88-9.09k
R135	1kΩ, 1%, 1/8W,MtF	2/C4	126/D4	PRP	**	R-88-1k
R136	47kΩ, 5%, 1/4W,CarbF	2/A4	127/D4	MEP	CR25*	R-76-47k
R137	Thick Film	2/Several	128/C4	K-I		TF-85
R138	4.99kΩ, 1%, 1/8W,MtF	2/C3	129/B4	PRP	**	R-88-4.99k
R139	47kΩ, 5%, 1/4W,CarbF	1/D4	130/E4	MEP	CR25*	R-76-47k
R140	47kΩ, 5%, 1/4W,CarbF	2/A5	131/D5	MEP	CR25*	R-76-47k
R141	330kΩ, 5%, 1/4W,CarbF	2/B3	132/D5	MEP	CR25*	R-76-330
R142	910kΩ, 5%, 1/4W,CarbF	1/E4	133/E5	MEP	CR25*	R-76-910k
R143	910kΩ, 5%, 1/4W,CarbF	1/G4	134/D5	MEP	CR25*	R-76-910k
R144	910kΩ, 5%, 1/4W,Comp	1/G3	135/E5	A-B	CB-914-5%	R-282-910k
R145	270Ω, 5%, 1/4W,CarbF	4/D4	136/B5	MEP	CR25*	R-76-270
R146	Thick Film	2/Several	137/C5	K-I		TF-86
R147	390Ω, 5%, 1/4W,CarbF	3/C2	138/F5	MEP	CR25*	R-76-390
R148	910kΩ, 5%, 1/4W,CarbF	1/C4	139/E3	MEP	CR25*	R-76-910k
R149	820kΩ, 5%, 1/4W,CarbF	1/C4	140/E3	MEP	CR25*	R-76-820k
R150	630kΩ, 5%, 1/4W,CarbF	1/D3	141/E4	MEP	CR25*	R-76-630k

RESISTORS (R) (CON'T)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
R151	100kΩ, 10%, 1W,Comp	1/A2	142/G4	A-B	GB-104-10%	R-2-100k
R152	100kΩ, 10%, 1W,Comp	1/A2	143/G5	A-B	GB-104-10%	R-2-100k
R153	1.5MΩ, 10%, 1/4W,CarbF	2/D3	144/C5	MEP	CR25*	R-76-1.5M
R154	4.02kΩ, 1%, 1/8W,MtF	1/F5	145/E4	PRP	**	R-88-4.02k
R155	35.7kΩ, 1%, 1/8W,MtF	1/F5	146/D4	PRP	**	R-88-35.7k
R156	24.3kΩ, 1%, 1/8W,MtF	1/F6	147/D4	PRP	**	R-88-24.3k
R157	27kΩ, 5%, 1/4W, CarbF	2/A4	148/D4	MEP	CR25*	R-76-27k
R158	10Ω, 5%, 1/4W,CarbF	4/D2	149/B5	MEP	CR25*	R-76-10
R159	10Ω, 5%, 1/4W,CarbF	4/D3	150/B5	MEP	CR25*	R-76-10

"200" Series (Sch 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-25)

R201	Thick Film	3/F2	23/B3	K-I		TF-90
R202	Thick Film	3/D2	24/C3	K-I		TF-82
R203	Thick Film	3/E2	25/E3	K-I		TF-91

"300" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

R301	3.3kΩ, 5%, 1/4W,CarbF	3/B5	16/B1	MEP	CR25*	R-76-3.3K
R302	3.3kΩ, 5%, 1/4W,CarbF	3/A3	17/B2	MEP	CR25*	R-76-3.3K
R303	3.3kΩ, 5%, 1/4W,CarbF	3/B5	18/B2	MEP	CR25*	R-76-3.3K

Model 1910 AC Volts Option
"400" Series (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
R401	Pot,50Ω, 10%, 3/4W	F3	52/B2	BRN	3006P 50	RP-89-50
R402	249Ω, .1%, 1/10W,WW	E4	53/B2	IRC	MAR6 249	R-241-249
R403	2191Ω, .1%, 1/10W,WW	F3	54/B2	IRC	MAR6 2191	R-241-2191

RESISTORS (R) (CON'T)
Model 1910 AC Volts Option
"400" Series (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
R404	150kΩ, 5%, 1/4W,CarbF	G2	55/B2	MEP	CR25*	R-76-150K
R405	150kΩ, 5%, 1/4W,CarbF	F2	56/B2	MEP	CR25*	R-76-150K
R406	10kΩ, 5%, 1/4W,CarbF	F4	57/B3	MEP	CR25*	R-76-10K
R407	264.2Ω, 5%,Part of Match Set	D6	58/B2	K-I		R-266
R408	240Ω, 5%, 1/4W,CarbF	D2	59/B3	MEP	CR25*	R-76-240
R409	Pot, 100Ω, 10%, 3/4W	D5	60/B2	BRN	3006P 100	RP-89-100
R410	Pot, 10kΩ, 10%, 3/4W	D3	61/B2	BRN	3006P 10K	RP-89-10K
R411	Pot,1kΩ, 10%, 3/4W	D4	62/C2	BRN	3006P 1K	RP-89-1K
R412	4.75kΩ, .5%,Part of Matched Set	C5	63/B2	K-I		R-266
R413	54.7KΩ, .5%, Film	C4	64/B2	K-I		R-275-54.7K
R414	Thick Film,5%, Special	Several	65/C2	K-I		TF-72
R415	495kΩ, .5%,Part of Matched Set	C3	66/C2	K-I		R-266
R416	33kΩ, 5%, 1/4W,CarbF	D4	67/D2	MEP	CR25*	R-76-33K
R417	47kΩ ,5%, 1/4W,CarbF	B1	68/E2	MEP	CR25*	R-76-47K
R418	2MΩ, .5%,Part of Matched Set	B2	69/E2	K-I		R-266

* Manufacturers Designation includes Part Description; e.g., CR 25, 22, 5%, 1/4W, Comp. for R102

** Manufacturers Designation is GP 1/4, 1%, T100, Resistance Value.

SWITCHES (S)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
S101	11 Station Pushbutton	Several	194/E3-5	K-I		~~29994~~ SW-415
S102	Switch DPDT	4/A2	195/A4	C-W	GF326-0006	SW-397

TRANSFORMER (T)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
T101	Transformer, Standard V3rsion	4/B3	178/B2	K-I		TR-173
T101	Transformer, Japanese Version	4/B3	179/B2	K-I		TR-177

INTERGRATED CIRCUITS (U)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
U101	Selected-Part of Matched Set	1/E3	153/C2	K-I		29996
U102	BI-FET,OP-Amp (Selected IC-176)	1/F3	154/D2	K-I		30154
U103	BI-FET,Op-Amp (Selected IC-176)	1/G5	155/D2	K-I		30154
U104	Hex Inverter	2/Several	156/B3	NAT	74LS04	IC-186
U105	Up/Down Counter	2/F6	157/C3	MOT	MC74LS 193P	IC-214
U106	Dual D-Type Flip-Flop	2/F3,G3	158/B3	MOT	MC74S 74P	IC-216
U107	Voltage Comparator	2/G2	159/C4	NAT	LM311N	IC-173
U108	Transistor array, 14-pin DIP (Selected IC-53)	2/Several	160/B4	K-I		29198
U109	BI-FET,Op-Amp	2/E3	161/C4	NAT	LF351N	IC-176
U110	Transistor array, 14-pin DIP (Selected IC-53)	2/E3,E4	162/C4	K-I		29198
U111	BI-FET,Op-Amp	2/C5	163/C4	NAT	LF351N	IC-176
U112	Itegrated Circuit (Selected IC-218)	2/C3	164-D4	K-I		30167
U113	BI-FET,Op-Amp (Selected IC-176)	2/D3	165/C5	K-I		30163
U114	BI-FET,Op-Amp (Selected IC-176)	2/E1	166/C5	K-I		30154
U115	Voltage Quad Comparator	2/A5,A6	167/D5	NAT	LM339	IC-219
U116	Quad 2-Input Nand Gate	2/Several	168/B3	NAT	74LS00	IC-163

INTEGRATED CIRCUITS (U) (CON'T)

"200" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 486 - Pg. 7-25)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
U201	MOS to LED segment and Digit Driver	3/D3	28/B2	F-I	75492	IC-169
U202	BCD to seven segment Latch/Decoder/Driver	3/E2	29/E2	MOT	MC145 11CP	IC-168

"300" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
U301	Dual 4 Bit Decade and Binary Counter	3/A6	21/B1	T-I	SN74LS 390	IC-212
U302	8 Bit Microprocessor	3/A4	22/C2	MOT	MC6802	LSI-18
U303	Peripheral Interface Adaptor	3/B4	23/C3	AMI	S6820L	LSI-8
U304*	4096 Bit Cmos UV E-PROM	3/A2	D2	K-I		PRO-102-02
U305*	4096 BIT CMOS UV E-PROM	3/B2	25/D3	K-I		PRO-101-02
U305*	1024 X 8 BIT ROM	3/B2	25/D3	K-I		LSI-23
U306	Quad 2-Input Nand Gate	3/Several	26/E2	NAT	74L500	IC-163
U307	Dual 4 BIT Decade and Binary Counter	3/E6	27/E2	T-I	SN74LS 393	IC-213
U308	Dual 4 BIT Decade and Binary Counter	3/B6	28/E2	T-I	SN74LS 393	IC-213
U309	Integrated Circuit Flip-Flop	3/F5	29/E2	NSC	DM74LS 74N	IC-144
U310	Quadruple 2-Input Positive-And Gate	3/Several	30/E2	NAT	DM74L 508N	IC-215
U311	Quad 2-Input Nand Gate	3/Several	31/E3	NAT	74L500	IC-163

* Revision A,B and some C Digital Boards use two E-PROMS (IC-220 Programmed). All later revisions use one ROM (LSI-23).

Model 1910 AC Voltage Option
"400" (Sch. 29960D - Pg. 7-27)
(PC-Board 496 - Pg. 7-28)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
U401	Monolithic JFET	C2	72/D2	NAT	LF356H	IC-152

VOLTAGE REGULATORS (VR)
"100" Series (Sch 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
VR101	Three Terminal Positive Voltage Regulator	4/D2	170/B3	MOT	MC-7815 CP	IC-96
VR102	Three Terminal Negative Voltage Regulator	4/E3	171/B4	NAT	LM79 15CT	IC-174
VR103	Zener Diode	1/D4	172/E4	MOT	IN751	DZ-59
VR104	Three Terminal +5V Voltage Regulator	4/D4	173/B5	MOT	MC7805 CP	IC-93
VR105	Zener Diode	2/C5	174/C5	MOT	IN4577	DZ-58
VR106	Zener Diode	2/C6	175/C5	MOT	IN4577	DZ-58
VR107	Zener Diode	2/C4	176/C5	SIE	IN4571	DZ-60

CRYSTAL (Y)
"100" Series (Sch. 30162D - Pgs. 7-19, 20, 21, 22)
(PC-Board 489 - Pgs. 7-23, 24)

Circuit Desig.	Description	Sch. Pg./ Location	PC-Board Item No./ Location	Mfg. Code	Mfg. Desig.	Keithley Part No.
Y101	Crystal,4.0MHz	2/D6	181/B2	CTS	MP040	CR-10

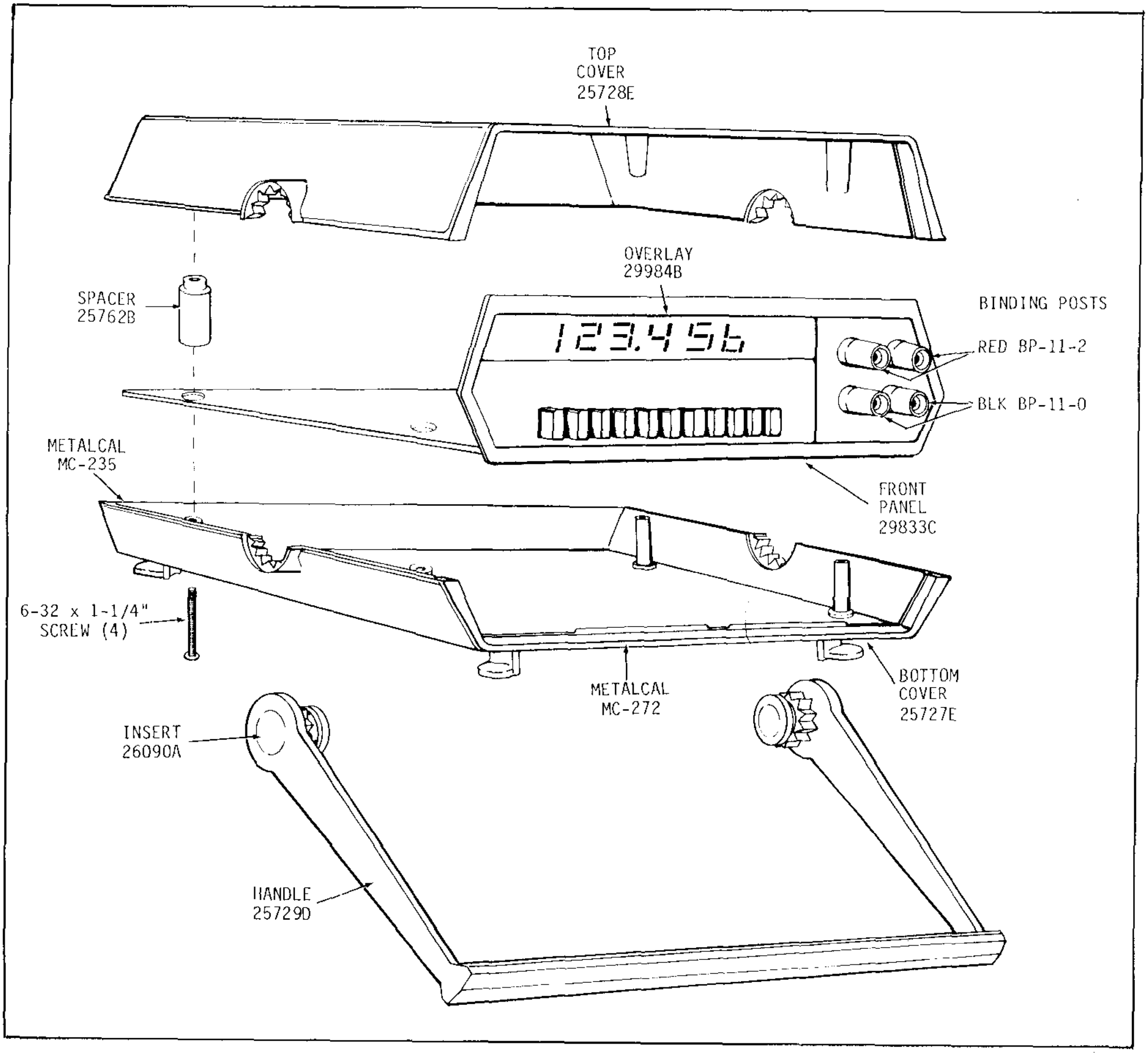
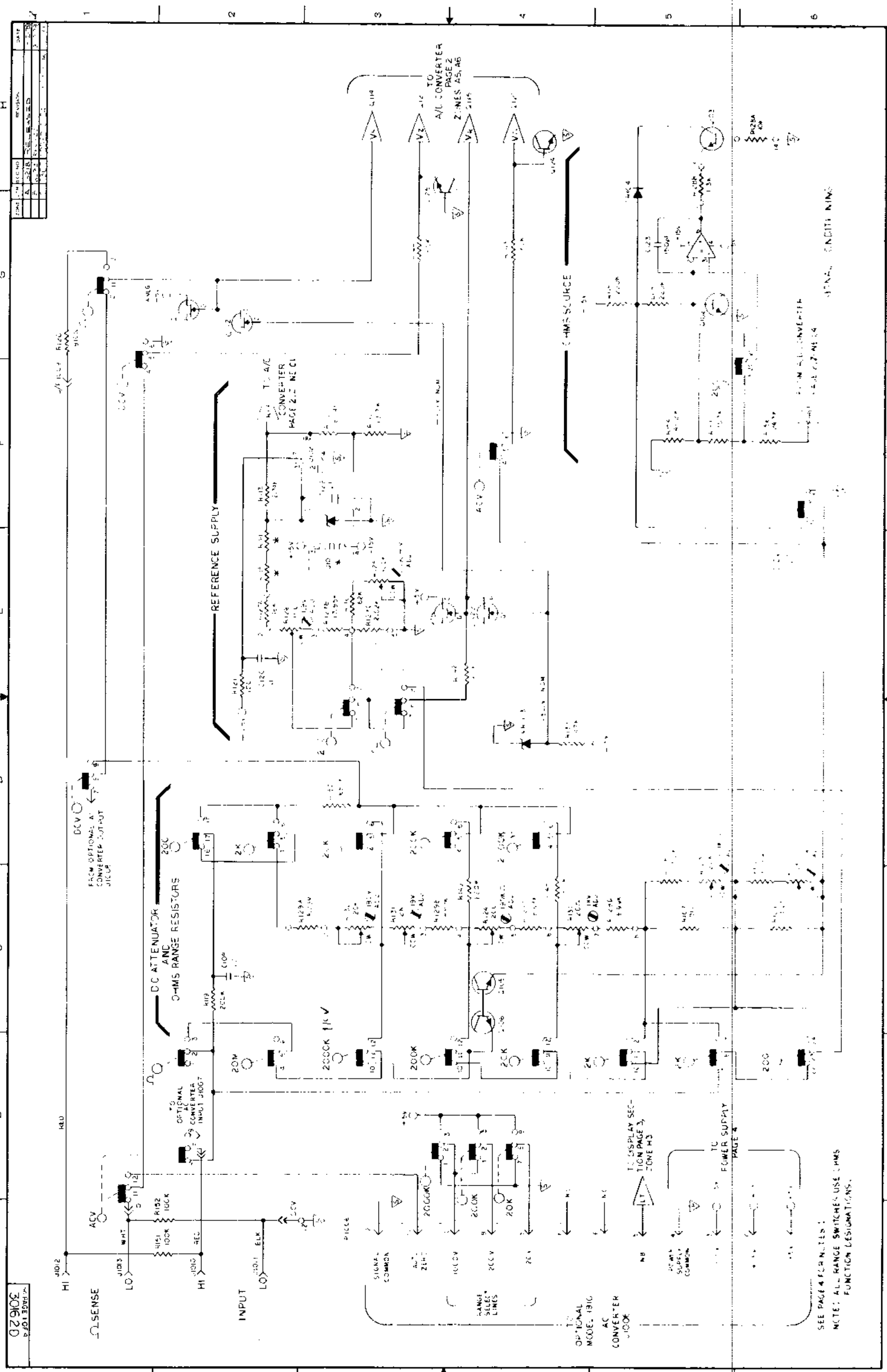
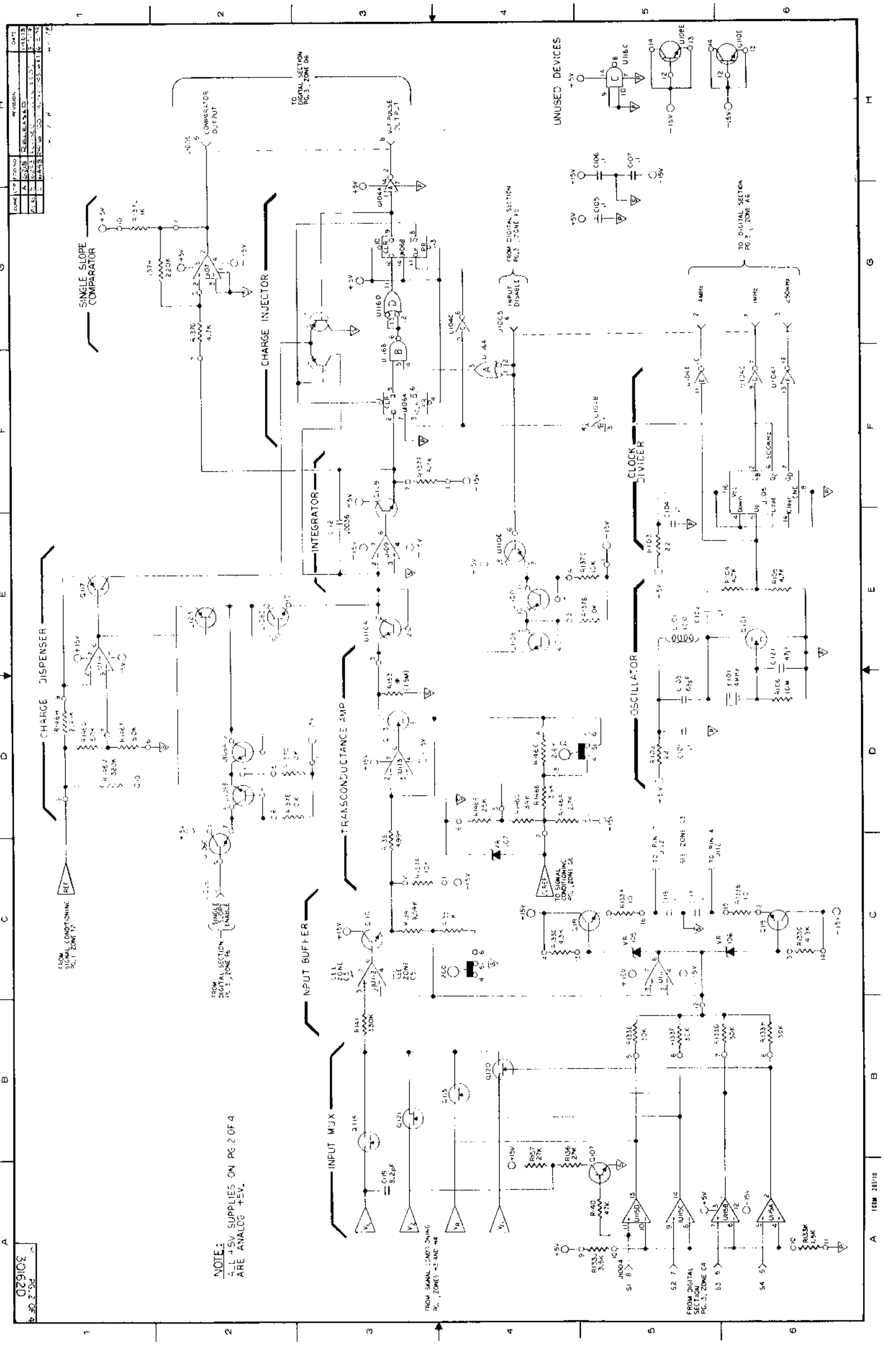
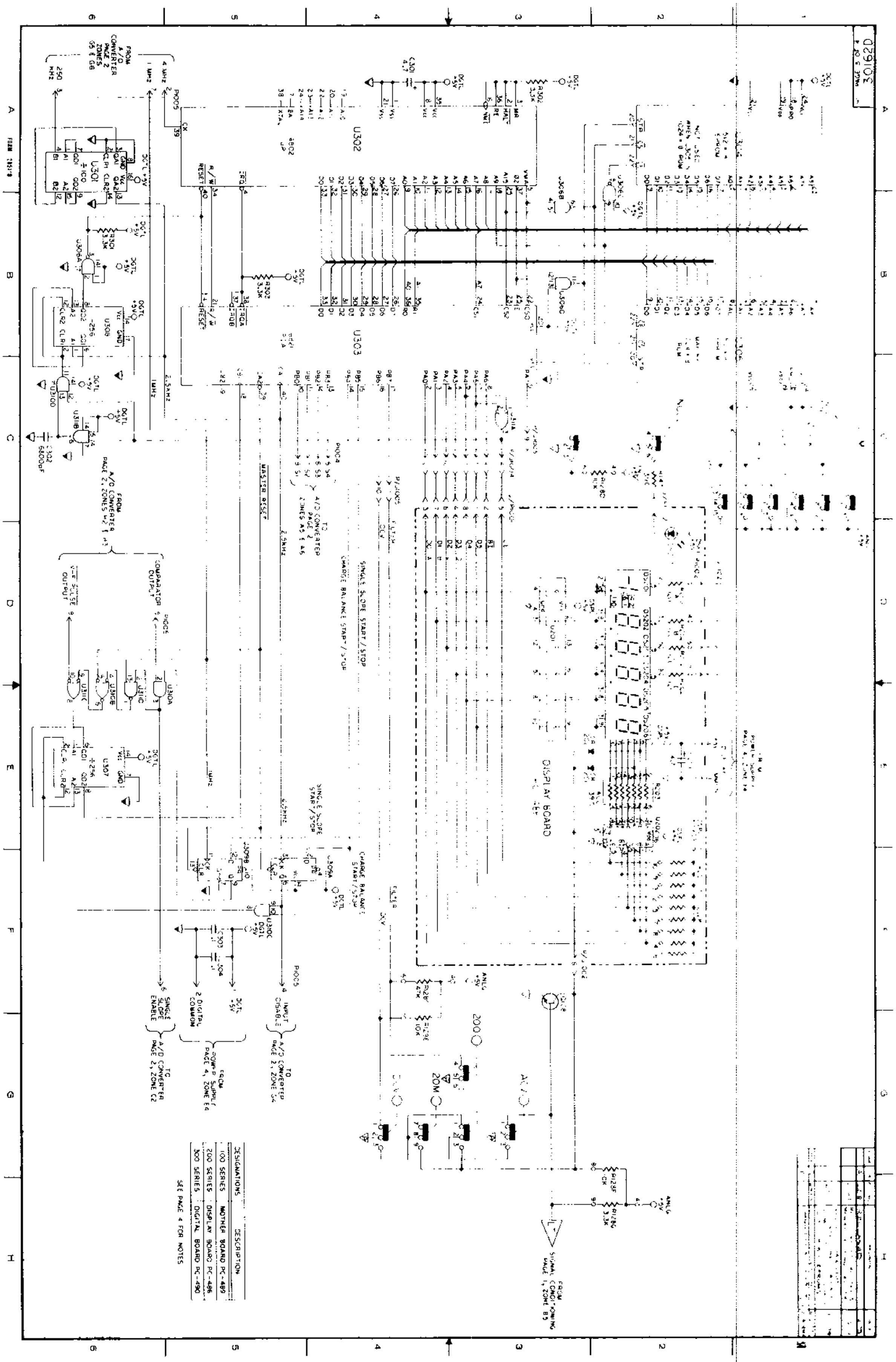
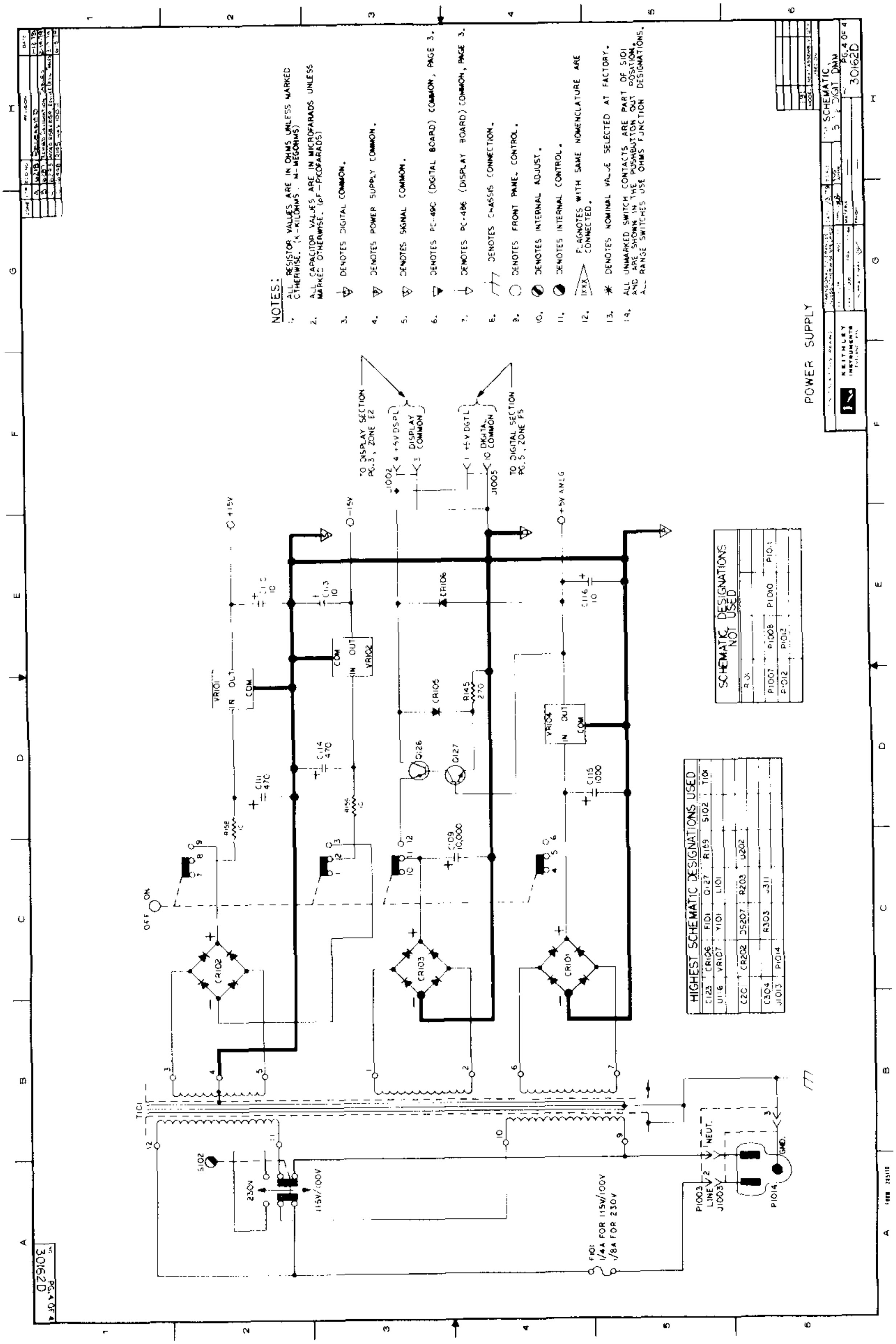


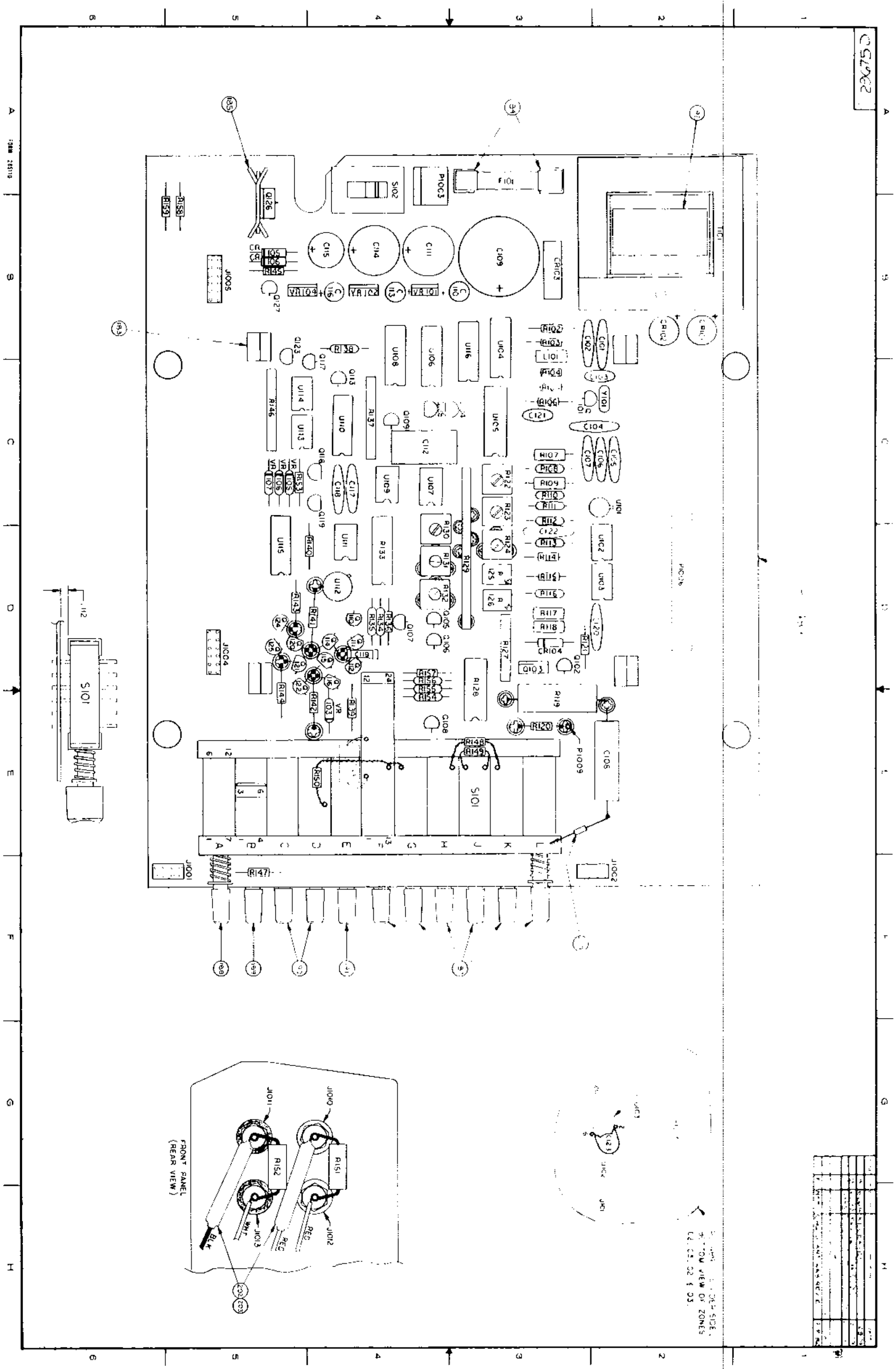
FIGURE 7-1. Covers and Panels


REFERENCE SUPPLY
DC ATTENUATOR AND OHMS RANGE RESISTORS
OHMS SOURCE
INPUT
Ω SENSE
30162D


UNUSED DEVICES
SINGLE SLOPE COMPARATOR
CHARGE INJECTOR
INTEGRATOR
CLOCK DIVIDER
CHARGE DISPENSER
TRANSCONDUCTANCE AMP
OSCILLATOR
INPUT BUFFER
INPUT MUX
NOTE: ALL +5V SUPPLIES ON PG 2 OF 4 ARE ANALOG +5V.
30162D


30162D
U301
U302
U303
U307
U308
DISPLAY BOARD
MASTER RESET
SINGLE SLOPE START/STOP
CHARGE BALANCE START/STOP
SEE PAGE 4 FOR NOTES


POWER SUPPLY
KEITHLEY INSTRUMENTS
SCHEMATIC
30162D
HIGHEST SCHEMATIC DESIGNATIONS USED
SCHEMATIC DESIGNATIONS NOT USED
NOTES:


FRONT PANEL (REAR VIEW)
S101
S102
F101
J1001
J1002
J1004
J1005
J1010
J1011
J1012
J1013

ZONE	LTR	ECO NO	REVISION	DATE
	A	6264	RELEASED	1-29-79
	B	6293	REVISED (SEE ECO)	3-7-79
	C	6448	[illegible]	[illegible]
M	D	6901	ADDED [illegible]	6-21-79
	E	7267	[illegible]	[illegible]
	F	8551	CHG'D. PC ART. WAS REV E	9-9-82

29675D

ITEM	PART NO	SCHEM DESIG	ZONE
1	30120B	PC-499	[illegible]
2			
3			
4			
5	C-238-.1	C101	B2
6	"	C102	B2
7	C-64-68P	C103	
8	C-238-.1	C104	
9	"	C105	
10	"	C106	
11	"	C107	
12	C-286-.01	C108	
13	C-304-10,000	C109	
14	C-179-10	C110	
15	C-276-470	C111	
16	C-138-3600	C112	
17	C-179-10	C113	
18	C-276-470	C114	
19	C-304-1,000	C115	
20	C-179-10	C116	
21	C-238-.1	C117	
22	"	C118	
23	C-282-8.2	C119	
24	C-238-.1	C120	
25	C-64-47pF	C121	
26	C-238-.1	C122	
27	C-64-50pF	C123	
28	[illegible]	C124	
29	RF-46	CR101	
30		CR102	
31	RF-36	CR103	
32	RF-38	CR104	
33	RF-41	CR105	
34	RF-38	CR106	
35			
36	FU-17 (117V) OR	F101	
37	FU-20 (230V)		
38			
39	CS-356-4	J1001	
40	"	J1002	
41			
42	CS-356-6	J1004	
43	"	J1005	
44			
45			
46	BP-11-2	J1010	
47	BP-11-0	J1011	
48	BP-11-2	J1012	
49	BP-11-0	J1013	

ITEM	PART NO	SCHEM DESIG	ZONE
50			
51	C4-14	[illegible]	B3
52			
53			
54	CS-288-3	P1003	A4
55	29995A	[illegible]	[illegible]

ITEM	PART NO	SCHEM DESIG	ZONE
99	R-88-73.2K	R108	C3
100	R-263-101.15	R109	C3
101	R-88-3.06K	R110	C3
102	R-88-13.7K	R111	C3
103	R-88-6.04K	R112	C3

Rev C or below
can use
DD-30 & DD-31
for DD-16 & DD-17

Rev D DD-20
use DD-30. DD-21
no replacement
Rev E use
DD-30 DD-31

ITEM	PART NO	SCHEM DESIG	ZONE
148	R-76-27K	R157	D4
149	R-76-[illegible]	R158	[illegible]
150		R159	E5
151			
152			
153	[illegible]	U101	C2
154	30154A	U102	D2
155		U103	D2
156	IC-86	U104	B3
157	IC-24	U105	C3
158	IC-216	U106	B3
159	IC-73	U107	C4
160	29199A	U108	B4
161	IC-76	U109	C4
162	29198A	U110	C4
163	IC-76	U111	C4
164	30167A	U112	D4
165	30163A	U113	C5
166	30154A	U114	C5
167	IC-219	U115	C5
168	IC-163	U116	B3
169			
170	IC-96	VR101	B3
171	IC-174	VR102	B4
172	DZ-59	VR103	E4
173	IC-93	VR104	B5
174	DZ-58	VR105	C5
175	"	VR106	C5
176	DZ-60	VR107	C5
177			
178	TR-173	T101	B2
* 179	TR-177	T101	B2
180			
181	CR-10	Y101	B2
182			
183	FA-99	4 REQ'D	B2, B2, B2, B2
184	FH-12	2 REQ'D	A3
185	HS-2	1 REQ'D	A5
186			
187	29465C-2	6 REQ'D	F3
188	29465C-3	1 REQ'D	F5
189	29465C-4	1 REQ'D	F5
190	29465C-6	2 REQ'D	F5
191	29465C-7	1 REQ'D	F4
192	MC-221	1 REQ'D	A2
193			
194	29994B	S101	E5-5
195	SW-397	S102	A4
196			

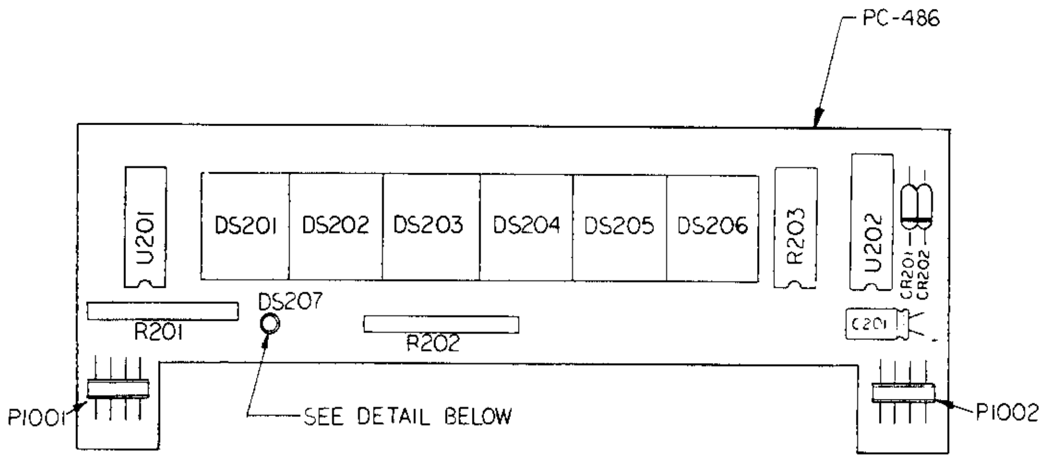
ITEM	PART NO	SCHEM DESIG	ZONE
197			
198			
199			
200			
201	[illegible]		F3
202	[illegible]		H5
203	[illegible]		H5
204			
205			
206			
207			
208			
209			
210			
211			

Item 202: 4 REQ'D; item 203: 2 REQ'D

* NOTE: FOR 100V JAPANESE VERSION SUSTITUTE TR-177

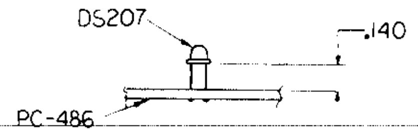
FORM 285110

ZONE	LTR	ECO NO.	REVISION	DATE
	A	6269	RELEASED	-29-79
	D	6913	CHANGED ARTWORK	2-4-80
	E	6927	CHG'D ITEM 3 WAS C-179-4.7	6-5-80



ITEM	PART NO	SCHEM DESIG	ZONE
1	29668C	PC-486	E1
2			
3	C-314-4.7	C201	E3
4			
5	RF-28	CR201	E2
6	"	CR202	E2
7			
8	DD-21	DS201	B2
9	DD-20	DS202	C2
10	"	DS203	C2
11	"	DS204	D2
12	"	DS205	D2
13	"	DS206	E2
14	PL-63	DS207	B3
15			
16			
17	CS-355-4	P1001	A3
18	"	P1002	F3
19			
20			
21			
22			

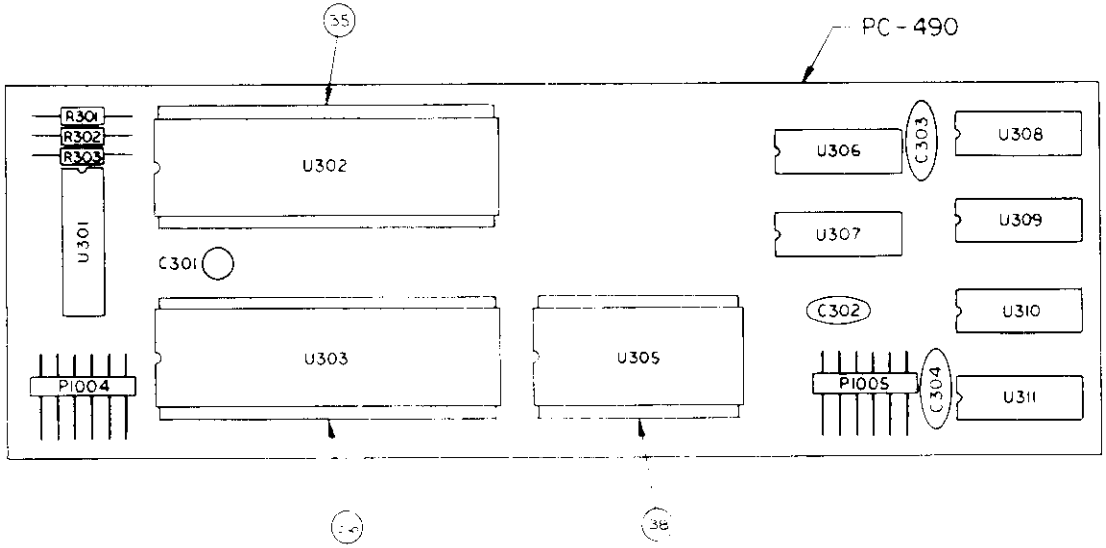
ITEM	PART NO	SCHEM DESIG	ZONE
23	TF-90	R201	B3
24	TF-82	R202	C3
25	TF-91	R203	E3
26			
27			
28	IC-169	U201	B2
29	IC-168	U202	E2
30			
31			
32			



DS207 MOUNTING DETAIL

29679C

ZONE	LTR	ECO NO	REVISION	DATE
	B	6281	REVISED & REDRAWN	2-14-79
	C	6311	[illegible]	3-15-79



ITEM	PART NO	SCHEM DESIG	ZONE
1	29680[illegible]	PC-490	E1
2			
3			
4	C-179-4.7	C301	B2
5	C-22-.6800[illegible]	C302	E2
6	C-238-[illegible]	C303	E2
7		C304	E3
8			
9			
10			
11			
12	CS-355-6	P1004	B3
13		P1005	E3
14			
15			
16	R-76-33K	R301	B1
17		R302	B2
18		R303	B2
19			
20			

ITEM	PART NO	SCHEM DESIG	ZONE
21	[illegible]-212	U301	B1
22	LSI-18	U302	C2
23	LSI-18	U303	C3
24			
25	LSI-23	U305	D3
26	[illegible]-163	U306	E2
27	[illegible]-213	U307	E2
28		U308	E2
29	[illegible]-144	U309	E2
30	[illegible]-215	U310	E2
31	[illegible]-163	U311	E3
32			
33			
34			
35	[illegible]-84-40		[illegible]
36			C3
37			
38	[illegible]-48		D3
39			
40			

MODEL	NEXT ASSEMBLY	QTY
191		

USED ON

DO NOT SCALE THIS DRAWING

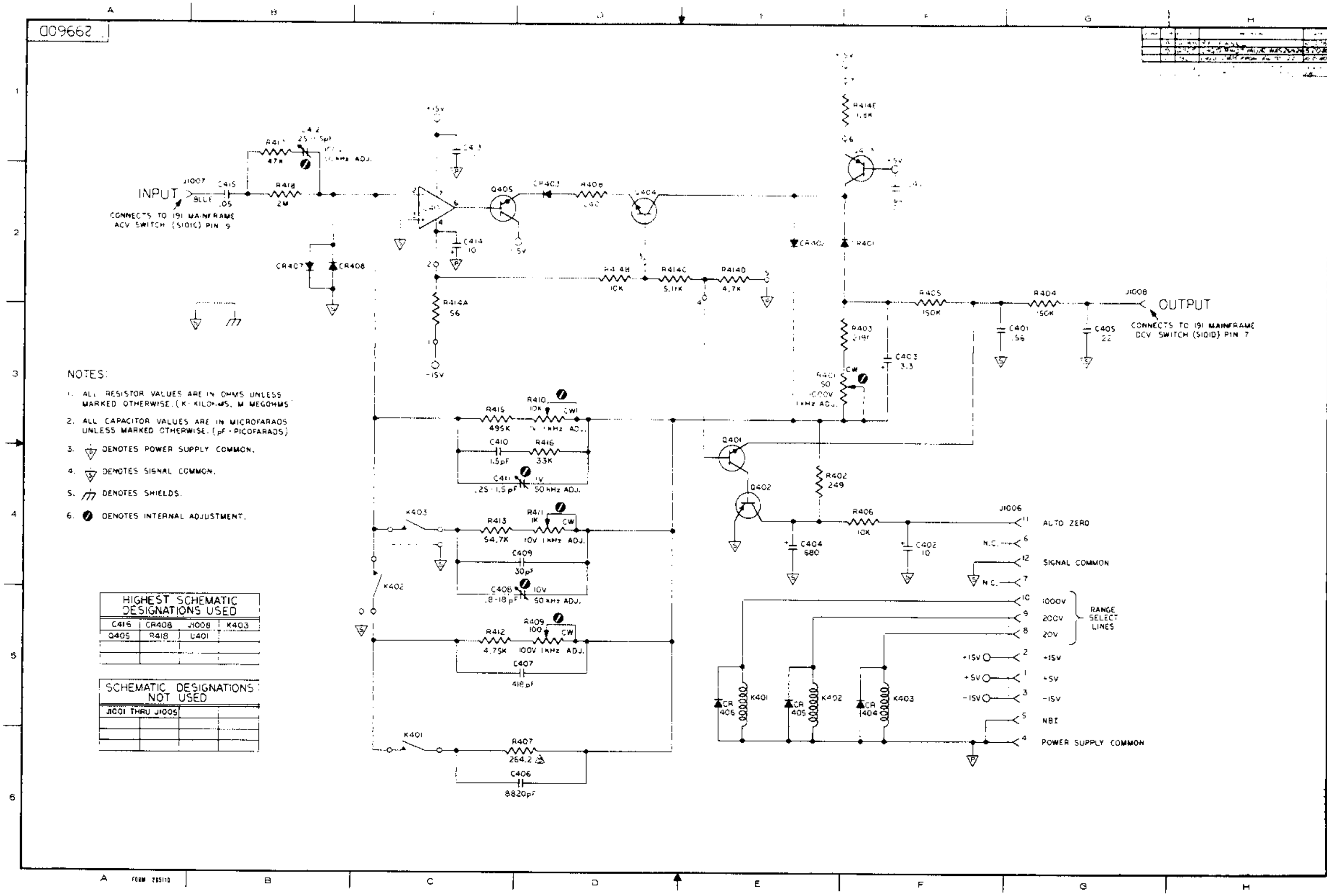
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG = ±1°
XXX = ± .005 FRAC = ±1/64
SURFACE MAX

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DATE 2-7-79 SCALE 2:1
DRN R. SMITH ENG APPR
MATERIAL
FINISH

TITLE COMPONENT LAYOUT, PC-490

NO 29679C



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K = KILOHMS, M = MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF = PICOFARADS)
3. ⏚ DENOTES POWER SUPPLY COMMON.
4. ⏚ DENOTES SIGNAL COMMON.
5. ⫽ DENOTES SHIELDS.
6. ⊘ DENOTES INTERNAL ADJUSTMENT.

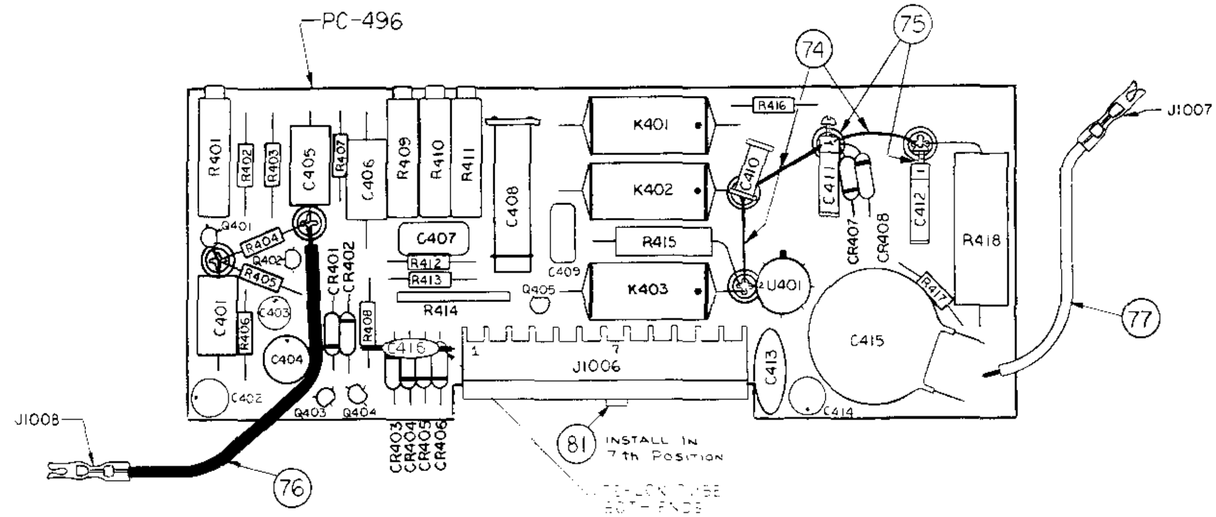
HIGHEST SCHEMATIC DESIGNATIONS USED			
C415	CR408	J1008	K403
Q405	R418	U401	

SCHEMATIC DESIGNATIONS NOT USED
J1001 THRU J1005

FORM 285110

ZONE	LTR.	ECO NO	REVISION	DATE
	A	6148	RELEASED	10-20-78
	B	6533	C409 WAS C-77-30pF	12-2-78
	C	6327	[illegible]	3-14-79
	D	6925	CHG'D PC ARTWORK FROM REV C TO REV D	5-20-80
	E	7301	CHG'D ITEM 9 FROM C-201-.56 TO C-201-.22	10-21-80
	F	7661	CHG'D ITEM 8 FROM C-297-680 TO C-333-680	6-10-81
	G	7784	[illegible]	[illegible]
	H	7852	CHG'D ARTWORK FROM REV D TO REV E. C402 & C414 FROM C-179-10 TO C-314-10 AND C403 FROM C-179-3.3 TO C-321-3.3	10-28-81
	J	8323	C404 WAS C-333-680	4-19-82

No. 29956C



ITEM	PART NO	SCHEM DESIG	ZONE	ITEM	PART NO	SCHEM DESIG	ZONE	ITEM	PART NO	SCHEM DESIG	ZONE
1	29956 3	PC-496	B1	30	RF-28	CR407	D2	59	R-76-240	R408	B3
2				31	"	CR408	E2	60	RP-89-100	R409	B2
3				32		—		61	RP-89-10K	R410	B2
4				33				62	RP-89-1K	R411	C2
5	C-201-.56	C401	B2	34	CS-337-12	J1006	C3	63	R-266-4.75K	R412	B2
△H 6	C-314-10	C402	B3	35	LU-90	J1007	F1	64	R-275-54.7K	R413	B2
△H 7	C-321-3.3	C403	B3	36	"	J1008	A3	65	TF-72	R414	C2
△F 8	C-297-680	C404	B3	△ 37				66	R-266-495K	R415	C2
△E 9	C-201-.22	C405	B2	38				67	R-76-33K	R416	D2
10	C-299-8820pF	C406	B2	39				68	R-76-47K	R417	E2
11	C-278-418pF	C407	C2	40	RL-56	K401	C2	69	R-266-2M	R418	E2
12	C-225	C408	C2	41	RL-57	K402	C2	70			
△B 13	C-236-30pF	C409	C2	42	"	K403	C2	71			
14	C-282-1.5pF	C410	D2	43				72	IC-152	U401	D2
15	C-216	C411	D2	44				73			
16	C-216	C412	E2	45	TG-62	Q401	A2	74	#22 GA BUSS WIRE	3 REQ'D	D2
17	C-238-.1	C413	D3	46	TG-61	Q402	B2	75	WA-53	2 REQ'D	D2/E2
△H 18	C-314-10	C414	D3	47	"	Q403	B3	76	SC-55 (BRN)	—	B3
19	C-298-.05	C415	E2	48	TG-47	Q404	B3	77	SC-55 (BLUE)	—	F2
△ 20	C-64-10P	[illegible]	[illegible]	49	TG-84	Q405	C2	78	30124A	—	F4
21				50				79	30122A	—	G4
22				51				80	GR-1	2 REQ'D	F5
23				52	RP-89-50	R401	B2	81	CS-345	—	C3
24	RF-28	CR401	B3	53	R-241-249	R402	B2	82	MC-255-3	—	F4
25	"	CR402	B3	54	R-241-2191	R403	B2				
26	"	CR403	B3	55	R-76-.50K	R404	B2				
27	"	CR404	B3	56	"	R405	B2				
28	"	CR405	B3	57	R-76-10K	R406	B3				
29	"	CR406	B3	58	R-266-264.2	R407	B2