HP 740B

# 740B
# DC STANDARD/ DIFFERENTIAL VOLTMETER

## OPERATING AND SERVICE MANUAL

HEWLETT hp PACKARD

HP 740B

HEWLETT-PACKARD

## CERTIFICATION

*The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.*

## WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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OPERATING AND SERVICE MANUAL

(HP PART NO. 00740-90002)

# MODEL 740B
# DC STANDARD/DIFFERENTIAL VOLTMETER

SERIALS PREFIXED: 610-, 722-


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DC STANDARD

RANGES:

Output Voltage: 0 to 1000* volts in 4 decade ranges with outputs as follows:

- 0 to 1.000000 volts in 1 $\mu$V steps
- 0 to 10.00000 volts in 10 $\mu$V steps
- 0 to 100.0000 volts in 100 $\mu$V steps
- 0 to 1000.000 volts in 1 mV steps

PERFORMANCE RATING:

Accuracy: $\pm$(0.002% of setting + 0.0004% of range) at 23°C $\pm$ 1°C, less than 70% relative humidity, constant load.

Stability: Rated accuracy is met after 1 hour warm-up period, with a 30-day calibration cycle.

Short Term: 1 ppm of setting + 0.5 ppm of range/hour; 5 ppm of setting + 1 ppm of range/day. (< 100 volts output.)

Temp. Coefficient: Less than (2 ppm of setting or 1 ppm of range whichever is greater) per °C; 10°C to 40°C.

OUTPUT CHARACTERISTICS:

Output Current: Current limiter continuously adjustable 5-50 mA nominal. Max. output current, 50 mA decreasing linearly to 20 mA at 1000 volts output.

Output Resistance: Less than (0.0002 + 0.0001 Eo) ohms at DC.

Load Regulation: Less than (0.0005% + 10 $\mu$V) change, no load to full load.

Line Regulation: Less than $\pm$(0.0005% of setting + 0.0001% of range) for 10% line voltage change.

Noise and Hum: .01 to 1 Hz: less than 1 ppm of range; 1 Hz to 1 MHz: 100 dB below full scale or 100 $\mu$V rms, whichever is greater.

Output Terminals: Plus and minus output, plus and minus sense, circuit guard, and chassis ground. Banana jacks mounted on remote terminal box (Accessory 11055B, furnished). Output and sense terminals are solid copper, gold flashed. A maximum of 500 Vdc may be applied between chassis ground and guard or circuit ground.

Zero Control Limits: $\pm$0.001% of range nominal.

Readout: 5 digital display tubes indicate first 5 digits; meter displays 6th digit.

DC DIFFERENTIAL VOLTMETER

Voltage Ranges: 1 mV to 1000 V* DC in 7 decade ranges.

Resolution: Null ranges give full scale indication of $\pm$0.01% of range. Max. resolution 1 ppm at full scale. Max. usable null sensitivity: 1 $\mu$V full scale.

PERFORMANCE RATING:

Accuracy: $\pm$ (0.005% of reading + 0.0004% of range + 1 $\mu$V) at 23°C $\pm$1°C, less than 70% relative humidity.

Stability: Rated accuracy is met after a 1 hour warm-up period, with a 30-day calibration cycle.

Short-term: 1 ppm/hr., 5 ppm/day exclusive of zero drift. (< 100 volts input.)

Zero stability: (1 ppm of range + 2 $\mu$V)/day.

Temp. Coefficient: Less than $\pm$(2 ppm of reading + 1 $\mu$V)/ °C, 10°C to 40°C.

Line Regulation: Less than $\pm$(0.001% of reading + 2 $\mu$V) change for 10% line voltage change.

# SECTION I
# GENERAL INFORMATION

## 1-1. INTRODUCTION.

1-2. This section contains general information about the Model 740B DC Standard/Differential Voltmeter.

## 1-3. DESCRIPTION.

1-4. The Hewlett-Packard Model 740B is a precision multifunction instrument that operates as a dc standard voltage source, a dc differential voltmeter, a high impedance dc voltmeter and a dc power and voltage amplifier. The instrument is designed for use in both the standards laboratory and the field.

### 1-5. DC STANDARD.

1-6. When used as a dc standard, the Model 740B provides output voltages from 0 to 1000 V in 4 decade ranges: 1 V, 10 V, 100 V and 1000 V. The output voltage on each range can be set with 6-digit resolution.

Table 1-1. Specifications (Cont'd)

INPUT CHARACTERISTICS:
Input Resistance: $> 10^{10}$ ohms 100 mV to 1000 V ranges.
$> 10^9$ ohms on 10 mV range.
$> 10^8$ ohms on 1 mV range.
Independent of null condition.
Superimposed AC Noise Rejection: Less than 0.001% error for ac voltages above 60 Hz equal to DC signal (25 V rms max.).
Effective AC Common Mode Rejection: > 120 dB at 60 Hz with 1 kΩ unbalance.
Input Terminals: Plus, minus, guard, and chassis ground; Banana jacks mounted on remote terminal Box. Plus and minus terminals are solid copper, goldflashed. 500 Vdc maximum may be connected between chassis ground and guard or circuit ground.

HIGH IMPEDANCE VOLTMETER

Voltage Ranges: 1 μV to 1000* volts end scale in 10 zero centered ranges. (1 μV to 1 mV ranges obtained by using null sensitivity pushbuttons.)

PERFORMANCE RATING:
Accuracy: ±(2% of end scale + 0.1 μV).

INPUT CHARACTERISTICS:
Input Resistance: $> 10^{10}$ ohms 100 mV to 1000 V ranges.
$> 10^9$ ohms on 10 mV range.
$> 10^8$ ohms on 1 μV to 1 mV ranges.
Zero Control Limits: ±10 μV nominal.
Zero Drift: Less than 2 μV per day after 30 minute warm-up.
Superimposed AC Rejection: Ac voltages above 60 Hz; 60 dB greater than end scale affects reading less than 2% (25 V rms max.).

RECORDER OUTPUT

Adjustable 0 to ±1 Vdc at 1 mA for end scale meter indication. Recorder negative terminal common with input negative terminal.

AMPLIFIER

Voltage Gain: Recorder Output: 120 dB max.
Output terminals:

60 dB on 1 mV range
40 dB on 10 mV range
20 dB on 100 mV range
Unity on 1 V to 1000 V ranges

Performance Rating: (output terminals)
Gain Accuracy: ±(0.001% + 5 ppm of range + 2 μV) referred to input.
Linearity: ±0.002% on any range. (1 mV and above)
Output Current: Same as DC Standard.
Bandwidth: DC to 0.2 Hz.
Input Resistance: Same as ΔVM.
Line Regulation: Less than 0.0005% of reading + 2 μV referred to input for 10% line voltage change.
Noise: .01 Hz to 1 Hz (referred to input) < .5 μV pk-pk at 60 dB < 1.0 μV pk-pk at 40 dB gain. < 3 μV pk-pk at 20 dB gain. Unity gain (1 μV range and above) same as DC Standard.
1 Hz to 1 MHz: 1 V to 1000 V ranges: same as DC Standard. Below 1 V range: < 100 μV RMS.

GENERAL

Operating Temperature: $+10^oC$ to $+40^oC$.
Storage Temperature: $-40^oC$ to $+65^oC$.
RFI: Meets MIL Spec. 6181D. **
Power Supply: 115/230 Vac ±10%, 50 Hz to 1000 Hz, 125 watts max.

* A maximum of -500 Vdc with respect to line ground can be applied to or obtained from the -hp- Model 740B.

** Positive or negative output terminals of the output box (-hp- 11055B) connected to chassis, and guard and chassis terminals of the input box (-hp- 11054A) connected together.

The output voltage is accurate to within ±(0.002% of setting + 0.0004% of range). Output voltage is indicated on digital readout tubes (first five digits) and the meter (sixth digit). Maximum output current is 50 mA on the 1 V range decreasing linearly to 20 mA at full output voltage on the 1000 V range. The front panel CURRENT LIMIT control allows adjustment of the maximum output current from approximately 10% to 100% of the available output current at each voltage setting. Remote sensing allows the output voltage to be regulated at the load, eliminating the effects of lead resistance. The output circuit is floating and guarded. A pushbutton switch allows the output voltage to be switched on and off without resetting the voltage dials.

1-7 DIFFERENTIAL VOLTMETER.

1-8. Used as a differential voltmeter, the Model 740B measures dc voltage on seven decade ranges from 1 mV to 1000 V. Voltage measurements are accurate within ±(0.005% of reading + 0.0004% of range + 1 μV). The measured voltage is indicated on five digital readout tubes (first five digits) and the meter (sixth digit). High input resistance (> $10^{10}$ Ω on all ranges above 10 mV) is maintained regardless of whether or not the voltage dials are nulled. The input circuit is floating and guarded, allowing accurate measurements to be made under conditions where ground loops are a problem.

1-9. HIGH IMPEDANCE VOLTMETER.

1-10. The Model 740B can also be used as a ± 2% floating and guarded dc voltmeter with 10 voltage ranges from 1 μV to 1000 V. Input resistance is > $10^{10}$ Ω on all ranges above 10 mV The measured voltage is indicated on the meter.

1-11. AMPLIFIER.

1-12. The Model 740B can be used as a dc power amplifier in the Voltmeter and Differential Voltmeter modes of operation by connecting the source to the input terminals and taking the output from the output terminals. Voltage gain is unity on the 1 V range and higher, but increases in 20 dB steps on the lower ranges to a maximum of 60 dB on the 1 mV range. Output current characteristics are the same as the DC Standard mode and the high input resistance characteristics of the Voltmeter and Differential Voltmeter modes are retained. Voltage gain accuracy is ±(0.01% + 5 ppm of range + 2 μV).

1-13. The Model 740B can also be used as a voltage amplifier in the Voltmeter and Differential Voltmeter modes with up to 120 dB of voltage gain available at the rear panel RECORDER OUTPUT terminals. Voltage at these terminals is directly proportional to meter deflection and is 0 to ±1 V on all ranges, 1 μV to 1000 V.

1-14. INTERNAL ADJUSTMENT.

1-15. An internal bridging arrangement, requiring no external equipment, allows resistors in the first and second decades and the range divider to be ratio matched to compensate for long term aging effects. The front panel meter serves as a bridge null indicator and an internal alignment switch sets up the bridge. A total of 12 adjustments match the resistors. The only other adjustment affecting basic instrument accuracy can easily be made with a standard cell or other known voltage source. The internal alignment procedure is outlined on the instrument internal guard cover and described in detail in Section V of this manual.

## 1-16. SPECIFICATIONS.

1-17. Table 1-1 lists the specifications for the Model 740B. Specifications are listed by instrument function. Those specifications listed with a function apply to that function only.

## 1-18. INSTRUMENT IDENTIFICATION.

1-19. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, a Manual Change Sheet supplied with this manual will define differences between your instrument and the Model 740B described in this manual. If a letter prefixes the serial number, the instrument was manufactured outside the United States.

## 1-20. ACCESSORY EQUIPMENT SUPPLIED.

1-21. The accessory equipment supplied with the Model 740B is listed in Table 1-2.

Table 1-2. Accessory Equipment Supplied

| -hp- Part No. | Quantity | Description |
|---|---|---|
| 11054A | 1 | Input Cable Assembly |
| 11055B | 1 | Output Cable Assembly |
| 5000-4932 | 1 | Printed Circuit Board Extractor |
| 5060-0776 | 1 | 7 inch Rack Mounting Kit |
| 8120-0078 | 1 | AC Power Cord |
| 00740-66535 | 1 | Printed Circuit Board Extender |
| 00740-90002 | 1 | Operating and Service Manual |

## 1-22. ACCESSORY EQUIPMENT AVAILABLE.

1-23. Accessory equipment available for the Model 740B is listed in Table 1-3.

Table 1-3. Accessory Equipment Available

| -hp- Part No. | Description |
|---|---|
| 11000A | Test Cable: dual banana plug to dual banana plug (44 in.) |
| 11002A | Test Cable: dual banana plug to alligator clips (60 in.) |
| 11003A | Test Cable: dual banana plug to probe and alligator clip (60 in.) |

# SECTION II
# INSTALLATION

## 2-1. INTRODUCTION.

2-2. This section contains information on preparing the Model 740B for use and repackaging the instrument for shipment.

## 2-3. INITIAL INSPECTION.

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage that occurred in transit. If the instrument was damaged in transit, file a claim with the carrier. Check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Paragraph 5-5. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

## 2-5. POWER REQUIREMENTS.

2-6. The Model 740B can be operated from any source of 115 or 230 volts (±10%), at 50 to 1000 Hz. With the instrument disconnected from the ac power source, move the slide switch (located on the rear panel) until the desired line voltage appears. Power dissipation is 125 watts maximum.

## 2-7. GROUNDING REQUIREMENTS.

2-8. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-9. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

## 2-10. INSTALLATION.

2-11. The Model 740B is fully transistorized; therefore, no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds +40°C (104°F) or the relative humidity exceeds 70%.

## 2-12. BENCH MOUNTING.

2-13. The Model 740B is shipped with plastic feet and tilt stand in place, ready for use as a bench instrument.

## 2-14. RACK MOUNTING.

2-15. The Model 740B may be rack mounted by using the 7" Rack Mount Kit (-hp- Part No. 5060-0776). Instructions for the conversion are included with the kit. The rack mount for the Model 740B is an EIA standard width of 19 inches. When mounted in a rack using the rack mount kit, additional support at the rear of the instrument should be provided if vibration or similar stress is likely.

## 2-16. REPACKAGING FOR SHIPMENT.

2-17. The following paragraphs contain a general guide for repackaging of the instrument for shipment. Refer to Paragraph 2-18 if the original container is to be used; 2-19 if it is not. If you have any questions, contact your local -hp- Sales and Service Office. (See Appendix B for office locations.)

NOTE

> If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and serial number.

2-18. If original container is to be used, proceed as follows:

a. Place instrument in original container with appropriate packing material. If original container is not available, one can be purchased from your nearest -hp- Sales and Service Office.

b. Ensure that container is well sealed with strong tape or metal bands.

2-19. If original container is not to be used, proceed as follows:

a. Wrap instrument in heavy paper or plastic before placing in an inner container.

b. Place packing material around all sides of instrument and protect panel face with cardboard strips.

c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

d. Mark shipping container with "DELICATE INSTRUMENT," "FRAGILE," etc.

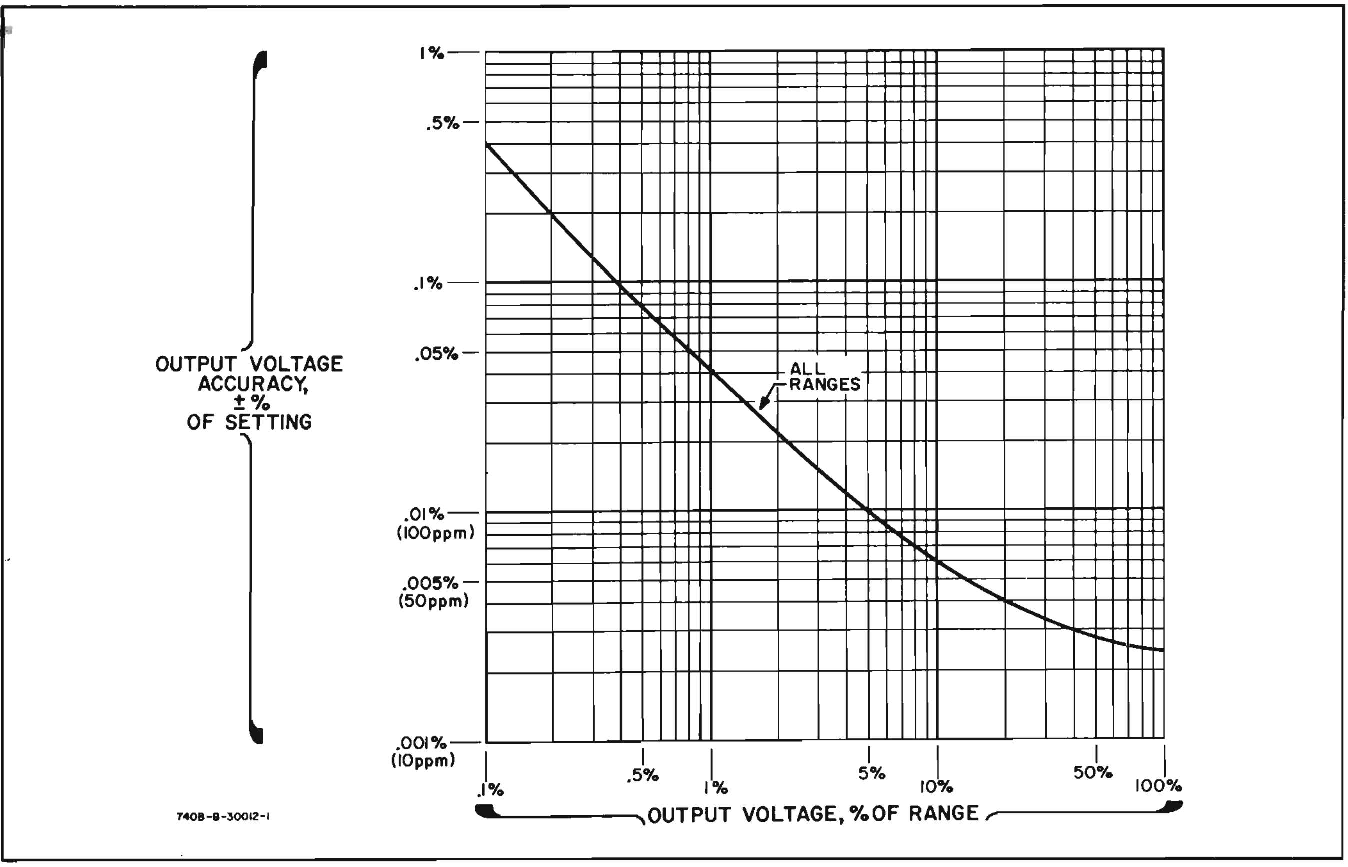



Figure 3-1. Output Voltage Accuracy, STD Mode

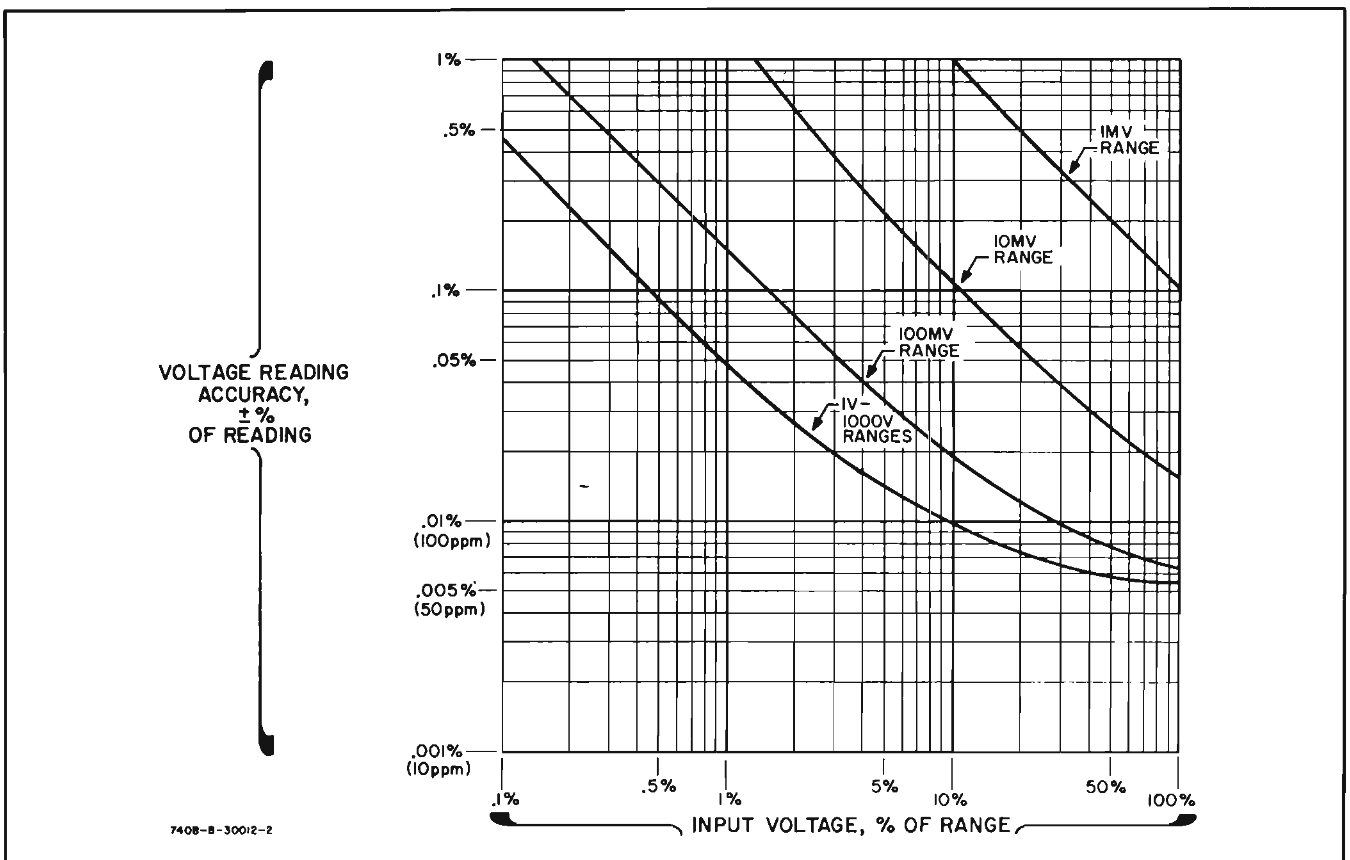



Figure 3-2. Voltage Reading Accuracy, ΔVM Mode

# SECTION III
# OPERATING INSTRUCTIONS

## 3-1. INTRODUCTION.

3-2. This section contains instructions and information on operating the Model 740B. Included is a discussion of the accuracy specifications, operating precautions, identification of controls, indicators and connectors and step-by-step operating instructions for each instrument function.

## 3-3. ACCURACY SPECIFICATIONS.

3-4. When operated as a dc standard, the Model 740B accuracy specification is: ±(0.002% of setting+0.0004% of range). The differential voltmeter accuracy specification is ± (0.005% of reading + 0.0004% of range + 1 μV). The instrument should operate within these limits providing it has been calibrated within the past 30 days and is operated at the ambient temperature present at the time of calibration. If operated at a different ambient temperature, the accuracy specifications should be derated according to the following:

a. Standard Mode Temperature Coefficient: Less than (2 ppm of setting or 1 ppm of range, whichever is greater) per °C; 10°C to 40°C.

Example: Normal allowable accuracy deviation for a 1 V output on the 1 V range is ±24 μV (0.002% of setting + 0.0004% of range). If the ambient temperature differs by 5°C from the ambient temperature at the time of calibration, the allowable accuracy deviation becomes ± 34 μV for the 1 V output (original deviation of 24 μV plus the TC correction factor of 10 μV).

b. Differential Voltmeter Mode Temperature Coefficient: Less than ± (2 ppm of reading + 1 μV) per °C; 10°C to 40°C.

Example: Normal allowable accuracy deviation for a 1 V reading on the 1 V range is ± 55 μV (0.005% of reading + 0.0004% of range + 1 μV). If the ambient temperature differs by 5°C from the ambient temperature at the time of calibration, the allowable accuracy deviation becomes ± 70 μV for the 1 V reading (original deviation of 55 μV plus the TC correction factor of 15 μV).

3-5. Figure 3-1 shows how the output voltage accuracy in Standard Mode varies with percentage of range. Notice that the output accuracy at 100% of range is ± 0.0024% (24 ppm). However, as the magnitude of the output decreases with respect to full scale, the accuracy decreases. At 10% of range, the accuracy is ± 0.006% (60 ppm) of setting. At 1% of range, the accuracy decreases to ± 0.042% (420 ppm) of setting. Whenever optimum accuracy is desired, the Model 740B should be operated as near full scale as possible.

3-6. Figure 3-2 shows how the voltage reading accuracy in Differential Voltmeter Mode varies with percentage of range. Again, greatest accuracy is achieved at 100% of range. Separate curves show the accuracy characteristics on the millivolt ranges. The accuracy decreases on each descending millivolt range due to the effects of signal noise on low level dc inputs. Inputs of 1 mV and below are measured with nearly the same accuracy on the 1 mV and 10 mV ranges. A 1 mV input, for example, would be measured with an accuracy of ± 0.105% of reading on the 1 mV range and ± 0.11% of reading on the 10 mV range. However, measurement resolution (the capability of detecting small changes in the input) would be ten times greater on the 1 mV range.

## 3-7. OPERATING PRECAUTIONS.

3-8. The following precautions should be observed whenever using the Model 740B.

a. BEFORE APPLYING POWER TO THE MODEL 740B, VERIFY THAT THE REAR PANEL LINE VOLTAGE SWITCH INDICATES THE LINE VOLTAGE TO BE USED.

b. DO NOT FLOAT -INPUT OR -OUTPUT TERMINAL MORE THAN 500 VDC ABOVE OR BELOW CHASSIS (POWERLINE) GROUND.

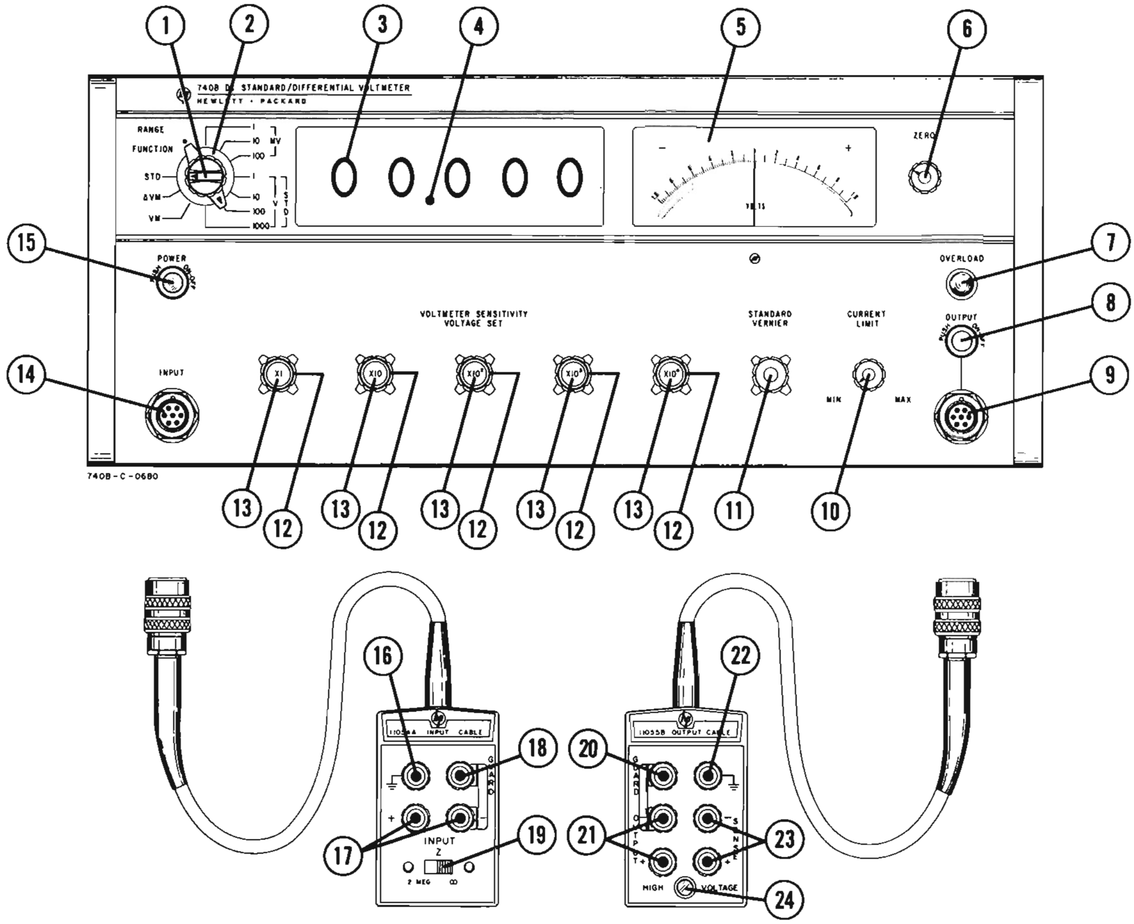
c. DISCHARGE INPUT BY MOMENTARILY SETTING INPUT Z SWITCH (ON INPUT BOX) TO 2 MEG POSITION FOLLOWING ALL HIGH VOLTAGE MEASUREMENTS.

NOTE

Be sure to return switch to ∞ position after discharging input to avoid introducing a loading error in the following measurements.

## 3-9. CONTROLS, INDICATORS AND CONNECTORS.

3-10. Each operating control, indicator and connector located on the Model 740B is identified in Figure 3-3. The description of each component is keyed to the illustrations which are included within the figure.



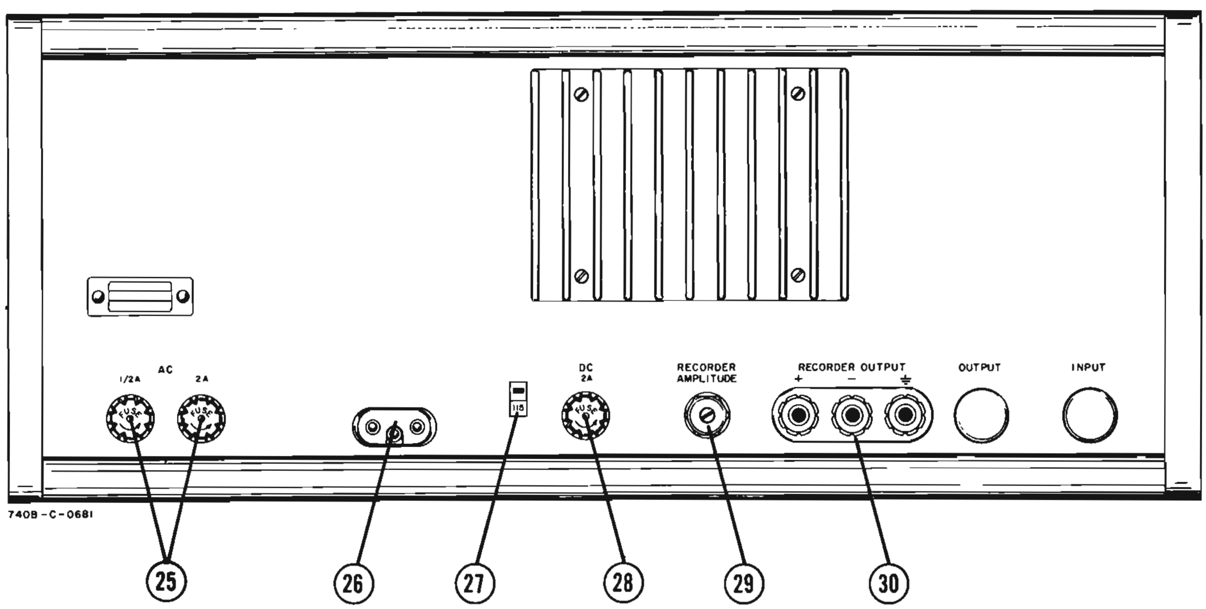

| INDEX NO. | NAME | FUNCTION |
|---|---|---|
| 1 | FUNCTION Rotary Switch | Selects one of the three basic modes of operation:<br>STD - DC Standard<br>ΔVM - DC Differential Voltmeter<br>VM - DC Voltmeter |
| 2 | RANGE Rotary Switch | Selects one of seven full scale ranges in the Differential Voltmeter and DC Voltmeter modes of operation; selects one of four output ranges in the DC Standard mode of operation. |
| 3 | Digital Readout Tubes | Display the first five digits in the Differential Voltmeter and DC Standard modes of operation. |
| 4 | Decimal Point Indicators | Light to indicate position of decimal point in first five significant digits in DC Standard and Differential Voltmeter modes of operation. |
| 5 | VOLTS Meter | Indicates sixth digit of input voltage in Differential Voltmeter mode of operation; indicates sixth digit of output voltage in DC Standard mode of operation; indicates value of input voltage in DC Voltmeter mode of operation. |
| 6 | ZERO Adjustment | Adjusts meter to 0 with input shorted in Differential Voltmeter and DC Voltmeter modes of operation; used to zero the output or null out external offset voltages in DC Standard mode of operation. |

Figure 3-3. Front and Rear Panel Controls, Indicators and Connectors

| INDEX NO. | NAME | FUNCTION |
|---|---|---|
| 7 | OVERLOAD Indicator | Indicates an input voltage in excess of the selected range in the Differential Voltmeter and DC Voltmeter modes of operation; indicates the selected current limit has been exceeded in the DC Standard mode of operation; may light momentarily when RANGE, FUNCTION or VOLTAGE SET is changed to indicate circuit instability. |
| 8 | OUTPUT PUSH ON-OFF Pushbutton-Indicator | Lights when depressed to indicate application of output voltage to OUTPUT CABLE terminals in DC Standard mode of operation; goes out when depressed second time to indicate removal of output voltage. |
| 9 | OUTPUT Receptacle | Supplies output voltage in DC Standard mode of operation when the OUTPUT CABLE, -hp- accessory 11055B, is connected; supplies output voltage whenever the Model 740B is used as a power amplifier. |
| 10 | CURRENT LIMIT Control | Provides adjustment of maximum output current supplied to the OUTPUT terminals. |
| 11 | STANDARD VERNIER Rotary Switch | Controls sixth digit of output voltage in the DC Standard Mode of operation. |
| 12 | VOLTAGE SET Rotary Switches | Provide first five significant digits of output voltage in DC Standard or input voltage in Differential Voltmeter mode of operation. |
| 13 | VOLTMETER SENSITIVITY Pushbuttons | Select decade and meter sensitivity in Differential mode of operation; select meter sensitivity in DC Voltmeter mode of operation. |
| 14 | INPUT Receptacle | Accepts INPUT CABLE, -hp- accessory 11054A. Used in Differential Voltmeter and DC Voltmeter modes of operation. |
| 15 | POWER ON-OFF Pushbutton-Indicator | Lights when depressed to indicate application of line voltage to the instrument. Goes out when depressed second time to indicate removal of line voltage. |
| 16 | Ground ( $\perp$ ) Terminal | Accepts lead for connecting to power line ground. This terminal and the instrument case are connected to power line ground through the center conductor of the power cord. |
| 17 | + and - INPUT Terminals | Accept leads for application of dc input voltage. |
| 18 | Input GUARD Terminal | Connected to the internal guard shield. For making guarded measurements, the GUARD terminal is connected to the reference potential of the source. For making unguarded measurements, strap on GUARD terminal is connected to the - INPUT terminal. |
| 19 | INPUT Z 2-position Switch | Varies instrument input impedance. The ∞ position is used for making most voltage measurements. The 2 MEG position is used for discharging the input circuit following high voltage measurements. |
| 20 | Output GUARD Terminal | Connected to the internal guard shield. Accepts lead for guard connections when providing guarded outputs in the DC Standard mode of operation. For unguarded outputs, strap on GUARD terminal is connected to the - OUTPUT terminal. |

Figure 3-3. Front and Rear Panel Controls, Indicators and Connectors (Cont'd)

| INDEX NO. | NAME | FUNCTION |
|---|---|---|
| 21 | + and - OUTPUT Terminals | Accept leads for application of output voltage to remote location. |
| 22 | Ground ( $\perp$ ) Terminal | Accepts lead for connecting to power line ground. This terminal and the instrument case are connected to power line ground through the center conductor of the power cord. |
| 23 | + and - SENSE Terminals | Accept leads for remote sensing of output voltage. When not using remote sensing, the + SENSE terminal is shorted to the + OUTPUT terminal and the - SENSE terminal is shorted to the - OUTPUT terminal. |
| 24 | HIGH VOLTAGE Indicator | Lights to indicate presence of high voltage (>120 Vdc) at the OUTPUT terminals. |




| INDEX NO. | NAME | FUNCTION |
|---|---|---|
| 25 | AC Fuses | Protect Primary Power Circuitry. |
| 26 | AC Power Connector | Accepts power cable supplied with the instrument. |
| 27 | Line Voltage Two-Position Slide Switch | Sets the instrument for either 115 Vac or 230 Vac operation. |
| 28 | DC Fuse | Protects internal -42 V supply. |
| 29 | RECORDER AMPLITUDE Adjustment | Variable attenuator which enables adjustment of RECORDER OUTPUT voltage. |
| 30 | RECORDER OUTPUT +, - and $\perp$ Terminals | Provide output voltage proportional to meter deflection for recorder applications. |

Figure 3-3. Front and Rear Panel Controls, Indicators and Connectors (Cont'd)

## 3-11. DC STANDARD.

### 3-12. DESCRIPTION.

3-13. In Standard mode, the Model 740B amplifies an internally generated reference voltage. The VOLTAGE SET switches operate a voltage divider that varies the reference supply output. The reference supply output (0 to 1 V) is applied to the main loop amplifier where it is amplified by 0 dB (1 V range), 20 dB (10 V range), 40 dB (100 V range) or 60 dB (1000 V range). The gain of the amplifier is determined by the position of the RANGE switch. The amplifier output voltage (0-1000 V) is applied to the + and - OUTPUT terminals when the OUTPUT pushbutton/indicator is lighted. The + and - SENSE terminals provide voltage feedback to the main loop amplifier and ensure proper voltage regulation. The CURRENT LIMIT control varies the maximum available output current. The OVERLOAD indicator lights whenever the output current exceeds the setting of the CURRENT LIMIT control. The ZERO control is used to zero the amplifier output or to null out the effects of small external offset voltages. The output voltage is indicated directly on the digital readout tubes (first five digits) and the meter (sixth digit). The decimal point is automatically placed.

### 3-14. OPERATING PROCEDURE.

3-15. To operate the Model 740B in Standard mode, proceed as follows:

a. Set rear panel LINE VOLTAGE switch to correct position for available line voltage.

b. Connect ac power cord to ac power connector; connect cord plug to ac line.

c. Turn on the Model 740B by depressing the POWER pushbutton (indicator glows). Allow the instrument to warm up for one hour.

d. Set FUNCTION to STD.

e. Check OUTPUT indicator. If glowing, depress to turn output off.

f. Connect output cable assembly (-hp- Model 11055B) to OUTPUT Receptacle.

g. Connect output box terminals for the output condition desired, using the information in Table 3-1.

NOTE

1. Make sure all connections are tight. Use insulated solid copper wire for all leads. + and - OUTPUT leads should be 20 gauge or larger.
2. Sensing is explained in Paragraph 3-16.
3. Guarding is explained in Paragraph 3-24.
4. Negative outputs are explained in Paragraph 3-26.

h. Set RANGE to range nearest above desired output voltage.

NOTE

1. The 1 mV, 10 mV and 100 mV ranges are inoperative in STD mode. OVERLOAD indicator will glow if these ranges are selected.
2. OVERLOAD light may also glow temporarily when RANGE, FUNCTION or VOLTAGE SET controls are changed to indicate temporary loop instability.

i. Set ZERO control for desired output zero reference. (See Paragraph 3-31 for a detailed discussion on using the ZERO control.)

Table 3-1. Output Terminal Connections

| TYPE OF OUTPUT | CONNECT OUTPUT TERMINALS | | | | | |
|---|---|---|---|---|---|---|
| | + OUTPUT | - OUTPUT | + SENSE | - SENSE | GUARD | ⏚ |
| Local output, unguarded | Directly to load | Directly to load | To + OUTPUT | To - OUTPUT | To - OUTPUT | Not Connected |
| Remote output, unguarded | To load via a test cable | To load via a test cable | To load + via a test cable | To load - via a test cable | To - OUTPUT | Not Connected |
| Local output, guarded | Directly to load | Directly to load | To + OUTPUT | To - OUTPUT | To load guard | Not Connected |
| Remote output, guarded | To load via a test cable | To load via a test cable | To load + via a test cable | To load - via a test cable | To load guard | Not Connected |

j. Set VOLTAGE SET control for first five digits of desired output voltage as indicated by the digital readout tubes. Set STANDARD VERNIER control for sixth digit of output voltage as indicated by the meter.

NOTE

Each integer of the sixth digit is represented by one major division on the meter.

k. Set CURRENT LIMIT control to desired maximum limit of output current. (See Paragraph 3-38 for a detailed discussion on using the CURRENT LIMIT control.)

l. Depress OUTPUT pushbutton. OUTPUT indicator glows to indicate application of output voltage to load.

m. To remove output voltage, depress OUTPUT pushbutton. Indicator light goes out to indicate removal of output voltage from OUTPUT terminals.

**WARNING**

ALWAYS DE-ENERGIZE OUTPUT OR SET VOLTAGE SET AND STANDARD VERNIER CONTROLS TO ZERO WHEN MAKING CHANGES IN THE OUTPUT TERMINAL CONNECTIONS.

3-16. SENSING.

3-17. The purpose of the SENSE terminals is to furnish voltage feedback from the load to the main loop amplifier. If current is being drawn from the OUTPUT terminals, small voltage drops occur in the output leads since they are not perfect conductors. This results in slightly low voltage at the load. If the SENSE leads are connected to the load, this low voltage condition is "sensed" by the main loop amplifier. The amplifier then increases its output voltage to compensate for the voltage drop in the output leads. Voltage drop in the SENSE leads is insignificant, since very little current flows in these leads.

3-18. LOCAL SENSING.

3-19. Local sensing can be used whenever the operating conditions require little or no current from the 740B output or when the load is connected directly (through very short leads) to the output box terminals.

3-20. Local sensing is accomplished by connecting the + SENSE terminal to the + OUTPUT terminal and connecting the - SENSE terminal to the - OUTPUT terminal (Figure 3-4). The connections should be made with short conductors, preferable solid copper wire.

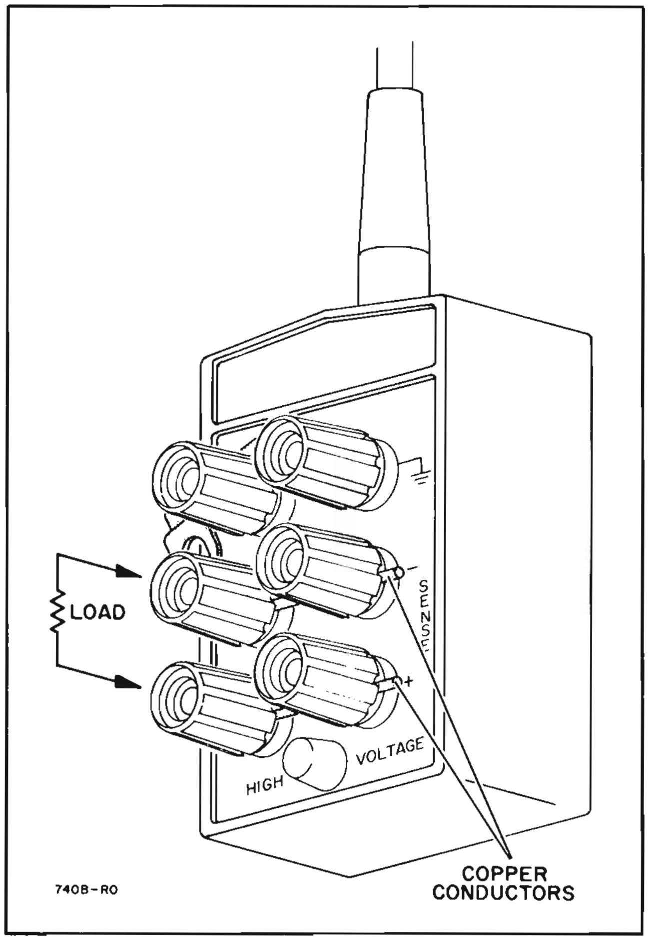



Figure 3-4. Local Sensing

3-21. REMOTE SENSING.

3-22. Remote sensing should be used whenever the 740B is delivering current to a load and whenever the load is away from the output terminal box.

3-23. Remote sensing is accomplished by connecting the + and - SENSE terminals to the load using extension leads. The + SENSE terminal must be connected to the + end of the load and the - SENSE terminal must be connected to the - end of the load (Figure 3-5).

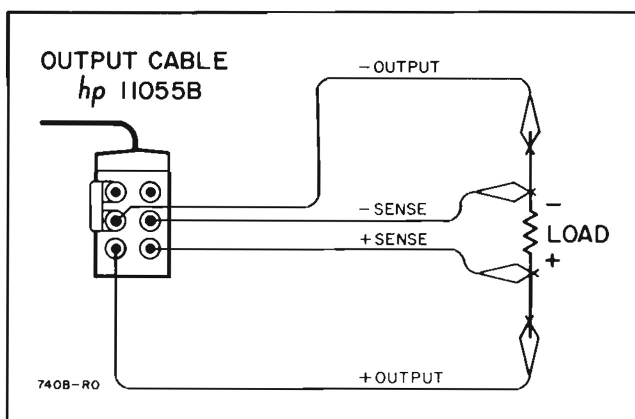



Figure 3-5. Remote Sensing

NOTE

Either local or remote sensing must be used at all times in Standard mode.

3-24. GUARDING.

3-25. The output cable GUARD terminal is connected to the Model 740B guard chassis and may be used to reference the guard chassis to a desired potential. Normally the GUARD terminal is connected to the - OUTPUT terminal using the strap attached to the GUARD terminal. The GUARD terminal may, however, be connected to a reference potential or guard terminal in the load to reduce the effects of unequal ground potentials, stray ac pickup, etc.

3-26. NEGATIVE OUTPUTS.

3-27. FLOATING.

3-28. Negative output voltage not referenced to earth ground is obtained by connecting the + OUTPUT and + SENSE terminals to the high (least negative) side of the load and connecting - OUTPUT and - SENSE to the low (most negative) side of the load. The INPUT and OUTPUT ⏚ terminals must not be connected to any of the other terminals.

3-29. GROUNDED.

3-30. Negative outputs referenced to earth ground are obtained by connecting the + OUTPUT and + SENSE leads to the ground reference point in the circuit under test. The 740B then drives the - OUTPUT and - SENSE leads negative with respect to the ground reference. Again, the INPUT and OUTPUT ⏚ terminals must not be connected to any of the other terminals.

CAUTION

DO NOT FLOAT - OUTPUT TERMINAL MORE THAN 500 V ABOVE OR BELOW EARTH GROUND ( ⏚ ).

3-31. USING THE ZERO CONTROL.

3-32. In Standard mode, the ZERO control sets the output voltage zero reference. The ZERO control range of adjustment varies with the voltage range selected (Table 3-2).

Table 3-2. ZERO Control Range

| Model 740B Voltage Range | ZERO Control, Approximate Range of Adjustment |
|---|---|
| 1 V | ± 10 μV |
| 10 V | ± 100 μV |
| 100 V | ± 1 mV |
| 1000 V | ± 10 mV |

3-33. The ZERO control may be used to set the output to exactly zero volts or to null the effects of small dc offset voltages existing in a test setup. Offset voltage is present if the load (divider, potentiometer, etc.) produces a small voltage with no apparent drive voltage applied. Such voltages are usually produced when contact is made between dissimilar metals, temperature gradients exist in a test setup, etc.

3-34. SETTING THE OUTPUT TO ZERO.

3-35. To set the output voltage zero reference to 0 V, proceed as follows:

a. Set 740B FUNCTION to STD, RANGE to the desired range, VOLTAGE SET and STANDARD VERNIER to zero and OUTPUT on.

b. Connect a sensitive dc null detector across the + and - OUTPUT terminals.

c. Set null detector range to obtain an off-null indication.

d. Set 740B ZERO control to obtain a null indication.

e. Disconnect null detector.

NOTE

The ZERO control setting varies slightly from range to range. Readjust ZERO control each time RANGE is changed.

3-36. NULLING EXTERNAL OFFSETS.

3-37. To null the effects of external dc offset voltage; proceed as follows:

a. Set 740B FUNCTION to STD, RANGE to the desired range, VOLTAGE SET and STANDARD VERNIER to zero and OUTPUT on.

b. Connect the OUTPUT terminals to the load.

c. Connect a sensitive null detector across the load (or across the reference leg of the load).

d. Set null detector range to obtain an off-null indication.

e. Set 740B ZERO control to obtain a null indication.

NOTE

The ZERO control setting varies slightly from range to range. Readjust ZERO control each time RANGE is changed.

3-38. USING THE CURRENT LIMIT CONTROL.

3-39. Maximum output current available at the OUTPUT terminals depends on both the value of the output voltage and the setting of the CURRENT LIMIT control. With the CURRENT LIMIT control set to maximum (fully cw), the maximum output current varies from 50 mA at voltage outputs less than 1 V to 20 mA for a 1000 V output (Figure 3-6). When the CURRENT LIMIT control is set to minimum (fully ccw) the maximum output current varies from 5 mA (less than 1 V output) to 2 mA (1000 V output). These figures and the values represented in Figure 3-6 should be regarded only as typical, since the current limit circuit is affected by temperature and the setting of the maximum current limit adjustment (A10R8).

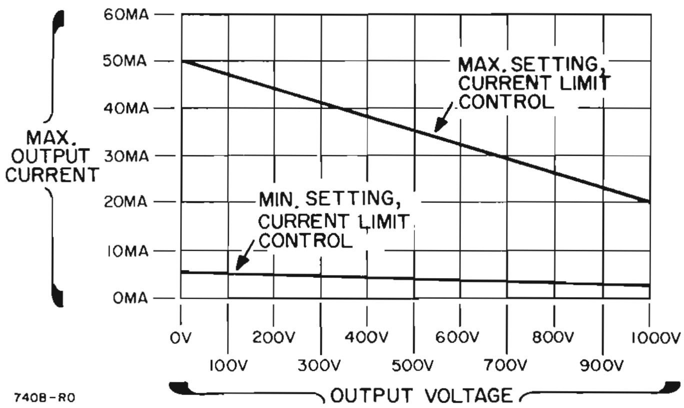



Figure 3-6. Maximum Output Current Characteristics

3-40. Since the setting of the CURRENT LIMIT control corresponds to different current values at different voltage outputs, accurate setting of the CURRENT LIMIT control can be accomplished only at the desired voltage output. The following procedure can be used to set the CURRENT LIMIT control to limit output current to a specific value.

a. Calculate the load resistance value needed to draw the desired output current at the desired output voltage:

$$R_{load} = \frac{E_{out}}{I_{desired}}$$

b. Calculate the load resistance power rating:

$$\text{Power rating} = I_{desired} \times E_{out}$$

c. Connect a resistor meeting the requirements of a and b across the Model 740B + and - OUTPUT terminals.

d. Turn CURRENT LIMIT control fully ccw.

e. Set Model 740B for the desired output voltage. Turn Output on. (OVERLOAD light will glow.)

f. Rotate the CURRENT LIMIT control slowly cw until the OVERLOAD light just goes out. The Model 740B will now limit current at the desired current value.

## 3-41. DIFFERENTIAL VOLTMETER.

### 3-42. DESCRIPTION.

3-43. In the Differential Voltmeter mode, the 740B measures the input voltage by nulling feedback voltage from the main loop amplifier with an internally generated reference voltage. The value of the reference voltage is controlled by a voltage divider operated by the VOLTAGE SET controls. The meter indicates the difference between the reference voltage and the feedback voltage. The SENSITIVITY pushbuttons control the meter sensitivity; and moving left to right depressing each successive pushbutton, increases the meter sensitivity by a factor of 10. The ZERO control sets the input zero reference. The OVERLOAD indicator lights whenever the input voltage exceeds the selected range and may also light temporarily whenever RANGE, FUNCTION or VOLTAGE SET is changed. The input voltage is indicated directly on the digital readout tubes (first five digits) and the meter (sixth digit). The decimal point is automatically placed.

3-44. High input impedance is maintained at all times regardless of null condition. An off-null condition does not load the voltage source being measured.

### 3-45. OPERATING PROCEDURE.

3-46. To make a differential measurement, proceed as follows:

a. Set rear panel LINE VOLTAGE switch to correct position for available line voltage.

b. Connect ac power cord to ac power connector; connect cord plug to ac line.

c. Turn on the Model 740B by depressing the POWER pushbutton (indicator glows). Allow the instrument to warm up for one hour.

d. Set FUNCTION to ΔVM.

e. Check OUTPUT indicator. If glowing, depress to turn Output off.

f. Connect Input Cable Assembly (-hp- 11054A) to INPUT receptacle. Set INPUT Z switch to ∞.

g. Set RANGE to the range nearest above voltage to be measured.

h. Set VOLTAGE SET controls to zero (all fully ccw).

i. Connect a shorting wire from + to - INPUT terminals.

j. Depress $X10^4$ SENSITIVITY. (If 1 mV range is selected, depress $X10^3$ SENSITIVITY.)

Table 3-3. Input Terminal Connections

| TYPE OF MEASUREMENT | CONNECT INPUT TERMINALS | | | |
|---|---|---|---|---|
| | + | - | GUARD | ⏚ |
| Unguarded | To high (most positive) of source | To low (most negative) of source | To - terminal | Not Connected |
| Guarded | To high (most positive) of source | To low (most negative) of source | To reference potential of source | Not Connected |

k. Adjust ZERO if necessary to obtain a zero meter indication.

NOTE

The ZERO control has the greatest effect on the lower ranges and no noticeable effect on the 100 V and 1000 V ranges. Paragraph 3-47 explains how to cancel the effects of small offset voltages with the ZERO control.

l. Depress X1 SENSITIVITY and remove short from input terminals.

m. Connect input box terminals for the type of measurement desired using the information in Table 3-3.

NOTE

1. Make sure all terminals are tight. Use insulated solid copper wire for all leads.
2. When measuring the voltage drop across a current carrying load, be careful to connect the + and - INPUT leads directly to the load and not to the current supply wires. Voltage drop along the current carrying wires can cause a significant measurement error.
3. Paragraph 3-49 explains guarded measurements.

n. Meter should indicate between +0.1 and +1.0. If necessary, change setting of RANGE switch until a reading of +0.1 to +1.0 is obtained.

o. Turn X1 VOLTAGE SET clockwise until the meter deflection is between 0 and +0.1. Each step of the VOLTAGE SET switch changes the meter deflection by one major scale division.

p. Depress X10 SENSITIVITY and turn the corresponding VOLTAGE SET control cw to obtain a meter reading between 0 and +0.1.

q. Repeat step p for X$10^2$, X$10^3$ and X$10^4$ SENSITIVITY buttons and VOLTAGE SET controls.

r. Read the first five digits from the digital readout tubes; sixth digit from the meter (Figure 3-7).

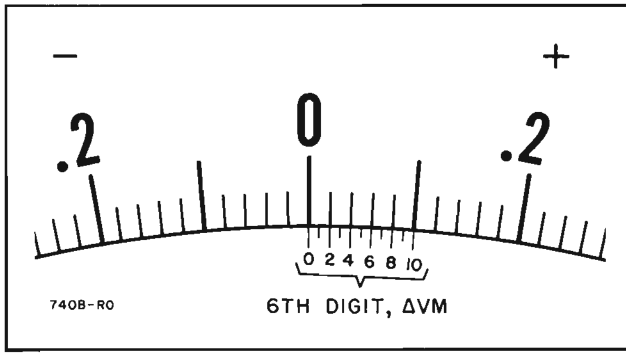



Figure 3-7. Sixth Digit ΔVM

NOTE

A full scale input (1 V on the 1 V range, for example) is indicated by the digital readout tubes indicating 9-9-9-9-9 (first five digits) and the meter indicating 10 (sixth digit).

s. Before removing leads from device under test, depress X1 SENSITIVITY.

CAUTION

THE 740B INPUT SHOULD BE DISCHARGED FOLLOWING ALL HIGH VOLTAGE MEASUREMENTS TO PREVENT CARRYING THE STORED CHARGE TO THE NEXT POINT OF MEASUREMENT.

t. Remove leads from device under test or deenergize voltage source and place INPUT Z switch to 2 Meg position to discharge Model 740B input. Return INPUT Z switch to ∞ after discharging input.

## 3-47. ZEROING EXTERNAL OFFSET VOLTAGES.

3-48. Quite often small offset voltages exist in a test setup as a result of contact between dissimilar metals, thermals, etc. Offset voltage is present if a test setup produces a voltage with no apparent drive voltage applied. The effects of offset voltage up to approximately ± 10 $\mu$V can be eliminated by the following procedure:

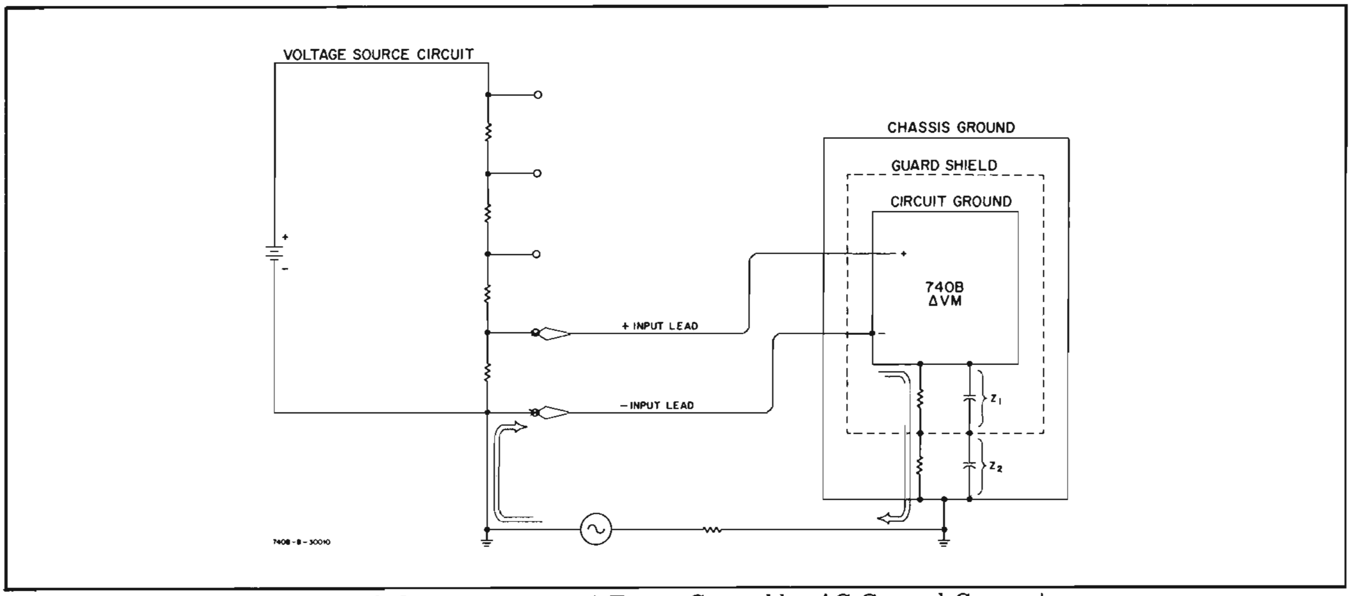



Figure 3-8. Measurement Error Caused by AC Ground Currents

a. Connect + and - INPUT terminals to circuit under test. Do not turn on circuit or apply drive voltage.

b. Set 740B RANGE to 1 mV; depress X$10^3$ SENSITIVITY.

c. Adjust ZERO control for a zero meter indication.

NOTE

If the resistance connected between the + and - INPUT terminals is greater than 10 kΩ, this adjustment may be difficult due to stray voltage pickup caused by electrostatic charges, low humidity, etc.

3-49. GUARDING.

3-50. The Model 740B is a floating instrument; however, a finite impedance exists from the - INPUT terminal (circuit ground) to earth ground ( ⏚ ). This impedance is represented by $Z_1$ and $Z_2$ in Figure 3-8.

3-51. Induced ac ground currents can generate a potential between the voltage source ground and the 740B ground. This current will cause an ac voltage to appear at the - INPUT terminal which may cause a measurement error, especially when making low level measurements. Also, the - INPUT terminal may be driven at a potential above ground in the voltage source circuit (Figure 3-9). The impedance from - INPUT to chassis ground ($Z_1$ and $Z_2$) parallels part of the voltage source circuit (R4) and causes a larger current to flow through R1, R2 and R3, increasing the apparent voltage across R3. (Arrows

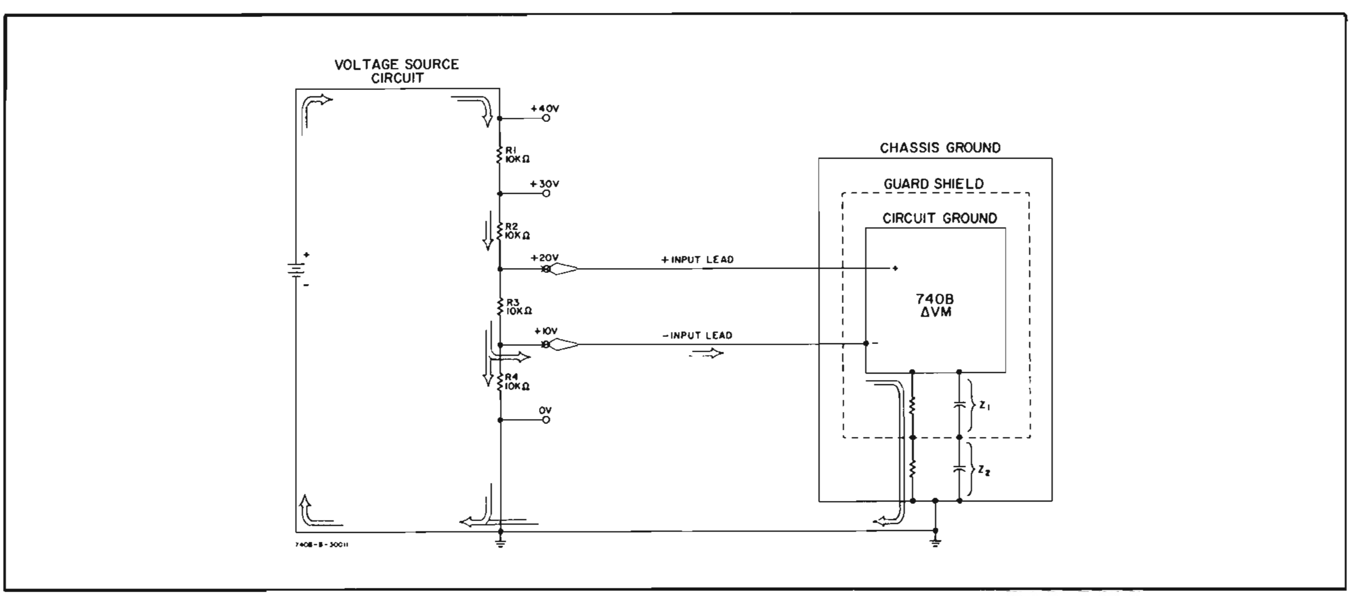



Figure 3-9. Measurement Error Caused by DC Ground Currents

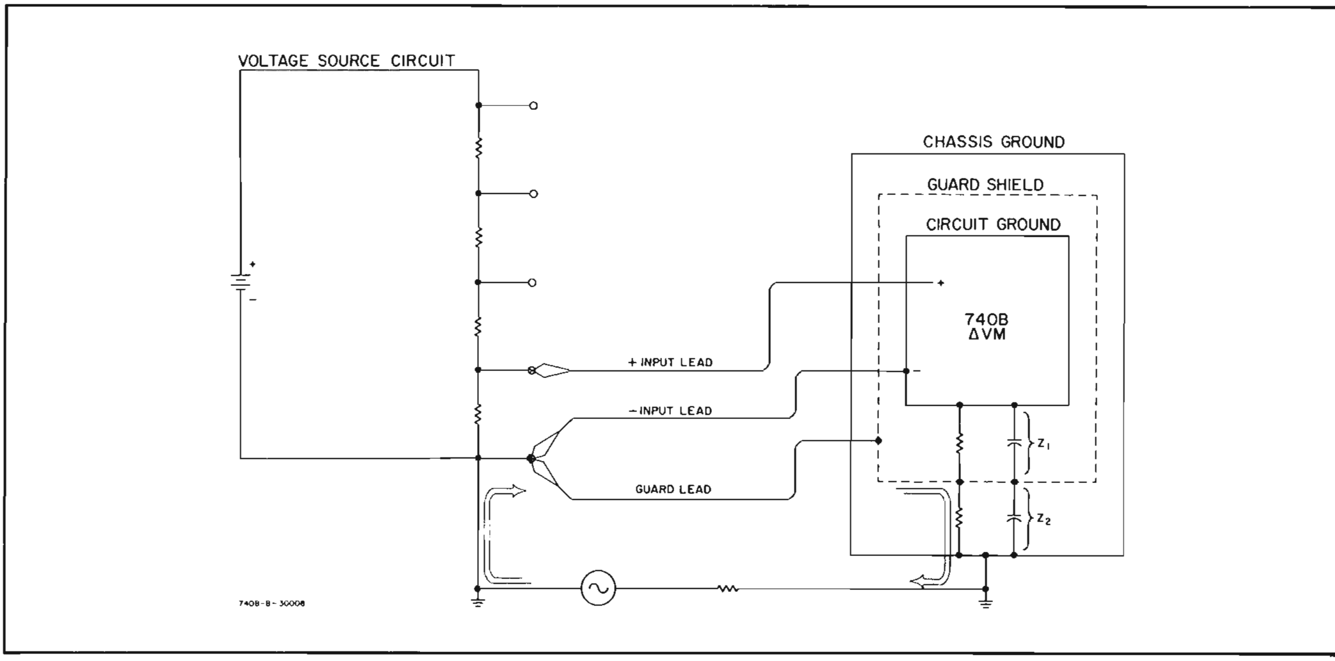



Figure 3-10. Guarding Against AC Ground Currents

indicate direction of current flow in the conventional manner: positive to negative.)

3-52. Guarding is a procedure for eliminating these problems. Induced ac ground currents can be eliminated by connecting the guard shield to the ground reference point ( ⏚ ) in the voltage source circuit (Figure 3-10). The induced ground current now flows through the GUARD lead and $Z_2$, bypassing the -INPUT lead.

3-53. The error current caused by floating the -INPUT terminal above ground (Figure 3-9) can be eliminated by connecting the guard shield to a potential equal to, but isolated from, the - INPUT potential (Figure 3-11). In the example shown, this potential is derived from an added string of resistors, R5 - R8. The added resistors may be somewhat less accurate than R1 - R4 and do not even have to be the same value providing they closely duplicate the voltages available at the taps on the R1 - R4 divider. By connecting the GUARD lead to the corresponding tap on the R5 - R8 divider, the 740B guard shield is referenced to the same potential as the - INPUT terminal. Current through $Z_1$ is thus eliminated and the loading current now flows through the GUARD lead, $Z_2$ and the ground return, eliminating the loading effect on the R1 - R4 divider.

3-54. If the voltage source circuit is not referenced to earth ground there is no need for guarding. In this case the GUARD and - INPUT terminals should be connected together at the output terminal box using the shorting strap attached to the GUARD terminal.

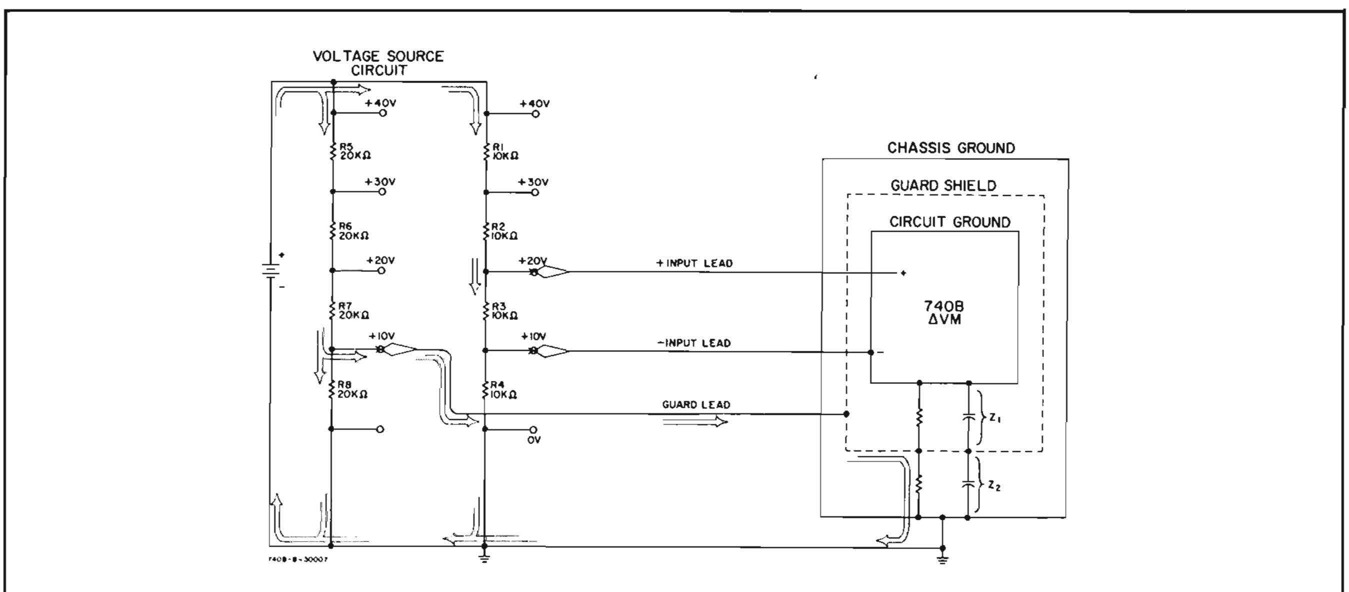



Figure 3-11. Guarding Against DC Ground Currents

## 3-55. VOLTMETER.

### 3-56. DESCRIPTION.

3-57. In the Voltmeter mode, the Model 740B functions as a high impedance dc voltmeter with end scale ranges from 1 μV to 1000 V. Ranges below 10 mV are obtained by using the SENSITIVITY pushbuttons to increase meter sensitivity. The input voltage is indicated on the meter.

### 3-58. OPERATING PROCEDURE.

3-59. The following steps describe the procedure for using the Model 740B in the Voltmeter mode:

a. Set rear panel LINE VOLTAGE switch to correct position for available line voltage.

b. Connect ac power cord to ac power connector; connect cord plug to ac line.

c. Turn on the Model 740B by depressing the POWER pushbutton (indicator glows).

d. Set FUNCTION to VM.

NOTE

Digital readout tubes will not glow in VM mode.

e. Check OUTPUT indicator. If glowing, depress to turn output off.

f. Connect input cable assembly (-hp- 11054A) to INPUT receptacle. Set INPUT Z switch to ∞.

g. Set RANGE and SENSITIVITY for the desired end scale voltage (Table 3-4).

NOTE

An additional end scale voltage range of 0.1 μV could be obtained by setting RANGE to 1 mV and depressing X10$^4$ SENSITIVITY. Meaningful measurements cannot, however, be made on this range due to the problems of noise at this extremely low voltage level.

Table 3-4. VM Mode RANGE and SENSITIVITY Settings

| Desired End Scale Voltage Range | RANGE | SENSITIVITY |
|---|---|---|
| 1000 V | 1000 V | X1 |
| 100 V | 100 V | X1 |
| 10 V | 10 V | X1 |
| 1 V | 1 V | X1 |
| 100 mV | 100 mV | X1 |
| 10 mV | 10 mV | X1 |
| 1 mV | 10 mV | X10 |
| 100 μV | 10 mV | X10$^2$ |
| 10 μV | 10 mV | X10$^3$ |
| 1 μV | 10 mV | X10$^4$ |

h. Zero the 740B input (1 mV range and below) by connecting a shorting wire from + to - INPUT terminals and adjusting ZERO control for zero meter deflection.

i. Connect input box terminals for the type of measurement desired using the information in Table 3-5.

NOTE

Negative voltages up to 1 V can be measured in VM mode without reversing the + and - INPUT terminal connections.

j. Read the input voltage on the 740B meter.

CAUTION

THE 740B INPUT SHOULD BE DISCHARGED FOLLOWING ALL HIGH VOLTAGE MEASUREMENTS TO PREVENT CARRYING THE STORED CHARGE TO THE NEXT POINT OF MEASUREMENT.

k. Remove leads from device under test or de-energize voltage source and place INPUT Z switch to 2 MEG position to discharge 740B input.

Table 3-5. Input Terminal Connections

| TYPE OF MEASUREMENT | CONNECT INPUT TERMINALS | | | |
|---|---|---|---|---|
| | + | - | GUARD | ⏚ |
| Unguarded (floating) | To high (most positive) of source | To low (most negative) of source | To - terminal | Not Connected |
| Guarded (floating) | To high (most positive) of source | To low (most negative) of source | To reference potential of source | Not Connected |

## 3-60. AMPLIFIER.

3-61. In the Voltmeter and Differential Voltmeter modes of operation, the Model 740B may be used as a power and voltage amplifier. Two separate amplifier outputs are available.

### 3-62. POWER AMPLIFIER.

3-63. DESCRIPTION.

3-64. Whenever an input voltage is applied to the Model 740B in Voltmeter or Differential Voltmeter modes, a voltage is present at the + and - OUTPUT terminals when the Output is turned on. This voltage is equal to the input voltage on the 1 V range and above. Output voltage on the millivolt ranges exceeds the input voltage by 20 dB, 40 dB or 60 dB on the 100 mV, 10 mV and 1 mV ranges respectively (Table 3-6). Output current characteristics are the same as Standard mode; the high input resistance characteristics of the Voltmeter and Differential Voltmeter modes are retained. When used as a power amplifier in Voltmeter mode, up to 110% of range may be applied to and obtained from the Model 740B with no loss of gain accuracy.

Table 3-6. Power Amplifier Output Voltage

| RANGE | VOLTAGE GAIN | OUTPUT VOLTAGE (With full scale input applied) |
|---|---|---|
| 1000 V | 0 dB | 1000 V |
| 100 V | 0 dB | 100 V |
| 10 V | 0 dB | 10 V |
| 1 V | 0 dB | 1 V |
| 100 mV | +20 dB | 1 V |
| 10 mV | +40 dB | 1 V |
| 1 mV | +60 dB | 1 V |

3-65. OPERATING PROCEDURE.

3-66. To use the Model 740B as a power amplifier, proceed as follows:

a. Turn on the Model 740B and allow one hour for instrument warmup.

b. Set FUNCTION to ΔVM or VM as desired.

c. If measurement of input voltage is desired, perform steps e through r of Paragraph 3-46 for ΔVM position or e through j of Paragraph 3-59 for VM position. If measurement of input is not desired, set RANGE to the range nearest above the input voltage.

d. Check OUTPUT pushbutton-indicator. If glowing, depress to turn Output off.

e. Connect Output Cable (-hp- Accessory 11055B) to Output Receptacle.

f. Connect OUTPUT terminals for the output condition desired (Table 3-1).

g. Set CURRENT LIMIT control for the desired maximum limit of output current (Paragraph 3-38).

h. Depress OUTPUT pushbutton indicator. Indicator lights to indicate dc output. OVERLOAD indicator, if glowing, indicates the current limit has been exceeded or no remote or local sensing is in effect.

### 3-67. VOLTAGE AMPLIFIER.

3-68. DESCRIPTION.

3-69. The rear panel RECORDER OUTPUT terminals provide a dc voltage which is proportional to meter

Table 3-7. RECORDER OUTPUT Voltage Gain as a Function of RANGE and SENSITIVITY

| RANGE | SENSITIVITY | | | | |
|---|---|---|---|---|---|
| | X1 | X10 | X10$^2$ | X10$^3$ | X10$^4$ |
| 1000 V | -60 dB | -40 dB | -20 dB | 0 dB | +20 dB |
| 100 V | -40 dB | -20 dB | 0 dB | +20 dB | +40 dB |
| 10 V | -20 dB | 0 dB | +20 dB | +40 dB | +60 dB |
| 1 V | 0 dB | +20 dB | +40 dB | +60 dB | +80 dB |
| 100 mV | +20 dB | +40 dB | +60 dB | +80 dB | +100 dB |
| 10 mV | +40 dB | +60 dB | +80 dB | +100 dB | +120 dB |
| 1 mV | +60 dB | +80 dB | +100 dB | +120 dB | +140 dB* |

* Not recommended

deflection. Polarity of this voltage depends upon the polarity of the meter deflection. Magnitude of the voltage depends upon the degree of meter deflection and the setting of the RECORDER AMPLITUDE control. With the RECORDER AMPLITUDE control set to maximum (fully cw) the output voltage is approximately 1 Vdc into a 1 kΩ load. The RECORDER AMPLITUDE control may be useful in matching the output voltage scale to an external recorder or monitoring device. Normally the RECORDER AMPLITUDE control is adjusted for a 1 Vdc output (with recorder or monitoring device connected) for an end scale meter deflection.

3-70. Voltage gain from the Model 740B input to the RECORDER OUTPUT terminals depends on the RANGE and SENSITIVITY selected. Table 3-7 shows the gain produced by different combinations of RANGE and SENSITIVITY.

3-71. The - RECORDER OUTPUT terminal is connected in common with the - INPUT and - OUTPUT terminals on the Model 740B. All of these terminals are isolated from earth ground ( ⏚ ) although the main chassis and cabinet are connected to earth ground through the center pin of the line cord plug. This allows the Model 740B to make floating measurements (measurements where the - INPUT terminal is referenced above or below earth ground) without danger to the operator since the chassis and cabinet remain at earth ground potential. The chassis and cabinet of most recorders, however, are not isolated from the recorder's - input terminal. This means that floating measurements usually cannot be safely made with a recorder connected to the RECORDER OUTPUT terminals since the recorder's chassis and cabinet would be connected to the floating potential. Using an isolation transformer or 3 prong to 2 prong adapter to isolate the power input to the recorder would not help. The recorder's cabinet and chassis would be floated at the same potential as the Model 740B - INPUT terminal and a dangerous condition would exist. The only safe way to make floating measurements using a recorder is to select a recorder with a floating input (- input terminal isolated from the recorder cabinet and chassis) and a grounded chassis and cabinet.

3-72. OPERATING PROCEDURE.

3-73. To use the Model 740B as a voltage amplifier, proceed as follows:

a. Turn on the Model 740B and allow one hour for instrument warmup.

b. Connect recorder or monitoring device to RECORDER OUTPUT terminals.

**CAUTION**

DO NOT ATTEMPT TO FLOAT MODEL 740B -INPUT TERMINAL UNLESS RECORDER - TERMINAL IS ALSO FLOATED (PARAGRAPH 3-71).

c. Set FUNCTION to STD; turn STANDARD VERNIER fully cw (meter deflects to + end scale).

d. Adjust RECORDER AMPLITUDE control for desired end scale voltage value as indicated on recorder or monitoring device.

e. Return STANDARD VERNIER control to zero (fully ccw).

f. Set FUNCTION to ΔVM or VM as desired.

g. Perform steps e through r of Paragraph 3-46 if ΔVM mode is selected; steps c through j of Paragraph 3-59 if VM mode is selected.

h. Observe RECORDER OUTPUT voltage on recorder or monitoring device.

# SECTION IV
# THEORY OF OPERATION

## 4-1. MODES OF OPERATION.

4-2. The Model 740B has three basic modes of operation: 1) Standard, 2) Differential Voltmeter, and 3) Voltmeter. Through the use of a function switching technique, many of the same basic circuits are used in each mode of operation. These circuits are: 1) a Main Loop, 2) a Meter Loop, and 3) a Reference Loop. The Standard and Differential Voltmeter modes utilize all of these basic circuits. The Voltmeter mode utilizes all of them except the Reference Loop. The following paragraphs discuss the theory for each mode of operation.

4-3. STANDARD (Figure 7-2).

4-4. In Standard mode of operation, the Model 740B Reference Loop generates a very stable and accurate reference voltage. The value of the reference voltage (0 to 1 V) is controlled by the front panel VOLTAGE SET and STANDARD VERNIER switches. The voltage is then amplified by the Main Loop and applied through the output cable to the + and - OUTPUT terminals.

4-5. The Reference Loop consists of a 1 V reference supply, a binary coded decimal divider and a step vernier control. The reference supply generates a very stable +1 Vdc which is applied to the binary coded decimal divider. Divider ratios in the binary coded decimal divider are controlled by the five front panel VOLTAGE SET switches. The step vernier control, operated by the front panel STANDARD VERNIER switch, further divides the reference supply output. The resultant output of the Reference Loop is a dc level adjustable in 1 $\mu$V steps from 0 to +1 Vdc. The output is applied to the Main Loop.

4-6. Basically, the Main Loop is a high gain dc amplifier which uses degenerative voltage feedback to obtain precise gain characteristics, high input resistance and low output resistance. The Main Loop consists of several internal amplifiers and a feedback network connected from the Main Loop output to the input. The amplifiers in the Main Loop are connected in cascade and collectively have an open loop gain (gain without feedback) of from $10^5$ on the 1 V range to $10^8$ on the 1000 V range (Table 4-1). The feedback network monitors the actual value of the output voltage and feeds a controlled fraction of the output back to the input. The feedback voltage is compared to the input in such a way that it subtracts from the input voltage. The amplifier then amplifies only the error voltage: the difference between the input voltage and the feedback voltage. Since the amplifier input voltage is greatly reduced by the degenerative feedback, the effective (closed loop) gain is much smaller than open loop gain -- providing a sizable portion of the output is used as feedback. The closed loop gain is the effective voltage gain of the amplifier and can be calculated from the following formula:

$$G = \frac{A}{1 + \beta A}$$

where:

G = closed loop gain

A = open loop gain

$\beta$ = portion (fraction) of the output voltage that is used as degenerative feedback.

4-7. Mathematically, it can be shown that when A becomes very large, the formula can be essentially reduced to:

$$G = \frac{1}{\beta}$$

Note that closed loop gain depends only on $\beta$ whenever open loop gain (A) is very high. Closed loop gain accuracy then is dependent almost entirely on the accuracy of the voltage divider which determines $\beta$. The Main Loop Feedback Divider is made from stable, precision wire-wound resistors enabling the Main Loop to have stable, precise closed loop gain characteristics.

Table 4-1. Main Loop Gain Characteristics

| Range | A | $\beta$ | G |
|---|---|---|---|
| 1 V | $10^5$ | 1 | 1 |
| 10 V | $10^6$ | 0.1 | 10 |
| 100 V | $10^7$ | 0.01 | $10^2$ |
| 1000 V | $10^8$ | 0.001 | $10^3$ |

4-8. Closed loop gain increases by a factor of ten on each increasing voltage range. The input to the Main Loop from the Reference Loop is 0 to 1 V in 1 $\mu$V steps on all ranges. This results in available outputs from the Main Loop of:

| | |
|---|---|
| 0 to 1 V in 1 $\mu$V steps | (1 V range) |
| 0 to 10 V in 10 $\mu$V steps | (10 V range) |
| 0 to 100 V in 100 $\mu$V steps | (100 V range) |
| 0 to 1000 V in 1 mV steps | (1000 V range) |

The output of the Main Loop is applied through an internal switch to the + and - OUTPUT terminals whenever the Output is turned on. The SENSE terminals provide voltage feedback to the Main Loop Feedback Divider.

4-9. The only purpose of the Meter Loop in Standard mode is to indicate the value of the sixth digit of the output voltage. The value of the sixth digit is controlled by a deck of the ten position STANDARD VERNIER switch. A second deck of the switch selects a voltage proportional to the sixth digit from a voltage divider. The output from the second deck of the switch is 0 to +0.1 V in 0.01 V steps. The 0 to +0.1 V output of the STANDARD VERNIER switch is applied as an input to the Meter Loop.

4-10. The Meter Loop, like the Main Loop, is basically a voltage feedback amplifier. In Standard Mode, the feedback factor ($\beta$) is always 0.1 resulting in a constant closed loop gain (G) of 10.

4-11. The Meter Loop consists of a meter amplifier, a meter, and a feedback network. The output of the meter amplifier drives the meter. The meter drives from 0 (mid scale) to +1.0 in .1 steps as the STANDARD VERNIER switch is rotated clockwise. The decimal point in the meter indication is not considered present in Standard mode, resulting in a 0 to 10 indication for the sixth digit.

4-12. DIFFERENTIAL VOLTMETER (Figure 7-1).

4-13. In the Differential Voltmeter mode of operation, the unknown voltage is applied to the Main Loop. Feedback voltage from the Main Loop output to the input controls the closed loop gain. The magnitude of the feedback voltage is proportional to the unknown input voltage.

4-14. The Main Loop feedback voltage, or a portion of it (depending on range), is applied in series opposition to the Reference Loop output. The Reference Loop generates a very stable reference voltage. Magnitude of the reference voltage (0 to 1 V) is controlled by the front panel VOLTAGE SET switches.

4-15. The Meter Loop Monitors the difference between the Main Loop feedback and the Reference Loop output and indicates null (0) when the two voltages are equal. The value of the input voltage is then indicated on the digital readout tubes (first five digits) and the meter (sixth digit).

4-16. The input voltage is applied through the Overload Protection circuit and Input Filter to the Main Loop. The Overload Protection circuit protects the instrument from voltages that exceed the selected range. The input filter removes any ac signal and noise superimposed on the dc input.

4-17. The operation of the Main Loop in Differential Voltmeter mode is similar to its operation in Standard Mode. The Main Loop Feedback Divider determines the closed loop gain by controlling the amount of feedback returned to the input on each range. Table 4-2 shows the gain relationships.

4-18. Regardless of the range selected, the feedback voltage to the Main Loop input is of the same polarity and nearly the same amplitude as the unknown dc input. The Main Loop amplifies the difference between the two voltages. Since the feedback and input voltages are almost equal, very little current is drawn from the input voltage source by the Main Loop and the input section presents a very high impedance to the signal source.

4-19. On the 1 V range and below, the feedback voltage from the Main Loop output is applied directly to the Reference Loop. Closed loop gain of the Main Loop is 1, 10, $10^2$ and $10^3$ on the 1 V, 100 mV, 10 mV and 1 mV ranges respectively, which result in a 0 to 1 V input to the Reference Loop on these ranges. On the ranges above 1 V, the feedback voltage from the Main Loop output is divided by 10, 100 and 1000 on the 10 V, 100 V and 1000 V ranges respectively before being applied to the Reference Loop. On all ranges, the input to the Reference Loop is 0 to 1 V, proportional to the unknown dc input voltage (Table 4-2).

4-20. The operation of the Reference Loop in Differential Voltmeter mode is very similar to its operation in Standard mode. The reference supply furnishes a stable and accurate 1 V reference voltage to the binary coded decimal divider. Divider ratios are controlled by the five VOLTAGE SET switches. The STANDARD VERNIER control, however, is not used in Differential Voltmeter mode. The resultant output of the divider is 0 to +1 Vdc in 10 $\mu$V steps. The divider output is applied through the SENSITIVITY switch and FUNCTION switch in series opposition to the 0 to 1 V from the Main Loop feedback. If the voltages are not equal, current will flow through the Reference Loop. This current is applied to the Meter Loop.

Table 4-2. Main Loop Gain ($\Delta$VM)

| Range | $\beta$ | Closed Loop Gain, G $(\frac{1}{\beta})$ | Main Loop Output with Full Scale Input Applied | Input to Reference Loop with Full Scale Input Applied |
|---|---|---|---|---|
| 1 mV | .001 | $10^3$ | 1 V | 1 V |
| 10 mV | .01 | $10^2$ | 1 V | 1 V |
| 100 mV | .1 | 10 | 1 V | 1 V |
| 1 V | 1 | 1 | 1 V | 1 V |
| 10 V | 1 | 1 | 10 V | 1 V |
| 100 V | 1 | 1 | 100 V | 1 V |
| 1000 V | 1 | 1 | 1000 V | 1 V |

4-21. The Meter Loop is basically a voltage feedback amplifier. Closed loop gain of the Meter Loop is determined by the SENSITIVITY pushbuttons which control the feedback factor, $\beta$. Moving left to right, depressing each successive SENSITIVITY pushbutton increases the closed loop gain by a factor of ten. Table 4-3 shows the gain relationships.

Table 4-3. Meter Loop Gain ($\Delta$VM and VM)

| SENSITIVITY | Closed Loop Gain, G $(\frac{1}{\beta})$ | Required Input for End-Scale Meter Deflection |
|---|---|---|
| X1 | 1 | 1 V |
| X10 | 10 | 100 mV |
| X$10^2$ | $10^2$ | 10 mV |
| X$10^3$ | $10^3$ | 1 mV |
| X$10^4$ | $10^4$ | 100 $\mu$V |

4-22. VOLTMETER (Figure 7-1).

4-23. In Voltmeter mode of operation, the Main Loop amplifies the input voltage and provides a high input impedance to the signal source. Feedback voltage from the Main Loop Feedback Divider is applied directly to the Meter Loop. By depressing the SENSITIVITY pushbuttons, the Meter Loop provides additional gain, extending the instrument useful sensitivity down to 1 $\mu$V end-scale (10 mV Range, X$10^4$ Sensitivity). An additional range of 0.1 $\mu$V end-scale can be obtained by selecting the 1 mV Range and X$10^4$ Sensitivity. Meaningful measurements, however, cannot be made under these conditions due to the problems of noise at this extremely low voltage level. The Reference Loop is not used in the Voltmeter mode of operation.

## 4-24. CIRCUIT DESCRIPTION.

4-25. INPUT CIRCUITS.

4-26. INPUT CABLE ASSEMBLY (Figure 7-4).

4-27. In Voltmeter and Differential Voltmeter modes of operation, the unknown dc input voltage is applied to the + and - INPUT terminals located on the Input Cable Assembly (-hp- Accessory 11054A). The INPUT Z switch on the Input Box provides a selection of input resistances. In the $\infty$ position, the input resistance is determined by the very high input resistance characteristics of the Main Loop. The resulting input resistance for the various ranges are as follows:

1 mV range: $> 10^8\ \Omega$

10 mV range: $> 10^9\ \Omega$

100 mV to 1000 V range: $> 10^{10}\ \Omega$

4-28. When the INPUT Z switch is placed in the 2 MEG position, a 2 M$\Omega$ resistor is connected across the + and - INPUT terminals. Normally, this switch position is used only to discharge any residual voltage charge maintained by the input circuit following high voltage measurements. The voltage charge might otherwise be maintained indefinitely due to the very high input resistance characteristics of the Main Loop. The switch may be left in the 2 MEG position when making voltage measurements; however, the loading effects of the 2 M$\Omega$ resistor will cause a measurement error. The GUARD terminal on the Input Cable Assembly is connected through the cable to the instrument internal guard shield. The guard shield contains all of the critical circuits and isolates them from the instrument main chassis. Also, the guard shield may be referenced to a different potential than the main chassis by connecting the GUARD terminal to a reference potential. Guarded measurements are explained in Paragraph 3-49.

4-29. The ⏚ terminal is connected through the cable to the cabinet and main chassis and to powerline ground through the center conductor of the line cord. The ⏚ terminal may be used to ground external test equipment.

4-30. INPUT PROTECTION CIRCUIT AND INPUT FILTER (Figure 7-3).

4-31. The +INPUT terminal is connected through the INPUT receptacle to A9V2. Under non-overload conditions, A9V2 is in its low resistance state and the applied signal is fed through A9V2 to the Input Filter. With no overload, A9V2 remains in its low resistance state in the following manner: Transistor A9Q1 is normally conducting due to the forward bias conditions established by the -30 V supply and A9R1. When A9Q1 conducts, A9DS2 turns on and illuminates the photocell, A9V2. The light on A9V2 causes its resistance to be low and the input signal is conducted through A9V2 to the Input Filter.

4-32. Assume now that an input voltage greatly in excess of the selected range is applied to the + and -INPUT terminals: A9DS1 is connected from the Main Loop Feedback line to the Input Filter. With a large overload, the Main Loop feedback voltage cannot match the input voltage because the amplifiers in the Main Loop saturate. When the difference between feedback and input reaches about 90 V, A9DS1 ionizes and illuminates A9V1. A9V1 goes to a low resistance state and turns off A9Q1. With A9Q1 turned off, A9DS2 goes out and A9V2 goes to a high resistance state and blocks the input voltage. With the overload voltage felt across A9V2, A9DS3 now ionizes and allows enough overload current to flow to keep A9DS1 ionized and prevent oscillations. A9R3 limits current through A9DS3 to protect the input circuits. Removal of the overload returns the circuit to the normal state.

4-33. The Input Filter is a 2-section LC filter consisting of L2, C6 and C7. The filter presents a high rejection to unwanted noise superimposed on the dc input. In Standard mode, the output of the Reference Loop is fed through part of the filter to the Main Loop input. The filter removes any superimposed noise on the reference voltage.

## 4-34. MAIN LOOP VOLTAGE FEEDBACK AMPLIFIER (Figure 7-3).

4-35. The input circuits feed a dc voltage to the Main Loop. The dc voltage is the unknown dc input in Voltmeter and Differential Voltmeter modes, or the Reference Loop output in Standard Mode. The purpose of the Main Loop is to furnish extremely high input resistance, precise voltage gain and high current gain. Extremely high input resistance allows high impedance voltage sources to be measured without loading errors. It also allows the Reference Loop to be well isolated from a load connected to the Output terminals in Standard mode. Precise voltage gain is necessary for accurate measurements in Voltmeter and Differential Voltmeter modes and for accurate outputs in Standard mode. High current gain allows the Main Loop output to drive a load in Standard mode without drawing significant current from the Reference Loop. It also allows the Model 740B to be used as a dc power amplifier in Voltmeter and Differential Voltmeter modes. Significant loads can be driven by the output without loading the signal source applied to the input.

4-36. The Main Loop consists of a Low Voltage Section and a High Voltage Section. The two sections operate together as a voltage feedback amplifier. Degenerative feedback voltage from the output of the High Voltage Section is fed back to the input of the Low Voltage Section and determines the closed loop (effective) gain. The feedback controls the closed loop gain in the following manner: Assume 1 Vdc is applied as an input to the Low Voltage Section of the Main Loop (Voltmeter mode, 1 V range). The open loop (actual) gain of the Main Loop is $10^5$ (Table 4-1). The voltage at the Main Loop output starts at zero and increases in a positive direction. On the 1 V range, the feedback factor, $\beta$, is 1 (unity) which means all of the Main Loop output is fed back to the input. After a very short time, the value of the feedback voltage approaches the value of the input voltage (1 V). The feedback voltage is compared to the input voltage in such a manner as to subtract from it and the Main Loop amplifies only the error difference between the two voltages. Since the feedback voltage is rapidly approaching the input voltage, the error voltage rapidly approaches zero. When the error voltage reaches approximately 10 $\mu$V, the Main Loop output stabilizes at 0.999990 V. 10 $\mu$V represents the smallest error voltage that will produce a feedback voltage nearly equal to the 1 V input voltage when amplified by the $10^5$ open loop gain.

4-37. The 10 $\mu$V error causes outputs to be slightly low in Standard mode and indications to be slightly high in Differential Voltmeter mode. Generally, greatest instrument accuracy is desired in Standard mode. The effects of the 10 $\mu$V error in Standard mode are compensated by adjusting the 1 V Reference Supply until the Main Loop produces an accurate 1 V at the Output terminals (Paragraph 5-62 steps m through p). This procedure provides best instrument accuracy in Standard mode with a slight loss of accuracy in Differential Voltmeter mode. If optimum accuracy is desired in Differential Voltmeter mode (with some loss of accuracy in Standard mode), the Reference Supply calibration can be performed in Differential Voltmeter mode. Paragraph 5-62, step p describes this procedure. The effects of the small gain error are not great enough to affect instrument performance in Voltmeter mode.

## 4-38. LOW VOLTAGE SECTION.

4-39. The Low Voltage Section consists of the chopper stabilized Low Level Amplifier (A3) and the Operational Filter (part of A4).

4-40. Low Level Amplifier, A3 (Figure 7-3 and 7-7). In the Voltmeter and Differential Voltmeter modes of operation, the unknown dc input is applied through the input circuits to the Modulator, A17. In Standard mode, the Reference Loop output (0 to +1 V) is applied through a section of the Input Filter to the Modulator.

4-41. The Modulator consists of two photocells, A17V1 and A17V2, and two neon lamps, A17DS1 and A17DS2. The photocells are in a low resistance state when lighted by the neons, and a high resistance state when not lighted. The neons are driven by pulses from the Neon Driver, A8. The neons light alternately at a rate of 162 Hz. A17V1 is in series with the voltage from the Input Filter. A17V2 is in series with the Main Loop feedback. The resultant output of the Modulator is a 162 Hz ac error signal proportional in peak-to-peak amplitude to the difference between input voltage and feedback voltage. The ac error signal rides on a dc level equal to the input voltage.

4-42. The 162 Hz error signal is fed through the Range and Function Switch to the Low Level Amplifier, A3. An ac attenuator on the Range Switch, consisting of S1C1, S1R1, S1C2, S1R2, S1R3 and S1R4, reduces the amplitude of the signal by a factor of ten on each increasing range above 1 V in the Voltmeter and Differential Voltmeter modes. In Standard mode, the ac error signal bypasses the attenuator and goes directly to A3 pin 1.

4-43. A3C1 removes the dc component from the ac error signal. CR1 limits large negative spikes that occur when the selected range is exceeded or when the input voltage changes faster than the Main Loop can respond. A3Q1 through A3Q3 comprise a cascade-coupled, three-stage amplifier. Degenerative ac feedback from the emitter of A3Q3 to the emitter of A3Q1 ensures gain stability. DC feedback from the collector of A3Q3 to the base of A3Q1 controls the bias on Q1 and provides some gain correction for varying input voltages. The signal from the collector of A3R9* (typically 22 k$\Omega$) is factory selected to set the gain of the Low Level Amplifier to properly match the gain characteristics of the other Main Loop components. Paragraph 5-91 explains the A3R9* selection procedure. A3Q3 is capacitively coupled to A3Q4. A3Q4 and A3Q5 comprise a variable gain differential amplifier. The output of the amplifier, at the collector of A3Q4 is proportional to the difference in signal levels between the base of A3Q4 and the base of A3Q5. The signal applied to the base of A3Q5 is degenerative feedback from the output stage of the Low Level Amplifier. The feedback is divided by the A3R19/A3R11 divider before being applied to the differential amplifier. A3R20 is switched in parallel with A3R19 on the 1 V range and above to increase the amount of degenerative feedback and reduce the Low Level Amplifier gain on these ranges. The output of the differential amplifier is applied to the base of A3Q6, amplified by A3Q6 and applied to A3Q7 and A3Q8. A3Q7 and A3Q8 comprise a class AB push-pull amplifier which provides additional gain to the error signal. A3R13, A3CR2, A3CR3 and A3R17 keep A3Q7 and A3Q8 slightly forward biased under no-signal conditions, eliminating crossover distortion and providing temperature compensation for the circuit. The output of the push-pull amplifier can be monitored at A3TP10.

4-44. The amplified error signal from the push-pull output circuit is monitored by the Overload Detector circuit. A3C6 couples the ac signal to A3CR4 and A3CR5 which form a peak detector. If the ac signal is large enough to turn on A3CR4 and A3CR5, negative pulses appear at the anode of A3CR4. A3C7 filters the pulses and the resulting dc is applied through A3R21 to A3Q9, causing A3Q9 to conduct. When A3Q9 conducts, A3Q10 is forward biased and begins to conduct, turning on DS1, the front-panel OVERLOAD light. When the error signal is small, A3CR4 and A3CR5 turn off, and A3C7 discharges through A3R22, removing the forward bias from A3Q9. A3Q10 then turns off and the OVERLOAD light goes out.

4-45. The output of the Low Level Amplifier is coupled through C5 to the Demodulator, A17. The Demodulator consists of two photocells, A17V3 and A17V4. The photocells are lighted alternately by A17DS1 and A17DS2, the same neons that control the modulator photocells (A17V1 and A17V2). Demodulation takes place and the resultant output of the demodulator is a dc level proportional in magnitude to the ac error signal amplitude. Magnitude of the dc level is approximately 0 to -10 mV on all ranges and functions. Voltage gain of the Low Level Amplifier is approximately $10^3$ on the 1 V to 1000 V ranges; $10^4$ on the mV ranges.

4-46. The Demodulator output is fed through the Gain Check switch, S10, to the Operational Filter, part of A4. The Gain Check switch, when depressed, introduces a dc offset into the Main Loop and provides a way of checking Low Level Amplifier gain (Paragraph 5-76).

4-47. Operational Filter, p/o A4 (Figure 7-8). The Operational Filter is basically a frequency selective, voltage feedback amplifier. Capacitively coupled degenerative feedback from the amplifier's output stage to the input stage greatly reduces the amplifier's ac gain. DC voltage gain is approximately 100. The net effect is to greatly increase the signal-to-noise ratio without the use of large filter capacitors or inductors which would reduce the response time of the Main Loop when an input is applied.

4-48. The 0 to -10 mV input to the Operational Filter is proportional to the Main Loop input voltage and represents the "error" between the Main Loop input and feedback voltages. The dc input is applied through A4R1 and A4R2 to the base of A4Q1. The quiescent voltage at the base of A4Q1 is controlled by A4Q3, A4R5 and A4R6. A4R6 (BAL ADJ) is adjusted for 0 V at the base of A4Q1 with no input signal applied. Generally, A4R6 does not need to be adjusted unless A4Q1 or A4Q2 is replaced. A4TP11 monitors the voltage at the base of A4Q1.

4-49. The input stage consists of a differential pair, A4Q1 and A4Q2. A4Q2 establishes the zero reference for the circuit and provides temperature compensation for A4Q1. A4R13 (INT ZERO) sets the operating point of A4Q2. A4CR2 and A4CR3 regulate the + and - supply voltages for the Operational Filter to +6.8 V and -6.8 V respectively. The output of A4Q1 is further amplified by A4Q4 and A4Q5.

4-50. The output of A4Q5, at the junction of A4R17 and A4R18, is fedback degeneratively through 2 paths to the base of A4Q1. DC feedback is divided by the A4R19/A4R20 divider and fed back through A4R21 to A4Q1, setting the dc gain of the Operational Filter at about 100. Degenerative ac feedback is fed directly through A4C4 to the base of A4Q1. A4C4 is a very low impedance feedback path for ac and the ac gain of the Operational Filter at most frequencies approaches zero. On instruments above Serial No. 610-00376, A4C4 is discharged when switching modes or when switching between the 10 V, 100 V and 1000 V ranges. The discharge path is from A4 pin 8 to A4 pin 22 through S1R20. The path is completed by momentary shorting contacts on the Range and Function Switch, S1. The contacts briefly complete the discharge path when the Range or Function switch is between positions.

4-51. The dc output of A4Q5 is further filtered by two 39 $\mu$F electrolytic capacitors, A4C5 and A4C6. A4C5 and A4C6 are connected back-to-back which results in a 19.5 $\mu$F, non-polarized, low leakage filter. Shunt limiter A4CR4 through A4CR9, limits the Operational Filter output to values between -1.8 V and +1.8 V. The Operational Filter output (0 to +1 Vdc) is applied to the Differential Amplifier (Paragraph 5-54).

4-52. HIGH VOLTAGE SECTION.

4-53. The High Voltage Section is a voltage feedback amplifier within the Main Loop. In Standard mode, the High Voltage Section generates the desired output voltage and current. In Voltmeter and Differential Voltmeter modes, 1 V range and above, the High Voltage Section duplicates the unknown dc input voltage. On the ranges below 1 V, the High Voltage Section generates 0 to 1 V proportional to the unknown dc input voltage. Closed loop gain of the High Voltage Section is controlled by voltage feedback from the output stage to the Differential Amplifier input stage. The High Voltage Section has a closed loop gain of 1 (unity) on the 1 V range and below; 10 on the 10 V, $10^2$ on the 100 V Range; $10^3$ on the 1000 V Range.

4-54. Differential Amplifier p/o A4 (Figure 7-8). The Differential Amplifier is the input stage of the High Voltage Section of the Main Loop. The differential Amplifier compares the output of the Operational Filter to feedback voltage from the output stage of the High Voltage Section. It then furnishes a voltage to the Pulse Width Converter (part of A5) which is proportional to the difference between the two voltages.

4-55. The dc output of the Operational Filter is applied to the base of A4Q7. The base of A4Q7 is grounded through A4 pin 8 and a deck of the Range and Function Switch whenever operation on the mV ranges in Standard mode is attempted, preventing operation of the High Voltage Section. The Differential Amplifier consists of A4Q7 through A4Q10. A4Q7/A4Q8 and A4Q9/A4Q10 are Darlington Pairs which provide high gain and sensitivity to the amplifier. Whenever a current is drawn from the + and - OUTPUT terminals which exceeds the setting of the CURRENT LIMIT control, A4Q12 is forward biased by an input from A5, and lowers the voltage at the emitters of A4Q8 and A4Q9, reducing the output of the differential amplifier. The dc output of the Differential Amplifier is further amplified and inverted by A4Q11 and fed through A4 pin 3 to the Pulse Width Converter. The signal at this point varies from approximately +8.4 V (for a 0 V Main Loop output) to +6 V (for a 1000 V 20 mA Main Loop output).

4-56. Pulse Width Converter and 20 kHz Clock, p/o A5 (Figure 7-9). The dc input to the Pulse Width Converter from the Differential Amplifier is a dc level that varies from approximately +8.4 V (0 V Main Loop output) to +6 V (1000 V 20 mA Main Loop output). The Pulse Width Converter converts this input voltage to 20 kHz pulses that vary in width proportional to the Main Loop output voltage and current. The 20 kHz Clock controls the pulse frequency.

4-57. The 20 kHz Clock consists of A5Q1 and A5Q2 which form an astable (free-running) multivibrator. A5R1, A5C2 and A5R5 determine the 20 kHz switching frequency. The multivibrator output is differentiated by A5C1, A5C4 and A5C3. A5CR1 removes the negative spikes. The remaining 20 kHz positive spikes are applied through A5CR2 to the Pulse Width Converter at the collector of A5Q3.

4-58. A5Q3 and A5Q4 form a Schmitt-Trigger that functions as a monostable (one-shot) multivibrator. In the stable state, A5Q4 is conducting and A5Q3 is cut off. Each positive pulse from the 20 kHz Clock causes the multivibrator to switch to the unstable state. The length of time the multivibrator stays in the unstable state is determined by the voltage at the base of A5Q3 from the Differential Amplifier. When this voltage is +8.4 V (representing a 0 V Main Loop output) the unstable state is very short -- approximately the same length as the triggering pulse from the 20 kHz Clock. As the voltage at the base of A5Q3 decreases toward +6 V, the multivibrator stays in the unstable state longer each time it is triggered. When the A5Q3 base voltage reaches +6 V (representing maximum voltage and current output from the Main Loop), the unstable state reaches a maximum duration of approximately 20 $\mu$sec. The resultant output of the Pulse Width Converter at the collector of A5Q4 is a series of negative 20 kHz pulses, varying in width from approximately 2 $\mu$sec to 20 $\mu$sec, proportional to the Main Loop output voltage and current. A5Q5, an emitter follower, provides current gain for the pulses. The pulses are then fed out A5 pin 19 and through T3 to the Power Switch Driver, part of A7.

4-59. Power Switch Driver and Power Switch (Figure 7-11). The Power Switch Driver and Power Switch provide current gain and shaping to the variable-width 20 kHz pulses from the Pulse Width Converter.

4-60. The variable-width 20 kHz pulses from A5 pin 19 are transformer-coupled to A7 pin 1. From A7 pin 1 the pulses are applied through A7R1 and A7L1 to A7Q1. The leading edge of each pulse turns on A7Q1. When A7Q1 conducts, negative voltage from the emitter of A7Q1 turns on the Power Switch Transistors, Q1 and Q2. When Q1 and Q2 conduct, current flows from the emitter of A7Q1 through A7R10 to the base of Q2. This base current through A7R10 keeps A7Q2 and A7Q3 cut off for the duration of the pulse.

4-61. The trailing edge of the variable-width pulse turns off A7Q1. The emitter of A7Q1 is then clamped to approximately +1.2 V by A7CR1 and A7CR2. The positive voltage turns off the Power Switch Transistors, Q1 and Q2, and turns on A7Q2 and A7Q3. Conduction of A7Q2 and A7Q3 helps discharge the emitter-base capacitance of the Power Switch Transistors, greatly decreasing their turn-off time at the end of the variable-width pulse. A7C8* (typically 0.0068 $\mu$F) is factory selected to match the reactive characteristics of the Power Switch Driver with the Power Switch transistors, Q1 and Q2. Paragraph 5-95 explains the A7C8* selection procedure.

4-62. Internal Current Limit, p/o A7 (Figure 7-11). The -42 V Power Supply supplies collector current to Q1 and Q2 through R4, F3 and the primary of T4. At high output voltage and power levels, the voltage pulses across R4 increase in amplitude. A7R14 and A7C7 integrate these pulses and the resulting average voltage is applied across A7CR3 and the emitter-base junction of A7Q5. At excessive output voltage and power levels, the voltage across R4 becomes sufficient to forward-bias A7Q5. The effect is further amplified by A7Q4 which applies a positive voltage to the base of A7Q1. A7Q1 then reduces or blocks the variable width pulses from T3, resulting in lower output voltage and current from the Main Loop.

4-63. High Voltage Pulse Transformer, T4, and High Voltage Rectifier, p/o A11 (Figure 7-3). The Power Switch transistors, Q1 and Q2, function to store and release energy in the High Voltage Transformer, T4. The release of energy from the secondary of T4 is converted to dc by the High Voltage Rectifier, A11CR1.

4-64. Q1 and Q2 conduct for the duration of each 20 kHz pulse from the Power Switch Driver. During this conduction time, a magnetic field builds up around T4 as a result of the large current drawn through the primary winding. The voltage across the secondary winding reverse biases the High Voltage Rectifier, A11CR1, and no current flows in the secondary.

4-65. When the trailing edge of the 20 kHz pulse turns off Q1 and Q2, the following events occur: The magnetic field around T4 begins to collapse attempting to induce current flow in both the primary and secondary windings. The primary circuit, however, is incomplete since Q1 and Q2 are in the non-conducting state. The collapse of the field around the secondary winding forward biases the High Voltage Rectifier, A11CR1, and a large current flows in the secondary circuit. The secondary current charges several capacitors in the output circuit. These capacitors charge to a value determined by the energy in the collapsing magnetic field around T4.

4-66. The energy transferred to the secondary of T4 depends on several factors. Q1 and Q2 turn off very rapidly at the end of each 20 kHz pulse, partly due to the action of A7Q2 and A7Q3 (Paragraph 4-61). This extremely sudden interruption of primary current in T4 results in a very high voltage across the secondary winding. The power delivering capability of the secondary winding depends on how much energy is available in the collapsing magnetic field. The energy content of the magnetic field is determined mainly by the length of time the Power Switch allows current to flow through the primary of T4 each time a 20 kHz pulse is applied. A wide pulse applied to the Power Switch allows a large magnetic field to be developed and a large amount of power to be delivered by the secondary. Conversely, a narrow pulse results in a small amount of power delivered by the secondary of T4.

4-67. The output of High Voltage Rectifier, A11CR1, is fed through A11R1 to the output circuits.

4-68. Output Circuits (Figure 7-3). The positive spikes from the High Voltage Rectifier are filtered in several places. The filtering is provided by A5C4, C4 and A11L1 on the 1 V range and below; A5C5, A5C8, C4 and A11L1 on the 10 V range; A5C8, C3, A11L1 and C4 on the 100 V range; and C3, A11L1 and C4 on the 1000 V range.

4-69. The filtered output voltage is fed through the Output Rotary Switch, K1, to the +OUTPUT terminal when K1 is energized. K1 is a two-position solenoid-actuated rotary switch that energizes when the Output Pushbutton Switch, S11, is depressed. -42 V is supplied to one lead of the switch solenoid. Depressing S11 connects the other lead of the solenoid to ground, completing the path for current through the solenoid and energizing K1. In the energized position, current through the solenoid is limited by R3 to prevent over-heating.

4-70. An interlock from pin 1 to pin 5 in the Output Cable Assembly prevents K1 from energizing when the Output Cable Assembly is not connected to the Output Jack, J2. When S11 is turned on, S11DS1 lights. When S11 is depressed a second time the ground is removed from K1; K1 de-energizes and S11DS1 goes out. The operation of S11DS1 is not affected by the interlock for K1. Cycling S11 without the Output Cable Assembly connected to the Output Jack will cause S11DS1 to alternately light and go out even though K1 will not energize.

4-71. The Floating 12 V Power Supply (p/o A5) references the -Output terminal to +12 V with respect to the negative lead of the High Voltage Pulse Transformer, T4. This condition causes the High Voltage Section to generate an output in series-opposition to the +12 V from the floating supply. The High Voltage Section then must generate a +12 V output just to maintain 0 V across the + and - Output terminals. This action is necessary in order to keep the Pulse Width Converter and Power Switch circuits in the linear region of their dynamic range when the Main Loop is generating an output near 0 V.

4-72. High Voltage Section Feedback Divider (Figure 7-3). The closed loop gain of the High Voltage Section is controlled by degnerative feedback from the output stage to the Differential Amplifier input stage (p/o A4). Feedback is controlled by the High Voltage Section Feedback Divider, S1R11 through S1R14. On the 1 V range and below, the feedback factor ($\beta$) is 1 (unity) resulting in a closed loop gain of 1. On the 10 V, 100 V and 1000 V ranges, $\beta$ decreases to 0.1, 0.01, and 0.001 resulting in closed loop gains of 10, $10^2$ and $10^3$ respectively. Precise closed loop gain characteristics in the High Voltage Section are not essential since the overall Main Loop feedback controls the Main Loop accuracy and will overcome small gain errors in both the Low Voltage and High Voltage sections.

4-73. External Current Limit, p/o A5 (Figure 7-9). The External Current Limit Circuit functions to protect the Model 740B from excessive loads connected to the Output terminals. The External Current Limit Circuit is comprised of the front Panel CURRENT LIMIT Control, the Current Limit Adjustment (A10R8) and the Current Limit Detector, p/o A5.

4-74. R12 (CURRENT LIMIT Control), A10R1 and A10R8 are in series with the -Output from the Main Loop. The voltage drop across this series combination appears across A5 pin 17 and A5 pin 6 and is directly proportional to the current delivered by the Output terminals. Under no-load conditions, the voltage at both pin 17 and pin 6 is approximately -12 V, caused by the operation of the Floating 12 V Supply. Under these conditions, A5Q6 is turned off and the voltage level coupled from A5Q6 to the base of A5Q7 keeps A5Q7 from conducting. The collector of A5Q7 is connected through A5 pin 15 and A4 pin 20 to a voltage divider consisting of A4R35, A4CR11 and A4CR12 (Figure 7-8). The voltage divider clamps the collector of A4Q7 and the bases of A4Q6 and A4Q12 to approximately -1 V. A4Q6 and A4Q12 function as diodes and do not conduct unless an overload condition exists.

4-75. When excessive current is delivered by the Main Loop Output, a significant voltage drop occurs across R12, A10R1 and A10R8 causing A5Q6 to conduct. This causes A5Q7 to conduct and the collector of A5Q7 goes positive, overcoming the -1 V from A4R35, A4CR11 and A4CR12. The positive level at the collector of A5Q7 is coupled through A5 pin 15 and A4 pin 20 to the bases of A4Q6 and A4Q12. A4Q6 and A4Q12 are then forward biased, reducing the gain of the Operational Filter and Differential Amplifier, and the Main Loop output voltage decreases to a safe level.

4-76. The CURRENT LIMIT Control (R12) varies the sensitivity of the Current Limit Detector by changing the resistance in series with the -Output. When the

CURRENT LIMIT Control is set to MIN (fully ccw), R12 is set at maximum resistance, causing a larger voltage drop across the R12/A10R1/A10R8 combination for a given output current. The Current Limit Adjustment (A10R8) sets the range of the CURRENT LIMIT Control.

4-77. Output voltage also affects the Current Limit Detector. At low voltage outputs, the sensitivity of the circuit depends almost entirely on the current through R12, A10R1 and A10R8 and the circuit is calibrated to limit output current to approximately 50 mA when the CURRENT LIMIT Control is set to MAX. At high output voltages, positive prebias voltage from A11R4 (Figure 7-3) starts to forward bias the emitter-base junction of A5Q6. This increases the sensitivity of the Current Limit Detector causing the maximum output current to decrease to approximately 20 mA when the output voltage reaches 1000 V.

4-78. MAIN LOOP FEEDBACK DIVIDER (Figure 7-3).

4-79. The closed loop voltage gain accuracy of the Main Loop is almost entirely determined by the accuracy of the Main Loop Feedback Divider. The divider controls the Main Loop Gain on all ranges and functions as an input attenuator for the Meter Loop on all ranges above 1 V.

4-80. The Main Loop Feedback Divider consists of A9R4 through A9R12 which comprise a 3 MΩ decade divider. A9R4 through A9R9 are precision wirewound resistors that are factory matched to have similar temperature coefficient characteristics. A9R10, A9R11 and A9R12 calibrate the divider for precision decade division ratios of 10:1, 100:1 and 1000:1.

4-81. ZERO CONTROL CIRCUIT (Figure 7-3).

4-82. The Zero Control circuit functions to set the Main Loop zero reference in all modes of operation. The Zero Control circuit is comprised of A10BT1, the front panel ZERO Control (R13) and several other resistors. 1.4 V from A10BT1 is dropped across A10R6, A10R7 and A10R13. Part of this series string is paralleled by S1R9, S1R10, S1R8 and R13 (ZERO Control). Varying R13 causes the voltage across S1R10 to vary approximately $\pm 15\ \mu V$, introducing a small offset voltage in the Main Loop feedback path. A10BT1 discharges constantly through the resistors that comprise the Zero Control Circuit. Discharge current is extremely low -- approximately $0.2\ \mu A$ -- and the service life of the cell approaches normal shelf-life. The variable offset can be used to compensate for small external offset voltages existing in a measurement setup or to set the Main Loop input or output to exactly zero.

4-83. <u>REFERENCE LOOP.</u>

4-84. The Reference Loop supplies a stable, accurate voltage to the Main Loop input in Standard mode. In Differential Voltmeter mode, the Main Loop feedback voltage (or a portion of it) is compared to the Reference Loop output voltage. The Reference Loop is comprised of the 1 V Reference Supply and the Reference Divider which is operated by the front panel VOLTAGE SET and STANDARD VERNIER Controls.

4-85. 1 V REFERENCE SUPPLY (Figure 7-13).

4-86. The Reference Oven Assembly (A13) contains the Control Differential Amplifier (A13Q3, A13Q4) and the Oven Heater and Regulator Circuits.

4-87. A13CR1 is a pre-aged Zener diode selected to have excellent stability characteristics. A13CR1 establishes the reference voltage for the Control Differential Amplifier (A13Q3 and A13Q4). Also, the voltage across A13CR1 is used to develop the +1 V output of the 1 V Reference Supply. The operating voltages for the Control Differential Amplifier are generated by the +34 V Supply (p/o A6) and pre-regulated by A2Q14 and A2Q15. The output from A13CR1 is dropped across the Reference Adjustment resistors (p/o A1), S3R1 and S3R2. The REF COARSE and FINE adjustments (A1R40 and A1R41) set the voltage at the junction of S3R1 and S3R2 to +1 V.

4-88. The Oven Heater and Regulator Circuits function to keep the interior temperature of the Reference Oven Assembly at a constant 80°C. This allows the reference diode, A13CR1, to develop a very stable output voltage, regardless of ambient temperature.

4-89. The Temperature Sensing Bridge is balanced only when the oven temperature reaches 80°C. A termistor, A13R7, functions as the heat-sensing element. When the bridge is not balanced, the voltage at the collector of A13Q2 changes. This change is amplified by the Error Amplifier, A2Q12 and A2Q13. The output from the collector of A2Q13 is fed to the Heater Control transistor, Q3. Q3 controls the current through the Oven heating element, HR1. The current through HR1 is increased or decreased according to the temperature Sensing Bridge output until the oven temperature stabilizes at 80°C, balancing the bridge.

4-90. The A13 circuit components are factory matched and aged. For this reason, the components in A13 are not separately replaceable.

4-91. REFERENCE DIVIDER (Figure 7-14).

4-92. The Reference Divider supplies a 0 to +1.00000 V output in Standard mode; 0 to +0.99999 V output in Differential Voltmeter mode. The divider consists of the five front panel VOLTAGE SET switches, the STANDARD VERNIER switch and some padding resistors on A1.

4-93. The +5.9 V output of the 1 V Reference Supply at A1 pin 22 (Figure 7-13) is dropped across S3R1 and S3R2. The 10 kΩ resistance of the X1 VOLTAGE SET divider is in parallel with S3R2, causing the parallel resistance of S3R2 and the X1 divider to be 1 kΩ. The voltage across the parallel resistance is a stable and accurate 1 V.

4-94. Regardless of how the resistors in the X1 divider are switched, there will be a total of 9 kΩ within the X1 divider which will make from 0 to +0.9 V in 0.1 V steps available at the X1 divider output. The remaining 0.1 V is dropped across the parallel combination of S4R5 and the X10 divider resistance.

4-95. The X10 divider is arranged in the same manner as the X1 divider. The X10 divider input resistance is 10 kΩ: 9 kΩ within the divider and 1 kΩ from the exterior combination of S5R5 and the $X10^2$ divider. The X10 divider divides the input voltage in 0.01 V steps resulting in an output across the entire Reference Divider of 0 to +0.99 V. The $X10^2$, $X10^3$ and $X10^4$ dividers operate in the same manner. Each divider adds resolution to the output resulting in a 0 to +0.99999 V output when all five VOLTAGE SET Controls are rotated.

4-96. In Standard mode, the output voltage is taken from the Standard Vernier Divider which drops the remaining 0.00001 V in steps of 1 μV, from 0 to +10 μV. The resultant Reference Divider output in Standard mode is 0 to +1.00000 V.

4-97. Each decade of the Reference Divider utilizes 4 resistors to derive the 1 to 0.1 division ratios. The resistor values are 1 kΩ (R1), 2 kΩ (R2), 2 kΩ (R3) and 4 kΩ (R4). The VOLTAGE SET switches, S4 thru S8, rearrange the connections between the four resistors to obtain nine combinations, each combination producing a different division ratio, yet maintaining a resistance of 9 kΩ within each divider. The output of each decade divider is paralleled with the resistance of an external resistor (S4R5, S5R5, etc.) and the complex resistance of the following decade dividers. The entire series-parallel resistance combination remains at 1 kΩ, regardless of the settings of the VOLTAGE SET switches.

4-98. Resistors in the X1 and X10 dividers are individually matched by adjusting variable padding resistors on A1 (Figure 7-5). The A1 padding resistors allow compensation to be made for aging of the resistors on S4 and S5. The padding resistors are adjusted when performing the Internal Alignment Procedure (Paragraph 5-57).

4-99. METER LOOP.

4-100. The Meter Loop consists of the Meter Filter, the Meter Amplifier, the front panel meter and part of the Sensitivity switching. The meter displays the input voltage in Voltmeter mode, the 6th digit of the input voltage in Differential Voltmeter mode and the 6th digit of the output voltage in Standard mode.

4-101. The input to the Meter Loop comes from the Main Loop voltage feedback path in Voltmeter mode. On the 1 mV to 1 V ranges, the Meter Loop input is 0 to 1 Vdc -- the same voltage fed back from the output of the Main Loop to the Main Loop Feedback Divider. On the 10 V, 100 V and 1000 V ranges, the Main Loop Feedback Divider attenuates the Meter Loop input by a factor of 0.1, 0.01 and 0.001 respectively, resulting in a constant 0 to 1 V input on all ranges in Voltmeter mode.

4-102. In Differential Voltmeter mode, the Meter Loop input is connected to ▽2, the Reference Supply common. The Meter Loop is referenced to ▽1, the ground reference for all of the critical circuits in the Main Loop. Whenever the Reference Loop output differs from the Main Loop feedback voltage, current flows through the Meter Loop, proportional to the error between the Main Loop feedback and Reference Loop output voltages. The Meter Loop detects and displays the error voltage, allowing a differential measurement to be made. The X1 through $X10^4$ SENSITIVITY pushbuttons control the Meter Loop sensitivity.

4-103. In Standard Mode, the Meter Loop input comes from the Standard Vernier Divider, p/o S9. The input varies from 0 to +0.1 V according to the position of the STANDARD VERNIER Control. Meter Loop gain is 10 in Standard mode resulting in a 0 to + end-scale deflection as the STANDARD VERNIER Control is turned clockwise.

4-104. METER FILTER AND AC AMPLIFIER (Figure 7-6).

4-105. The input to the Meter Loop is applied to the Meter Filter, C8, C9, C10 and R6. The Meter Filter removes noise from the dc input. The dc output of the Meter Filter is applied to the Modulator, A16V1 and V2.

4-106. The Modulator consists of two photocells that are lighted alternately by neon lamps A16DS1 and A16DS2. The lamps are driven by a 95 Hz square wave from A8. The modulated output of A16V1/V2 is a 95 Hz square wave proportional to the difference between the Meter Loop input and degenerative feedback voltage from the output. After the Meter Loop responds to an input, the amplitude of the square wave is very small due to the high gain of the Meter Amplifier.

4-107. The ac error signal from the Modulator is applied through A2 pin 1 and A2C1 to the base of A2Q1. A2C1 decouples the ac error signal from the input dc level. A2CR1 limits large negative spikes that may occur when changing ranges or functions. A2Q1 through A2Q3 comprise a cascade-coupled, three-stage amplifier. Degenerative feedback within the three-stage amplifier ensures gain stability and provides some gain correction for varying input voltages. The output of the three-stage amplifier is coupled through A2C4 to A2Q4.

4-108. A2Q4 and A2Q5 comprise a differential amplifier. Gain of the amplifier is affected by feedback voltage from the collector of A2Q16 through A2R15 to A2Q5. When the $X10^2$. $X10^3$ or $X10^4$ SENSITIVITY pushbutton is depressed, the degenerative feedback is reduced by switching A2R11 in parallel with A2R12, reducing the feedback impedance to ground. This results in increased gain for the A2Q4/A2Q5 differential amplifier. The output of the differential amplifier is amplified by A2Q16 and coupled through A2C7 and A2 pin 8 to the Demodulator. A2TP8 provides a convenient point to monitor the operation of the Meter Amplifier AC Section.

4-109. The amplified ac error signal is demodulated by A16V3 and A16V4. The Demodulator photocells are lighted by A16DS1 and A16DS2, the same neons that light the Modulator photocells. The Demodulator output is a dc level proportional to the input ac error signal. The Demodulator output voltage is applied to the Meter Driver through A2 pin 10.

4-110. METER DRIVER AND FEEDBACK DIVIDER.

4-111. From A2 pin 10, the dc signal is fed through A2R17 and A2R19* to A2Q6. A2R19* (typically 22 kΩ) is factory selected to set the gain of the Meter Driver. (Paragraph 5-86 describes the procedure for selecting A2R19*.) A2Q6 amplifies the dc level and drives A2Q8. A2Q7 provides temperature compensation for A2Q6. The signal is amplified by A2Q8 and A2Q9 and applied to the class AB push-pull output stage, A2Q10 and A2Q11. A2CR3 and A2CR4 keep A2Q10 and A2Q11 slightly forward-biased under no-signal conditions in order to prevent crossover distortion. Degenerative ac feedback from the emitters of A2Q10 and A2Q11 to A2Q6 causes the Meter Driver to have good noise rejection. DC gain of the Meter Driver is controlled by degenerative dc feedback through A2R32 and A2R31 to A2Q6. DC gain is approximately 200.

4-112. The output of the Meter Driver drives the Meter, M1. C13 bypasses any sharp transients around M1. A10R3 and A10R10 match the meter characteristics to the output of the Meter Driver. A10R10 calibrates the meter end-scale deflection. The Meter Driver output voltage is also applied across R14 to the RECORDER OUTPUT terminals. R14 varies the voltage from 0 to approximately 1 V for an end-scale meter deflection, allowing the output voltage to be matched to an external recorder or monitoring device.

4-113. The Meter Loop Feedback Divider controls the Meter Loop gain. The divider is comprised of S2R1 through S2R5 and the Sensitivity switch, S2. When the X1 SENSITIVITY button is depressed, all of the Meter Driver output voltage is fed back to the Modulator, A16V1/V2, setting the effective gain of the Meter Loop at 1 (unity). Depressing the X10 through $X10^4$ pushbuttons decreases the feedback by a factor of ten each time, resulting in an end-scale sensitivity of 100 $\mu$V on the $X10^4$ Sensitivity. The divider resistors (S2R1 through S2R5) are precision wirewound resistors. The divider is calibrated by adjusting A10R9 which changes the effective resistance of S2R5.

4-114. Zero offsets in the Meter Loop are nulled out by a controlled opposing offset voltage from A10R12. The voltage from the wiper of A10R12 is fed through A10R5 to the Meter Loop Feedback Divider.

4-115. POWER SUPPLIES (Figure 7-3).

4-116. Power is supplied to the Model 740B from an external 115 Vac or 230 Vac source through the Power Input Receptacle, J3. The power is applied through L6 and L7 to the POWER ON-OFF Switch, S12, and the 115-230 Switch, S13. S12DS1 lights when S12 is in the ON position. S13 switches the primary windings of T1 from series-connected to parallel-connected when 115 Vac operation is selected. The voltage across one primary winding of T1 is fed to the primary of T2. T1 provides power to the Unguarded Power Supplies; T2 provides power to the Guarded Power Supplies.

4-117. GUARDED POWER SUPPLIES.

4-118. Floating 12 V Power Supply, p/o A5 (Figure 7-9). The Floating 12 V Power Supply consists of a full-wave rectifier (A5CR6 and A5CR7) and a filter (A5C7). A secondary winding of T2 provides approximately 30 V rms to the power supply. The Floating 12 V Power Supply keeps Zener Diode A5CR4 in permanent breakdown. A5R18 limits the breakdown current. The voltage across A5CR4 introduces a permanent 12 V offset in the -Output stage of the Main Loop, allowing linear operation at low output voltage (Paragraph 4-71).

4-119. ±22 V, ±10V, -30 V and +34 V Supplies. A6 (Figure 7-10). T2 provides approximately 40 V rms to bridge rectifier A6CR1 through A6CR4. The +output of the bridge is filtered by A6C5 and the resultant +22 V is fed out A6 pin 13. The -output of the bridge is filtered by A6C11 and the resultant -22 V is fed out A6 pin 12. The + and -22 V supplies are unregulated.

4-120. The +10 V Supply consists of a Darlington-connected series regulator, A6Q1 and A6Q2. A6CR5 provides the reference voltage for the control amplifier, A6Q3. A6Q3 provides the correct bias for the series regulator. The +10 V Supply obtains primary power from the +output of the bridge rectifier, A6CR1 through A6CR4. The regulated +10 V output is filtered by C1 and fed out A6 pin 21.

4-121. The -10 V Supply is similar to the +10 V Supply. The major difference is the voltage reference for the control amplifier, A6Q4, which is derived from the output of the +10 V Supply dropped across A6R11 and A6R10. The -10 V regulated output is fed out A6 pin 18.

4-122. The -30 V and +34 V Supplies consist of bridge rectifiers A6CR10 through A6CR13 and A6CR6 through A6CR9. The -30 V output is fed out A6 pin 14 and filtered by C12. The +34 V output is filtered by A6C13 and fed out A6 pin 3. The +34 V Supply is referenced to $\nabla_2$ but may be measured with respect to $\nabla_1$ in Standard mode when the two grounds become electrically common. The -30 V and +34 V Supplies are unregulated.

4-123. UNGUARDED POWER SUPPLIES.

4-124. -42 V Supply (Figure 7-3). T1 provides primary power for Z1 located on the main chassis. The rectified output of Z1 is filtered by C1, L1 and C2. An interlock on A7 pins 13 and 14 interrupts the -42 V Supply whenever A7 is removed. The -42 V Supply provides power to the Power Switch (Q1 and Q2) and supplies energizing current for the Output Rotary Switch, K1. The output of the -42 V Supply is referenced to $\nabla_4$. ($\nabla_3$ and $\nabla_4$ are electrically common).

4-125. ±16.5 V Power Supply, p/o A7 (Figure 7-11). T1 supplies approximately 26 V rms to bridge rectifier A7CR4 through A7CR7. The + output of the bridge is filtered by A7C2 and connected to A6 pin 17. The -output of the bridge is filtered by A7C1 and connected to A7 pin 18. The Output Switch Interlock is connected across A7 pins 17 and 18. The interlock consists of relay A7K1 and A7R19. The interlock interrupts the -42 V supply output to the Output Switch, K1, when the instrument is turned off. K1 would otherwise remain energized for several seconds due to the long discharge time of the -42 V Power Supply filters, C1 and C2. The + and - 16.5 V Supplies are referenced to ⏚4. (⏚3 and ⏚4 are electrically common).

4-126. +180 V, +360 V Power Supply, p/o A8 (Figure 7-12). The +180 V Power Supply consists of A8CR2 and A8C2 which comprise a half-wave unregulated supply. A8CR1 and A8C1 along with the +180 V Supply components form a voltage doubler for generating +360 V. Both supplies are referenced to ⏚4. (⏚3 and ⏚4 are electrically common). The output of the +180 V Supply provides operating voltages for the Neon Drivers (p/o A8). The +360 V output is fed out A8 pin 1 to the digital indicator tubes in Standard and Differential Voltmeter modes.

4-127. CHOPPER NEON DRIVERS, p/o A8 (Figure 7-12).

4-128. METER LOOP NEON DRIVER.

4-129. The Meter Loop Neon Driver supplies a 95 Hz square wave to the Meter Chopper neons A16DS1 and A16DS2. The Meter Loop Neon Driver is a free-running multivibrator consisting of A8Q1, A8Q2 and associated components. A8R3 is adjusted to set the multivibrator frequency to 95 Hz. A8R8* and A8R9* are factory selected to set the range of adjustment of A8R3. Paragraph 5-99 describes the procedure for selecting A8R8* and A8R9*. The square wave can be observed at A8TP21.

4-130. A16DS1 and A16DS2 are connected to opposite sides of the multivibrator which causes them to flash alternately. A16DS1 illuminates A16V2 and A16V4; A16DS2 illuminates A16V1 and A16V3.

4-131. MAIN LOOP NEON DRIVER.

4-132. The Main Loop Neon Driver supplies pulses to the Main Loop Chopper Neons, A17DS1 and A17DS2. A8Q3 and A8Q4 and associated components comprise a free-running multivibrator. The frequency is adjusted to 162 Hz by A8R20.

4-133. A8Q5, A8Q6 and associated components act together to shorten each of the square wave alternations from the multivibrator. The leading edge of the positive half of the square wave from A8Q4 triggers A8Q5 and A8Q5 conducts until A8C10 discharges. The discharge time occurs approximately half way through the positive alternation of the square wave. When A8Q5 conducts, A17DS2 lights. A8Q3 and A8Q6 function in a similar manner. A17DS1 lights when A8Q6 conducts. This results in the neons lighting alternately; but each neon goes out approximately 1.5 msec before the other neon lights.

Table 5-1. Required Test Equipment

| EQUIPMENT TYPE | REQUIRED CHARACTERISTICS | RECOMMENDED MODEL |
|---|---|---|
| DC Null Detector/Voltmeter | Accuracy: ±3%<br>Sensitivity: 10 μV end-scale to 500 V end-scale<br>Input Resistance: > 1 MΩ on ranges above 100 mV<br>Input: Floating | -hp- Model 419A DC Null Voltmeter |
| 1 V Reference Supply | Accuracy: 1 V ±0.0002% (See Appendix C)<br>Stability: 10 ppm/month | -hp- Model 735A DC Transfer Standard |
| Precision Decade Divider | Division Ratios: 10:1, 100:1 and 1000:1 | -hp- 11100A Series Resistors (See Appendix C) |
| Variable Line Transformer | Voltage Outputs: 102 Vac to 128 Vac or 207 Vac to 253 Vac<br>Output Power: 125 Watts | Superior Type UC1MB (115 V) or UC2MB 230 V) |
| Oscillator | Frequency: 70 Hz ± 5%<br>Output: 1 V rms (adjustable) | -hp- Model 651B Test Oscillator |
| AC Voltmeter | Accuracy: ± 5% from 1 Hz to 1 MHz<br>Response: Average or RMS responding RMS calibrated<br>Sensitivity: 100 μV end-scale to 10 mV end-scale | -hp- Model 403A AC Voltmeter |
| Oscilloscope | Bandwidth: DC to 20 MHz<br>Vertical Sensitivity: 5 mV/cm<br>Time Buse: 20 μsec/cm to 20 msec/cm | -hp- Model 180A/1801A/1802A Oscilloscope |
| Frequency Counter | Accuracy: ±1%<br>Range: 50 Hz to 400 Hz | -hp- Model 5211A Electronic Counter |
| 1-1000 V Power Supply | Stability: .001%/24 hours<br>Resolution: .0001% | -hp- Model 740B or 741B DC Standard |
| Clip-On DC Milliammeter | Range: 1 mA to 100 mA full-scale<br>Accuracy: ±3% | -hp- Model 428B Clip-On Milliammeter |
| Resistors | 20 Ω ±1% 1/2 W<br>1 kΩ ±10%<br>1 kΩ ±5% 5 W<br>10 kΩ ±10%<br>100 kΩ ±10% | -hp- Part No. 0811-0305<br>-hp- Part No. 0684-1021<br>-hp- Part No. 0812-0099<br>-hp- Part No. 0684-1031<br>-hp- Part No. 0811-0050 |
| Capacitor | 2 μF ±20% non-polarized | -hp- Part No. 0170-0002 |

# SECTION V
# MAINTENANCE

## 5-1. INTRODUCTION.

5-2. This section contains maintenance instructions for the Model 740B. Included are performance tests, adjustment and calibration procedures, and trouble-shooting and repair procedures.

## 5-3. REQUIRED TEST EQUIPMENT.

5-4. Table 5-1 lists the required test equipment for maintenance of the Model 740B. Included for each piece of test equipment are required characteristics and a recommended commercial model. If the recommended model is not available, select another model with similar characteristics.

## 5-5. PERFORMANCE TESTS.

5-6. The performance tests presented in the following paragraphs are front-panel procedures designed to compare the Model 740B with its specifications (Table 1-1). These tests may be used for incoming inspection, periodic maintenance and for specification tests after repair or adjustment. The tests may also be useful as a first step in troubleshooting (Paragraph 5-69).

5-7. A Performance Check Test Card is included in this section on pages 5-32a and 5-32b. The card lists the test limits and provides spaces for recording the test readings. The card can be removed from the manual and used in conjunction with incoming inspection to provide a permanent record of the instrument performance.

5-8. In order to verify the accuracy specifications with a high degree of certainty, it is necessary to use a calibration system that is at least three times as accurate as the specification being checked. The most accurate mode of the Model 740B is Standard where accuracy is within ±24 ppm at maximum output voltage on any range. This requires using a calibration system accurate to within ±8 ppm to verify this specification.

5-9. A calibration system consisting of a precision divider, a 1 V reference supply and a null detector is used (in various forms) in the accuracy tests which follow. The divider is a string of adjustable transfer resistors which have been accurately ratio matched. Overall ratio accuracy is within ±2 ppm at all taps, with no need to use correction factors. The 1 V reference supply is a dc transfer standard, calibrated to 1 V ±2 ppm. The null detector is a sensitive dc null voltmeter capable of resolving off-null conditions of less than 0.25 $\mu$V. Using the technique described, the overall accuracy of the system is within about ±5 ppm -- well within the required ±8 ppm.

5-10. Appendix C gives details on calibrating the transfer standard and building the divider. Fixed value standard resistors may be used in the divider providing the correction factors for each resistor are known (or derived) and applied.

5-11. The Meter Mechanical Zero Adjustment (Paragraph 5-36) and the Internal Alignment Procedure (Paragraph 5-57) should be performed before proceeding with the Performance Tests. These adjustments calibrate the instrument for the temperature existing at the time of adjustment. If the instrument is mounted in a rack or otherwise relocated to an area of different ambient temperature, the allowable accuracy deviations (given in Tables 5-2, 5-3, and 5-4) must be increased according to the following Temperature Coefficient specifications:

a. DC Standard mode: Less than (2 ppm of setting or 1 ppm of setting, whichever is greater) per $^{o}$C, 10$^{o}$C to 40$^{o}$C.

   Example: Normal allowable accuracy deviation for a 1 V output on the 1 V range is ±24 $\mu$V obtained from the accuracy specification: ±(0.002% of setting + 0.0004% of range). If the temperature is changed 5$^{o}$C, the allowable accuracy deviation becomes ±34 $\mu$V for the 1 V output (original deviation of ±24 $\mu$V plus the temperature correction factor of 10 $\mu$V). 2 ppm/°C

b. Differential Voltmeter mode: (2 ppm of reading + 1 $\mu$V) per $^{o}$C, 10$^{o}$C to 40$^{o}$C.

   Example: Normal allowable accuracy deviation for a 1 V measurement on the 1 V range is ±55 $\mu$V obtained from the accuracy specification: ±(0.005% of reading + 0.0004% of range + 1 $\mu$V). If the temperature is changed 5$^{o}$C, the allowable accuracy deviation becomes ±70 $\mu$V for the same measurement (original deviation of ±55 $\mu$V plus the temperature correction factor of 15 $\mu$V).

NOTE

1. Ambient calibration temperature and ambient operating temperature must be between 10$^{o}$C and 40$^{o}$C. Relative humidity must be less than 70%.

2. Allow a one hour warm-up period before proceeding with the performance tests.

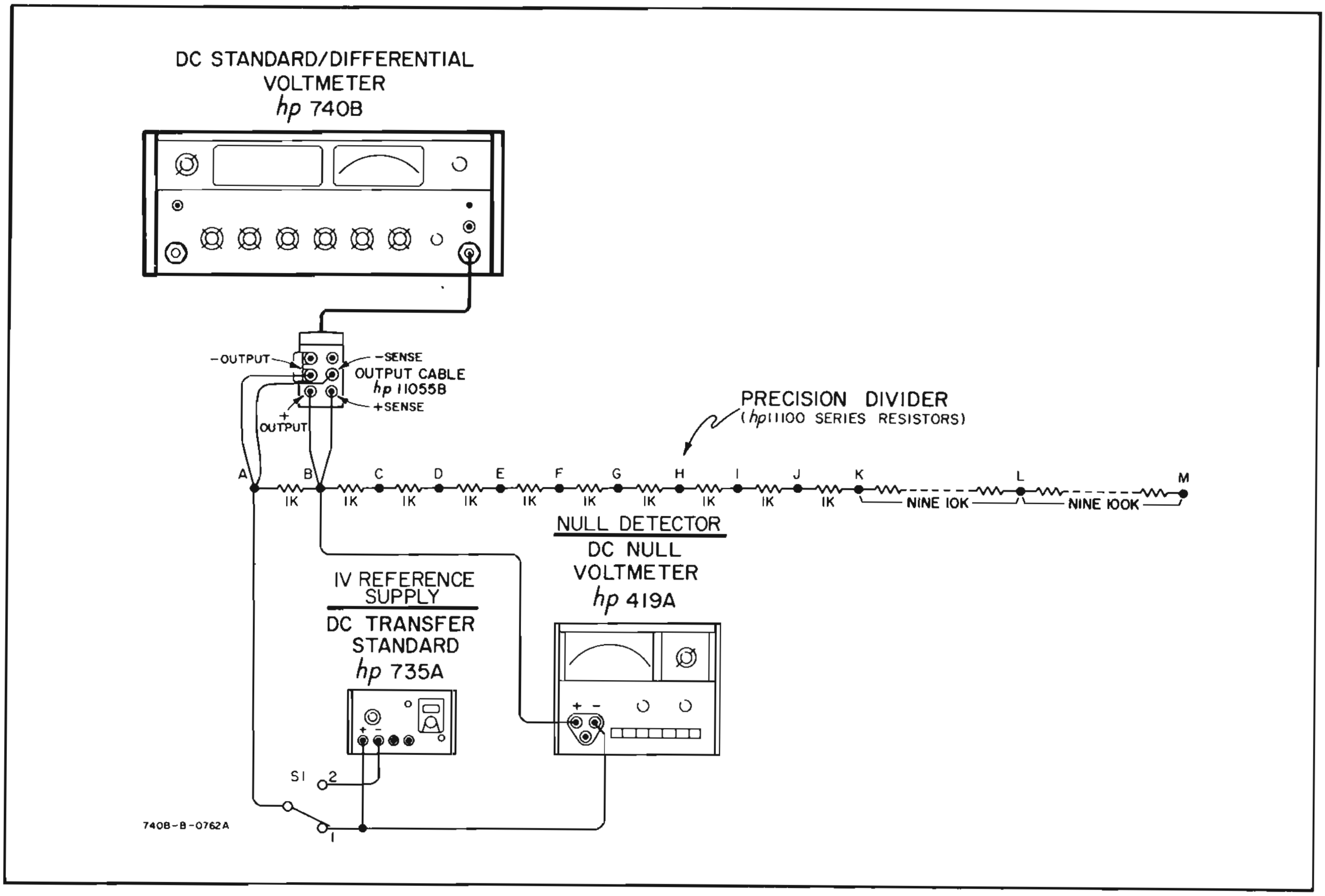



Figure 5-1. DC Standard Accuracy Test

## 5-12. DC STANDARD PERFORMANCE TESTS.

### 5-13. OUTPUT VOLTAGE ACCURACY, LINEARITY AND LINE REGULATION TEST.

5-14. This test compares the Model 740B output voltage accuracy with the specification: ± (0.002% of setting + 0.0004% of range). As the line voltage is increased or decreased 10%, the output voltage should not change more than ± (0.0005% of setting + 0.0001% of range). A precision voltage divider (-hp- 11100A series Resistors), a 1 V ± 0.0002% reference supply (-hp- Model 735A DC Transfer Standard), a dc null detector (-hp- Model 419A DC Null Voltmeter) and a variable line transformer (Superior Type VC1MB or VC2MB) are required for this test.

NOTE

Appendix C gives details on constructing the precision divider and calibrating the 1 V reference supply to the accuracies required.

a. Construct test setup shown in Figure 5-1. Make all connections with insulated solid copper wire, 20 gauge or larger. S1 should be a solid copper contact knife switch. Connect Model 740B power input to a variable line transformer supplying 115 or 230 Vac.

b. Set 740B controls as follows:

| | |
|---|---|
| FUNCTION | STD |
| RANGE | 1 V |
| VOLTAGE SET | .00000 |
| STANDARD VERNIER | 0 |
| CURRENT LIMIT | MAX |
| OUTPUT | On |

c. Zero the null detector on the 3 $\mu$V range.

NOTE

Periodically rezero the null detector.

d. Zero the 740B output by placing S1 in position 1 and adjusting the ZERO control for a null indication ±1 $\mu$V on the null detector (3 $\mu$V range).

e. Set VOLTAGE SET and STANDARD VERNIER controls to 9-9-9-9-9-10 (all fully cw) for a 1 V output.

f. Set S1 to position 2 to compare 740B output with the precision 1 V reference supply output.

g. Adjust null detector range to obtain an on-scale reading. Null detector reading should not exceed ±24 $\mu$V. Record reading: ______ .

Table 5-2. DC Standard-Accuracy and Linearity Test Data

| RANGE | OUTPUT | DIVIDER CONNECTIONS 740B | DIVIDER CONNECTIONS PRECISION 1 V REFERENCE | DIVIDER RATIO | NULL DETECTOR READINGS (MAX) |
|---|---|---|---|---|---|
| 1 V | 1.00000 | A and B | A and B | 1:1 | ±24 μV |
| 10 V | 1.00000 | A and B | A and B | 1:1 | ±60 μV |
| 10 V | 2.00000 | A and C | A and B | 2:1 | ±40 μV |
| 10 V | 3.00000 | A and D | A and B | 3:1 | ±33 μV |
| 10 V | 4.00000 | A and E | A and B | 4:1 | ±30 μV |
| 10 V | 5.00000 | A and F | A and B | 5:1 | ±28 μV |
| 10 V | 6.00000 | A and G | A and B | 6:1 | ±27 μV |
| 10 V | 7.00000 | A and H | A and B | 7:1 | ±26 μV |
| 10 V | 8.00000 | A and I | A and B | 8:1 | ±25 μV |
| 10 V | 9.00000 | A and J | A and B | 9:1 | ±24 μV |
| 10 V | 10.0000 | A and K | A and B | 10:1 | ±24 μV |
| 100 V | 100.000 | A and L | A and B | 100:1 | ±24 μV |
| 10000 V | 1000.00 | A and M | A and B | 1000:1 | ±24 μV |

* Readings are maximum allowable deviation at calibration temperature. If performance checks are performed at a different temperature, the allowable deviation must be increased (Paragraph 5-11).

NOTE

The reading of the null detector in μV gives the accuracy deviation of the Model 740B, 1. V output, 1 V range. Deviation should not exceed ±24 μV, obtained from the Standard mode accuracy specification: ±(0.002% of setting + 0.0004% of range).

h. Increase the 740B line voltage from 115 V to 126.5 V (115 V operation) or from 230 V to 253 V (230 V operation). Record null detector reading: ______. Reduce line voltage to 103.5 V (115 V operation) or 207 V (230 V operation). Record null detector reading: ______. The readings obtained in this step should not differ from the reading recorded in step g by more than ±6 μV.

NOTE

The changes in the null detector reading gives the 740B output voltage change for a 10% line voltage change. Changes of 6 μV or less verify the line regulation specification: ±(0.0005% of setting + 0.0001% of range) for a 10% line voltage change.

i. Return 740B line voltage to 115 or 230 V.

j. Place S1 to position 1 to remove the 1 V reference from the divider.

k. Return 740B VOLTAGE SET and STANDARD VERNIER to 0-0-0-0-0-0 to remove the output from the divider.

l. Set 740B RANGE to 10 V and zero the output by adjusting ZERO control for a null indication (±10 μV) on the null detector.

m. Set 740B for a 1 V output (1-0-0-0-0-0) on the 10 V range.

n. Place S1 to position 2 to compare the 740B output with the precision 1 V reference. The null detector should indicate ±60 μV or less.

o. De-energize 740B output and connect +OUTPUT and +SENSE leads to point C on the divider.

p. Set 740B for a 2 V output (2-0-0-0-0-0).

q. Null detector reading should not exceed ±40 μV.

NOTE

The null detector indicates the difference between the 1 V reference and one half of the 740B output. Allowable accuracy deviation for a 2 V output on the 10 V range is ±80 μV. Since the output is divided in half by the divider, only half of the error (40 μV or less) will be indicated by the null detector.

r. Repeat the procedure in steps o through q for the other outputs listed in Table 5-2.

CAUTION

ALWAYS DE-ENERGIZE THE 740B OUTPUT WHEN MAKING CHANGES IN THE TEST SETUP.

NOTE

Zero the 740B output according to the procedure in step l whenever changing ranges. Use the 100 μV and 1 mV ranges on the null detector for the 100 V and 1000 V ranges respectively on the 740B.

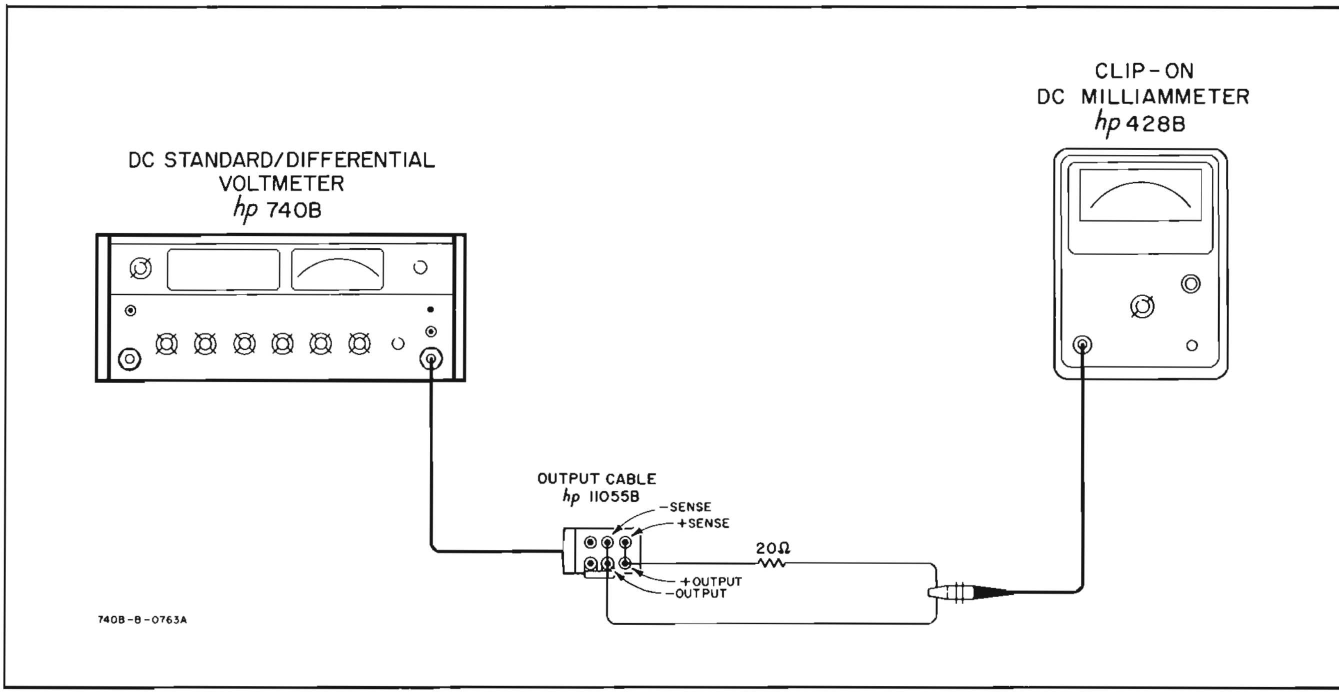



Figure 5-2. Current Limit Test

5-15. OUTPUT CURRENT AND CURRENT LIMIT TEST.

5-16. This test checks the maximum output current (at least 50 mA) and the range of the CURRENT LIMIT control (5-50 mA nominal). A 20 Ω ±1% 1/2 W resistor (-hp- Part No. 0811-0305) and a clip-on dc milliammeter (-hp- Model 428B Clip-On DC Milliammeter) are required for this test.

a. Connect test setup shown in Figure 5-2.

b. Set 740B controls as follows:

| | |
|---|---|
| FUNCTION . . . . . . | STD |
| RANGE . . . . . . . . | 10 V |
| VOLTAGE SET . . . | 1.50000 |
| CURRENT LIMIT . . . | MAX |
| OUTPUT . . . . . . . | On |

NOTE

OVERLOAD indicator will glow.

c. The milliammeter should indicate 50 mA or greater.

d. Turn CURRENT LIMIT control fully ccw (MIN).

e. The milliammeter reading should decrease to 5 mA or less.

5-17. LOAD REGULATION AND OUTPUT RESISTANCE TEST.

5-18. This test measures the no-load to full-load output voltage excursion of the Model 740B. From this voltage, the load regulation and output resistance can be calculated. A 20 Ω ±1% 1/2 W resistor (-hp-Part No. 0811-0305), a 1 V ±0.0002% reference supply (-hp- Model 735A DC Transfer Standard) and a dc null detector (-hp- Model 419A DC Null Voltmeter) are required for this test.

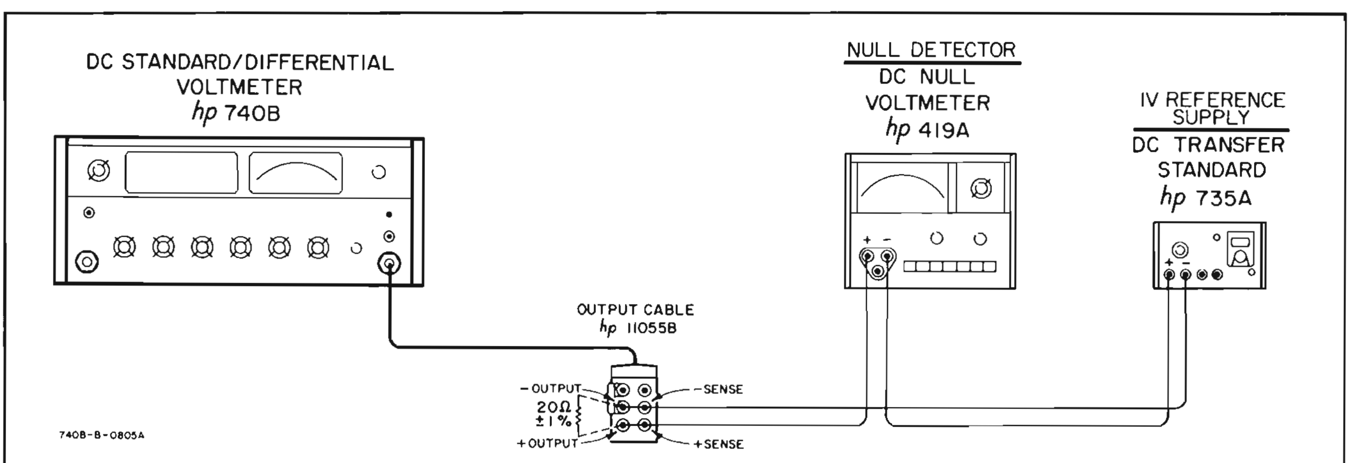



Figure 5-3. Load Regulation and Output Resistance Test

a. Connect test setup shown in Figure 5-3. Leave the 20 Ω resistor disconnected.

b. Set Model 740B controls as follows:

| | |
|---|---|
| FUNCTION | STD |
| RANGE | 1 V |
| VOLTAGE SET | 0.99999 |
| STD VERNIER | 1.0 (fully cw) |
| CURRENT LIMIT | MAX |
| OUTPUT | On |

c. Using ZERO and STANDARD VERNIER controls, make small changes in the 740B output voltage until the null detector indicates null on the 10 $\mu$V range.

NOTE

If null cannot be reached, the 740B reference supply should be adjusted even though the instrument may be operating within specifications. Paragraph 5-62 steps m through p gives the procedure for adjusting the reference supply.

d. Connect the 20 Ω resistor across the 740B + and - OUTPUT terminals.

e. The null detector reading should be ±15 $\mu$V or less.

NOTE

1. An indication of 15 $\mu$V or less verifies the load regulation specification: less than (0.0005% + 10 $\mu$V) change, no-load to full-load.

2. An indication of 15 $\mu$V or less also verifies an output resistance of 0.0003 Ω or less, obtained from the output resistance specification: less then (0.0002 + 0.0001 $E_{out}$) ohms at dc. Output resistance can be calculated from the formula:

$$R_o = \frac{\Delta E}{\Delta I}$$

where $R_o$ = output resistance in ohms.

$\Delta E$ = change in output voltage, no load to full load (null detector reading).

$\Delta I$ = change in output current, no load to full load (0.05 A).

5-19. RADIO FREQUENCY INTERFERENCE (RFI).

5-20. If the Model 740B is to be checked for RFI in accordance with MIL Spec. 6181D, connect the input and output terminals as shown in Figure 5-4.

5-21. OUTPUT NOISE AND HUM TEST.

5-22. This test measures noise and hum superimposed on the 740B output. A sensitive dc voltmeter (-hp- Model 419A DC Null Voltmeter) and a 1 Hz to 1 mHz ac voltmeter (-hp- Model 403A AC Voltmeter) are required for this test.

a. Set 740B controls as follows:

| | |
|---|---|
| FUNCTION | STD |
| RANGE | 1 V |
| VOLTAGE SET | 00000 |
| STANDARD VERNIER | 0 |
| DC OUTPUT | On |

b. Connect the dc voltmeter across the 740B + and - OUTPUT terminals.

c. Zero the 740B output by adjusting ZERO control for a null indication on the voltmeter (10 $\mu$V range).

d. Voltmeter pointer movement (0.01 Hz to 1 Hz noise) should not exceed ±1 $\mu$V. This verifies the 0.01 Hz to 1 Hz noise specification: less than 1 ppm of range.

e. In a similar manner, check the 0.01 Hz to 1 Hz noise on the 10 V, 100 V and 1000 V ranges. Table 5-3 lists the maximum voltmeter pointer movement.

NOTE

Zero the 740B output each time before the 0.01 to 1 Hz noise is measured.

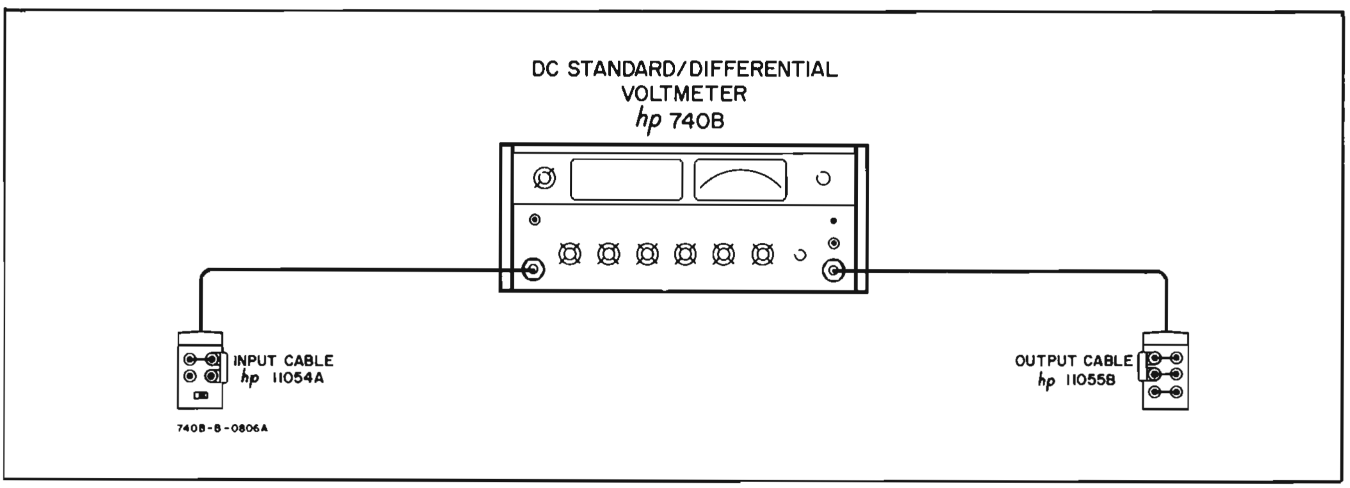



Figure 5-4. RFI Test

Table 5-3. Output Noise and Hum Test Data

| 740B RANGE | DCVM POINTER MOVEMENT (Max.) | ACVM READING (Max.) |
|---|---|---|
| 1 V | ± 1 μV | 100 μV |
| 10 V | ± 10 μV | 100 μV |
| 100 V | ±100 μV | 1 mV |
| 1000 V | ± 1 mV | 10 mV |

f. Connect the ac voltmeter across the + and - OUTPUT terminals and check the 1 Hz to 1 MHz noise on the 1 V, 10 V, 100 V and 1000 V ranges. Table 5-3 lists the noise limits for each range.

5-23. ZERO CONTROL LIMITS TEST.

5-24. This test checks the range of the front panel ZERO control. A sensitive dc voltmeter (-hp- Model 419A DC Null Voltmeter) is required for this test.

a. Set 740B controls as follows:

FUNCTION . . . . . . . . STD
RANGE . . . . . . . . . . . 1 V
VOLTAGE SET . . . . . 00000
STANDARD VERNIER . . 0
OUTPUT . . . . . . . . . On

b. Connect + and - OUTPUT terminals to voltmeter input.

c. Vary 740B ZERO control from one extreme to the other. Voltmeter indication should vary from at least -10 μV to at least +10 μV.

5-25. DIFFERENTIAL VOLTMETER AND HIGH IMPEDANCE VOLTMETER PERFORMANCE TESTS.

5-26. INPUT RESISTANCE TEST.

5-27. This test measures the Model 740B input resistance. A 1 V reference supply (-hp- Model 735A DC Transfer Standard), a 100 kΩ ±1% resistor (-hp- Part No. 0811-0050) and a solid copper contact knife switch are required for this test.

a. Connect test setup shown in Figure 5-5.

b. Measure the 1 V reference output in ΔVM mode. Leave the X10$^4$ SENSITIVITY button depressed.

c. Open the switch to place the 100 kΩ resistor in series with the 740B input. The 740B meter reading should change less than 10 μV (1 major division).

NOTE

A change of less than 10 μV verifies the input resistance specification: greater than $10^{10}$ Ω (1 V range). Input resistance can be calculated from the formula:

$$R_{in} = \frac{R_s E_a}{\Delta E_a}$$

where $R_s$ = input resistance
$E_a$ = applied voltage (1 V)
$\Delta E_a$ = voltage change (less than 10 μV) when series resistance is added

5-28. SUPERIMPOSED AC REJECTION TEST.

5-29. This test measures the error introduced when an ac signal is superimposed on the dc input to the Model 740B. A 1 V source (-hp- Model 735A DC Transfer Standard), an oscillator (-hp- Model 651B Test Oscillator), an ac voltmeter (-hp- Model 403A), a 10 kΩ ±10% resistor (-hp- Part No. 0684-1031), and a 2 μF ±20% capacitor (-hp- Part No. 0170-0002) are required for this test.

a. Connect test setup shown in Figure 5-6. Do not turn on oscillator yet.

b. Measure the 1 V output of the dc transfer standard in ΔVM. Leave the X10$^4$ SENSITIVITY button depressed.

c. Turn on oscillator; set frequency to 70 Hz; adjust amplitude for a reading of 1 V on the ac voltmeter.

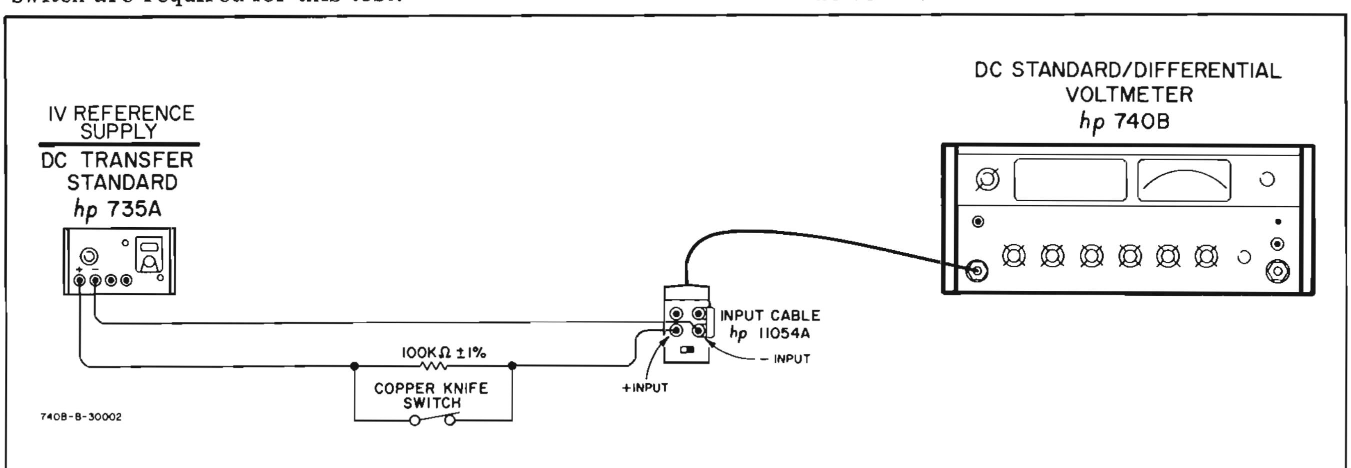



Figure 5-5. Input Resistance Test

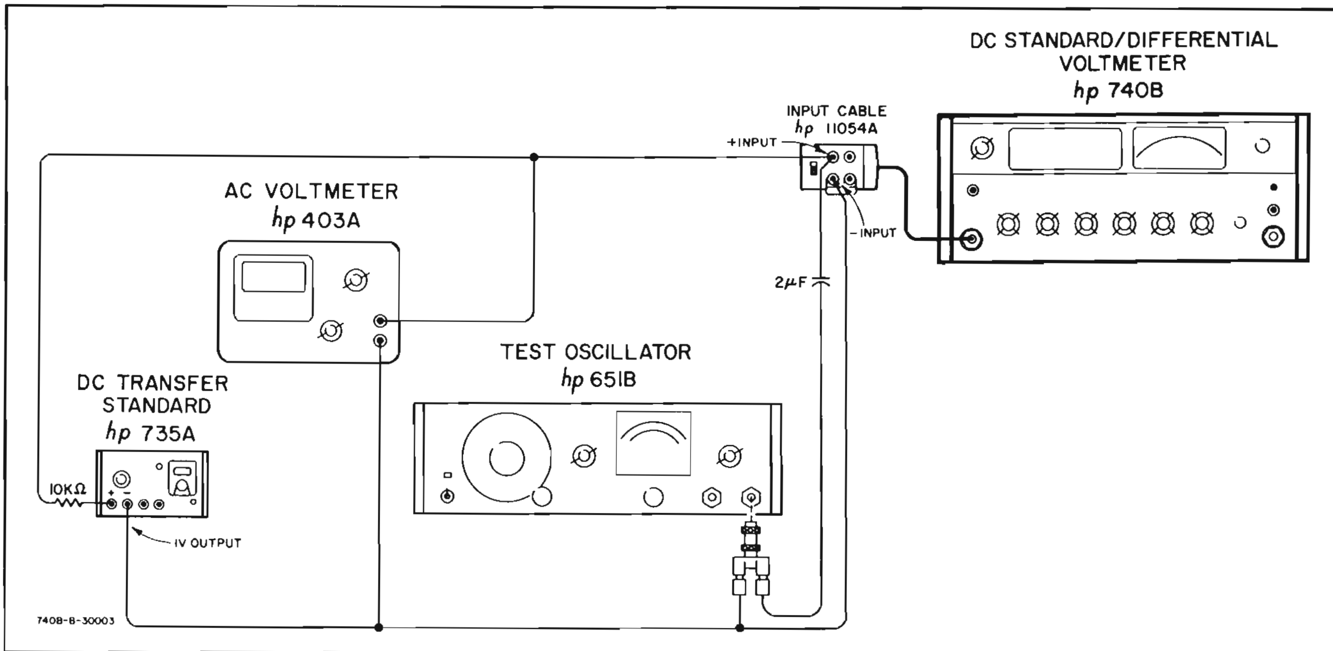



Figure 5-6. Superimposed AC Rejection Test

d. After the initial transient, the 740B reading should return to within 10 $\mu$V (1 major meter division) of the initial reading. This verifies the specification: Less than 0.001% error for ac voltages above 60 Hz equal to the DC signal (25 V rms, maximum).

5-30. AC COMMON MODE REJECTION TEST.

5-31. This test measures the error introduced by an ac signal applied between the + INPUT and ⏚ terminals with a 1 kΩ unbalance across the + and - INPUT terminals. A test oscillator (-hp- Model 651B), an ac voltmeter (-hp- Model 403A), and a 1 kΩ ± 10% resistor (-hp- Part No. 0684-1021) are required for this test.

a. Set 740B controls as follows:

| | |
|---|---|
| FUNCTION . . . . . . . | VM |
| RANGE . . . . . . . . . | 1 V |
| SENSITIVITY . . . . . | X$10^4$ |
| INPUT . . . . . . . | Shorted |

b. Adjust ZERO control to zero the 740B meter.

c. Remove short from input terminals.

d. Construct test setup shown in Figure 5-7.

e. Set oscillator frequency to 60 Hz; adjust amplitude to 10 V rms as indicated by the ac voltmeter.

f. 740B meter deflection should be less than 10 $\mu$V (1 major division). This verifies ac common mode rejection > 120 dB where:

$$\text{Common Mode Rejection} = \frac{E_{\text{Oscillator (rms)}}}{E_{740B}}$$

5-32. ACCURACY AND LINE REGULATION TEST.

5-33. This test compares the measuring accuracy of the Model 740B with the specifications:

±(0.005% of reading + 0.0004% of range + 1 $\mu$V) . . . . . . . . . ΔVM mode
±(2% of end scale + 0.1 $\mu$V) . . . VM mode

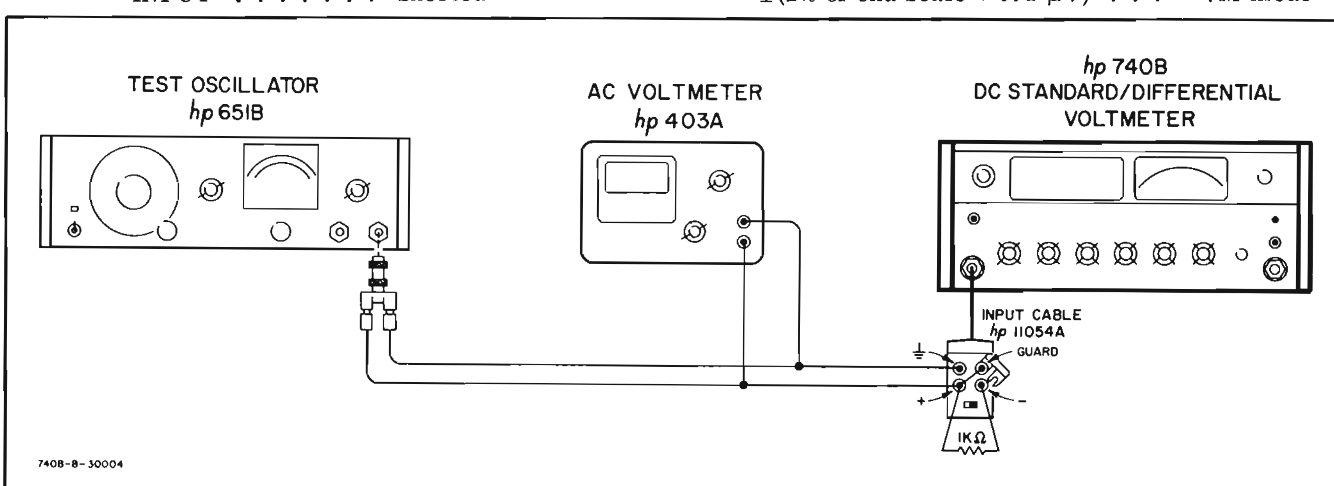



Figure 5-7. AC Common Mode Rejection Test

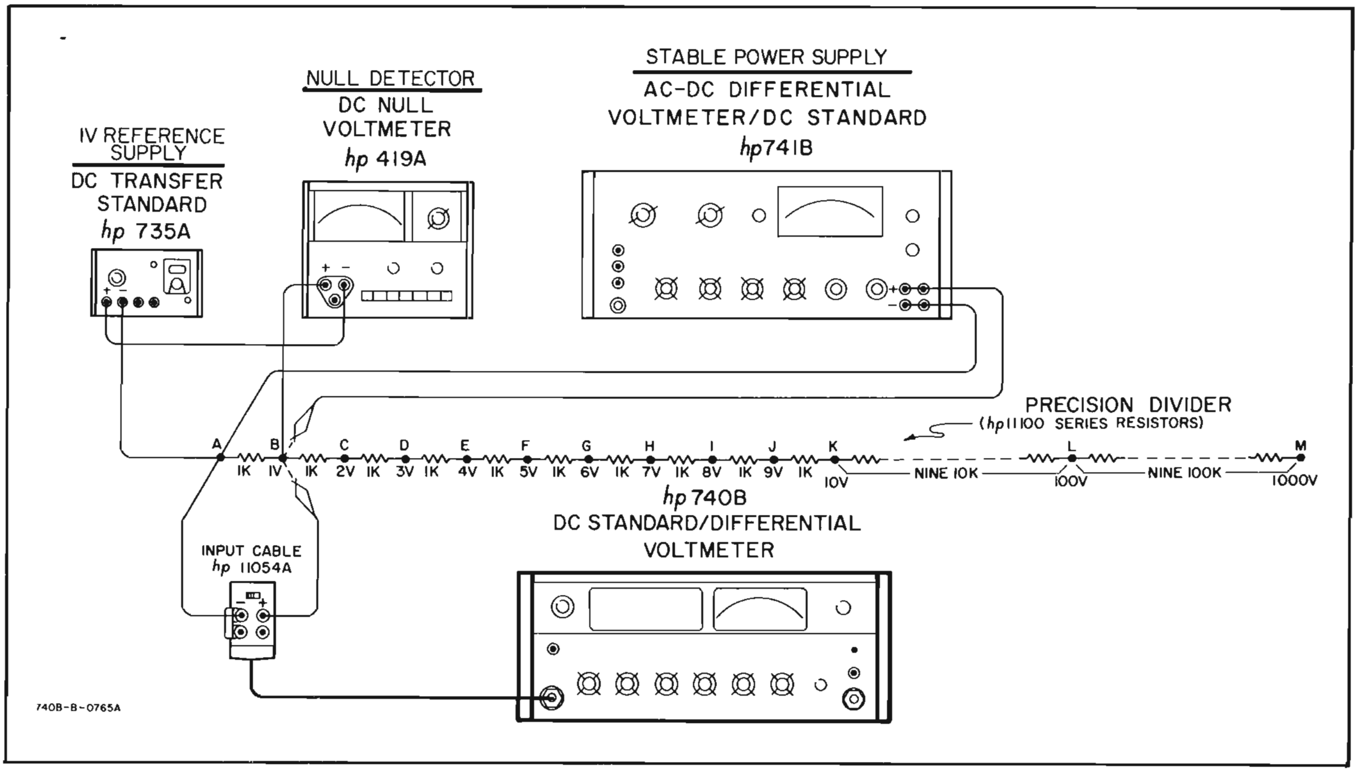



Figure 5-8. ΔVM and VM Accuracy Test, 1 V - 1000 V

As the line voltage is increased or decreased 10%, the indicated voltage (ΔVM mode) should not change more than ±(0.001% of reading + 2 μV). A precision voltage divider (-hp- 11100 series Resistors), a stable 1-1000 Vdc power supply (-hp-Model 741B or 740B), a dc null detector (-hp- Model 419A DC Null Voltmeter) and a variable line transformer (Superior type VC1MB or VC2MB) are required for this test.

NOTE

Appendix C gives details on constructing the precision divider and calibrating the 1 V reference supply to the accuracies required.

a. Construct test setup shown in Figure 5-8. Make all connections with insulated solid copper wire, 20 gauge or larger. Connect 740B power input to the variable line transformer supplying 115 or 230 Vac.

b. Connect power supply + lead to point B on the divider.

c. Set power supply output to 1 V. Make minor changes in the voltage source output, if needed, to maintain a null indication on the null detector (10 μV range).

NOTE

Periodically check null detector zero.

d. Set 740B controls as follows:

| | |
|---|---|
| FUNCTION . . . . . . . | ΔVM |
| RANGE . . . . . . . . . | 1 V |
| VOLTAGE SET . . . . | .00000 |
| SENSITIVITY . . . . . . | $X10^4$ |

e. Zero the 740B input by connecting the + INPUT lead to the - INPUT lead (point A on the divider) and adjusting ZERO control for a zero meter indication.

f. Connect 740B + INPUT lead to point B on the divider.

g. Measure the voltage (ΔVM mode). 740B should indicate 1 V ± 55 μV (Table 5-4). Record 740B indication: ______ .

h. Increase the 740B line voltage from 115 V to 126.5 V (115 V operation) or from 230 V to 253 V (230 V operation). Record 740B voltage indication: ______ . Reduce line voltage to 103.5 V (115 V operation) or 207 V (230 V operation). Record 740B voltage indication: ______ . The readings obtained in this step should not differ from the reading recorded in step g by more than ±12 μV. Return line voltage to 115 V or 230 V.

i. Depress X1 SENSITIVITY and set FUNCTION to VM. 740B meter should indicate 1 V ±0.02 V (Table 5-4).

j. Set 740B RANGE to 10 V, FUNCTION to ΔVM and zero the input on the $X10^4$ SENSITIVITY (step e).

k. Move power supply + OUTPUT lead and 740B + INPUT lead to point C on the divider.

**WARNING**

DE-ENERGIZE POWER SUPPLY OUTPUT WHEN MAKING CHANGES IN THE TEST SETUP.

Table 5-4. ΔVM and VM Accuracy Test Data, 1 V - 1000 V

| DIVIDER CONNECTIONS, 740B INPUT AND POWER SUPPLY OUTPUT | IN-TOLERANCE 740B INDICATIONS | |
|---|---|---|
| | ΔVM MODE | VM MODE |
| A and B | 1 V ±0.000055 V | 1 V ±0.02 V |
| A and C | 2 V ± 0.00014 V | 2 V ± 0.2 V |
| A and D | 3 V ± 0.00019 V | 3 V ± 0.2 V |
| A and E | 4 V ± 0.00024 V | 4 V ± 0.2 V |
| A and F | 5 V ± 0.00029 V | 5 V ± 0.2 V |
| A and G | 6 V ± 0.00034 V | 6 V ± 0.2 V |
| A and H | 7 V ± 0.00039 V | 7 V ± 0.2 V |
| A and I | 8 V ± 0.00044 V | 8 V ± 0.2 V |
| A and J | 9 V ± 0.00049 V | 9 V ± 0.2 V |
| A and K | 10 V ± 0.00054 V | 10 V ± 0.2 V |
| A and L | 100 V ± 0.0054 V | 100 V ± 2 V |
| A and M | 1000 V ± 0.054 V | 1000 V ± 20 V |

l. Set power supply output to 2 V. Make minor changes in the output voltage, if needed, to maintain a null indication on the null detector (10 μV range).

m. Measure the voltage in ΔVM and VM modes. Indicated voltage should be within the tolerances listed in Table 5-4.

n. Progressively move up the divider, applying the voltage shown at each point and measuring the voltage at that point in ΔVM and VM modes with the 740B. Compare the voltage readings with the tolerances listed in Table 5-4.

NOTE

1. Make minor changes in the power supply output at each point to maintain null on the null detector.
2. Periodically check null detector zero.
3. Zero the 740B input whenever changing ranges.

o. Reconnect the test setup as shown in Figure 5-9. Do not connect the reference supply and power supply + leads yet.

p. Set 740B controls as follows:

FUNCTION . . . . . . ΔVM
RANGE . . . . . . . 100 mV
VOLTAGE SET . . . 00.000
SENSITIVITY . . . . . X10$^4$

q. Adjust ZERO control for a zero indication on the 740B meter.

NOTE

It is not necessary to short the + and - leads when adjusting ZERO control due to the low impedance (1 kΩ) across the input terminals.

r. Connect the 1 V reference supply and stable power supply + leads to point K on the divider. Adjust the power supply output for null on the null detector.

s. Measure the voltage (at point B) with the 740B (ΔVM mode). Compare the reading with the tolerances listed in Table 5-5.

t. Switch FUNCTION to VM; depress X1 SENSITIVITY. Compare the 740B meter reading with the tolerances listed in Table 5-5.

u. Move the 1 V reference supply and power supply + leads to point L and then to point M on the divider, measuring the voltages each time at point B in both ΔVM and VM modes. Compare the indications with the tolerances given in Table 5-5.

NOTE

1. Zero the 740B input each time RANGE is changed. The ZERO control is more sensitive on the lower ranges. Depress X10$^3$ SENSITIVITY to zero the input on the 1 mV range.
2. Periodically check null detector for null and adjust (if necessary) the stable power supply output to maintain null.

Table 5-5. ΔVM and VM Accuracy Test Data, 1 mV - 100 mV

| 1 V REFERENCE SUPPLY AND STABLE POWER SUPPLY + LEADS | VOLTAGE AT POINT B | IN-TOLERANCE 740B INDICATIONS | |
|---|---|---|---|
| | | ΔVM | VM |
| Point K | 100 mV | 100 ±0.0064 mV | 100 mV ±2 mV |
| Point L | 10 mV | 10 ±0.0015 mV | 10 mV ±.2 mV |
| Point M | 1 mV | 1 ± 0.001 mV | 1 mV ±.02 mV |

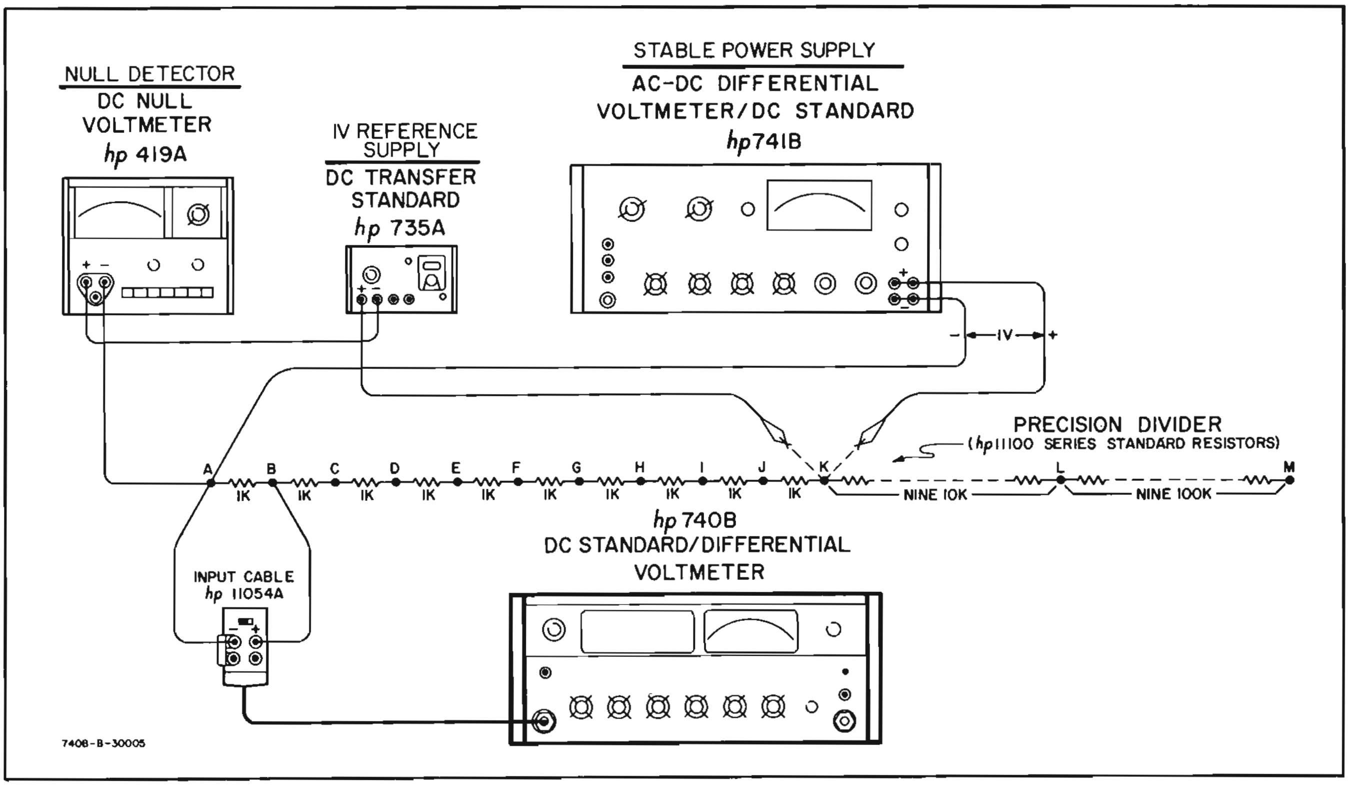



Figure 5-9. ΔVM and VM Accuracy Test, 1 mV - 100 mV

## 5-34. ADJUSTMENT AND CALIBRATION.

5-35. The following paragraphs contain a complete adjustment and calibration procedure for the Model 740B. This procedure should be performed every 30 days to maintain in-specification operation. Allow the instrument to warmup for at least one hour before performing the procedure. Be sure to complete all of the adjustments in the order given, as several of the adjustments interact. Figure 5-11 shows the location of the internal adjustments.

5-36. METER MECHANICAL ZERO ADJUSTMENT.

5-37. The meter mechanical zero should be checked when the instrument has been turned off for one minute following a normal (60 minute) warmup period. If the meter pointer does not rest exactly on the meter zero calibration mark, perform the following adjustment:

a. Rotate the meter mechanical zero adjustment screw to position the meter pointer to the left of zero.

b. Carefully rotate the adjustment screw clockwise; stop when the pointer is exactly at zero. If the pointer overshoots zero, repeat steps a and b.

c. When pointer is exactly on zero, rotate the adjustment screw approximately 15 degrees counterclockwise to free the adjustment screw from the meter suspension. If pointer moves during this step because the adjustment screw is turned too far counterclockwise, repeat steps a, b and c.

5-38. METER CHOPPER FREQUENCY ADJUSTMENT (A8R3).

5-39. The meter chopper frequency adjustment (A8R3) adjusts the frequency of the square wave applied to the neons in the Meter Chopper Assembly (A16). An electronic counter (-hp- Model 5211A) is required for this adjustment procedure.

a. Connect counter input to A8TP21. Connect counter ground clip to ③ (Figure 5-11).

b. Adjust A8R21 for an indication of 95 ± 1 pulses per second on the counter.

5-40. ALTERNATE METHOD.

If an electronic counter is not available, the following procedure may be used to adjust A8R3.

a. Connect an oscilloscope to A8TP21 and ③ (Figure 5-11).

b. Adjust A8R3 for a square wave repetition period of 10. 5 msec (Figure 5-10).

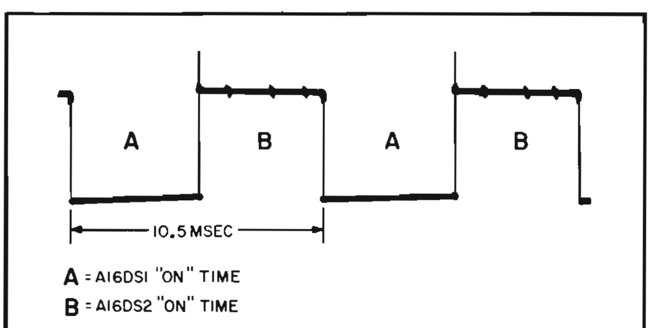
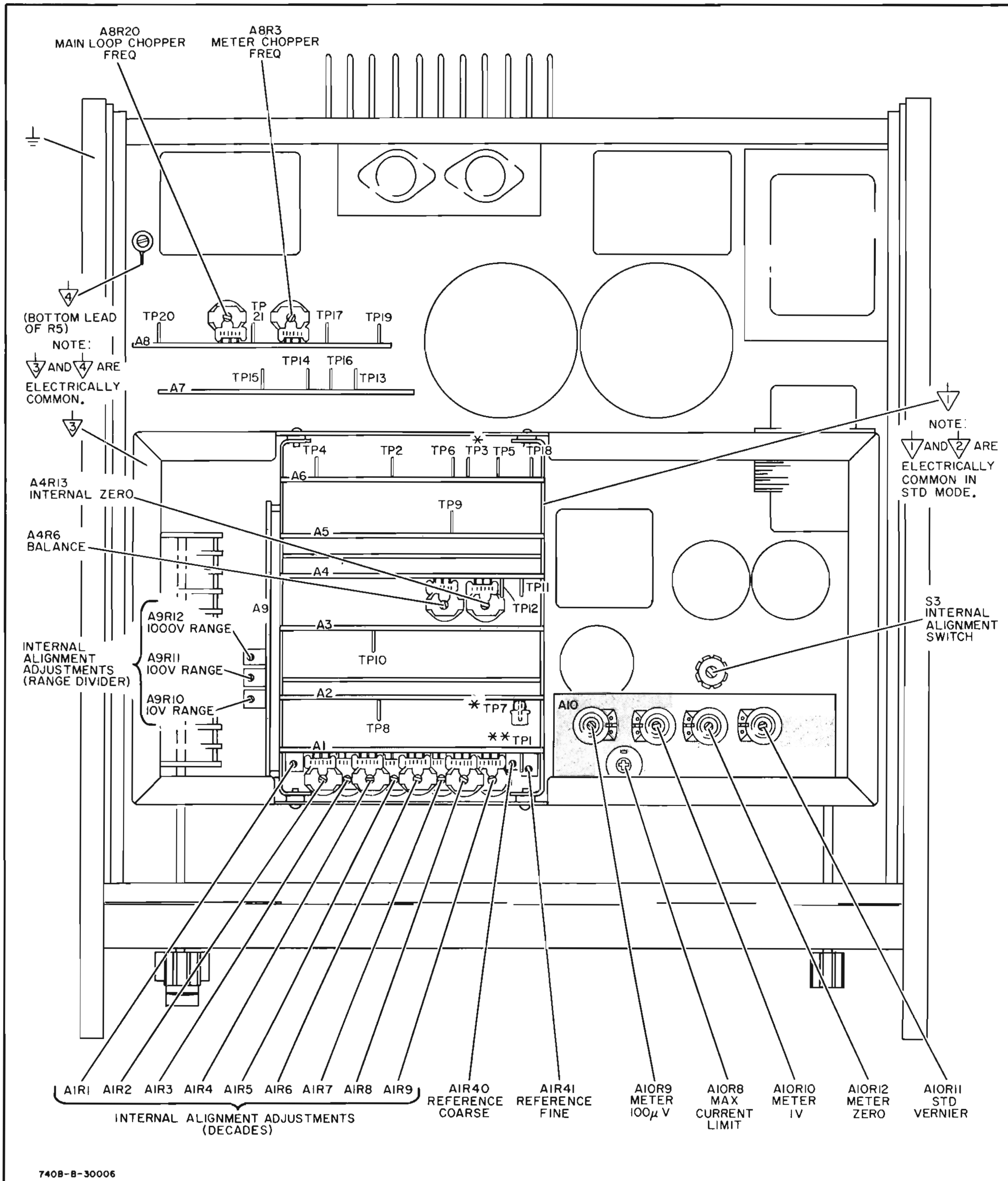



Figure 5-10. Meter Loop Chopper Waveshape




* Test point located below top edge of circuit board.

** Designated TP13 on Serial Nos. 610-00375 and below.

Not shown: 2. See Figure 7-14.

Figure 5-11. Internal Adjustments and Test Points

## 5-41. MAIN LOOP CHOPPER FREQUENCY ADJUSTMENT (A8R20).

5-42. The main loop chopper frequency adjustment (A8R20) adjusts the frequency of the neon driver waveshape applied to the neons in the Main Loop Chopper Assembly (A17). An electronic counter (-hp- Model 5211A) is required for this adjustment procedure.

a. Connect counter input to A8TP20. Connect counter ground clip to ⏚3 (Figure 5-11).

b. Adjust A8R20 for an indication of 324 ±2 pulses per second on the counter.

NOTE

324 pulses per second corresponds to a chopper frequency of 162 Hz since the firing pulses for both neons are present at A8TP20.

## 5-43. ALTERNATE METHOD.

If an electronic counter is not available, the following procedure may be used to adjust A8R20.

a. Connect an oscilloscope to A8TP20 and ⏚3 (Figure 5-11).

b. Adjust A8R20 for a repetition period (2 cycles) of 6.17 msec (Figure 5-12).

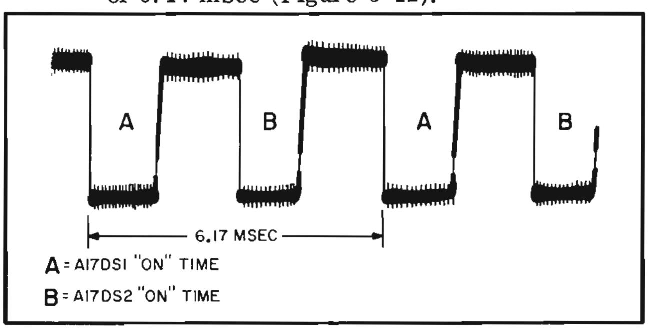



Figure 5-12. Main Loop Chopper Waveshape

NOTE

2 cycles in 6.17 msec corresponds to a chopper frequency of 162 Hz since the firing pulses for both neons are present at A8TP20.

## 5-44. INTERNAL ZERO ADJUSTMENT (A4R13).

5-45. The internal zero adjustment (A4R13) adjusts the main loop zero reference. A sensitive dc voltmeter (-hp- Model 419A DC Null Voltmeter) is required to perform this adjustment.

a. Set Model 740B controls as follows:

RANGE . . . . . . . . . . . 100 V
FUNCTION . . . . . . . . . ΔVM
VOLTAGE SET . . . . . 00.000
INPUT . . . . . . . . . . shorted

b. Connect a sensitive dc voltmeter across the + and - OUTPUT terminals.

NOTE

Make sure that the + SENSE terminal is connected to the + OUTPUT terminal and that the - SENSE terminal is connected to the - OUTPUT terminal.

c. Set voltmeter to 1 mV range and adjust A4R13 (INT. ZERO) for a zero indication ±100 $\mu$V on the voltmeter.

## 5-46. BALANCE ADJUSTMENT (A4R6).

5-47. The balance adjustment, A4R6, is factory set to match the operating characteristics of A4Q1 and A4Q2 and does not need to be adjusted unless A4Q1 or A4Q2 is replaced. If one of these transistors is replaced, proceed as follows:

a. Perform internal zero adjustment (Paragraph 5-44).

b. Remove instrument guard shield cover.

c. Connect a dc voltmeter (-hp- Model 419A) to A4TP12 and ⏚1 (Figure 5-11).

d. Set voltmeter range to 10 mV.

e. Adjust A4R6 for 0 ±3 mV on the voltmeter.

f. Replace instrument guard shield cover.

g. Recheck internal zero adjustment (Paragraph 5-44).

## 5-48. METER LOOP ADJUSTMENTS.

5-49. The meter loop adjustments consist of the meter zero adjustment (A10R12), the 1 V adjustment (A10R10) and the 100 $\mu$V adjustment (A10R9). The meter zero adjustment sets the meter deflection to zero when no input is applied to the meter loop. The 1 V adjustment varies current through the meter, and in this manner matches meter deflection to the meter amplifier output. The 100 $\mu$V adjustment calibrates the meter amplifier gain on the X10 thru X$10^4$ SENSITIVITY ranges. No external test equipment is required to perform these adjustments.

## 5-50. METER ZERO ADJUSTMENT (A10R12).

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . . ΔVM
RANGE . . . . . . . . . . . . 1 V
VOLTAGE SET . . . . . . .00000
SENSITIVITY . . . . . . . X$10^4$
INPUT . . . . . . . . . . shorted

b. Adjust A10R12 (METER ZERO) for a zero indication on the Model 740B meter.

5-51. 1 V ADJUSTMENT (A10R10).

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . ΔVM
RANGE . . . . . . . . . . . 1 V
VOLTAGE SET . . . .00000
SENSITIVITY . . . . . . $X10^4$
INPUT . . . . . . . . shorted

b. Zero the meter with the front panel ZERO control.

c. Depress X1 SENSITIVITY and rotate X1 VOLTAGE SET to 9 (fully clockwise).

d. Adjust A10R10 (METER 1 V ADJ.) for a meter deflection of -0.9.

5-52. 100 μV ADJUSTMENT (A10R9).

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . ΔVM
RANGE . . . . . . . . . . . 1 V
VOLTAGE SET . . . .00000
SENSITIVITY . . . . . $X10^4$
INPUT . . . . . . . . shorted

b. Zero the meter with the front panel ZERO control.

c. Rotate $X10^3$ VOLTAGE SET to 1 (one position cw).

d. Adjust A10R9 (METER 100 μV ADJ.) for a meter deflection of -1.0.

5-53. STANDARD VERNIER ADJUSTMENT (A10R11).

5-54. The standard vernier adjustment adjusts the voltage applied to the meter loop input in STD mode. No external test equipment is required to perform this adjustment.

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . . STD
STD VERNIER . . . . . fully cw

b. Adjust A10R11 (STD VERNIER ADJ.) for a meter deflection of +1.0.

5-55. MAXIMUM CURRENT LIMIT ADJUSTMENT (A10R8).

5-56. The maximum current limit adjustment (A10R8) sets the maximum available output current by adjusting the range of the front panel CURRENT LIMIT control. A 1 kΩ ±5% 5 W resistor (-hp- Part No. 0812-0099) is required for this adjustment procedure.

a. Set Model 740B controls as follows:

RANGE . . . . . . . . . . . . 100 V
FUNCTION . . . . . . . . . STD
VOLTAGE SET . . . . . 60.000
STD VERNIER . . . . fully ccw
CURRENT LIMIT . . . MAX
OUTPUT . . . . . . . . . . . off

b. Connect a 1 kΩ resistor across + and - OUTPUT terminals.

c. Depress OUTPUT pushbutton to apply 60 V to load.

d. Turn A10R8 (MAX. CURRENT LIMIT) cw until front panel OVERLOAD light glows.

e. Turn A10R8 slowly ccw until OVERLOAD light just goes out.

5-57. INTERNAL ALIGNMENT PROCEDURE.

5-58. The internal alignment procedure is a method of accurately calibrating and adjusting the VOLTAGE SET dividers, the Precision Range Divider and the Reference Supply.

5-59. The VOLTAGE SET resistors are ratio matched with the front panel meter serving as the null indicator. Meter ratio sensitivity is very high --approximately 8 ppm full scale --and a perfect null is both hard to achieve and unnecessary. The adjustments should be set as near null as possible and rechecked after the procedure is completed. If null is maintained within 10% (one major meter division) of 0, the instrument will operate well within its specifications. The first adjustment, A1R1, calibrates a 2:1 divider used as a reference for the following adjustments. The next eight adjustments (A1R2 through A1R9) match the VOLTAGE SET resistors by adjusting the corresponding parallel padding resistance on A1. After a long period of time, one or more of the VOLTAGE SET resistors may drift beyond the adjustment range of the variable padding resistance. Paragraph 5-63 explains the procedure for modifying the padding resistance to compensate for the long term drift.

5-60. A9R10, A9R11 and A9R12 are adjusted to meter indication values printed on the guard shield cover. These values are determined at the factory for each instrument and should not be changed unless the precision divider (A9R4 through A9R9) is replaced. If the precision divider is replaced, the new numbers can be determined using the procedure given in Paragraph 5-109.

5-61. The last two adjustments of this procedure (A1R40 and A1R41) calibrate the internal reference supply. An external reference voltage (-hp- Model 735A DC Transfer Standard) and a null detector (-hp- Model 419A DC Null Voltmeter) are required for these adjustments.

5-62. The following steps describe the internal alignment procedure. The procedure is also outlined on the instrument guard shield cover.

a. Turn on the instrument and allow it to warm-up for at least 60 minutes.

NOTE

In-tolerance instrument performance can be expected when the internal alignment procedure is performed after a normal (60 minute) warmup period. For optimum instrument accuracy, this procedure may be repeated after an eight hour (or longer) warmup period.

b. Remove instrument top cover.

c. Set front panel controls as follows:

| | |
|---|---|
| RANGE . . . . . . . . . . . | 100 V |
| FUNCTION . . . . . . . . . | VM |
| VOLTAGE SET . . . . . | 00.000 |
| SENSITIVITY . . . . . . . | $X10^4$ |
| INPUT . . . . . . . . . | Shorted |

d. Adjust A10R12 (Meter Zero) for zero meter indication.

e. Switch RANGE to "Dot" position (fully ccw).

f. Turn INTERNAL ALIGNMENT switch to position 1. If meter pointer is off-scale, depress $X10^3$ SENSITIVITY.

g. Alternate between positions 1 and 2 adjusting A1R1 for equal meter deflection (and same polarity) at both positions.

h. Adjust A1R2 for zero meter indication ($X10^4$ SENSITIVITY). Positions 1 and 2 should now both read zero on the meter. If not, repeat steps g and h.

i. Progressively switch to positions 3 through 9 adjusting the corresponding controls (A1R3 through A1R9) for a zero meter indication in each position.

j. Adjust A9R10, R11 and R12 to the values indicated in step B-6 of the internal alignment procedure printed on the guard shield. The optimum values for these adjustments are determined at the factory and will vary from instrument to instrument.

k. Return INTERNAL ALIGNMENT switch to OPERATE position.

l. Set FUNCTION to ΔVM and check meter indication. Adjust A10R12 (METER ZERO ADJ.) for a zero meter indication.

NOTE

There is generally a slight zero turn-over error between VM and ΔVM modes and this is quite normal. A10R12 must be readjusted in ΔVM mode before proceeding with the following steps.

m. Set FUNCTION to STD and RANGE to 1 V. Using a sensitive dc voltmeter (10 $\mu$V range) adjust 740B front panel ZERO control for 0 Vdc at the + and - OUTPUT terminals.

NOTE

If a standard cell is used in the following steps, zero the 740B output (step m) on the 10 V range.

n. Connect 740B OUTPUT terminals as shown in Figure 5-13. Set VOLTAGE SET and STD VERNIER controls to the value of the known external reference voltage.

NOTE

If a dc transfer standard is used, it should be calibrated to 1 V ±2 ppm according to the procedure in Appendix C.

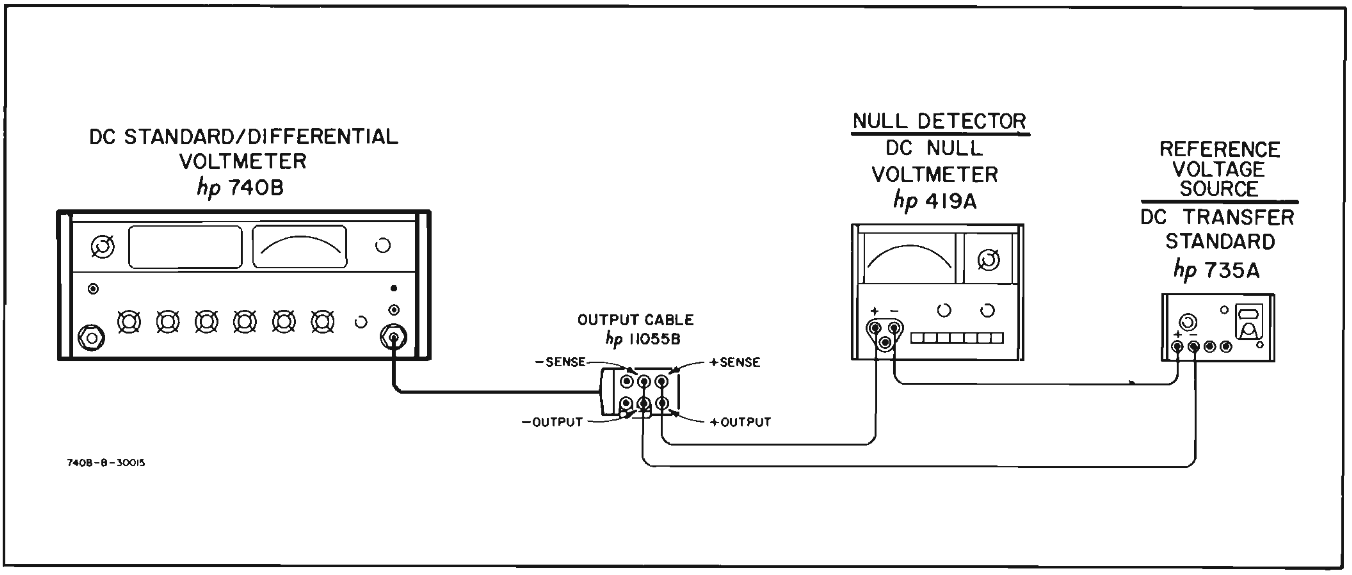



Figure 5-13. Reference Supply Calibration

Table 5-6. Changing the Padding Resistance with Jumper Wires

| Variable Padding Resistor | Required Change In Series Resistance To Move Meter In A | | To Increase Series Resistance, Clip Jumper Across | To Decrease Series Resistance, Add Jumper Across |
|---|---|---|---|---|
| | Positive Direction | Negative Direction | | |
| R2 | Increase | Decrease | R14 or R15 | R14 or R15 |
| R3 | Decrease | Increase | R17 or R18 | R17 or R18 |
| R4 | Decrease | Increase | R20 or R21 | R20 or R21 |
| R5 | Decrease | Increase | R24 or R25 | R24 or R25 |
| R6 | Decrease | Increase | R27 or R28 | R27 or R28 |
| R7 | Decrease | Increase | R30 or R31 | R30 or R31 |
| R8 | Decrease | Increase | R33 or R34 | R33 or R34 |
| R9 | Decrease | Increase | R37 or R38 | R37 or R38 |

o. Depress OUTPUT pushbutton to compare 740B output with external voltage.

p. Adjust A1R40 (REF COARSE ADJ) and A1R41 (REF FINE ADJ) as necessary to produce a null indication on the null voltmeter 10 $\mu$V range. This calibrates the internal 1 V referency supply for best accuracy in STD mode.

NOTE

For better than specified instrument accuracy in the ΔVM mode (with a slight loss of accuracy in STD mode) the reference supply adjustments can be made with the known external voltage applied to the + and - INPUT terminals (ΔVM mode). Set VOLTAGE SET controls to indicate first five digits of known external voltage. Adjust A1R40 (REF COARSE ADJ) and A1R41 (REF FINE ADJ) to give correct meter indication for sixth digit with X$10^4$ SENSITIVITY depressed.

5-63. VOLTAGE SET DRIFT CORRECTION.

5-64. The following paragraphs describe the procedure for changing the range of adjustment of the VOLTAGE SET padding resistor adjustments, A1R2 through A1R9. This procedure should be performed only when one or more of the resistors cannot be adjusted for a null indication when performing the internal alignment procedure (Paragraph 5-57). Refer to Figure 7-5, Internal Alignment Schematic and Component Location Diagram, for the following discussion.

5-65. The range of adjustment of each variable padding resistor (A1R2 through A1R9) is controlled by several series resistors. Some of the series resistors are shunted by jumper wires during manufacture.

5-66. If null cannot be achieved, determine if the padding resistance must be increased or decreased (Table 5-6). To increase the resistance, clip one of the jumper wires shunting one of the padding resistors associated with the appropriate adjustable resistor (Table 5-6). For example, if it is necessary to increase the resistance in series with A1R2, clip the jumper wire shunting A1R14 or A1R15. To decrease the resistance, a jumper must be added across A1R14 or A1R15.

5-67. In some cases, both jumper wires may already have been clipped or removed and it is necessary to increase the resistance in series with one of the variable resistors. In this case, it will be necessary to increase the value of one of the fixed resistors. Table 5-7, lists the recommended changes and gives the -hp- part number of the new resistor.

5-68. It may be necessary to decrease the series resistance even though two of the series resistors are already shunted by a jumper. In this case, the linearizing resistor associated with the appropriate variable resistor must be changed. Table 5-7 lists the recommended change and gives the -hp- part number of the new resistor.

Table 5-7. Changing the Padding Resistors

| Variable Padding Resistor | To Increase Series Resistance When Both Jumpers Are Already Removed, Change | -hp- Part No. of New Resistor | To Decrease Series Resistance When Both Jumpers Are Installed, Change | -hp- Part No. of New Resistor |
|---|---|---|---|---|
| R2 | R14 to 255 kΩ | 0698-3149 | R13 to 750 kΩ | 0757-0486 |
| R3 | R17 to 511 kΩ | 0757-0482 | R16 to 1.3 MΩ | 0757-0872 |
| R4 | R20 to 511 kΩ | 0757-0482 | R19 to 1.3 MΩ | 0757-0872 |
| R5 | R24 to 1 MΩ | 0698-5475 | R22 to 1 MΩ | 0698-5475 |
| R6 | R27 to 255 kΩ | 0698-3149 | R26 to 600 kΩ | 0698-4077 |
| R7 | R30 to 511 kΩ | 0757-0482 | R29 to 1.3 MΩ | 0757-0872 |
| R8 | R33 to 511 kΩ | 0757-0482 | R32 to 1.3 MΩ | 0757-0872 |
| R9 | R37 to 1 MΩ | 0698-5475 | R35 to 1 MΩ | 0698-5475 |

## FRONT PANEL TROUBLESHOOTING TREE

**ISOLATING THE TROUBLE TO A SECTION**

NOTES

1. Use a sensitive dc voltmeter (-hp- Model 419A) connected to Output terminals to monitor output voltage and noise.
2. Refer to Functional Diagram, Figure 7-3, to observe overall instrument operation.
3. All checks (except No. 19) should be performed with instrument covers and shields in place.
4. Procedure assumes board pins are clean and making good contact and power supplies are working. Refer to Figure 7-3 for power supply voltages and test points.

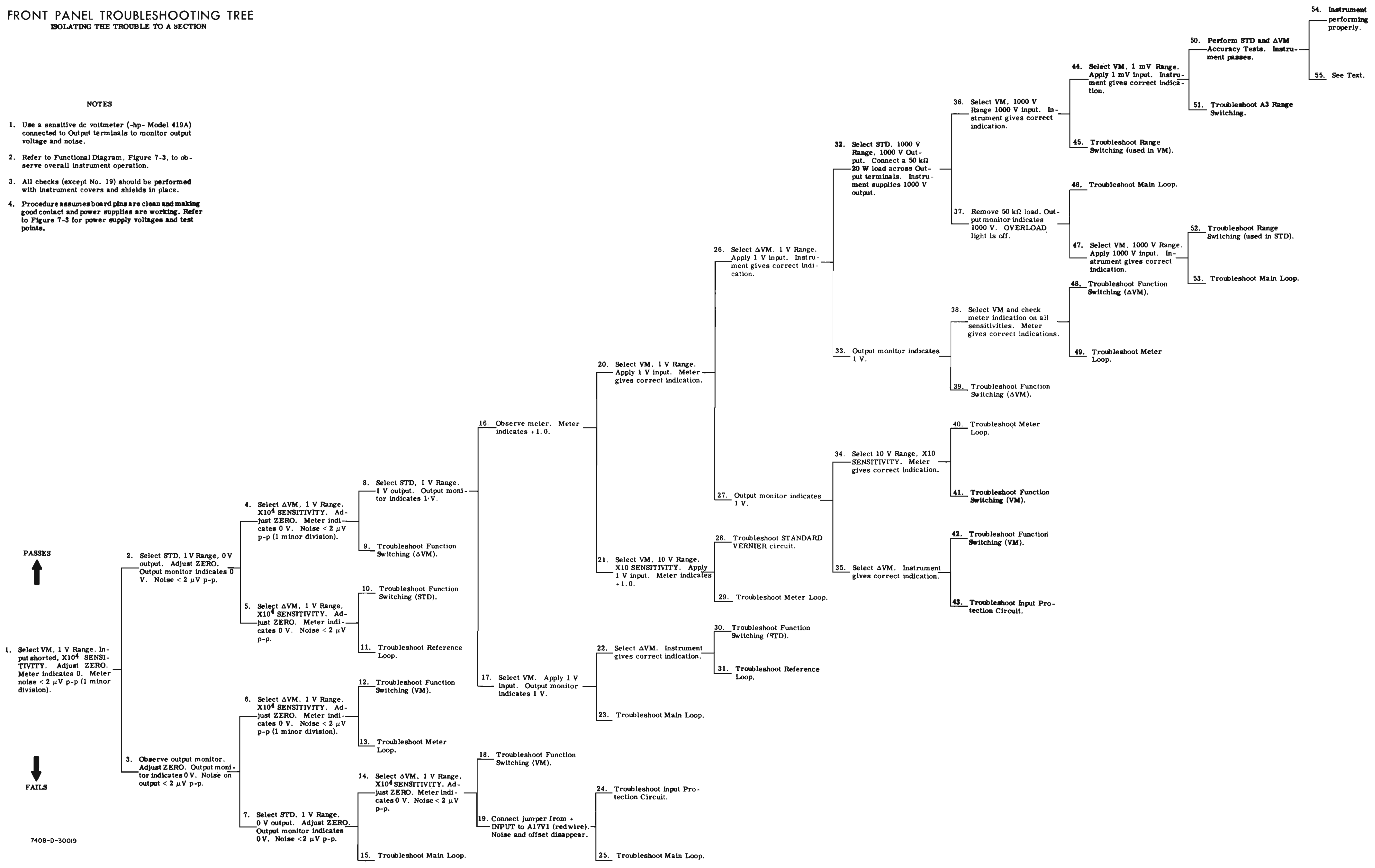



Figure 5-14. Front Panel Troubleshooting Tree





Table 5-8. Preliminary Checks

| SYMPTOM | POSSIBLE CAUSE/CORRECTIVE ACTION |
|---|---|
| Inoperative (any or all modes) | 1. Check AC Fuses.<br>2. Make sure Internal Alignment Switch (S3) is in "Operate" position.<br>3. Check Power Supply Voltages (Figure 7-3, Sheet 2 of 4). |
| Erratic Operation or Poor Repeatability | Switches may be dirty. Turn instrument off; rotate all switches several times (including Internal Alignment Switch, S3). Switches are self-cleaning (Paragraph 5-108). |
| OVERLOAD Light On (all modes) | Check DC Fuse. If blown, replace. If fuse blows again, Q1 or Q2 may be shorted. Proceed to Main Loop Troubleshooting Tree, step 34. |
| OVERLOAD Light On (STD mode, mV Ranges) | Normal indication. In STD mode, mV Ranges are inoperative (Paragraph 3-15, step h). |
| Output voltage inaccurate | 1. Make sure SENSE terminals are connected correctly (Paragraph 3-17). Remote Sensing must be used for remote loads.<br>2. Make sure ZERO control is set properly (Paragraph 3-31). |
| ΔVM mode inaccurate | 1. Make sure INPUT Z Switch is set to ∞ position.<br>2. Make sure ZERO control is set properly (Paragraph 3-46, 3-47). |
| Unable to zero Input or Output with ZERO control | 1. Recheck Internal Zero Adjustment (Paragraph 5-44), Balance Adjustment (Paragraph 5-46) and Meter Zero Adjustment (Paragraph 5-50).<br>2. Check A10BT1 (1.3 V minimum). |
| OUTPUT Indicator lighted when Output Cable is not connected | Normal indication. OUTPUT Indicator lights when depressed even when Output Cable Assembly is not connected. The Output Rotary Switch (K1), however, does not energize. |
| Internal Buzzing when changing Ranges or exceeding Current Limit | This is normal. The noise comes from the Internal Current Limit Circuit. |
| Noisy meter on 1 mV Range, $X10^4$ Sensitivity | Normal indication. (Paragraph 3-59, step g) |

## 5-69. TROUBLESHOOTING PROCEDURE.

5-70. The following paragraphs contain information on troubleshooting the Model 740B. Before troubleshooting the Model 740B, attempt the Adjustment and Calibration Procedure (Paragraph 5-34). Some apparent malfunctions can be corrected using this procedure. For example, inaccuracy or non-linearity may be corrected by performing the Internal Alignment Procedure (Paragraph 5-57).

5-71. Check Table 5-8, Preliminary Checks, for the trouble symptom. If the symptom is not listed, the Troubleshooting Trees (Paragraph 5-72) should be helpful.

### 5-72. TROUBLESHOOTING TREES.

5-73. The Front Panel Troubleshooting Tree in Figure 5-14 consists of some fairly rapid checks arranged to isolate trouble to a major loop and occasionally traces trouble to a specific circuit. In addition, the Front Panel Tree checks most of the Range and Function Switching.

5-74. The Main Loop, Meter Loop and Reference Loop Troubleshooting Trees (Figures 5-15, 5-16, 5-17) can be helpful in isolating trouble to a specific circuit within these major circuits.

5-75. To use the Troubleshooting Trees, decide if step 1 passes or fails, and proceed to the next step along the appropriate branch of the tree. The steps in each tree are explained in detail in a table adjacent to the tree. The checks outlined in the trees do not usually isolate trouble to a specific circuit component. Once the trouble is isolated to a specific circuit, additional checks will probably be required to isolate the faulty component. Waveshapes and operating voltages shown on the schematic diagrams may give additional help.

Table 5-9. FRONT PANEL TROUBLESHOOTING

1. A correct indication shows that the Main Loop and Meter Loop are probably working.
2. A correct indication shows that STD mode Function switching is probably working and that the Reference Loop is relatively noise free.
3. A correct indication shows that the Main Loop is not causing the noise or offset shown on the 740B meter.
4. A correct indication shows that the Main Loop, Reference Loop and Meter Loop are all relatively free of noise and offset.
5. A correct indication shows that the Reference Loop is probably not causing the noise or offset.
6. A correct indication shows that the Meter Loop is probably not causing the noise or offset problem.
7. If the output is free of noise and offset in STD mode, the Main Loop is probably not at fault.
8. A correct indication verifies that the Reference Loop and Main Loop are operative.
9. Since trouble occurs only in ΔVM, the trouble is most likely in ΔVM Function switching. Possible trouble areas: Deck S1H(F), S1I(F) and S1G(R) of Range/Function Switch, S1 (Figure 7-3).
10. Trouble is probably in STD mode Function switching. Possible trouble areas: Deck S1I(F), S1H(R) and S1H(F) of Range/Function Switch. S1 (Figure 7-3).
11. Follow procedure in Reference Loop Troubleshooting Tree (Figure 5-17).
12. Function Switching used in VM is probably at fault. Possible Trouble areas: Deck S1I(F) and S1H(R) of Range/Function Switch, S1 (Figure 7-3).
13. Since the Main Loop is not causing noise or offset and the trouble occurs in both VM and ΔVM, the problem is most likely in the Meter Loop. Follow procedure in Meter Loop Troubleshooting Tree (Figure 5-16).
14. A correct indication shows that the Main Loop is capable of operating properly.
15. Since noise and offset are present at Output terminals in all modes, the trouble is most likely in the Main Loop. Follow procedure in Main Loop Troubleshooting Tree (Figure 5-15).
16. A correct indication shows that the Meter Loop and the Standard Vernier Circuit are functioning.
17. A correct indication shows that the Main Loop is operating.
18. VM mode Function switching in Main Loop is probably at fault. Possible trouble areas: Deck S1G(R) and S1H(F) of Range/Function Switch, S1 (Figure 7-3).
19. If noise and offset disappears, the Main Loop is not at fault.
20. A correct indication verifies proper operation of the Input Protection Circuits, VM mode Function switching and the Meter Loop (X1 Sensitivity).
21. These settings duplicate the Meter Loop operation attempted in step 16. A correct indication shows that the Meter Loop is not at fault.
22. A correct indication in ΔVM shows that the Reference Loop and Main Loop are probably not at fault.
23. Follow procedure in Main Loop Troubleshooting Tree (Figure 5-15).

Table 5-9. FRONT PANEL TROUBLESHOOTING (Cont'd)

24. Troubleshoot Input Protection Circuit (Figure 7-3). Possible trouble: Bad A9Q1, A9DS2 or A9V2.

25. If noise and offset are still present at Output terminals, trouble is probably in the Main Loop. Check Range/Function switching between A17V1, V2 (Modulator) and A3 pin 1; also check Range/Function switching associated with the Main Loop Feedback Divider (p/o A9). If trouble cannot be found, follow procedure in Main Loop Troubleshooting Tree (Figure 5-15).

26. A good indication verifies proper operation of ΔVM Function switching and Meter Loop operation on the higher Sensitivities.

27. A correct voltage at the Output terminals verifies proper operation of the Main Loop.

28. The trouble is probably in the Standard Vernier Divider, S9A (Figure 7-3). Also check for continuity (STD mode) between pins 7 and 8, deck S1I(F), of Range/Function Switch, S1.

29. Follow procedure in Meter Loop Troubleshooting Tree (Figure 5-16).

30. STD mode Function switching is probably at fault. Possible trouble areas: Deck S1J(F), S1H(R), S1H(F) and S1I(F) of Range/Function Switch, S1 (Figure 7-3).

31. Follow procedure in Reference Loop Troubleshooting Tree (Figure 5-17).

32. A correct output verifies proper operation of the Main Loop on the 1000 V Range.

33. A correct indication verifies proper ΔVM Function switching in the Main Loop.

34. A correct indication shows that VM mode Function switching is probably not at fault.

35. A correct indication shows that the Input Protection Circuit is not at fault.

36. A correct indication shows that the Main Loop works properly in VM mode, 1000 V Range.

37. A correct output with no load indicates low gain or Current Limit problems in the Main Loop.

38. Correct indications verify proper operation of the Meter Loop.

39. ΔVM Function Switching in the Main Loop is probably at fault. Possible trouble areas: Deck S1H(F) and S1G(R) of Range/Function Switch, S1 (Figure 7-3).

40. Follow procedure in Meter Loop Troubleshooting Tree (Figure 5-16).

41. Check deck S1I(R) pins 4 and 5 for continuity in VM mode (Figure 7-3). If trouble cannot be found, follow procedure in Meter Loop Troubleshooting Tree (Figure 5-16).

42. VM mode Function switching is probably at fault. Possible trouble areas: Deck S1G(R), S1H(R), S1H(F) and S1I(F) of Range/Function Switch, S1 (Figure 7-3).

43. Since the trouble occurs in both VM and ΔVM modes, the trouble is probably in the Input Protection Circuit (Figure 7-3). Possible trouble: Bad A9Q1, A9DS2 or A9V2.

44. A correct indication shows that the Main Loop provides the necessary increased gain on the mV Ranges.

45. Range switching used only in VM and ΔVM is probably at fault. Possible trouble area: Deck S1C(R) of Range/Function Switch, S1 (Figure 7-3).

46. Perform Loop Gain Check (Paragraph 5-76). If instrument passes, proceed to step 49 in Main Loop Troubleshooting Tree (Figure 5-15).

47. A correct indication shows that the Main Loop is capable of functioning on the 1000 V Range.

48. ΔVM Function switching in Meter Loop or Reference Loop is probably at fault. Possible trouble areas: Deck S1I(F) and S1H(R) of Range/Function Switch, S1 (Figure 7-3).

49. Follow procedure in Meter Loop Troubleshooting Tree (Figure 5-16).

50. STD and ΔVM Accuracy tests are outlined in the Performance Tests section (Paragraph 5-5).

51. Range switching used only on the mV Ranges may be at fault. Possible trouble areas: Deck S1B(F) and S1F(F) of Range/Function Switch, S1 (Figure 7-3). If trouble cannot be found, proceed to step 2 in Main Loop Troubleshooting Tree (Figure 5-15).

52. Range Switching used in STD mode is probably at fault. Possible trouble areas: Deck S1B(R) and S1C(F) of Range/Function Switch, S1 (Figure 7-3).

53. Trouble is probably in the High Voltage Section of the Main Loop. Proceed to step 16 in Main Loop Troubleshooting Tree (Figure 5-15).

54. If instrument passes all of the previous checks, all of the major loops are functioning properly.

55. If the instrument fails one or more of the accuracy tests, the trouble is probably associated with circuits or switching peculiar to that test. For example: If inaccuracy occurs only on the 100 V Range and only in STD mode, the trouble may be in Range Switching for the 100 V Range that is used only in STD (Deck S1B(R) of Range/Function Switch, S1).

## MAIN LOOP TROUBLESHOOTING TREE

NOTES

1. Refer to Figure 7-3, Functional Diagram, for overall Main Loop operation.
2. Use a sensitive dc voltmeter (-hp- Model 419A) to observe output voltage and noise.
3. All measurements should be made with respect to ⏚ unless otherwise specified.
4. Place circuit board on a printed circuit board extender to monitor voltages or waveshapes at board pins.

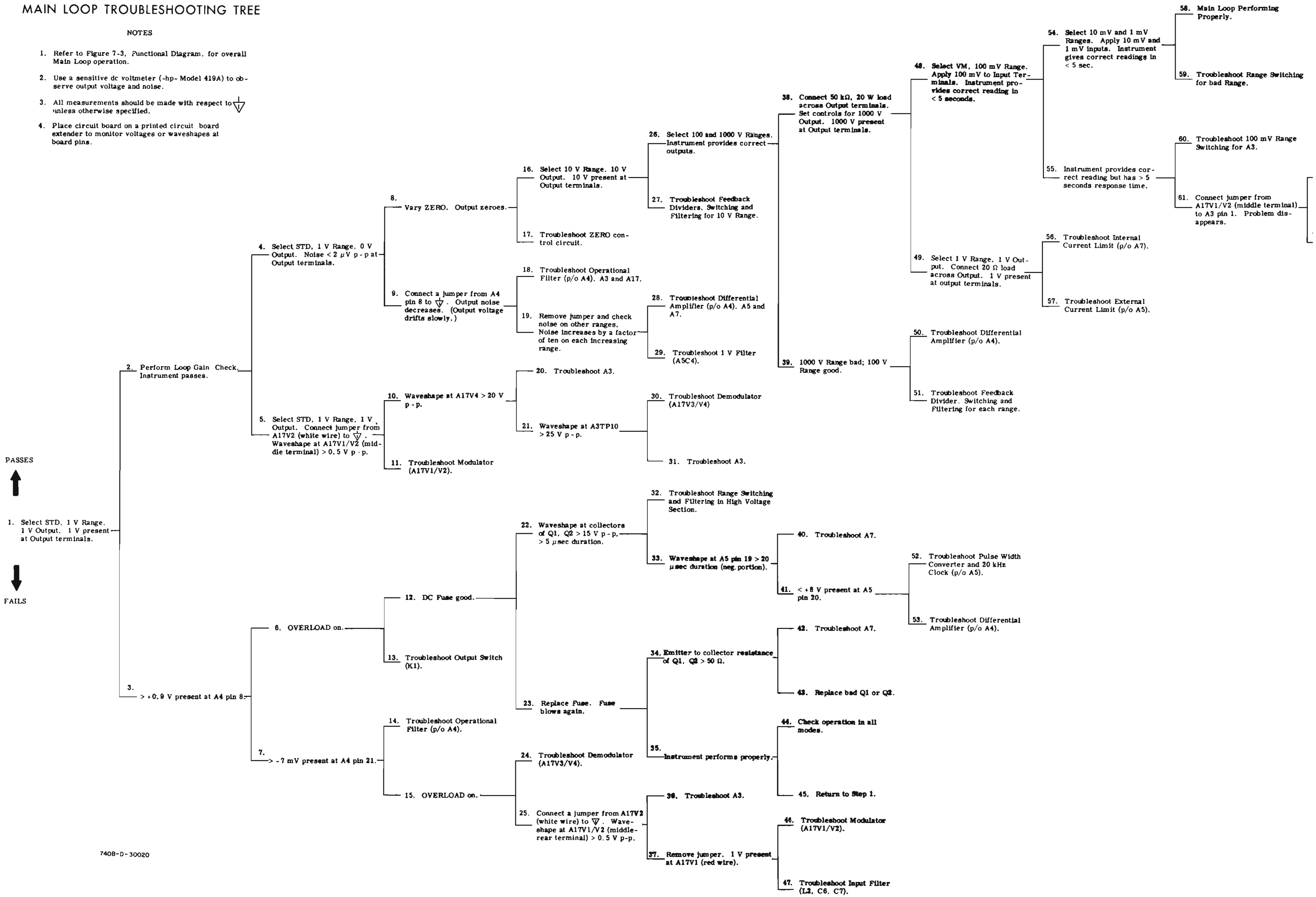



Figure 5-15. Main Loop Troubleshooting Tree

Table 5-10. MAIN LOOP TROUBLESHOOTING

1. A correct voltage at the Output terminals shows that the Main Loop is functioning.
2. The Loop Gain Check is given in Paragraph 5-76.
3. > +0.9 V at A4 pin 8 verifies that the Low Voltage Section of the Main Loop is functioning.
4. A correct output shows that the Main Loop is relatively noise-free.
5. Connecting a jumper wire from A17V2 to ⏚ creates a 1 V difference between the Main Loop input voltage (+1 V from the Reference Loop) and the feedback voltage (0 V). If the Modulator output exceeds 0.5 V p-p, the Modulator is probably not at fault.
6. If the OVERLOAD Light is on, the Low Level Amplifier (A3) is probably functioning.
7. > -7 mV present at A4 pin 21 indicates that the Operational Filter is receiving a drive voltage.
8. If output zeroes, the ZERO Control Circuit is working properly.
9. If noise decreases when jumper wire is connected to A4 pin 8, the circuits between the output of the Operational Filter and the Output terminals are probably not causing noise.
10. A waveshape > 20 V p-p at A17V4 verifies proper operation of the Demodulator (A17V3/V4).
11. Troubleshoot the Modulator (A17V1/V2) according to the procedure in Paragraph 5-80.
12. If the DC Fuse is not blown, the Power Switch transistors (Q1 and Q2) are probably not at fault.
13. Since the OVERLOAD Light is not on, the Main Loop is probably stable. Since no voltage (or an incorrect voltage) is present at the Output terminals, the Output Rotary Switch, K1, is likely at fault (Figure 7-3).
14. The Operational Filter (p/o A4) is receiving a sufficient input (> -7 mV) but not producing a sufficient output. Troubleshoot Operational Filter (Figure 7-8).
15. If the OVERLOAD Light is on, the Low Level Amplifier (A3) is producing an output and probably is not at fault.
16. A 10 V output verifies proper operation of the feedback switching and filtering (10 V range) in the High Voltage Section of the Main Loop.
17. Check the voltage of A10BT1 (1.3 V minimum). If A10BT1 is good, check the other ZERO control Circuit components (Figure 7-3).
18. Since noise decreased when the Operational Filter output was connected to ⏚ (step 9), the noise source is between the Main Loop input and the Operational Filter output (A4 pin 8). Noise at A4 pin 8 should be about 1% the amplitude of the noise at A4 pin 21 if the Operational Filter is functioning. (Observe noise with oscilloscope). If the Operational Filter is functioning, the trouble is probably in the Low Level Amplifier, A3 (Figure 7-7), or A17. Paragraph 5-80 gives the procedure for troubleshooting A17.
19. If noise increases by a factor of ten on each increasing range, the 1 V Filter is probably not at fault.
20. The Modulator and Demodulator are functioning (steps 5 and 10) but the Low Voltage Section of the Main Loop has insufficient gain (step 2). The trouble is probably low gain in the Low Level Amplifier, A3 (Figure 7-7).
21. A waveshape > 25 V p-p at A3TP10 shows that the Low Level Amplifier is producing a good output when driven to saturation.
22. A waveshape > 15 V p-p and > 5 μsec duration shows that the Power Switch (Q1, Q2) and Power Switch Driver (p/o A7) are functioning.
23. If fuse does not blow again, the instrument may be working properly. Blown fuse may have been caused by an excessive overload at the Output terminals.
24. The Low Level Amplifier is producing a good output (step 15) but the Operational Filter is not receiving a correct input (step 7). The Demodulator (A17V3/V4) is probably at fault. Troubleshoot the Demodulator according to the procedure in Paragraph 5-80.
25. Connecting the jumper wire from A17V2 to ⏚ creates a 1 V difference between the Main Loop input voltage (1 V) and the feedback voltage (0 V). If the Modulator output exceeds 0.5 V p-p, the Modulator is probably working correctly.
26. If the instrument provides correct output voltages on the 100 V and 1000 V ranges, range switching for these ranges is functioning properly.
27. The Main Loop provided a correct output on the 1 V range (step 1) so the trouble is probably in one of the Feedback Dividers, (A9R4 - 12 and S1R11 - 14), Range switching, or the 10 V Filter, A5C5 (Figure 7-3).

Table 5-10. MAIN LOOP TROUBLESHOOTING (Cont'd)

28. Since noise increases by a factor of ten on each increasing range, filtering for each range is probably not at fault. The noise is probably originating in the Pulse Width Converter, p/o A5 (Figure 7-9) or the Differential Amplifier, p/o A7 (Figure 7-11).

29. Filtering for the 1 V range is probably causing the trouble. Check for bad A5C4 (Figure 7-9).

30. The Demodulator receives a correct input from A3 (step 21) but produces a low output (step 10). Troubleshoot the Demodulator (A17V3/V4) according to the procedure in Paragraph 5-80.

31. The Low Level Amplifier (A3) does not produce a satisfactory output when driven to saturation (step 21). Troubleshoot the Low Level Amplifier (Figure 7-7).

32. The Power Switch circuits are functioning (step 22) but no voltage (or an incorrect voltage) is present at the Output terminals (step 1). The trouble is probably in Range Switching or Filtering (Figure 7-3).

33. If waveshape at A5 pin 19 is greater than 20 $\mu$sec duration, the Pulse Width Converter (p/o A5) is furnishing T3 with a proper input.

34. Connect negative lead of ohmmeter to ⏚3 or ⏚4 ; positive lead to collectors of Q1 and Q2 (blue wires). If resistance measures > 75 Ω, Q1 and Q2 are probably working.

35. Check voltage at Output terminals.

36. The Modulator is apparently working (step 25) but the Low Level Amplifier is not turning on the Overload Light (step 15). Troubleshoot Low Level Amplifier (Figure 7-7).

37. If +1 V is present at A17V1, the Modulator is receiving a correct input voltage from the Reference Loop.

38. A correct output voltage shows that the Main Loop can deliver maximum rated output power (20 W), verifying proper operation of the Internal and External Current Limit circuits.

39. If the 1000 V range is the only range that malfunctions, the range switching probably is not at fault.

40. The Pulse Width Converter is producing a correct output (step 33) but the Power Switch is not producing proper pulses (step 22). The trouble is probably in T3 or the Power Switch Driver (p/o A7). Refer to Figure 7-11.

41. < +8 V at A5 pin 20 verifies that the Differential Amplifier (p/o A4) is furnishing a correct Output to the Pulse Width Converter.

42. Since fuse blows (step 23) and Q1 and Q2 are not shorted (step 34), the Power Switch Driver, p/o A7, is probably at fault (Figure 7-3). Possible trouble: shorted A7Q1.

43. Replace bad Q1 or Q2. Figure 7-1, Detail D shows the assembly sequence for Q1, Q2 and attaching hardware. A layer of silicon grease should be applied to both sides of the mica insulator (MP45) before reassembly.

44. Verify operation in VM and ΔVM modes. If operating, there is probably no other malfunction. If a problem occurs in VM or ΔVM, perform procedure in Front Panel Troubleshooting Tree (Figure 5-14).

45. Since the instrument does not operate, a problem still exists in the High Voltage Section. Proceed to step 22.

46. The Modulator is receiving a correct input voltage from the Reference Loop (step 37) but does not produce a good output (step 25). Troubleshoot the Modulator according to the procedure in Paragraph 5-80.

47. The absence of +1 V at A17V1 may be caused by trouble in the Input Filter: L2, C6, C7 (Figure 7-3). Check for open L2 or shorted C6 or C7. If Filter is not at fault, the Reference Loop is not generating +1 V. Follow procedure in Reference Loop Troubleshooting Tree (Figure 5-17).

48. A correct indication shows that the 100 mV Range switching is operative.

49. If the instrument provides a correct output (1 V across 20 Ω), the External Current Limit circuit is probably not at fault.

50. Marginal gain in the Operational Filter (p/o A4) will probably show up only on the 1000 V Range. Using an oscilloscope, compare the noise amplitude at A4 pin 8 with the amplitude at A4 pin 21. Waveform at pin 8 should be approximately 1% the amplitude at pin 21 if Operational Filter has sufficient gain. If Operational Filter appears to be functioning, troubleshoot 1000 V Range switching (Figure 7-3) and Differential Amplifier (Figure 7-8).

51. If the trouble also occurs on the 100 V range, filtering or switching for the bad range(s) is probably at fault. Troubleshoot C3 and Range switching (Figure 7-3) and 100 V Filter, A5C6 (Figure 7-9).

52. The Pulse Width Converter (p/o A5) is receiving a correct input (step 41) but is not generating a correct output (step 33). Troubleshoot the Pulse Width Converter and 20 kHz Clock (Figure 7-9).

Table 5-10. MAIN LOOP TROUBLESHOOTING (Cont'd)

53. The Operational Filter is producing a correct output to the Differential Amplifier (step 3) but the Differential Amplifier is not generating a correct output (step 41). Troubleshoot the Differential Amplifier, p/o A4 (Figure 7-8).

54. Correct indications verify proper Range switching operation on the 10 mV and 1 mV range.

55. A correct indication (but excessive response time) shows that range switching for the Main Loop Feedback Divider is operating.

56. Since the instrument is capable of delivering maximum output current at low voltages (step 49) the trouble is probably in the Internal Current Limit circuit, p/o A7 (Figure 7-11).

57. Since output current is insufficient at both high and low voltages (steps 38 and 49) the trouble is probably in the External Current Limit circuit (Figures 7-3 and 7-9).

58. If the instrument passes all of the preceding checks, the Main Loop is functioning properly.

59. Troubleshoot Range switching for the inoperative range (Figure 7-3).

60. Excessive response time but a correct final indication (step 55) may be caused by incorrect mV Range switching for the Low Level Amplifier. Check for a short between A3 pin 21 and A3 pin 17. If short is present, troubleshoot Deck S1B(F) of Range/Function Switch, S1 (Figure 7-3).

61. If problem disappears when jumper wire is connected, the Main Loop Feedback Divider switching is not at fault.

62. If problem disappears when jumper wire is connected, there is probably a bad switch contact between A17V1/V2 and pin 1 (Figure 7-3). Check for continuity between these points on the mV ranges (VM and ΔVM modes).

63. Since trouble is not caused by Range/Function switching between A17 and A3 (step 61), the trouble may be mV Range switching associated with the Main Loop Feedback Divider (Figure 7-3).

## METER LOOP TROUBLESHOOTING TREE

NOTES

1. All measurements should be made with respect to ⏚
2. Meter Loop schematic and component location diagrams are shown in Figure 7-6.
3. Put A2 on a printed circuit board extender to monitor voltages and waveshapes at board pins.

PASSES ↑

FAILS ↓

1. Select VM, 1 V Range, 1 V Input, X1 SENSITIVITY. Connect a jumper from A16V2 (white wire) to ⏚ . Waveshape at A2 pin 1 > 0.5 V p-p.
2. Waveshape at A2 pin 10 > 6 V p-p.
3. +1 V present at A16V1 (terminal nearest A13).
4. Observe waveshape at A2 pin 1. Reduce 740B input voltage until waveshape at A2 pin 1 is approximately 50 mV p-p. Waveshape at collector of A2Q3 > 5 V p-p.
5. Waveshape at A2TP8 > 8 V p-p.
6. Troubleshoot Modulator (A16V1/V2).
7. Troubleshoot Main Loop.
8. Reduce input voltage until waveshape at collector of A2Q3 is 1 V p-p. Waveshape at A2TP8 is 1 V p-p or greater.
9. Troubleshoot A2Q1, Q2, Q3.
10. Troubleshoot Demodulator (A16V3/V4).
11. Waveshape at collector of A2Q3 > 5 V p-p.
12. Depress X10$^2$ SENSITIVITY. Waveshape at A2TP8 > 9 V p-p.
13. Troubleshoot A2Q4, Q5 and Q16.
14. Troubleshoot A2Q4, Q5 and Q16.
15. Troubleshoot A2Q1, Q2 and Q3.
16. Depress X1 SENSITIVITY. Apply +1 V to Input terminals. Remove jumper from A17V2. Meter indicates +1 V within 3 seconds.
17. Troubleshoot A2Q4, Q5, Q16 and Sensitivity Gain Switching.
18. Reverse input polarity. Meter indicates -1 V.
19. Connect jumper from A2 pin 12 to A16V2 (white wire). Problem disappears.
20. Check other Sensitivity positions. If trouble occurs, troubleshoot corresponding Sensitivity Switching and S2R1 through S2R4.
21. Troubleshoot Meter Driver (A2Q6 through Q11).
22. Troubleshoot Feedback Switching.
23. Troubleshoot Meter Driver (A2Q6 through Q11) and M1.

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Figure 5-16. Meter Loop Troubleshooting Tree

Table 5-11. METER LOOP TROUBLESHOOTING

1. Connecting a jumper wire from A16V2 to ⏚ creates a 1 V difference between the Meter Loop input voltage (+1 V from the Main Loop) and the feedback voltage (0 V). If the Modulator output exceeds 0.5 V p-p, the Modulator is probably not at fault.

2. A waveshape >6 V p-p at A2 pin 10 shows that the Demodulator (A16V3/V4) is probably not at fault.

3. If +1 V is present, the Meter Loop is receiving a correct input voltage from the Main Loop.

4. Reducing 740B input voltage to 50 mV allows the gain of A2Q1, Q2 and Q3 to be evaluated. >5 V p-p at collector of A2Q3 indicates sufficient gain between A2 pin 1 and A2Q3 collector.

5. A waveshape >8 V p-p at A2TP8 shows that the Demodulator (A16V3/V4) is receiving a correct input from A2 pin 8.

6. The Modulator is receiving a correct input (step 3) but not producing a correct output (step 1). Troubleshoot A16 according to the procedure in Paragraph 5-78.

7. Since the Meter Loop is not receiving an input voltage from the Main Loop (step 3), the Main Loop is probably at fault. Before troubleshooting the Main Loop, check for shorted C9 or C10 (Meter Filter).

8. Further reduction of 740B input voltage allows the operation of A2Q4, A2Q5 and A2Q6 to be evaluated (X1 SENSITIVITY). 1 V p-p or more at A2TP8 indicates A2Q4, A2Q5 and A2Q16 are functioning.

9. Gain between A2 pin 1 and collector of A2Q3 is low (step 4). Troubleshoot A2Q1, A2Q2 and A2Q3.

10. The Demodulator is receiving a correct input from A2 pin 8 (step 5) but is not producing a correct output (step 2). Troubleshoot A16 according to the procedure in Paragraph 5-78.

11. A waveshape >5 V p-p at the collector of A2Q3 shows that A2Q1, Q2 and Q3 are not at fault.

12. A waveshape >9 V p-p at A2TP8 shows that the gain of A2Q4, A2Q5 and A2Q16 is effectively increased on the higher sensitivities.

13. Since the output of A2Q16 is low (step 8), there is insufficient gain between A2Q3 collector and A2TP8. Troubleshoot A2Q4, A2Q5 and A2Q16.

14. A2Q3 is providing A2Q4, A2Q5 and A2Q16 with a correct input (step 11) but the output of A2Q16 is low (step 5). Troubleshoot A2Q4, A2Q5 and A2Q16. Probable trouble: A2Q16.

15. A2Q1 is provided with a correct input (step 1) but the output of A2Q3 is low (step 11). Troubleshoot A2Q1, A2Q2 and A2Q3.

16. End-scale deflection within 3 seconds indicates adequate Meter Loop response time.

17. Since the output of A2Q16 did not increase on the X10$^2$ SENSITIVITY, the gain is low. Troubleshoot A2Q4, A2Q5, A2Q16, and Sensitivity Gain Switch (S2).

18. If meter deflects to -1 V, Meter Driver is working.

19. If response time changes when jumper is connected, the trouble is not in the Meter Amplifier.

20. If the only problem is slow response when X10$^4$ SENSITIVITY is depressed, reselect A2R19* (Paragraph 5-86). If response is still too slow, troubleshoot A16 (Paragraph 5-78).

21. If meter deflects positive (step 16) but will not deflect negative, trouble is probably in Meter Driver. Troubleshoot A2Q6 through A2Q11.

22. Check for loss of continuity between A2 pin 12 and A16V2 (white wire), with X1 SENSITIVITY depressed.

23. If meter does not deflect to full scale, the Meter Driver is probably at fault. Troubleshoot A2Q6 through A2Q11.

    If meter deflects to full scale but has >3 seconds response time, reselect A2R19* (Paragraph 5-86).

## REFERENCE LOOP TROUBLESHOOTING TREE

NOTES

1. All voltage measurements made with respect to ⏚. Function Switch must be set to STD.
2. Reference Loop schematic and component location diagrams are shown in Figures 7-13 and 7-14.
3. A13, Oven Assembly, is not field reparable.

PASSES ↑

FAILS ↓

- 1. Select STD, 1 V Range. +5.9 V present at A1TP1 (A1TP7 on instruments below Serial No. 610-00376).
  - 2. +12 V ±0.6 V present at A2TP7.
    - 4. Approximately -23 Vdc present at A2 pin 18 when instrument is first turned on--decreases to approximately -13 V after warmup.
      - 8. +1 V present at S4E(F-6) (white/red/blue wire on X1 Divider).
        - 12. Select ΔVM; Input Shorted; 1000 V Range. Successively depress X1 thru $X10^4$ SENSITIVITY buttons while varying corresponding VOLTAGE SET from 0 to 9 and back to 0. Meter deflects from 0 to -0.9 and back to 0 on each check.
          - 16. Reference Loop working properly.
          - 17. Troubleshoot corresponding VOLTAGE SET and SENSITIVITY Switching.
        - 13. Remove A1. Resistance from S4E (F-6) (white/red/blue wire) to ⏚ is 1 kΩ.
          - 18. Troubleshoot S3R1.
          - 19. Troubleshoot S4.
      - 9. Remove A13 and measure resistance from A13 pin 11 to A13 pin 12. Resistance approximately 65 Ω.
        - 14. Replace A13. Voltage at A2 pin 16 approximately -4 V when instrument is first turned on.
          - 20. Troubleshoot Error Amplifier (A2Q12 and Q13) and Heater Control (Q3).
          - 21. A13 Temperature Sensing Bridge bad. Replace A13.
        - 15. A13 Heater bad. Replace A13.
    - 5. Troubleshoot Series Regulator (A2Q14 and Q15).
  - 3. +12 V present at A2TP7.
    - 6. +5.9 V present at A1 pin 21.
      - 10. Troubleshoot Reference Adjustments (p/o A1).
      - 11. A13 Control Differential Amplifier bad. Replace A13.
    - 7. Troubleshoot Series Regulator (A2Q14 and Q15).

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Figure 5-17. Reference Loop Troubleshooting Tree

Table 5-12. REFERENCE LOOP TROUBLESHOOTING

1. If +5.9 V is present at A1TP1, the Reference Supply is generating a voltage.

2. If +12 V ±0.6 V is present at A2TP7, Series Regulator (p/o A2) is functioning.

3. +12 V at A2TP7 shows that the Series Regulator (p/o A2) is probably not at fault.

4. Correct indications show that the Oven Heater and Regulator circuits are working correctly.

5. If no voltage is present at A2TP7 (step 2) the Series Regulator (p/o A2) is probably at fault. See Figure 7-13.

6. +5.9 V at A1 pin 21 shows that the Control Differential Amplifier (p/o A13) is probably not at fault.

7. Since +12 V is not present at A2TP7, the Series Regulator (p/o A2) may be at fault. Remove A2 and check for +34 V at pin 22 of A2 jack. If voltage is not present, troubleshoot +34 V supply, p/o A6 (Figure 7-10). If +34 V is present, troubleshoot Series Regulator, p/o A2 (Figure 7-13).

8. +1 V at S4E (F-6) shows that the VOLTAGE SET Dividers are receiving a correct input from the Reference Supply.

9. A correct reading shows that the Oven Heater is probably not at fault.

10. Check for open A1R40.

11. The Control Differential Amplifier (p/o A13) is receiving a correct input (step 6). Remove A1 and measure voltage at pin 21 of A1 jack. If voltage is between +5.9 V and +6.4 V, trouble may be in VOLTAGE SET Dividers. Proceed to step 13. If voltage does not measure between +5.9 V and +6.4 V, the Control Differential Amplifier (p/o A13) is not working. A13 must be replaced. (Components in A13 are not separately replaceable.)

12. Correct indications show that the VOLTAGE SET and STANDARD VERNIER Dividers are functioning properly.

13. VOLTAGE SET and STANDARD VERNIER controls must be set to first position (0) to make this check. If resistance is 1 kΩ, S4 and S4R5 are probably not at fault.

14. A correct indication shows that the Temperature Sensing Bridge is probably not at fault.

15. If Heater is bad, entire A13 assembly must be replaced. Components in A13 are not separately replaceable.

16. If the instrument passes all of the previous checks, the Reference Loop is probably not at fault.

17. Trouble in one of the VOLTAGE SET Switches will probably show up only when that switch is varied. Once the trouble is isolated, check the switching associated with the malfunctioning switch position (Figure 7-14). If one of the switches is completely inoperative, troubleshoot corresponding SENSITIVITY Switch.

18. Check for open, shorted or changed-value S3R1.

19. To further isolate the trouble, select ΔVM and measure resistance from S4E (F-6) to 2 (S2A pin 10). If resistance now measures 1 kΩ, trouble is in STD mode FUNCTION Switching. Probable trouble area: deck S1I(F) of Range/Function Switch, S1 (Figure 7-3). If trouble remains, troubleshoot S4.

20. Since the Temperature Sensing Bridge is working, the trouble is probably in the Error Amplifier or Heater Control (Figure 7-13).

21. Remove A2 and measure voltage at pin 16 of A2 jack. If approximately -4 V is present, the Error Amplifier (p/o A2) or Heater Control is probably at fault. If approximately -4 V is not present, the Temperature Sensing Bridge is not working. Entire A13 assembly must be replaced since individual components in A13 are not separately replaceable.

5-76. LOOP GAIN CHECK.

5-77. The following steps outline a method of evaluating open loop gain of the Main Loop. If gain is too high or too low, reselection of A3R9* (Paragraph 5-91) may be helpful. Generally, insufficient gain causes slow instrument response to an input voltage and may cause inaccuracy in ΔVM or STD modes. Excessive gain may cause output noise and instability. To perform the Loop Gain Check, proceed as follows.

a. Set Model 740B controls as follows:

| | |
|---|---|
| FUNCTION | VM |
| RANGE | 10 mV |
| SENSITIVITY | X10 |
| INPUT | Shorted |

b. Depress Gain Check Switch, S10 (on bottom of instrument, behind Guard Shield).

c. Meter should deflect to between +8% of end-scale and +15% of end-scale. If meter deflects to more than +15% end-scale, gain is too low; if deflection is less than +8%, gain is too high. If meter does not deflect, check A11BT1 (1.3 V minimum).

5-78. METER LOOP CHOPPER CHECK.

5-79. The following procedure can be used to evaluate the performance of the Meter Loop Chopper, A16. The chopper photocells change impedance somewhat during instrument warmup; some effects of the impedance change do not disappear for at least 24 hours. A meaningful check of the chopper operation can be performed only if the instrument has been turned off for 24 hours (or longer) prior to performing the check. The tests should be performed in a controlled environment with the ambient temperature remaining at 24°C ±2°C (75°F ±4°F). Since the chopper impedance changes during warmup, all of the checks should be performed during the period of 1 minute to 5 minutes after instrument turn-on. Steps d and e check the Chopper Modulator; steps f and g check the Demodulator. A high input impedance ohmmeter (-hp- Model 427A), a 1 μF capacitor (-hp- Part No. 0160-3033) and a 20 μF capacitor (-hp- Part No. 0180-0300) are required for the check. Do not turn on the instrument until step d.

a. Connect a 1 μF capacitor between the Common and Ohms leads of the ohmmeter. Leave the capacitor connected while making the impedance measurements.

b. Remove A2 and DC Fuse. Set RANGE to 1 V.

c. Connect ohmmeter leads to A16V1 (terminal nearest A13) and A16V2 (terminal nearest T2). Carefully turn FUNCTION Switch to a position between ΔVM and VM. Ohmmeter reading will increase when switch is positioned correctly. This isolates the Modulator from any input voltage.

d. Turn on the instrument; wait at least one minute. Ohmmeter should indicate >346 kΩ (Modulator series impedance).

e. Move one of the ohmmeter leads to the rear-middle terminal. Connect a jumper wire from A16V1 (terminal nearest A13) to A16V2 (terminal nearest T2). Ohmmeter should indicate < 38 kΩ (Modulator parallel impedance).

f. Connect ohmmeter leads to A16V3 (black wire) and A16V4 (white/black/yellow wire). Ohmmeter should indicate > 78 kΩ (Demodulator series impedance).

g. Leave ohmmeter leads connected to A16V3 and A16V4. Connect a 20 μF capacitor across A16V3 (black wire and white/yellow/blue wire). Ohmmeter should indicate < 64 kΩ (Demodulator output impedance).

NOTE

If the instrument passes all of the checks, A16 is working properly. If one or more of the check results are marginal (within 20% of passing) and the Meter Loop performance is worse than marginal, A16 may not be the source of trouble. Before replacing A16, check the waveshape at A8TP21 to verify proper operation of the Meter Loop Neon Driver. The correct waveshape is shown in Figure 7-12. Components in A16 are not separately replaceable.

5-80. MAIN LOOP CHOPPER CHECK.

5-81. The following procedure can be used to evaluate the performance of the Main Loop Chopper, A17. The chopper photocells change impedance somewhat during instrument warmup; some effects of the impedance change do not disappear for at least 24 hours. A meaningful check of the chopper operation can be performed only if the instrument has been turned off for 24 hours (or longer) prior to performing the check. The tests should be performed in a controlled environment with the ambient temperature remaining at 24°C ±2°C (75°F ±4°F). Since the chopper impedances change during warmup, all of the checks should be performed during the period of 1 minute to 5 minutes after instrument turn-on. Steps d and e check the Modulator; steps f and g check the Demodulator. A high impedance ohmmeter (-hp- Model 427A), a 1 μF capacitor (-hp- Part No. 0160-3033) and a 20 μF capacitor (-hp- Part No. 0180-0300) are required for the check. Do not turn on the instrument until step d.

a. Connect a 1 μF capacitor between the Common and Ohms leads of the ohmmeter. Leave the capacitor connected while making the impedance measurements.

b. Remove A3, A4, A5 and rear panel dc fuse. Set FUNCTION to VM; RANGE to 1 V.

c. Connect ohmmeter to A17V1 (red wire) and A17V2 (white wire).

d. Turn on instrument; wait at least 1 minute. Ohmmeter should indicate > 160 kΩ (Modulator series impedance).

e. Move one of the ohmmeter leads to the middle terminal on A17. Connect a jumper wire from A17V1 (red wire) to A17V2 (white wire). Ohmmeter should indicate < 30 kΩ (Modulator parallel impedance).

f. Connect ohmmeter leads to A17V3 (black wire) and A17V4 (white/red/blue wire). Ohmmeter should indicate > 132 kΩ.

g. Leave ohmmeter leads connected to A17V3 and A17V4. Connect a 20 μF capacitor across A17V3 (middle terminal and black wire). Ohmmeter should indicate < 42 kΩ (Demodulator output impedance).

NOTE

If the instrument passes all of the checks, A17 is working properly. If one or more of the check results are marginal (within 20% of passing) and the Main Loop performance is worse than marginal, A17 may not be the source of trouble. Before replacing A17, check the waveshape at A8TP20 to verify proper operation of the Main Loop Neon Driver. The correct waveshape is shown in Figure 7-12. Components in A17 are not separately replaceable.

## 5-82. REPAIR PROCEDURES.

5-83. The following paragraphs contain information on special repair procedures and replacement parts selection for the Model 740B.

**WARNING**

TO PROTECT THE OPERATOR FROM POSSIBLE HIGH VOLTAGE SHOCK WHEN FLOATING THE MODEL 740B, CHECK THE CONTROL KNOBS FOR PRESENCE OF INSULATING MATERIAL IN SET-SCREW HOLES. IF MATERIAL IS NOT PRESENT, FILL THE SET-SCREW HOLES WITH GENERAL ELECTRIC TRANSLUCENT SILICON RUBBER RTV-108 (-hp- PART NUMBER 0470-0304).

5-84. <u>REPLACEMENT OF FACTORY SELECTED COMPONENTS.</u>

5-85. Certain components within the Model 740B are individually selected in order to compensate for slightly varying circuit parameters. These components are identified by an asterisk (*) on the schematic diagrams and a typical value is shown. The following paragraphs describe the function of the factory selected components and give replacement instructions.

5-86. A2R19*.

5-87. A2R19* is factory selected to set the response time of the Meter Loop to 2 to 3 seconds on the X$10^4$ Sensitivity. A2R19* is a 1/4 watt composition ±10% resistor with a typical value of 68 kΩ. A2R19* may have to be reselected if the Meter Loop Chopper (A16) is replaced or if repair work is performed on the Meter Amplifier (p/o A2).

5-88. Use the following procedure to evaluate the selection of A2R19*.

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . . . . VM
RANGE . . . . . . . . . . . . 1000 V
SENSITIVITY . . . . . . . . . X1

b. Apply a + 0.1 V input voltage to the Input terminals.

c. Depress X$10^4$ SENSITIVITY. Meter should deflect to + end scale in 2 to 3 seconds.

5-89. If response time is longer than 3 seconds, decrease the value of A2R19* in 5 kΩ steps until response time is between 2 and 3 seconds. Do not use a value less than 30 kΩ for A2R19*.

5-90. If response time is shorter than 2 seconds, increase the value of A2R19* in 5 kΩ steps until response time is between 2 and 3 seconds. Do not use a value greater than 100 kΩ for A2R19*.

5-91. A3R9*.

5-92. A3R9* is factory selected to control the gain of the Low Level Amplifier (A3). A3R9* is a 1/4 watt composition ±10% resistor with a typical value of 22 kΩ. A3R9* may have to be reselected if the Main Loop Chopper (A17) is replaced or if repair work is performed on A3. To determine if A3R19* is the correct value, perform the Loop Gain Check (Paragraph 5-76). If the instrument passes, A3R9* should not be changed.

5-93. If the instrument has low gain (meter deflection > 15% end-scale), increase the value of A3R9* in 5 kΩ steps until the meter deflection is between 8% and 15% of end-scale. Do not use a value greater than 47 kΩ for A3R9*.

5-94. If the instrument has too much gain (meter deflection <8% end-scale), decrease the value of A3R9* in 5 kΩ steps until the meter deflection is between 8% and 15% of end-scale. Do not use a value less than 6.8 kΩ for A3R9*.

5-95. A7C8*.

5-96. A7C8* is factory selected to compensate for the effects of inter-element capacitance in the Power Switch transistors (Q1 and Q2). A7C8* is a ± 20% ceramic 1000 V capacitor with a typical value of 0.0068 μF. A7C8* may have to be reselected if Q1 or Q2 is replaced or if repair work is performed on the Pulse Width Converter (p/o A5).

5-97. To determine if A7C8* is the correct value, perform the following procedure.

a. Set Model 740B controls as follows:

FUNCTION . . . . . . . . . . . STD
RANGE . . . . . . . . . . . . . 1 V
VOLTAGE SET. . . . . . . .00000

b. Observe waveshape at Q1 - Q2 collectors. (Waveshape is shown in Figure 7-11). Waveshape should be stable and noise-free.

5-98. If the waveshape is unstable or noisy, reselect A7C8*. Change A7C8* in approximately 0.002 $\mu$F steps (either increasing or decreasing) until Q1 - Q2 collector waveshape stabilizes. Value limits for A7C8* are 0 to 0.02 $\mu$F.

5-99. A8R8*, A8R9*.

5-100. A8R8* and A8R9* control the range of adjustment of the Meter Loop Chopper Frequency Adjustment, A8R3. A8R8* and A8R9* are 1/4 W composition $\pm 5\%$ resistors with a typical value of 75 k$\Omega$. A8R8* and A8R9* may have to be reselected if repair work is performed on the Meter Loop Neon Driver (p/o A8). A8R8* and A8R9* should be reselected only if the Meter Chopper Frequency Adjustment cannot be set to 95 Hz (Paragraph 5-38).

5-101. To reselect A8R8* and A8R9*, use the following procedure.

a. Set A8R3 (Meter Chopper Frequency Adjustment) to mid-value.

b. Measure Meter Chopper Frequency (Paragraph 5-38).

c. If measured frequency is greater than 100 Hz, increase the value of A8R8* and A8R9*. If frequency is less than 90 Hz, decrease the values of A8R8* and A8R9*. A resistance change of 10 k$\Omega$ affects the chopper frequency approximately 20 Hz. The resistance values for A8R8* and A8R9* must be equal and should never be changed to less than 40 k$\Omega$ or greater than 150 k$\Omega$.

5-102. A13R13*, A13R14*.

5-103. A13R13* and A13R14* are factory selected to match the voltage characteristics of A13CR1 with the output voltage requirements of the Reference Oven Assembly (A13). Components within A13 are factory matched and aged. For this reason, none of the components within A13 are separately replaceable.

5-104. SERVICING ETCHED CIRCUIT BOARDS.

5-105. The Model 740B contains plated-through double-sided, etched circuit boards. When working on these boards, observe the following rules to prevent damage to the circuit board or components:

a. Use a low-heat (25 to 50 watts) soldering iron with a small tip.

b. To remove a component, clip a heat sink (long nose pliers, commercial heat sink tweezers, etc.) on the component lead as close to the component as possible. Place the soldering iron directly on the component lead, and pull up on the lead. If a component is obviously damaged or faulty, clip the leads close to the component, and remove the leads from the board.

**CAUTION**

EXCESSIVE OR PROLONGED HEAT CAN LIFT THE CIRCUIT FOIL FROM THE BOARD OR CAUSE DAMAGE TO COMPONENTS.

c. Clean the component lead holes by heating the solder in the hole, quickly removing the soldering iron, and inserting a pointed, non-metallic object such as a toothpick.

d. To mount a new component, shape the leads and insert them in the holes. Clip a heat sink on the component, heat with the soldering iron, and add solder as necessary to obtain a good electrical connection.

5-106. SERVICING ROTARY SWITCHES.

5-107. The Model 740B contains several rotary switches: S1 RANGE/FUNCTION Switch, S4 - S8 VOLTAGE SET Switches, S9 STANDARD VERNIER Switch, and K1 Output Rotary Switch (solenoid-actuated). When replacing components on these switches, observe the following rules:

a. Use a low heat (25 to 50 watts) soldering iron with a small tip.

b. When replacing components, attempt to dress them as nearly to their original alignment as possible.

c. Clean excessive flux from the connection and adjoining area.

d. After cleaning the switch, apply a light coat of lubriplate to the switch detent balls. DO NOT apply lubricant to switch contacts or allow lubricant to contaminate components.

e. If switch knobs were removed and reinstalled during the switch repair, the set screw holes should be filled with General Electric Translucent Silicon Rubber RTV-108 (-hp- Part No. 0470-0304).

5-108. The switches are self-cleaning in normal use; but may, with time, build up a dust accumulation. Generally, the effects of dust can be eliminated by rotating the switches from stop-to-stop several times. (K1 can be rotated by cycling the OUTPUT pushbutton switch several times with the instrument turned on and the Output Cable Assembly connected.) If dust accumulation is severe, a small amount of distilled water may be used as a cleaning agent. DO NOT use

Freon, Carbon Tetrachloride or any chemical solvent on the switches.

5-109. MAIN LOOP FEEDBACK DIVIDER REPLACEMENT (A9R4 through A9R9).

5-110. The Main Loop Feedback Divider consists of A9R4 through A9R12. A9R4 through A9R9 are a matched set of precision wirewound resistors. A9R10, A9R11 and A9R12 are adjustments that calibrate the divider and are adjusted for meter indication values printed on the guard shield cover when performing the Internal Alignment Procedure (Paragraph 5-57). The meter indication values are derived at the factory for each resistor set/instrument combination and should be valid for the life of the resistors. If A9R4-A9R9 are ever replaced, new meter indication values for adjustments A9R10, A9R11 and A9R12 must be derived. After installing the new resistors, the following procedure should be performed.

a. Perform steps a through i of Paragraph 5-62.

b. Set INTERNAL ALIGNMENT switch to positions 10, 11 and 12 adjusting A9R10, A9R11 and A9R12 for a meter indication of zero at each position. Return INTERNAL ALIGNMENT Switch to Operate position.

c. Connect Model 740B to a Precision Divider, 1 V Reference Supply and Null Detector setup in the configuration shown in Figure 5-1.

NOTE

1. The Precision Divider must be very accurate -- preferably better than ± 5 ppm division accuracy at the 10:1, 100:1 and 1000:1 taps. Construction of the divider shown in Figure 5-1 is described in Appendix C.

2. Calibration of the 1 V Reference Supply is not highly important for this procedure, but the Supply must have good short-term stability characteristics.

d. Set Model 740B controls as follows:

| | |
|---|---|
| FUNCTION | STD |
| RANGE | 1 V |
| VOLTAGE SET | .00000 |
| STANDARD VERNIER | 0 (fully ccw) |
| OUTPUT | On |

e. Set S1 (in test setup) to position 1.

f. Adjust Model 740B ZERO Control for a null indication (±1 $\mu$V) on the Null Detector.

g. Set S1 to Position 2. Set Model 740B VOLTAGE SET and STANDARD VERNIER Controls to 9-9-9-9-9-10 for a 1 V output on the 1 V Range. Do not change ZERO Control Setting.

h. Adjust Model 740B REFERENCE COARSE and FINE Adjustments (A1R40 and A1R41) until 0 V ±1 $\mu$V is indicated by the Null Detector. (Periodically check Null Detector Zero setting). The Model 740B output now matches the 1 V Reference Supply output.

i. Return Model 740B VOLTAGE SET and STANDARD VERNIER Controls to 0-0-0-0-0-0. Set S1 to position 1.

j. Connect Model 740B + SENSE and + OUTPUT leads to point K (10:1 division tap) on the divider.

k. Set Range to 10 V and adjust ZERO Control for a null indication (±1 $\mu$V) on the Null Detector.

l. Set S1 to position 2; set Model 740B controls for a 10 V output on the 10 V Range. Do not vary ZERO Control.

m. Adjust A9R10 until Null Detector indicates null (±1 $\mu$V). This calibrates the 10:1 division accuracy of the new Main Loop Feedback Divider resistors.

n. Return 740B controls to 0 V; set S1 to position 1; connect + SENSE and +OUTPUT to point L (100:1 division tap) on the divider.

o. Set RANGE to 100 V and ZERO control for a null indication (±1 $\mu$V) on the Null Detector.

p. Set S1 to position 2; set Model 740B controls for a 100 V output on the 100 V Range. Do not vary ZERO Control.

q. Adjust A9R11 until Null Detector indicates null (±1 $\mu$V). This calibrates the 100:1 division accuracy of the new resistors.

r. Return 740B controls to 0 V; set S1 to position 1; connect +SENSE and +OUTPUT to point M (1000:1 division tap) on the divider.

s. Set RANGE to 1000 V and adjust ZERO Control for a null indication (±1 $\mu$V) on the Null Detector.

t. Set S1 to position 2; set Model 740B controls for a 1000 V output. Do not vary ZERO Control.

u. Wait 60 seconds for the effects of self-heating to stabilize and then adjust A9R12 until Null Detector indicates null (±1 $\mu$V). This calibrates the 1000:1 division accuracy of the new resistors.

v. Return VOLTAGE SET and STANDARD VERNIER Controls to 0-0-0-0-0-0. Disconnect test setup.

w. Set Model 740B controls as follows:

RANGE. . . . . "Dot" position (fully ccw)
FUNCTION . . . . . . . . . . . . VM
SENSITIVITY . . . . . . . . . . . $X10^4$
INPUT . . . . . . . . . . . . . Shorted

x. Turn INTERNAL ALIGNMENT Switch to position 1 and then position 2 adjusting A1R1 for equal meter deflection (and same polarity) at both positions.

y. Set INTERNAL ALIGNMENT Switch to position 10. Note meter deflection and polarity; record this value in first blank in step B-6 on the guard shield cover.

z. Set INTERNAL ALIGNMENT Switch to position 11 and then to position 12; record the observed meter deflection values in the second and third blanks of step B-6 on the guard shield cover. (Wait 60 seconds before recording reading at position 12.)

# PERFORMANCE CHECK TEST CARD

Hewlett-Packard Model 740B
DC Standard/Differential Voltmeter

Tests performed by ____________
Date ____________

Serial No. ___ - _____

| TEST | READING | TEST LIMITS |
|---|---|---|
| A. DC STANDARD | | |
| 1. 1 V output, 1 V range | ____________ | -24 μV to +24 μV |
| 2. Line Regulation, high line | ____________ | Within 6 μV of #1. |
| 3. Line Regulation, low line | ____________ | Within 6 μV of #1. |
| 4. 1 V output, 10 V range | ____________ | -60 μV to +60 μV |
| 5. 2 V output, 10 V range | ____________ | -40 μV to +40 μV |
| 6. 3 V output, 10 V range | ____________ | -33 μV to +33 μV |
| 7. 4 V output, 10 V range | ____________ | -30 μV to +30 μV |
| 8. 5 V output, 10 V range | ____________ | -28 μV to +28 μV |
| 9. 6 V output, 10 V range | ____________ | -27 μV to +27 μV |
| 10. 7 V output, 10 V range | ____________ | -26 μV to +26 μV |
| 11. 8 V output, 10 V range | ____________ | -25 μV to +25 μV |
| 12. 9 V output, 10 V range | ____________ | -24 μV to +24 μV |
| 13. 10 V output, 10 V range | ____________ | -24 μV to +24 μV |
| 14. 100 V output, 100 V range | ____________ | -24 μV to +24 μV |
| 15. 1000 V output, 1000 V range | ____________ | -24 μV to +24 μV |
| 16. Maximum Output Current | ____________ | 50 mA min |
| 17. Minimum Output Current | ____________ | 5 mA max |
| 18. Load Regulation | ____________ | -15 μV to +15 μV |
| 19. 0.01 Hz to 1 Hz noise, 1 V Range | ____________ | - 1 μV to + 1 μV |
| 20. 0.01 Hz to 1 Hz noise, 10 V Range | ____________ | -10 μV to +10 μV |
| 21. 0.01 Hz to 1 Hz noise, 100 V Range | ____________ | -100 μV to +100 μV |
| 22. 0.01 Hz to 1 Hz noise, 1000 V Range | ____________ | -1 mV to +1 mV |
| 23. 1 Hz to 1 MHz noise, 1 V Range | ____________ | 100 μV rms max |
| 24. 1 Hz to 1 MHz noise, 10 V Range | ____________ | 100 μV rms max |
| 25. 1 Hz to 1 MHz noise, 100 V Range | ____________ | 1 mV rms max |
| 26. 1 Hz to 1 MHz noise, 1000 V Range | ____________ | 10 mV rms max |
| 27. Zero Control Limits | ____________ | -10 μV to +10 μV min |

## PERFORMANCE CHECK TEST CARD(Cont'd)

| TEST | READING | TEST LIMITS |
|---|---|---|
| B. DIFFERENTIAL VOLTMETER AND HIGH IMPEDANCE VOLTMETER. | | |
| 1. Input Resistance | ______ | 10 $\mu$V max |
| 2. Superimposed AC Rejection | ______ | 10 $\mu$V change, max |
| 3. AC Common Mode Rejection | ______ | 10 $\mu$V max |
| 4. 1 V input, ΔVM | ______ | .999945 V to 1.000055 V |
| 5. Line Regulation, high line | ______ | Within 12 $\mu$V of #4 |
| 6. Line Regulation | ______ | Within 12 $\mu$V of #4 |
| 7. 1 V input, VM | ______ | 0.98 V to 1.02 V |
| 8. 2 V input, ΔVM | ______ | 1.99986 V to 2.00014 V |
| 9. 2 V input, VM | ______ | 1.8 V to 2.2 V |
| 10. 3 V input, ΔVM | ______ | 2.99981 V to 3.00019 V |
| 11. 3 V input, VM | ______ | 2.8 V to 3.2 V |
| 12. 4 V input, ΔVM | ______ | 3.99976 V to 4.00024 V |
| 13. 4 V input, VM | ______ | 3.8 V to 4.2 V |
| 14. 5 V input, ΔVM | ______ | 4.99971 V to 5.00029 V |
| 15. 5 V input, VM | ______ | 4.8 V to 5.2 V |
| 16. 6 V input, ΔVM | ______ | 5.99966 V to 6.00034 V |
| 17. 6 V input, VM | ______ | 5.8 V to 6.2 V |
| 18. 7 V input, ΔVM | ______ | 6.99961 V to 7.00039 V |
| 19. 7 V input, VM | ______ | 6.8 V to 7.2 V |
| 20. 8 V input, ΔVM | ______ | 7.99956 V to 8.00044V |
| 21. 8 V input, VM | ______ | 7.8 V to 8.2 V |
| 22. 9 V input, ΔVM | ______ | 8.99951 V to 9.00049 V |
| 23. 9 V input, VM | ______ | 8.8 V to 9.2 V |
| 24. 10 V input, ΔVM | ______ | 9.99946 V to 10.0005 V |
| 25. 10 V input, VM | ______ | 9.8 V to 10.2 V |
| 26. 100 V input, ΔVM | ______ | 99.9946 V to 100.005 V |
| 27. 100 V input, VM | ______ | 98 V to 102 V |
| 28. 1000 V input, ΔVM | ______ | 999.946 V to 1000.05 V |
| 29. 1000 V input, VM | ______ | 980 V to 1020 V. |
| 30. 100 mV input, ΔVM | ______ | 99.936 mV to 100.064 mV |
| 31. 100 mV input, VM | ______ | 98 mV to 102 mV |
| 32. 10 mV input, ΔVM | ______ | 9.9985 mV to 10.0015 mV |
| 33. 10 mV input, VM | ______ | 9.8 mV to 10.2 mV |
| 34. 1 mV input, ΔVM | ______ | .999 mV to 1.001 mV |
| 35. 1 mV input, VM | ______ | 0.98 mV to 1.02 mV |

# SECTION VI
# REPLACEABLE PARTS

## 6-1. INTRODUCTION.

6-2. This section contains information for ordering replacement parts. Table 6-1 lists the mechanical parts shown in Figure 6-1; Table 6-2 lists the electrical components and miscellaneous parts. Table 6-1 lists parts in numerical order of their reference designators and indicates the description, -hp- part number and total quantity of each part. Attaching hardware for each mechanical part is listed with that part. Table 6-2 lists the electrical components in alpha-numeric order of their reference designators and indicates the description and -hp- part number of each part, and provides the following:

a. Total quantity used in the instrument (TQ column). The total quantity is given the first time the part number appears.

b. Typical manufacturer of the part in a five-digit code. (See Appendix A for list of manufacturers).

c. Manufacturers part number.

6-3. Miscellaneous parts are listed at the end of Table 6-2.

## 6-4. ORDERING INFORMATION.

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix B for list of office locations.) Identify parts by their Hewlett-Packard part numbers. Include instrument model and serial numbers.

## 6-6. NON-LISTED PARTS.

6-7. To obtain a part that is not listed, include:

a. Instrument model and serial numbers.

b. Description of the part.

c. Function and location of the part.

DESIGNATORS

| | |
|---|---|
| A | = assembly |
| B | = motor |
| BT | = battery |
| C | = capacitor |
| CR | = diode |
| DL | = delay line |
| DS | = lamp |
| E | = misc electronic part |
| F | = fuse |
| FL | = filter |
| HR | = heater |
| IC | = integrated circuit |
| J | = jack |
| K | = relay |
| L | = inductor |
| M | = meter |
| MP | = mechanical part |
| P | = plug |
| Q | = transistor |
| QCR | = transistor-diode |
| R | = resistor |
| RT | = thermistor |
| S | = switch |
| T | = transformer |
| TC | = thermocouple |
| V | = vacuum tube, neon bulb, photocell, etc. |
| W | = cable |
| X | = socket |
| XDS | = lampholder |
| XF | = fuseholder |
| Z | = network |

ABBREVIATIONS

| | |
|---|---|
| Ag | = silver |
| Al | = aluminum |
| A | = ampere (s) |
| Au | = gold |
| C | = capacitor |
| cer | = ceramic |
| coef | = coefficient |
| com | = common |
| comp | = composition |
| conn | = connection |
| dep | = deposited |
| DPDT | = double-pole double-throw |
| DPST | = double-pole single-throw |
| elect | = electrolytic |
| encap | = encapsulated |
| F | = farad (s) |
| FET | = field effect transistor |
| fxd | = fixed |
| GaAs | = gallium arsenide |
| GHz | = gigahertz = $10^{+9}$ hertz |
| gd | = guard (ed) |
| Ge | = germanium |
| grd | = ground (ed) |
| H | = henry (ies) |
| Hg | = mercury |
| Hz | = hertz (cycle (s) per second) |
| ID | = inside diameter |
| impg | = impregnated |
| incd | = incandescent |
| ins | = insulation (ed) |
| kΩ | = kilohm (s) = $10^{+3}$ ohms |
| kHz | = kilohertz = $10^{+3}$ hertz |
| L | = inductor |
| lin | = linear taper |
| log | = logarithmic taper |
| m | = milli = $10^{-3}$ |
| mA | = milliampere (s) = $10^{-3}$ amperes |
| MHz | = megahertz = $10^{+6}$ hertz |
| MΩ | = megohm (s) = $10^{+6}$ ohms |
| met flm | = metal film |
| mfr | = manufacturer |
| mtg | = mounting |
| mV | = millivolt (s) = $10^{-3}$ volts |
| $\mu$ | = micro = $10^{-6}$ |
| $\mu$V | = microvolt (s) = $10^{-6}$ volts |
| my | = Mylar ® |
| nA | = nanoampere (s) = $10^{-9}$ amperes |
| NC | = normally closed |
| Ne | = neon |
| NO | = normally open |
| NPO | = negative positive zero (zero temperature coefficient) |
| ns | = nanosecond (s) = $10^{-9}$ seconds |
| nsr | = not separately replaceable |
| Ω | = ohm (s) |
| obd | = order by description |
| OD | = outside diameter |
| p | = peak |
| pc | = printed circuit |
| pF | = picofarad (s) = $10^{-12}$ farads |
| piv | = peak inverse voltage |
| p/o | = part of |
| pos | = position (s) |
| poly | = polystyrene |
| pot | = potentiometer |
| p-p | = peak-to-peak |
| ppm | = parts per million |
| prec | = precision (temperature coefficient, long term stability, and/or tolerance) |
| R | = resistor |
| Rh | = rhodium |
| rms | = root-mean-square |
| rot | = rotary |
| Se | = selenium |
| sect | = section (s) |
| Si | = silicon |
| sl | = slide |
| SPDT | = single-pole double-throw |
| SPST | = single-pole single-throw |
| Ta | = tantalum |
| TC | = temperature coefficient |
| $TiO_2$ | = titanium dioxide |
| tog | = toggle |
| tol | = tolerance |
| trim | = trimmer |
| TSTR | = transistor |
| V | = volt (s) |
| vacw | = alternating current working voltage |
| var | = variable |
| vdcw | = direct current working voltage |
| W | = watt (s) |
| w/ | = with |
| wiv | = working inverse voltage |
| w/o | = without |
| ww | = wirewound |
| * | = optimum value selected at factory, average value shown (part may be omitted) |
| ** | = no standard type number assigned (selected or special type) |

® Dupont de Nemours

REV G

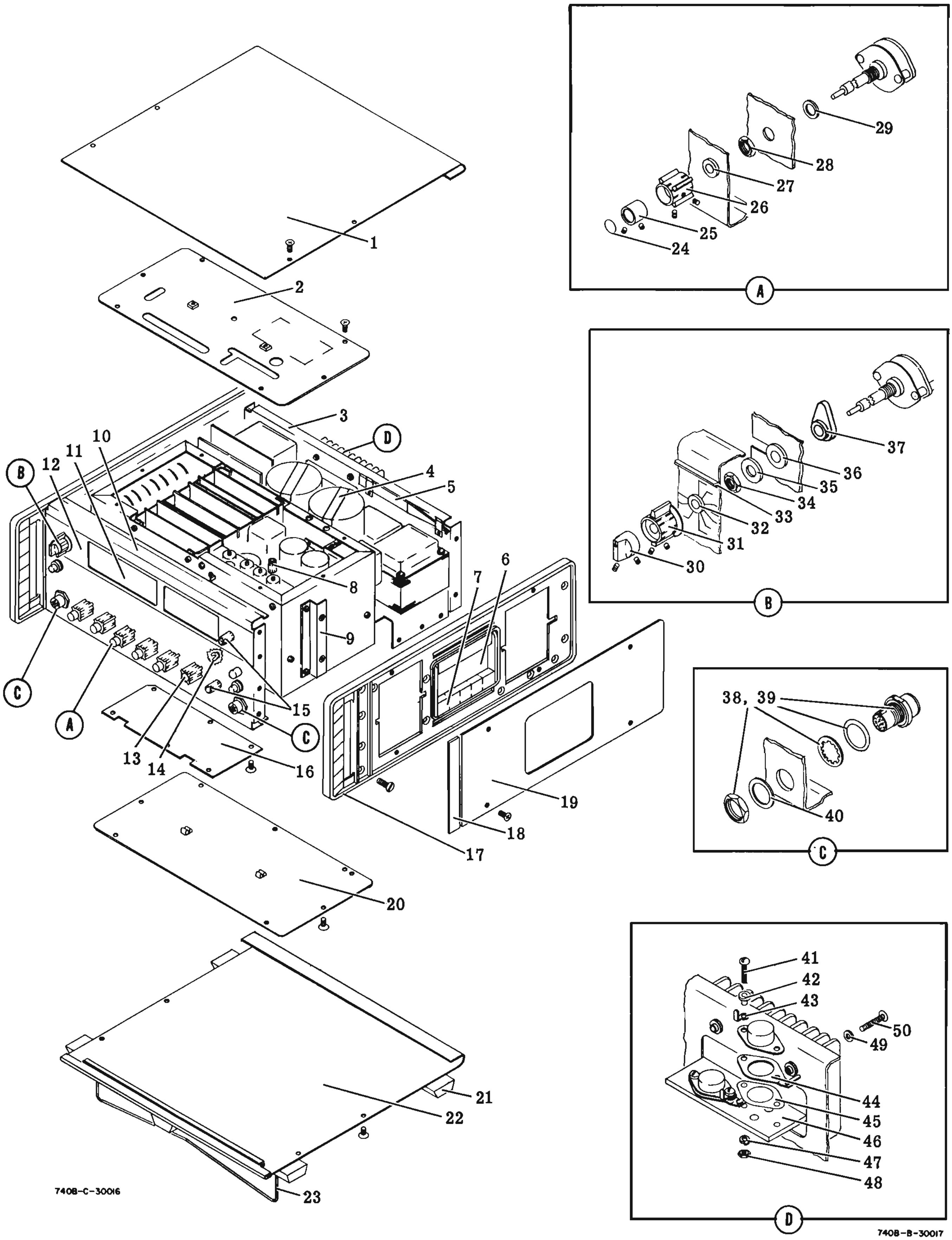



Figure 6-1. Mechanical Parts

Table 6-1. Mechanical Parts

| MP No. | -hp- Part No. | Description | Qty |
|---|---|---|---|
| 1 | 5060-0740 | Top Cover | 1 |
| | 2370-0013 | Screw: Phillips 3/8 in. (hardware for MP1) | 4 |
| 2 | 00740-00608 | Guard Shield Cover: Top | 1 |
| | 2370-0012 | Screw: Phillips 1/4 in. (hardware for MP2) | 6 |
| 3 | 00740-00204 | Rear Panel | 1 |
| 4 | 00740-01223 | Clamp: Capacitor Mounting | 2 |
| 5 | 5000-4932 | Extractor: PC Board | 1 |
| 6 | 5060-0765 | Retainer: Handle Assy (fits either side) | 2 |
| 7 | 5060-0763 | Handle Assy (fits either side) | 2 |
| 8 | 0370-0091 | Knob: black w/arrow | 1 |
| | 0370-0084 | Setscrew (p/o MP8) | 2 |
| 9 | 00740-01208 | Bracket: Chassis (fits either side) | 2 |
| 10 | 00740-00203 | Panel: Front | 1 |
| 11 | 1000-0031 | Filter: Digital Readout | 1 |
| 12 | 00740-09901 | Insert: Front Panel | 1 |
| 13 | 0370-0330 | Knob: black (STANDARD VERNIER) | 1 |
| | 3030-0033 | Setscrew (p/o MP13) | 2 |
| 14 | 0570-0131 | Screw: Thumb | 2 |
| 15 | 0370-0084 | Knob: black w/arrow (ZERO and CURRENT LIMIT) | 2 |
| | 3030-0005 | Setscrew (p/o MP15) | 2 |
| 16 | 00740-00613 | Shield: Bottom | 1 |
| | 2370-0012 | Screw: Phillips 1/4 in. (hardware for MP16) | 6 |
| 17 | 5060-0734 | Frame Assy: side (fits either side) | 2 |
| | 2530-0011 | Screw: Flathead 3/8 in. (hardware for MP17) | 12 |
| 18 | 5000-0052 | Trim Strip: Side Panel | 2 |
| 19 | 5000-0742 | Side Cover | 2 |
| | 2370-0012 | Screw: Phillips 1/4 in. (hardware for MP19) | 4 |
| 20 | 00740-00611 | Guard Shield Cover: Bottom | 1 |
| | 2370-0012 | Screw: Phillips 1/4 in. (hardware for MP20) | 7 |
| 21 | 5060-0767 | Foot Assy | 5 |
| 22 | 5060-0752 | Bottom Cover | 1 |
| | 2370-0013 | Screw: Phillips 3/8 in. (hardware for MP22) | 4 |
| 23 | 1490-0030 | Tilt Stand | 1 |
| 24 | 03420-04301 | Decal Set (5 decals) | 1 |
| 25 | 0370-0312 | Pushbutton: gray (SENSITIVITY) | 5 |
| | 3030-0033 | Setscrew (p/o MP25) | 2 |
| 26 | 0370-0329 | Knob: black (VOLTAGE SET) | 5 |
| | 3030-0033 | Setscrew (p/o MP26) | 2 |
| 27 | 1410-0091 | Bushing (VOLTAGE SET, STANDARD VERNIER and CURRENT LIMIT) | 7 |
| 28 | 2950-0001 | Nut: 1/2 in ID | 1 |
| 29 | 2190-0022 | Washer: 11/16 in ID | 1 |
| 30 | 0370-0115 | Knob: red w/arrow (FUNCTION) | 1 |
| | 3030-0033 | Setscrew (p/o MP30) | 2 |
| 31 | 0370-0113 | Knob: black w/arrow (RANGE) | 1 |
| | 3030-0005 | Setscrew (p/o MP31) | 2 |
| 32 | 1410-0289 | Bushing (RANGE/FUNCTION and ZERO) | 2 |
| 33 | 00740-20502 | Trim Strip: Front Panel | 2 |
| 34 | 2950-0001 | Nut: 1/2 in ID | 1 |
| 35 | 2190-0042 | Washer: 3/8 in ID | 1 |
| 36 | 5040-0647 | Washer: Plastic (RANGE/FUNCTION and RECORDER AMPLITUDE) | 2 |
| 37 | 5040-0656 | Switch Retainer: Plastic | 1 |
| 38 | 1251-0466 | Socket: INPUT Connector J1 (Includes nut, lockwasher and 0 ring) | 1 |
| 39 | 1251-0467 | Socket: OUTPUT Connector J1 (Includes nut, lockwasher and 0 ring) | 1 |
| 40 | 3050-0383 | Washer: 11/16 in ID (hardware for MP38 and MP39) | 2 |
| 41 | 2200-0025 | Screw: Roundhead 1/2 in. | 4 |
| 42 | 1200-0081 | Insulator: Nylon | 4 |
| 43 | 0360-0005 | Lug: 11/16 in. | 1 |
| 44 | 00735-64101 | Plate: Anodized | 2 |
| 45 | 1200-0077 | Insulator: Mica | 2 |
| 46 | 00740-21101 | Heat Sink (Q1, Q2) | 1 |
| 47 | 2190-0003 | Washer | 4 |
| 48 | 2260-0001 | Nut | 4 |
| 49 | 2190-0007 | Washer | 4 |
| 50 | 2360-0008 | Screw: Round head 5/8 in. | 4 |

Table 6-2. Replaceable Parts

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| **A1** | 00740-66521 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| R1 | 2100-1911 | | 1 | R: var 50 kΩ ±10% 1 W | 73490 | Type 55 PR503 |
| R2 | 2100-1795 | | 3 | R: var comp lin 250 kΩ ±20% 1/8 W | 71450 | QS200 |
| R3, R4 | 2100-1796 | | 4 | R: var comp lin 500 kΩ ±10% 1/8 W | 71450 | QS200 |
| R5 | 2100-1797 | | 2 | R: var comp lin 1 MΩ ±10% 1/8 W | 71450 | QS200 |
| R6 | 2100-1795 | | | R: var comp lin 250 kΩ ±20% 1/8 W | 71450 | QS200 |
| R7, R8 | 2100-1796 | | | R: var comp lin 500 kΩ ±10% 1/8 W | 71450 | QS200 |
| R9 | 2100-1797 | | | R: var comp lin 1 MΩ ±10% 1/8 W | 71450 | QS200 |
| R10, R11 | 0811-0407 | | 2 | R: fxd prec ww 10 kΩ ±0.02% 1/4 W | -hp- | |
| R12 | 0757-0156 | | 10 | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R13 | 0698-5187 | | 1 | R: fxd met flm 866 kΩ ±1% 1/8 W | 75042 | CEA T-O obd |
| R14, R15 | 0757-0271 | | 4 | R: fxd met flm 124 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R16 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R17, R18 | 0698-3149 | | 8 | R: fxd met flm 255 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R19 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R20, R21 | 0698-3149 | | | R: fxd met flm 255 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R22, R23 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R24, R25 | 0757-0482 | | 4 | R: fxd met flm 511 kΩ ±1% 1/8 W | 75042 | CEA T-O obd |
| R26 | 0757-0486 | | 1 | R: fxd met flm 750 kΩ ±1% 1/8 W | 75042 | CEA T-O obd |
| R27, R28 | 0757-0271 | | | R: fxd met flm 124 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R29 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R30, R31 | 0698-3149 | | | R: fxd met flm 255 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R32 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R33, R34 | 0698-3149 | | | R: fxd met flm 255 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R35, R36 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| R37, R38 | 0757-0482 | | | R: fxd met flm 511 kΩ ±1% 1/8 W | 75042 | CEA T-O obd |
| R39 | 0698-5095 | | 1 | R: fxd comp 12 Ω ±10% 1/4 W | 01121 | CB1201 |
| R40 | 2100-0972 | | 1 | R: var ww 20 Ω ±10% | 74868 | 994P.C. |
| R41 | 2100-1481 | | 1 | R: var ww 50 Ω ±5% 3/4 W | 12697 | 76JA30M32464 |
| R42 | 0684-6801 | | 1 | R: fxd comp 68 Ω ±10% 1/4 W | 01121 | CB6801 |
| R43 | 0757-0156 | | | R: fxd met flm 1.5 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| **A2** | 00740-66522 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 | 0160-0168 | | 8 | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |
| C2 | 0180-0155 | | 2 | C: fxd Ta elect 2.2 μF ±20% 20 vdcw | 56289 | 150D225X0020 A2-DYS |
| C3 | 0180-0032 | | 2 | C: fxd Al elect 10 μF +75% -10% 12 vdcw | 56289 | 30D106G012B A2-DSM |
| C4 | 0150-0024 | | 4 | C: fxd cer 0.02 μF +80% -20% 600 vdcw | 72982 | 841-000-Z5U-203Z |
| C5 | 0160-0127 | | | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |
| C6 | 0160-0174 | | | C: fxd cer 0.47 μF +80% -20% 25 vdcw | 56289 | 5C11B7 |
| C7 | 0160-0127 | | | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |
| C8 | 0180-0161 | | 3 | C: fxd Ta elect 3.3 μF ±20% 35 vdcw | 56289 | 150D335X0035 B2-DYS |
| C9, C10 | 0160-0127 | | | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |
| C11, C12 | 0180-0161 | | | C: fxd Ta elect 3.3 μF ±20% 35 vdcw | 56289 | 150D335X0035 B2-DYS |
| C13, C14 | | | | Not Assigned | | |
| C15 | 0150-0024 | | | C: fxd cer 0.02 μF +80% -20% 600 vdcw | 72982 | 841-000-Z5U-203Z |
| C16 | | | | Not Assigned | | |
| C17 | 0170-0038 | | 1 | C: fxd my 0.22 μF ±10% 200 vdcw | 56289 | Type 148P #148P 22492 |
| C18 | 0160-0168 | | | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A2 Cont'd | | | | | | |
| CR1 | 1901-0156 | | 2 | Diode: Si 50 mA at +1 V 20 wiv | 84411 | PS5553 |
| CR2 thru CR4 | 1901-0025 | | 35 | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| CR5 | 1902-0048 | | 4 | Diode: breakdown 6.81 V ±5% 400 mW | 04713 | SZ10939-134 |
| Q1 thru Q8 | 1854-0033 | | 25 | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q9 | 1853-0001 | | 12 | TSTR: Si PNP | 07263 | S-3251 |
| Q10 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q11 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q12 | 1854-0066 | | 3 | TSTR: Si NPN 2N2925 | 24446 | obd |
| Q13 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q14, Q15 | 1854-0039 | | 13 | TSTR: Si NPN 2N3053 | 01295 | obd |
| Q16 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| R1 | 0683-2045 | | 1 | R: fxd comp 200 kΩ ±5% 1/4 W | 01121 | CB2045 |
| R2 | 0683-2425 | | 1 | R: fxd comp 2400 Ω ±5% 1/4 W | 01121 | CB2425 |
| R3 | 0684-8251 | | 2 | R: fxd comp 8.2 MΩ ±10% 1/4 W | 01121 | CB8251 |
| R4 | 0683-8205 | | 1 | R: fxd comp 82 Ω ±5% 1/4 W | 01121 | CB8205 |
| R5 | 0684-1051 | | 10 | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R6 | 0684-2241 | | 3 | R: fxd comp 220 kΩ ±10% 1/4 W | 01121 | CB2241 |
| R7 | 0683-1645 | | 2 | R: fxd comp 160 kΩ ±5% 1/4 W | 01121 | CB1645 |
| R8 | 0684-2231 | | 11 | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R9 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R10 | 0684-5631 | | 2 | R: fxd comp 56 kΩ ±10% 1/4 W | 01121 | CB5631 |
| R11 | 0684-1031 | | 12 | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R12 | 0684-1061 | | 2 | R: fxd comp 10 MΩ ±10% 1/4 W | 01121 | CB1061 |
| R13 | 0684-2221 | | 8 | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R14 | 0684-1831 | | | R: fxd comp 18 kΩ ±10% 1/4 W | 01121 | CB1831 |
| R15 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R16 | 0684-1021 | | 6 | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R17 | 0684-6831 | | 4 | R: fxd comp 68 kΩ ±10% 1/4 W | 01121 | CB6831 |
| R18 | 0684-6821 | | 4 | R: fxd comp 6800 Ω ±10% 1/4 W | 01121 | CB6821 |
| R19* | | | | See Paragraph 5-86 for Replacement Instructions | | |
| R20 | 0684-2211 | | 3 | R: fxd comp 220 Ω ±10% 1/4 W | 01121 | CB2211 |
| R21 | 0698-5102 | | 1 | R: fxd C comp 1.2 MΩ ±10% 1/4 W | 01121 | CB1251 |
| R22 | 0698-5098 | | 4 | R: fxd C comp 2.7 MΩ ±10% 1/4 W | 01121 | CB2751 |
| R23 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R24 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R25 | 0684-6831 | | | R: fxd comp 68 kΩ ±10% 1/4 W | 01121 | CB6831 |
| R26 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R27 | 0698-5098 | | | R: fxd C comp 2.7 MΩ ±10% 1/4 W | 01121 | CB2751 |
| R28 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R29 | 0684-6831 | | | R: fxd comp 68 kΩ ±10% 1/4 W | 01121 | CB6831 |
| R30 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R31 | 0698-5098 | | | R: fxd C comp 2.7 MΩ ±10% 1/4 W | 01121 | CB2751 |
| R32 | 0684-1041 | | 8 | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R33 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R34 thru R37 | | | | Not Assigned | | |
| R38 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R39 | 0684-1011 | | | R: fxd comp 100 Ω ±10% 1/4 W | 01121 | CB1011 |
| R40 | 0684-3321 | | 6 | R: fxd comp 3300 Ω ±10% 1/4 W | 01121 | CB3321 |
| R41 | 0690-2721 | | 1 | R: fxd comp 2700 Ω ±10% 1 W | 01121 | GB2721 |
| R42 | 0687-6811 | | 1 | R: fxd comp 680 Ω ±10% 1/2 W | 78488 | RC-20 obd |
| R43 | 0684-6811 | | 1 | R: fxd comp 680 Ω ±10% 1/4 W | 01121 | CB6811 |
| R44 | 0684-3921 | | 2 | R: fxd comp 3900 Ω ±10% 1/4 W | 01121 | CB3921 |
| R45 | 0684-6821 | | | R: fxd comp 6800 Ω ±10% 1/4 W | 01121 | CB6821 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| **A3** | 00740-66523 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 | 0160-0168 | | | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |
| C2 | 0180-0155 | | | C: fxd Ta elect 2.2 μF ±20% 20 vdcw | 56289 | 150D225X0020 A2-DYS |
| C3 | 0180-0032 | | | C: fxd Al elect 10 μF +75% -10% 15 vdcw | 56289 | 30D106G012BA-2 DSM |
| C4 | 0160-0170 | | 2 | C: fxd cer 0.22 μF +80% -20% 25 vdcw | 56289 | 5C9B |
| C5 | 0160-0127 | | | C: fxd cer 1 μF ±20% 25 vdcw | 56289 | 5C13C |
| C6, C7 | 0160-0121 | | 2 | C: fxd cer 0.1 μF +80% -20% 50 vdcw | 56289 | 5C50B1 |
| C8 | 0160-0154 | | 1 | C: fxd my 0.0022 μF ±10% 200 vdcw | 56289 | 192P22292-PTS |
| C9 | 0150-0024 | | | C: fxd cer 0.02 μF +80% -20% 600 vdcw | 72982 | 841-000-Z5U-203Z |
| C10 | 0160-0170 | | | C: fxd cer 0.22 μF +80% -20% 25 vdcw | 56289 | 5C9B |
| CR1 | 1901-0156 | | | Diode: Si 50 mA at +1 V 20 wiv | 84411 | PS5553 |
| CR2 thru CR6 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| Q1, Q2 | 1854-0023 | | 2 | TSTR: Si NPN | 07263 | S-3620 |
| Q3 thru Q5 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q6 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q7 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| Q8, Q9 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q10 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| R1 | 0757-0469 | | 1 | R: fxd met flm 150 kΩ ±1% 1/8 W | 75042 | CEA T-O obd |
| R2 | 0757-0441 | | 1 | R: fxd met flm 8250 Ω ±1% 1/8 W | 75042 | CEA T-O obd |
| R3 | 0684-8251 | | | R: fxd comp 8.2 MΩ ±10% 1/4 W | 01121 | CB8251 |
| R4 | 0698-5101 | | 1 | R: fxd C comp 33 Ω ±10% 1/4 W | 01121 | CB3301 |
| R5 | 0757-0344 | | 1 | R: fxd met flm 1 MΩ ±1% 1/4 W | 19701 | MF6C T-O obd |
| R6 | 0757-0473 | | 1 | R: fxd met flm 221 kΩ ±1% 1/8 W | 19701 | MF5C T-O obd |
| R7 | 0683-1645 | | | R: fxd comp 160 kΩ ±5% 1/4 W | 01121 | CB1645 |
| R8 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R9* | | | | See Paragraph 5-91 for Replacement Instructions | | |
| R10 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R11 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R12 | 0684-1021 | | | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R13 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R14 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R15 | 0684-1021 | | | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R16 | 0684-2731 | | 1 | R: fxd comp 27 kΩ ±10% 1/4 W | 01121 | CB2731 |
| R17 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R18 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R19 | 0683-8245 | | 1 | R: fxd comp 820 kΩ ±5% 1/4 W | 01121 | CB8245 |
| R20 | 0683-5635 | | 1 | R: fxd comp 56 kΩ ±5% 1/4 W | 01121 | CB5635 |
| R21 | 0684-3331 | | 1 | R: fxd comp 33 kΩ ±10% 1/4 W | 01121 | CB3331 |
| R22 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R23 | 0684-4731 | | 3 | R: fxd comp 47 kΩ ±10% 1/4 W | 01121 | CB4731 |
| R24, R25 | 0684-4721 | | 5 | R: fxd comp 4700 Ω ±10% 1/4 W | 01121 | CB4721 |
| R26 | 0684-2211 | | | R: fxd comp 220 Ω ±10% 1/4 W | 01121 | CB2211 |
| **A4** | 00740-66524 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 | 0150-0024 | | | C: fxd cer 0.02 μF +80% -20% 600 vdcw | 72982 | 841-000-Z5U-203Z |
| C2 | 0150-0012 | | 3 | C: fxd cer 0.01 μF ±20% 1000 vdcw | 56289 | 29C214A3 |
| C3 | 0160-0127 | | | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A4 Cont'd | | | | | | |
| C4 | 0160-2323 | | 1 | C: fxd my 10 μF ±10% 50 vdcw | 56289 | 218P1069R5S4 |
| C5, C6 | 0180-0393 | | 2 | C: fxd Ta elect 39 μF ±10% 10 vdcw | 56289 | 150D396X9010 B2-DYS |
| C7 | 0180-0104 | | 2 | C: fxd Al elect 200 μF +75% -10% 15 vdcw | 56289 | 30D207G015DF4-DSM |
| C8 | 0160-0155 | | 1 | C: fxd my 0.0033 μF ±10% 50 vdcw | 56289 | 192P33292-PTS |
| C9 | 0180-0106 | | 1 | C: fxd Ta elect 60 μF ±20% 6 vdcw | 56289 | 150D606X0006 B2-DYS |
| C10 | 0150-0093 | | 1 | C: fxd cer 0.01 μF +80% -20% 100 vdcw | 91418 | TA |
| CR1 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| CR2, CR3 | 1902-0048 | | | Diode: breakdown 6.81 V ±5% 400 mW | 04713 | SZ10939-134 |
| CR4 thru CR12 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| Q1, Q2 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q3 | 1853-0010 | | 1 | TSTR: Si PNP | 07263 | obd |
| Q4 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q5 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q6 thru Q12 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| R1 | 0684-6831 | | | R: fxd comp 68 kΩ ±10% 1/4 W | 01121 | CB6831 |
| R2 | 0683-2055 | | 1 | R: fxd comp 2 MΩ ±5% 1/4 W | 01121 | CB2055 |
| R3, R4 | 0684-4751 | | 2 | R: fxd comp 4.7 MΩ ±10% 1/4 W | 01121 | CB4751 |
| R5 | 0698-5097 | | 1 | R: fxd C comp 1.5 MΩ ±10% 1/4 W | 01121 | CB1551 |
| R6 | 2100-1406 | | 2 | R: var comp lin 50 kΩ ±20% 1/8 W | 71450 | XQS-200 |
| R7 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R8 | 0698-5099 | | 1 | R: fxd C comp 3.9 MΩ ±10% 1/4 W | 01121 | CB3951 |
| R9 | 0698-5098 | | | R: fxd C comp 2.7 MΩ ±10% 1/4 W | 01121 | CB2751 |
| R10 | 0684-4711 | | 5 | R: fxd comp 470 Ω ±10% 1/4 W | 01121 | CB4711 |
| R11 | 0684-3921 | | | R: fxd comp 3900 Ω ±10% 1/4 W | 01121 | CB3921 |
| R12 | 0698-5096 | | 1 | R: fxd C comp 680 kΩ ±10% 1/4 W | 01121 | CB6841 |
| R13 | 2100-1406 | | | R: var comp lin 50 kΩ ±30% 1/8 W | 71450 | XQS-200 |
| R14 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R15 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R16 | 0684-4711 | | | R: fxd comp 470 Ω ±10% 1/4 W | 01121 | CB4711 |
| R17 | 0684-4721 | | | R: fxd comp 4700 Ω ±10% 1/4 W | 01121 | CB4721 |
| R18 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R19 | 0684-2241 | | | R: fxd comp 220 kΩ ±10% 1/4 W | 01121 | CB2241 |
| R20 | 0684-1831 | | | R: fxd comp 18 kΩ ±10% 1/4 W | 01121 | CB1831 |
| R21 | 0698-5100 | | 1 | R: fxd C comp 22 MΩ ±10% 1/4 W | 01121 | CB2261 |
| R22 | 0684-5631 | | | R: fxd comp 56 kΩ ±10% 1/4 W | 01121 | CB5631 |
| R23 | 0684-1061 | | | R: fxd comp 10 MΩ ±10% 1/4 W | 01121 | CB1061 |
| R24 | 0684-4731 | | | R: fxd comp 47 kΩ ±10% 1/4 W | 01121 | CB4731 |
| R25 | 0684-6821 | | | R: fxd comp 6800 Ω ±10% 1/4 W | 01121 | CB6821 |
| R26 | 0684-1021 | | | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R27 | 0684-4731 | | | R: fxd comp 47 kΩ ±10% 1/4 W | 01121 | CB4731 |
| R28 | 0684-2711 | | 1 | R: fxd comp 270 Ω ±10% 1/4 W | 01121 | CB2711 |
| R29 | 0684-8211 | | 2 | R: fxd comp 820 Ω ±10% 1/4 W | 01121 | CB8211 |
| R30 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R31 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R32 | 0684-2211 | | | R: fxd comp 220 Ω ±10% 1/4 W | 01121 | CB2211 |
| R33 | 0684-6821 | | | R: fxd comp 6800 Ω ±10% 1/4 W | 01121 | CB6821 |
| R34 | 0684-3321 | | | R: fxd comp 3300 Ω ±10% 1/4 W | 01121 | CB3321 |
| R35 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| **A5** | 00740-66525 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 | 0140-0200 | | 1 | C: fxd mica 390 pF ±5% | 04062 | RDM15F391J3C |
| C2 | 0160-0314 | | 1 | C: fxd my 0.01 μF ±5% 400 vdcw | 84411 | Type 663UW |
| C3 | 0160-0156 | | 1 | C: fxd my 0.0039 μF ±10% 200 vdcw | 56289 | 192P39292-PTS |
| C4 | 0180-0285 | | 1 | C: fxd Al elect non-polar 1200 μF +100% -10% 5 vdcw | 56289 | D31343 |
| C5 | 0180-0293 | | 1 | C: fxd Al elect 375 μF +75% -10% 15 vdcw | 56289 | obd |
| C6 | 0180-0282 | | 3 | C: fxd Al elect 35 μF +75% -10% 250 vdcw | 56289 | D38270 |
| C7 | 0180-0058 | | 1 | C: fxd Al elect 50 μF +75% -10% 25 vdcw | 56289 | 30D506G025 CC2-DSM |
| C8 | 0150-0012 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | 56289 | 29C214A3 |
| C9 | 0160-0127 | | | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |
| CR1 | 1910-0014 | | 2 | Diode: Ge IN277 | 03877 | obd |
| CR2 | 1901-0040 | | 1 | Diode: Si 30 mA 2 pF 2 ns 30 wiv | 07263 | FDG1088 |
| CR3 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| CR4 | 1902-0211 | | 1 | Diode: Si breakdown 12.1 V ±10% | 12954 | DZ70414Z |
| CR5, CR6 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| Q1, Q2 | 1850-0111 | | 3 | TSTR: Ge PNP 2N404A | 01295 | 2N404A |
| Q3 thru Q5 | 1853-0039 | | | TSTR: Si PNP 2N3638A | 07263 | obd |
| Q6 | 1854-0066 | | | TSTR: Si NPN 2N2925 | 24446 | obd |
| Q7 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| R1 | 0686-2725 | | 1 | R: fxd comp 2700 Ω ±5% 1/2 W | 01121 | EB2725 |
| R2 | 0684-3911 | | 1 | R: fxd comp 390 Ω ±10% 1/4 W | 01121 | CB3911 |
| R3 | 0687-1521 | | 1 | R: fxd comp 1500 Ω ±10% 1/2 W | 01121 | EB1521 |
| R4 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R5 | 0686-4725 | | 1 | R: fxd comp 4700 Ω ±5% 1/2 W | 78488 | RC-20 obd |
| R6, R7 | 0687-1221 | | 2 | R: fxd comp 1200 Ω ±10% 1/2 W | 01121 | EB1221 |
| R8 | 0683-5135 | | 1 | R: fxd comp 51 kΩ ±5% 1/4 W | 01121 | CB5135 |
| R9 | 0687-5621 | | 1 | R: fxd comp 5600 Ω ±10% 1/2 W | -hp- | |
| R10 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R11 | 0684-1021 | | | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R12, R13 | 0683-0365 | | 2 | R: fxd comp 3.6 Ω ±5% 1/4 W | 01121 | CB36G5 |
| R14 | 0812-0066 | | 1 | R: fxd ww 0.33 Ω ±5% 2 W | 75042 | BWH |
| R15 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R16 | 0683-4725 | | 1 | R: fxd comp 4700 Ω ±5% 1/4 W | 01121 | CB4725 |
| R17 | 0684-2241 | | | R: fxd comp 220 kΩ ±10% 1/4 W | 01121 | CB2241 |
| R18 | 0687-1821 | | 2 | R: fxd comp 1800 Ω ±10% 1/2 W | 78488 | RC-20 obd |
| R19 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R20, R21 | 0684-4721 | | | R: fxd comp 4700 Ω ±10% 1/4 W | 01121 | CB4721 |
| **A6** | 00740-66526 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 | 0180-0061 | | 4 | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015 DC2-DSM |
| C2 | 0180-0059 | | 2 | C: fxd Al elect 10 μF +75% -10% 25 vdcw | 56289 | 30D106G025 BB2-DSM |
| C3 | 0180-0061 | | | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015 DC2-DSM |
| C4 | 0160-0162 | | 3 | C: fxd my 0.022 μF ±10% 200 vdcw | 56289 | 192P22392-PTS |
| C5 | 0180-0284 | | 2 | C: fxd Al elect 200 μF +75% -10% 30 vdcw | 56289 | (Type 34D) D39070 |
| C6 | | | | Not Assigned | | |
| C7 | 0180-0061 | | | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015 DC2-DSM |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A6 Cont'd | | | | | | |
| C8 | 0180-0059 | | | C: fxd Al elect 10 μF +75% -10% 25 vdcw | 56289 | 30D106G25 BB2-DSM |
| C9 | 0180-0061 | | | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015 DC2-DSM |
| C10 | 0160-0168 | | | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |
| C11 | 0180-0284 | | | C: fxd Al elect 200 μF +75% -10% 30 vdcw | 56289 | (Type 34D) D39070 |
| C12 | | | | Not Assigned | | |
| C13 | 0180-0149 | | 1 | C: fxd Al elect 65 μF +100% -10% 60 vdcw | 56289 | (Type 30D) D36978 |
| CR1 thru CR4 | 1901-0026 | | 12 | Diode: Si 200 piv | 04713 | ST1358-8 |
| CR5 | 1902-0048 | | | Diode: Si junction 200 piv 15 A 1N3210 | 04713 | SZ10939-134 |
| CR6 thru CR9 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG-817 |
| CR10 thru CR13 | 1901-0026 | | | Diode: Si 200 piv | 04713 | SR1358-8 |
| Q1, Q2 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| Q3 | 1854-0066 | | | TSTR: Si NPN 2N2925 | 24446 | obd |
| Q4, Q5 | 1853-0001 | | | TSTR: Si PNP | 07263 | S-3251 |
| Q6 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| R1 | 0727-0115 | | 1 | R: fxd C flm 2000 Ω ±1% 1/2 W | 91637 | DCS-1/2-15 obd |
| R2 | 0727-0140 | | 1 | R: fxd C flm 6000 Ω ±1% 1/2 W | 91637 | DCS-1/2-15 obd |
| R3 | 0684-8211 | | | R: fxd comp 820 Ω ±10% 1/4 W | 01121 | CB8211 |
| R4, R5 | 0684-3321 | | | R: fxd comp 3300 Ω ±10% 1/4 W | 01121 | CB3321 |
| R6 | 0684-4711 | | | R: fxd comp 470 Ω ±10% 1/4 W | 01121 | CB4711 |
| R7 | 0761-0056 | | 1 | R: fxd met ox 430 Ω ±5% 1 W | 07115 | C32 |
| R8 | 0764-0033 | | 2 | R: fxd met ox 33 Ω ±5% 2 W | 75042 | L42 |
| R9 | | | | Not Assigned | | |
| R10 | 0758-0004 | | 1 | R: fxd met ox 2700 Ω ±5% 1/2 W | 07115 | C5 obd |
| R11 | 0727-0124 | | 1 | R: fxd C flm 3000 Ω ±1% 1/2 W | 91637 | DCS-1/2-15 obd |
| R12, R13 | 0684-3321 | | | R: fxd comp 3300 Ω ±10% 1/4 W | 01121 | CB3321 |
| R14 | 0684-4711 | | | R: fxd comp 470 Ω ±10% 1/4 W | 01121 | CB4711 |
| R15 | 0758-0043 | | 1 | R: fxd met ox 1800 Ω ±5% 1/2 W | 07115 | C5 obd |
| R16 | 0764-0033 | | | R: fxd met ox 33 Ω ±5% 2 W | 75042 | L42 |
| **A7** | 00740-66527 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1 thru C3 | 0180-0286 | | 4 | C: fxd Al elect 500 μF +75% -10% 25 vdcw | 56289 | (Type 34D) D38774 |
| C4 | 0180-0104 | | | C: fxd Al elect 200 μF +75% -10% 15 vdcw | 56289 | 30D207G015 DF4-DSM |
| C5 | 0180-0286 | | | C: fxd Al elect 500 μF +75% -10% 25 vdcw | 56289 | (Type 34D) D38774 |
| C6 | 0150-0098 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | -hp- | |
| C7 | 0160-0174 | | | C: fxd cer 0.47 μF +80% -10% 25 vdcw | 56289 | 5C11B7 |
| C8* | | | | See Paragraph 5-95 for Replacement Instructions | | |
| CR1 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG817 |
| CR2 | 1910-0014 | | | Diode: GE IN277 | 03877 | obd |
| CR3 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG817 |
| CR4 thru CR7 | 1901-0026 | | | Diode: Si 200 piv | 04713 | SR1358-8 |
| K1 | 0490-0343 | | 1 | Relay: reed | -hp- | |
| L1 | 9140-0029 | | 1 | Coil: R.F. choke 100 μH | 99848 | 3100-15-101 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A7 Cont'd | | | | | | |
| Q1 | 1853-0039 | | 1 | TSTR: Si PNP 2N3638A | 07263 | obd |
| Q2 | 1851-0017 | | 1 | TSTR: GE NPN 2N1304 | 01295 | 2N1304 |
| Q3 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| Q4 | 1850-0111 | | | TSTR: Ge PNP 2N404A | 01295 | 2N404A |
| Q5 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| R1 | 0684-1811 | | 1 | RL fxd comp 180 Ω ±10% 1/4 W | 01121 | CB1811 |
| R2 | 0690-2701 | | 1 | R: fxd C comp 27 Ω ±10% 1 W | 01121 | GB2701 |
| R3 | 0690-6801 | | 1 | R: fxd C comp 68 Ω ±10% 1 W | 01121 | GB6801 |
| R4 | 0686-5125 | | 1 | R: fxd comp 5100 Ω ±5% 1/2 W | 78488 | RC-20 obd |
| R5 | 0687-2211 | | 1 | R: fxd comp 220 Ω ±10% 1/2 W | 01121 | EB2211 |
| R6 | 0687-5611 | | 2 | R: fxd comp 560 Ω ±10% 1/2 W | 01121 | EB5611 |
| R7 | 0690-4701 | | 1 | R: fxd C comp 47 Ω ±10% 1 W | 01121 | GB4701 |
| E8 | 0687-1011 | | 1 | R: fxd comp 100 Ω ±10% 1/2 W | 01121 | EB1011 |
| R9 | 0687-1501 | | 1 | R: fxd comp 15 Ω ±10% 1/2 W | 01121 | EB1501 |
| R10 | 0684-1011 | | | R: fxd comp 100 Ω ±10% 1/4 W | 01121 | CB1011 |
| R11 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R12 | 0684-4711 | | | R: fxd comp 470 Ω ±10% 1/4 W | 01121 | CB4711 |
| R13 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R14 | 0684-1021 | | | R: fxd comp 1000 Ω ±10% 1/4 W | 01121 | CB1021 |
| R15 | 0687-1821 | | | R: fxd comp 1800 Ω ±10% 1/2 W | 78488 | RC-20 obd |
| R16 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R17 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| R18 | 0687-1021 | | 1 | R: fxd comp 1000 Ω ±10% 1/2 W | 01121 | EB1021 |
| R19 | 0684-2221 | | | R: fxd comp 2200 Ω ±10% 1/4 W | 01121 | CB2221 |
| **A8** | 00740-66528 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| C1, C2 | 0180-0282 | | | C: fxd Al elect 35 μF +75% -10% 250 vdcw | 56289 | D38270 |
| C3 | 0180-0091 | | 1 | C: fxd Al elect 10 μF +50% -10% 100 vdcw | 56289 | 30D106F100 DC2-DSM |
| C4 thru C6 | 0160-0168 | | | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |
| C7, C8 | 0160-0207 | | 2 | C: fxd my 0.01 μF ±5% 200 vdcw | 56289 | 192P10352-PTS |
| C9, C10 | 0160-0162 | | | C: fxd my 0.022 μF ±10% 200 vdcw | 56289 | 192P22392-PTS |
| CR1, CR2 | 1901-0029 | | 2 | Diode: Si 600 piv | 04713 | SR1358-10 |
| CR3 thru CR10 | 1901-0025 | | | Diode: Si 100 mA 12 pF 100 wiv | 03877 | SG817 |
| CR11 | 1902-3259 | | 1 | Diode: Si breakdown 24.3 V ±5% 400 mW | 07910 | obd |
| CR12 | 1902-3179 | | 1 | Diode: Si breakdown 11.8 V ±5% | 07910 | CD35727 |
| Q1, Q2 | 1854-0039 | | | TSTR: Si NPN 2N3053 | 01295 | obd |
| Q3, Q4 | 1854-0033 | | | TSTR: Si NPN 2N3391 | 24446 | 2N3391 |
| Q5, Q6 | 1854-0022 | | 2 | TSTR: | 01295 | SG1294 |
| R1 | 0687-2741 | | 1 | R: fxd comp 270 kΩ ±10% 1/2 W | 78488 | RC-20 obd |
| R2 | 0767-0011 | | 1 | R: fxd met ox 20 kΩ ±5% 3 W | 75042 | PMF-3 |
| R3 | 2100-1410 | | 1 | R: var comp lin 20 kΩ ±20% 1/8 W | 71450 | XQS-200 |
| R4 thru R7 | 0687-1531 | | 4 | R: fxd comp 15 kΩ ±10% 1/2 W | 01121 | EB1531 |
| R8*, R9* | | | | See Paragraph 5-99 for Replacement Instructions | | |
| R10, R11 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R12, R13 | 0684-2231 | | | R: fxd comp 22 kΩ ±10% 1/4 W | 01121 | CB2231 |
| R14, R15 | 0686-9135 | | 2 | R: fxd comp 91 kΩ ±5% 1/2 W | 78488 | RC-20 obd |
| R16 | 0683-3335 | | 2 | R: fxd comp 33 kΩ ±5% 1/4 W | 01121 | CB3335 |
| R17, R18 | 0683-5645 | | 2 | R: fxd comp 560 kΩ ±5% 1/4 W | 01121 | CB5645 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A8 Cont'd | | | | | | |
| R19 | 0683-3335 | | | R: fxd comp 33 kΩ ±5% 1/4 W | 01121 | CB3335 |
| R20 | 2100-1795 | | | R: var comp lin 250 kΩ ±20% 1/8 W | 71450 | QS200 |
| R21, R22 | 0683-6825 | | 2 | R: fxd comp 6800 Ω ±5% 1/4 W | 01121 | CB6825 |
| R23 | 0684-8231 | | 3 | R: fxd comp 82 kΩ ±10% 1/4 W | 01121 | CB8231 |
| R24, R25 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R26 | 0684-8231 | | | R: fxd comp 82 kΩ ±10% 1/4 W | 01121 | CB8231 |
| R27 | 0761-0019 | | 1 | R: fxd met ox 39 kΩ ±5% 1 W | 75042 | L32 |
| R28 | 0757-0765 | | 1 | R: fxd C flm 36.5 kΩ ±1% 1/2 W | 19701 | MF6C T-O obd |
| R29 | 0684-1031 | | | R: fxd comp 10 kΩ ±10% 1/4 W | 01121 | CB1031 |
| R30, R31 | 0684-1051 | | | R: fxd comp 1 MΩ ±10% 1/4 W | 01121 | CB1051 |
| R32 | 0684-1011 | | | R: fxd comp 100 Ω ±10% 1/4 W | 01121 | CB1011 |
| R33 | 0757-0786 | | 1 | R: fxd met flm 365 kΩ ±1% 1/4 W | 19701 | MF6C T-O obd |
| **A9** | 00740-66529 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| DS1 | 2140-0015 | | 2 | Lamp: neon T-2 bulb | 24446 | obd |
| DS2 | 2140-0213 | | 1 | Lamp: incandescent 28 V 40 mA | 71744 | CM7-387 |
| DS3 | 2140-0015 | | | Lamp: noen T-2 bulb | 24446 | obd |
| Q1 | 1853-0001 | | | TSTR: Si PNP | 07263 | S3251 |
| R1 | 0684-4731 | | | R: fxd comp 47 kΩ ±10% 1/4 W | 01121 | CB4731 |
| R2 | 0757-0815 | | 1 | R: fxd met flm 562 Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| R3 | 0690-1051 | | 1 | R: fxd C comp 1 MΩ ±10% 1 W | 01121 | GB1051 |
| R4 thru R9 | 0811-1519 | | 1 | R: matched set 6 resistors | -hp- | |
| R10 | 2100-1800 | | 1 | R: var ww 20 Ω ±10% 3/4 W 11 turn | 12697 | Series 76 Type 3 |
| R11 | 2100-1483 | | 1 | R: var ww lin 200 Ω ±5% 3/4 W 11 turn | 12697 | 76JA3CM32466 |
| R12 | 2100-1643 | | 1 | R: var ww 2000 Ω ±5% 3/4 W 10 turn | 12697 | Series 76 Type 3 |
| V1 | 1990-0021 | | 1 | Photocell | -hp- | |
| V2 | 1990-0022 | | 1 | Photocell | -hp- | |
| **A10** | 00740-66530 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| BT1 | 1420-0018 | | 2 | Battery: Mercury 1.34 V | 37942 | PX-13T2 |
| R1 | 0687-1201 | | 1 | R: fxd comp 12 Ω ±10% 1/2 W | 01121 | EB1201 |
| R2 | 0687-5611 | | | R: fxd comp 560 Ω ±10% 1/2 W | 01121 | EB5611 |
| R3 | 0698-3202 | | 1 | R: fxd met flm 1740 Ω ±1% 1/8 W | 000LM | obd |
| R4 | 0687-8241 | | 1 | R: fxd comp 820 kΩ ±10% 1/2 W | 78488 | RC-20 obd |
| R5 | 0687-2261 | | 1 | R: fxd comp 22 MΩ ±10% 1/2 W | 01121 | EB2261 |
| R6, R7 | 0687-1051 | | 2 | R: fxd comp 1 MΩ ±10% 1/2 W | 01121 | EB1051 |
| R8 | 2100-0388 | | 1 | R: var ww 20 Ω ±20% 2 W | 08984 | HHH2XYZ |
| R9 | 2100-0151 | | 1 | R: var C comp lin 500 Ω ±20% 2 W | 71450 | UPM70RE(hp) obd |
| R10 | 2100-0128 | | 1 | R: var C comp lin 250 Ω ±20% 1/15 W | 71450 | UPM70RE(hp) obd |
| R11 | 2100-0102 | | 1 | R: var C comp lin 500 kΩ ±30% 1/10 W | 71450 | UPM70RE(hp) obd |
| R12 | 2100-0096 | | 1 | R: var C comp lin 1 MΩ ±30% 1/10 W | 71450 | UPM70RE(hp) obd |
| R13 | 0687-6851 | | 1 | R: fxd comp 6.8 MΩ ±10% 1/2 W | 01121 | EB6851 |
| **A11** | 00740-66531 | | 1 | Assembly: Includes all mounted parts | -hp- | |
| BT1 | 1420-0018 | | | Battery: Mercury 1.34 V | 37942 | PX-13T2 |
| C1 | 0180-0305 | | 1 | C: fxd Al elect 1000 μF +75% -10% 2.5 vdcw | 56289 | 34D108G2R5 FJ4-DSB |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A11 Cont'd | | | | | | |
| CR1 | 1901-0172 | | 1 | Diode Assembly: Si 3000 piv | 14099 | SA1173 |
| CR2 | 1901-0028 | | 6 | Diode: Si 400 piv | 04713 | obd |
| L1 | 9100-1344 | | 3 | Coil: RF 400 $\mu$H ±100 $\mu$H | -hp- | |
| R1 | 0770-0008 | | 1 | R: fxd met ox 1000 Ω ±5% 4 W | 07115 | FP-4 |
| R2 | 0815-0042 | | 1 | R: fxd prec ww 200 kΩ ±5% 10 W | 91637 | RS-10 |
| R3 | | | | Not Assigned | | |
| R4 | 0690-1061 | | 1 | R: fxd comp 10 MΩ ±10% 1 W | 01121 | GB1061 |
| A12 | | | | Not Assigned | | |
| **A13** | 00740-66901 | | 1 | Oven Assembly: Diode selected (individual components not separately replaceable) | -hp- | |
| A14 | | | | Not Assigned | | |
| **A15** | 00740-65202 | | 1 | Holding Assembly: Includes DS1 thru DS9, R1 thru R6 | -hp- | |
| DS1 thru DS5 | 1970-0009 | | 5 | Tube: indicator 10 digit | 83594 | B5991 |
| DS6 thru DS9 | 2140-0028 | | 4 | Lamp: neon breakdown 65 Vac 90 Vdc | 24446 | NE2E4 |
| R1 thru R5 | 0757-0367 | | 5 | R: fxd met flm 100 kΩ ±1% 1/2 W | 19701 | MF7C T-O obd |
| R6 | 0686-1645 | | 2 | R: fxd comp 160 kΩ ±5% 1/2 W | 78488 | RC-20 obd |
| **A16** | 1990-0217 | | 1 | Photochopper Assembly: Meter Loop | -hp- | |
| **A17** | 1990-0216 | | 1 | Photochopper Assembly: Main Loop | -hp- | |
| **A18** | 11054A | | 1 | Input Cable Assembly | -hp- | |
| C1 | 0150-0023 | | 1 | C: fxd cer 0.002 $\mu$F ±20% 1000 vdcw | 56289 | 19C203A |
| J1 | 1510-0026 | | 3 | Binding post assembly: red w/solder turret | -hp- | |
| J2 | 1510-0027 | | 3 | Binding post assembly: black w/solder turret | -hp- | |
| J3 | 5060-0626 | | 1 | Binding post assembly: black | -hp- | |
| J4 | 1510-0009 | | 5 | Binding post: black | -hp- | |
| R1 | 0689-2255 | | 1 | R: fxd comp 2.2 MΩ ±5% 1 W | 01121 | GB2255 |
| S1 | 3101-0110 | | 1 | Switch: slide DPDT non-shorting 0.5 amp 125 vdc 3 amp 125 vac | 42190 | 11304 obd |
| | 1251-0468 | | 1 | Connector: plug quick disconnect 7 contact | 000LN | MDR07-7P-090 |
| | 1251-0470 | | 10 | Contact: male snap-in type crimp-on | 000LN | 800-20/32-1 |
| | 8120-0283 | | 1 | Cable: special purpose 3-1/2 feet long | -hp- | |
| | 8150-0005 | | 1 | Wire: elect 22 ga black 1/4 foot long | 83501 | BT Type C/U obd |
| | 8150-0007 | | 1 | Wire: elect 22 ga black 1/4 foot long | 83501 | BT Type C/U obd |
| | 11054-44401 | | 2 | Cabinet: molded | -hp- | |
| | 11054-44402 | | 2 | Base: molded | -hp- | |
| | 11054-48301 | | 2 | Boot assembly: cable | -hp- | |
| | 11054-48302 | | 2 | Boot assembly: cable | -hp- | |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| **A19** | 11055B | | 1 | Output Cable Assembly | -hp- | |
| C1 | 0160-0040 | | 1 | C: fxd 0.01 μF ±10% 1000 vdcw | 14655 | T ST-100 obd |
| DS1 | 1450-0048 | | 1 | Lamp: pilot indicator | 72765 | 599-124 obd |
| J1, J2 | 1510-0009 | | | Binding post assembly: black w/o solder turret | -hp- | |
| J3 | 1510-0026 | | | Binding post assembly: red w/solder turret | -hp- | |
| J4 | 1510-0027 | | | Binding post assembly: black w/solder turret | -hp- | |
| J5 | 1510-0026 | | | Binding post assembly: red w/solder turret | -hp- | |
| J6 | 1510-0027 | | | Binding post assembly: black w/solder turret | -hp- | |
| R1, R2 | 0689-4745 | | 2 | R: fxd comp 470 kΩ ±5% 1 W | 01121 | GB4745 |
| R3 | 0687-1061 | | 1 | R: fxd comp 10 MΩ ±10% 1/2 W | 01121 | EB1061 |
| | 1251-0467 | | 1 | Connector: plug quick disconnect 7 contact | 000LN | MDR07-7PB-090 |
| | 1251-0470 | | | Contact: male snap-in type crimp-on | 000LN | 800-20/32-1 |
| | 8120-0234 | | 1 | Cable: special purpose 3-1/2 feet long 3 conductor w/3 separate shields | -hp- | |
| | 11054-44401 | | | Cabinet: molded input terminal | -hp- | |
| | 11054-44402 | | | Base: molded | -hp- | |
| | 11054-48301 | | | Boot assembly: cable | -hp- | |
| | 11054-48302 | | | Boot assembly: cable | -hp- | |
| **CHASSIS MOUNTED COMPONENTS** | | | | | | |
| C1, C2 | 0180-0287 | | 2 | C: fxd Al elect 10,000 μF +75% -10% 60 vdcw | 56289 | (Type 32D) D38778 |
| C3, C4 | 0160-0102 | | 2 | C: fxd paper 4 μF ±10% 1000 vdcw | 56289 | P47655-050 |
| C5 | 0160-0128 | | 8 | C: fxd cer 1.0 μF ±20% 25 vdcw | 56289 | 5C13C |
| C6, C7 | 0160-0222 | | 2 | C: fxd poly 0.1 μF ±20% 1000 vdcw | 56289 | obd |
| C8 | 0160-0163 | | 1 | C: fxd my 0.033 μF ±10% 200 vdcw | 56289 | 192P33392-PTS |
| C9, C10 | 0160-0859 | | 3 | C: fxd my 1 μF ±10% 50 vdcw | 56289 | 148P335-PUM |
| C11 | 0150-0098 | | 5 | C: fxd cer 0.01 μF ±20% 1000 vdcw | -hp- | |
| C12 | 0180-0047 | | 1 | C: fxd Al elect 500 μF 75 vdcw | 56289 | D32443 |
| C13 | 0160-0859 | | | C: fxd my 1 μF ±10% 50 vdcw | 56289 | 148P335-PUM |
| C14, C15 | 0150-0119 | | 1 | C: fxd cer 2 x 0.01 μF ±20% 250 vdcw | 56289 | 36C219A |
| C16 | 0150-0052 | | 1 | C: fxd cer 0.05 μF ±20% 400 vdcw | 56289 | 33C17A |
| C17 | 0160-0174 | | 3 | C: fxd cer 0.47 μF +80% -20% 25 vdcw | 56289 | 5C11B7 |
| C18 | 0170-0022 | | 1 | C: fxd my 0.1 μF ±20% 600 vdcw | 84411 | HEW-7 |
| CR1 | 1901-0028 | | | Diode: Si 400 piv | 04713 | obd |
| DS1 | 2140-0054 | | 1 | Lamp: incandescent 10 V 14 mA (OVERLOAD) | 24446 | 344 |
| F1 | 2110-0006 | | 1 | Fuse: 2 A slow-blow 125 V | 000LM | MAL-2 |
| F2 | 2110-0012 | | 1 | Fuse: 1/2 A 250 V | 75915 | 312.500 |
| F3 | 2110-0002 | | 1 | Fuse: 2 A 250 V | 000LM | 31200Z |
| J1 | 1251-0466 | | 1 | Connector: socket, INPUT, 7 pin | 000LN | MDR04-7S-090 |
| J2 | 1251-0467 | | 1 | Connector: socket, OUTPUT, 7 pin | 000LN | MDR04-7SB-090 |
| J3 | 1251-0148 | | 1 | Connector: ac power 3 pin | 87930 | 1065-1 |
| J4 | 1510-0008 | | 1 | Binding post assembly: red w/o solder turret | -hp- | |
| J5, J6 | 1510-0009 | | 2 | Binding post assembly: black w/o solder turret | -hp- | |
| K1 | 3100-1735 | | 1 | Switch: output rotary | 76854 | obd |
| K1C1 | 0150-0098 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | -hp- | |
| K1R1 | 0687-4711 | | 1 | R: fxd comp 470 Ω ±10% 1/2 W | 01121 | EB4711 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| | | | | Chassis Mounted Components Cont'd | | |
| L1 | 9110-0106 | | 1 | Inductor: filter | -hp- | |
| L2 | 9110-0107 | | 1 | Inductor: input filter | -hp- | |
| L3 | 9140-0041 | | 1 | Coil: R.F. 2.5 mH ±10% | 95265 | SA-2500-I |
| L4, L5 | 9100-1332 | | 2 | Choke: R.F. 400 μH ±100 μH | -hp- | |
| L6, L7 | 9100-1344 | | | Choke: R.F. 400 μH ±100 μH | -hp- | |
| M1 | 1120-0916 | | 1 | Meter: calibrated | -hp- | |
| Q1 | 1850-0189 | | 1 | TSTR: Ge PNP | 16758 | 7297086 |
| Q2 | 1850-0160 | | 1 | TSTR: Ge PNP 2N2147 | 86684 | 2N2147 |
| Q3 | 1850-0098 | | 1 | TSTR: Ge PNP | 77068 | B-1493 |
| R1, R2 | | | | Not Assigned | | |
| R3 | 0816-0001 | | 1 | R: fxd ww 250 Ω ±5% 10 W | 91637 | HLW-12-11W (SP1) |
| R4 | 0811-0390 | | 1 | R: fxd prec ww 0.549 Ω ±1% 5 W | 91637 | RS-5 |
| R5 | 0816-0004 | | 1 | R: fxd ww 800 Ω ±5% 10 W | 91637 | HLW-12-11W (SP1) |
| R6 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| R7 thru R9 | | | | Not Assigned | | |
| R10 | 0687-8231 | | 1 | R: fxd comp 82 kΩ ±10% 1/2 W | 01121 | EB8231 |
| R11 | 0687-6831 | | 1 | R: fxd comp 68 kΩ ±10% 1/2 W | 01121 | EB6831 |
| R12 | 2100-0937 | | 1 | R: var comp 250 Ω ±10% 1.12 W (CURRENT LIMIT) | 01121 | Type J |
| R13 | 2100-1780 | | 1 | R: var prec ww lin 100 kΩ ±5% 2 W 10 turn (ZERO) | 12697 | Series 62 |
| R14 | 2100-0067 | | 1 | R: var lin 2500 Ω ±10% 1/2 W (RECORDER OUTPUT) | 11237 | Series 45 |
| R15 | 0687-3311 | | 1 | R: fxd comp 330 Ω ±10% 1/2 W | 78488 | RC-20 obd |
| S1 | 00740-61907 | | 1 | Switch assembly: RANGE and FUNCTION Includes all mounted parts | -hp- | |
| S1C1 | 0160-0168 | | | C: fxd my 0.1 μF ±10% 200 vdcw | 56289 | 192P10492-PTS |
| S1C2 | 0150-0098 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | -hp- | |
| S1R1 | 0686-1645 | | | R: fxd comp 160 kΩ ±5% 1/2 W | 78488 | RC-20 obd |
| S1R2 | 0686-1655 | | 1 | R: fxd comp 1.6 MΩ ±5% 1/2 W | 78488 | RC-20 obd |
| S1R3 | 0686-1635 | | 1 | R: fxd comp 16 kΩ ±5% 1/2 W | 01121 | EB1635 |
| S1R4 | 0686-1625 | | 1 | R: fxd comp 1600 Ω ±5% 1/2 W | 01121 | EB1625 |
| S1R5, S1R6 | | | | Not Assigned | | |
| S1R7 | 0684-1041 | | | R: fxd comp 100 kΩ ±10% 1/4 W | 01121 | CB1041 |
| S1R8, S1R9 | 0687-2251 | | 2 | R: fxd comp 2.2 MΩ ±10% 1/2 W | 01121 | CB2251 |
| S1R10 | 0687-8221 | | 1 | R: fxd comp 8200 Ω ±10% 1/2 W | 01121 | EB6821 |
| S1R11 | 0758-0006 | | 1 | R: fxd met ox 10 kΩ ±5% 1/2 W | 07115 | C5 obd |
| S1R12 | 0758-0053 | | 1 | R: fxd met ox 100 kΩ ±5% 1/2 W | 07115 | C5 obd |
| S1R13 | 0761-0102 | | 1 | R: fxd met ox 560 kΩ ±5% 1 W | 07115 | C32 |
| S1R14 | 0761-0099 | | 1 | R: fxd met ox 430 kΩ ±5% 1 W | 75042 | L32 |
| S1R15 | 0687-1801 | | 1 | R: fxd comp 18 Ω ±10% 1/2 W | 01121 | EB1801 |
| S1R16 | 0690-1811 | | 1 | R: fxd comp 180 Ω ±10% 1 W | 01121 | GB1811 |
| S1R17 | 0687-4721 | | 1 | R: fxd comp 4700 Ω ±10% 1/2 W | 01121 | EB4721 |
| S1R18 | 0687-1831 | | 1 | R: fxd comp 18 kΩ ±10% 1/2 W | 01121 | EB1831 |
| S1R19 | 0693-1211 | | 1 | R: fxd C comp 120 Ω ±10% 2 W | 01121 | HB1211 |
| S1R20 | 0687-1001 | | 1 | R: fxd comp 10 Ω ±10% 1/2 W (S1R20 not present on instruments before Serial No. 610-00376) | 01121 | EB1001 |
| S2 thru S8 | 00740-61906 | | 1 | Switch assembly: VOLTAGE SET, SENSITIVITY and INTERNAL ALIGNMENT (Includes all mounted parts) | -hp- | |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| S2 | 3101-0814 | | 1 | Switch: pushbutton (SENSITIVITY) Does not include mounted parts. | 76854 | obd |
| S2C1 | 0150-0012 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | 56289 | 29C214A3 |
| S2CR1 thru CR4 | 1901-0028 | | | Diode: Si 400 piv | 04713 | obd |
| S2R1 | 0811-1745 | | 1 | R: fxd prec ww 202.5 kΩ ±0.1% 1/8 W | 15909 | obd |
| S2R2 | 00740-82604 | | 1 | R: fxd ww 20.250 kΩ | -hp- | |
| S2R3 | 00740-82603 | | 1 | R: fxd ww 2.025 kΩ | -hp- | |
| S2R4 | 00740-82602 | | 1 | R: fxd ww 202.5 Ω | -hp- | |
| S2R5 | 0811-2095 | | 1 | R: fxd prec ww 22.75 Ω ±0.1% 1/8 W | 15909 | obd |
| S3 | 3100-0740 | | 1 | Switch: rotary (INTERNAL ALIGNMENT) | 76854 | JKN |
| S3R1, R2 | 0811-1110 | | 1 | R: matched set 7 resistors (also includes S4R1 thru S4R5) | -hp- | |
| S4 | 3100-1723 | | 1 | Switch: rotary (X1 VOLTAGE SET) Does not include mounted parts. | 76854 | obd |
| S4R1 thru R5 | 0811-1110 | | 1 | R: matched set 7 resistors (also includes S3R1 and S3R2) | -hp- | |
| S5 thru S8 | 3100-1724 | | 4 | Switch: rotary (VOLTAGE SET) Does not include mounted parts. | 76854 | obd |
| S5R1 thru R5 | 0811-1111 | | 1 | R: matched set 5 resistors (2 nd decade) | -hp- | |
| S6R1 thru R5 | 0811-1109 | | 1 | R: matched set 5 resistors ww (3 rd decade) | -hp- | |
| S7R1 | 0811-1737 | | 1 | R: fxd prec ww 1000 Ω ±0.025% 1/20 W | 15909 | obd |
| S7R2, R3 | 0811-1741 | | 2 | R: fxd prec ww 2000 Ω ±0.025% 1/20 W | 01686 | R344 |
| S7R4 | 0811-1743 | | 1 | R: fxd prec ww 4000 Ω ±0.025% 1/20 W | 01686 | R344 |
| S7R5 | 0811-1739 | | 1 | R: fxd prec ww 1111 Ω ±0.025% 1/20 W | 15909 | obd |
| S8R1 | 0811-1738 | | 1 | R: fxd prec ww 1000 Ω ±0.05% 1/20 W | 01686 | R344 obd |
| S8R2, R3 | 0811-1742 | | 2 | R: fxd prec ww 2000 Ω ±0.05% 1/20 W | 01686 | R344 obd |
| S8R4 | 0811-1744 | | 1 | R: fxd prec ww 4000 Ω ±0.05% 1/20 W | 01686 | R344 obd |
| S9 | 00740-61904 | | 1 | Switch assembly: (STANDARD VERNIER) Includes all mounted parts. | -hp- | |
| S9R1 thru R10 | 0683-1025 | | 10 | R: fxd comp 1000 Ω ±5% 1/4 W | 01121 | CB1025 |
| S9R11 thru R20 | 0757-0280 | | 10 | R: fxd met flm 1000 Ω ±1% 1/8 W | 19701 | MF5C T-O obd |
| S9R21 | 0811-1740 | | 1 | R: fxd prec ww 1111 Ω ±0.05% 1/20 W | 01686 | R344 obd |
| S10 | 3101-0014 | | 1 | Switch: pushbutton (GAIN CHECK) | 82389 | 4S-1106 |
| S11 | 3101-1071 | | 2 | Switch: pushbutton SPST (OUTPUT) | 000LO | 54-61681-26-A1G |
| S11C1 | 0150-0098 | | | C: fxd cer 0.01 μF ±20% 1000 vdcw | -hp- | |
| S11DS1 | 1450-0106 | | 2 | Lamp: neon (A1G) | | A1G |
| S11R1 | 0684-8231 | | | R: fxd comp 82 kΩ ±10% 1/4 W | 01121 | CB8231 |
| S12 | 3101-1071 | | | Switch: pushbutton SPST (POWER) | 000LO | 54-61681-26-A1G |
| S12DS1 | 1450-0106 | | | Lamp: neon (A1G) | | A1G |
| S13 | 3101-0033 | | 1 | Switch: slide 115 - 230 V DPDT | -hp- | |
| T1 | 9100-0305 | | 1 | Transformer: power | -hp- | |
| T2 | 9100-0306 | | 1 | Transformer: power | -hp- | |
| T3 | 9100-1320 | | 1 | Transformer: pulse coupling | -hp- | |
| T4 | 9130-0037 | | 1 | Transformer: pulse output | -hp- | |
| W1 | 8120-0078 | | 1 | Assembly: cable power cord black 3 pin | 70903 | KH-4147 |
| Z1 | 1901-0161 | | 1 | Diode:assembly: Si 100 piv 10 A bridge | 04713 | SDA 10047 |

Table 6-2. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| **MISCELLANEOUS** | | | | | | |
| | 1200-0038 | | 1 | Socket: 12 pin (for A13) | 02660 | 77-MIP-12TM-1005 |
| | 1251-0208 | | 3 | Connector: 22 pin (for A1, A7, A8) | 95354 | SD-622-UR (1158) |
| | 1251-0435 | | 5 | Connector: 22 pin (for A2 thru A6) | 95354 | SD-622W (125) (1158) |
| | 5000-4932 | | 1 | Extraator: PC Board | -hp- | |
| | 5060-0776 | | 1 | Rack Mounting Kit: 7 in. | -hp- | |
| | 00740-66535 | | 1 | Extender: PC Board, 22 pin | -hp- | |
| | 00740-90002 | | 1 | Manual: Operating and Service | -hp- | |
| | 00740-90301 | | 1 | Tag: Instruction | -hp- | |

# SECTION VII
# CIRCUIT DIAGRAMS

## 7-1. INTRODUCTION.

7-2. This section contains the circuit diagrams necessary for the operation and maintenance of the Model 740B. Included are block, functional, schematic, and component location diagrams.

### 7-3. BLOCK DIAGRAMS.

7-4. The block diagrams shows the relationship between the basic circuits in the Model 740B in the different modes of operation.

### 7-5. FUNCTIONAL DIAGRAM.

7-6. The overall operation of the Model 740B is shown on the functional diagram. Assemblies and significant portions of assemblies such as amplifiers and power supplies are not shown in schematic form, but are shown as triangles and blocks. Circuit elements which do not lend themselves to a simplified presentation, such as relays and switches, are shown in schematic form. Controls and adjustment points related to maintenance are identified on this diagram.

### 7-7. SCHEMATIC DIAGRAMS.

7-8. The circuits contained within individual replaceable assemblies are shown in the schematic diagrams. Circuits external to the assembly are shown to show the complete function of the assembly. The schematic diagrams are arranged in ascending order of reference designation.

### 7-9. COMPONENT LOCATION DIAGRAMS.

7-10. Each component in the Model 740B is located by reference designation. The component location diagrams adjacent to the schematic diagrams show the physical location of each component.

## GENERAL NOTES

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.
2. COMPONENT VALUES ARE SHOWN AS FOLLOWS UNLESS OTHERWISE NOTED.
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
3. DENOTES ASSEMBLY.
4. DENOTES MAIN SIGNAL PATH.
5. DENOTES DC FEEDBACK PATH.
6. DENOTES AC FEEDBACK PATH.
7. DENOTES FRONT PANEL MARKING.
8. DENOTES REAR PANEL MARKING.
9. DENOTES SCREWDRIVER ADJUST.
10. DENOTES FRONT PANEL CONTROL.
11. 924 DENOTES WIRE COLOR: COLOR CODE SAME AS RESISTOR COLOR CODE. FIRST NUMBER IDENTIFIES BASE COLOR, SECOND NUMBER IDENTIFIES WIDER STRIP, THIRD NUMBER IDENTIFIES NARROWER STRIP. (e.g. 924 = WHITE, RED, YELLOW.)
12. * DENOTES FACTORY SELECTED VALUE. SEE REPLACEMENT OF FACTORY SELECTED COMPONENTS, SECTION V, FOR REPLACEMENT INSTRUCTIONS.
13. SYSTEM GROUNDS ARE AS FOLLOWS:
    CHASSIS GROUND
    1 CIRCUIT GROUND, 2 REFERENCE SUPPLY COMMON — ELECTRICALLY COMMON IN STD MODE
    3 GUARD, 4 POWER SUPPLY GROUND — ELECTRICALLY COMMON (ALL MODES)
14. VOLTAGES INDICATED IN RED ARE MEASURED WITH A HIGH IMPEDANCE FLOATING VOLTMETER. SEE CORRESPONDING SCHEMATIC NOTES FOR VOLTAGE GROUND REFERENCE POINT. INDICATED VOLTAGES ARE TYPICAL AND WILL VARY SLIGHTLY FROM INSTRUMENT TO INSTRUMENT.
15. DENOTES WAVESHAPE; SEE WAVESHAPE DRAWING. WAVESHAPES SHOULD BE OBSERVED WITH A WIDE BANDWIDTH FLOATING OSCILLOSCOPE. SEE CORRESPONDING SCHEMATIC NOTES FOR WAVESHAPE GROUND REFERENCE POINT. WAVESHAPES ARE TYPICAL AND WILL VARY SLIGHTLY FROM INSTRUMENT TO INSTRUMENT.

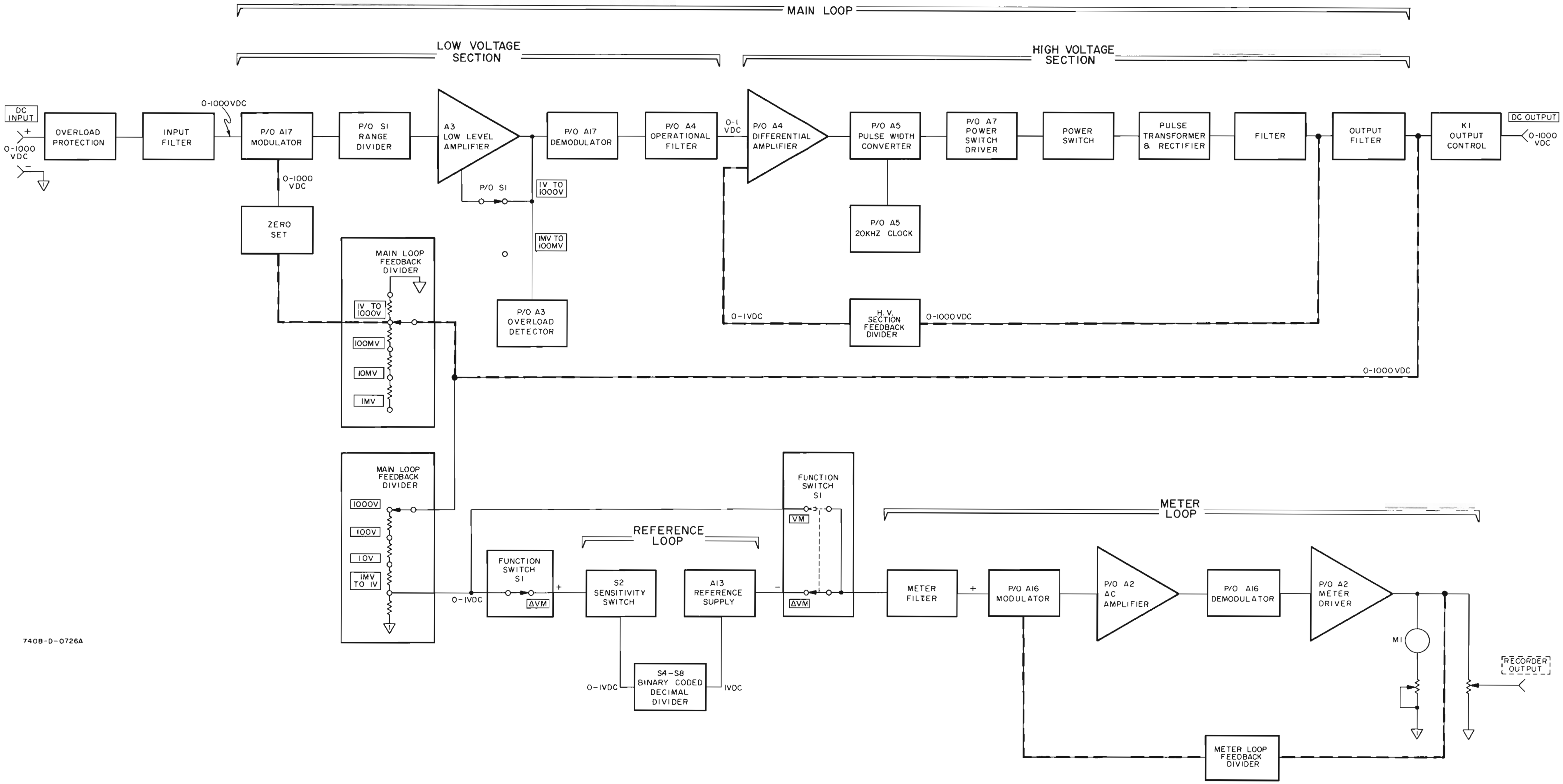



Figure 7-1. DC Voltmeter and Differential Voltmeter Block Diagram

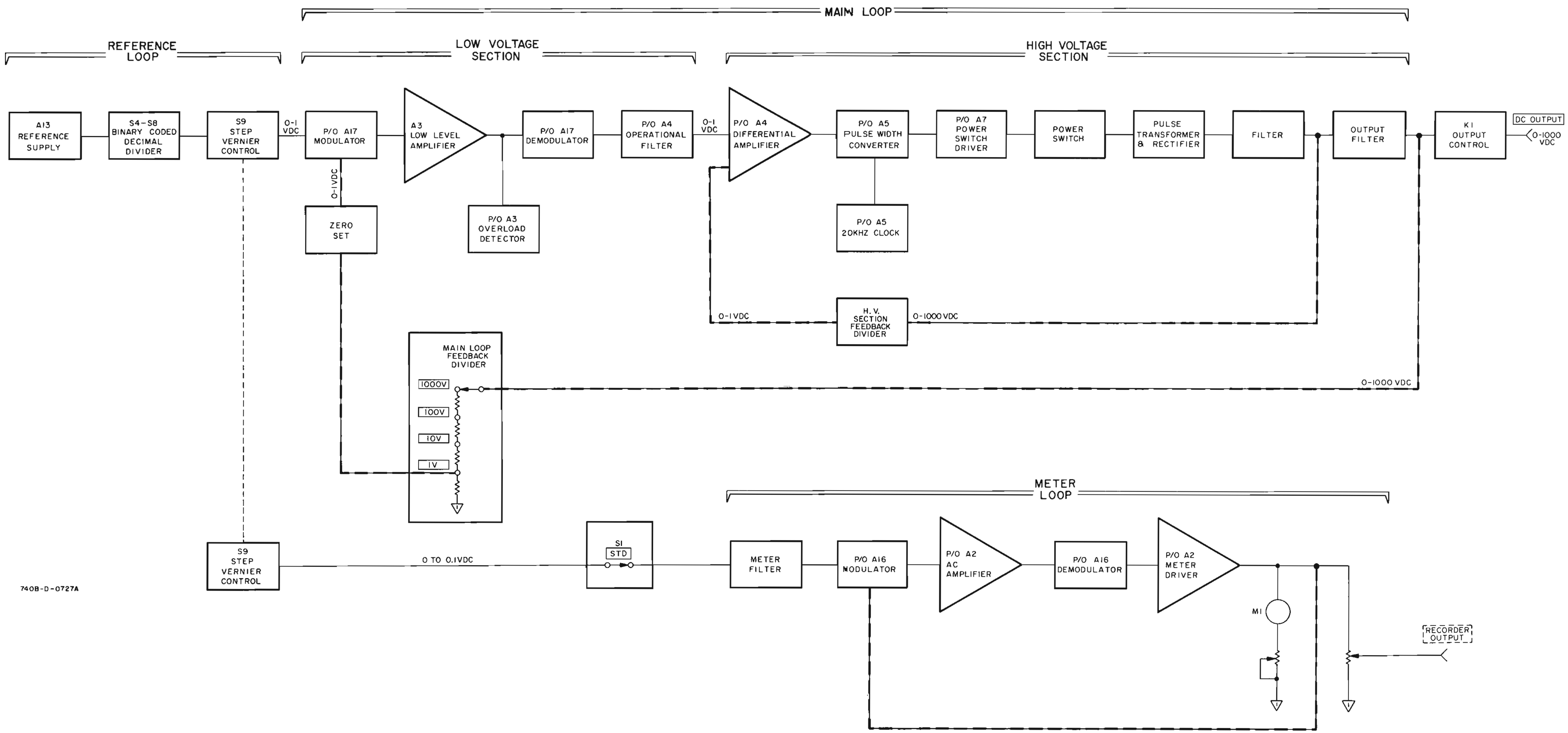
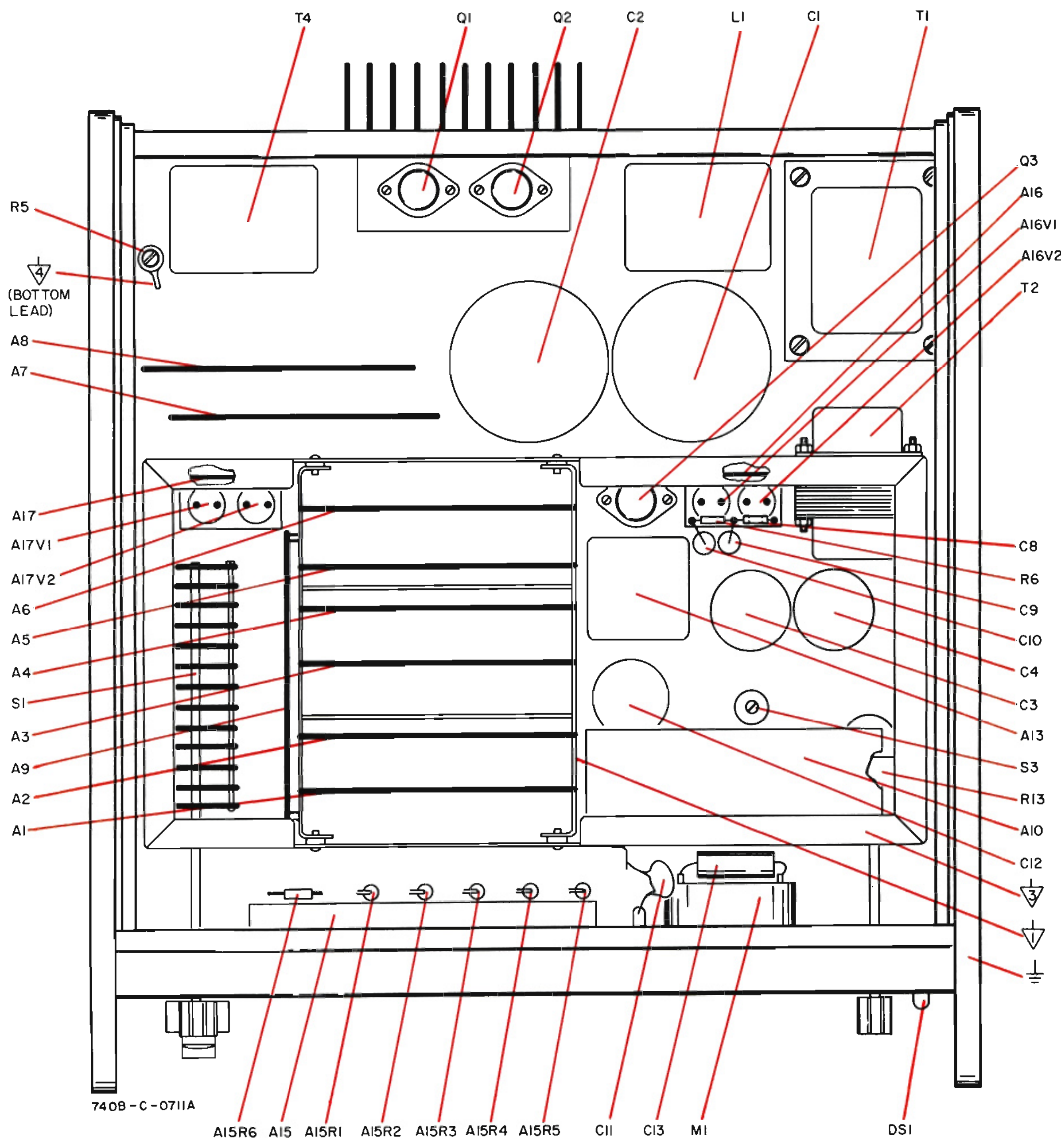
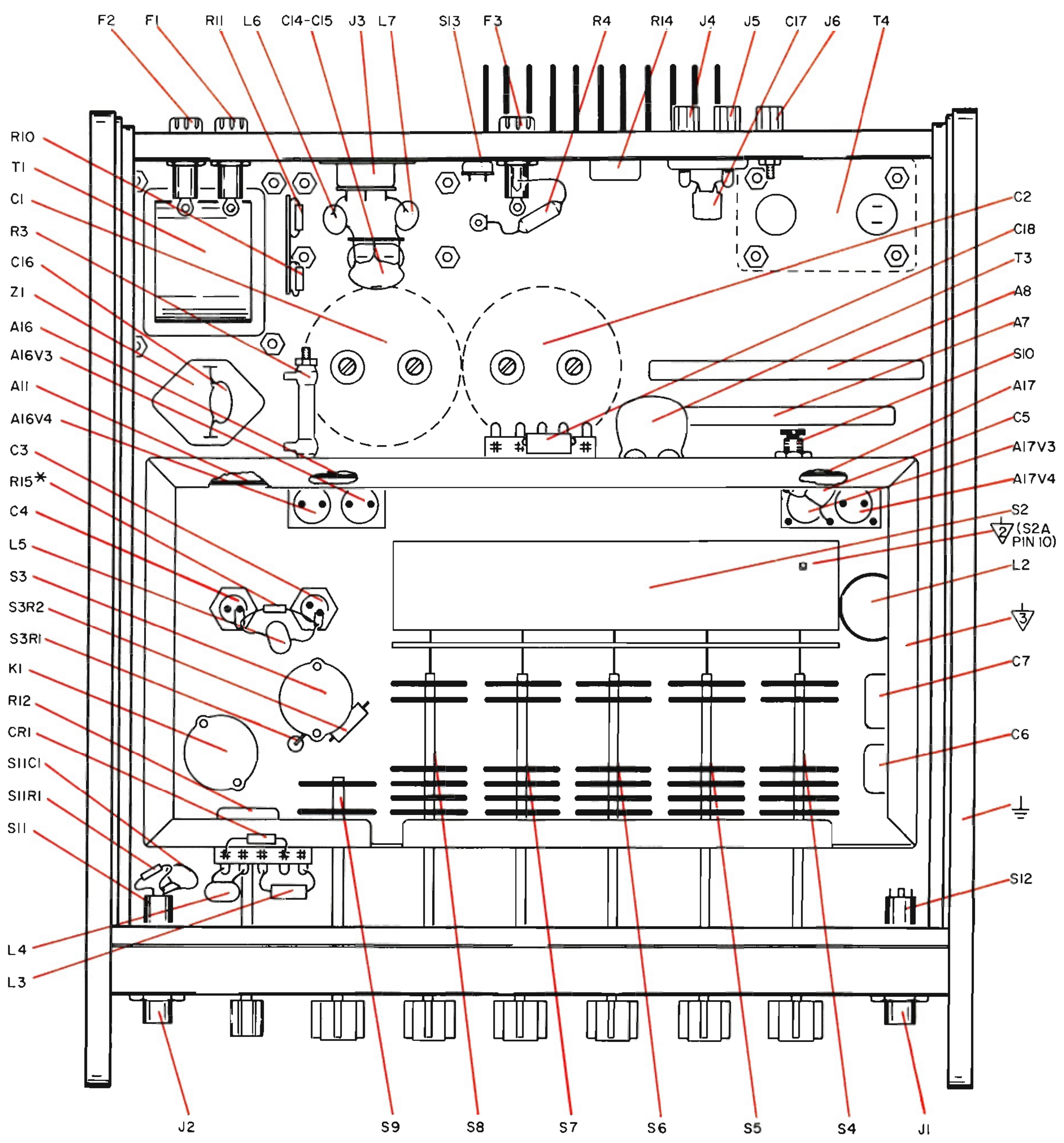


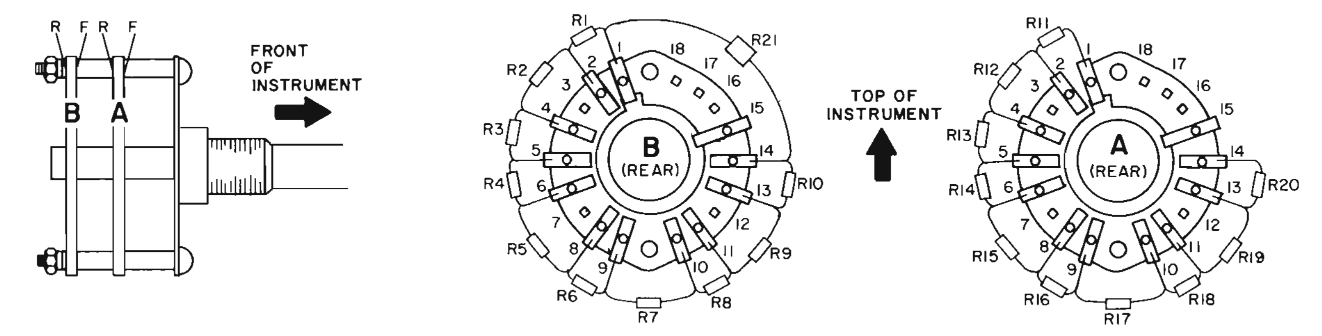

Figure 7-2. DC Standard Block Diagram




TOP VIEW




BOTTOM VIEW

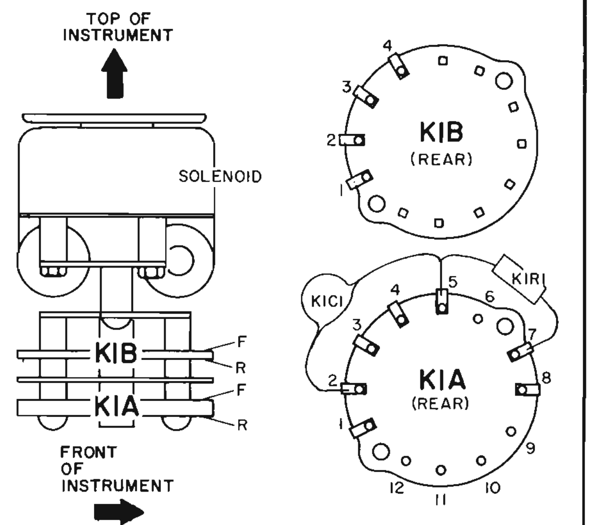



S9, STANDARD VERNIER SWITCH

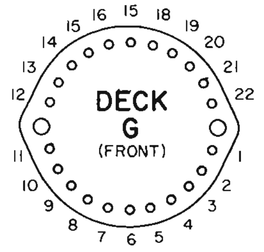
RANGE/FUNCTION SWITCH, S1, COMPONENT LOCATIONS

| REFERENCE DESIGNATOR | VALUE | CONNECTED BETWEEN PINS |
|---|---|---|
| C1 | 0.1 μF | F(F-7) and G(R-14) |
| C2 | 0.01 μF | F(F-8) and F(F-10) |
| R1 | 160 kΩ | F(F-10) and F(F-12) |
| R2 | 1.6 MΩ | F(F-5) and F(F-7) |
| R3 | 16 kΩ | F(R-2) and G(R-3) |
| R4 | 1.6 kΩ | F(R-4) and G(R-5) |
| R5 | NOT ASSIGNED | |
| R6 | NOT ASSIGNED | |
| R7 | 100 kΩ | I(F-8) and J(R-8) |
| R8 | 2.2 MΩ | H(F-2) and H(F-11) |
| R9 | 2.2 MΩ | H(F-4) and H(F-8) |
| R10 | 8.2 kΩ | H(F-8) and H(F-11) |
| R11 | 10 kΩ | D(F-7) and D(F-8) |
| R12 | 100 kΩ | D(F-8) and D(F-9) |
| R13 | 560 kΩ | C(F-10) and D(F-10) |
| R14 | 430 kΩ | C(F-10) and D(F-9) |
| R15 | 18 Ω | D(R-11) and D(R-12) |
| R16 | 180 Ω | D(R-4) and D(R-5) |
| R17 | 4.7 kΩ | E(F-8) and E(F-10) |
| R18 | 18 kΩ | E(F-6) and E(F-8) |
| R19 | 120 Ω | Sw. Shaft and J(R-5) |
| *R20 | 10 Ω | G(F-7) and G(F-15) |

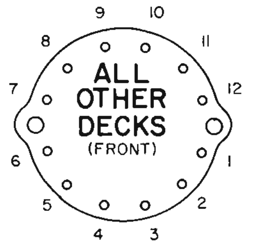
* SERIAL NUMBERS 610-00376 AND ABOVE. EARLIER SERIAL NUMBERS DO NOT HAVE THIS PART.

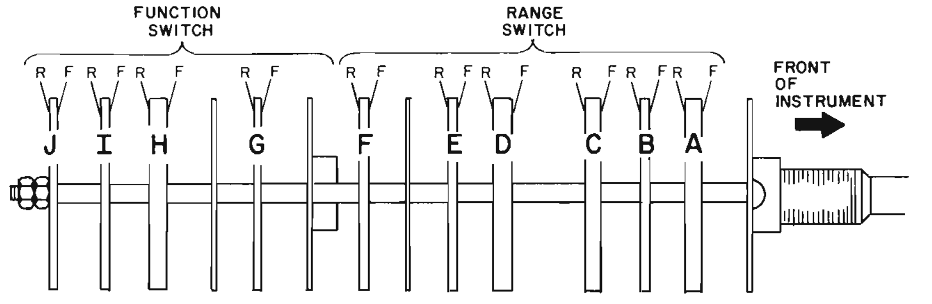



K1, OUTPUT ROTARY SWITCH



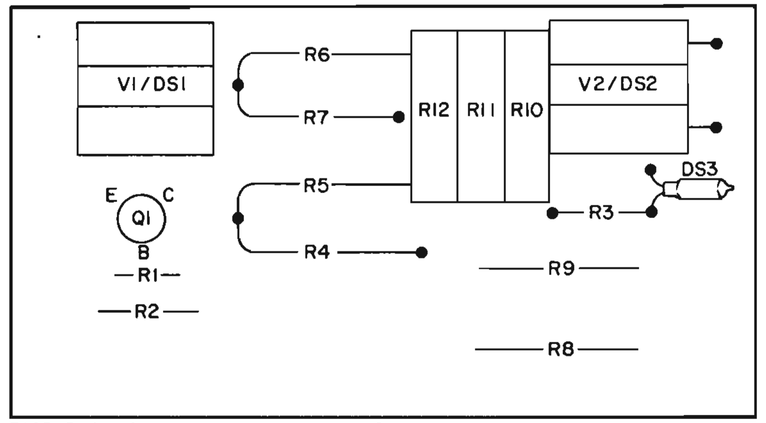

ALL PINS ARE NUMBERED CLOCKWISE AS VIEWED FROM FRONT OF INSTRUMENT.




S1, RANGE/FUNCTION SWITCH

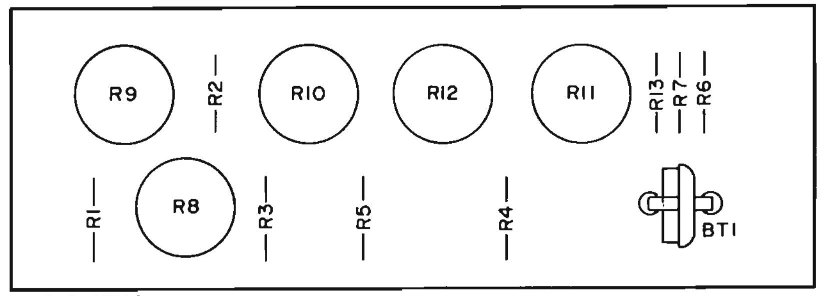
Figure 7-3. Functional and Component Location Diagram (Sheet 1 of 4)



740B-B-07511A

A9

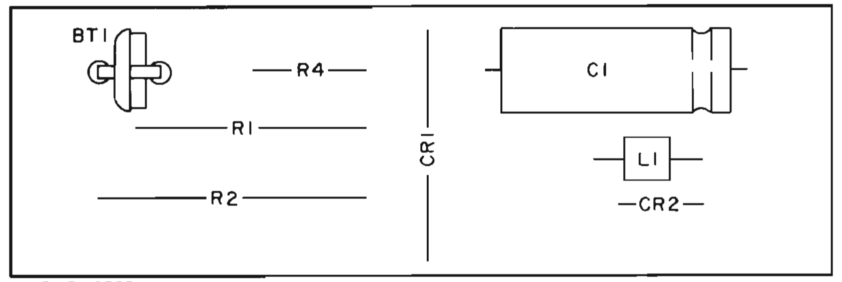
hp PART NO. 00740-66529



740B-B-0752A

A10

hp PART NO. 00740-66530



740B-B-0753A

A11

hp PART NO. 00740-66531

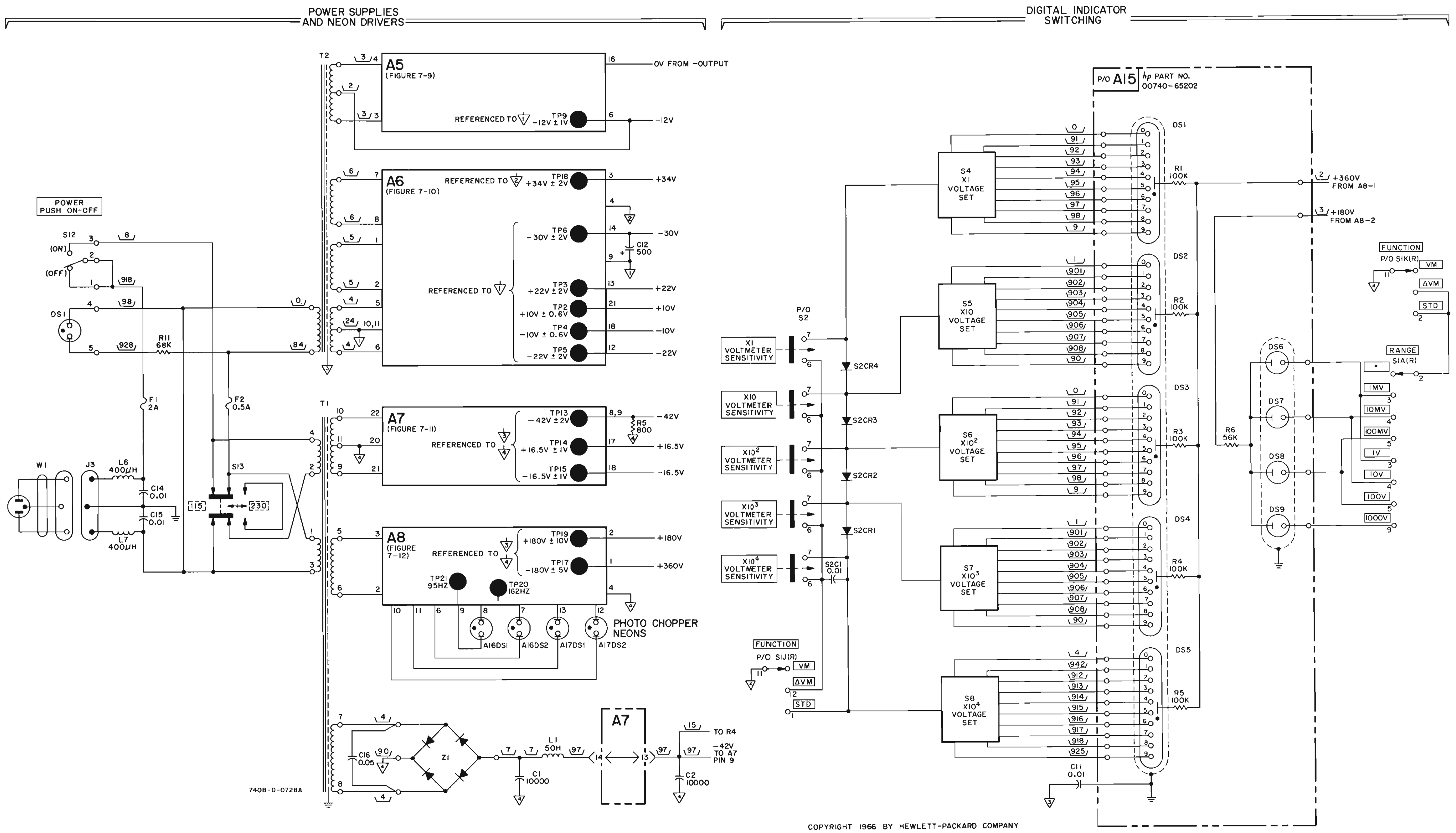





Figure 7-3. Functional and Component Location Diagram (Sheet 2 of 4)

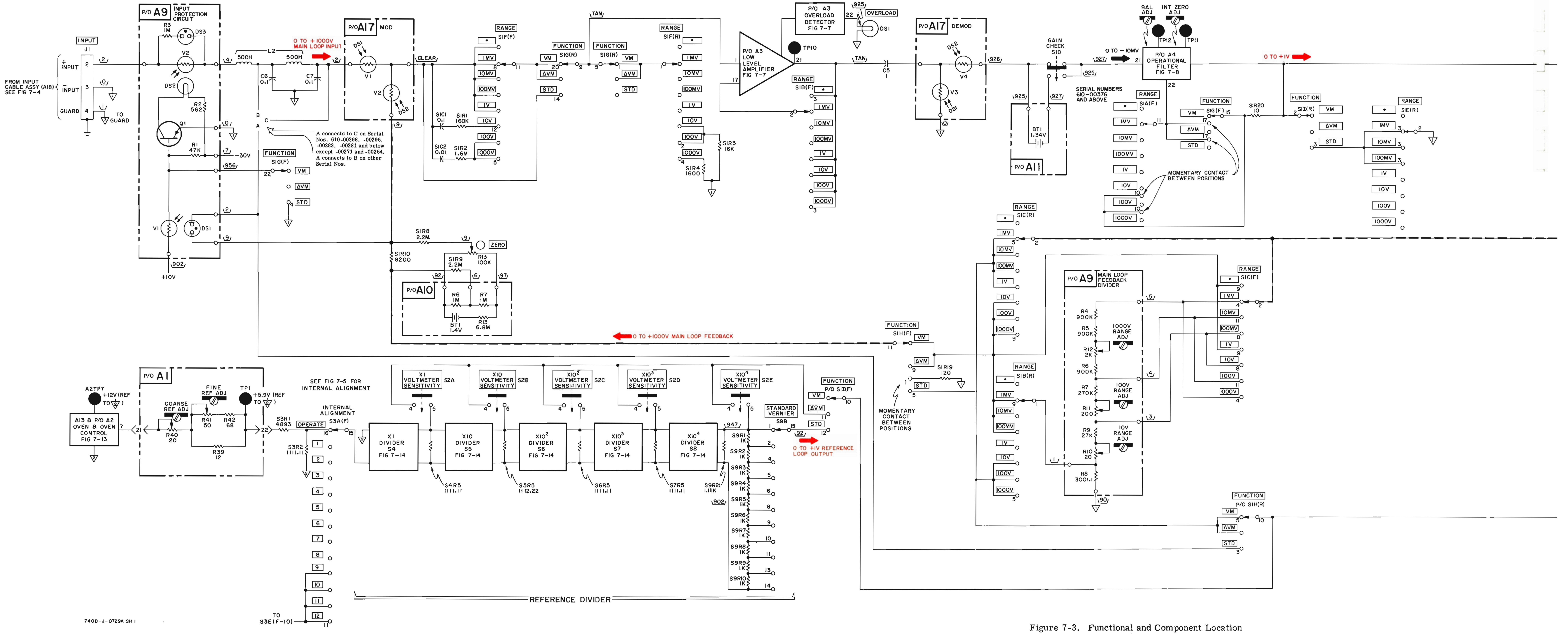



Figure 7-3. Functional and Component Location Diagram (Sheet 3 of 4)

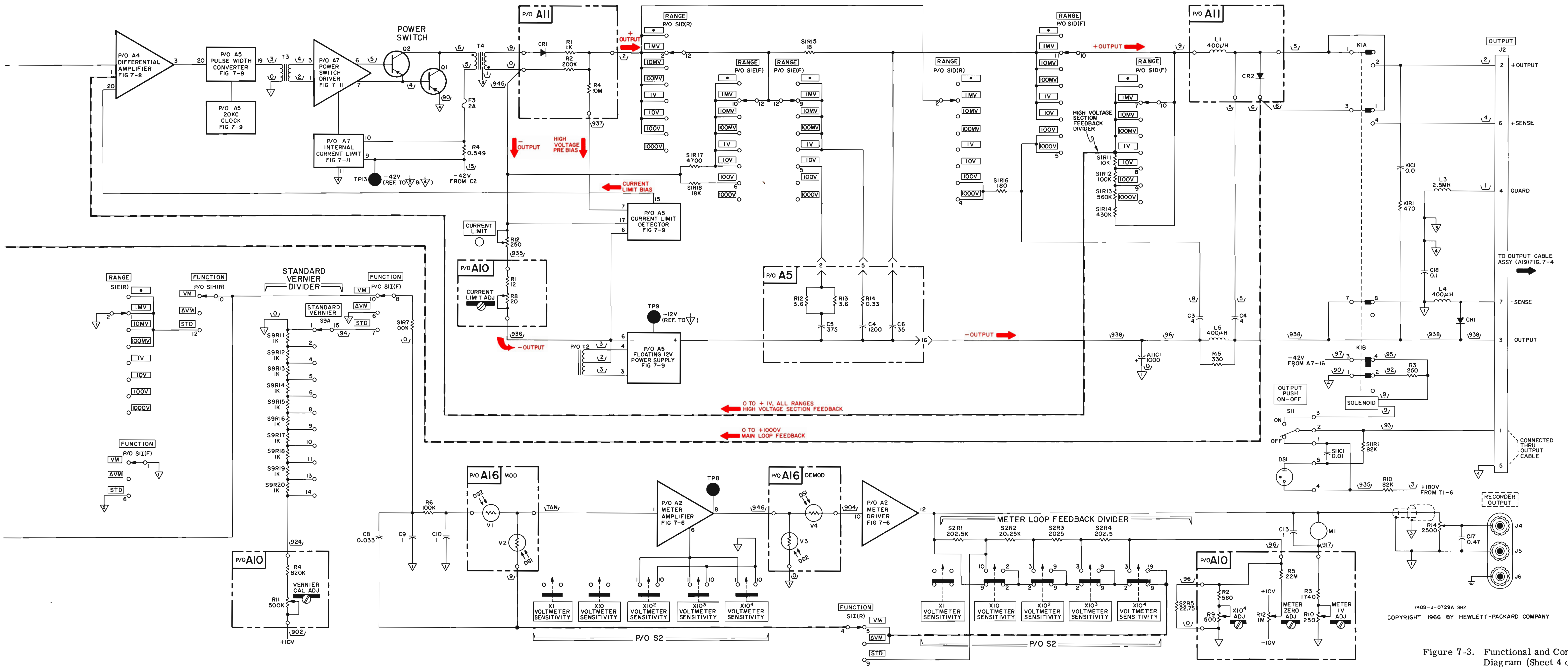


Figure 7-3. Functional and Component Location Diagram (Sheet 4 of 4)

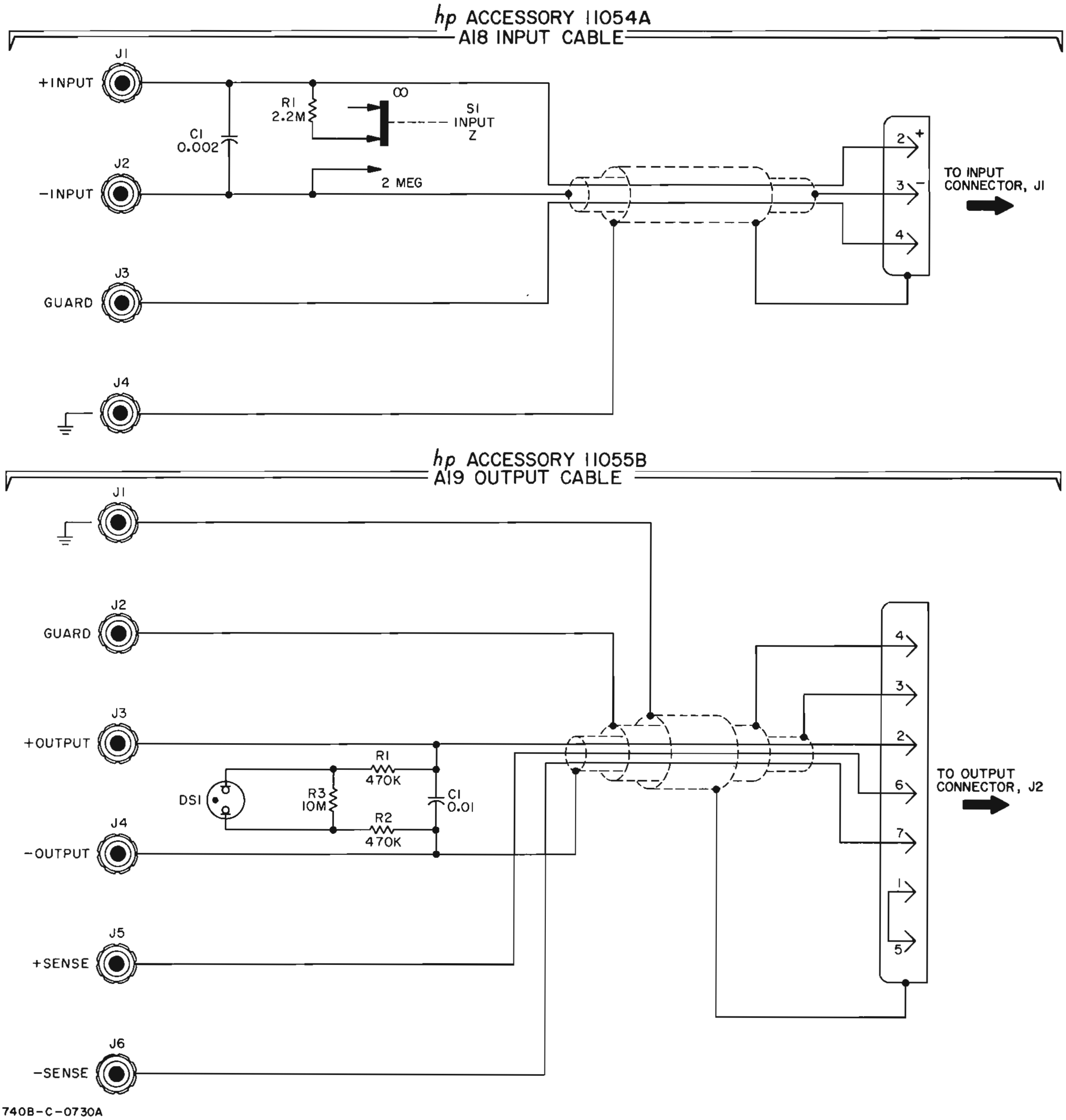
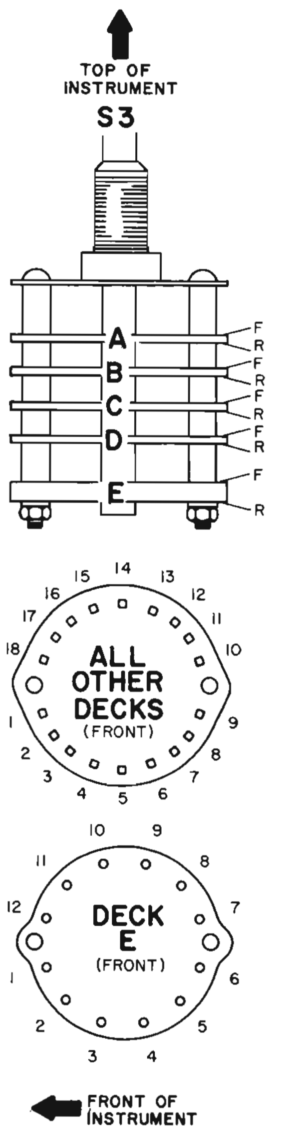
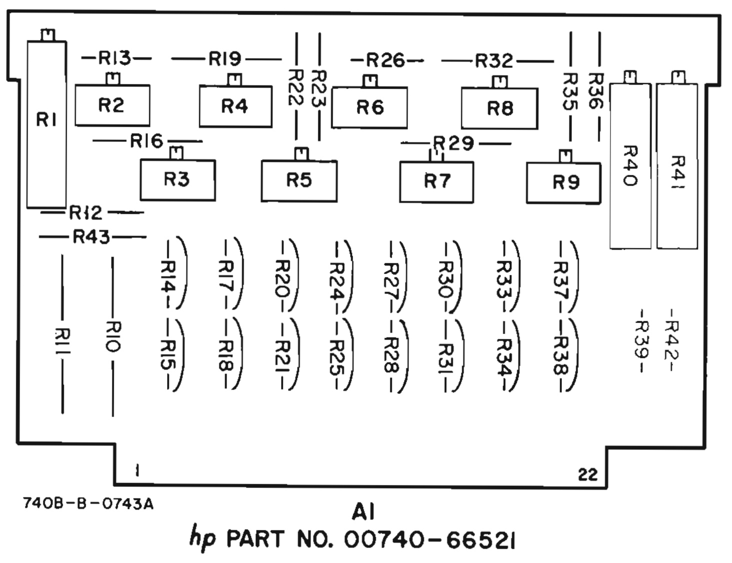


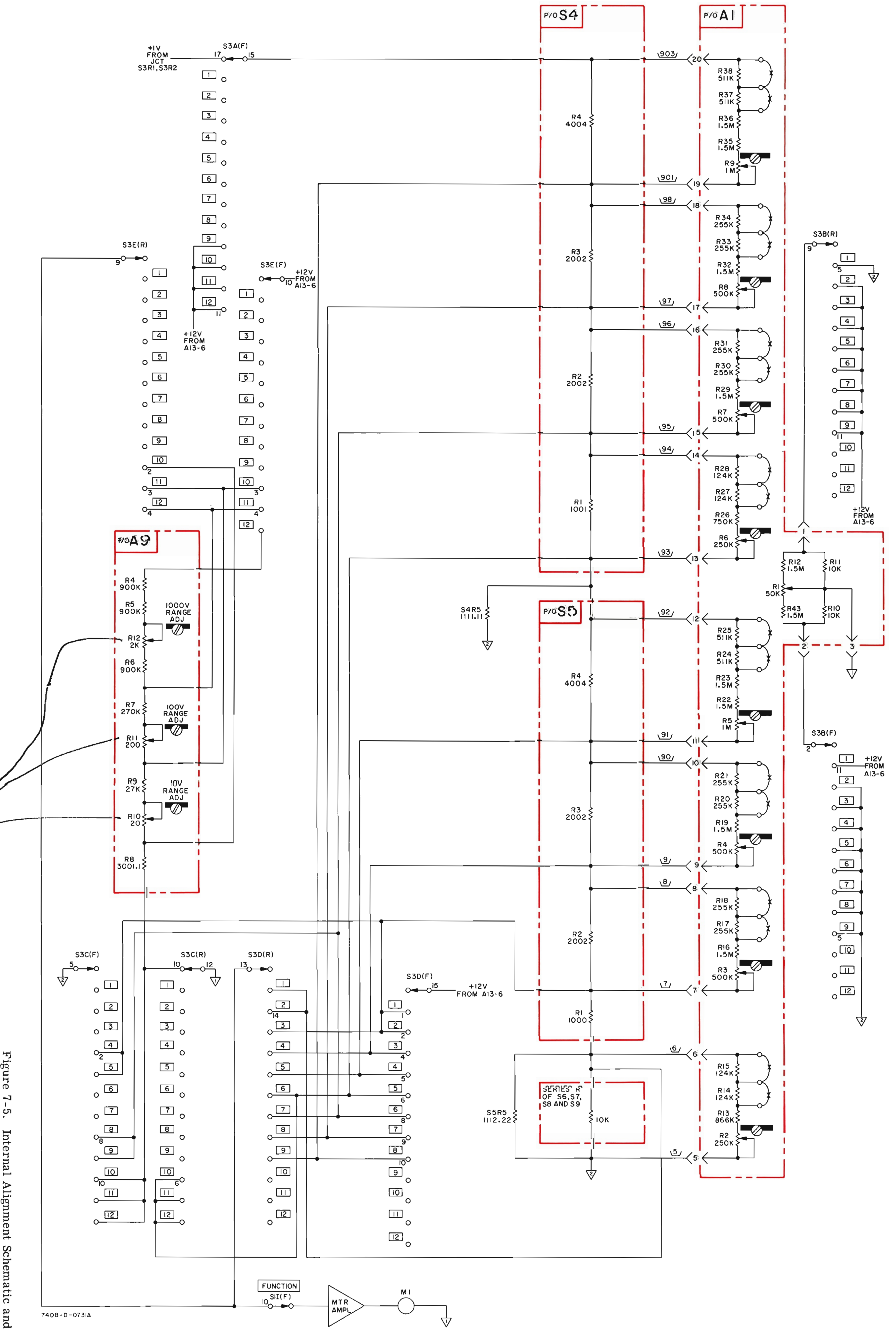

Figure 7-4. Input and Output Cable Assemblies Schematic Diagram




NOTES: FIGURE 7-5

1. DENOTES JUMPER WIRE. JUMPER WIRE MAY NOT BE PRESENT. (See Paragraph 5-63).
2. INDICATED VOLTAGES ARE MEASURED WITH RESPECT TO AND IN STD MODE; ONLY IN OTHER MODES.
3. S4, S5, S6, S7 and S8 (VOLTAGE SET SWITCHES) MUST BE IN FIRST POSITION ([0]) FOR INTERNAL CALIBRATION.

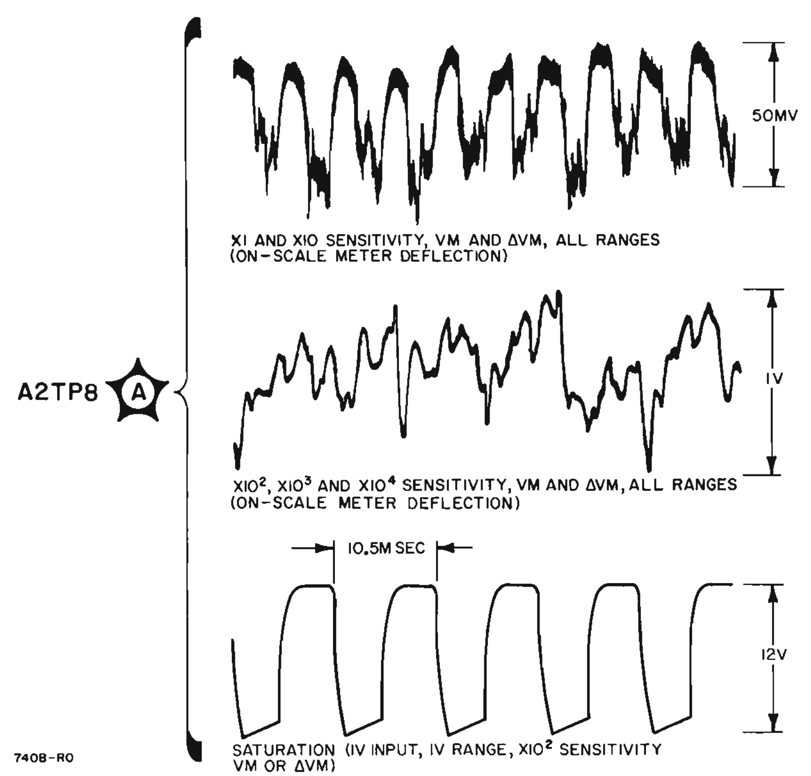


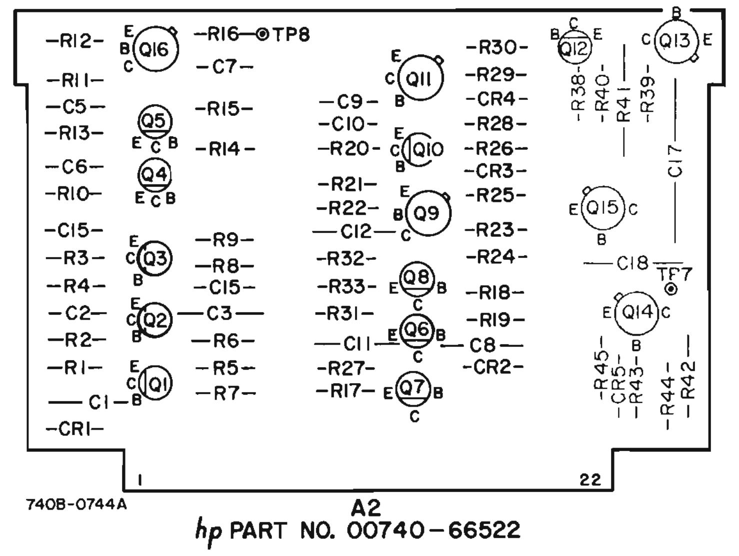

01794-1

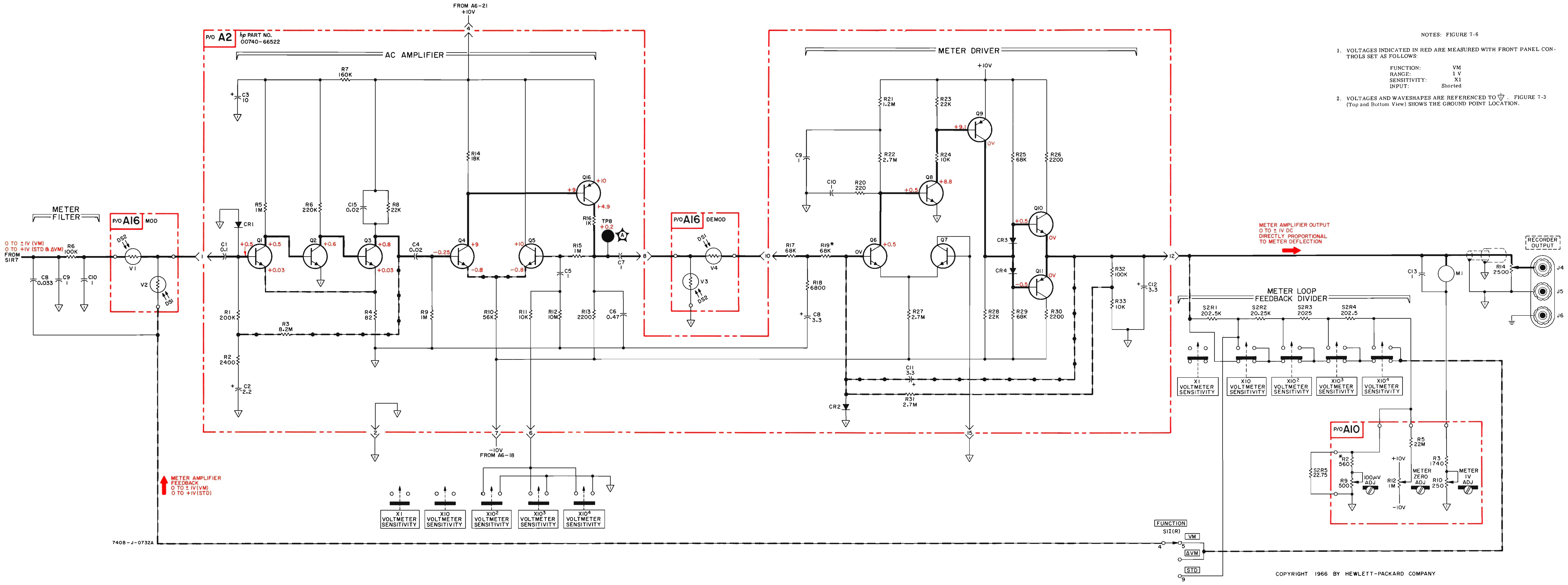
2.S.5-14

(49)

Figure 7-5. Internal Alignment Schematic and Component Location Diagram




NOTES: FIGURE 7-6

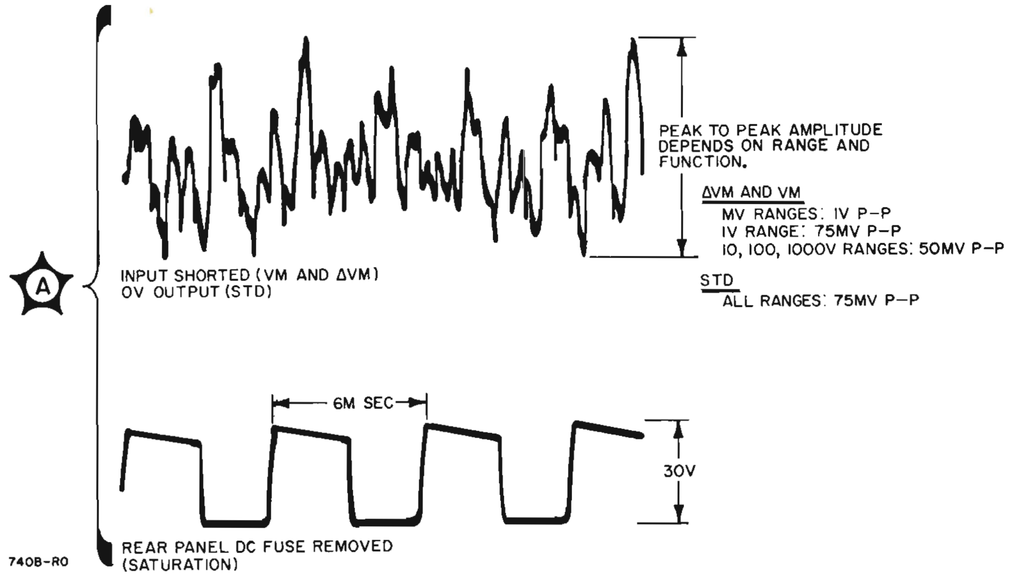
1. VOLTAGES INDICATED IN RED ARE MEASURED WITH FRONT PANEL CONTROLS SET AS FOLLOWS:

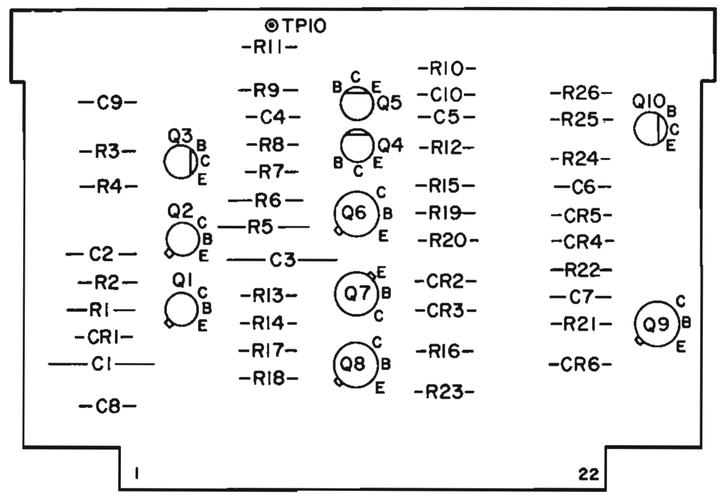
| | |
|---|---|
| FUNCTION: | VM |
| RANGE: | 1 V |
| SENSITIVITY: | X1 |
| INPUT: | Shorted |

2. VOLTAGES AND WAVESHAPES ARE REFERENCED TO ▽. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATION.

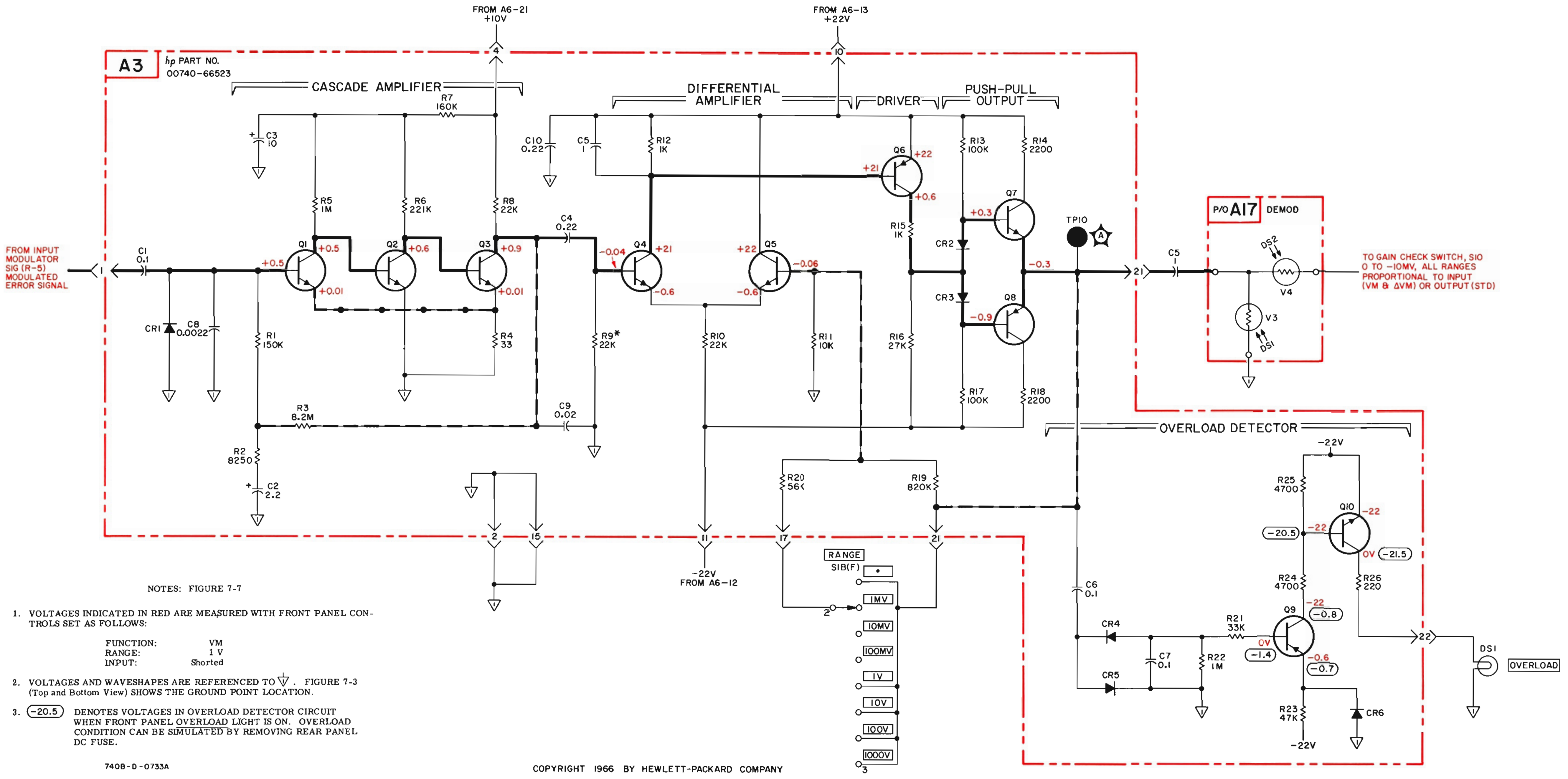


Figure 7-6. Meter Amplifier (p/o A2) Schematic and Component Location Diagram




A3
hp PART NO. 00740-66523




NOTES: FIGURE 7-7

1. VOLTAGES INDICATED IN RED ARE MEASURED WITH FRONT PANEL CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| FUNCTION: | VM |
| RANGE: | 1 V |
| INPUT: | Shorted |

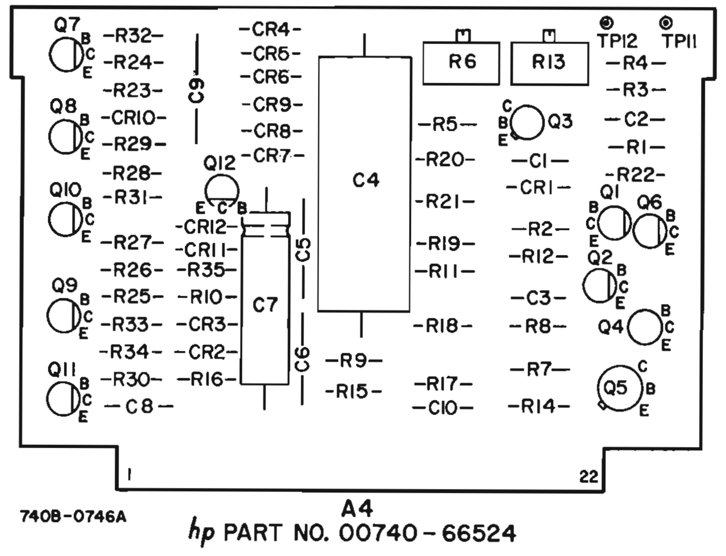
2. VOLTAGES AND WAVESHAPES ARE REFERENCED TO ⏚. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATION.

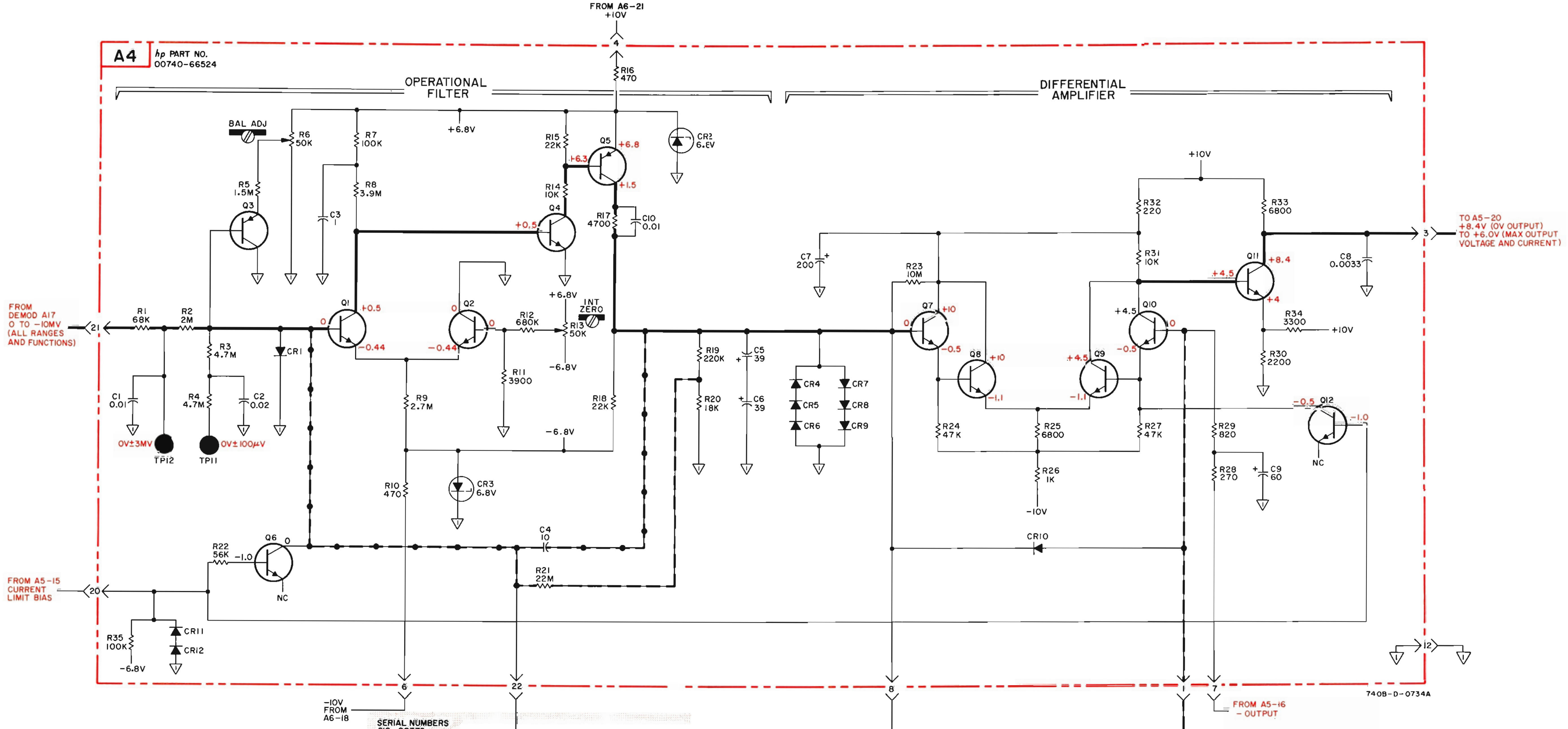
3. (-20.5) DENOTES VOLTAGES IN OVERLOAD DETECTOR CIRCUIT WHEN FRONT PANEL OVERLOAD LIGHT IS ON. OVERLOAD CONDITION CAN BE SIMULATED BY REMOVING REAR PANEL DC FUSE.

740B-D-0733A



Figure 7-7. Low Level Amplifier (A3) Schematic and Component Location Diagram




NOTES: FIGURE 7-8

1. VOLTAGES INDICATED IN RED ARE MEASURED WITH FRONT PANEL CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| FUNCTION: | VM |
| RANGE: | 1 V |
| INPUT: | Shorted |

2. VOLTAGES ARE REFERENCED TO ⏚. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATION.



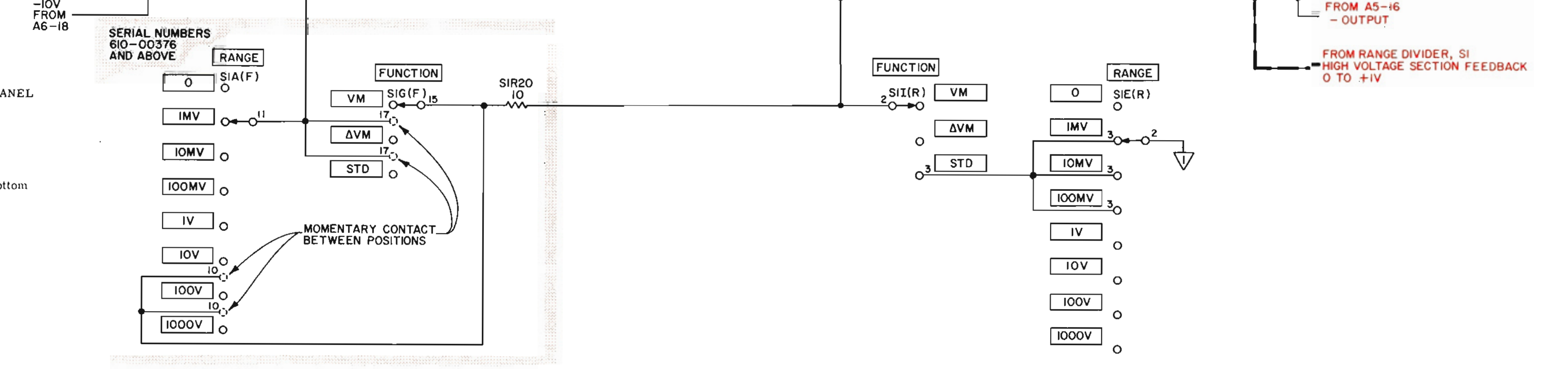



Figure 7-8. Operational Filter and Differential Amplifier (A4) Schematic and Component Location Diagram

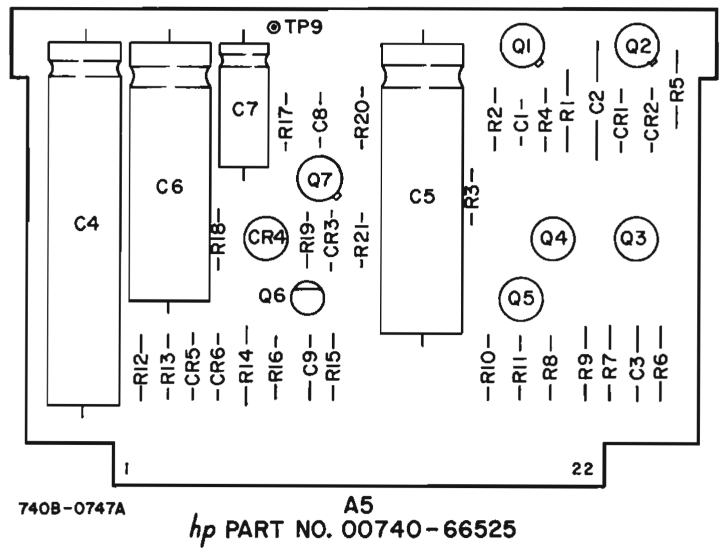
NOTES: FIGURE 7-9

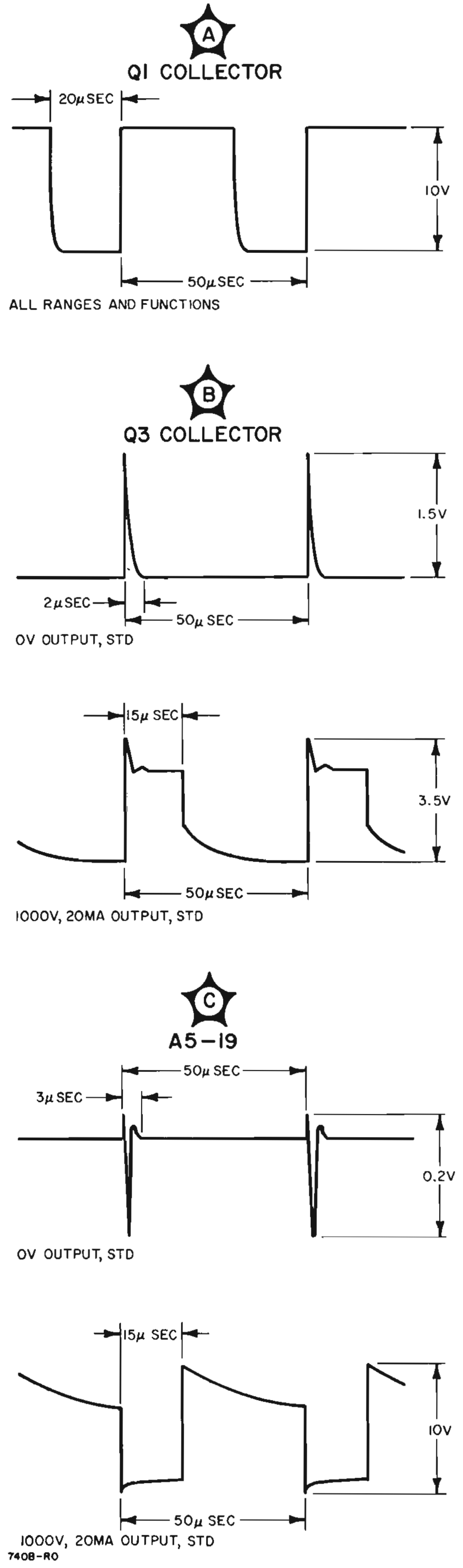
1. VOLTAGES INDICATED IN RED ARE MEASURED WITH FRONT PANEL CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| FUNCTION: | STD |
| RANGE: | 1 V |
| VOLTAGE SET: | .00000 |

2. VOLTAGES AND WAVESHAPES ARE REFERENCED TO ⏚. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATION.

3. (-12) DENOTES VOLTAGES IN CURRENT LIMIT DETECTOR CIRCUIT WHEN CURRENT LIMIT IS EXCEEDED (10 V OUTPUT, 100 Ω LOAD). INDICATED VOLTAGES WILL VARY WITH DEGREE OF OVERLOAD.



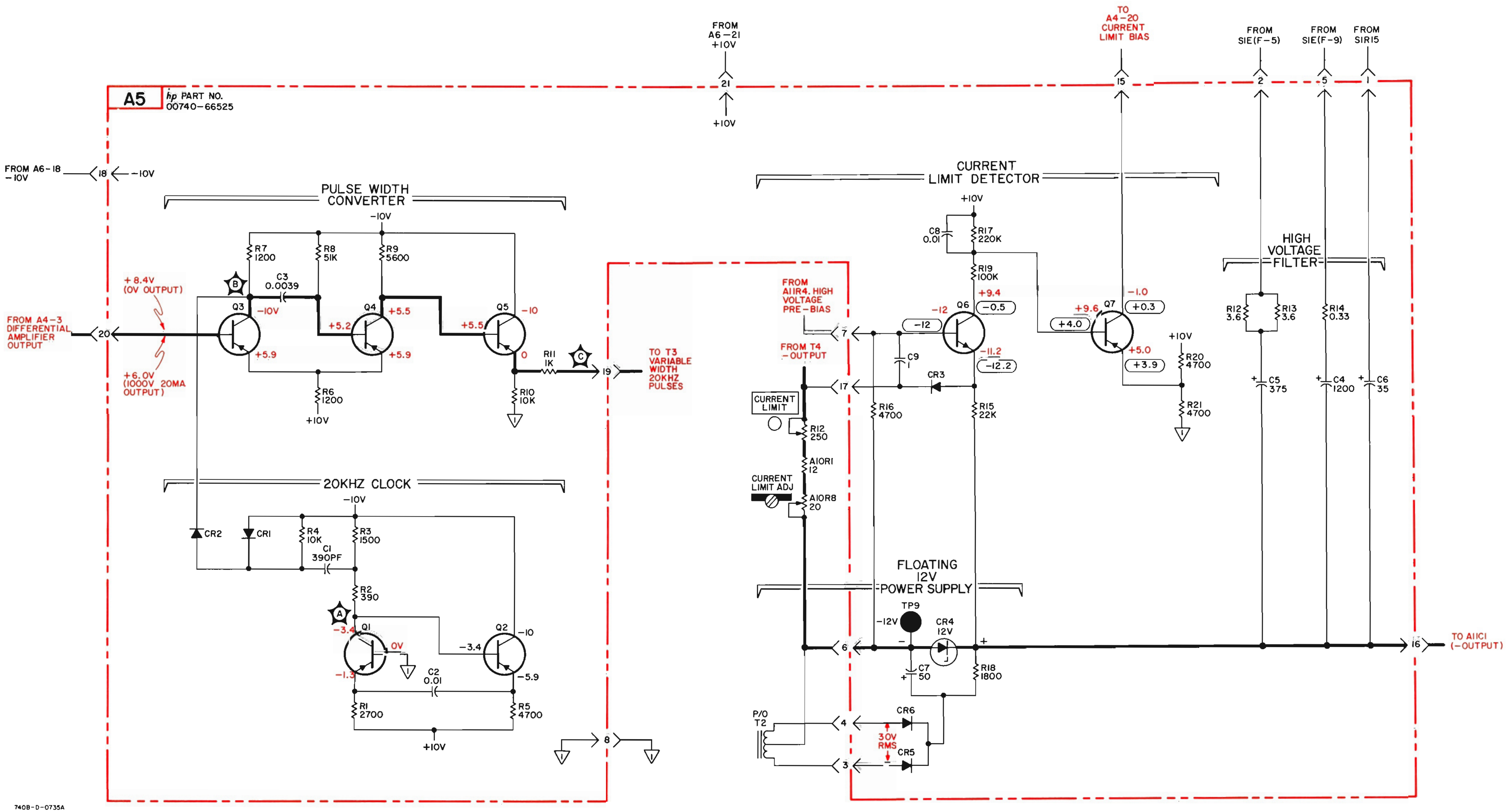
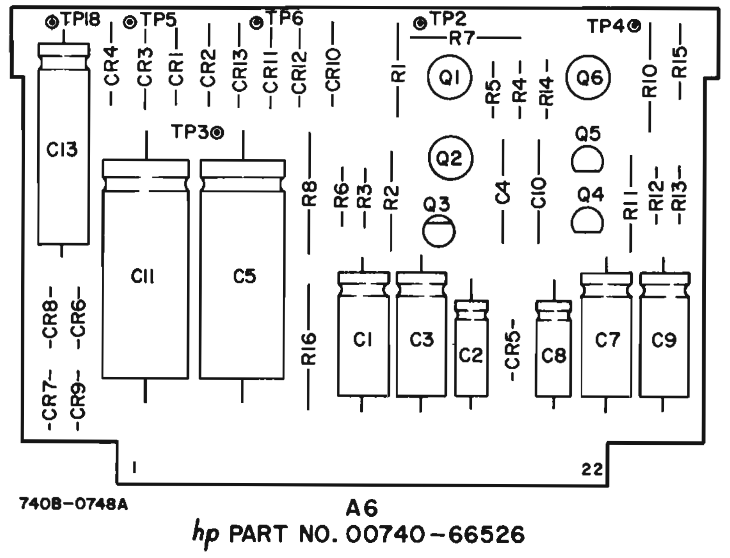
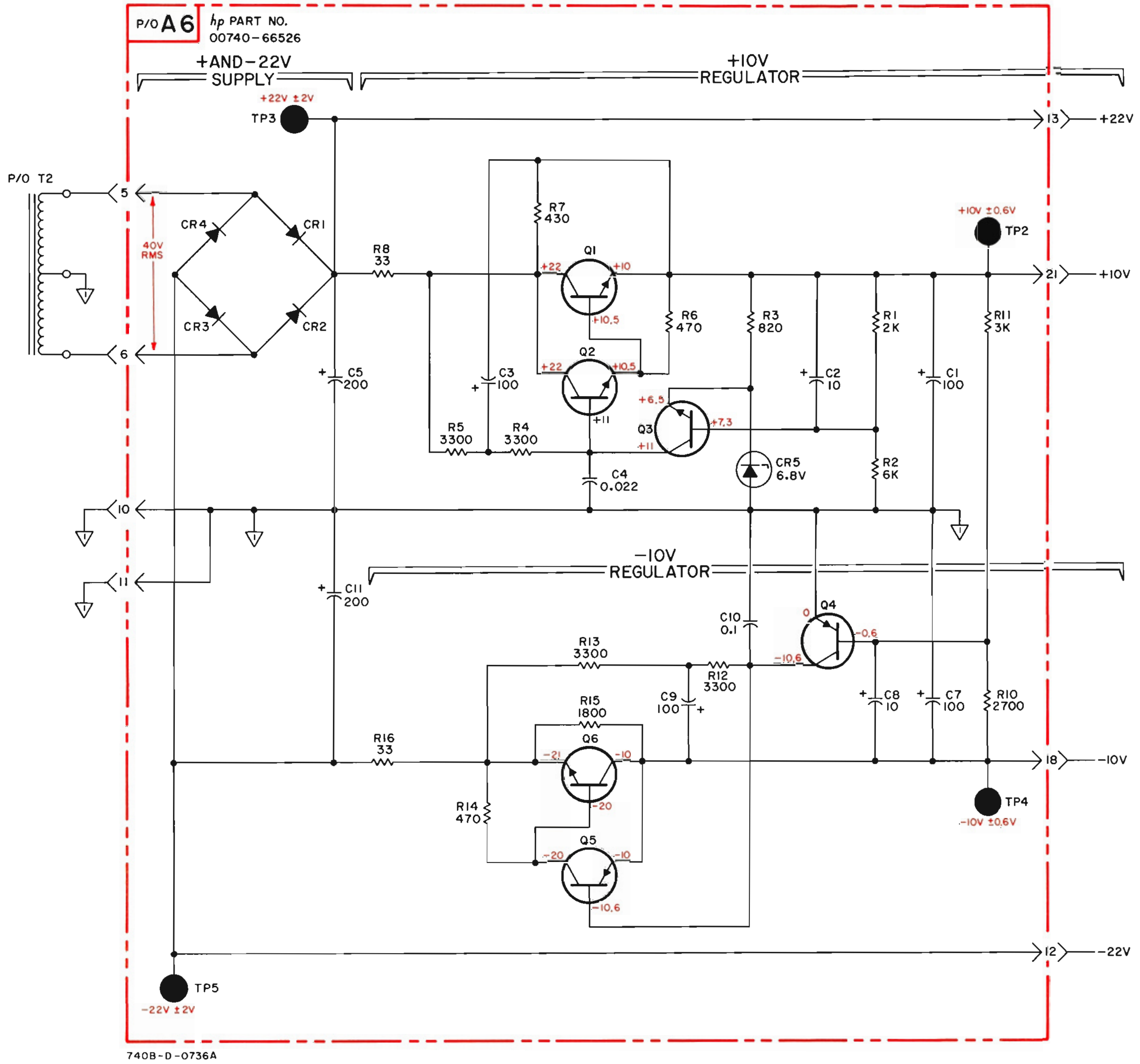
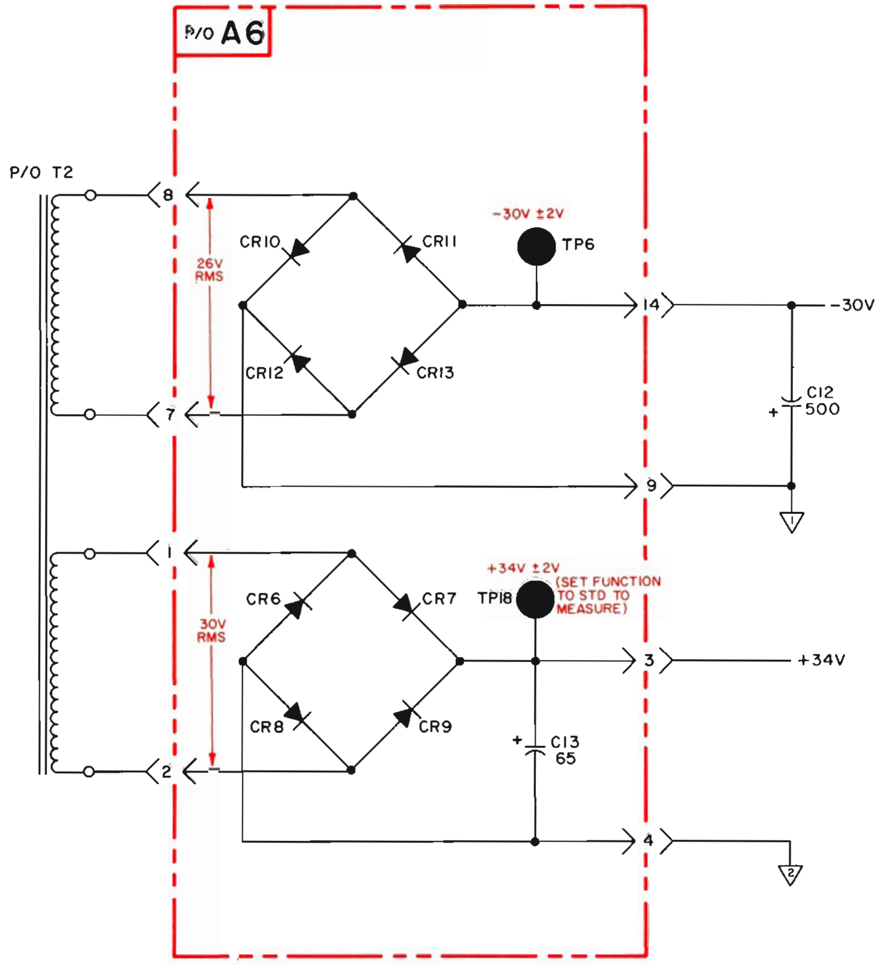






Figure 7-9. Pulse Width Converter, 20 kHz Clock and External Current Limit (A5) Schematic and Component Location Diagram




NOTES: FIGURE 7-10

1. VOLTAGES INDICATED IN RED ARE REFERENCED TO . FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATION.
2. AND ARE ELECTRICALLY COMMON IN STD MODE.



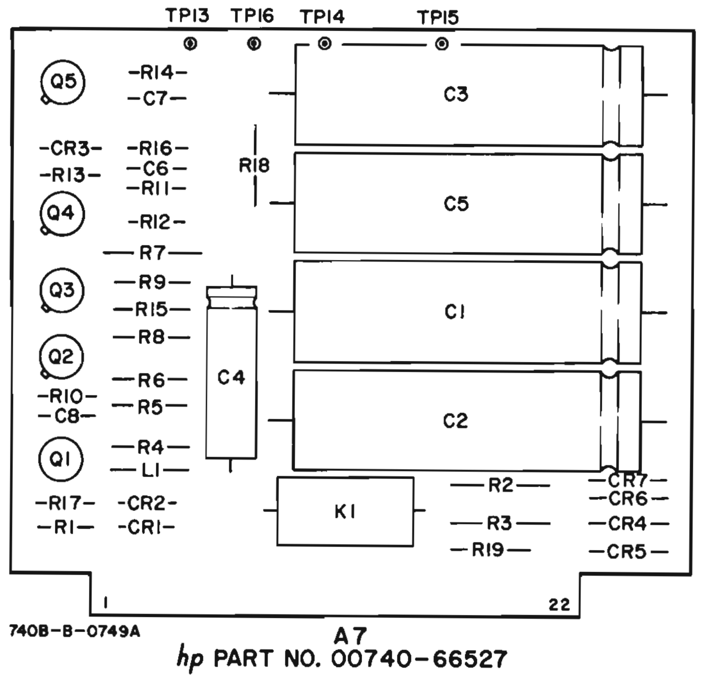
Figure 7-10. Guarded Power Supply (A6) Schematic and Component Location Diagram

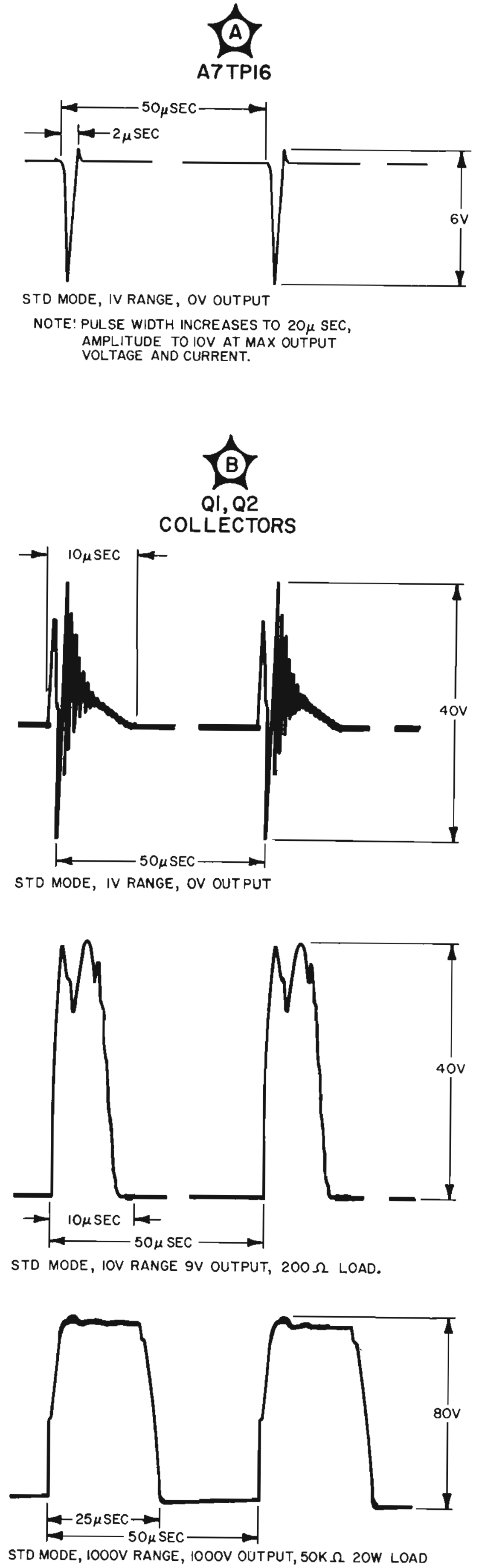
NOTES: FIGURE 7-11

1. VOLTAGES INDICATED IN RED ARE MEASURED WITH FRONT PANEL CONTROLS SET AS FOLLOWS:

   FUNCTION: STD
   RANGE: 1 V
   VOLTAGE SET: .00000

2. VOLTAGES AND WAVESHAPES ARE REFERENCED TO ⏚ AND ⏚. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATIONS.



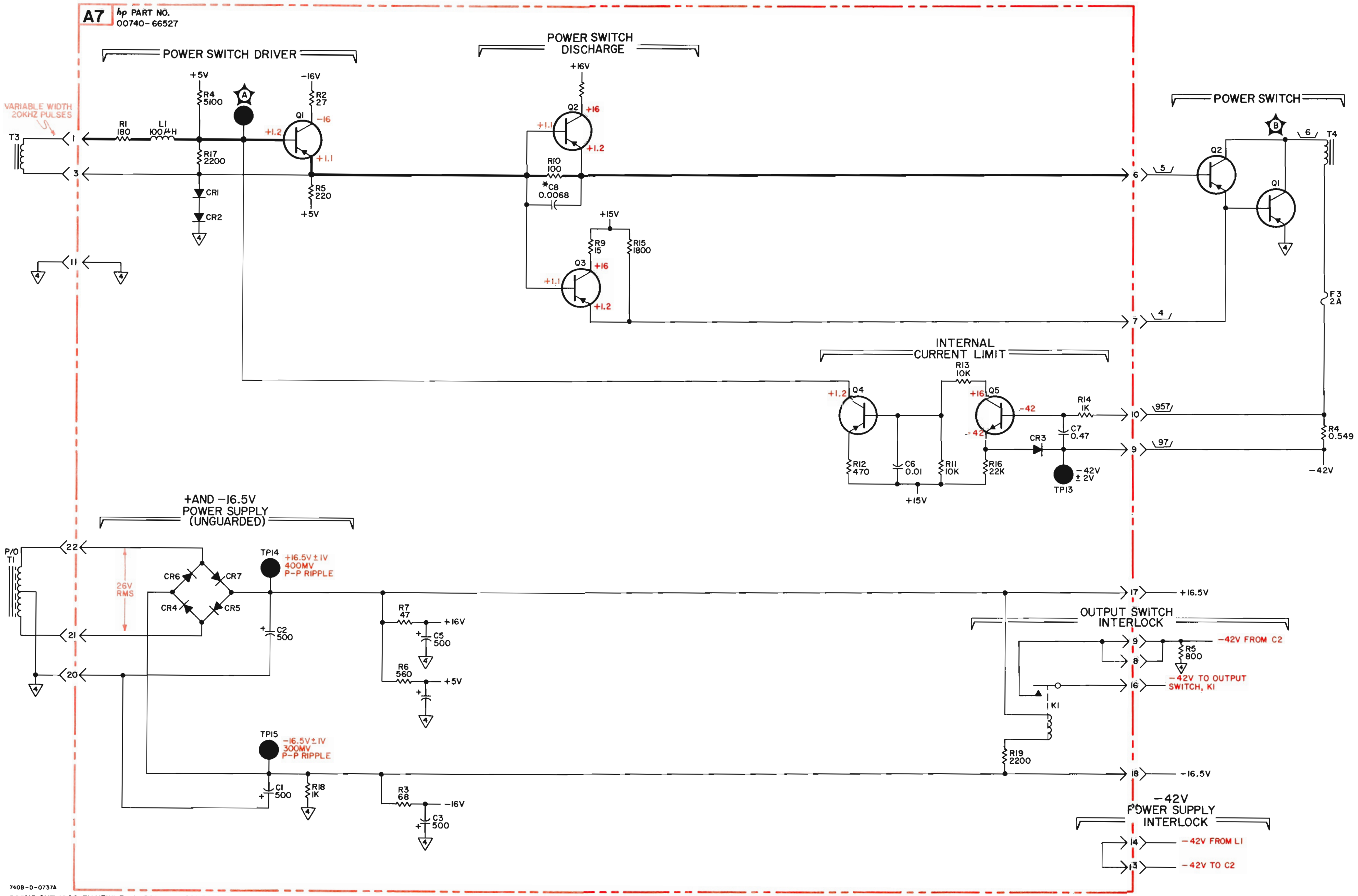
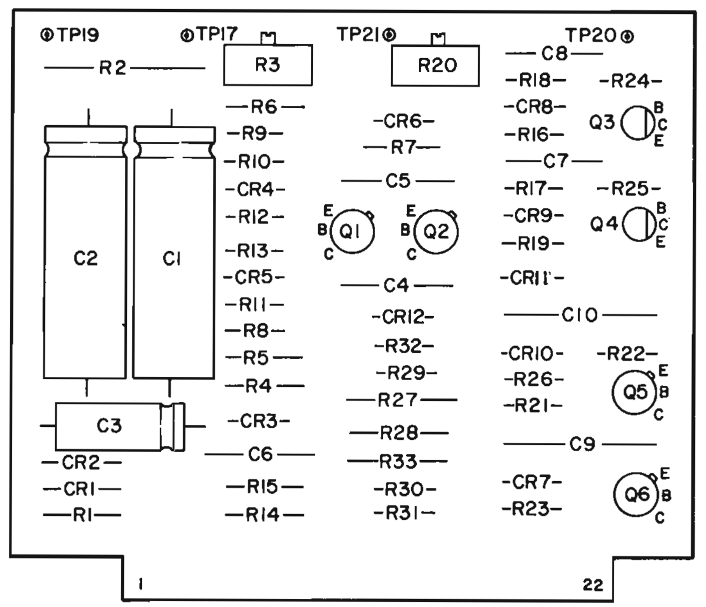



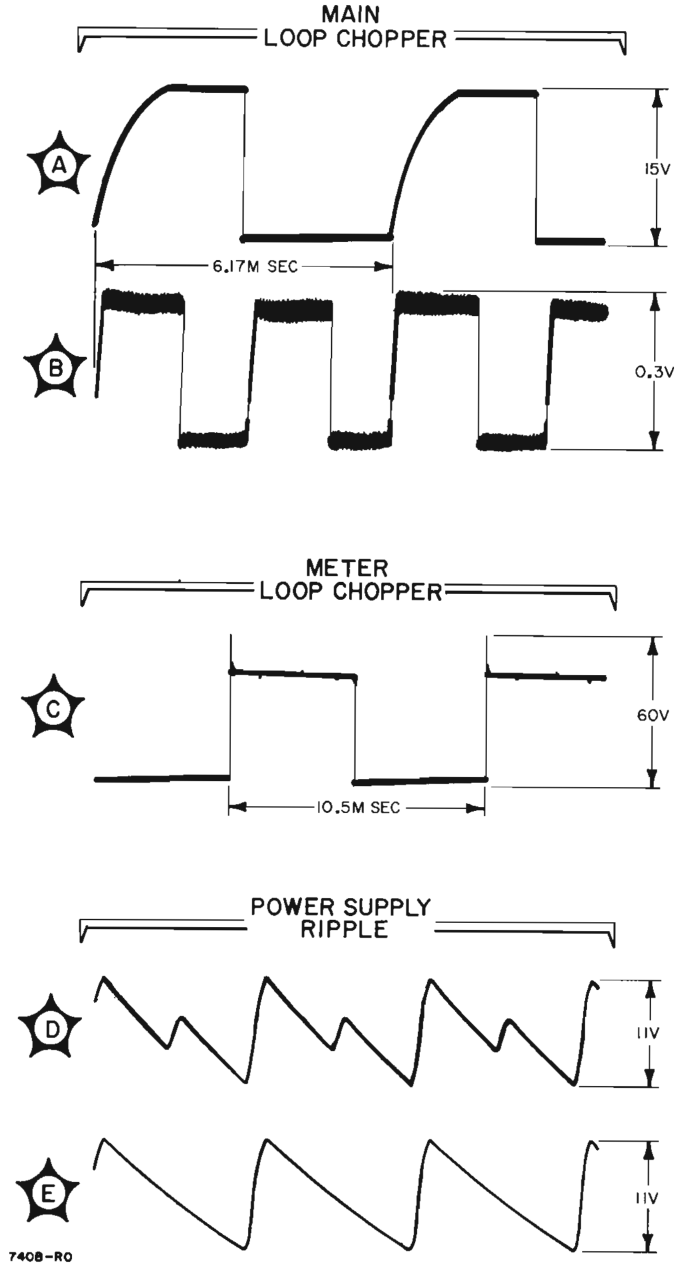


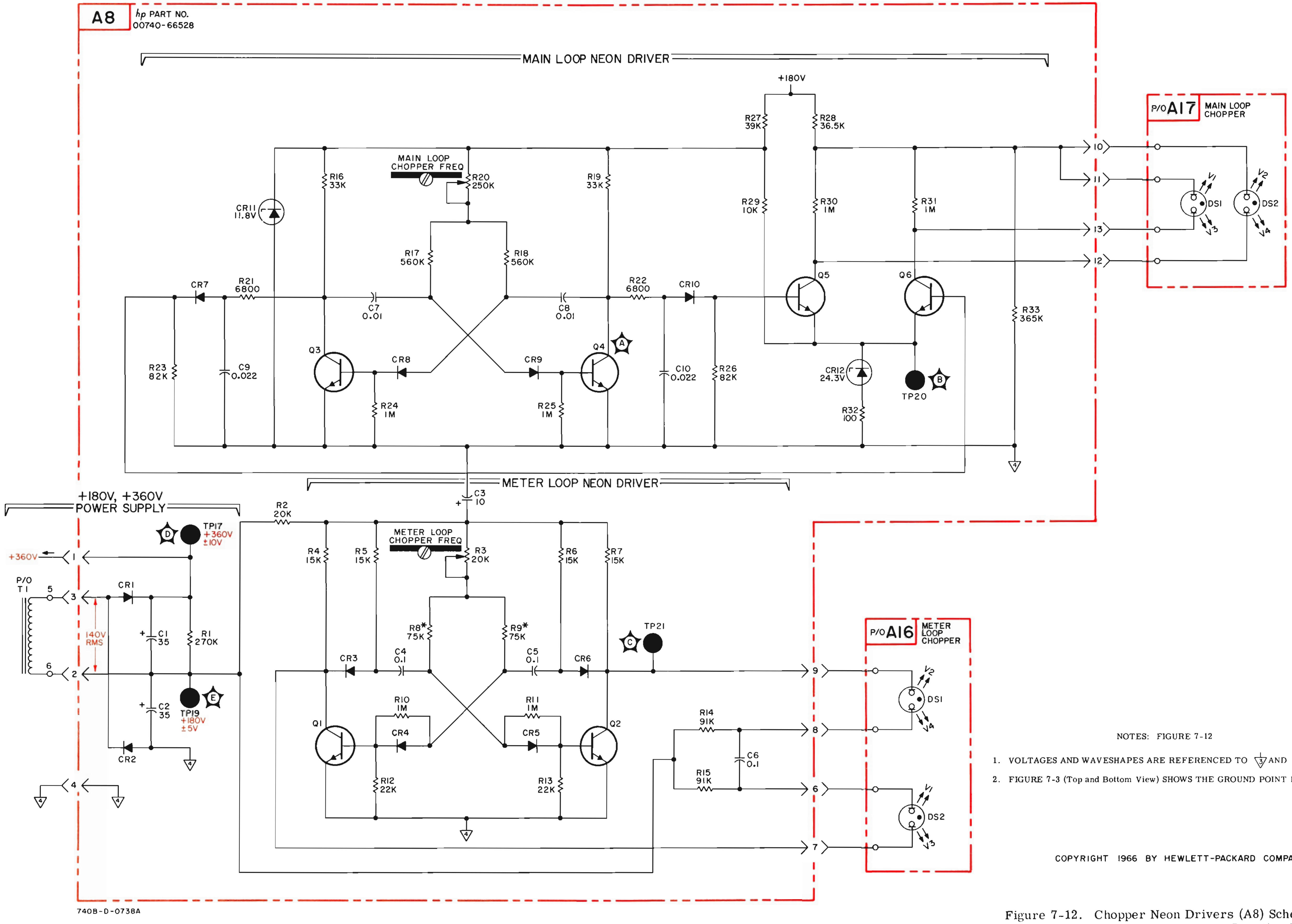

Figure 7-11. Power Switch Driver, Internal Current Limit and Unguarded Power Supply (A7) Schematic and Component Location Diagram




740B-B-0750A

A8
hp PART NO. 00740-66528




NOTES: FIGURE 7-12

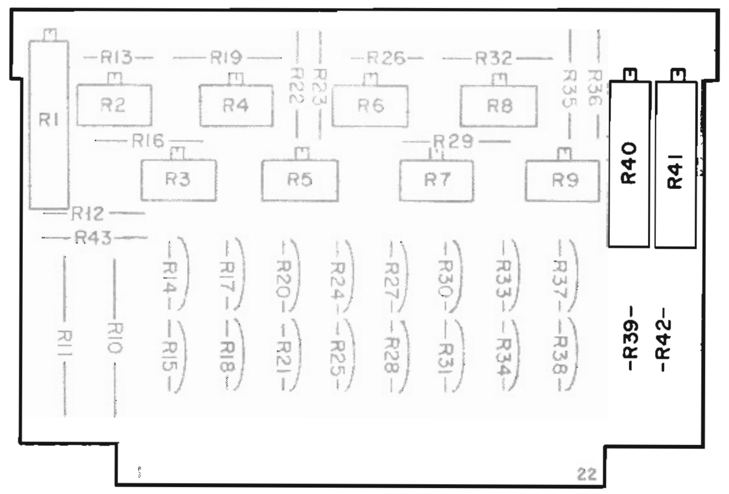
1. VOLTAGES AND WAVESHAPES ARE REFERENCED TO AND .
2. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATIONS.



Figure 7-12. Chopper Neon Drivers (A8) Schematic and Component Location Diagram

NOTES: FIGURE 7-13

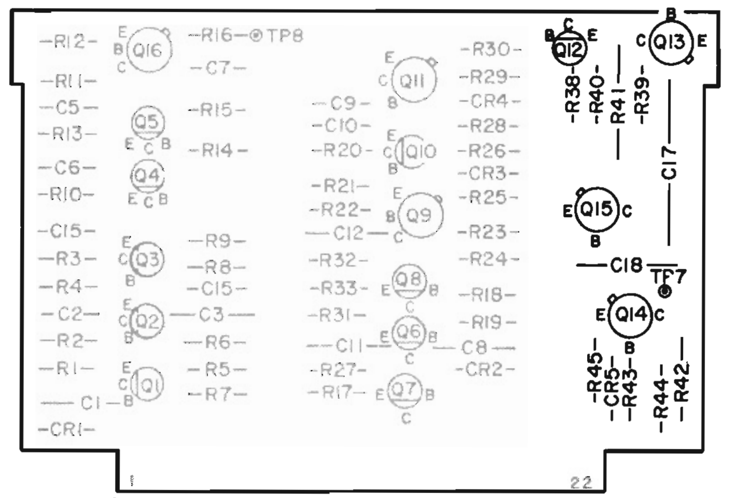
1. A13 COMPONENTS ARE FACTORY SELECTED AND ARE NOT SEPARATELY REPLACEABLE.
2. VOLTAGES INDICATED IN RED IN OVEN HEATER AND REGULATOR CIRCUIT ARE REFERENCED TO ▽.
3. VOLTAGES INDICATED IN RED IN 1 V REFERENCE SUPPLY CIRCUIT ARE REFERENCED TO ▽ AND ▽ IN STD MODE; ▽ ONLY IN OTHER MODES.
4. FIGURE 7-3 (Top and Bottom View) SHOWS THE GROUND POINT LOCATIONS.



740B-B-0743A

A1

hp PART NO. 00740-66521



740B-0744A

A2

hp PART NO. 00740-66522

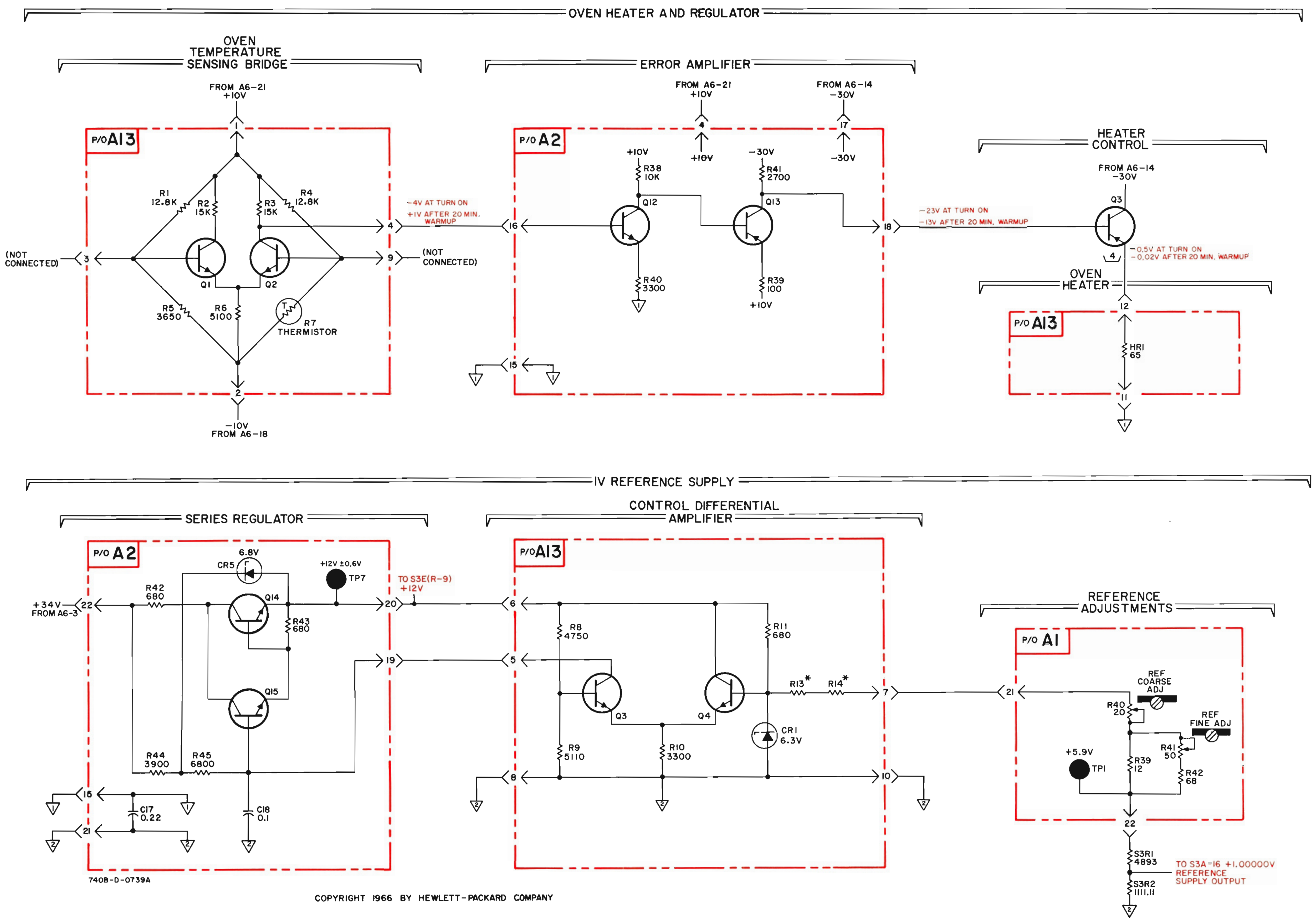
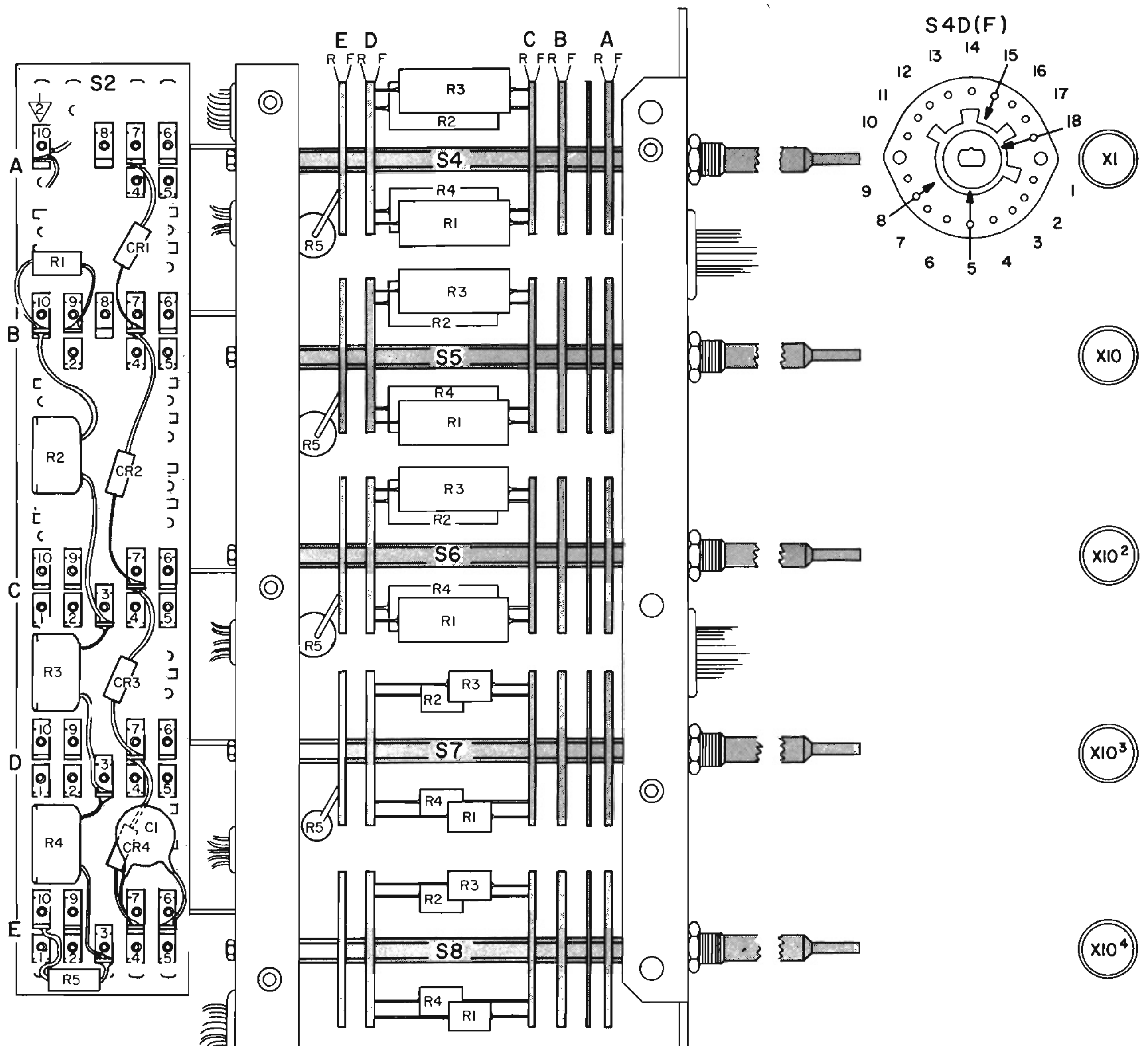




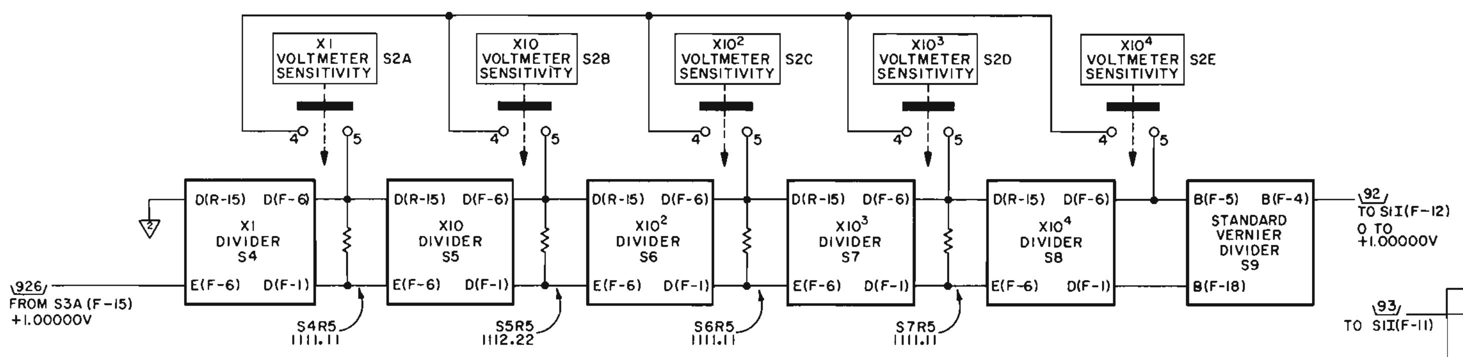

Figure 7-13. Oven Heater and 1 V Reference Supply (p/o A1, p/o A2, A13) Schematic and Component Location Diagram



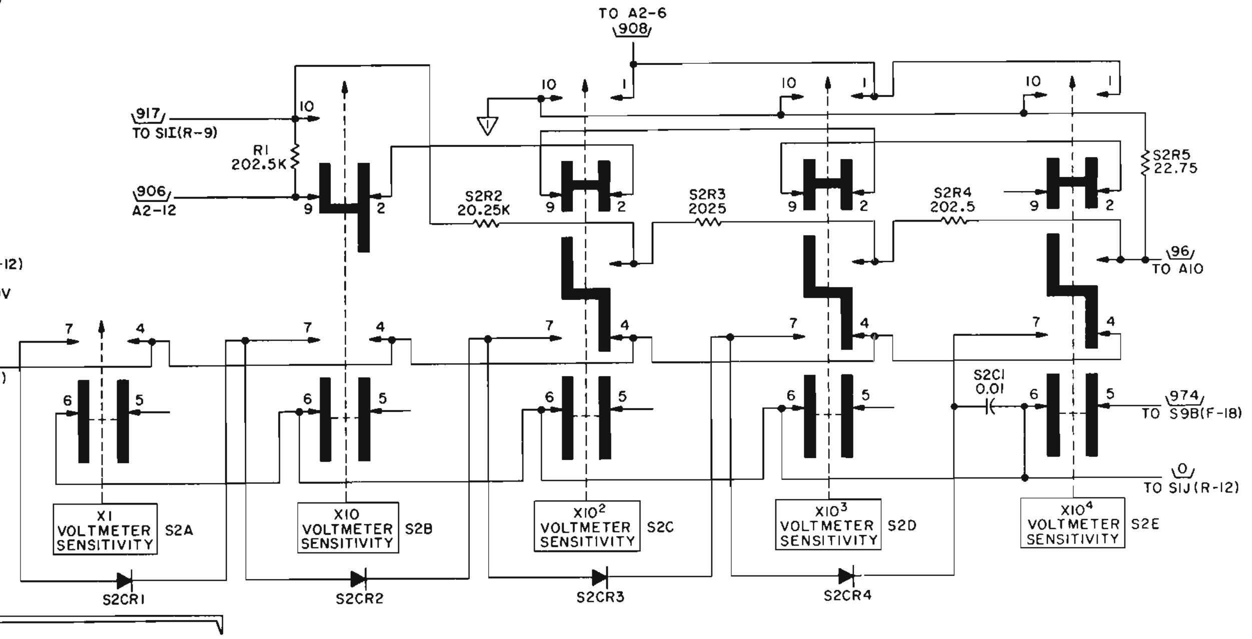

7408-C-30013

BOTTOM VIEW
S2, S4 THRU S8
hp PART NO. 00740-61906

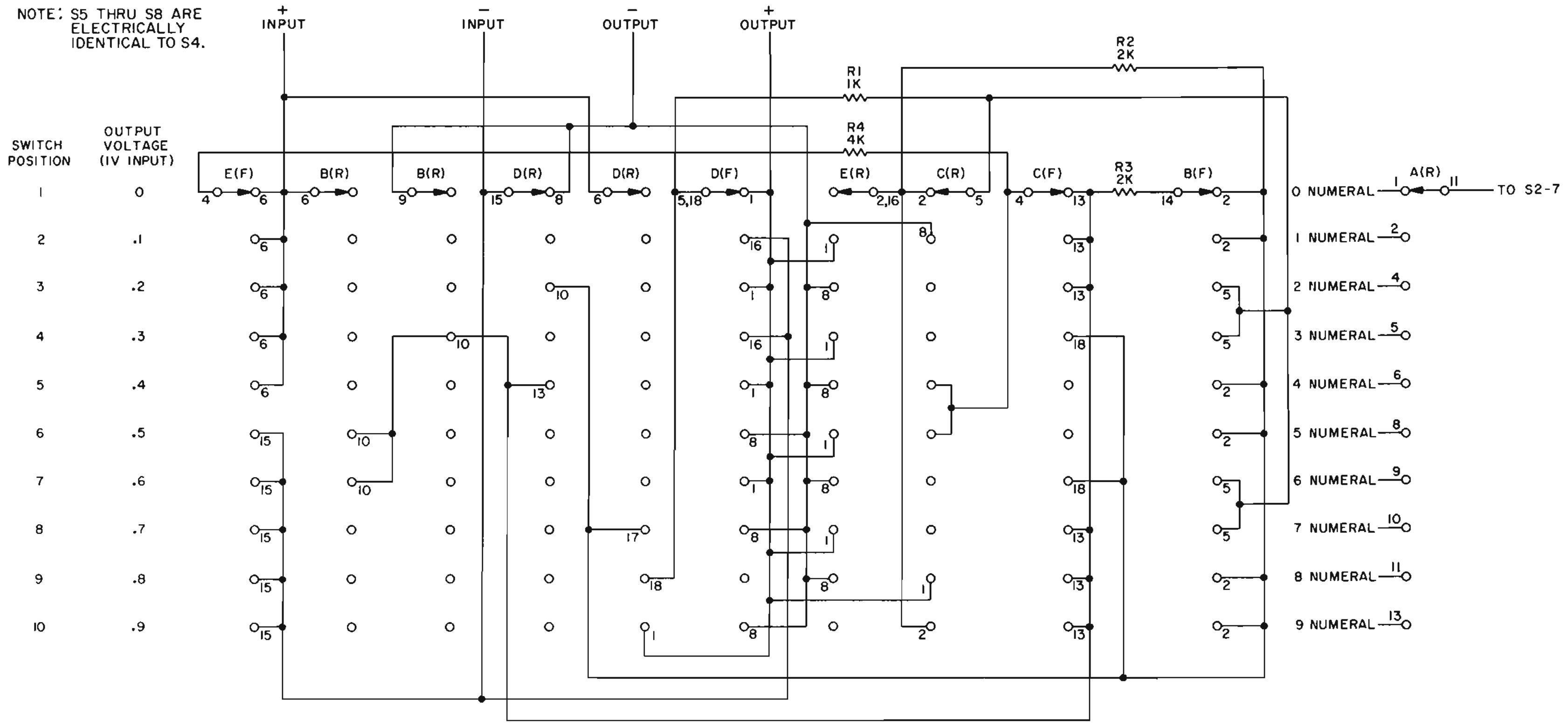
REFERENCE DIVIDER FUNCTIONAL DIAGRAM




S2, SENSITIVITY SWITCHING

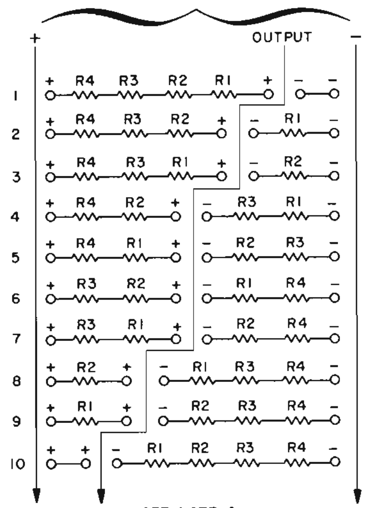



S4, VOLTAGE SET SWITCHING




7408-D-0740A

S4 THRU S8
SWITCHING LOGIC






S2
SWITCH NOTES

1. #6 CONTACTS CONTROL DIGITAL READOUTS.
2. #5 CONTACTS GO TO VOLTAGE SET SWITCHES.
3. OTHER CONTACTS CONTROL METER SENSITIVITY.

S4 THRU S8
SWITCH NOTES

1. WAFERS ARE ALPHABETICAL STARTING AT THE FRONT.
2. INDICATED VOLTAGES ARE MEASURED WITH RESPECT TO ⏚2.
3. S4 - 8 ARE IDENTICAL EXCEPT FOR R5 (ON S4 - 7), SHOWN IN THE UPPER LEFT PORTION OF THIS PAGE. ADDITIONAL CONNECTIONS TO S4 AND S5 ARE SHOWN IN THE UPPER LEFT PORTION OF THIS PAGE AND IN FIGURE 7-5.
4. WAFER "A" IS DIGITAL READOUT SWITCHING.
5. FOR COMPLETE DESIGNATION, PREFIX WITH SWITCH NUMBER (R1 IS S4R1 ETC.).
6. "SWITCHING LOGIC" SHOWS THE RESISTANCE BETWEEN THE POSITIVE AND NEGATIVE OUTPUTS FOR THE TEN POSITIONS OF THE SWITCH.

Figure 7-14. Voltage Set and Sensitivity Switching (S2, S4 thru S8) Schematic and Component Location Diagram

# APPENDIX C

# BUILDING A DC CALIBRATION SYSTEM

## C-1. BUILDING A PRECISION VOLTAGE DIVIDER.

C-2. Some of the Performance Tests presented in Section V require using a precision voltage divider. Dividers are available with the required accuracy at full scale (1:1 ratio). However, division accuracy generally decreases as the division ratio increases.

C-3. The following paragraphs outline a method of constructing a divider that achieves an accuracy of 1 to 2 ppm division accuracy at all points on the divider. The matching technique used compares resistors in a resistive matching bridge. The bridge is initially adjusted for null with a reference resistor at $R_X$ (Figure C-1). The reference resistor is then replaced with an unmatched resistor. Adjusting the unmatched resistor for bridge null matches it to the reference resistor it replaced. Decade matching is achieved by using a series string of ten resistors in place of the reference resistor. The series string is equal in total resistance to a single resistor of the next higher decade.

C-4. Self heating effects of the resistors are greatly reduced by placing them in a temperature-controlled, stirred-oil bath. The resistors are calibrated at their later intended working voltage which further reduces the chances of thermal error.

C-5. The following equipment and materials are required for setting up and calibrating the divider:

Table C-1. Materials for Building a Decade Divider

| ITEM | QUANTITY |
|---|---|
| Constant temperature oil bath (American Instrument Co.) | 1 |
| DC Null Voltmeter (-hp- Model 419A) | 1 |
| DC power supply (-hp- Model 740B) | 1 |
| 1 kΩ Adjustable Transfer Resistors (-hp- Model 11103A) | 10 |
| 10 kΩ Adjustable Transfer Resistors (-hp- Model 11104A) | 9 |
| 100 kΩ Adjustable Transfer Resistors (-hp- Model 11105A) | 9 |
| Insulated solid copper wire (20 gauge or larger) | as needed |

## C-6. SETTING UP THE CONSTANT TEMPERATURE BATH.

a. Turn on oil bath heater and adjust regulating temperature to approximately $2^{o}$C above ambient room temperature.

b. Place the set of 28 resistors in the oil and allow resistor temperatures to stabilize for at least 8 hours.

## C-7. MATCHING THE 1 kΩ RESISTORS.

a. Construct the matching bridge shown in Figure C-1, making all external connections to the bridge with insulated, solid copper wire, 20 gauge or larger. Select $R_X$ to be a recently calibrated 1 kΩ resistor.

b. Apply 2 Vdc from the Model 740B to the bridge.

c. Adjust R3 for a null on the Null Voltmeter, 3 μV range. Do not adjust $R_X$. If adjusting R3 does not produce null, adjust R1 or R2 until null is achieved. The bridge is now balanced.

**CAUTION**

ALWAYS DE-ENERGIZE THE MODEL 740B OUTPUT WHEN MAKING CHANGES IN THE MATCHING BRIDGE SETUP.

d. Replace $R_X$ with one of the six remaining 1 kΩ resistors. Do not disturb R1, R2 or R3.

e. Adjust $R_X$ for null on the Null Voltmeter. 3 μV range. This matches $R_X$ to the selected 1 kΩ resistor formerly used ad $R_X$.

f. Repeat steps d and e for the remaining five 1 kΩ resistors. This matches the remaining five resistors to the original $R_X$.

g. Rebuild the bridge using any three of the matched 1 kΩ resistors for R1, R2 and R3. Do not adjust the matched resistors. Use one of the three remaining unmatched 1 kΩ resistors of $R_X$.

h. Adjust $R_X$ for null on the null voltmeter, 3 μV range.

i. Replace $R_X$ with one of the two remaining unmatched 1 kΩ resistors.

j. Adjust $R_X$ for null on the null voltmeter.

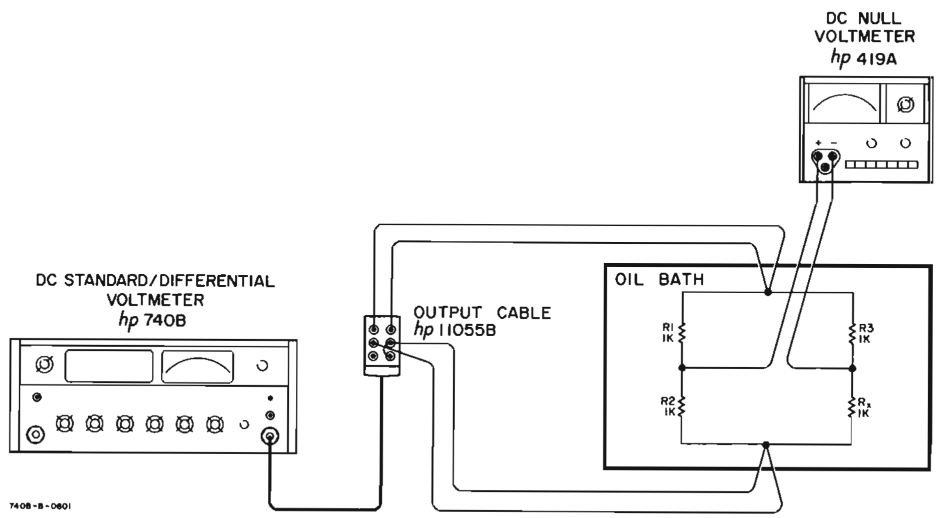



Figure C-1. 1 kΩ Matching Bridge

k. Repeat steps i and j for the remaining unmatched 1 kΩ resistor. All of the 1 kΩ resistors are now matched to each other and to the original reference resistor, $R_X$.

## C-8. MATCHING THE 10 kΩ RESISTORS.

a. Rebuild the matching bridge as shown in Figure C-2. $R_X$ is a series string of the 10 matched 1 kΩ resistors.

b. Set null voltmeter to the 30 $\mu$V range and check meter zero.

c. Apply 20 Vdc to the bridge from the Model 740B.

d. Adjust R3 for a null indication on the Null Voltmeter, 30 $\mu$V range. Do not adjust any of the 10 matched 1 kΩ resistors. If adjusting R3 does not produce null, adjust R1 or R2 until null is achieved.

**CAUTION**

ALWAYS DE-ENERGIZE THE 740B OUTPUT WHEN MAKING CHANGES IN THE MATCHING BRIDGE SETUP.

e. Replace $R_X$ (10 - 1 kΩ resistors) with one of the six remaining 10 kΩ resistors.

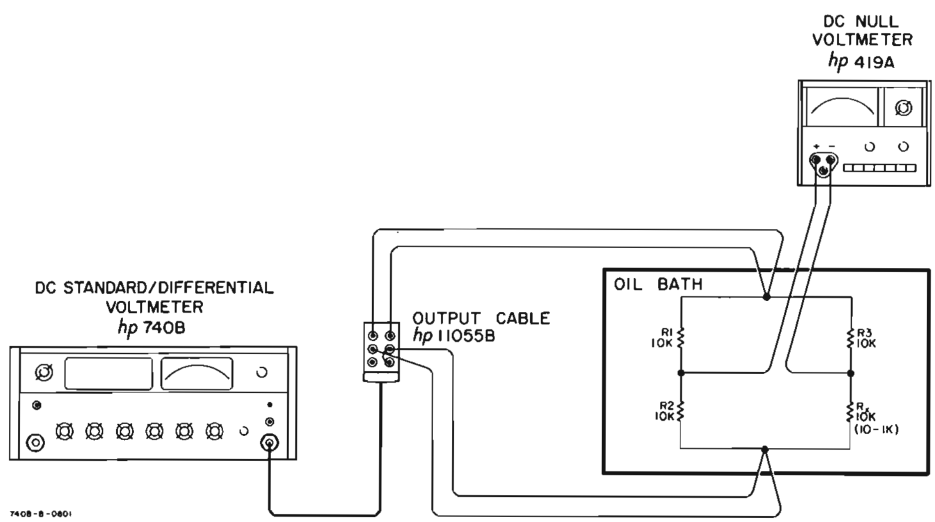



Figure C-2. 10 kΩ Matching Bridge

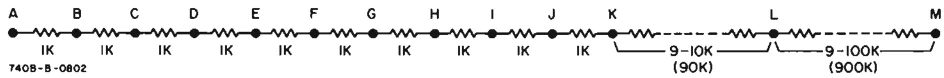



Figure C-3. Assembling the Divider

f. Adjust $R_X$ for a null indication on the Null Voltmeter, 30 $\mu$V range. This matches $R_X$ to the series string of 10 previously matched 1 kΩ resistors.

g. Repeat steps e and f for the five remaining 10 kΩ resistors. This matches the remaining five resistors to the original $R_X$ (series string of 10 matched 1 kΩ resistors).

h. Rebuild the matching bridge using any three of the matched 10 kΩ resistors for R1, R2 and R3. Do not adjust the matched resistors. Use one of the three remaining unmatched 10 kΩ resistors for $R_X$.

i. Adjust $R_X$ for null on the Null Voltmeter, 30 $\mu$V range.

j. Repeat steps h and i for the two remaining unmatched 10 kΩ resistors. All of the 10 kΩ resistors are now matched to each other and to the series string of 10 matched 1 kΩ resistors.

C-9. MATCHING THE 100 kΩ RESISTORS.

C-10. The 100 kΩ resistors can be matched using the 10 kΩ matching procedure with the following exceptions:

1. Use 200 Vdc to drive the matching bridge.
2. Set null voltmeter to the 300 $\mu$V range to read null.
3. Use a series string of 10 matched 1 kΩ resistors and 9 matched 10 kΩ resistors (total 100 kΩ) for the initial $R_X$.

C-11. ASSEMBLING AND USING THE DIVIDER.

a. Connect the matched resistors as shown in Figure C-3.

b. The divider is now ready for use. Maintain constant oil temperature whenever using the divider.

## C-12. CALIBRATING THE -hp- MODEL 735A TO 1 V 2 PPM

C-13. The following procedure can be used to calibrate a Model 735A DC Transfer Standard to 1 V ± 2 ppm. Table C-2 lists the required test equipment.

a. Turn on the Transfer Standard and allow it to warm up for at least 30 minutes.

b. Construct the calibration setup shown in Figure C-4. Make connections with insulated solid copper wire, 20 gauge or larger. Omit one connection to the standard cell.

c. Zero the Null Voltmeter on the 3 $\mu$V range. Return range to 300 $\mu$V.

d. Set Transfer Standard Function switch to 1.018 + Δ for saturated or 1.019 + Δ for unsaturated

Table C-2. Required Test Equipment

| ITEM | REQUIRED CHARACTERISTICS | RECOMMENDED MODEL |
|---|---|---|
| Standard Cell | NBS Calibrated | Eppley Laboratory, Inc. MIN type |
| 6 Dial Kelvin-Varley Divider | Accuracy: 0.0001% full scale<br>Resistance: 100 kΩ | Julie Research Laboratories Model VDR106 |
| DC Null Voltmeter | Range: 3 $\mu$V full scale | -hp- Model 419A |
| Fixed Resistors | 1000 Ω ±0.05% 1/4 W low TC wirewound<br><br>8543.5 Ω ±0.1% 1/4 W low TC wirewound | -hp- Part No. 0811-0936<br><br>-hp- Part No. 0811-0125 |
| Power Supply | Output: 8 to 10 V adjustable<br>Resolution: 1 ppm of range<br>Noise: < 1 ppm of range | -hp- Model 740B |

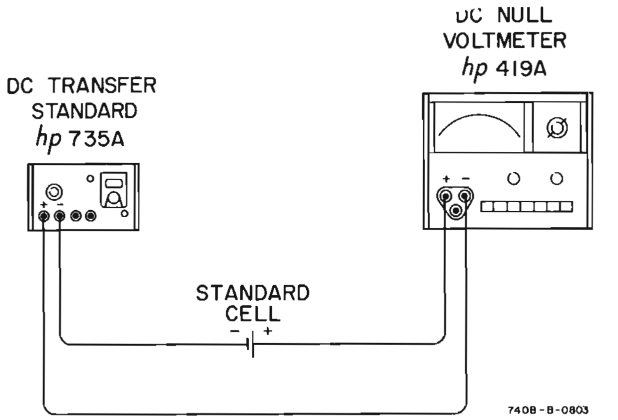



Figure C-4. Transferring the Standard Cell Voltage

standard cell. Adjust MICROVOLTS control so that the Function switch position plus MICROVOLTS setting is exactly equal to the certified voltage of the standard cell. Lock MICROVOLTS knob.

e. Connect remaining lead to the standard cell.

f. Adjust CAL control on the Transfer Standard and reduce Null Voltmeter range until null is obtained on the 3 $\mu$V range. This calibrates the Transfer Standard to the standard cell voltage.

g. Construct the calibration setup shown in Figure C-5.

h. Set the Kelvin-Varley divider for a 1:1 ratio. Set the 740B Range to 10 V and adjust output voltage for a null on the Null Voltmeter, 3 $\mu$V range. Make final adjustment for null using ZERO Control on the Model 740B. Model 740B output will be approximately 9.63 V.

NOTE

Self heating of R1 and R2 may cause slight changes in the ratio of R1:R2. Periodically readjust Model 740B output to maintain null. The resistors should stabilize after 10 to 15 minutes.

i. Set the Kelvin-Varley divider for a ratio equal to

$$\frac{1}{\text{transfer standard setting}}$$

j. Set the Transfer Standard to 1.000 V position and adjust the CAL control for a null on the Null Voltmeter 3 $\mu$V range. The Transfer Standard is now calibrated to 1 V $\pm 2$ ppm referenced to the standard cell used in steps a through f.

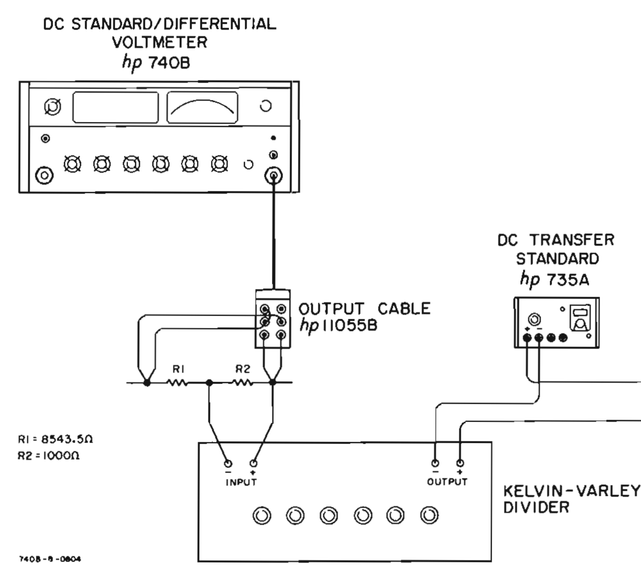



Figure C-5. Calibrating the Transfer Standard to 1 V

# APPENDIX
# CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

| Code No. | Manufacturer | Address |
|---|---|---|
| 00000 | U.S.A. Common | Any supplier of U.S. |
| 00136 | McCoy Electronics | Mount Holly Springs, Pa. |
| 00213 | Sage Electronics Corp. | Rochester, N.Y. |
| 00334 | Humidail Co. | Colton, Calif. |
| 00335 | Westrex Corp. | New York, N.Y. |
| 00373 | Garlock Packing Co., Electronic Products Div. | Camden, N.J. |
| 00656 | Aerovox Corp. | New Bedford, Mass. |
| 00779 | Amp, Inc. | Harrisburg, Pa. |
| 00781 | Aircraft Radio Corp. | Boonton, N.J. |
| 00815 | Northern Engineering Laboratories, Inc. | Burlington, Wis. |
| 00853 | Sangamo Electric Company, Ordill Division (Capacitors) | Marion, Ill. |
| 00866 | Goe Engineering Co. | Los Angeles, Calif. |
| 00891 | Carl E. Holmes Corp. | Los Angeles, Calif. |
| 01121 | Allen Bradley Co. | Milwaukee, Wis. |
| 01255 | Litton Industries, Inc. | Beverly Hills, Calif. |
| 01281 | TRW Semiconductors Inc. | Lawndale, Calif. |
| 01295 | Texas Instruments, Inc. Transistor Products Div. | Dallas, Texas |
| 01349 | The Alliance Mfg. Co. | Alliance, Ohio |
| 01561 | Chassi-Trak Corp. | Indianapolis, Ind. |
| 01589 | Pacific Relays, Inc. | Van Nuys, Calif. |
| 01930 | Amerock Corp | Rockford, Ill. |
| 01961 | Pulse Engineering Co. | Santa Clara, Calif. |
| 02114 | Ferroxcube Corp. of America | Saugerties, N.Y. |
| 02286 | Cole Mfg. Co. | Palo Alto, Calif. |
| 02660 | Amphenol-Borg Electronics Corp. | Chicago, Ill. |
| 02735 | Radio Corp. of America, Semiconductor and Materials Div. | Somerville, N.J. |
| 02771 | Vocaline Co. of America, Inc. | Old Saybrook, Conn. |
| 02777 | Hopkins Engineering Co. | San Fernando, Calif. |
| 03508 | G.E. Semiconductor Products Dept. | Syracuse, N.Y. |
| 03705 | Apex Machine & Tool Co. | Dayton, Ohio |
| 03797 | Eldema Corp. | El Monte, Calif. |
| 03877 | Transitron Electronic Corp. | Wakefield, Mass. |
| 03888 | Pyrofilm Resistor Co. | Morristown, N.J. |
| 03954 | Air Marine Motors, Inc. | Los Angeles, Calif. |
| 04009 | Arrow, Hart and Hegeman Elect. Co. | Hartford, Conn. |
| 04013 | Taurus Corp. | Lambertville, N.J. |
| 04062 | Elmenco Products Co. | New York, N.Y. |
| 04222 | Hi-Q Division of Aerovox | Myrtle Beach, S.C. |
| 04298 | Elgin National Watch Co., Electronics Division | Burbank, Calif. |
| 04354 | Precision Paper Tube Co. | Chicago, Ill. |
| 04404 | Dymec Division of Hewlett-Packard Co. | Palo Alto, Calif. |
| 04651 | Sylvania Electric Prods., Inc. Electronic Tube Div. | Mountain View, Calif. |
| 04713 | Motorola, Inc., Semiconductor Prod. Div. | Phoenix, Arizona |
| 04732 | Filtron Co., Inc., Western Div. | Culver City, Calif. |
| 04773 | Automatic Electric Co. | Northlake, Ill. |
| 04777 | Automatic Electric Sales Corp. | Northlake, Ill. |
| 04796 | Sequoia Wire & Cable Co. | Redwood City, Calif. |
| 04811 | Precision Coil Spring Co. | El Monte, Calif. |
| 04870 | P. M. Motor Company | Chicago 44, Ill. |
| 05006 | Twentieth Century Plastics, Inc. | Los Angeles, Calif. |
| 05277 | Westinghouse Electric Corp., Semi-Conductor Dept. | Youngwood, Pa. |
| 05347 | Ultronix, Inc. | San Mateo, Calif. |
| 05593 | Illumitronic Engineering Co. | Sunnyvale, Calif. |
| 05616 | Cosmo Plastic (c/o Electrical Spec. Co.) | Cleveland, Ohio |
| 05624 | Barber Colman Co. | Rockford, Ill. |
| 05728 | Tiffen Optical Co. | Roslyn Heights, Long Island, N.Y. |
| 05729 | Metropolitan Telecommunications Corp., Metro Cap. Division | Brooklyn, N.Y. |
| 05783 | Stewart Engineering Co. | Santa Cruz, Calif. |
| 05820 | Wakefield Engineering Inc. | Wakefield, Mass. |
| 06004 | The Bassick Co. | Bridgeport, Conn. |
| 06175 | Bausch and Lomb Optical Co. | Rochester, N.Y. |
| 06402 | E.T.A. Products Co. of America | Chicago, Ill. |
| 06475 | Western Devices, Inc. | Inglewood, Calif. |
| 06540 | Amatom Electronic Hardware Co. Inc. | New Rochelle, N.Y. |
| 06555 | Beede Electrical Instrument Co., Inc. | Penacook, N.H. |
| 06751 | U.S. Semcor Division of Nuclear Corp. of America | Phoenix, Arizona |
| 06812 | Torrington Mfg. Co., West Div. | Van Nuys, Calif. |
| 07088 | Kelvin Electric Co. | Van Nuys, Calif. |
| 07115 | Corning Glass Works Electronic Components Dept. | Bradford, Pa. |
| 07126 | Digitran Co. | Pasadena, Calif. |
| 07137 | Transistor Electronics Corp. | Minneapolis, Minn. |
| 07138 | Westinghouse Electric Corp. Electronic Tube Div. | Elmira, N.Y. |
| 07149 | Filmohm Corp. | New York, N.Y. |
| 07233 | Cinch-Graphik Co. | City of Industry, Calif. |
| 07261 | Avnet Corp. | Los Angeles, Calif. |
| 07263 | Fairchild Semiconductor Corp. | Mountain View, Calif. |
| 07322 | Minnesota Rubber Co. | Minneapolis, Minn. |
| 07387 | The Birtcher Corp. | Los Angeles, Calif. |
| 07700 | Technical Wire Products | Springfield, N.J. |
| 07910 | Continental Device Corp. | Hawthorne, Calif. |
| 07933 | Rheem Semiconductor Corp. | Mountain View, Calif. |
| 07966 | Shockley Semi-Conductor Laboratories | Palo Alto, Calif. |
| 07980 | Boonton Radio Corp. | Boonton, N.J. |
| 08145 | U.S. Engineering Co. | Los Angeles, Calif. |
| 08289 | Blinn, Delbert, Co. | Pomona, Calif. |
| 08358 | Burgess Battery Co. | Niagara Falls, Ontario, Canada. |
| 08717 | Sloan Company | Burbank, Calif. |
| 08718 | Cannon Electric Co., Phoenix Div. | Phoenix, Ariz. |
| 08792 | CBS Electronics Semiconductor Operations, Div. of C.B.S., Inc. | Lowell, Mass. |
| 08984 | Mel-Rain | Indianapolis, Ind. |
| 09026 | Babcock Relays, Inc. | Costa Mesa, Calif. |
| 09134 | Texas Capacitor Co. | Houston, Texas |
| 09145 | Atohm Electronics | Sun Valley, Calif. |
| 09250 | Electro Assemblies, Inc. | Chicago, Ill. |
| 09569 | Mallory Battery Co. of Canada, Ltd. | Toronto, Ontario, Canada |
| 09664 | The Bristol Co. | Waterbury, Conn. |
| 10214 | General Transistor Western Corp. | Los Angeles, Calif. |
| 10411 | Ti-Tal, Inc. | Berkeley, Calif. |
| 10646 | Carborundum Co. | Niagara Falls, N.Y. |
| 11236 | CTS of Berne, Inc. | Berne, Ind. |
| 11237 | Chicago Telephone of California, Inc. | So. Pasadena, Calif. |
| 11312 | Microwave Electronics Corp. | Palo Alto, Calif. |
| 11534 | Duncan Electronic, Inc. | Santa Ana, Calif. |
| 11711 | General Instrument Corporation Semiconductor Division | Newark, N.J. |
| 11717 | Imperial Electronic, Inc. | Buena Park, Calif. |
| 11870 | Melabs, Inc. | Palo Alto, Calif. |
| 12136 | Philadelphia Handle Co. | Camden, N.J. |
| 12697 | Clarostat Mfg. Co. | Dover, N.H. |
| 12859 | Nippon Electric Co., Ltd. | Tokyo, Japan |
| 12930 | Delta Semiconductor Inc. | Newport Beach, Calif. |
| 13103 | Thermolloy | Dallas, Texas |
| 13396 | Telefunken (G.M.B.H.) | Hannover, Germany |
| 13835 | Midland Mfg. Co. | Kansas City, Kansas |
| 14099 | Sem-Tech | Newbury Park, Calif. |
| 14193 | Calif. Resistor Corp. | Santa Monica, Calif. |
| 14298 | American Components, Inc. | Conshohocken, Pa. |
| 14655 | Cornell Dubilier Elec. Corp. | So. Plainfield, N.J. |
| 14960 | Williams Mfg. Co. | San Jose, Calif. |
| 15203 | Webster Electronics Co. Inc. | Brooklyn, N.Y. |
| 15291 | Adjustable Bushing Co. | N. Hollywood, Calif. |
| 15772 | Twentieth Century Coil Spring Co. | Santa Clara, Calif. |
| 15909 | The Daven Co. | Livingston, N.J. |
| 16037 | Spruce Pine Mica Co. | Spruce Pine, N.C. |
| 16352 | Computer Diode Corp. | Lodi, N.J. |
| 16688 | De Jur-Amsco Corporation | Long Island City 1, N.Y. |
| 16758 | Delco Radio Div. of G.M. Corp. | Kokomo, Ind. |
| 17109 | Thermonetics Inc. | Canoga Park, Calif. |
| 17474 | Tranex Company | Mountain View, Calif. |
| 18486 | Radio Industries | Des Plaines, Ill. |
| 18583 | Curtis Instrument Inc. | Mt. Kisco, N.Y. |
| 18873 | E.I. DuPont and Co., Inc. | Wilmington, Del. |
| 19315 | Eclipse Pioneer, Div. of Bendix Aviation Corp. | Teterboro, N.J. |
| 19500 | Thomas A. Edison Industries, Div. of McGraw-Edison Co. | West Orange, N.J. |
| 19701 | Electra Manufacturing Co. | Kansas City, Mo. |
| 20183 | Electronic Tube Corp. | Philadelphia, Pa. |
| 21226 | Executive, Inc. | New York, N.Y. |
| 21520 | Fansteel Metallurgical Corp. | No. Chicago, Ill. |
| 21335 | The Fafnir Bearing Co. | New Britain, Conn. |
| 21964 | Fed. Telephone and Radio Corp. | Clifton, N.J. |
| 24446 | General Electric Co. | Schenectady, N.Y. |
| 24455 | G.E., Lamp Division | Nela Park, Cleveland, Ohio |
| 24655 | General Radio Co. | West Concord, Mass. |
| 26365 | Gries Reproducer Corp. | New Rochelle, N.Y. |
| 26462 | Grobet File Co. of America, Inc. | Carlstadt, N.J. |
| 26992 | Hamilton Watch Co. | Lancaster, Pa. |
| 28480 | Hewlett-Packard Co. | Palo Alto, Calif. |
| 33173 | G.E. Receiving Tube Dept. | Owensboro, Ky. |
| 35434 | Lectrohm Inc. | Chicago, Ill. |
| 36196 | Stanwyck Corp. | Hawkesbury, Ontario, Canada |
| 37942 | P.R. Mallory & Co., Inc. | Indianapolis, Ind. |
| 39543 | Mechanical Industries Prod. Co. | Akron, Ohio |
| 40920 | Miniature Precision Bearings, Inc. | Keene, N.H. |
| 42190 | Muter Co. | Chicago, Ill. |
| 43990 | C.A. Norgren Co. | Englewood, Colo. |
| 44655 | Ohmite Mfg. Co. | Skokie, Ill. |
| 47904 | Polaroid Corp. | Cambridge, Mass. |
| 48620 | Precision Thermometer and Inst. Co. | Philadelphia, Pa. |
| 49956 | Raytheon Company | Lexington, Mass. |
| 52090 | Rowan Controller Co. | Baltimore, Md. |
| 63743 | Ward Leonard Electric | Mt. Vernon, N.Y. |
| 54294 | Shallcross Mfg. Co. | Selma, N.C. |
| 55026 | Simpson Electric Co. | Chicago, Ill. |
| 55933 | Sonotone Corp. | Elmsford, N.Y. |
| 55938 | Sorenson & Co., Inc. | So. Norwalk, Conn. |
| 56137 | Spaulding Fibre Co., Inc. | Tonawanda, N.Y. |
| 56289 | Sprague Electric Co. | North Adams, Mass. |
| 59446 | Telex, Inc. | St. Paul, Minn. |
| 59730 | Thomas & Betts Co. | Elizabeth 1, N.J. |
| 60741 | Tripplett Electrical Inc. | Bluffton, Ohio |
| 61775 | Union Switch and Signal, Div. of Westinghouse Air Brake Co. | Swissvale, Pa. |
| 62119 | Universal Electric Co. | Owosso, Mich. |
| 63743 | Ward-Leonard Electric Co. | Mt. Vernon, N.Y. |
| 64959 | Western Electric Co., Inc. | New York, N.Y. |
| 65092 | Weston Inst. Div. of Daystrom, Inc. | Newark, N.J. |
| 66295 | Wittek Manufacturing Co. | Chicago 23, Ill. |
| 66346 | Wollensak Optical Co. | Rochester, N.Y. |
| 70276 | Allen Mfg. Co. | Hartford, Conn. |
| 70309 | Allied Control Co., Inc. | New York, N.Y. |
| 70319 | Allmetal Screw Prod. Co., Inc. | Garden City, N.Y. |
| 70485 | Atlantic India Rubber Works, Inc. | Chicago, Ill. |
| 70563 | Amperite Co., Inc. | New York, N.Y. |
| 70903 | Belden Mfg. Co. | Chicago, Ill. |
| 70998 | Bird Electronic Corp. | Cleveland, Ohio |
| 71002 | Birnbach Radio Co. | New York, N.Y. |
| 71041 | Boston Gear Works Div. of Murray Co. of Texas | Quincy, Mass. |
| 71218 | Bud Radio Inc. | Cleveland, Ohio |
| 71286 | Camloc Fastener Corp. | Paramus, N.J. |
| 71313 | Allen D. Cardwell Electronic Prod. Corp. | Plainville, Conn. |
| 71400 | Bussmann Fuse Div. of McGraw-Edison Co. | St. Louis, Mo. |
| 71436 | Chicago Condenser Corp. | Chicago, Ill. |
| 71450 | CTS Corp. | Elkhart, Ind. |
| 71468 | Cannon Electric Co. | Los Angeles, Calif. |
| 71471 | Cinema Engineering Co. | Burbank, Calif. |
| 71482 | C.P. Clare & Co. | Chicago, Ill. |
| 71590 | Centralab Div. of Globe Union Inc. | Milwaukee, Wis. |
| 71616 | Commercial Plastics Co. | Chicago, Ill. |
| 71700 | The Cornish Wire Co. | New York, N.Y. |
| 71744 | Chicago Miniature Lamp Works | Chicago, Ill. |
| 71753 | A.O. Smith Corp., Crowley Div. | West Orange, N.J. |
| 71785 | Cinch Mfg. Corp. | Chicago, Ill. |
| 71984 | Dow Corning Corp. | Midland, Mich. |
| 72092 | Eitel-McCullough, Inc. | San Bruno, Calif. |
| 72136 | Electro Motive Mfg. Co., Inc. | Willimantic, Conn. |
| 71707 | Coto Coil Co., Inc. | Providence, R.I. |
| 72354 | John E. Fast & Co. | Chicago, Ill. |
| 72619 | Dialight Corp. | Brooklyn, N.Y. |
| 72656 | General Ceramics Corp. | Keasbey, N.J. |
| 72699 | General Instrument Corp., Semiconductor Div. | Newark, N.J. |
| 72758 | Girard-Hopkins | Oakland, Calif. |
| 72765 | Drake Mfg. Co. | Chicago, Ill. |
| 72825 | Hugh H. Eby Inc. | Philadelphia, Pa. |
| 72928 | Gudeman Co. | Chicago, Ill. |
| 72964 | Robert M. Hadley Co. | Los Angeles, Calif. |
| 72982 | Erie Resistor Corp. | Erie, Pa. |
| 73061 | Hansen Mfg. Co., Inc. | Princeton, Ind. |
| 73076 | H.M. Harper Co. | Chicago, Ill. |
| 73138 | Helipot Div. of Beckman Instruments, Inc. | Fullerton, Calif. |
| 73293 | Hughes Products Division of Hughes Aircraft Co. | Newport Beach, Calif. |
| 73445 | Amperex Electronic Co., Div. of North American Phillips Co, Inc. | Hicksville, N.Y. |
| 73490 | Beckman Helipot Corp. | So. Pasadena, Calif. |
| 73506 | Bradley Semiconductor Corp. | Hamden, Conn. |
| 73559 | Carling Electric, Inc. | Hartford, Conn. |
| 73682 | George K. Garrett Co., Inc. | Philadelphia, Pa. |
| 73734 | Federal Screw Prod. Co. | Chicago, Ill. |
| 73743 | Fischer Special Mfg. Co. | Cincinnati, Ohio |
| 73793 | The General Industries Co. | Elyria, Ohio |
| 73846 | Goshen Stamping & Tool Co. | Goshen, Ind. |
| 73899 | JFD Electronics Corp. | Brooklyn, N.Y. |
| 73905 | Jennings Radio Mfg. Co. | San Jose, Calif. |
| 74276 | Signalite Inc. | Neptune, N.J. |
| 74455 | J.H. Winns, and Sons | Winchester, Mass. |
| 74861 | Industrial Condenser Corp. | Chicago, Ill. |
| 74868 | R.F. Products Division of Amphenol-Borg Electronics Corp. | Danbury, Conn. |
| 74970 | E.F. Johnson Co. | Waseca, Minn. |
| 75042 | International Resistance Co. | Philadelphia, Pa. |
| 75173 | Jones, Howard B., Division of Cinch Mfg. Corp. | Chicago, Ill. |
| 75378 | James Knights Co. | Sandwich, Ill. |
| 75382 | Kulka Electric Corporation | Mt. Vernon, N.Y. |
| 75818 | Lenz Electric Mfg. Co. | Chicago, Ill. |
| 75915 | Littlefuse Inc. | Des Plaines, Ill. |
| 76005 | Lord Mfg. Co. | Erie, Pa. |
| 76210 | C.W. Marwedel | San Francisco, Calif. |
| 76433 | Micamold Electronic Mfg. Corp. | Brooklyn, N.Y. |
| 76487 | James Millen Mfg. Co., Inc. | Malden, Mass. |
| 76493 | J.W. Miller Co. | Los Angeles, Calif. |
| 76530 | Monadnock Mills | San Leandro, Calif. |
| 76545 | Mueller Electric Co. | Cleveland, Ohio. |
| 76854 | Oak Manufacturing Co. | Crystal Lake, Ill. |
| 77068 | Bendix Pacific Division of Bendix Corp. | No. Hollywood, Calif. |
| 77075 | Pacific Metals Co. | San Francisco, Calif. |
| 77221 | Phaostran Instrument and Electronic Co. | South Pasadena, Calif. |
| 77250 | Phoell Mfg. Co. | Chicago, Ill. |
| 77252 | Philadelphia Steel and Wire Corp. | Philadelphia, Pa. |
| 77342 | Potter and Brumfield, Div. of American Machine and Foundry | Princeton, Ind. |
| 77630 | Radio Condenser Co. | Camden, N.J. |
| 77638 | Radio Receptor Co., Inc. | Brooklyn, N.Y. |
| 77764 | Resistance Products Co. | Harrisburg, Pa. |
| 77969 | Rubbercraft Corp. of Calif. | Torrance, Calif. |
| 78189 | Shakeproof Division of Illinois Tool Works | Elgin, Ill. |
| 78283 | Signal Indicator Corp. | New York, N.Y. |
| 78290 | Struthers-Dunn Inc. | Pitman, N.J. |
| 78452 | Thompson-Bremer & Co. | Chicago, Ill. |
| 78471 | Tilley Mfg. Co. | San Francisco, Calif. |
| 78488 | Stackpole Carbon Co. | St. Marys, Pa. |
| 78493 | Standard Thomson Corp. | Waltham, Mass. |
| 78553 | Tinnerman Products, Inc. | Cleveland, Ohio |
| 78790 | Transformer Engineers | Pasadena, Calif. |
| 78947 | Ucinite Co. | Newtonville, Mass. |
| 79142 | Veeder Root, Inc. | Hartford, Conn. |
| 79251 | Wenco Mfg. Co. | Chicago, Ill. |
| 79727 | Continental-Wirt Electronics Corp. | Philadelphia, Pa. |
| 79963 | Zierick Mfg. Corp. | New Rochelle, N.Y. |
| 80031 | Mepco Division of Sessions Clock Co. | Morristown, N.J. |
| 80120 | Schnitzer Alloy Products | Elizabeth, N.J. |
| 80130 | Times Facsimile Corp. | New York, N.Y. |
| 80131 | Electronic Industries Association. Any brand tube meeting EIA standards | Washington, D.C. |
| 80207 | Unimax Switch, Div. of W.L. Maxson Corp. | Wallingford, Conn. |
| 80223 | United Transformer Corp. | New York, N.Y. |
| 80248 | Oxford Electric Corp. | Chicago, Ill. |
| 80294 | Bourns Laboratories, Inc. | Riverside, Calif. |
| 80411 | Acro Div. of Robertshaw Fulton Controls Co. | Columbus 16, Ohio |
| 80486 | All Star Products Inc. | Defiance, Ohio |
| 80509 | Avery Adhesive Label Corp. | Monrovia, Calif. |
| 80583 | Hammerlund Co., Inc. | New York, N.Y. |
| 80640 | Stevens, Arnold, Co., Inc. | Boston, Mass. |
| 81030 | International Instruments, Inc. | New Haven, Conn. |
| 81073 | Grayhill Co. | LaGrange, Ill. |
| 81095 | Triad Transformer Corp. | Venice, Calif. |
| 81312 | Winchester Electronics Co., Inc. | Norwalk, Conn. |

00015-39
Revised February, 1965

From: FSC. Handbook Supplements
H4-1 Dated DECEMBER 1964
H4-2 Dated MARCH 1962

# APPENDIX
## CODE LIST OF MANUFACTURERS (Sheet 2 of 2)

| Code No. | Manufacturer | Address |
|---|---|---|
| 81349 | Military Specification | ........ |
| 81415 | Wilkor Products, Inc. | Cleveland, Ohio |
| 81453 | Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations | Newton, Mass. |
| 81483 | International Rectifier Corp. | El Segundo, Calif. |
| 81541 | The Airpax Products Co. | Cambridge, Mass. |
| 81860 | Barry Controls, Inc. | Watertown, Mass. |
| 82042 | Carter Parts Co. | Skokie, Ill. |
| 82142 | Jeffers Electronics Division of Speer Carbon Co. | Du Bois, Pa. |
| 82170 | Allen B. DuMont Labs, Inc. | Clifton, N.J. |
| 82209 | Maguire Industries, Inc. | Greenwich, Conn. |
| 82219 | Sylvania Electric Prod. Inc. Electronic Tube Div. | Emporium, Pa. |
| 82376 | Astron Co. | East Newark, N.J. |
| 82389 | Switchcraft, Inc. | Chicago, Ill. |
| 82647 | Metals and Controls, Inc., Div. of Texas Instruments, Inc., Spencer Prods. | Attleboro, Mass. |
| 82866 | Research Products Corp. | Madison, Wis. |
| 82877 | Rotron Manufacturing Co., Inc. | Woodstock, N.Y. |
| 82893 | Vector Electronic Co. | Glendale, Calif. |
| 83053 | Western Washer Mfr. Co. | Los Angeles, Calif. |
| 83058 | Carr Fastener Co. | Cambridge, Mass. |
| 83086 | New Hampshire Ball Bearing, Inc. | Peterborough, N.H. |
| 83125 | Pyramid Electric Co. | Darlington, S.C. |
| 83148 | Electro Cords Co. | Los Angeles, Calif. |
| 83186 | Victory Engineering Corp. | Springfield, N.J. |
| 83298 | Bendix Corp., Red Bank Div. | Red Bank, N.J. |
| 83315 | Hubbell Corp. | Mundelein, Ill. |
| 83330 | Smith, Herman H., Inc. | Brooklyn, N.Y. |
| 83385 | Central Screw Co. | Chicago, Ill. |
| 83501 | Gavitt Wire and Cable Co., Div. of Amerace Corp. | Brookfield, Mass. |
| 83594 | Burroughs Corp., Electronic Tube Div. | Plainfield, N.J. |
| 83740 | Eveready Battery | New York, N.Y. |
| 83777 | Model Eng. and Mfg., Inc. | Huntington, Ind. |
| 83821 | Loyd Scruggs Co. | Festus, Mo. |
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| 84970 | Sarkes Tarzian, Inc. | Bloomington, Ind. |
| 85454 | Boonton Molding Company | Boonton, N.J. |
| 85471 | A.B. Boyd Co. | San Francisco, Calif. |
| 85474 | R.M. Bracamonte & Co. | San Francisco, Calif. |
| 85660 | Koiled Kords, Inc. | New Haven, Conn. |
| 85911 | Seamless Rubber Co. | Chicago, Ill. |
| 86197 | Clifton Precision Products | Clifton Heights, Pa. |
| 86579 | Precision Rubber Products Corp. | Dayton, Ohio |
| 86684 | Radio Corp. of America, RCA Electron Tube Div. | Harrison, N.J. |
| 87216 | Philco Corporation (Lansdale Division) | Lansdale, Pa. |
| 87473 | Western Fibrous Glass Products Co. | San Francisco, Calif. |
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| 89665 | United Transformer Co. | Chicago, Ill. |
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| 98978 | International Electronic Research Corp. | Burbank, Calif. |
| 99109 | Columbia Technical Corp. | New York, N.Y. |
| 99313 | Varian Associates | Palo Alto, Calif. |
| 99515 | Marshall Industries, Electron Products Division | Pasadena, Calif. |
| 99707 | Control Switch Division, Controls Co. of America | El Segundo, Calif. |
| 99800 | Delevan Electronics Corp. | East Aurora, N.Y. |
| 99848 | Wilco Corporation | Indianapolis, Ind. |
| 99934 | Renbrandt, Inc. | Boston, Mass. |
| 99942 | Hoffman Semiconductor Div. of Hoffman Electronics Corp. | Evanston, Ill. |
| 99957 | Technology Instrument Corp of Calif. | Newbury Park, Calif. |

THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

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| J0000 | Winchester Electronics, Inc. | Santa Monica, Calif. |
| 0000F | Malco Tool and Die | Los Angeles, Calif. |
| 0000M | Western Coil Div. of Automatic Ind., Inc. | Redwood City, Calif. |
| 0000P | Ty-Car Mfg. Co., Inc. | Holliston, Mass. |
| 0000Z | Willow Leather Products Corp. | Newark, N.J. |
| 000AA | British Radio Electronics Ltd. | Washington, D.C. |
| 000AB | ETA | England |
| 000AC | Indiana General Corp., Elect. Div. | Indiana |
| 000BB | Precision Instrument Components Co. | Van Nuys, Calif. |
| 000MM | Rubber Eng. & Development | Hayward, Calif. |
| 000NN | A "N" D Manufacturing Co. | San Jose 27, Calif. |
| 000QQ | Cooltron | Oakland, Calif. |
| 000SS | Control of Elgin Watch Co. | Burbank, Calif. |
| 000WW | California Eastern Lab. | Burlingame, Calif. |
| 000YY | S.K. Smith Co. | Los Angeles 45, Calif. |



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