KEITHLEY

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KEITHLEY

Service Manual

Model 1765

Contains Servicing/Calibration Information for

Models 135 and 176

Keithley Instruments, Inc.
28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and shipping instructions.

REPAIRS AND CALIBRATION

Keithley Instruments maintains a complete repair and calibration service as well as a standards laboratory in Cleveland, Ohio.

A Keithley service facility at our Munich, Germany office is available for our customers throughout Europe. Service in the United Kingdom can be handled at our office in Reading. Additionally, Keithley representatives in most countries maintain service and calibration facilities.

To insure prompt repair or recalibration service, please contact your local field representative or Keithley headquarters directly before returning the instrument. Estimates for repairs, normal recalibrations and calibrations traceable to the National Bureau of Standards are available upon request.

KEITHLEY

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Model 135/176 Service Manual
Section 1. General Information

1-1. INTRODUCTION

1-2. The Models 135/176 are low cost, 4-1/2 digit, LCD display digital multimeters. The two meters are unique in that they are similar in electronic design yet different in case design. The most obvious difference is the physical difference. The 176 is designed into a more traditional DMM case while the 135 is designed into a hand held case. The 176 has more current ranges and a wider frequency span for ACV. They both have a basic DC accuracy of 0.05% and also a basic OHMS accuracy of 0.2%. They also basically have the same A/D converter.

1-3. This manual is a combination of service information for both DMM's (135 and 176). It contains information necessary to maintain, calibrate and troubleshoot the Model 135 and the Model 176.

1-4. FEATURES

1-5. The 135 and 176 have many distinct features and advantages some of which are listed below:

- A 20000 count (4-1/2 digit) liquid crystal display. (LCD) with large 0.6 inch numerals. The 176 has function and range indicators. The 135 and 176 have a low battery indicator that lights when there is less than 10% battery life remaining. Appropriate decimal point and minus sign (-) are also displayed, positive polarity is implied.

- The Model 135 and 176 are built rugged. The hand held case and the bench size case are molded from impact-resistant plastic. Effective input protection prevents damage on all functions.

- The 176 pushbuttons are color coded to the front panel for quick and easy selection of function and range. The 135 rotary function and range switch are easily positioned to color coded functions and ranges. The decimal point is automatically positioned by the range pushbutton/rotary switch. The 176 display annunciators indicate the selected function and range. Improper range and function combinations are indicated by contradicting function and/or range annunciators appearing at the same time.

- State of the art technology and stable precision components have been used in these two DMM's to provide long term accuracy and minimize maintenance. Calibration is required only once a year. If alkaline batteries are used (six C cells in the 176 or one 9 volt cell for the 135) battery life can be as long as 1000 hours for the 176 and 100 hours for the 135.

- Optional accessories can be ordered to extend the measurement capability of the 135 and 176. Some of these accessories are:

  High frequency (RF) probe allows your DMM to measure from 0.25V to 30V rms AC over a frequency range from 100KHz to 100MHz.

  50 ampere current shunt allows your DMM to measure up to 50A, AC or DC.

  Clamp on AC current probe allows your DMM to measure up to 200A rms AC.

  High Voltage Probe allows your DMM to measure from 1000V to 40KV DC.

NOTE

Refer to Section 2 for more detailed information on accessories.

1-6. WARRANTY INFORMATION

1-7. The warranty is given on the inside front cover of this instruction manual. If there is a need to exercise the warranty contact the Keithley Representative in your area to determine the proper action to be taken. Keithley maintains service facilities in the United Kingdom, West Germany and in the United States. Check the inside front cover of this manual for addresses.

1-8. MANUAL ADDENDUMS

1-9. Improvements or changes that affect these instruments which occur after printing of the Instruction Manual will be explained on an addendum sheet attached to the inside back cover.

1-10. SAFETY SYMBOLS AND TERMS

1-11. Safety symbols used in this manual are as follows

The symbol ⚠ on the instrument denotes that the user should refer to the operating instructions.

The symbol ⚡ on the instrument denotes that 1000V or more may be present on the terminal(s).

The **WARNING** used in this manual explains dangers that could result in personal injury or death.

The **CAUTION** used in this manual explains hazards that could damage the instrument.

1-12. UNPACKING AND INSPECTION

1-13. The Models 135 and 176 were carefully inspected both mechanically and electrically before shipment. Upon receiving either or both of these instruments, unpack all items from the shipping container and check for any obvious damage that may have occurred during transit. Report any damage to the shipping agent. Retain and use the original packaging materials if reshipment is necessary. The following items are shipped with all 135 and 176 orders:

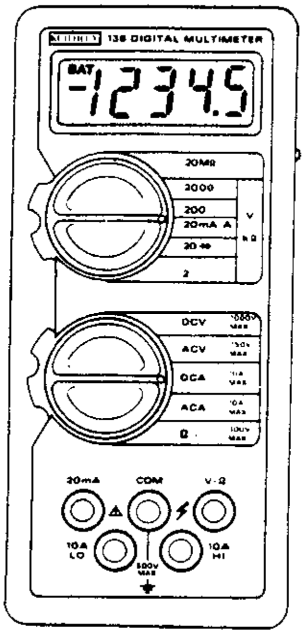


FIGURE 1-1
135 DIGITAL MULTIMETER

A. Model 135 or 176.
B. A copy of the appropriate Operator's Manual.
C. Supplied Accessories: 176 (Model 1768 Battery Pack with batteries, Model 1691 Test Lead Set) 135 (9V battery, Model 1691 Test Lead Set).
D. Installed or separate optional accessories, as ordered.

1-14. SPECIFICATIONS

1-15. Detailed specifications for both instruments are given on the following pages.

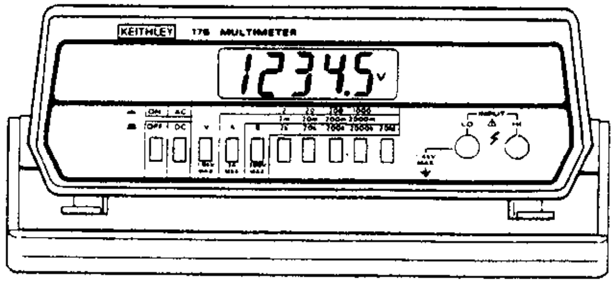


FIGURE 1-2
176 DIGITAL MULTIMETER

176 SPECS

DC VOLTS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C
2 V	1.9999	0.05% + 1d	0.012% + 0.3d
20 V	19.999	0.05% + 1d	0.012% + 0.3d
200 V	199.99	0.1 % + 1d	0.012% + 0.3d
1000 V	1000.0	0.1 % + 1d	0.012% + 0.3d

INPUT RESISTANCE: 10MΩ.

NMRR: Greater than 60dB @ 50Hz, 60Hz.

CMRR (1kΩ unbalance): Greater than 120dB @ DC, 50Hz & 60Hz.

MAXIMUM ALLOWABLE INPUT: 1000V continuous on 20V, 200V, 1000V ranges: 300V continuous on 2V range: 1000V momentary (3 seconds) on 2V range.

DC AMPS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C	MAXIMUM VOLTAGE BURDEN
2 mA	1.999	0.5% + 2d	0.05% + 0.3d	0.25V
20 mA	19.99	0.5% + 2d	0.05% + 0.3d	0.25V
200 mA	199.9	0.5% + 2d	0.05% + 0.3d	0.3 V
2000 mA	1999	0.5% + 2d	0.05% + 0.3d	0.7 V

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

OHMS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C	MAX TEST CURRENT
2 kΩ	1.9999	0.25% + 5d	0.05% + 0.3d	2.5mA
20 kΩ	19.999	0.2 % + 2d	0.01% + 0.5d	500 μA
200 kΩ	199.99	0.2 % + 2d	0.01% + 0.5d	50 μA
2000 kΩ	1999.9	0.2 % + 2d	0.01% + 0.5d	5 μA
20MΩ	19.999	0.75% + 2d	0.1 % + 0.5d	0.5 μA

MAXIMUM ON-RANGE VOLTAGE: 2V.

MAXIMUM OPEN CIRCUIT VOLTAGE: 5V.

OVERLOAD PROTECTION: 300V AC or DC on all ranges.

GENERAL

DISPLAY: 0.6" LCD digits with decimal and polarity indications, low battery warning, range and function annunciators.

CONVERSION PERIOD: 400ms.

OVERRANGE INDICATION: Flashing leading digit.

MAXIMUM COMMON MODE VOLTAGE: 1400V.

OPERATING ENVIRONMENT: 0°-50°C; less than 80% relative humidity up to 35°C, less than 70% relative humidity from 35°-50°C.

AC VOLTS (above 2000 counts)

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C
2 V	1.9999	1% + 15d, 45Hz-10kHz*
20 V	19.999	1% + 15d, 45Hz-10kHz*
200 V	199.99	1% + 15d, 45Hz- 5kHz
1000 V	1000.0	1% + 15d, 45Hz- 1kHz

*5% + 15d, 10kHz-20kHz

RESPONSE: Average responding, calibrated in rms of a sine wave.

INPUT IMPEDANCE: 1MΩ shunted by less than 100pF.

CMRR (1kΩ unbalance): Greater than 60dB (40dB on 1000V range) @ DC, 50Hz & 60Hz.

MAXIMUM ALLOWABLE INPUT: 1000V rms, 1400V peak continuous on 20V, 200V, 1000V ranges; 300V rms continuous on 2V range, 1000V momentary; 10^{6}V•Hz max.

TEMPERATURE COEFFICIENT: Less than (0.1 × applicable accuracy)/°C (0°-18°C & 28°-50°C).

AC AMPS

RANGE	MAXIMUM READING	ACCURACY 45Hz-1kHz ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C	MAXIMUM VOLTAGE BURDEN
2 mA	1.999	1.5% + 5d	0.15% + 0.5d	0.25V
20 mA	19.99	1.5% + 5d	0.15% + 0.5d	0.25V
200 mA	199.9	1.5% + 5d	0.15% + 0.5d	0.3 V
2000 mA	1999	1.5% + 5d	0.15% + 0.5d	0.7 V

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

STORAGE ENVIRONMENT: −35°C to 60°C.

POWER: Six 1.5V "C" cells.

BATTERY LIFE: 1000 hours (typical) with alkaline "C" cells.

BATTERY INDICATOR: Display indicates "BAT" when less than 10% of life remains.

DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep (3½" × 9¼" × 10¾"). Net weight 1.7kg (3.6 lb.).

ACCESSORIES SUPPLIED: Model 1768 Battery Pack with batteries, Model 1691 Test Lead Set, Operator's Manual.

ACCESSORIES AVAILABLE:
- Model 1010: Single Rack Mounting Kit
- Model 1017: Dual Rack Mounting Kit
- Model 1301: Temperature Probe
- Model 1600A: High Voltage Probe
- Model 1651: 50A Curent Shunt
- Model 1681: Clip-On Test Lead Set
- Model 1682A: RF Probe
- Model 1683: Universal Test Lead Kit
- Model 1684: Hard Shell Carrying Case
- Model 1685: Clamp-On Current Probe
- Model 1691: General Purpose Test Leads
- Model 1766: Battery Eliminator
- Model 1768: Battery Pack (for converting 176/1766 to battery power)
- Model 1769: Spare Parts Kit

135 SPECS

DC VOLTS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C
2 V	1.9999	0.05% + 1d	0.012% + 0.3d
20 V	19.999	0.05% + 1d	0.012% + 0.3d
200 V	199.99	0.1 % + 1d	0.012% + 0.3d
1000 V	1000.0	0.1 % + 1d	0.012% + 0.3d

INPUT RESISTANCE: 10MΩ.

NMRR: Greater than 60dB @ 50Hz, 60Hz.

CMRR (1kΩ unbalance): Greater than 120dB @ DC, 50Hz & 60Hz.

MAXIMUM ALLOWABLE INPUT: 1000V continuous on 20V, 200V, 1000V ranges; 300V continuous on 2V range. 1000V momentary (3 seconds) on 2V range.

AC VOLTS (above 2000 counts)

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C
2 V	1.9999	1% + 15d, 45Hz- 10kHz*
20 V	19.999	1% + 15d, 45Hz-500 Hz
200 V	199.99	1% + 15d, 45Hz-120 Hz
750 V	750.0	1% + 15d, 45Hz-120 Hz

*5% + 15d 10kHz-20kHz

RESPONSE: Average responding, calibrated in rms of a sine wave.

INPUT IMPEDANCE: 10MΩ shunted by less than 100pF.

CMRR (1kΩ unbalance): Greater than 60dB (40dB on 1000V range) @ DC, 50Hz & 60Hz.

MAXIMUM ALLOWABLE INPUT: 750V rms, 1000V peak continuous on 20V, 200V, 750V ranges, 10^{7}V•Hz max; 300V rms continuous on 2V range, 750V momentary.

TEMPERATURE COEFFICIENT: Less than (0.1 × applicable accuracy)/°C (0°-18°C & 28°-50°C).

OHMS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C	MAX TEST CURRENT
2 kΩ	1.9999	0.25% + 5d	0.05% + 0.3d	2.5mA
20 kΩ	19.999	0.2 % + 2d	0.01% + 0.5d	500 μA
200 kΩ	199.99	0.2 % + 2d	0.01% + 0.5d	50 μA
2000 kΩ	1999.9	0.2 % + 2d	0.01% + 0.5d	5 μA
20MΩ	19.999	1 % + 2d	0.1 % + 0.5d	0.5 μA

MAXIMUM ON-RANGE VOLTAGE: 2V.

MAXIMUM OPEN CIRCUIT VOLTAGE: 3.5V.

OVERLOAD PROTECTION: 300V AC or DC on all ranges.

DC AMPS

RANGE	MAXIMUM READING	ACCURACY ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C	MAX VOLTAGE BURDEN
20mA	19.99	0.5% + 2d	0.05% + 0.3d	0.25V
10 A	10.00	1 % + 2d	0.05% + 0.3d	0.3 V

OVERLOAD PROTECTION: 0.75A fuse (250V), externally accessible (10A input: 20A for 15s unfused)

AC AMPS

RANGE	MAXIMUM READING	ACCURACY, 45Hz-1kHz ±(%rdg + digits) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + digits)/°C 0°-18°C & 28°-50°C
20mA	19.99	1.5% + 5d	0.15% + 0.5d
10 A	10.00	1.5% + 5d	0.15% + 0.5d

OVERLOAD PROTECTION: 0.75A fuse (250V), externally accessible (10A input: 20A for 15s unfused)

GENERAL

DISPLAY: 0.6" LCD digits with decimal and polarity indications, low battery warning.

CONVERSION PERIOD: 400ms.

OVERRANGE INDICATION: Flashing leading digit

MAXIMUM COMMON MODE VOLTAGE: 500V

OPERATING ENVIRONMENT: 0°-50°C, less than 80% relative humidity up to 35°C, less than 70% relative humidity from 35°-50°C

STORAGE ENVIRONMENT: −35°C to 60°C.

POWER: One 9V alkaline or carbon-zinc battery (NEDA 1604)

BATTERY LIFE: 100 hours (typical) with alkaline battery

BATTERY INDICATOR: Display indicates "BAT" when less than 10% of life remains.

DIMENSIONS, WEIGHT: 178mm long × 78mm wide × 38mm thick (7.0" × 3.1" × 1.5") Net weight 282gm (10 oz.)

ACCESSORIES SUPPLIED: Battery, Model 1691 Test Lead Set, Model 1355 Operator's Manual.

ACCESSORIES AVAILABLE:
- Model 1301: Temperature Probe
- Model 1304: Soft Carrying Case & Stand
- Model 1306: Deluxe Carrying Case
- Model 1359: Spare Parts Kit
- Model 1600A: High Voltage Probe
- Model 1651: 50-Ampere Current Shunt
- Model 1681: Clip-On Test Lead Set
- Model 1682A: RF Probe
- Model 1683: Universal Test Lead Kit
- Model 1685: Clamp-On Current Probe
- Model 1691: General Purpose Test Lead Set

Section 2. Accessories

2-1. GENERAL

This section describes the various accessories and options available for use with the Models 135 and 176. Some of the following accessories are for use only with the Model 135 and some are for use only with the Model 176. These accessories will be clearly pointed out as to which instrument they are used with.

2-2. MUTUAL ACCESSORIES

The following accessories can be used with either the Model 135 or the Model 176.

2-3. Model 1600A High Voltage Probe

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

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

Specifications: Voltge Range: 0 to 40,000 volts DC.
Input Resistance: 1000 megohms.
Division Ratio: 1000:1
Ratio Accuracy:
1000 to 1 ±2% terminated in 10MΩ
2000 to 1 ±5% terminated in 1MΩ

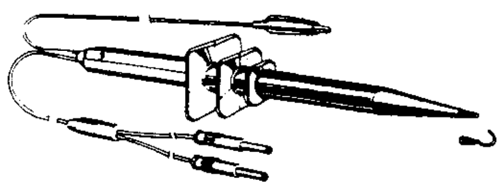


FIGURE 2-1
1600 HIGH VOLTAGE PROBE

2-4. Model 1651 50 Ampere Shunt

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

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

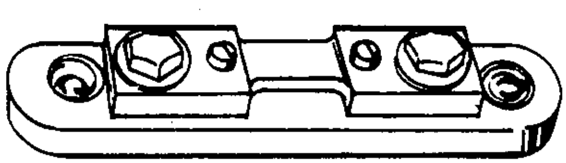


FIGURE 2-2
1651 50 AMPERE SHUNT

2-5. Model 1681 Clip-On Test Lead Set

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

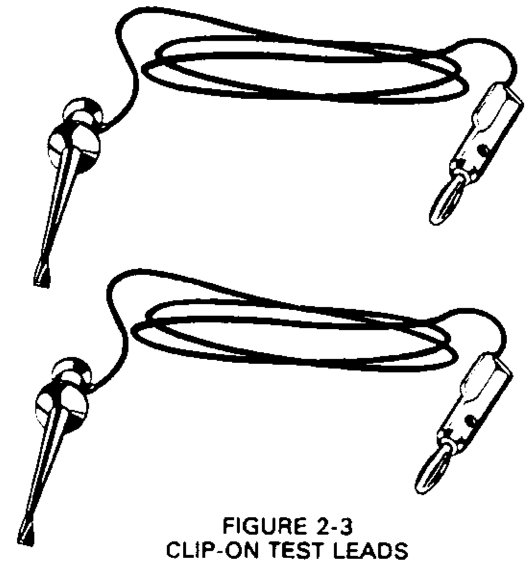


FIGURE 2-3
CLIP-ON TEST LEADS

2-6. Model 1682A RF Probe

Model 1682A RF Probe allows voltage measurements from 100kHz to 250MHz.

To Operate: Set the DMM to DCV and appropriate range. Connect the Model 1682A to the DMM input jacks.

Specifications
AC to DC Transfer Accuracy: (23°C ± 5°C): ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in rms of a sine wave, compatible with instruments with 10MΩ input resistance
Voltage Range: 0.25V to 15V rms
Maximum Allowable Input: 50V AC peak, 200V (DC+AC peak)
Maximum Common Mode Voltage: 30V rms, 42 peak
Input Capacitance: 5pF Typical
Operating Temperature: 0° to 50°C
Cable Length: 1.5 meters
Accessories Supplied: BNC Adapter, Insulating Tip, IC Tip, Spring Hook, Carrying Pouch

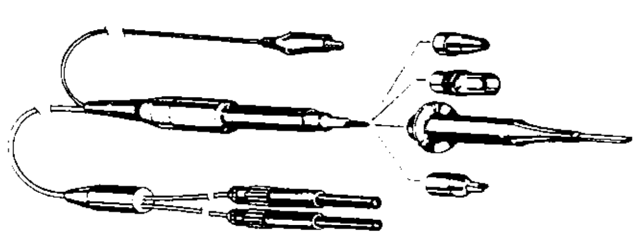


FIGURE 2-4
1682 RF PROBE

2-7. Model 1683 Universal Test Lead Kit
Two test leads, 1.2m (48 inches) long with 12 screw-in tips, 2 banana plugs, 2 spade lugs, 2 alligator clips with boots, 2 needle tips with chucks and 4 heavy duty tip plugs.

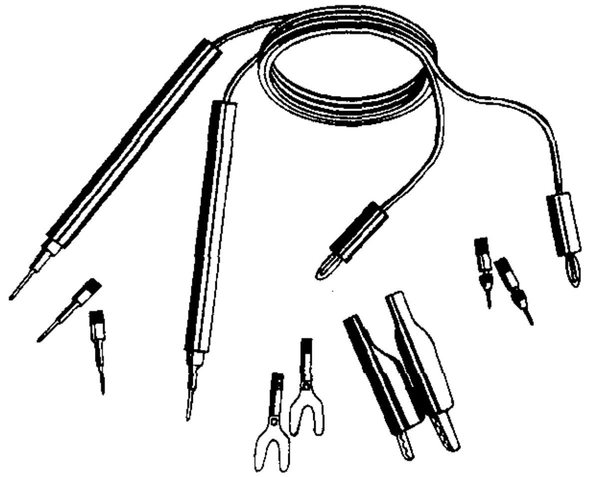


FIGURE 2-5
1683 TEST LEAD KIT

2-8. Model 1685 Clamp-On AC Current Probe
The Model 1685 measures AC current by clamping onto a single conductor. Interruption of the current path is unnecessary. The Model 1685 detects current by sensing the magnetic field produced by the current flow.
To Operate: Set the DMM to ACV and the appropriate range. The DMM will display 0.1V rms per ampere.

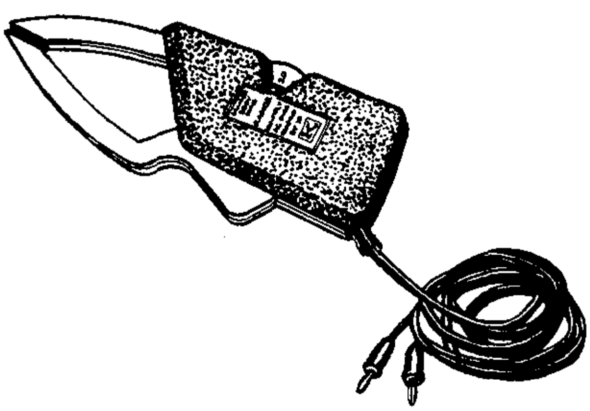


FIGURE 2-6
1685 CLAMP-ON AC CURRENT PROBE

2-9. Model 1691 General Purpose Test Lead Set
The Model 1691 General Purpose Test Lead Set consists of two 0.91mm (36 inches) test leads with probe tips terminated in banana plugs.

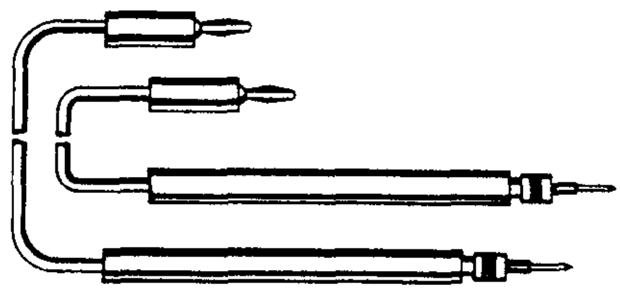


FIGURE 2-7
1691 TEST LEAD SET

2-10. MODEL 135 EXCLUSIVE ACCESSORIES

2-11. Model 1304 Soft Carrying Case and Stand.
The Model 1304 is a soft carrying case and stand (tilt bail) for Keithley's line of hand held instruments.

The instrument can be secured inside the case with the thumbscrew (supplied), if desired. The thumbscrew is also used to secure the stand (tilt bail) to set the instrument upright.

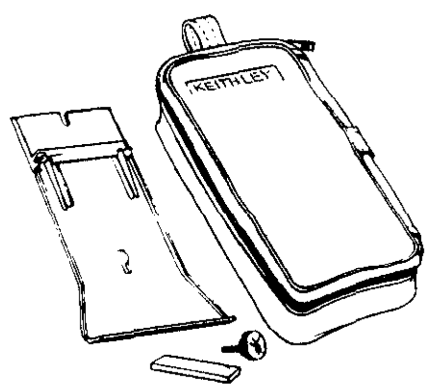


FIGURE 2-8
SOFT CASE AND STAND

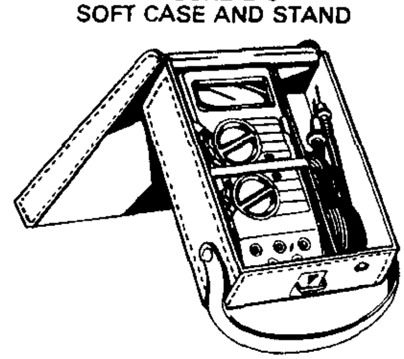


FIGURE 2-9
1306 DELUXE CASE

2-12. Model 1306 Deluxe Carrying Case
Model 1306 Deluxe Case is a rugged DMM carrying case that is large enough to accommodate the 135 plus various other DMM articles such as a spare battery, test leads, etc.

2-13. Model 1359 Spare Parts Kit
The Model 1359 is a spare parts kit for the Model 135. It consists of a complement of specially selected spare parts that will maintain several 135 DMM's for one year. The parts are listed in Table 6-2 of Section 6, Replaceable Parts.

2-14. MODEL 176 EXCLUSIVE ACCESSORIES

2-15. Model 1010 Rack Mounting Kit
The Model 1010 Rack Mounting Kit permits the mounting of a single DMM to a standard 5-1/4 in x 19 in rack.

2-16. Model 1017 Rack Mounting Kit .
The Model 1017 Rack Mounting Kit permits the mounting of two DMM's side by side in a standard 5-1/4 in x 19 in rack.

2-17. Model 1684 Hard Shell Carrying Case
The Model 1684 hard shell carrying case is a hard vinyl case which is 4 in x 13 in x 14 in (100mm x 300mm x 350mm). It has a fitted foam insert with room for the DMM, instruction book and small accessories.

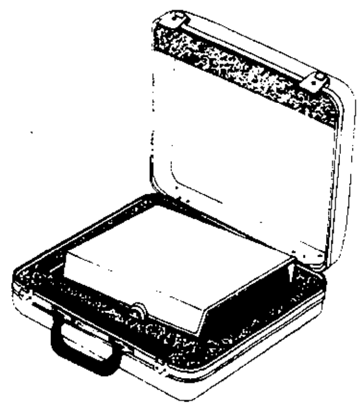


FIGURE 2-10
HARD CASE

2-18. Model 1766 Battery Eliminator
The Model 1766 Battery Eliminator permits the user to operate the 176 or 169 from line power. The 1766 provides the necessary DC voltage to operate the 176 or 169. The 1766 fits in place of the battery pack (Model 1768) so therefore, precludes the use of the battery pack (Model 1768). The Model 1766 is capable of working from a wide range of line voltages such as from 105VAC to 250VAC to 50HZ or 60HZ.

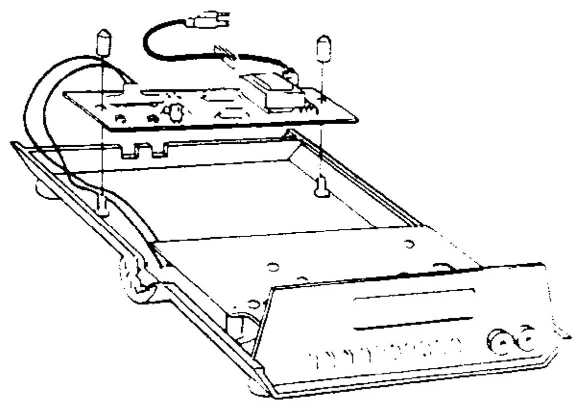


FIGURE 2-11
1766 ELIMINATOR

2-19. Model 1768 Battery Pack
The Model 1768 is a battery pack for the Model 176. One Model 1768 with batteries is supplied with each 176. The Model 1768 is positioned at the rear of the 176 supported by the two spacers (25762B). There are 6 standard carbon zinc "C" cells provided in the 1768 which give approximately 500 hrs (typical) of battery life. With the 1768 installed the Model 176 is completely portable. Therefore, it is free to tackle "in the field" measurements without the sometimes cumbersome line cord.

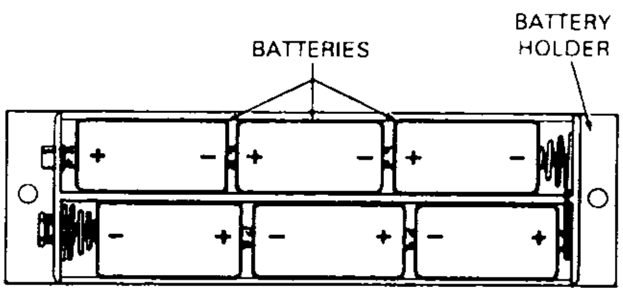


FIGURE 2-12
BATTERY PACK

2-20. Model 1769 Spare Parts Kit
The Model 1769 is a spare parts kit for the Model 176. It consists of a complement of specially selected spare parts that will maintain several 176 DMM's for one year. The parts are listed in Table 6-3 of Section 6, Replaceable Parts.

Section 3. Performance Verification

3-1. GENERAL
This section gives a Performance Verification procedure for both the Model 135 and the Model 176. Each procedure will be presented separately in order to avoid confusion.

3-2. Performance Verification may be performed upon receipt of either instrument (135 or 176) to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of either instrument's accuracy and following calibration, if desired.

NOTE

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

3-3. Environmental Conditions For Both Instruments
In order to perform the Performance Verification the instrument to be verified must be between 18°C to 28°C at less than 80% R.H.

3-4. Recommended Test Equipment
Recommended test equipment for performance verification of both instruments is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy is not at least 3 times better than the instruments specifications, additional allowance must be made in the readings obtained.

3-5. Initial Conditions
Before beginning the verification procedure the instruments must meet the following conditions

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

B. Turn the instrument to be verified on and check for low battery indication. If the low battery indicator (BAT) is on, remove and replace the battery or batteries

WARNING

All service information is intended for qualified electronic maintenance personnel only.

WARNING

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

CAUTION

Do not exceed maximum allowable input voltage. Instrument damage may occur. Maximum allowable input is stated in the specifications

TABLE 3-1
RECOMMENDED TEST EQUIPMENT

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	1V, 10V, 100V, 1000V ±0.002%	Fluke	343A
B	AC Calibrator	1V, 10V, 100V ±0.022%	H-P	745A
C	High Voltage Amplifier (Used with Model 745A)	1000V ±0.04%	H-P	746A
D	Decade Resistor	1K, 10K, 100K, 1000K, 10M ±.02%	ESI	DB62
E	Current Calibrator	1mA, 10mA, 100mA, 1000mA, 10A ±.03% DCA, ±.05% ACA	Valhalla	2500A

3-6. MODEL 135 PERFORMANCE VERIFICATION

3-7. DC Volts Verification

A. Select the DCV function.
B. Connect the DC Calibrator (Item A, Table 3-1) to the 135 V-Ω and COM terminals. Refer to Figure 3-1.
C. Follow Table 3-2 and apply the required DC Voltage for each range. Verify that each reading is within specifications listed in Table 3-2.
D. Repeat all checks with negative voltage.

TABLE 3-2
DC VOLTAGE PERFORMANCE CHECK

Range	Applied Voltage	Allowable Reading at 18°C to 28°C
2V	1.0000V	.9994 to 1.0006
20V	10.000V	9.994 to 10.006
200V	100.00V	99.89 to 100.11
1000V	1000.0V	998.9 to 1001.1

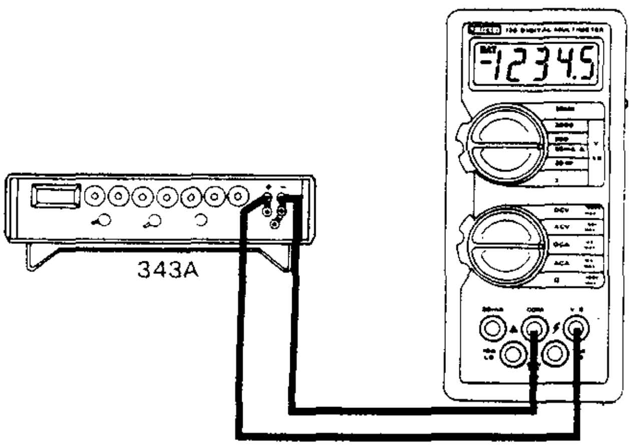


FIGURE 3-1
135 DC VOLTS VERIFICATION

3-8. AC Volts Verification

A. Select the ACV function.
B. Connect the AC calibrator (Item B, Table 3-1) to the 135 V-Ω and COM terminals. Refer to Figure 3-2.
C. Follow Table 3-3 and apply the required AC Voltage for each range. Verify that the reading is within specifications listed in Table 3-3.

TABLE 3-3
AC VOLTAGE PERFORMANCE CHECK

Range	Applied Voltage	Allowable Reading at 18°C to 28°C
2V	1.0000V at 10KHz	.9885 to 1.0115
20V	10.000V at 500Hz	9.885 to 10.115
200V	100.00V at 120Hz	98.85 to 101.15
750V	750.0V at 120Hz*	741.0 to 759.0

*High Voltage Amplifier (Item C) to be connected to 745 AC Calibrator to obtain 750V (See Figure 3-3).

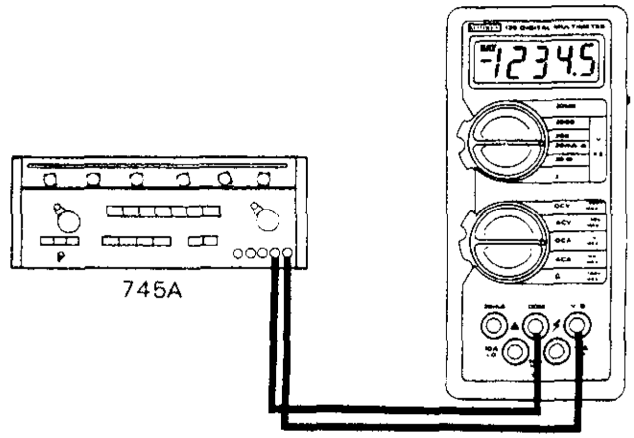


FIGURE 3-2
135 AC VOLTS VERIFICATION

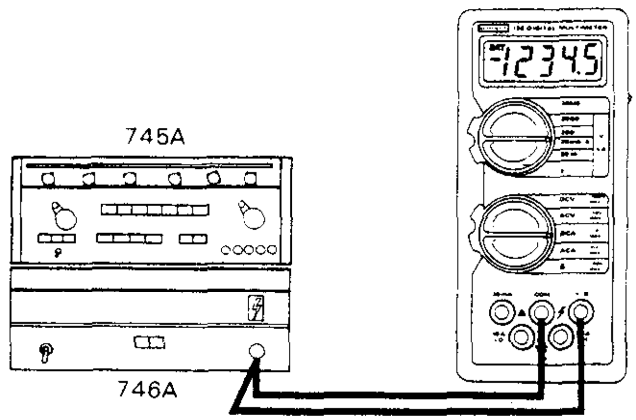


FIGURE 3-3
135 HI VOLTAGE ACV VERIFICATION

3-9. Resistance Verification

A. Select the OHMS function.
B. Connect the Decade Resistor (Item D, Table 3-1) to the 135 V-Ω and COM terminals. Refer to Figure 3-4.
C. Follow Table 3-4 and apply the required resistance for each range. Verify that each reading is within specifications listed in Table 3-4.

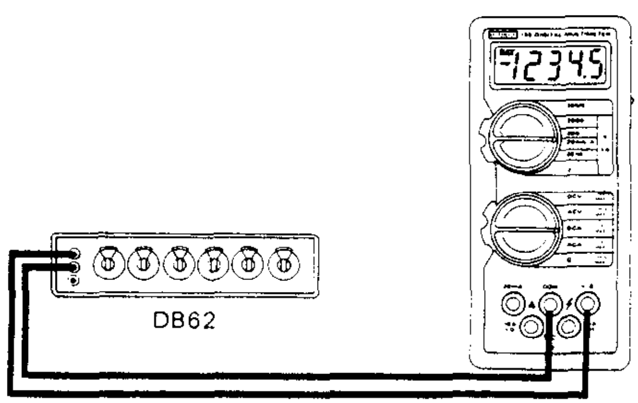


FIGURE 3-4
135 RESISTANCE VERIFICATION

TABLE 3-4
RESISTANCE PERFORMANCE CHECK

Range	Applied Resistance	Allowable Reading at 18°C to 28°C
2KΩ	1.0000KΩ	.9970 to 1.0030
20KΩ	10.000KΩ	9.978 to 10.022
200KΩ	100.00KΩ	99.78 to 100.22
2000KΩ	1000.0KΩ	997.8 to 1002.2
20MΩ	10.000MΩ	9.898 to 10.102

3-10. DC Amps Verification

A. Select the DC Amps function.
B. Connect the DC Calibrator (Item A, Table 3-1) to the input of the Current Calibrator (Item E, Table 3-1). Connect the output of the Current Calibrator to the 135's mA and COM terminals. Refer to Figure 3-5.
C. Select the 20mA range and apply a 10.00mA current to the 135. Verify that the reading is within 9.93 to 10.07.
D. Select the 10A range and connect the output of the Current Calibrator to the 135's 10A HI and 10A LO terminals. Refer to Figure 3-6.
E. Apply 10.00A to the 135 and verify that the reading is within 9.88 to 10.12.

3-11. AC Amps Verification

A. Select the AC Amps function and the 20mA range.
B. Connect the AC Calibrator (Item B, Table 3-1) to the input of the Current Calibrator (Item E, Table 3-1). Connect the output of the Current Calibrator to the 135's mA and COM terminals. Refer to Figure 3-7.
C. Apply a 10.00 mA current at 500Hz and verify that the reading is within 9.80 to 10.20.
D. Select the 10A range and connect the output of the Current Calibrator to the 135's 10A HI and 10A LO terminals. Refer to Figure 3-8.
E. Apply a 10.00A current at 500Hz and verify that the reading is within 9.80 to 10.20.

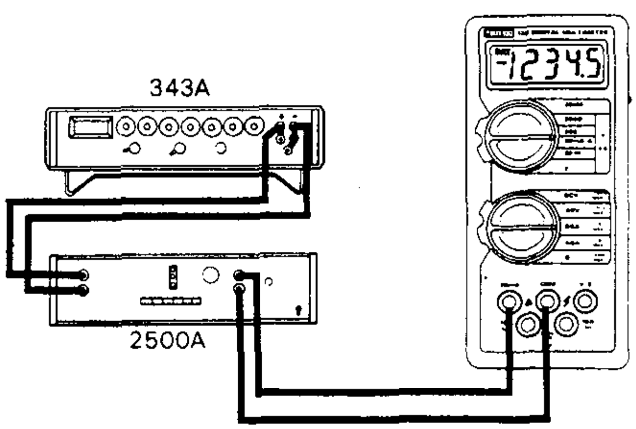


FIGURE 3-5
135 DC AMPS VERIFICATION

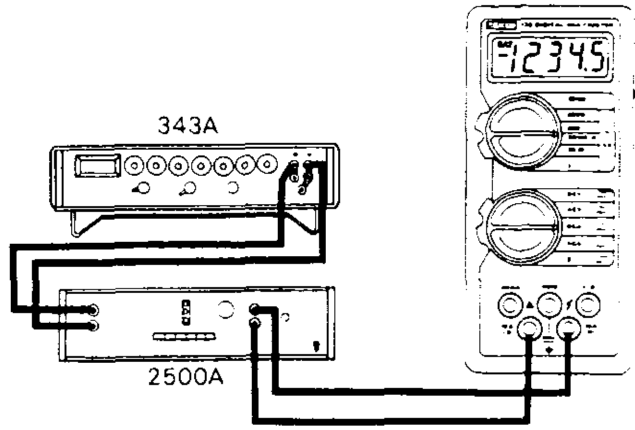


FIGURE 3-6
135 10A DC AMPS VERIFICATION

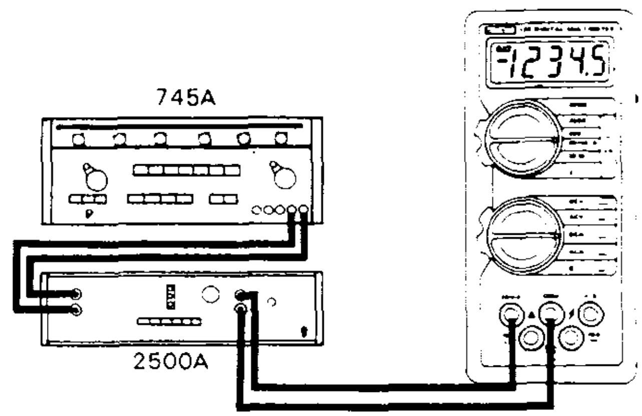


FIGURE 3-7
135 AC AMPS VERIFICATION

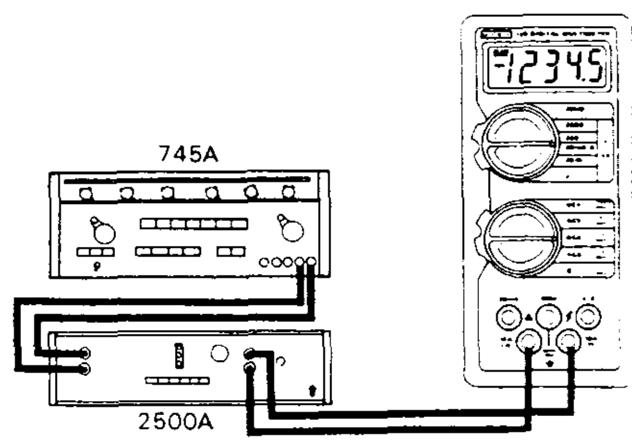


FIGURE 3-8
135 10A AC AMPS VERIFICATION

3-12. MODEL 176 PERFORMANCE VERIFICATION

3-13. DC Volts Verification

A. Select the DC Volts function.
B. Connect the DC Calibrator (Item A, Table 3-1) to the 176's HI and LO input terminals. Refer to Figure 3-9.
C. Follow Table 3-5 and apply the required DC Voltage for each range. Verify that each reading is within specifications listed in Table 3-5.
D. Repeat all checks with negative voltage.

TABLE 3-5
DC VOLTAGE PERFORMANCE VERIFICATION

Range	Applied Voltage	Allowable Reading at 18°C to 28°C
2V	1.0000V	.9994 to 1.0006
20V	10.000V	9.994 to 10.006
200V	100.00V	99.89 to 100.11
1000V	1000.0V	998.9 to 1001.1

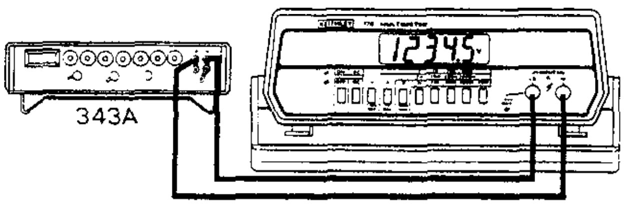


FIGURE 3-9
176 DC VOLTS VERIFICATION

3-14. AC Voltage Verification

A. Select the AC Volts function.
B. Connect the AC Calibrator and HV Amplifier (Items B and C, Table 3-1) to the 176's HI and LO terminals. Refer to Figures 3-10 and 3-11.
C. Follow Table 3-6 and apply the required AC Voltage for each range. Verify that each reading is within specifications listed in Table 3-6.

TABLE 3-6
AC VOLTAGE PERFORMANCE CHECK

Range	Applied Voltage	Allowable Reading at 18°C to 28°C
2V	1.0000V at 1KHz	.9885 to 1.0115
2V	1.0000V at 10KHz	.9885 to 1.0115
2V	1.0000V at 20KHz	.9485 to 1.0515
20V	10.000V at 1KHz	9.885 to 10.115
20V	10.000V at 10KHz	9.885 to 10.115
20V	10.000V at 20KHz	9.485 to 10.515
200V	100.00V at 1KHz	98.85 to 101.15
1000V	1000.0V at 1KHz	988.5 to 1011.5

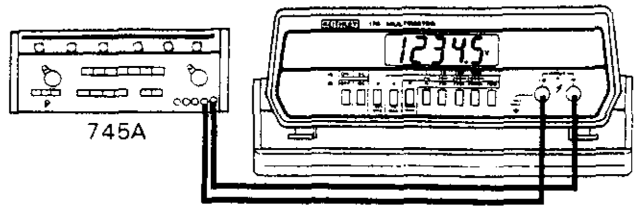


FIGURE 3-10
176 AC VOLTS VERIFICATION

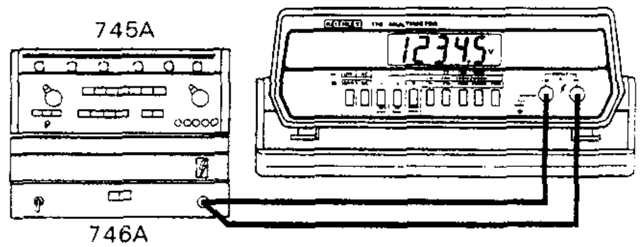


FIGURE 3-11
176 HIGH VOLTAGE ACV VERIFICATION

3-15. Resistance Verification

A. Select the OHMS function.
B. Connect the Decade Resistor (Item D, Table 3-1) to the 176 HI and LO input terminals. Refer to Figure 3-12.
C. Follow Table 3-7 and apply the required resistance for each range. Verify that each reading is within specifications listed in Table 3-7.

TABLE 3-7
RESISTANCE VERIFICATION

Range	Applied Resistance	Allowable Reading at 18°C to 28°C
2KΩ	1.0000KΩ	.9970 to 1.0030
20KΩ	10.000KΩ	9.978 to 10.022
200KΩ	100.00KΩ	99.78 to 100.22
2000KΩ	1000.0KΩ	997.8 to 1002.2
20MΩ	10.000MΩ	9.923 to 10.077

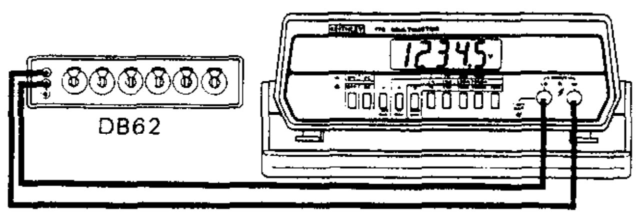


FIGURE 3-12
176 RESISTANCE VERIFICATION

3-16. DC Amps Verification

A. Select the DC Amps function.

B. Connect the DC Calibrator (Item A, Table 3-1) to the input of the Current Calibrator (Item E, Table 3-1). Connect the output of the Current Calibrator to the 176 HI and LO input terminals. Refer to Figure 3-13.

C. Follow Table 3-8 and apply the required current for each range. Verify that each reading is within specifications listed in Table 3-8.

TABLE 3-8
DC AMPS VERIFICATION

Range	Applied Current	Allowable Reading at 18°C to 28°C
2mA	1.000mA	.993 to 1.007
20mA	10.00mA	9.93 to 10.07
200mA	100.0mA	99.3 to 100.7
2000mA	1000 mA	993 to 1007

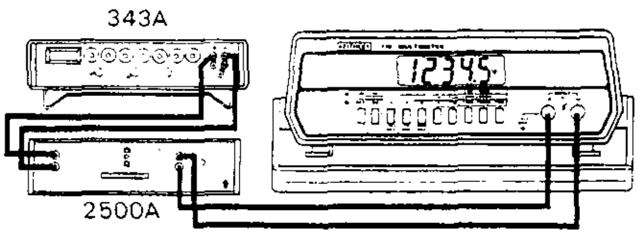


FIGURE 3-13
176 DC AMPS VERIFICATION

3-17. AC Amps Verification

A. Select the AC Amps function.

B. Connect the AC Calibrator (Item B, Table 3-1) to the input of the Current Calibrator (Item E, Table 3-1). Connect the output of the Current Calibrator to the 176 HI and LO terminals. Refer to Figure 3-14.

C. Follow Table 3-9 and apply the required current for each range. Verify that each reading is within specifications listed in Table 3-9.

TABLE 3-9
AC AMPS VERIFICATION

Range	Applied Current	Allowable Reading at 18°C to 28°C
2mA	1.000mA at 1KHz	980 to 1.020
20mA	10.00mA at 1KHz	9.80 to 10.20
200mA	100.0mA at 1KHz	98.0 to 102.0
2000mA	1000.mA at 1KHz	980. to 1020

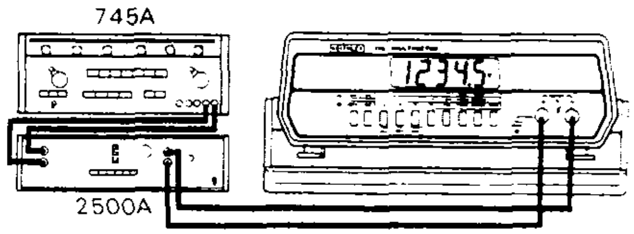


FIGURE 3-14
176 AC AMPS VERIFICATION

Section 4. Theory of Operation

4-1. GENERAL

This section contains the circuit descriptions for the Model 135 and Model 176. The following discussions of circuit theory will be separated into 2 major sections. The 2 major sections are:

1) Model 135 Circuit Theory
2) Model 176 Circuit Theory

The information contained in each of these sections is arranged in the following manner.

1) Overall Functional Description
2) Signal Conditioning
3) A/D Converter
4) Display
5) Power Supply

To facilitate understanding, each description is accompanied with simplified schematics, block diagrams, tables and graphs. Detailed schematics of the Model 135 and Model 176 are provided in Section 6.

4-2. MODEL 135 OVERALL FUNCTIONAL DESCRIPTION

The Model 135 is a 4-1/2 digit, ±20,000 count hand held DMM. It has 4 DC voltage ranges, 4 AC voltage ranges, 5 resistance ranges, 2 DC current ranges and 2 AC current ranges. Along with these functions and ranges it has 100μVDC and AC Volts sensitivity with 100mΩ Resistance sensitivity. The DC and AC current sensitivity is 10μA.

The 135 was designed for high performance at low cost. To meet these design goals the 135 takes advantage of standard "off the shelf" components. The A/D converter was designed from scratch using discrete components for lower power consumption and improved performance over presently available LSI A/D converters.

Figure 4-1 shows the overall block diagram for the model 135.

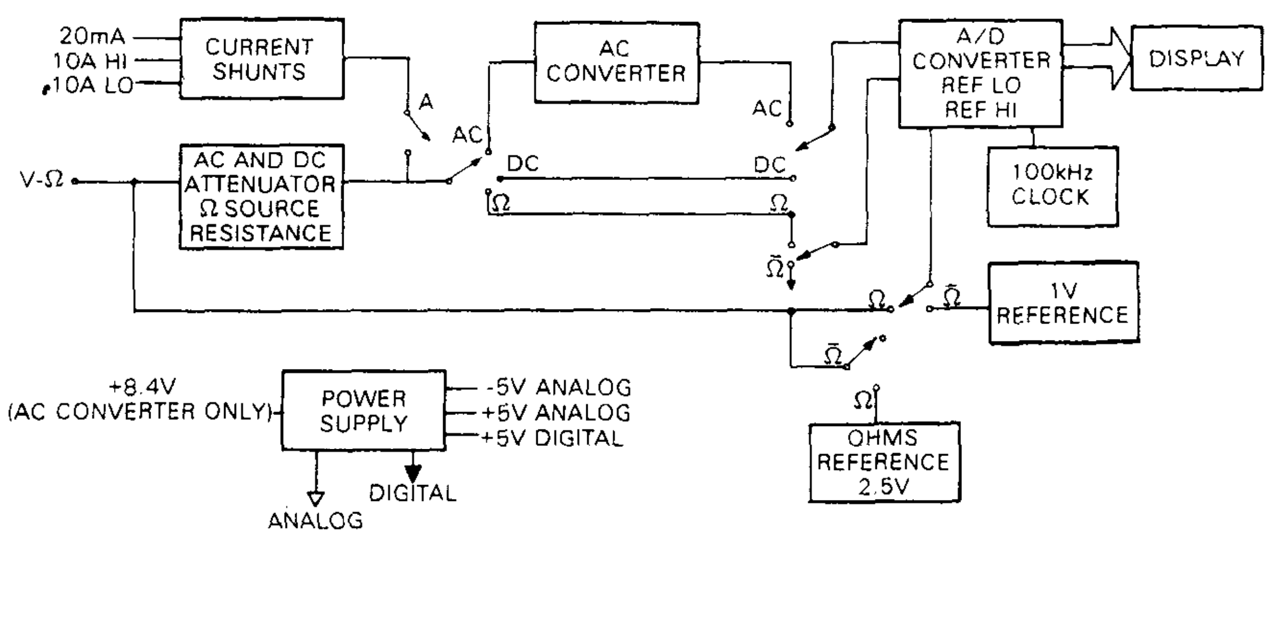


FIGURE 4-1
135 BLOCK DIAGRAM

4-3. Signal Conditioning
The Signal Conditioning for the Model 135 includes DC attenuation (except on the 2 Volt range), AC attenuation, AC/DC conversion, Ohms conversion and current shunts.

A. DCV Signal Conditioning consists of one 10MΩ passive divider. The taps from this divider are inputted directly to the A/D converter through the rotary range switch S102. Table 4-1 states the associated attenuation with each range. Potentiometer R113 trims the gain for the 20 Volt range. The overload protection is provided by the limiting resistor R115.

TABLE 4-1
ACV AND DCV ATTENUATION

Range	Attenuation Factor
2V	÷1
20V	÷10
200V	÷100
1000V*	÷1000

*750V range for ACV

B. ACV Signal Conditioning consists of a 10MΩ passive divider, AC buffer amplifier and AC converter. The scaling is accomplished by the same 10MΩ passive divider that is used for DCV scaling. After the divider the signal is AC coupled into U105 the AC Buffer Amplifier. The signal is then applied to the averaging precision rectifier U104. It is driven at low impedance by the AC coupled buffer. U104 performs the AC conversion. It then passes through a two stage low pass filter which converts it to DC. This DC level is applied to the A/D converter. Input resistance for the AC converter is 10MΩ shunted by less than 100 pf.

R111 establishes AC zero while R109 determines the full scale gain (19000 counts). R105 and C108 provide the low pass filter to average the half wave rectified output. Overload protection is provided by diodes CR104 and CR105 and current limiting resistor R110. Figure 4-2 shows a simplified schematic of the AC converter.

C. Resistance Signal Conditioning is accomplished ratiometrically. That is, a precision reference resistor and Rx are put in series with a 2.5 volt reference. Therefore, the current developed in the two resistors is the same. Taking the ratio of the voltage drop across Rx to the drop across $R_{Reference}$ correctly calculates ohms. The value of the voltage reference is irrelevant, as it only serves to apply a source of current to the resistors (Rx and $R_{Reference}$). The preceding theory is illustrated mathematically in the following equations. Refer to Figure 4-3.

$$I = \frac{Vref}{Rref + Rp + Rx}$$

$$Vdisplay = \frac{Vin\ HI - Vin\ LO}{Vref\ HI - Vref\ LO} \times 10{,}000$$

$$Vdisplay = \frac{I\,[Rx] - 0}{I\,[Rref + Rp + Rx] - I\,[Rp + Rx]} \times 10{,}000$$

$$Vdisplay = \frac{IRx}{I\,[Rref + Rp + Rx - Rp - Rx]} \times 10{,}000$$

$$Vdisplay = \frac{IRx}{IRref} \times 10{,}000 = \frac{Rx}{Rref} \times 10{,}000$$

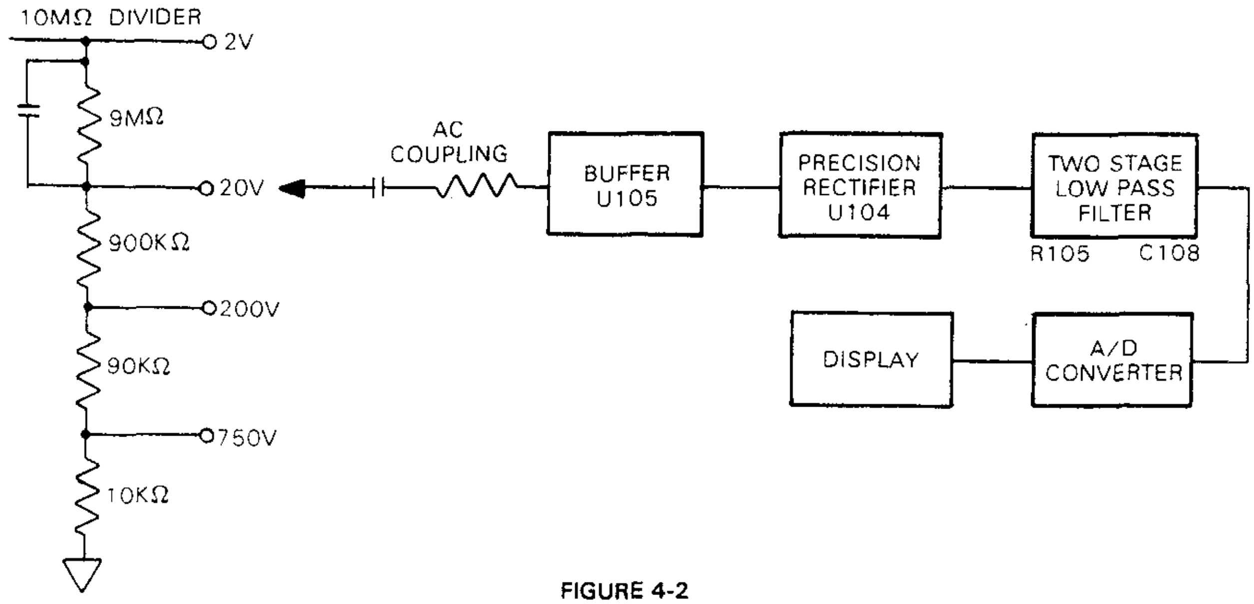


FIGURE 4-2
SIMPLIFIED AC CONVERTER BLOCK DIAGRAM

The precision reference resistors are available from the DC divider. Rp and Q204 form the overload protection for the Ref LO input. Vref is approximately 2.5 volts and is provided by pass transistor Q101. Q204 conducts much like a zener diode at approximately 9 volts to absorb the initial overload as Rp heats up, its resistance goes from 1K to several megohms effectively limiting current.

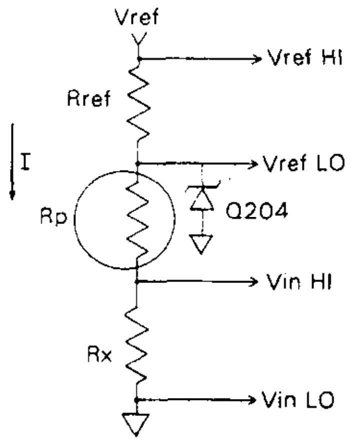


FIGURE 4-3
SIMPLIFIED OHMS SCHEMATIC

D. AC/DC Current measurements have two ranges; the 20mA range and the 10A range. These two ranges are 3-1/2 digit readings in order to keep the burden voltage under 250mV. The 20mA range is protected by diodes CR108, CR109 and Fuse F101. The current shunt for the 10A range is designed to minimize internal heating in the event of overload. Figure 4-4 is a simple block diagram showing AC/DC current measurements.

CAUTION

Do not exceed maximum allowable input. Instrument damage may occur. **10A range** is unfused.

4-4. A/D Converter

The A/D converter is really the heart of the instrument. It is engineered from discrete SSI CMOS and low power analog circuitry. The operation of the A/D converter is of the dual slope principle. The timing of the dual slope measurement is divided into 3 periods; Auto Zero, Signal Integrate and Reference Integrate. The following three steps illustrate the three measurement periods.

1) Auto Zero
   The Auto Zero period is 100 msec in length which corresponds to 10,000 clock pulses. During this period the reference voltage is stored on capacitor C205. Capacitor C206 stores +Vos1-Vos2. Refer to Figure 4-5.

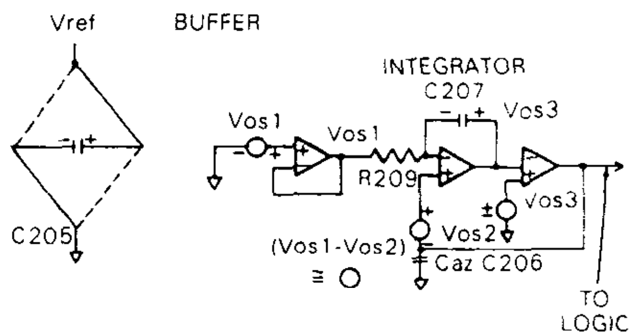


FIGURE 4-5
AUTO ZERO

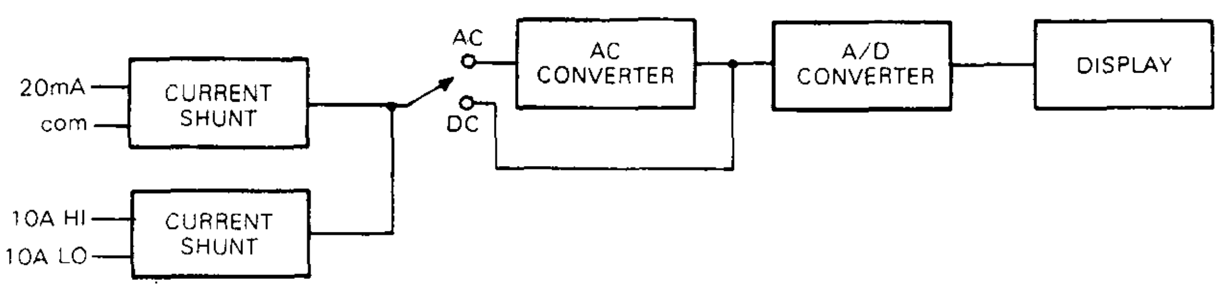


FIGURE 4-4
BLOCK DIAGRAM FOR CURRENT MEASUREMENT

2) Signal Integrate
As with the Auto Zero phase the Signal Integrate phase is of 100 msec duration. The input of the A/D converter is first buffered by one half of U213 and then the signal is integrated by the other half of U213. When positive signals are applied to the A/D the integrator generates a negative going ramp. This can be seen at the output of the integrator (pin 1). When negative signals are applied to the A/D the integrator generates a positive going ramp. The level of the integrated signal at the end of this period (signal integrate) is proportional to the average of the applied signal during this period. Since Signal Integration is a constant 100 msec. the converter exhibits high rejection at 50Hz and 60Hz. Refer to Figure 4-6 for a simplified diagram of Signal Integrate.

SIGNAL INTEGRATE (10K COUNTS)

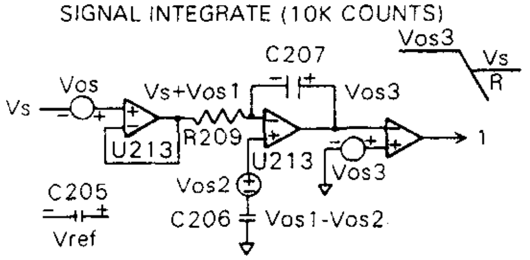


FIGURE 4-6
SIGNAL INTEGRATE

3) Reference Integrate
The Reference Integrate period for a full scale input (20,000 counts) is 200 msec. During this period the integrator is returned to a baseline level by applying a reference voltage of a polarity opposite to that of the signal. This is accomplished by grounding the appropriate side of the reference capacitor. The digital output is generated from the latches within U101 which store the number of clock pulses required for the integrator to return to baseline levels.
For inputs less than full scale (full scale = 20,000 counts). the A/D automatically reverts to Auto Zero. This happens in the time period of the 200 msecs remaining after the return to baseline level. Refer to Figures 4-7 and 4-8 for a simplified diagram of Reference Integrate.

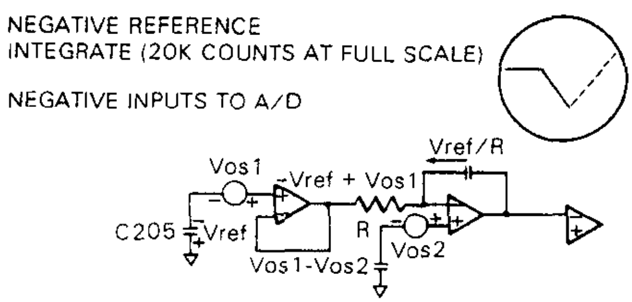


FIGURE 4-7
NEGATIVE REFERENCE INTEGRATE

POSITIVE REFERENCE INTEGRATE
(20K COUNTS AT FULL SCALE)

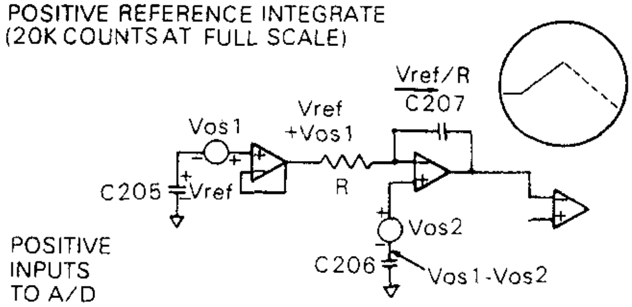


FIGURE 4-8
POSITIVE REFERENCE INTEGRATE

Also included in the A/D are 2 adjustment potentiometers. R205 is part of a translation network which insures that the comparator output during autozero is at or near the threshold of U204C, which is the zero crossing flip flop. Therefore this adjustment controls symmetry between positive and negative inputs. Shorting C204 (as in the cal procedure) and adjusting R205 for a reading of .0000 accomplishes this symmetry adjustment.
The A/D gain control (R102) is the other adjustment. This potentiometer controls the reference voltage and compensates for all gain errors within the dual slope A/D converter.
The A/D is ratiometric, with differential reference inputs. Therefore

$$\text{Vdisplay} = \frac{\text{Vinput}}{(\text{Ref Hi} - \text{Ref Lo})} \times 10{,}000$$

The full scale inputs for the A/D are as follows:

ACV,DCV,Ω,DCA,ACA = ±2V (full scale input)

4-5. Input Buffer
The analog switches used for the A/D converter are CMOS (U210, U211, U212). A low drift, low bias current buffer (U214) precedes the A/D input. The offset for this amplifier (U214) is nulled with potentiometer R207.

4-6. Reference Voltage
The reference voltage (V_{ref}) is provided by a divider network placed across a temperature compensated zener (CR110). One half of U102 provides the zener with a self regulating bias. The reference voltage is approximately 1.0 volts and can be finely adjusted by R102.

4-7. Display
The 4-1/2 digit Liquid Crystal Display is driven by LSI counter/driver U101. The Backplane and the segments of the digits are driven directly by U101. The zebra strip connector transfers the drive signals from the P-C board onto the LCD.
A low battery indicator is detected and actuated by one half of U102. This annunciator, the minus sign, and all

decimal points are driven by the exclusive OR gate arrays U201 and U202.

The digitized measurement data is presented by output lines to the LCD. These lines are driven by a square wave having the same amplitude and frequency as the Backplane line. When the lines to the display segments are driven 180° out of phase with the Backplane the segments are ON. Conversely, when in phase the segments are OFF. The decimal points and the LO battery indicator are turned OFF and ON similarly.

4-8. Power Supply

The precision reference current source U102A also doubles as the +5 volt supply. Pin 1 of U102 is the V+ supply. The 5 volt supply is generated by a power inverter circuit (U103). This device charges capacitor C102 and then reverses it. This effectively generates -5 volts. A voltage doubler circuit consisting of C103, C104, CR101 and CR102 generates +8.4 volts. This voltage is only used on U104 which is the precision rectifier amplifier (U104) of the AC converter.

4-9. MODEL 176 OVERALL FUNCTIONAL DESCRIPTION

The Model 176 is a 4-1/2 digit, ±20,000 count portable bench DMM. It has 4 DC voltage ranges, 4 AC voltage ranges, 5 resistance ranges, 4 DC current ranges and 4 AC current ranges. Along with these functions and ranges it has 100µVDC and AC volts sensitivity with 100mΩ resistance sensitivity. The DC and AC current sensitivity is 1µA.

The 176 was designed for high performance at low cost. To meet these design goals the 176 takes advantage of standard "off the shelf" components, passive signal conditioning and multifunction components and circuits. The A/D converter was designed from scratch using discrete SSI CMOS components for low power consumption and improved performance over presently available LSI A/D converters.

Figure 4-9 shows the overall block diagram for the Model 176.

4-10. Signal Conditioning

The Signal Conditioning circuitry consists of the voltage dividers, current shunts, AC converter input buffer and protection circuitry.

4-11. DC Volts

The DC Volts Signal Conditioning consists of a passive divider R107 and R108. The taps from this divider are applied to the input of the Input Buffer Amplifier then to the A/D converter. Table 4-2 reveals the associated attenuation with each range.

The reference voltage 1.2V (attenuated to 1 Volt by R113 and R115) is applied to the A/D converter during DCV measurements. Therefore the A/D converter accepts an input voltage between -2 Volts and +2 Volts without going into an overrange condition. Take note that the 2V calibration (R130) adjusts the reference voltage and the 20V calibration (R107) adjusts the DC divider. This means that miscalibration of the 2V adjust (R130) will affect every function except Ohms. Miscalibration of the 20V adjust (R107) will affect the 20V, 200V and the 1000VDC ranges as well as the 20MΩ range. Refer to Figure 4-10 for a simplified schematic of the DC Volts signal conditioning circuitry.

TABLE 4-2
ACV AND DCV ATTENUATION

Range	Attenuation Factor
2V	÷1
20V	÷10
200V	÷100
1000V	÷1000

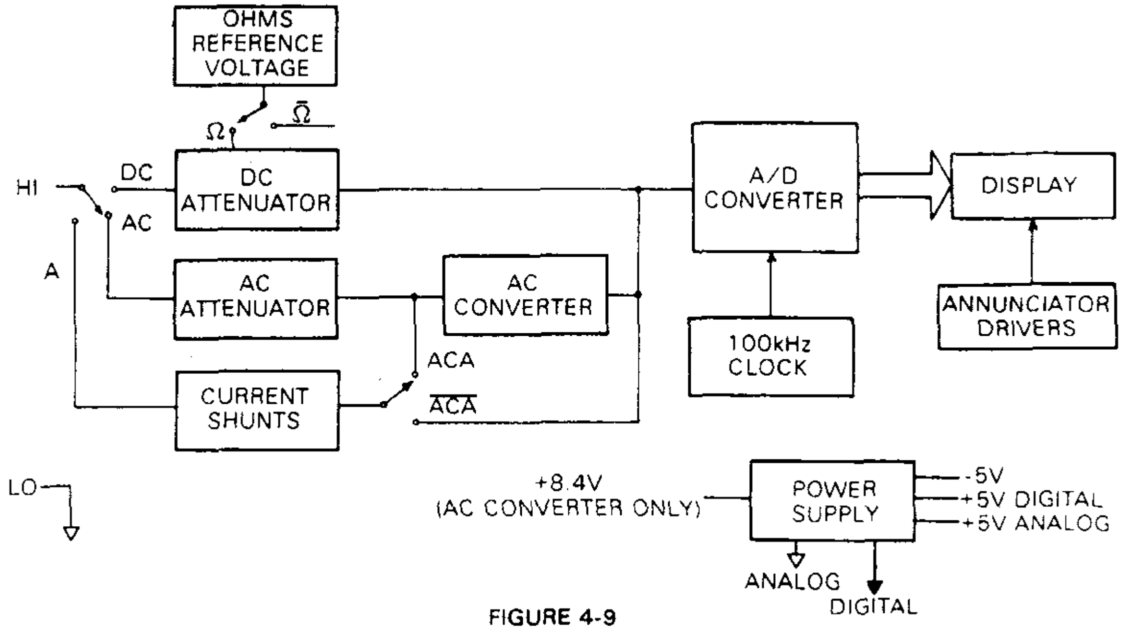


FIGURE 4-9
176 BLOCK DIAGRAM

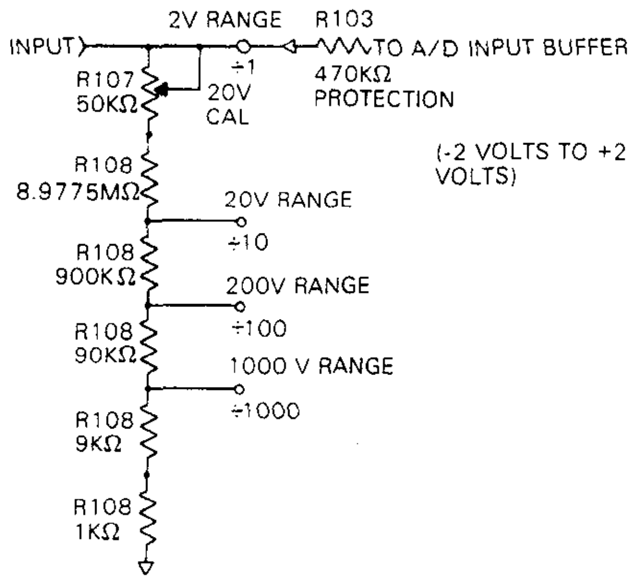


FIGURE 4-10
DCV SIGNAL CONDITIONING

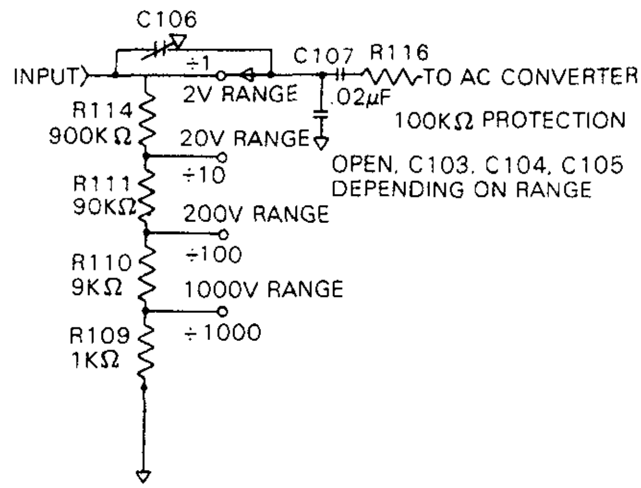


FIGURE 4-11
AC VOLTS DIVIDER

4-12. AC Volts

The AC Volts Signal Conditioning consists of a passive divider (R109 - R111, R114 and C103 - C106) and the AC converter. During AC Voltage measurements the measured signal is applied to the divider and is attenuated by 1, 10, 100 or 1000 for the 2V, 20V, 200 or 1000V range respectively. The capacitors (C103 - C106) are used for compensation for stray capacitance and for frequency characteristics of the resistors. There is no capacitor used on the 2V range for frequency compensation. There are only two capacitors in the circuit for any other range. This reduces interaction between ranges and allows easy isolation of faulty capacitors. The output from the AC divider is applied to the AC converter where it is rectified and scaled before being applied to the A/D converter. Refer to Figure 4-11.

The AC converter is a precision half wave rectifier with high impedance input and sufficient gain to produce a DC output equal to the rms value of a sine wave input. Following the signal path, C107 is used as a DC blocking capacitor so that DC offsets in the measured signal do not affect the reading. U108 is a unity gain buffer used to eliminate loading of the AC divider and provide low impedance drive for the actual AC converter U109. Capacitors C109 and C110 eliminate any problem due to the offset voltage of U108. R119 - R121 adjust the gain of the AC converter required to convert from the rectified waveform average to rms equivalent. Resistors R117 and R118 adjust out any error at zero due to offsets in U109. U109 uses feed forward compensation provided by C114 and will become unstable when any capacitive load (such as a scope probe) is attached near the output circuitry of the op amp (U109). Refer to Figure 4-12.

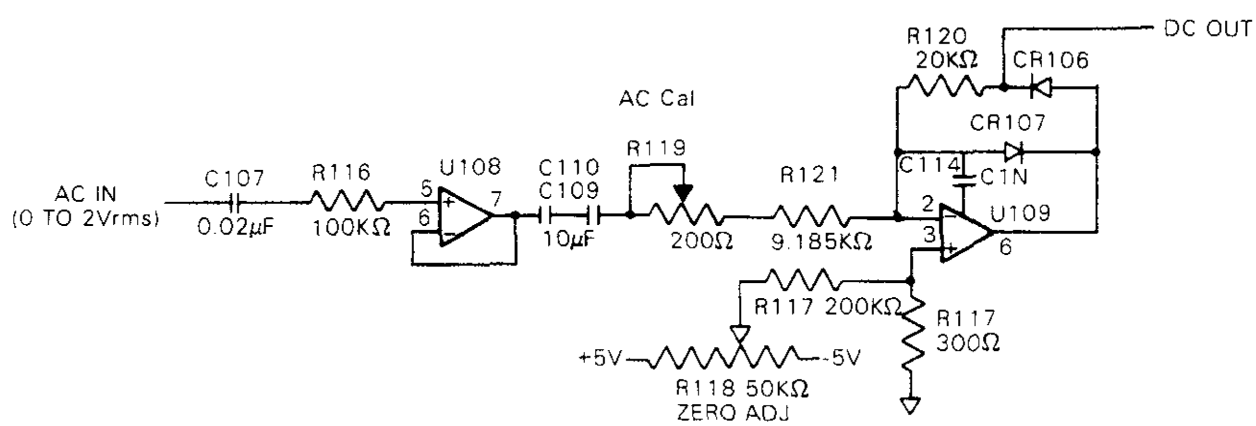
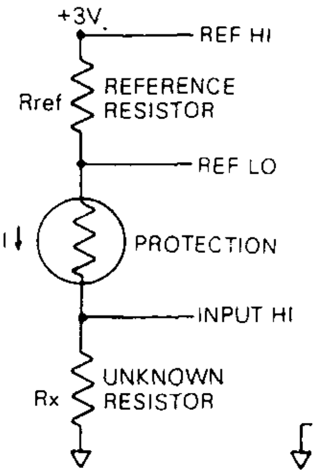


FIGURE 4-12
AC CONVERTER

4-13. Ohms

The Ohms signal conditioning circuitry consists of reference resistors R107 and R108 and an ohms reference voltage source. The actual ohms measurement is done ratiometrically which means the displayed reading is the ratio of the input voltage of the A/D converter to the reference voltage. This can be accomplished because the A/D converter was designed to have floating reference inputs. By placing a reference resistor in series with an unknown resistor, the ratio of the two resistors is equal to the ratio of the voltage across each resistor. The reference resistors R107and R108 are also the DCV divider. Using the 1KΩ, 10KΩ, 100KΩ, 1000KΩ and 10 MΩ taps on the divider for the 2KΩ, 20KΩ, 200KΩ, 2000KΩ and 20 MΩ ranges, the displayed reading is the actual resistance of the unknown resistor.

For ratiometric ohms, a stable, low impedance voltage source is required. U108 is used to supply the required source without drawing excess current from the batteries. Refer to Figure 4-13 and 4-14 for schematic diagrams.



$$\frac{\text{Input Hi - Input Lo}}{\text{Ref Hi - Ref Lo}} = \frac{(Rx)(I)}{(Rref)(I)} = \frac{Rx}{Rref}$$

FIGURE 4-14
OHMS SIGNAL CONDITIONING SIMPLIFIED

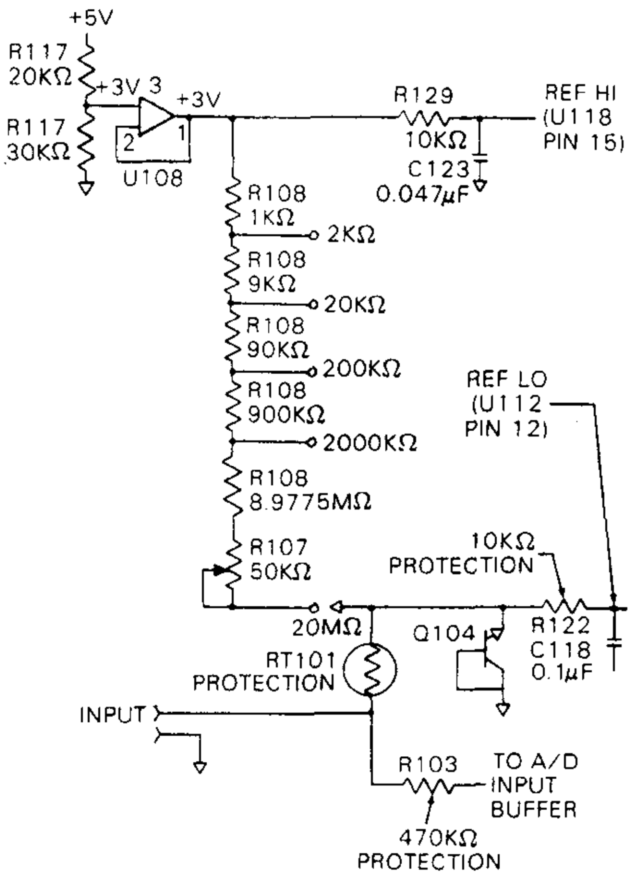


FIGURE 4-13
OHMS SIGNAL CONDITIONING

4-14. Amperes AC or DC

The Amps signal conditioning circuitry consists of the current shunts and protection circuitry. During AC Amps measurement the AC converter is switched into the circuit. Current is measured by placing 100Ω, 10Ω, 1Ω, or 0.1Ω in series with the current signal for the 2mA, 20mA, 200mA or the 2000mA range respectively and measuring the voltage drop across the appropriate resistor.

For DC current, the output voltage goes to the A/D input buffer amplifier and for AC current the output voltage is applied to the AC converter. The reference that is applied to the A/D converter is reduced from 1 volt to 0.1 volt in order to keep the burden voltage low. This makes the A/D converter operate at 0.2 volts full scale. During the current function the least significant digit is blanked out by U105 and U106. This makes the display 3-1/2 digits. Refer to Figure 4-15 for a simplified schematic for Amps signal conditioning.

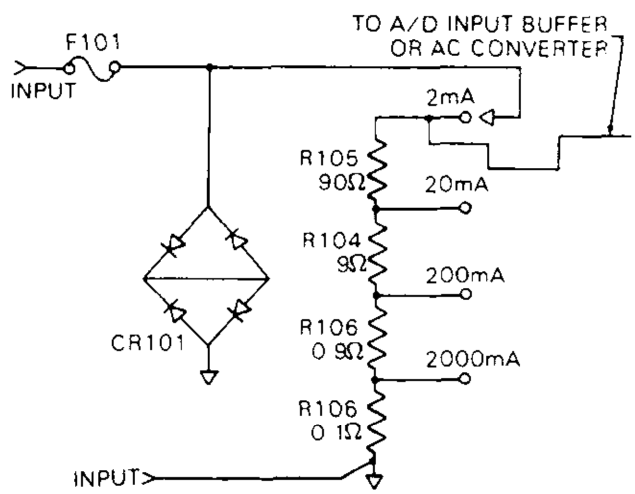


FIGURE 4-15
AMPS SIGNAL CONDITIONING

4-15. Input Buffer

The input buffer consists of low drift op amp U110 and its associated components. The input buffer is placed between the signal conditioning circuitry and the A/D converter. It prevents the A/D from loading down the signal conditioning. Refer to Figure 4-16, a simplified schematic of the input buffer.

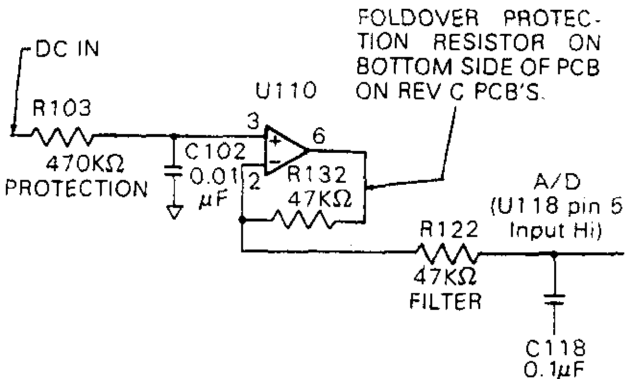


FIGURE 4-16
INPUT BUFFER

4-16. A/D Converter

The 176 A/D converter is essentially the heart of the instrument. It has been engineered with discrete SSI CMOS and low power analog circuitry. This A/D converter is very similiar to the model 135 A/D converter. The dual slope principle is employed by the A/D converter. The timing of the dual slope measurement is divided into 3 periods: Auto Zero, Signal Integrate and Reference Integrate. The following three steps illustrate the three measurement periods.

1) Auto Zero

   The Auto Zero period is 100 msec in length which corresponds to 10,000 clock pulses. During this period the reference voltage is stored on capacitor C117. Capacitor C120 stores $+V_{OS1} - V_{OS2}$. Refer to Figure 4-17.

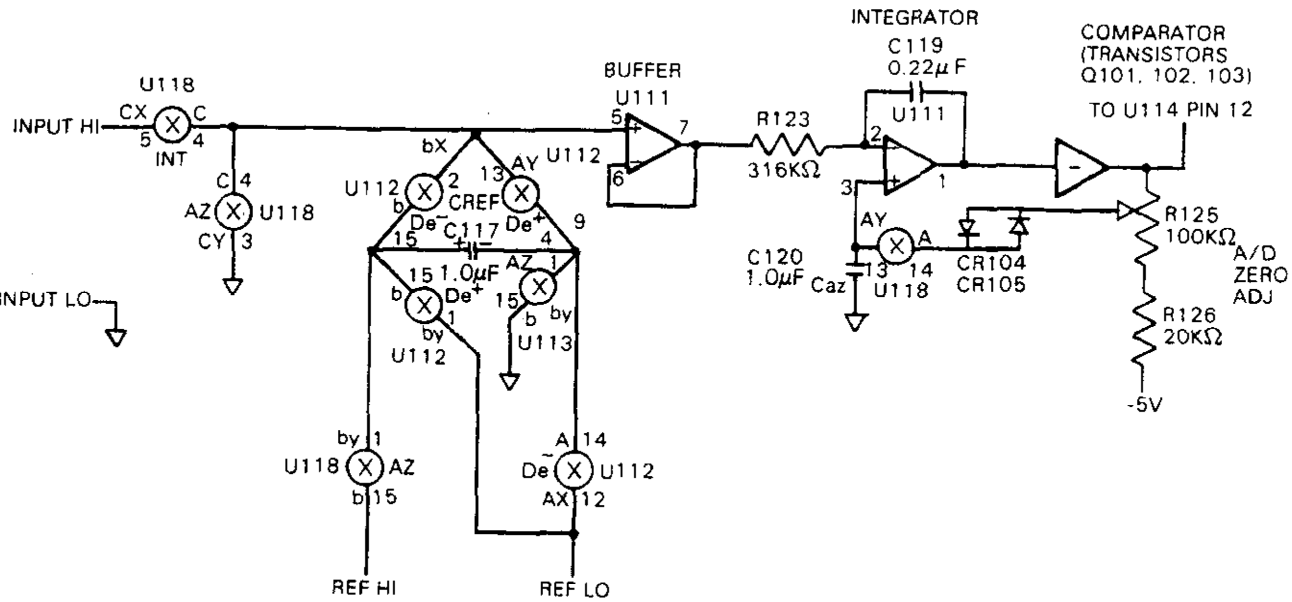
2) Signal Integrate

   As with the Auto Zero phase the Signal Integrate phase is of 100 msec duration. The input of the A/D converter is first buffered by U110 and then it is integrated by U111. When positive signals are applied to the A/D the integrator generates a negative going ramp. This can be seen at the output of the integrator (pin 1). When negative signals are applied to the A/D the integrator generates a positive going ramp.

   The level of the integrated signal at the end of this period (signal integrate) is proportional to the average of the applied signal during this period. Since Signal Integrate is a constant 100 msec, the A/D converter exhibits high rejection at 50Hz and 60Hz. Refer to Figure 4-17.

3) Reference Integrate

   The Reference Integrate period for a full scale input (20,000 counts) is 200 msec. During this period the



Control Lines			Phase		
			Az	Int.	DE
U112	A, B, C	High for positive inputs, low for negative inputs	1/0	1/0	1/0
	Inh	Low during De phase, high all other times	1	1	0
U113	A, B, C	High during Az phase, low all other times	1	0	0
	Inh	Always tied low	0	0	0
U118	A, B, C	High during Az phase, low all other times	1	0	0
	Inh	High during Dephase, low all other times	0	0	1

FIGURE 4-17
A/D CONVERTER

integrator is returned to a baseline level by applying a reference voltage of a polarity opposite to that of the signal. This is acomplished by grounding the appropriate side of the reference capacitor. The digital output is generated from the latches within U107 which store the number of clock pulses required for the integrator to return to baseline levels.

For inputs less than full scale (full scale = 20,000 counts), the A/D automatically reverts to Auto Zero. This happens in the time period of the 200 msec remaining after the return to baseline level.

Also included in the A/D are 2 adjustment potentiometers. R125 is part of a translation network which insures that the comparator output during Auto Zero is at or near the threshold of U114C, which is the zero crossing flip flop. Therefore this adjustment controls symmetry between positive and negative inputs. Shorting C118 (as in the Cal Procedure) and adjusting R125 for a reading of .0000 accomplishes this symmetry adjustment.

The A/D gain control (R130) is the other adjustment. This potentiometer controls the reference voltage and compensates for all gain errors within the dual slope A/D converter.

The A/D converter is ratiometric with differential reference inputs. Therefore

$$\text{Vdisplay} = \frac{\text{Vinput}}{(\text{Ref Hi} - \text{Ref Lo})} \times 10{,}000$$

The full scale inputs for the A/D are as follows:

1. ACV = +2V (full scale input)
2. DCV = ±2V (full scale input)
3. Ω = +2V (full scale input)
4. ACA = +.2V (full scale input)
5. DCA = ±.2V (full scale input)

4-17. Protection Circuitry

A. DC Volts
In reference to Figure 4-10, R103 protects the instrument from damage by limiting the current to the input buffer to about 2mA maximum. Extended application of greater than 300 volts on the 2VDC range may damage R116.

B. AC Volts
In reference to Figure 4-11, R116 protects the instrument from damage by limiting the current to the AC converter to approximately 10mA maximum. Extended application of greater than 300 volts on the 2V AC range may damage R103.

C. Ohms
In reference to Figure 4-13, there are three components that protect the instrument in the event voltage is applied to the input while on the Ohms function. These components are R103, RT101 and Q104. R103 works exactly like it does for DC voltage measurements by limiting current into the input buffer amplifier. Q104 is used as a low leakage zener with a breakdown voltage of approximately 10 volts. RT101 is a positive temperature coefficient thermistor. RT101 limits the current going to Q104 by increasing its resistance greatly when heated. This happens when voltage above 10 volts is applied to the input. When voltages of much greater value than 300 volts are applied to the input when in the Ohms function, Q104 usually fails by becoming leaky or shorted causing reading errors.

D. Amps AC or DC
In reference to Figure 4-15, CR101 protects the low current range resistors by clamping the burden voltage to approximately 2 volts. Above the clamping voltage excessive current is drawn which blows the 2 Amp fuse F101. On the high current ranges (200mA and 2000mA) F101 protects the shunts by limiting the current to approximately 2A. Take note that F101 is the underlying protection for current measurements and is only useful below 250 volts.

4-18. Display and Annunciator Drivers

The 4-1/2 digit Liquid Crystal Display is driven by LSI counter/driver U107. This display is of the nonmultiplexed type with a common backplane (BP) and a separate line for each segment and annunciator to be displayed. To keep any DC voltage from damaging the display the backplane line is driven with a low frequency square wave. When the lines to the display segments and annunciators are driven 180° out of phase with the backplane they turn on. Conversely, when the lines to the segments and annunciators are driven in phase, they turn off. The backplane signal is generated by U107. To drive the annunciators, the backplane signal is applied to one input of an exclusive OR gate for each annunciator. The other input to each exclusive OR gate becomes the control line (i.e. +5 volts to the control line causes the exclusive OR gate to invert the backplane signal turning that annunciator on. Zero volts tied to the control input causes the backplane signal to go through the exclusive OR gate unchanged. This turns the annunciator off)

During the Ohms measurements, the AC annunciator is forced off (regardless of the position of the AC switch), by inverting the backplane signal twice (which is the same as backplane). The "k" annunciator does the same thing as it gets turned on with the "Ω" annunciator and turned off when the 20MΩ button is depressed.

The "BAT" annunciator is also driven by an exclusive OR gate, but the control line for the gate (103B) comes from U123 instead of the switch assembly. U123 is used as a comparator to warn when the battery voltage gets too low. U105 and U106 are CMOS transmission gates. When on they allow U107 to light the least significant digit of the display.

During the Current measurements, U105 and U106 are turned off. R101 then pulls the 7 segment lines of that digit (least significant digit) to the backplane signal. This is how the least significant digit is blanked for the current measurements.

4-19. Power Supply/Reference Circuit

Refer to the schematic diagram of the Model 176 30947D. Power is supplied by the batteries or if the 1766 battery eliminator is installed power is supplied through it. Diode CR110 protects the instrument from reverse battery installation and will also fuse open in the event of a severe short within the instrument.

Analog and digital power supply regulation is accomplished by U123 and its associated components. The regulated +5 volt supply powers CR111 (1.2V band gap reference). This voltage is fed back to U123 to regulate the +5 volt supply. The regulated +5 volts is applied to U117 pin 8 and CR108's anode. U117 is a high efficiency power converter which generates -5 volts by charging C127 with the +5V supply, then switching the positive lead of C127 to ground and charging C130 to -5 volts. CR108, CR109, C124 and C126 form a simple voltage doubler driven by C127. The result of the doubler equals +8.4 volts which is used exclusively by U109 in the AC converter.

The +5 volt supply is split into two separate lines. One for the analog circuitry and one for the digital circuitry. The -5 volt supply is used for the comparator, the analog switches and most of the op amps.

The fact that CR111 is stable with time and temperature enables it to also be used to derive the precise 1.0000 volt and 0.1000 volt reference signals that are used for Volts and Amps, respectively. During voltage measurements the CR111 voltage is attenuated to 1.0000 volts by R113, R115 and R130. The 1.0000V signal is fed to the A/D reference input. During the Amps function R115 is replaced by a section of R108. This attenuates the 1.0000V to 0.1000V which is applied to the A/D reference input.

Section 5. Maintenance (Troubleshooting, Calibration)

5-1. GENERAL

This section contains information necessary to maintain the Models 135 and 176. In order to avoid confusion between the two instruments, their maintenance information will be discussed separately. The maintenance information includes: Adjustment/Calibration, Troubleshooting, Battery replacement, Fuse replacement. These subsections will appear in the following order:

Model 135	Calibration
Model 135	Troubleshooting
Model 135	Battery Replacement, Fuse Replacement
Model 176	Calibration
Model 176	Troubleshooting
Model 176	Battery Replacement, Fuse Replacement
Model 1766	Troubleshooting

5-2. MODEL 135 CALIBRATION

The Model 135 recommended calibration equipment is listed in Table 5-1. Alternate equipment may be used. However, the accuracy of the alternate equipment must be at least 3 times better than the Model 135's specifications or equal to Table 5-1 specifications.

5-3. Environmental Conditions

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

5-4. Calibration Procedure

NOTE

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

CAUTION

Do not exceed the maximum allowable input voltage. Instrument damage may occur. Maximum allowable inputs are stated in the specification.

Perform the following procedure and make the adjustments indicated to calibrate the Model 135. In order to reach the calibration adjustments, the 135's bottom cover must be removed. To do this use the following procedure.

WARNING

To prevent a shock hazard, all test leads should be removed from the INPUT terminals before separating the instrument's top cover from the bottom cover.

1) Place the unit face down on a bench or other similar surface and remove the battery compartment cover. Disconnect and remove the battery. Remove the two No. 4-40 x 7/8 retaining screws. Grasp the bottom cover and lift gently at the input jack end.
2) Then GENTLY lift the bottom cover away from the PC board. The two latches securing the top and bottom cover will disengage. Lift the bottom cover completely away from the rest of the 135.
3) The battery can now be reconnected for troubleshooting and/or calibration. To read the display some light downward pressure at the top end of the circuit board may be required in order to make contact, through the elastomer contact strip, between the circuit board and the LCD.

With the adjustment points exposed you can now follow this procedure to calibrate the 135.

A. Select the DCV function and also select the 1000V range.
B. Short C204 (there are two pads provided on the A/D board in order to short C204, refer to Figure 5-1) and adjust R205 for 000.0.

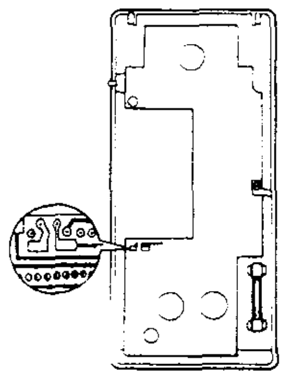


FIGURE 5-1
SOLDER SIDE OF A/D BOARD

TABLE 5-1
RECOMMENDED CALIBRATION EQUIPMENT

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	10V, 100V, 1000V ±.002%	Fluke	343A
B	AC Calibrator	.1V, 1V, 10V, 100V ±.022%	H-P	745A

C. Remove the short from C204. Select the 2V range and short the input terminals (V-Ω to COM). Adjust R207 for .0000.
D. Remove the short from the input terminals (V-Ω to COM). Apply +1.9000VDC to V-Ω and COM and adjust R102 for +1.9000.
E. Select the 20V range and apply +19.000VDC to V-Ω and COM and adjust R113 for +19.000.
F. Select the ACV function and the 750V range. Short the input terminals (V-Ω to COM) and adjust R111 for 000.0.
G. Select the 2V range. Apply 1.9000VAC at 500 Hz to V-Ω and COM and adjust R109 for 1.9000.

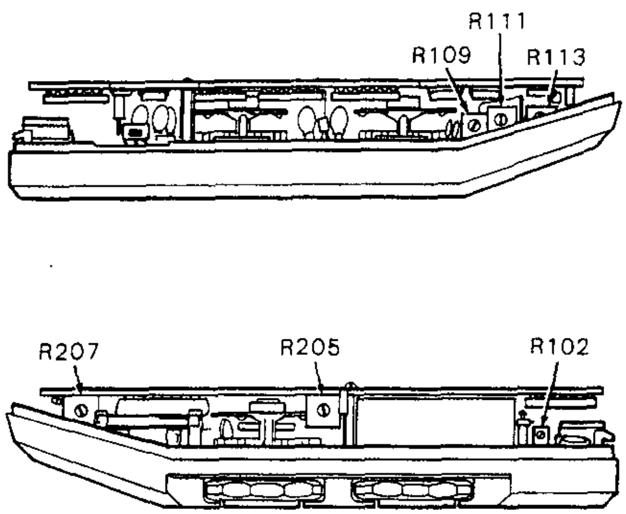


FIGURE 5-2
SIDE VIEWS OF CALIBRATION ADJUSTMENTS

5-5. TROUBLESHOOTING

The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital circuitry used in a precision test instrument. The instructions have been written to assist in isolating the defective circuit or subcircuit. Isolating the defective component has been left to the technician.

NOTE

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

5-6. Special Handling of Static Sensitive Devices

CMOS devices are designed to function at very high impedance levels for low power consumption. For this reason, a normal static charge build up on your person or clothing can be sufficient to destroy these devices. The following steps list the static sensitive devices in your Model 135 and provide instruction on how to avoid damaging them when they must be removed or replaced.

A. Static sensitive devices:

Reference Designation	Keithley Part Number
U101	IC-286
U102	IC-288
U103	IC-287
U201, U202	IC-226
U203, U209	IC-103
U204	IC-284
U205	IC-285
U206	IC-139
U207	IC-138
U208	IC-102
U210 - U212	31847-1

B. The above integrated circuits should be handled and transported only in protection containers. Typically they will be received in anti-static tubes or electrically conductive foam. Keep the devices in their original containers until ready for use.
C. Remove the devices from their protective containers only at a properly grounded work bench or table, and only after grounding yourself by using a wrist strap.
D. Handle the devices only by the body. Do not touch the pins.
E. Any printed circuit board into which a device is to be inserted must also be grounded to the bench or table.
F. Use only anti-static type solder suckers.
G. Use only grounded tip soldering irons.
H. After soldering the device into the board, or properly inserting it into the mating receptacle, the device is adequately protected and normal handling can be resumed.

5-7. Troubleshooting Procedure

This section contains tables listing step-by-step checks of the major DMM circuits described in Section 4, Theory of Operation. The following steps outline the use of these tables and provide instruction for preparing the DMM for troubleshooting. Read all of these steps before troubleshooting the instrument.

To troubleshoot the instrument it is necessary to disassemble the 135 case. To do this follow the steps outlined in paragraphs 5-4-1, 5-4-2, 5-4-3.

A. Power Supply
   Start off troubleshooting with the power supply. In Table 5-1 there are several steps and checks that will verify if the power supply is providing the appropriate voltage to the circuitry. If all checks in Table 5-1 prove to be correct then proceed to step B.
B. The next step is to check proper operation of the display and the A/D converter. Check these circuits by following Tables 5-2 and 5-3.
C. The signal conditioning circuitry should be next in line to be checked. Problems with DCV or Ohms may involve the attenuator. Follow Table 5-4 for DCV troubleshooting procedure and Table 5-5 for Ohms troubleshooting procedure.

NOTE

Make sure that the PC board is free of contaminants (oil, dirt, etc.). Contaminants on the PC board will degrade performance on DCV and Ohms ranges.

D. Problems with AC voltage or AC current may involve the AC converter. Check this circuit by following Table 5-6. If the problem exists with AC current only see step E.

E. If problems occur with current readings, check the shunts and related circuitry as outlined in Table 5-7. It should be noted that AC and DC current ranges use the same shunts, therefore problems will occur on the same ranges if the shunts are at fault.

F. If a gross failure exists that indicates a possible blown fuse, refer to paragraph 5-9 for fuse replacement instructions.

G. All measurements are referenced to analog common (COM input jack) unless otherwise noted in tables.

WARNING

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

5-8. Power Supply Checks

Remove the two PC boards from the front cover. Remove the two screws (along with standoffs) that secure the two boards together. Gently separate the boards. All power supply checks will be made on the switch board (PC-568). To troubleshoot the power supply follow Table 5-1.

NOTE

The absence of +5 volts can be the result of a short on the +5 volt supply or the -5 volt supply. Check the battery for excessive current drain. Reassemble the two boards and check to see that the digital board is not shorting the power supply.

For troubleshooting the A/D converter the instrument should be reassembled into the front cover so that you can monitor the display while following Table 5-3. Some light pressure on the back of the LCD will be necessary in order to allow the display to function properly.

TABLE 5-1
POWER SUPPLY CHECKS

Step	Item/Component	Required Condition	Remarks
1	J1019	Connected to a fresh +9V battery	
2	S101	Turn on power	
3	U102, pin 1	+5 Volts ±5%	
4	CR110, cathode	+1.25 Volts ±5%	Reference Zener
5	U103, pin 5	-5 Volts ±5%	Inverter Output
6	U103, pin 8	+5 Volts ±5%	From U102
7	CR101, cathode C104, +terminal	+8.4 Volts ±10%	Voltage Doubler Output

TABLE 5-2
DISPLAY CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on Power, select any function or range except ohms.	
2	U101, pin 1	+5 Volts ±5%	
3	U101, pin 5	Backplane, 100Hz -300Hz square wave.	
4	U101 pins 2, 3, 4, 6-26, 37-40	5 volt square waves in or out of phase with backplane signal	
5	U201 pins 9 and 13 U202 pins 1, 5, 9, 13	Backplane Waveform	Bat, minus sign and decimal point drivers
6	U202 pins 2, 6, 8, 12	Appropriate DP line high (on)	Select all ranges to check all decimal points.

TABLE 5-3
A/D CONVERTER CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on Power, select 2VDC range, short Volts input.	
2	Monitor Display	.0000 ±1 digit	
3	U214 pin 6	0000 Volts	Buffer Output, A/D input
4	U211 pin 15	+1.00 Volts	Reference Output
5	U211 short pins 5 and 15		Connects reference output to A/D input
6	Monitor Display	1.0000 ±10 digits	If steps 4 and 6 are correct then the A/D is functioning properly.
7	U101 pin 32	0 to +5 Volt square wave 100KHz ±100Hz	Clock signal
8	C206	0.0 Volts ±100m Volts	Stored Auto Zero Voltage
9	U213 pin2	0.0 Volts ±100m Volts	Integrator Summing Junction
10	U213 pin 1	1Volt ±0.3 Volts	Integrator Output
11	U213 pin 5	0 Volts	Buffer Input
12	U213 pin 7	0 Volts ±40m Volts	Buffer Output
13	External DC supply such as 343A	Apply +1.9000V	Calibration Point
14	Monitor Display	1.9000 ±1 digit	If different check U214 input
15	U213 pin 1	Waveform as shown in Figure 5-3.	Integrator Output
16	U204 pin 12	Waveform as shown in Figure 5-4.	Comparator Output

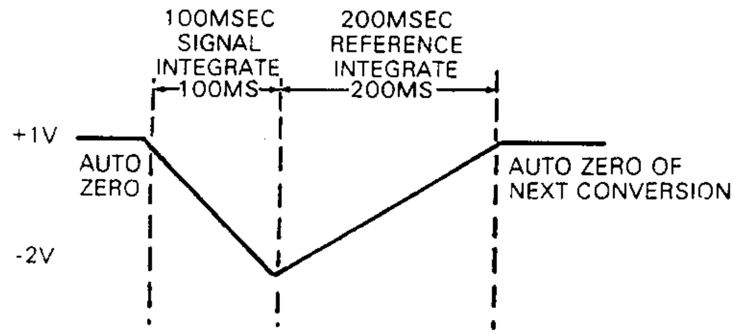


FIGURE 5-3
INTEGRATOR OUTPUT WAVEFORM

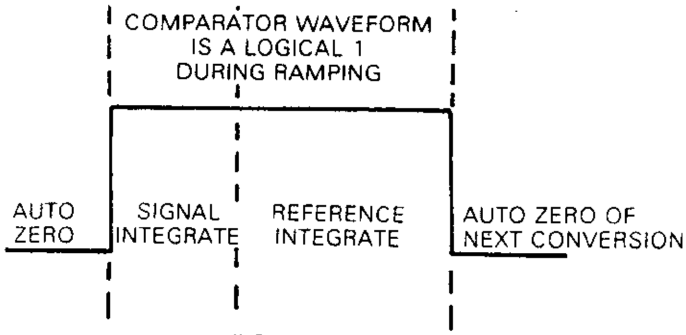


FIGURE 5-4
COMPARATOR OUTPUT WAVEFORM

For troubleshooting the DC attenuator follow Table 5-4.

TABLE 5-4
DC ATTENUATION CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on power, select the 2VDC range. Short the input and adjust R207 for .0000 at output of U214.	
2	External DC supply such as 343A	Apply +1.9000 Volts	Calibrated Input
3	U214 pin 6	1.9Volts	Buffer Output
4	External DC supply such as 343A	Select 20V range. Apply 19.000 Volts.	Calibrated Input
5	U214 pin 6	1.9 volts ±10 digits	Buffer Output
6	External DC supply such as 343A	Select 200V range. Apply 190.00 Volts.	Calibrated Input
7	U214 pin 6	1.9 Volts ±20 digits	Buffer Output
8	External DC supply such as 343A	Select 1000V range. Apply 1000 Volts.	Calibrated Input
9	U214 pin 6	1.000 Volts ±10 digits	Buffer Output

AC Converter

Since ACV and DCV use the same attenuator, verification of the DC attenuator is sufficient to insure that the AC attenuator is functioning properly.

TABLE 5-5
AC ATTENUATION CHECKS

Step	Item/Component	Required Condition	Remarks
1		Select the 2VAC range and short the input.	
2	Monitor Display	0000 ±5 digits	R111 zero adjust
3	External AC source such as H-P745A	Apply 1.0000 Volt RMS at 1KHz	Calibrated Input
4	Wiper of R107	1 Volt RMS nominal	AC Buffer Output AC Converter Input
5	R105 pin 9	+1 Volt DC	Output of U104 Gain of U104 is adjusted to provide +1 VDC for 1 Volt AC.
6	External AC source such as H-P745A	Select 20VAC range and apply 19.000V at 500Hz	Calibrated Input
7	Monitor Display	19.000V Nominal	
8	External AC source such as H-P745A with 746A	Select 200VAC range and apply 190.0V at 500Hz	Calibrated Input
9	Monitor Display	190.00V Nominal	
10	External AC source H-P745A with 746A	Select 1000Vac range and apply 500V at 100Hz	Calibrated Input
11	Monitor Display	500.0V Nominal	

TABLE 5-6
OHMS ATTENUATION CHECK

Step	Item/Component	Required Condition	Remarks
1		Check A/D Converter	
2		Select the 2kΩ range and short the input	
3	Monitor Display	.0000 ±1 digit	
4	R105 pin 4	Approximately 2.5 Volts	
5	Input HI to LO	Remove short and connect ammeter from Input HI to LO. Current is approximately 2mA.	If incorrect check Q101, RT101 or Q204
6	Input HI to LO	Measure open circuit voltage 3.5 Volts max	
7	1KΩprecision resistor	Apply to input	Calibrated resistance
8	Monitor Display	1.0000 ±30 digits	Checks accuracy of R116 -1KΩ
9	10KΩprecision resistor	Select 20KΩ range and apply 10KΩ to input	Calibrated resistance
10	Monitor Display	10.000 ±22 digits	Checks accuracy of R116 -9KΩ
11	100KΩprecision resistor	Select 200KΩ range and apply 100 KΩ to input	Calibrated resistance
12	Monitor Display	100.00 ±22 digit	Checks accuracy of R116-90KΩ
13	1000 KΩprecision resistor	Select 200KΩ range and apply 1000 KΩ to input	Calibrated resistance
14	Monitor Display	1000.0 ±22 digits	Checks accuracy of R116-900KΩ
15	10MΩprecision resistor	Select 10MΩ range and apply 10MΩ to the input	Calibrated resistance
16	Monitor Display	10.000 ±102 digits	Checks accuracy of R116-9M.Ωleakage of Q204 and leakage of C-211.

TABLE 5-7
CURRENT SHUNTS CHECKS

Step	Item/Component	Required Condition	Remarks
1	F101	Continuity	
2	R112, R114	Correct shunt value for specified range	Apply a known 1/2 full scale current and measure voltage across shunt
3		Turn on power and select DCA, 20mA range	
4	External DC voltage	0 to 1 Volt	Clamping must occur at ±0.7 Volts

WARNING

Disconnect the test leads and turn the 135 off before replacing the battery or fuse. Put the covers back into place on the compartments before resuming use of the instrument.

5-9. Battery and/or Fuse Replacement

A. A 9V battery is supplied with the instrument but not installed. To install or replace the battery, remove the cover from the battery compartment by sliding it off in the direction of the arrow located on the battery cover. The battery connector snaps on and off the terminal of the battery. Improper installation of the battery will cause the connecting wires to be severed by excess strain. Proper installation requires that the battery be positioned in such a manner (shown in Figure 5-5) that the leads protruding from the boot of the battery connector face toward the outside of the battery compartment. If the instrument is going to be stored for a long period of time or in a high temperature environment, remove the battery to prevent leakage damage.

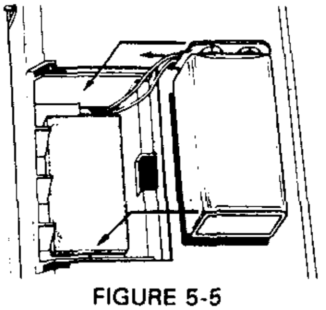


FIGURE 5-5
BATTERY INSTALLATION

B. A .75 amp fuse protects the 20mA range. To gain access to the fuse, remove the fuse compartment cover in the same manner as removing the battery compartment cover. Remove the fuse by pulling outward on the plastic tab that encircles the fuse body. Install the plastic tab on the new fuse and snap the fuse back into the fuse holder. Do not replace the fuse with a higher rated value or instrument damage that is not covered by warranty may occur.

NOTE

Some fuse covers incorrectly indicate the fuse value at 2A. 0.75A is the correct value.

5-10. MODEL 176 CALIBRATION

The Model 176 recommended calibration equipment is listed in Table 5-1. Alternate equipment may be used. However, the accuracy of the alternate equipment must be at least 3 times better than the Model 176's specifications or equal to Table 5-1 specifications.

5-11. Environmental Conditions

The environmental conditions that are required to calibrate the 176 are outlined in paragraph 5-3.

5-12. Calibration Procedure

Calibration should be performed by qualified personnel using accurate and reliable equipment. Perform the following procedure and make the adjustments indicated to calibrate the Model 176. To gain access to the calibration adjustments, the 176's top cover must be removed. Use the following procedure to accomplish this.

WARNING

To prevent a shock hazard, all test leads should be removed from the input terminals before removing the top cover.

CAUTION

Do not exceed maximum allowable input voltage. Instrument damage may occur. Maximum allowable inputs are stated in the specifications.

A. Turn off the power (if the Model 1766 is installed, disconnect the line cord).
B. Turn the instrument over so that the bottom cover is facing up. loosen the four screws in the bottom panel.
C. Hold the top and bottom covers together to prevent their separation and turn the 176 over to normal position.
D. Carefully lift off the top cover.

The calibration adjustment points are shown on the shield of the 176. The schematic designations of the adjustments are given below in numbered sequence. The numbered sequence corresponds to the numbered sequence on the shield. Use the following procedure to calibrate the 176.

1. Select the DCV function and the 20V range. Place a short across C118. Adjust R125 for a display of 0.000. Remove the short from C118 after the adjustment is made.
2. Select the 2V range and short the input terminals (HI and LO). Adjust R102 for a display of .0000.
3. Select the ACV function and the 1000V range. With the short still applied to the input terminals adjust R118 for a display of 000.0. Remove the short from the input terminals (HI and LO) after the adjustment is made.
4. Select the DCV function and the 2V range. Apply +1.9000V to the input terminals (HI and LO) from the DC calibrator (Item A, Table 5-1). Adjust R130 for a display of 1.9000V.
5. Select the 20V range and apply +19.000V to the input terminals (HI and LO) from the DC calibrator (Item A, Table 5-1). Adjust R107 for a display of 19.000V.
6. Select the ACV function and the 2V range. Apply 1V at 1KHz to the input terminals (HI and LO) from the AC calibrator (Item B, Table 5-1). Adjust R119 for a display of 1.0000.
7. Select the 200V range and apply 100.00V at 5KHz to the input terminals from the AC calibrator (Item B, Table 5-1). Adjust C106 for a reading of 100.00V.
8. Select the 20V range and apply 10.000V at 10KHz to the input terminals from the AC calibrator (Item B, Table 5-1). Adjust C105 for a reading of 10.000V.

5-13. MODEL 176 TROUBLESHOOTING

The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital circuitry used in a precision test instrument. The instructions and tables have been written to assist in isolating the defective circuit or subcircuit. Isolating the defective component has been left to the technician.

NOTE

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

5-14. Special Handling of Static Sensitive Devices
CMOS devices are designed to function at very high impedance levels for low power consumption. For this reason, a normal static charge build up on your person or clothing can be sufficient to destory these devices. The following table is a list of the static sensitive devices located in your 176. Instructions on how to avoid damaging these devices when they must be removed or replaced are located in paragraph 5-6.

Static Sensitive Devices

Reference Designation	Keithley Part Number
U101 - U104	IC-226
U105, U106	IC-149
U107	IC-286
U112, U113, U118	31847-1
U114	IC-284
U115	IC-285
U116, U122	IC-103
U117	IC-287
U119	IC-138
U120	IC-139
U121	IC-102
U123	IC-288

5-15. Troubleshooting Procedure
This section contains tables listing step-by-step checks of the major DMM circuits described in Section 4, Theory of Operation. The following steps outline the use of these tables and provide instruction for preparing the DMM for troubleshooting. Read all of these steps before troubleshooting the instrument.
To troubleshoot the instrument it is necessary to remove the top cover. This can be accomplished by following the procedure outlined in paragraph 5-11A, B, C and D.

A. Power Supply
Start off troubleshooting with the power supply. In Table 5-8 there are several steps and checks that will verify if the power supply is providing the appropriate voltage to the circuitry. If all the checks in Table 5-8 prove to be correct, then proceed to step B.

B. A/D Converter
The next step is to check proper operation of the A/D converter. Check the A/D converter by following Table 5-9.

C. The next step is to check the signal conditioning circuitry. Depending on the discrepancy, start with the appropriate attenuator. Table 5-10 outlines the DCV attenuator. Table 5-11 outlines the ACV attenuator and AC converter. Table 5-12 outlines the current attenuation.

D. Ohms Source
The Ohms source troubleshooting procedure is outlined in Table 5-13.

E. If a gross failure exists that indicates a possible blown fuse, refer to paragraph 5-16 for fuse replacement instructions.

TABLE 5-8
POWER SUPPLY CHECKS

Step	Item/Component	Required Condition*	Remarks
1		Turn on Power	
2	Batteries	>6.5V	6 fresh "C" cells
3	Test Point 1 TP1	>6.2V	CR110 check
4	TP2	+5.0V ±20%	Analog +5V check. This is supplied from the batteries through U123.
5	TP3	-5.0V ±20%	Analog -5V check. This is supplied from Analog +5V supply via U117.
6	TP5	1.20V to 1.25V	Band Gap Reference Check (CR111)
7	U109 pin 7	+8.4V nominal	Analog +8.4V check supplied by U117, used only for U109.

*All voltages are measured with respect to input LO.

TABLE 5-9
A/D CONVERTER CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select the 2VDC range. Short the input (HI and LO).	
2	Monitor Display	.0000V ±1 digit	
3	TP6	±0.0001V	U110 Input Buffer Zero
4	TP7	±0.0001V	Input to A/D converter
5	U118 pin 15	+1.00V	Reference Voltage
6		Short U118 pin 5 to pin 15	
7	Monitor Display	1.0000 ±3 digits	
8		Remove the short on U118 pin 5 to pin 15. Short U118 pin 15 to U110 pin 3.	
9	Monitor Display	1.0000 ±3 digits	If steps 5, 7 and 9 are correct the A/D is functioning properly. If not, continue with step 10. Remove short on U118 pin 15 to U110 pin 3
10	U120 pin 10	100KHz nominal, 0 to +5V square wave	Master Oscillator
11	U107 pin 28	10Hz, 0 to +5V square wave	Divide by 10,000
12	U115 pin 1	5Hz, 0 to +5V square wave	Timing
13	U115 pin 15	2.5Hz, 0 to +5V square wave	Timing
14	U111 pin 3	±70mV	Auto Zero Voltage
15	U111 pin 7	±30mV	U111 check
16	U111 pin 1	Nominal +1.2V	Auto Zero Loop check
17	External Voltage Source (343A)	Apply +1.0V to HI and LO input	
18	U111 pin 7	Figure 5-6	Buffer
19	U111 pin 1	Figure 5-7	Integrator

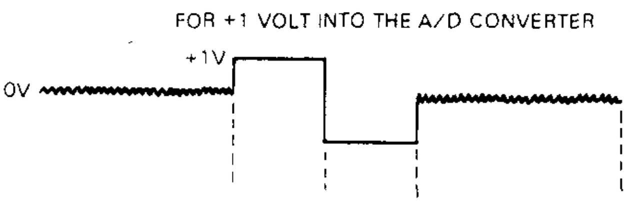


FIGURE 5-6
BUFFER WAVEFORM

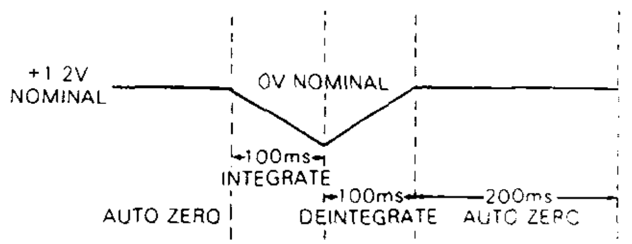


FIGURE 5-7
INTEGRATOR WAVEFORM

TABLE 5-10
DC ATTENUATOR CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select 2VDC range	
2	External Source (343A)	Apply +1.9V	
3	TP6	1.9V	Input Buffer Check
4	Monitor Display	1.9000V	R130 reference adjust
5		Select the 20VDC range	
6	External Source (343A)	Apply +19V	
7	Monitor Display	19.000V	R107 divide by 10 adjust
8		Select the 200V range	
9	External Source (343A)	Apply +190V	
10	Monitor Display	190.00V nominal	Divide by 100 check
11		Select the 1000VDC range	
12	External Source (343A)	Apply 1000VDC	
13	Monitor Display	1000.0V nominal	Divide by 1000 check

TABLE 5-11
AC CONVERTER CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select the 2VAC range	
2	External AC Source (745A)	Apply 1Vrms at 1KHz	Calibrated input
3	U108 pin 7	1.0Vrms	Unity Gain Buffer
4	R117 pin 9	+1.0VDC	Output of AC converter. R119 is adjusted to give 1.0 VDC output for 1.0 VAC input. (High impedance measuring here will load down the reading. Measuring at output of U109 will cause oscillation.
5	External AC source (745A)	Select the 2VAC range and apply 1VAC at 20KHz	
6	Monitor Display	1.0000V nominal	
7	External AC source (745A)	Select 20VAC range and apply 10Vrms at 10KHz	
8	Monitor Display	10.000V nominal	High frequency response (compensation C106, C105)
9	External AC source (745A)	Select the 200VAC range and apply 100Vrms at 5KHz	
10	Monitor Display	100.00 nominal	High frequency response (compensation C106, C104)
11	External AC source (745A and 746A)	Select the 1000VAC range and apply 1000VAC at 1KHz	
12	Monitor Display	1000.0V nominal	High frequency response (compensation C106, C103)

TABLE 5-12
CURRENT CHECKS

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select the 2mADC range	
2	HI and LO terminals	100Ω nominal	Check fuse continuity. CR101 short, or resistor open
3	R108 pin 4	+1.0V	
4	R108 pin 5	+0.1V	reference voltage check
5	U118 pin 15	+0.1V nominal	reference switching check
6	U106 pin 6	0V	digit blanking signal

TABLE 5-13
OHMS CHECK

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select 2KΩ range	
2	U108 pin 1	+3V nominal	Ohms reference check
3	R108 pin 6	+3V nominal	Check for Q104 short
4	Meter input	+3V nominal	RT101 continuity check

5-16. Battery and/or Fuse Replacement

To replace the batteries the top cover must be removed. To do this follow the procedure outlined in paragraph 5-11 A, B, C and D. Install the batteries in the holder as shown in Figure 5-8. Installation of the battery pack is shown in Figure 5-9.

WARNING

To prevent a shock hazard, all test leads should be removed from the input terminals before removing the top cover.

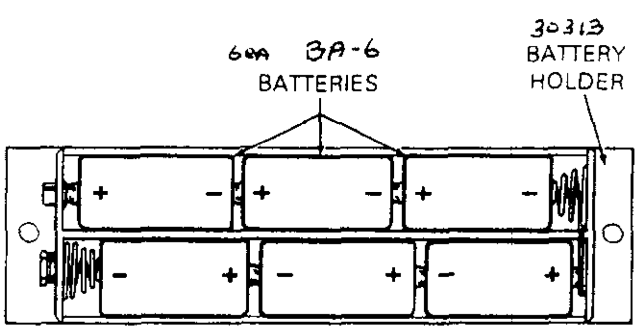


FIGURE 5-8
BATTERY INSTALLATION

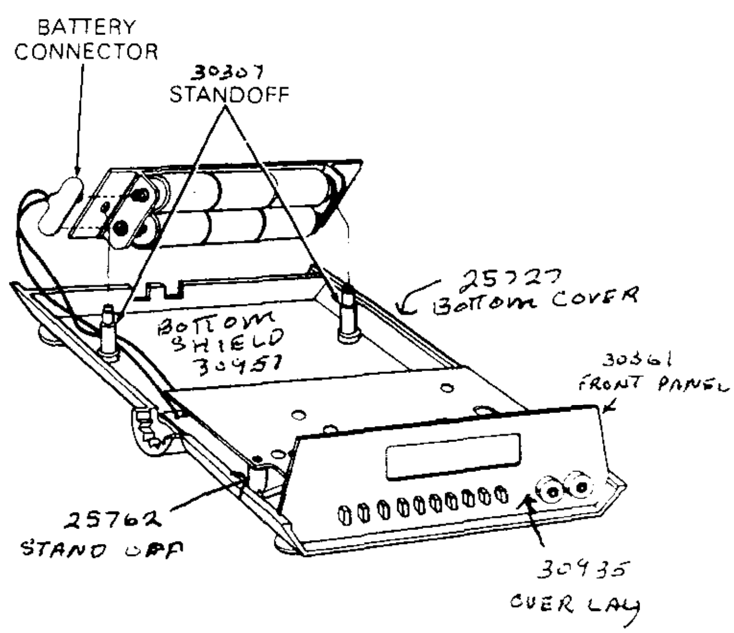


FIGURE 5-9
BATTERY PACK INSTALLATION

5-17. CURRENT FUSE REPLACEMENT

WARNING

To prevent a shock hazard, disconnect all circuits from the INPUT terminals before removing current fuse.

To remove the current fuse, turn the DMM over and lay it carefully on its top. Insert a small screwdriver blade into the slot on the fuse holder, press gently and turn 1/4-turn counter-clockwise. Lift the holder and fuse out of the receptacle. The fuse can now be removed for checking or replacement. Replace with one of the following types:
A. U.S.A. Use - 3AG, 250V, 2A, Normal Blow
B. Europe Use - 5 x 20mm, 250V, 2A, Normal Blow

CAUTION

Installing a higher rated fuse than the one specified could result in damage to the instrument.

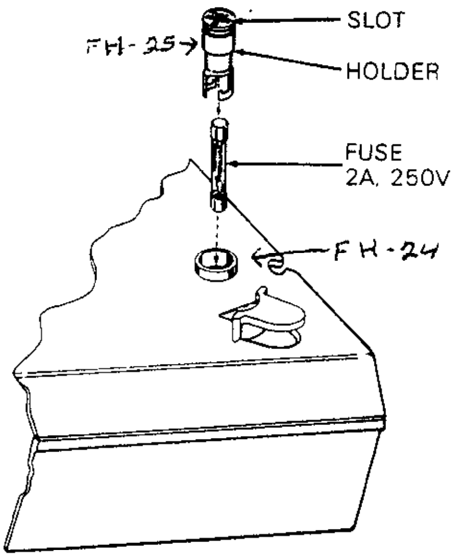


FIGURE 5-10
CURRENT FUSE REMOVAL/REPLACEMENT

5-18. MODEL 1766 TROUBLESHOOTING

The Model 1766 Battery Eliminator troubleshooting is relatively simple when following the steps outlined in Table 5-14.

The Turns ratio between the primary winding and the secondary winding is approximately 5 to 1. Measured from the primary coil designated by pins 8 and 11 to secondary coil designated by pins 4 and 6.

5-19. Rotary Switch Rotation

Rotary switch S103 may be confusing when trying to visualize the rotation of the contact wipers. The following Figures illustrate the five different positions of both sides of S103.

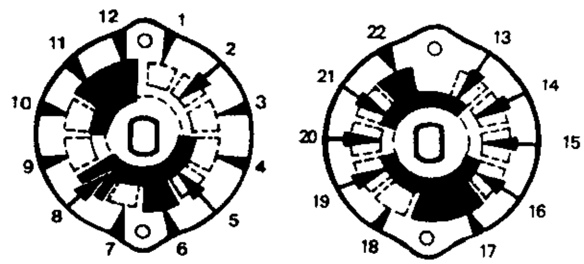


FIGURE 5-11
SWITCH S103 IN THE OHMS POSITION

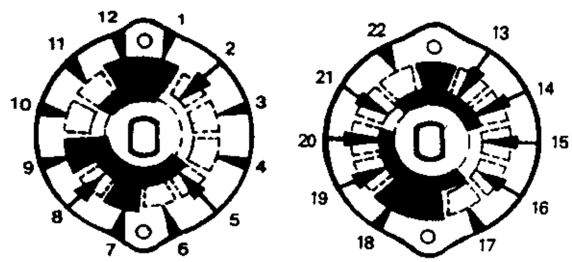


FIGURE 5-12
SWITCH S103 IN THE ACA POSITION

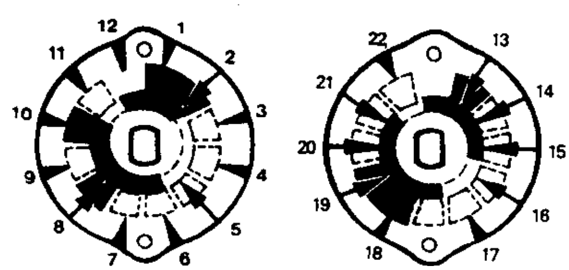


FIGURE 5-13
SWITCH S103 IN THE DCA POSITION

TABLE 5-14
MODEL 1766 TROUBLESHOOTING

Step	Item/Component	Required Condition	Remarks
1	F201 line fuse	Continuity	
2	P1006	Plugged into live receptacle. Turn on power.	
3	Emitter of Q201	+8.5V nominal	1766 output Voltage
4	Cathode C202	9.1V nominal	Zener Voltage

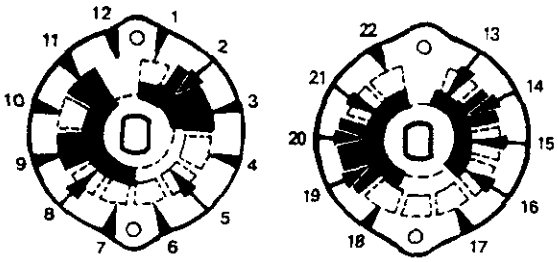


FIGURE 5-14
SWITCH S103 IN THE ACV POSITION

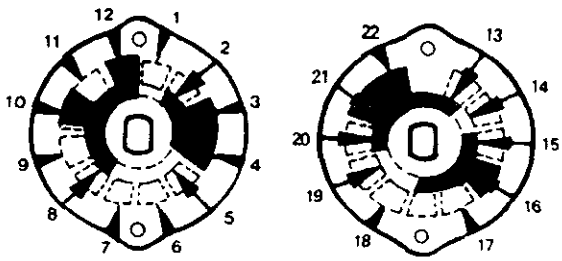


FIGURE 5-15
SWITCH S103 IN THE DCV POSITION

Section 6. Replaceable Parts

6-1. GENERAL

This section contains information for ordering replacement parts for the Models 135 and 176. The parts lists are separated from each other in order to avoid confusion. The parts lists are arranged in alphabetical order of the circuit designations of their components. Table 6-4 lists the components of the Model 176. Table 6-5 lists the components of the Model 135. A cross reference list of manufacturers, including their addresses is given in Table 6-1

6-2. Ordering Information

To place an order or to obtain information concerning replacement parts contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering include the following information:

A. Instrument Model Number
B. Instrument Serial Number
C. Part Description
D. Circuit Description (if applicable)
E. Keithley Part Number

6-3. Factory Service

If the instrument is to be returned to the factory for service, please photo copy and complete the service form which follows this section and return it with the instrument.

6-4. Schematics

The Model 176 schematic and PC layout are located on page 6-9 and page 6-10 respectively. The Model 135 schematic and PC layouts are located on page 6-11, 6-12 and 6-13 respectively. The Model 1766 schematic is located on page 6-14.

TABLE 6-1
CROSS REFERENCE OF MANUFACTURERS

MFR Code	Name and Address	Federal Supply Code	MFR Code	Name and Address	Federal Supply Code
A-B	Allen-Bradley Corp. Milwaukee, WI 53204	01121	INT	Intersil, Inc. Cupertino, CA 95014	32293
ACI	American Components, Inc. Conshohocken, PA 19428	14298	IRC	IRC Division Burlington, IA 52601	07716
BRN	Bourns, Inc. Riverside, CA 92507	80294	ITT	ITT Semiconductor Lawrance, MA 01841	15238
CAD	Caddock Riverside, CA 92507	19647	L-F	Little Fuse, Inc Des Plains, IL 60016	75915
CLB	Centralab Division Milwaukee, WI 53201	71590	MEP	Mepco, Inc Morristown, NJ 07960	80031
CNW	Continental Wirt Electronics Warminister, PA	79727	MDW	Midwest Components, Inc Muskegon, MI 49443	04713
DLE	Dale Electronics Columbus, NE 68601	91637	MOT	Motorola Semi Products, Inc Phoenix, AZ 85008	04713
ECI	Electro-cube, Inc. San Gabriel, CA 91776	83701	NAT	National Semi Corp Santa Clara, CA 94086	18324
EDI	Electronic Devices Yonkers, NY 10710	83701	NIC	Nichicon Corp Chicago, IL 60645	
EFJ	E. F. Johnson Waseca, MN 56093	74970	PNC	Panel Components Corp Berkeley, CA 94710	
ERI	Erie Technological Products Erie, PA 16512	72982	P&B	Potter and Brumfield Princeton, IN 47670	
G-E	General Electric Corp. Syracuse, NY 13201	03508	PLY	Plessey Capacitors Westlake Village, CA 91361	

TABLE 6-1 CONTINUED

MFR Code	Name and Address	Federal Supply Code
RCA	RCA Corporation Moorestown, NJ 08050	02734
R&H	Reeves and Hoffman Carlisle, PA 17013	82567
RIC	Richey Electronics Nashville, TN 37207	29309
SHG	Shigoto New York, NY 10036	
SPG	Sprague Electric Co. Visalia, CA 93278	14679
T-I	Texas Instrument Dallas, TX 75231	01295
TRW	TRW Electr. Components IRC Boone, NC 28607	11502

TABLE 6-2
MODEL 1359 PARTS LIST

Qty.	Keithley P/N	Schematic Designation	Description
1	IC-286	U101	Counter
1	IC-288	U102	CMOS OP Amp
1	31847-1	U210, U211, U212	Analog Switch, Selected IC-283
1	IC-226	U201-U202	Exclusive OR gates
1	30985A	CR110, R117	Resistor and Zener Diode
1	TG-138	Q104	Transistor
1	RF-38	CR103, CR108, CR109	Diode
2	RF-28	CR101, CR102, CR104-CR107	Diode
5	FU-14	F101	Fuse, 75A, 3AG
1	BH-29	J1019	Battery Clip
1	PA-130		Packing List
1	RT-7	RT101	Thermistor

TABLE 6-3
MODEL 1769 PARTS LIST

Qty.	Keithley P/N	Schematic Designation	Description
1	IC-286	U107	Counter
1	IC-288	U123	CMOS OP Amp
1	31847-1	U112, U113, U118	Analog Switch, Selected IC-283
1	IC-226	U101-U104	Exclusive OR gates
1	30986A	(CR111, R113)	Resistor and Zener Diode
1	TG-138	Q104	Transistor
1	RT-7	RT101	Thermistor
1	RF-39	CR110	Diode
2	RF-28	CR102-CR109	Diode
5	FU-13	F101	Fuse, 2A-3AG
5	FU-48	F101	Fuse, 2A, 5x20mm
1	PA-129		Packing List

TABLE 6-4
REPLACEABLE PARTS LIST
PC-565 - SCHEMATIC 30947D

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
BAT	Battery 1.5V "C" Cell	HI	—	Ever-eady	935	BA-6
C102	.01µF, 600V Polycarb	B5	4/B4	P&B	4200F103M	C-215-.01
C104	390p, 1000V, Cer D	B3	6/B4	CLB	DD-391	C-64-390p
C105	1.9p to 15.7p, 250V	B3	7/C4	EFJ	187-0109-005	C-284-1.9 to 15.7p
C106	.5p to 1.5p, 2000V	B2	8/D4	EFJ	273-1-1	C-184-.5 to 1.5p
C107	.02, 1000V, Cer D	B1	9/D3	SPG	5622-5VAA 102AM203M	C-298-.02
C108	10p, 1000V, Cer D	D2	10/D3	CLB	DD-100	C-64-10p
C109	10µF, 20V, ETT	C1	11/D3	ITT	Tap/F 35V, 20%	C-179-10
C110	10µF, 20V, ETT	C1	12/D3	ITT	Tap/F 35V, 20%	C-179-10
C111	250µF, 25V, Alum	E1	13/D4	NIC	25ULA25D-T	C-314-250
C112	.01µF, 1000V, Cer D	C2	14/D4	SPG	10SS-S15	C-22-.01
C113	.1µF, 200V, Polycarb	D1	15/D4	ECI	625B1C104	C-221-.1
C114	150p, 500V, Cer D	D1	16/D4	CLB	DD-151	C-22-150p
C115	5p, 500V, Cer D	D1	17/E4	CLB	DD-050	C-22-5p
C116	10p, 1000V, Cer D	C5	18/B4	CLB	DD-100	C-64-10p
C117	.1µF, 50V, Polycarb	B4	19/B4	ECI	625B1A105	C-215-.1
C118	.1µF, 200V, Polycarb	B4	20/B5	ECI	625B1C104	C-221-.1
C119	.22µF, 50V, Polyprop	C5	21/A5	TRW	X363UW	C-269-.22
C120	.1µF, 50V, Polycarb	D6	22/A5	ECI	625B1A105	C-215-.1
C121	100p, 1000V, Cer D	H2	23/C5	CLB	DD-101	C-64-100p
C122	.1µF, 100V, Mtl Poly	D2	24/C5	PLY	160-0.1MFD	C-305-.1
C123	.047µF, 100V, Mtl Poly	B5	25/C5	PLY	160.047MFD	C-305-.047
C124	10µF, 25V, Alum	F1	26/D4	NIC	25ULA10D-T	C-314-10
C125	.01, 1000V, Cer D	D1	27/E4	SPG	10SS-S15	C-22-.01
C126	10µF, 25V, Alum	F1	28/D4	NIC	25ULA10D-T	C-314-10
C127	10µF, 25V, Alum	F1	29/D5	NIC	25ULA10D-T	C-314-10
C128	10µF,25V, Alum	E1	30/D5	NIC	25ULA10D-T	C-314-10
C129	4.7µF, 25V, Alum	D1	31/D5	NIC	25ULA4R7 D-T	C-314-4.7
C130	250µF, 25V, Alum	D2	32/D5	NIC	25ULA250 D-T	C-314-250
C131	.01µF, 50V, Polycarb	D2	33/B4	ECI	625B1A105	C-215-.01
C132	10µF, 25V, Alum	D2	34/E5	NIC	25AU250D-T	C-314-10
CR102	Rectifier, 75mA, 75V	B1	39/D3	T-I	1N914	RF-28
CR103	Rectifier, 75mA, 75V	C1	40/D3	T-I	1N914	RF-28
CR104	Rectifier, 75mA, 75V	C4	41/B5	T-I	1N914	RF-28
CR105	Rectifier, 75mA, 75V	C4	42/B5	T-I	1N914	RF-28
CR106	Rectifier, 75mA, 75V	D1	43/E4	T-I	1N914	RF-28
CR107	Rectifier, 75mA, 75V	D1	44/E4	T-I	1N914	RF-28
CR108	Rectifier, 75mA, 75V	F1	45/D4	T-I	1N914	RF-28
CR109	Rectifier, 75mA, 75V	F1	46/D4	T-I	1N914	RF-28
CR110	Rectifier	H1	47/D5	MOT	1N4006	RF-38
*CR111	Low Voltage Reference (Zener)	E1	48/D5	MOT	LM385Z	30986A
CR112	Rectifier	B5	49/B5	ITT	IN5400	RF-34
CR113	Rectifier		50/B3	ITT	IN5400	RF-34
CR114	Zener		51/E3	ITT	IN7518	DZ-59

*CR111 is part of a set for the reference circuit that is selected at the factory.

TABLE 6-4 CONTINUED

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
F101	Fuse, 2A, 250V, 3AG, U.S.A. Models	A3		L-F	312002	FU-13
F101	Fuse, 2A, 250V, 5 x 20mm, European Models	A3		PNC	034.1519	FU-48
J1001	Battery Clip	H1	52/E6	SHG	YOS/1893 6ASE-12	H-28
Q101	Transistor, NPN	C6	59/A4	NAT	2N3904	TG-47
Q102	Transistor, PNP	C5	60/B4	MOT	2N3906	TG-84
Q103	Transistor, NPN	C6	61/A4	NAT	2N3904	TG-47
Q104	Transistor, NPN	A5	62/C4	G-E	GES-5818	TG-138
R101	Thick Film	H3,4	67/B2	Epitek	TF-130	TF-130
R102	100K, 10%, Cermet Trimmer	B5	68/A4	BRN	3386-F-1-104	RP-97-100K
R103	470K, 10%, 2W, Comp	B5	69/B4	A-B	HB4745	R-3-470K
R104	9Ω, .1%, 1/2W, MtF	B3	70/B3	IRC	—	R-135-9
R105	90Ω, .1%, 1/8W, MtF	B3	71/B3	DLE	MFF-1/8	R-179-90
R106	.0999Ω, .8991Ω	A4	72/B3	DLE	SPR-1012	R-297
R107	50K, 10%, Cermet Trimmer	A1	73/B4	BRN	3386F-1-053	RP-97-50K
R108	Thick Film	A1,2	74/B4	CAD	TF-126	TF-126
R109	1K, .1%, 1/8W, MtF	B3	75/B4	DLE	MFF-1/8	R-179-1K
R110	9K, .1%, 1/8W, MtF	B3	76/C4	DLE	MFF-1/8	R-179-9K
R111	90K, .1%, 1/2W, MtF	B3	77/C4	IRC	—	R-135-90K
R113	Selected	B1	79/D4	K-I	—	30986A
R114	900K, .1%, 2W, MtF	B2	80/C4	ACI	C-3CM-2	R-267-900K
R115	10K, .1%, 1/10W, MtF	B1	81/D3	ACI	—	R-263-10K
R116	100K, 10%, 2W, Comp	B1	82/D3	A-B	HB	R-3-100K
R117	Thick Film	SEV	83/D3	Epitek	TF-123	TF-123
R118	50K, 10%, Cermet Trimmer	C2	84/D4	BRN	3386F-1-053	RP-97-50K
R119	200Ω, 10%, Cermet Trimmer	C1	85/D4	BRN	3386F-1-201	RP-97-200
R120	20K, .1%, 1/8W, MtF	C1	86/E4	DLE	—	R-179-20K
R121	9.1K, .1%, 1/8W, MtF	C1	87/D4	ACI	—	R-179-9.1K
R123	316K, 1%, 1/8W, MtF	D6	89/A5			R-88-316K
R124	1M, 5%, 1/4W, Carb	E3	90/B5	A-B	HB	R-76-1M
R125	100K, 10%, Cermet Trimmer	C4	91/B5	BRN	3386F-1-104	RP-97-100K
R126	20K, 5%, 1/4W, Carb	C4	92/B5	MEP	CR25	R-76-20K
R127	47K, 5%, 1/4W, Carb	H2	93/B5	A-B	HB	R-76-47K
R128	22M, 5%, 1/4W, Carb	H2	94/C5			R-76-22M
R130	200Ω, 10%, 3/4W	C1	96/D4	BRN	3006P-1-201	RP-89-200
R131	Thick Film	SEV	97/D5	Epitek	TF-124	TF-124
R133	47K, 5%, 1/4W, Carb	B5	98/A4	A-B	HB	R-76-47K
R134	10K, 5%, 1/4W, Carb	B5	99/A4	A-B	HB	R-76-10K
R135	10K, 5%, 1/4W, Carb	B5	100/A4	A-B	HB	R-76-10K
R136	10K, 5%, 1/4W, Carb	C5	101/A4	A-B	HB	R-76-10K
R137	10K, 5%, 1/4W, Carb	C6	102/A4	A-B	HB	R-76-10K
R138	10K, 5%, 1/4W, Carb	C5	103/A4	A-B	HB	R-76-10K
R139	10K, 5%, 1/4W, Carb	C6	104/A4	A-B	HB	R-76-10K
R140	47K, 5%, 1/4W, Carb	E2	105/D5	A-B	HB	R-76-47K
RT101	Thermistor, 8mA, 500V, PTC	A2	105/C4	MDW	180Q10200	RT-7

TABLE 6-4 CONTINUED

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
S101	Switch	SEV	107/C3	CLB	—	SW-429
	Pin Cutting for S101					30964B
U101	CMOS, Exclusive OR gates	SEV	113/A2	RCA	CD4070	IC-226
U102	CMOS, Exclusive OR gates	SEV	114/B2	RCA	CD4070	IC-226
U103	CMOS, Exclusive OR gates	SEV	115/A2	RCA	CD4070	IC-226
U104	CMOS, Exclusive OR gates	SEV	116/B2	RCA	CD4070	IC-226
U105	CMOS, Quad Bilateral Switch	G3	117/B2	RCA	CD4066AE	IC-149
U106	CMOS, Quad Bilateral Switch	H3	118/C2	RCA	CD4066AE	IC-149
U107	LCD Counter	F,G2	119/D2	INT	ICML7224	IC-286
U108	J FET OP AMP	C1,A3	120/D3	T-I	TL062CP	IC-279
U109	Linear OP AMP	D1	121/D4	NAT	M308	IC-99
U110	Linear OP AMP	B5	122/A4	MOT	LM11CLN	IC-315
U111	J FET OP AMP	C,D6	123/A5	T-I	TL062CP	IC-279
U112	CMOS, Analog Multiplexer	B4	124/B5	MOT	CD4053BC	IC-283
U113	CMOS, Analog Multiplexer	B4	125/B5	MOT	CD4053BC	IC-283
U114	CMOS, D type Flip Flops	SEV	126/C5	MOT	CD4017BC	IC-284
U115	CMOS, J K type Flip Flops	F2	127/C5	MOT	CD4027BC	IC-285
U116	CMOS, D type Flip Flops	D,E3	128/D5	MOT	CD4013	IC-103
U117	CMOS, Voltage Converter	F1	129/D5	INT	ICL7660CPA	IC-287
U118	CMOS, Analog Multiplexer	C4	130/B5	MOT	CD4053BC	IC-283
U119	CMOS, Two Input AND gates	SEV	131/B5	RCA	CD4081BE	IC-138
U120	CMOS, Inverters	SEV	132/C5	RCA	CD4069BE	IC-139
U121	CMOS, Two Input NAND gates	SEV	133/C5	RCA	CD4011	IC-102
U122	CMOS, D type Flip Flops	SEV	134/D5	MOT	CD4013	IC-103
U123	CMOS, Low Power OP AMP	SEV	135/D5	INT	ICL7621	IC-288
Y101	Crystal 100KHz	H2	142/C5	R&H	RH-170	CR-15
—	Battery Holder Assembly	—	—	—	—	30313B**
**Assembly consists of Battery Holder BH-27 and a Battery Holder Plate 30303B.						
Front Panel Assembly						
—	Front Panel	—	—	—	—	30816D
—	Overlay, Front Panel	—	—	—	—	30935C
—	Liquid Crystal Display	—	—	—	—	DD-26
—	Connector, Zebra Strip	—	—	—	—	CS-376-3
—	Liquid Crystal Spacer	—	—	—	—	31404B

TABLE 6-5
REPLACEABLE PARTS LIST
PC-567 - SCHEMATIC 30554C

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
C201	.1μF, 50V Cer	G1	4/B3	ERI	8121-050 625-104M	C-237-.1
C202	100p, 1000V, Cer D	D2	5/D3	CLB	DD-101	C-64-100p
C203	10p, 1000V, Cer D	C5	6/E3	CLB	DD-100	C-64-10p

TABLE 6-5 CONTINUED

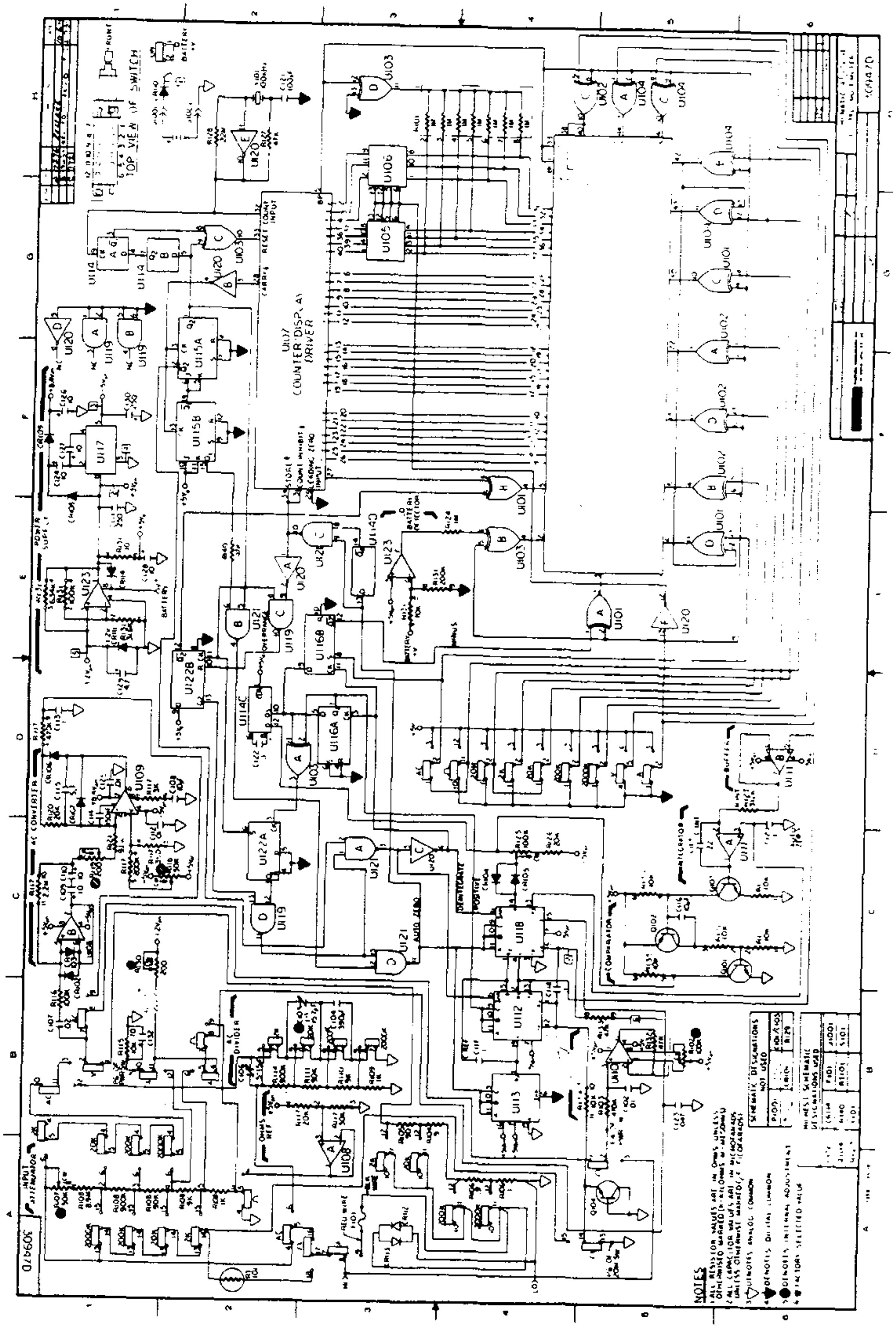
Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
C204	.1μF, 50V, Cer	B5	7/D2	ERI	8121-050 651-104M	C-237-.1
C205	1μF, 50V, Polycarb	C4	8/E2	ECI	625B1A105	C-215-1
C206	1μF, 50V, Polycarb	D5	9/E2	ECI	625B1A105	C-215-1
C207	.22μF, 50V, Polycarb	D5	10/E2	TRW	X363UW	C-269-.22
C208	.1μF, 50V, Cer	B5	11/F2	ECI	625B1A	C-237-.1
C209	.1μF, 50V, Cer	F2	12/F2	ERI	8121-050 625-104M	C-237-.1
C210	.1μF, 50V, Cer	G2	13/F2	ERI	8121-050 625-104M	C-237-.1
C211	.01, 50V, Polycarb	B4	14/F3	ECI	625B1A103	C-215-.01
CR201	Rectifier	B5	18/E2	T-I	1N914	RF-28
CR202	Rectifier	B5	19/E2	T-I	1N914	RF-28
Q201	Transistor, NPN	C5	33/E3	NAT	2N3904	TG-47
Q202	Transistor, NPN	D5	34/E3	NAT	2N3904	TG-47
Q203	Transistor, PNP	C5	35/E3	NAT	2N3906	TG-84
Q204	Transistor, NPN	A4	36/E2	G-E	GES-5818	TG-138
R201	1M, 5%, 1/4W, Carb	E6	39/B2	A-B	HB	R-76-1M
R202	Thick Film	SEV	40/B2	Epitek	TF-129	TF-129
R203	22M, 5%, 1/4W, Carb	D1	41/C3			R-76-22M
R204	47K, 5%, 1/4W, Carb	D2	42/D3	A-B	HB	R-76-47K
R205	100K, 10%, Pot	C5	43/D3	BRN	3386H-1-104	RP-111-100K
R206	Thick Film	SEV	44/E3	Epitek	TF-127	TF-127
R207	50K, 10%, Pot	A5	45/F3	BRN	3386H-1-100	RP-111-50K
R208	10K, 5%, 1/4W, Carb	B4	46/E2	A-B	HB	R-76-10K
R209	316K, 1%, 1/8W, MtF	D5	47/E2			R-88-316K
R210	10K, 5%, 1/4W, Carb	B5	48/F2	A-B	H-B	R-76-10K
R211	47K, 5%, 1/4W, Carb	A6	49/E2	A-B	H-B	R-76-47K
U201	CMOS, Exclusive OR gates	SEV	52/B2	RCA	CD4070	IC-226
U202	CMOS, Exclusive OR gates	SEV	53/B2	RCA	CD4070	IC-226
U203	CMOS, D type Flip Flops	E4	54/B2	MOT	CD4013	IC-103
U204	CMOS, D type Flip Flops	SEV	55/B2	NAT	74C175N	IC-284
U205	CMOS, JK type Flip Flops	E2	56/B3	MOT	CD4027BC	IC-285
U206	CMOS, Inverter	SEV	57/C3	RCA	CD4069BE	IC-139
U207	CMOS, Two Input AND gates	SEV	58/B3	RCA	CD4081BE	IC-138
U208	CMOS, Two Input NAND gates	SEV	59/C3	RCA	CD4011	IC-102
U209	CMOS, D type Flip Flops	D3	60/D3	MOT	CD4013BC	IC-103
U210	CMOS, Analog Multiplexer	C4	61/D2	MOT	CD4053BC	31847-1
U211	CMOS, Analog Multiplexer	B5	62/D2	MOT	CD4053BC	31847-2
U212	CMOS, Analog Multiplexer	C4	63/E2	MOT	CD4053BC	31847-3
U213	J FET OP AMP	D5	64/E2	T-I	TL062P	IC-279
U214	Linear OP AMP	A5	65/F3	NAT	LM11CLN	IC-294
Y101	Crystal, 100KHz	D1	68/D3	R&H	RH-170	CR-15
	LCD Assembly	—	—	—	—	
	LCD	—	—	—	—	DD-25
	Connector, Zebra Strip	—	—	—	—	CS-376-2
	Window, LCD	—	—	—	—	30195A

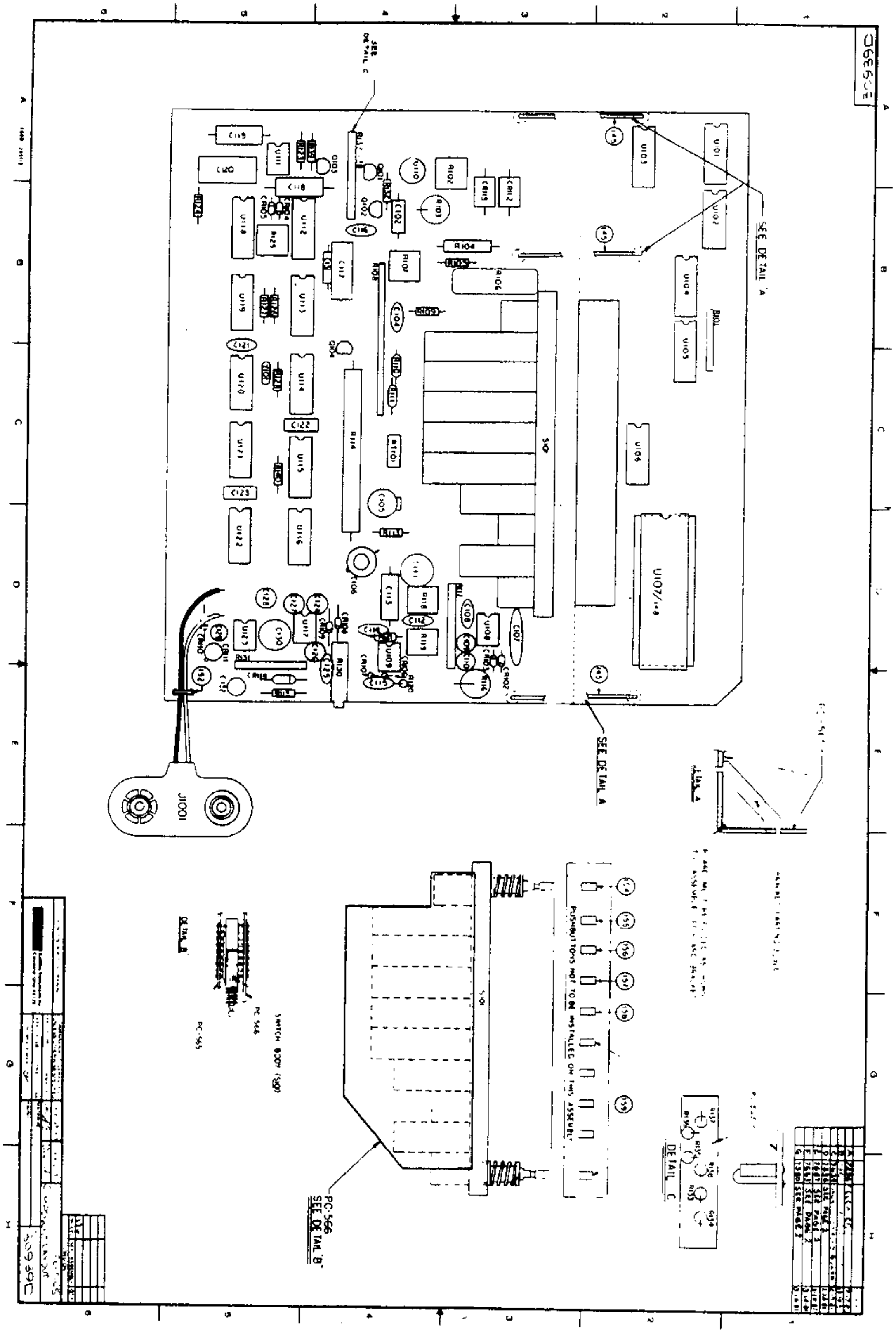
TABLE 6-5 CONTINUED

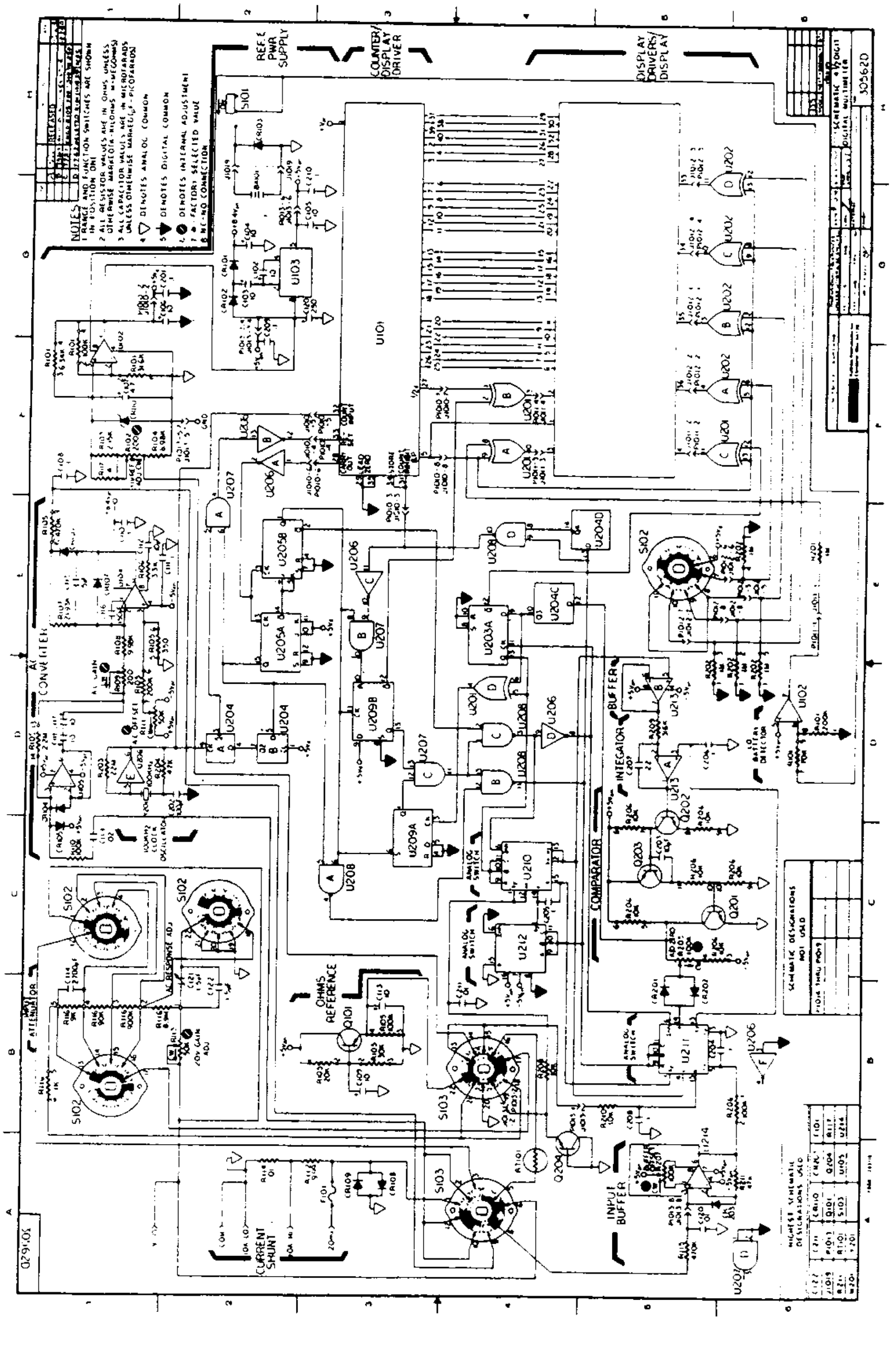
Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
	Gasket	—	—	—	—	30172A
	Support, LCD	—	—	—	—	30194A
	Tape	—	—	—	—	30382A
BA101		G2				BA-14
C101	250μF, 25V, Alum	G2	3/B2	RIC	HC-4B-250 25-8P	C-314-250
C102	10μF, 16V, Alum	G2	4/B2	NIC	16ULA10DT	C-313-10
C103	10μF, 16V, Alum	G2	5/B2	NIC	16ULA10DT	C-313-10
C104	10μF, 16V, Alum	G2	6/B2	NIC	16ULA10DT	C-313-10
C105	10μF, 16V, Alum	G2	7/B2	NIC	16ULA10DT	C-313-10
C106	10μF, 16V, Alum	G1	8/B2	NIC	16ULA10DT	C-313-10
C107	4.7μF, 25V, Alum	F1	9/C2	NIC	25ULA4 R7D-T	C-314-4.7
C108	.1μF, 50V, Cer	F1	10/B3	ERI	8121-050 625-104M	C-237-.1
C109	10μF, 16V, Alum	B3	11/B3	NIC	16ULA10DT	C-313-10
C110	.1μF, 50V, Cer	E1	12/A3	ERI	8121-050 625-104M	C-237-.1
C111	.1μF, 50V, Cer	E1	13/A3	ERI	8121-050 625-104M	C-237-.1
C112	10p, 50V, Cer	E1	14/B4		SR151A 100KAA	C-237-10p
C113	10μF, 16V, Alum	B3	15/B3	NIC	16ULA10DT	C-313-10
C114	2700p, 500V, Cer D	B1	16/C3			C-22-2700p
C115	5p, 1000V, Cer D	E1	17/B4	CLB	DD-050	C-64-5p
C116	150p, 1000V, Cer D	E1	18/B5	CLB	DD-151	C-64-150p
C117	10μF, 16V, Alum	D1	19/B4	NIC	16KUB10DK	C-321-10
C118	10μF, 16V, Alum	D1	20/B4	NIC	16KUB10DK	C-321-10
C119	.02μF, 500V, Cer D	C1	21/B4	ERI	811-000-Z5U	C-316-.02
C120	.01μF, 50V, Polycarb	A5	22/B6	ECI	625B1A103	C-215-.01
C121	.5p to 1.5p, 2000V	B2	23/C2	EFJ	273-1-1	C-183-1.5p
C122	1.5p, 50V, Cer D	B2	24/C2	CLB	DTZ1R5	C-291-1.5p
CR101	Rectifier	G2	27/B2	T-I	1N914	RF-28
CR102	Rectifier	G2	28/B2	T-I	1N914	RF-28
CR103	Rectifier	H2	29/A3	MOT	1N4006	RF-38
CR104	Rectifier	D1	30/B4	T-I	1N914	RF-28
CR105	Rectifier	C1	31/B4	T-I	1N914	RF-28
CR106	Rectifier	E1	32/B4	T-I	1N914	RF-28
CR107	Rectifier	E1	33/B4	T-I	1N914	RF-28
CR108	Rectifier	A3	34/B5	MOT	1N4006	RF-38
CR109	Rectifier	A3	35/B5	MOT	1N4006	RF-38
CR110	Low Voltage Reference (Zener)	F1	36/C2	MOT	LM385Z	30985A
F101	.75A, Fuse, 250V Max	A3		L-F	312.750	FU-14
Q101	Transistor, NPN	B3	56/C2	NAT	2N3904	TG-47
R101	Thick Film	SEV	60/B2	Epitek	TF-127	TF-128
R102	200Ω, 10%, 3/4W, Pot	F1	61/C2	BRN	3006P-1-201	RP-89-200
R103	2.15K, .1%, 1/10W, MtF	F1	62/C2	ACI	CR	R-263-2.15K
R104	8.98K, .1%, 1/10W, MtF	F2	63/C2	ACI	CR	R-263-8.98K
R105	Thick Film	SEV	64/B3	Epitek	TF-131	TF-131

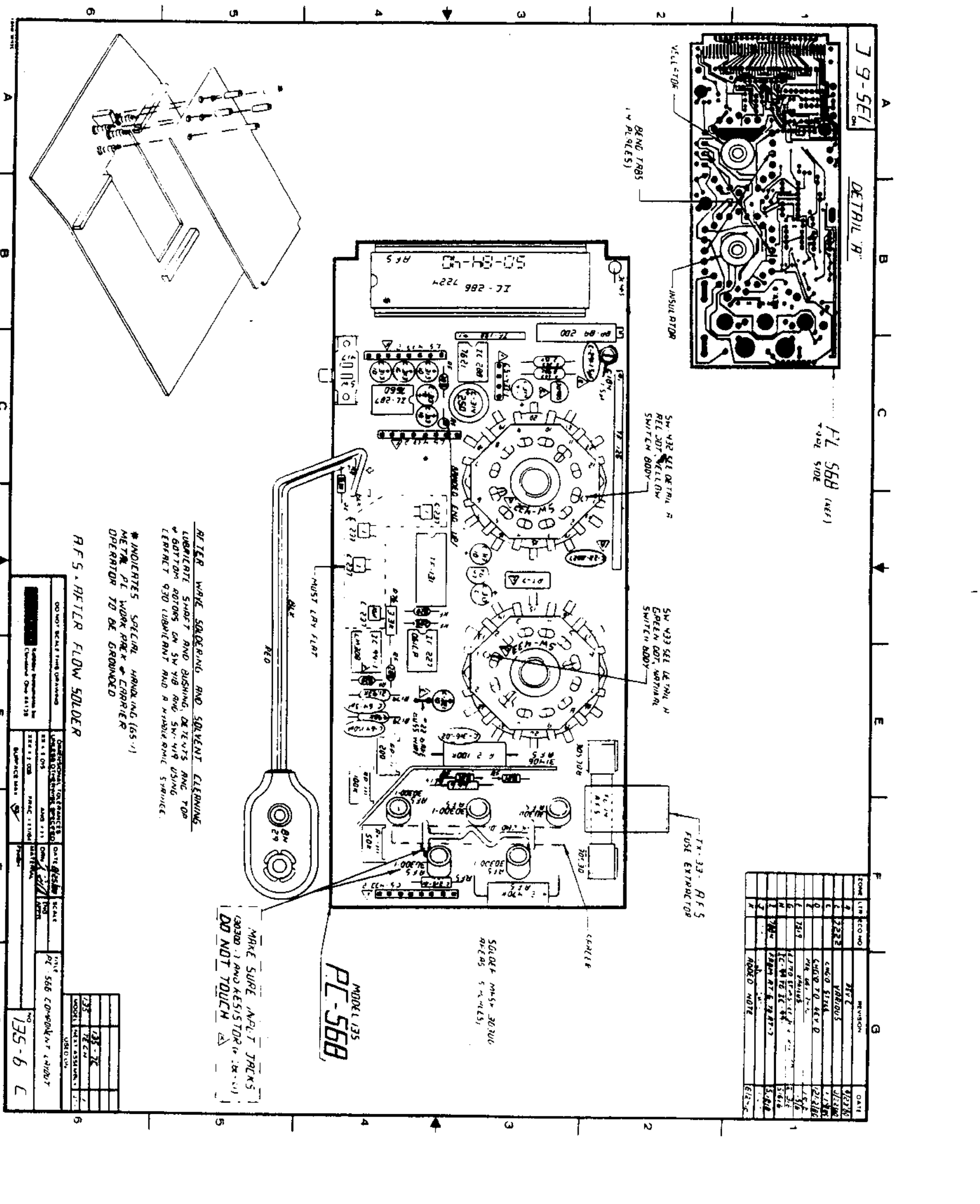
TABLE 6-5 CONTINUED

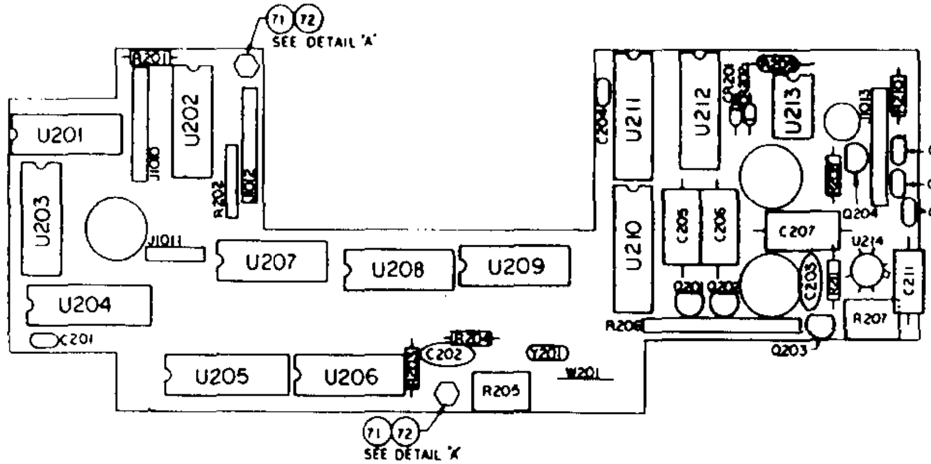
Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfg. Desig.	Keithley Part No.
R106	3.3K, 5%, 1/4W, Carb	E1	65/B4	A-B	CB	R-76-3.3K
R107	21.93K, .1%, 1/8W, MtF	E1	66/B4			R-179-21.93K
R108	9.98K, .1%, 1/8W, MtF	E1	67/B4	ACI	CR	R1-79-9.98K
R109	200Ω, 10%, Pot	D1	68/B5	BRN	3386H-1-201	RP-111-200
R110	100K, 10%, 1W, Carb	C1	69/B5	A-B	CB	R-2-100K
R111	100K, 10%, Pot	D2	70/B5	BRN	3386H-1-1 104	RP-111-100K
R112	9.99, .1%, 1/8W, MtF	A3	71/B5	ACI	CR	R-179-9.99
R113	50K, 10%, Pot	B2	72/B5	BRN	3386H-1-103	RP-111-50K
R114	.01Ω, .5%, 1W, WW	A2	73/B5	DLE	—	R-280-.01
R115	470K, 10%, 1W, Carb	A5	74/B6	IRC	GBT1W	R-2-470K
R116	Thick Film	SEV	75/C2	CAD	TF-126	TF-126
R117	* 1%, 1/8W, MtF	F1	76/C1	—	—	R-88-*
*Part of a set selected at the factory. (30985A) (The set includes CR110 and R117.)						
RT101		A4	78/B3			RT-7
S101	Switch	H2	80/A2	CNW	—	SW-417
S102	Switch, Rotary	SEV	81/C3	CLB	—	SW-432
S103	Switch, Rotary	SEV	82/C4	CLB	—	SW-433
U101	LCD, Counter	G3	84/B1	INT	ICML7224	IC-286
U102	CMOS, Low Power OP AMP	F1	85/B2	INT	ICL7621	IC-288
U103	CMOS, Voltage Converter	G2	86/B2	INT	ICL7660CPA	IC-287
U104	Linear OP AMP	E1	87/B4	NAT	LM308	IC-99
U105	JFET OP AMP	D1	88/B4	T-I	TL061CP	IC-227
—	Test Lead Kit	—	—	—	—	CA-8
	Cover, Battery	—	—	—	—	30186C
	Cover, Fuse	—	—	—	—	30187C




SEE DETAIL A
J1001
PC-566 SEE DETAIL 'B'
DETAIL C


REF & PWR SUPPLY
COUNTER/ DISPLAY DRIVER
DISPLAY DRIVERS/ DISPLAY
NOTES
AC CONVERTER
OHMS REFERENCE
COMPARATOR
INTEGRATOR
BUFFER
INPUT BUFFER
CURRENT SHUNT
ATTENUATOR
U101
30562D

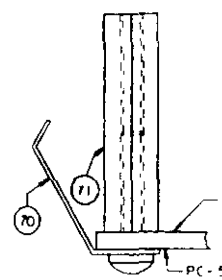

DETAIL "A"
PC-568
MODEL 135
MAKE SURE INPUT JACKS
DO NOT TOUCH
AFS - AFTER FLOW SOLDER
135-6



ITEM	PART NO	SCHEM DESIG	ZONE
1	30555C	PC-567	D3
2			
3			
4	C-237-.1	C201	B3
5	C-64-100pF	C202	D3
6	C-64-10pF	C203	E3
7	C-237-.1	C204	D2
8	C-215-1	C205	E2
9	"	C206	E2
10	C-269-.22	C207	E2
11	C-237-.1	C208	F2
12	"	C209	F2
13	"	C210	F2
14	C-215-.01	C211	F3
15			
16			
17			
18	RF-28	CR201	E2
19	"	CR202	E2
20			
21			
22			
23			
24			

ITEM	PART NO	SCHEM DESIG	ZONE
25	CS-434-2	J1010	B2
26	CS-434-1	J1011	B2
27	CS-434-2	J1012	C2
28	"	J1013	F2
29			
30			
31			
32			
33	TG-47	Q201	E3
34	"	Q202	E3
35	TG-84	Q203	E3
36	TG-138	Q204	E2
37			
38			
39	R-76-1M	R201	B2
40	TF-129	R202	B2
41	R-76-22M	R203	C3
42	R-76-47K	R204	D3
43	RP-111-100K	R205	D3
44	TF-127	R206	E3
45	RP-111-50K	R207	F3
46	R-76-10K	R208	E2
47	R-88-316K	R209	E2
48	R-76-10K	R210	F2

ITEM	PART NO	SCHEM DESIG	ZONE
49	R-76-47K	R211	E2
50			
51			
52	IC-226	U201	B2
53	"	U202	B2
54	IC-103	U203	B2
55	IC-284	U204	B3
56	IC-285	U205	B3
57	IC-139	U206	C3
58	IC-138	U207	B3
59	IC-102	U208	C3
60	IC-103	U209	D3
61	31847-1	U210	D2
62	31847-2	U211	D2
63	31847-3	U212	E2
64	IC-279	U213	E2
65	IC-294	U214	F3
66			
67	J-3	W201	D3
68	CR-15	Y201	D3
69			
70	31443A	1 REQ'D	C3
71	ST-119	2 REQ'D.	C2 & C3
72	[illegible]	2 REQ'D	C2 & C3



DETAIL 'A'
SCALE 4x

LTR	ECO NO	REVISION	DATE
A		RELEASED	
B		ADDED R211 ITEM 49	12-3-80
C	T464	CHGD ITEM 14 FROM C-201-.01 TO C-215-.01	
D		UPDATED	
E	T580	CHGD ITEM 61 FROM IC-283 TO 31847-1; CHGD ITEM 62 FROM IC-283 TO 31847-2; CHGD ITEM 63 FROM IC-283 TO 31847-3	2-16-81

DO NOT SCALE THIS DRAWING

[redacted]

SCALE 2:1

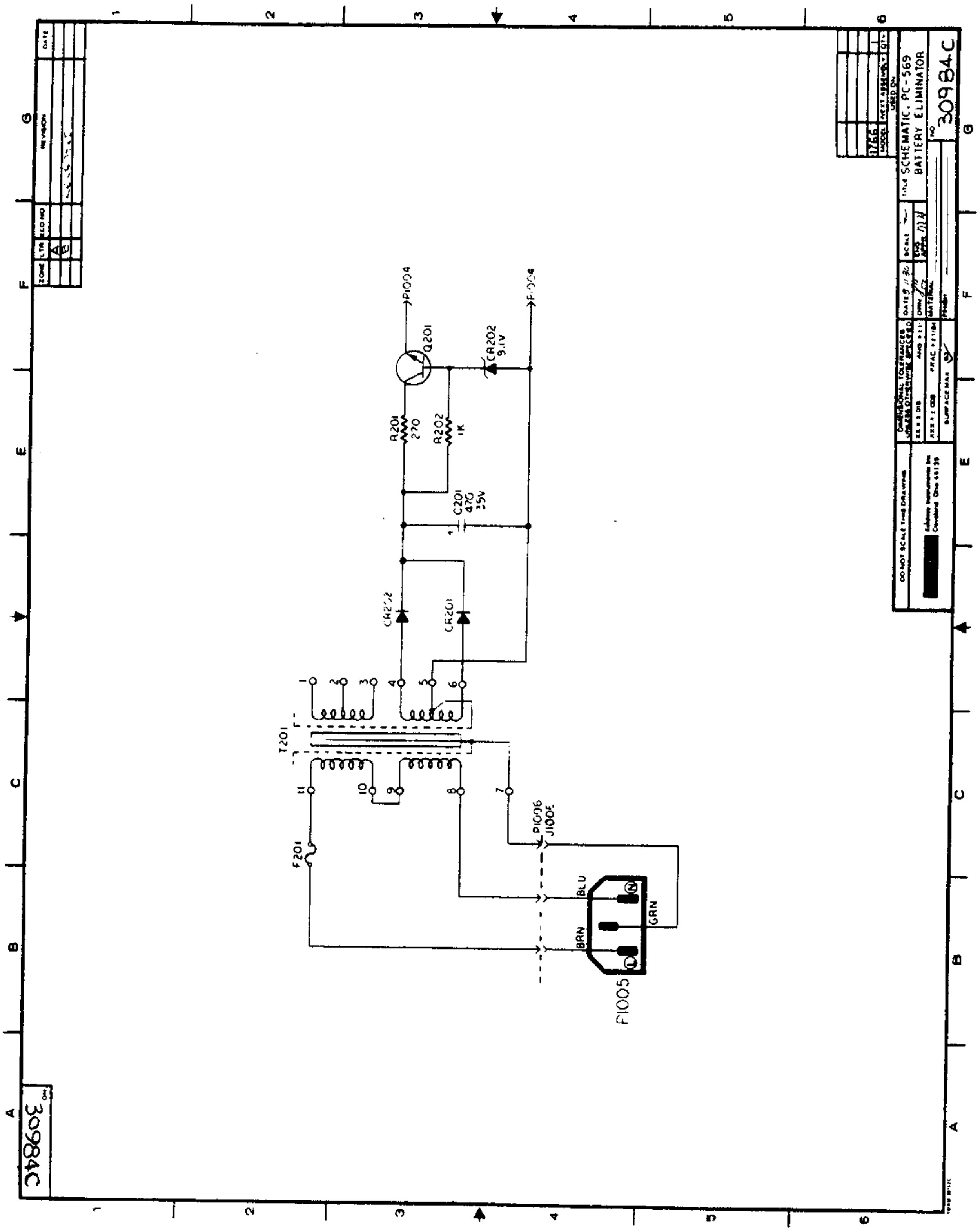
SURFACE MAX

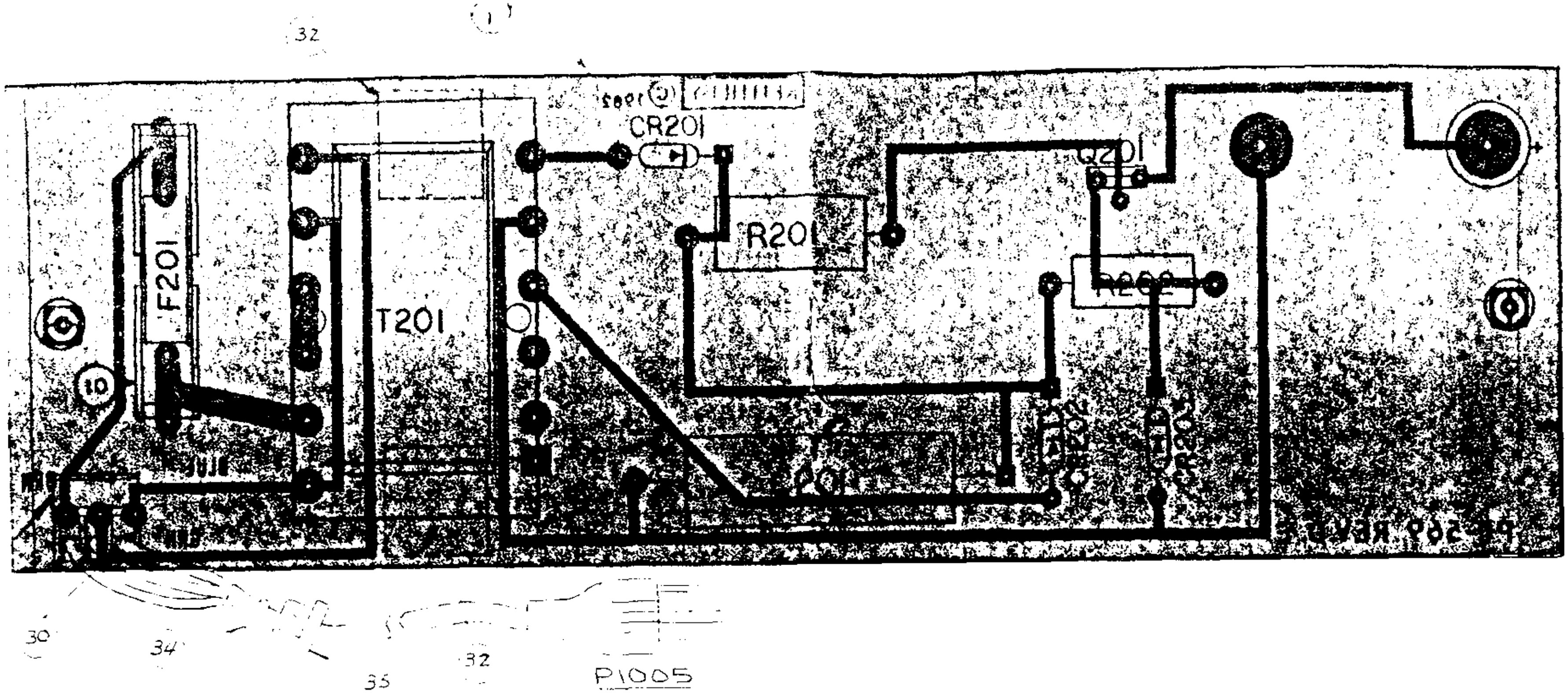
MODEL	NEXT ASSEMBLY	QTY
135		

USED ON

TITLE PC-567 COMPONENT LAYOUT

SIZE C NO 30554


SCHEMATIC, PC-569
BATTERY ELIMINATOR
30984C
1766
P1004
Q201
CR202
9.1V
R201
270
R202
1K
C201
470
35V
CR202
CR201
T201
F201
P1006
J1006
BLU
BRN
GRN
P1005



ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	31449C	PC-569	
2	C-289-470	C201	D4
3			
4	RF-38	CR201	D3
5	RF-38	CR202	E4
6	DZ-56	CR203	E4
7			
8			
9	FU-11	F201	B3
10	305303	2 REQ'D	B3
11			
12			
13			
14			
15			
16			
17	CO-9	P1005	C4
19	TG-124	Q201	E3
20			
21	R-3-270	R201	D3
22	R-2-1K	R202	E3
23			
24			
25	TR-168	T201	C3
26			
27			
28	CS-288-3	P1006	B4
29	CS-287-3	J1006	B4
30	CS-276	3 REQ'D	B4
31			
32	FE-12	—	C3
33			
34	CC-38-2	1 REQ'D	B4
35	STRAIN RELIEF	"	B4

NOTE:

△ 1.) CABLE CLAMP (ITEM 34) IS TO BE INSTALLED AT A DISTANCE OF 5" FROM MOLEX CONNECTOR (ITEM 29

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KEITHLEY

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