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Model 617
Programmable Electrometer
Instruction Manual



Contains Operating and Servicing Information

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Model 617 Programmable Electrometer
Instruction Manual

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SPECIFICATIONS

VOLTS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C
200mV	10 μV	0.05+4	0.004+3
2 V	100 μV	0.05+1	0.004+0.3
20 V	1mV	0.05+1	0.005+0.1
200 V	10mV	0.07+1	0.007+0.1

*When properly zeroed.

NMRR: Greater than 80dB on 200mV, 60dB on 2V and 20V, 55dB on 200V range, at 50Hz or 60Hz ±0.1%.

CMRR: Greater than 120dB at dc, 50Hz or 60Hz.

INPUT IMPEDANCE: Greater than 200TΩ in parallel with 20pF (< 2pF guarded).

AMPS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C
2 pA	100aA	1.6 +66	0.15 +8
20 pA	1 fA	1.6 + 7	0.15 +1
200 pA	10 fA	1.6 + 1	0.15 +0.1
2 nA	100 fA	0.25+ 5	0.015+3
20 nA	1pA	0.25+ 1	0.015+0.3
200 nA	10pA	0.25+ 1	0.015+0.1
2 μA	100pA	0.15+ 4	0.005+3
20 μA	1nA	0.15+ 1	0.005+0.3
200 μA	10nA	0.15+ 1	0.006+0.1
2mA	100nA	0.15+ 4	0.005+3
20mA	1μA	0.15+ 1	0.005+0.3

*When properly zeroed.

INPUT BIAS CURRENT: Less than 5fA (5×10^{-15}A) at 23°C.

INPUT VOLTAGE BURDEN: Less than 1mV except 3mV on 20mA range.

PREAMP SETTLING TIME (to 1% of final value): 2.5s on pA, 15ms on nA , 5ms on μA and mA ranges.

NMRR: Greater than 95dB on pA, 60dB on nA, μA and mA ranges at 50Hz or 60Hz ±0.1%.

COULOMBS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C
200pC	10 fC	0.4+4	0.02+3
2nC	100 fC	0.4+1	0.02+0.3
20nC	1pC	0.4+1	0.02+0.1

*When properly zeroed.

INPUT BIAS CURRENT: Less than 5fA (5×10^{-15}A) at 23°C.

OHMS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	TEST CURRENT ±1.5%
2 kΩ	100 mΩ	0.20+4	0.01+3	100μA
20 kΩ	1 Ω	0.15+1	0.01+0.3	100μA
200 kΩ	10 Ω	0.25+1	0.01+0.3	10μA
2MΩ	100 Ω	0.25+1	0.02+0.3	1μA
20MΩ	1 kΩ	0.25+1	0.02+0.3	100nA
200MΩ	10 kΩ	0.30+1	0.02+0.3	10nA
2 GΩ	100 kΩ	1.5 +1	0.04+0.3	1nA
20 GΩ	1MΩ	1.5 +1	0.04+0.1	1nA
200 GΩ	10MΩ	1.5 +1	0.04+0.1	1nA

*When properly zeroed.

MAXIMUM OPEN CIRCUIT VOLTAGE: 300V dc.

PREAMP SETTLING TIME (To 0.1% of final value, unguarded, with less than 100pF input capacitance): 2kΩ through 20MΩ, 15ms; 200MΩ, 150ms. **(To 1% of final value with Input Guard on and less than 1pF of unguarded input capacitance):** 2GΩ, 10ms, 20GΩ, 100ms; 200GΩ, 1s.

V/I MODE: Used with V-source, displays resistance (5×10^{4} to 10^{15}Ω) calculated from measured current. V/I Ohms accuracy equal to accuracy of V-Source plus accuracy of selected Amps range.

VOLTAGE SOURCE

OUTPUT: −102V to +102V in 50mV steps.

ACCURACY (1 Yr., 18°-28°C): ±(0.2% +50mV).

TEMPERATURE COEFFICIENT: ±(0.005% +1mV)/°C.

MAXIMUM OUTPUT CURRENT: ±2mA; active current limit at less than 4mA with annunciation.

SETTLING TIME: Less than 3ms to rated accuracy.

NOISE: < (1ppm of output voltage +200μV) p-p from 0.1Hz to 10Hz.

IEEE BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Function, Range, Zero Check, Zero Correct, Zero Suppress, EOI, Trigger, Terminator, 100-rdg Store and Retrieval, Calibration, V-Source Output, Display Format, SRQ, Status (including V-Source I-Limit), Output Format.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

TRIGGER TO READING DONE: 350ms typical.

GENERAL

DISPLAY: 4½-digit numeric LEDs with appropriate decimal point and polarity indication; signed two-digit alphanumeric exponent.

OVERRANGE INDICATION: Display reads "OL".

CONVERSION TIME: 330ms. **RANGING:** Automatic or manual.

DATA STORE and MIN/MAX: 100-reading store capacity; records data at one of six selectable rates from every reading to 1 reading/hour, or by manual triggering. Also detects and stores maximum and minimum readings continuously while in the Data Store mode.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

MAXIMUM INPUT: 250V peak, dc to 60Hz sine wave; 10s per minute max on mA ranges.

MAXIMUM COMMON-MODE VOLTAGE (dc to 60Hz sine wave): Electrometer, 500V peak; V-Source, 100V peak.

INPUT CONNECTOR: Two lug triaxial on rear panel.

OUTPUT CONNECTORS: 5-way binding posts on rear panel for V-source, preamp, and analog outputs. Rear panel BNC for External Trigger and Meter Complete.

2V ANALOG OUTPUT: 2V for full range input. Inverting in Volts and Ohms modes. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Volts and Ohms measurements. Can be used as an inverting output or with external feedback in Amps and Coulombs modes. Output Impedance: 100Ω.

EXTERNAL TRIGGER: TTL compatible External Trigger and Electrometer Complete.

V, Ω GUARD SWITCH: OFF Position: Inner shield of triax is Input LO, input capacitance is less than or equal to 20pF. ON Position: Inner shield of triax is Guard (follows Input HI). Input capacitance is less than or equal to 2pF. Use Analog Output COM for Input LO connection.

ENVIRONMENT: Operating: 0°-50°C. Relative Humidity: 70% non-condensing, up to 35°C. **Storage:** −25° to +65°C.

SHIELDING: Double shielded.

WARMUP: 2 hours to rated accuracy.

POWER: 105-125V, or 210-250V (internal switch selected), 90-110V available; 50-60Hz, 25 VA.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.6kg (8 lbs.).

ACCESSORY SUPPLIED: Model 6011 Triaxial Input Cable.

ACCESSORIES AVALIABLE:

Model 1019A: Universal Fixed Rack Mounting Kit
Model 1019S: Universal Slide Rack Mounting Kit
Model 6011: Triaxial Input Cable (3 ft.)
Model 6011-10: Triaxial Input Cable (10 ft.)
Model 6103C: Voltage Divider Probe (1000:1)
Model 6012: Triaxial-to-Coaxial UHF Adapter
Model 6104: Test Shield
Model 6105: Resistivity Chamber
Model 6146: Triaxial Tee Adapter
Model 6147: Triaxial-to-BNC Adapter
Model 6171: 3 Lug Male-to-2 Lug Female Triaxial Adapter
Model 6172: 2 Lug Male-to-3 Lug Female Triaxial Adapter
Model 7008-3: IEEE-488 Digital Cable (3 ft.)
Model 7008-6: IEEE-488 Digital Cable (6 ft.)
Model 7023: Female Triaxial Connector
Model 7024-3: Triaxial Cable (3 ft.)
Model 7024-10: Triaxial Cable (10 ft.)
Model 8573: IEEE-488 Interface to IBM PC

Specifications subject to change without notice.

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SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 617.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before operating this instrument.

Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Do not exceed 500V peak between input low and earth ground. Do not connect PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth ground when floating input.

Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace with test leads that have the same measure of safety as those supplied with the instrument.

For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors, before connecting or disconnecting the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.

Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

Safe operation and good measurement practice dictates use of an external resistor when necessary to limit input currents to less than 30mA.

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Keithley Model 617 Programmable Electrometer is a highly sensitive instrument designed to measure voltage, current, charge, and resistance. Two forms of resistance measurements are included in the standard configuration: a constant current method, and a constant voltage method that uses a built in voltage source for greater sensitivity. The measuring range of the Model 617 is between 10μV and 200V for voltage measurements, 0.1fA and 20mA in the current mode, 0.1Ω and 200GΩ (up to 10^{16}Ω using the built in voltage source), and 10fC and 20nC in the coulombs mode. The very high input impedance and extremely low input offset current allow accurate measurement in situations where many other instruments would have detrimental effects on the circuit being measured. A 4½ digit display and standard IEEE-488 interface give the user easy access to instrument data.

1.2 FEATURES

Some important Model 617 features include:

- 4½ Digit Display—An easy to read front panel LED display includes a 4½ digit mantissa plus a two-digit alpha or numeric exponent.
- Autoranging—Included for all functions and ranges.
- Digital Calibration—The instrument may be digitally calibrated from the front panel or over the IEEE-488 bus.
- Zero Correct—A front panel zero correct control allows the user to cancel any offsets.
- Baseline Suppression—One button suppression of a baseline reading is available from the front panel or over the IEEE-488 bus.
- One-shot Triggering—A front panel control for triggering one-shot readings from the front panel is included.
- Isolated 100V Voltage Source—A built in 100V source is isolated from the electrometer section. The voltage source is programmable in 50mV steps.
- Selectable Guarding—A selectable driven cable guard is included to optimize speed.
- Standard IEEE-488 Interface—The interface allows full bus programmable operation of the Model 617.
- Analog Outputs—Both preamp and 2V full range analog outputs are included on the rear panel.
- 100-Point Data Store—An internal buffer that can store up to 100 readings is accessible from either the front panel or over the IEEE-488 bus.
- Minimum and maximum data points can be stored and are accessible from the front panel or over the IEEE-488 bus.

1.3 WARRANTY INFORMATION

Warranty information for your Model 617 may be found inside the front cover of this manual. Should you need to use the warranty, contact your Keithley representative or the factory for information on obtaining warranty service. Keithley Instruments, Inc. maintains service facilities in the United States, West Germany, Great Britain, France, the Netherlands, Switzerland, and Austria. Information concerning the operation, application, or service of your instrument may be obtained from the applications engineer at any of these locations.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with this manual. Please be sure that you read this information before attempting to operate or service your instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual and found on the instrument:

The  symbol on the instrument indicates that the user should refer to the operating instructions in this manual for further details.

The **WARNING** heading as used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

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1.6 SPECIFICATIONS

Detailed Model 617 specifications may be found immediately preceding the table of contents of the manual. Note that accuracy specifications assume that the instrument has been properly zero corrected, as discussed in Section 2.

1.7 USING THIS INSTRUCTION MANUAL

This manual contains all the information necessary for you to operate and service your Model 617 Programmable Electrometer. The manual is divided into the following sections:

- Section 1 contains general information about your instrument including that necessary to unpack the instrument and get it operating as quickly as possible.
- Section 2 contains detailed operating information on how to use the front panel controls and programs, make connections, and basic measuring techniques for each of the available measuring functions.
- Information necessary to connect the Model 617 to the IEEE-488 bus and program operating modes and functions from a controller is contained in Section 3.
- Typical applications for the Model 617 are included in Section 4. At least one application for each of the measuring functions is included in this section.
- Performance verification procedures for the instrument may be found in Section 5. This information will be helpful if you wish to verify that the instrument is operating in compliance with its stated specifications.
- Section 6 contains a complete description of operating theory for the Model 617. Analog, digital, power supply, and IEEE-488 interface operation is included.
- Should your instrument ever require servicing, refer to the information located in Section 7. This section contains information on fuse replacement, line voltage selection, calibration, and troubleshooting.
- Replacement parts may be ordered by using the information contained in Section 8. Parts lists as well as schematic diagrams and component layouts are located in this section.

1.8 UNPACKING AND INSPECTION

The Model 617 Programmable Electrometer was carefully inspected before shipment. Upon receiving the instrument, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage that might have occurred during shipment. Report any damage to the shipping agent at once. Retain the original packing material in case reshipment becomes necessary.

The following items are included with every Model 617 shipment:

Model 617 Programmable Electrometer
Model 617 Instruction Manual.
Model 6011 Triaxial Input Cable
Additional accessories as ordered

If an additional instruction manual is required, order the manual package (Keithley Part Number 617-901-00). The manual package includes an instruction manual and all pertinent addenda.

1.9 GETTING STARTED

The Model 617 Programmable Electrometer is a highly sophisticated instrument with many capabilities. Although there are a number of complex aspects about the instrument, you can use the following procedure to get your instrument up and running quickly. For more detailed information, you should consult the appropriate section of the manual.

1. Carefully unpack your instrument as described in paragraph 1.8.
2. Locate the power cord and plug it into the rear panel power jack. Plug the other end of the line cord into an appropriate power source. See Section 2 for more complete information.
3. Connect the supplied triaxial cable to the rear panel input jack. Make sure the rear panel V, Ω GUARD switch is in the off position.
4. Press in the front panel POWER switch to apply power to the instrument. The instrument will power up the the autorange volts mode with zero check enabled. Thus, you could simply connect the red and black input leads to a voltage source and take a voltage reading at this point by disabling zero check. Remember that the Model 617 measures DC voltages up to 200V.
5. To change to a different measuring function, simply press the desired function button. For example, to measure resistance, simply press the OHMS button.
6. Complete detailed operation concerning Model 617 front panel operation may be found in Section 2. If you wish to control these functions over the IEEE-488 bus, consult Section 3.

1.10 PREPARATION FOR USE

Once the instrument is unpacked, it must be connected to an appropriate power source as described below.

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Line Power—The Model 617 is designed to operate from 105-125V or 210-250V power sources. A special power transformer may be installed for 90-110V and 195-235V ranges. The factory set range is marked on the rear panel of the instrument. Note that the line plug is designed to mate with the supplied 3-wire power cord.

CAUTION
Do not attempt to operate the instrument on a supply voltage outside the indicated range, or instrument damage might occur.

Line Voltage Selection—The operating voltage of the instrument is internally selectable. Refer to Section 7 for the procedure to change or verify the line voltage setting.

Line Frequency—The Model 617 may be operated from either 50 or 60Hz power sources.

IEEE-488 Primary Address—If the Model 617 is to be programmed over the IEEE-488 bus, it must be set to the correct primary address. The primary address is set to 27 at the factory, but it may be programmed from the front panel as described in Section 3.

1.11 REPACKING FOR SHIPMENT

Before shipping, the instrument should be carefully packed in its original packing material.

If the instrument is to be returned to Keithley Instruments for repair or calibration, include the following:

Write ATTENTION REPAIR DEPARTMENT on the shipping label.
Include the warranty status of the instrument.
Complete the service form at the back of this manual.

1.12 ACCESSORIES

The following accessories are available to enhance Model 617 capabilities.

Models 1019A and 1019S Rack Mounting Kits—The Model 1019A is a fixed or stationary rack mounting kit with two front panels provided to enable either single or dual side-by-side mounting of the Model 617 or other similar Keithley instrument. The Model 1019S is a similar rack mounting kit with a sliding mount configuration.

Model 6011 and 6011-10 Triaxial Cables—The Model 6011 is made up of 3 feet of triaxial cable that is terminated with a triax plug on one end and 3 alligator clips on the other end. The Model 6011-10 is a similar cable 10 feet in length. Note that the Model 6011 is supplied with the Model 617.

Model 6012 Triax to UHF Adapter—The Model 6012 allows the Model 617 to be used with accessories having UHF type connectors.

Model 6101A Shielded Test Lead—The Model 6101A is a straight through probe and shielded lead equipped with 0.8m (30") of shielded low noise cable terminated by a Teflon-insulated UHF connector. The Model 6012 must be used to adapt the Model 6101A to the Model 617 triaxial input.

Model 6103C Voltage Divider Probe—The Model 6103C extends Model 617 voltage measurement range to 30kV. The Model 6103C has a division ratio of 1000:1 with a nominal accuracy of 5%. The probe has an input resistance of $4.5 \times 10^{11}\Omega$ and is equipped with a UHF male plug. The Model 6012 adapter must be used to connect the Model 6103C to the Model 617.

Model 6104 Test Shield—The Model 6104 facilitates resistance, voltage, or current measurements with either 2- or 3-terminal guarded connections at voltages up to 1200V. The Model 6104 provides excellent electrostatic shielding and high isolation resistance. Clips plug into banana jacks, allowing custom connections. The Model 6104 has a BNC connector on one side and binding posts on the other. The Model 6147 adapter (below) is required to connect the Model 6104 to the Model 617.

Model 6105 Resistivity Chamber—The Model 6105 is a guarded test fixture for measuring voltage and surface resistivities. The unit assures good electrostatic shielding and high insulation resistance. The complete system requires the use of an external high-voltage supply such as the Model 247 as well as the Model 617. Volume resistivity up to $10^{9}\Omega$/cm and surface resistivity up to $10^{18}\Omega$ can be measured in accordance with ASTM test procedures. Sheet samples 64 to 102mm (2½ × 4") in diameter and up to 6.4mm (¼") thickness can be accommodated. Excitation voltages up to 1000V may be used.

Model 6146 Triax Tee Adapter—The Model 6147 allows the simultaneous connection of two triaxial cables to the single triaxial input of the Model 617.

Model 6147 Triax to BNC Adapter—The Model 6147 allows the Model 617 input to be connected to accessories having BNC connectors.

Model 6171 and 6172 3 Lug-to-2 Lug Adapters—The Model 6171 is a 3 lug male-to-2 lug female triaxial adapter, while the Model 6172 is a 2 lug male-to-3 lug female triaxial adapter.

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Model 7008 IEEE-488 Cables—The Model 7008 cables are designed to connect the Model 617 to the IEEE-488 bus and are available in two similar versions. The Model 7008-3 is 0.9m (3 ft.) in length, while the Model 7008-6 is 1.8m (6 ft.) long. Each cable is terminated with a standard IEEE-488 connector on each end, and each connector is equipped with two metric screws.

Model 7023 Female Triaxial Connector—The Model 7023 is a chassis mount connector that mates with the Models 6011 and 7024 triaxial cables.

Model 7024 Triaxial Cables—The Model 7024 cables are similar units with male triaxial connectors on each end. The Model 7024-1 is 0.3m (1 ft.) in length, while the Models 7024-3 and 7024-10 are 0.9m (3 ft.) and 3.0m (10 ft.) long respectively. These cables may be used to connect the Model 617 signal input to other equipment having similar triaxial connections.

Model 8573 IEEE-488 Interface for the IBM PC—The Model 8573 allows the Model 617 to be connected to and controlled from the IBM PC via the IEEE-488 bus.

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SECTION 2
OPERATION

2.1 INTRODUCTION

Operation of the Model 617 may be divided into two general categories: front panel operation and IEEE-488 bus operation. This section contains information necessary to use the instrument on a front-panel basis. Note that many of these functions can also be programmed over the IEEE-488 bus, as described in Section 3.

The following paragraphs contain a complete description of Model 617 front panel operation. First a complete description of each front and rear panel function is presented. Next the complete procedure for each of the measuring functions is presented, followed by a description of the built in voltage source. Finally, the analog output and guard functions are described along with a method to apply external feedback.

2.2 POWER UP PROCEDURE

Use the procedure below to connect the Model 617 to line power and power up the instrument.

1. Connect the female end of the power cord to the AC receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded AC outlet.

WARNING

The Model 617 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.

CAUTION

Be sure that the power line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage. If necessary, the line voltage may be changed as decribed in Section 7.

2. Turn on the power by pressing in the front panel POWER switch. The switch will be at the inner most position when the instrument is turned on.
3. The instrument will power up in the volts function, in the autorange mode and with zero check enabled, as indicated by the associated front panel LEDs. All other LEDs will be off when the instrument is first turned on.

2.3 POWER UP SELF TEST AND DISPLAY MESSAGES

The RAM memory is automatically tested as part of the power up procedure. If a RAM memory error occurs, the "rr" message will remain on the display. If the instrument was not able to read the stored calibration constants and configuration, the decimal points in the two exponent digits will flash.

If such errors occur, the instrument may be partially or completely inoperative. Refer to Section 7 for more complete details.

A power up self test may be run and the software revision level may be displayed by pressing and holding the TRIG button when the unit is first turned on. During the test, all front panel LEDs and the display segments will turn on as in the example below:

$$-1.8.8.8.8.*.*.$$

The instrument will then display the software revision level when TRIG is released, for example:

E.4

The instrument will then enter the diagnostic mode, which is used as an aid in troubleshooting problems within the instrument. See Section 7 for details. The power must be turned off to remove the instrument from the diagnostic mode.

NOTE

If the instrument is still under warranty (less than one year from the date of shipment), and problems develop, it should be returned to Keithley Instruments for repair. See paragraph 1.11 for details on returning the instrument.

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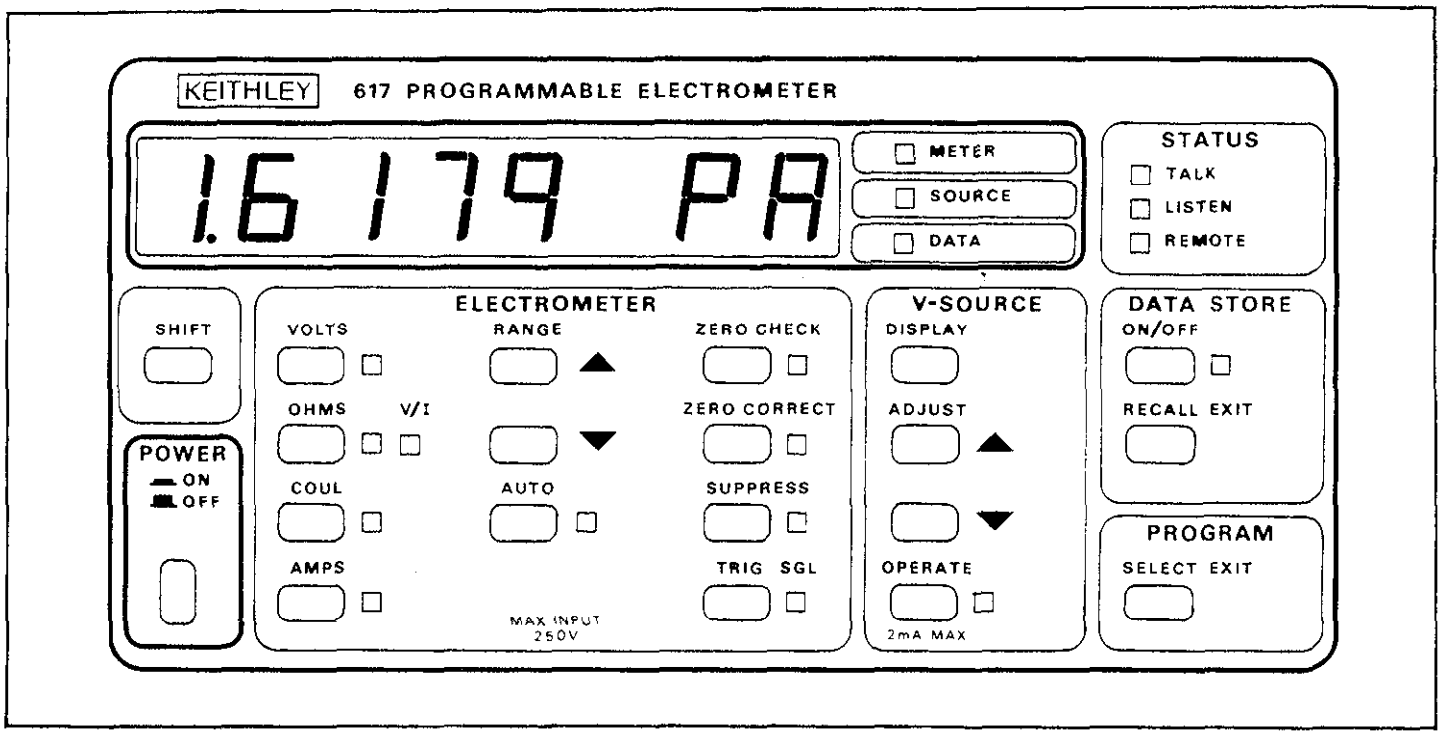


Figure 2-1. Model 617 Front Panel

2.4 FRONT PANEL FAMILIARIZATION

The front panel layout of the Model 617 is shown in Figure 2-1. The front panel may be divided into two sections: controls and display indicators. The following paragraphs describe each of these items in detail.

2.4.1 Controls

All front panel controls except POWER are momentary contact switches. Many control buttons include an annunciator light to indicate the selected mode. Some buttons have a secondary function that is entered by pressing the SHIFT button before pressing the desired button. All such buttons (except ADJUST) are marked in yellow. The controls are color coded into functional groups for ease of operation.

POWER—The POWER switch controls AC power to the instrument. Depressing and releasing the switch once turns the power on. Depressing and releasing the switch a second time turns the power off. The correct positions for on or off are marked on the front panel immediately above the POWER switch.

SHIFT—The SHIFT button adds a secondary function to some of the other front panel controls, including VOLTS, TRIG, OHMS, RECALL and PROGRAM SELECT. Note that the shift function is entered by pressing SHIFT before the second button rather than pressing the two simultaneously.

ELECTROMETER—The ELECTROMETER buttons control the measuring functions, selection of instrument ranges, and such items as zero check, zero and suppression, and front panel triggering.

VOLTS—The VOLTS button places the instrument in the DC volts measuring mode. When VOLTS is pressed, the indicator next to the button turns on, showing that the instrument is set for that mode. Note that the Model 617 will be in this mode when it is first turned on. Pressing SHIFT/VOLTS will place the instrument in the external feedback mode, as described in paragraph 2.12.

OHMS—Pressing OHMS places the unit in the resistance measuring function. The indicator next to the OHMS button will be illuminated when the instrument is in this mode. Note that there are two ways to measure resistance with the Model 617. Pressing OHMS alone will cause the instrument to measure resistance using the constant current method. Pressing the SHIFT button before pressing OHMS places the in-

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strument in the V/I mode of resistance measurement, as described in paragraph 2.8. The V/I indicator will light when the instrument is in this mode.

COUL—The Model 617 may be set up to measure charge by pressing the COUL button. The indicator next to the COUL button will illuminate when the instrument is set for this mode.

AMPS—Pressing AMPS switches the instrument to the current-measuring function. The AMPS indicator will turn on when the instrument is in this mode.

RANGE—These two buttons allow you to increment or decrement the range the instrument is in. Pressing the up arrow button will move the instrument up one range each time it is operated, while the down arrow button will move the instrument down range one increment each time it is pressed. Note that pressing either of these buttons will cancel autorange if that mode was previously selected. The display mantissa will remain blank until the first reading is ready to be displayed.

AUTO—The AUTO button places the instrument in the auto range mode. While in this mode, the Model 617 will switch to the best range to measure the applied signal. Note that the instrument will be in the autorange mode when it is first turned on. Autoranging is available for all functions and ranges. Autoranging may be cancelled either by pressing the AUTO button or one of the two RANGE buttons.

ZERO CHECK—The zero check mode is used in conjunction with the ZERO CORRECT control to cancel any offsets within the instrument and is also used as a standby mode. Pressing ZERO CHECK once will enable this mode, as shown by the associated indicator light. When zero check is enabled, the electrometer input circuit configuration changes (see paragraph 2.11). No readings can be be taken with zero check enabled. Pressing ZERO CHECK a second time will disable this mode. Zero check should be enabled when making connections or when changing functions.

ZERO CORRECT—The zero correct mode works with zero check to cancel electrometer offsets. If zero check is enabled, pressing ZERO CORRECT will store a new value that will be used to cancel any offset. If the range is changed while zero correct is enabled, the stored value will be scaled accordingly. Zero correct may be cancelled by pressing the ZERO CORRECT button a second time. More information on using zero correct may be found in paragraph 2.11.

SUPPRESS—The suppress mode allows you to cancel external offsets or store a baseline value to be subtracted from subsequent readings. For example, if you applied 10V to the instrument and enabled suppress, that value would then be subtracted from subsequent readings. Once suppress is enabled, the value is scaled when the range is changed. Suppress may be disabled by pressing the SUPRESS button a second time, and is cancelled if the function is changed.

TRIG—The TRIG button allows you to enter the one-shot trigger mode and trigger single readings from the front panel. To enter the one-shot mode, press SHIFT then TRIG. The SGL indicator light will show that the instrument is in the one-shot mode. Each time the TRIG button is pressed, a single reading will be processed and displayed. The displayed reading will flash when the TRIG button is pressed. The one-shot trigger mode can be cancelled by pressing SHIFT then TRIG a second time. Additional information on triggering may be found in paragraphs 2.13 and 3.10.14.

V-SOURCE—These buttons control the internal ±100V source within the instrument. More information on the using the voltage source is located in paragraph 2.8.

DISPLAY—The DISPLAY button toggles the front panel display between the voltage source and the present display mode (electrometer or data store). Pressing DISPLAY once will switch the display from the present mode to the source mode, as indicated by the LEDs adjacent to the display (more information on the display is located in paragraph 2.4.2). Pressing DISPLAY again will return the display to the previous display mode.

ADJUST—These two buttons control the voltage source output value. The up arrow button increases the voltage value in 50mV increments, while the down arrow decreases the voltage source output in 50mV increments. The values may be scrolled by holding the desired ADJUST arrow in. The instrument will stop on the value currently displayed when the button is released. The scrolling can be made more rapid by pressing the SHIFT key before pressing the desire ADJUST key. Note that the ADJUST keys are also used with certain front panel programs, as described in paragraph 2.5. Note that the maximum voltage values are +102.4V and −102.35V.

OPERATE—The OPERATE button turns the actual voltage source output on or off. Pressing the OPERATE button once turns on the output. The LED next to the OPERATE button will be illuminated when the source is turned on. Pressing the OPERATE button a second time will turn off the output (00.00V). Note that the OPERATE LED will flash when the 2mA current limit is exceeded.

DATA STORE—The two DATA STORE buttons control the internal 100-reading data store mode of the instrument. Through these two buttons, data storage may be enabled or disabled, the storage rate may be selected, and readings may be recalled to the front panel display. Paragraph 2.12 contains a complete description of data store operation.

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ON/OFF—This control enables or disables data store operation. In addition, reading rates can be selected by holding the button in when first enabling data store. When data store is enabled, the indicator light next to the ON/OFF button will be on. Minimum and maximum values are stored and updated as long as the ON/OFF LED is on.

RECALL/EXIT—This single button serves to recall readings previously stored by data store. Pressing and holding this button causes the instrument to scroll through the pointer addresses as indicated on the display. Once the desired reading number is displayed, releasing the button causes the actual reading to be displayed. To exit the recall mode, press SHIFT EXIT.

PROGRAM—A single PROGRAM button controls such modes as IEEE address, alpha or numeric display exponent, and digital calibration. Paragraph 2.5 further describes front panel programming.

SELECT/EXIT—This button enters the program mode to allow access to parameters described above. Pressing SELECT repeatedly causes the instrument to scroll through a program menu. To cancel the program mode, press SHIFT and then SELECT/EXIT in that order. Note that the program mode is cancelled by pressing SELECT/EXIT after a program parameter change is made.

2.4.2 Display and Indicators

The operation of the 4½ digit display and various indicators is described below. The display updates at about three readings per second.

Display—The Model 617 has a display made up of a 4½ digit signed mantissa as well as a two-digit signed exponent. The exponent can be represented either in scientific notation, or with an alphanumeric subsript such as nA. The exponent display mode can be changed with a front panel program, as described in paragraph 2.5. Note that, when scientific notation is used, the decimal point remains fixed as in 1.9999. The range is indicated by the exponent. In addition, the display has a number of front panel error messages, as shown in Table 2-1.

Display Indicators—The METER, SOURCE, and DATA LEDs indicate what the display is actually showing. When the METER LED is on, the display represents an electrometer reading. When the SOURCE LED is illuminated, the voltage source value is being displayed. A data store reading is displayed when the DATA LED is turned on. Normally, the display will be the the meter mode, but the DISPLAY and RECALL buttons will switch the display to the source and data modes respectively.

STATUS Indicators—These three indicators apply to operation of the Model 617 over the IEEE-488 bus. The REMOTE indicator shows when the instrument is in the IEEE-488 remote state, while the TALK and LISTEN indicators show when the instrument is in the talk and listen states respectively. See Section 3 for more information on using the Model 617 over the IEEE-488 bus.

2.4.3 Tilt Bail

The tilt bail, which is located on the bottom of the instrument, allows the front panel to be elevated to a convenient viewing height. To extend the bail, rotate it out 90° from the bottom cover and latch it into place. To retract the bail, pull out until it unlatches and rotate it against the bottom cover.

2.5 FRONT PANEL PROGRAMS

The Model 617 has three front panel programs that can be used to set the primary address, set the display exponent mode (alpha or numeric), or calibrate the instrument from the front panel. To select a program, press PROGRAM SELECT button repeatedly while observing the display. The instrument will scroll through the available programs with identifying messages, as shown in Table 2-2. When in the program mode, the DISPLAY and DATA STORE RECALL buttons are inoperative; the data store mode may be turned off, but not on. The operation of the various programs is described in the following paragraphs. To exit a program, press SHIFT EXIT. If a change was made, pressing SELECT alone will exit the program.

2.5.1 IEEE-488 Address

Selection of the IEEE-488 address program is indicated by the following message:

IEEE 27

Along with the message, the presently programmed IEEE-488 address (27 in this example) will be displayed. To select a new address, use the V-SOURCE ADJUST keys. When the desired value is shown in the display, press SHIFT then SELECT EXIT to return to normal operation (or if a change was made, simply press SELECT). For complete information on using the Model 617 over the IEEE-488 bus, refer to Section 3.

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Table 2-1. Display Error Messages

Message	Description
OL	Overrange input applied (- for negative value).
b Err	Bus Error: Instrument programmed while not in remote; or illegal command or command option sent.*
n Err	Number Error: Calibration or voltage source value out of limits.*
t Err	Trigger Overrun Error: Instrument triggered while processing reading from previous trigger.

*See Section 3.

Table 2-2. Front Panel Program Messages

Message	Program Description
IEEE	Displays/sets IEEE primary address.
dISP	Sets numeric or alpha exponent.
CAL	Allows calibration of instrument.

2.5.2 Exponent Mode (Alpha or Numeric)

The display exponent of the Model 617 can be operated in either the alpha mode or the numeric mode. In the alpha mode, the exponent is given in actual units such as mA. In the numeric mode, the exponent is given in scientific notation. Table 2-3 gives typical examples, including units.

To select the exponent program, scroll through the program menu until the following message is displayed:

dISP

Use either of the V-SOURCE ADJUST buttons to set the exponent to the desired mode. In the numeric mode, the display might show:

dISP -3

The display in the alpha mode appears as:

dISPm

Once the desired exponent mode is selected, press SHIFT then SELECT EXIT to return to normal operation (or simply PROGRAM SELECT if a change was made).

2.5.3 Calibration

An advanced feature of the Model 617 is its digital calibration program. The instrument can be calibrated from the front panel or over the IEEE-488 bus. To use the front panel calibration program, refer to the calibration procedures outlined in Section 7.

2.6 REAR PANEL FAMILIARIZATION

The rear panel of the Model 617 is shown in Figure 2-2.

2.6.1 Connectors and Terminals

AC Receptacle—Power is applied through the supplied power cord to the AC receptacle. Note that the supply voltage is marked adjacent to the receptacle.

IEEE-488 Connector—This connector is used to connect the instrument to the IEEE-488 bus. IEEE-488 function codes are marked above the connector.

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Table 2-3. Typical Display Exponent Values

Display	Engineering Units	Scientific Notation	Value
PA	pA	10^{-12}A	Picoamperes
nC	nC	10^{-9}C	Nanocoulombs
μA	μA	10^{-6}A	Microamperes
mV	mV	10^{-3}V	Millivolts
kΩ	kΩ	$10^{3}\Omega$	Kilohms
MΩ	MΩ	$10^{6}\Omega$	Megohms
GΩ	GΩ	$10^{9}\Omega$	Gigohms
TΩ	TΩ	$10^{12}\Omega$	Teraohms
PΩ	PΩ	$10^{15}\Omega$	Petaohms

INPUT—The INPUT connector is a 2-lug triax connector to be used for all electrometer signal inputs. Note that you should not confuse a triaxial connector with the BNC type that is used for the EXTERNAL TRIGGER and ELECTROMETER COMPLETE connections. Also, do not attempt to force a 3-lug triaxial connector onto the INPUT Connector. The Models 6171 and 6172 adapters are available to make the necessary conversion.

2V ANALOG OUTPUT—The 2V ANALOG OUTPUT provides a scaled 0-2V output from the electrometer (2V output for full range input). The output uses a standard 5-way binding post and is inverting in the volts and ohms modes.

PREAMP OUT—The PREAMP OUT provides a guard output for voltage and resistance measurements. This output can also be used as an inverting output or with external feedback when measuring current or charge. The PREAMP OUT has a maximum output value of ±300V and uses a standard 5-way binding post.

WARNING

Hazardous voltage may be present at the PREAMP OUT, depending on the input signal.

COM Terminal—The COM terminal is a 5-way binding post that provides a low connection for both the 2V ANALOG OUTPUT and the PREAMP OUT. This terminal is also used for input low connection when in guarded mode; COM is internally connected to input low through a 100Ω resistor. Do not connect PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth when floating input.

V-SOURCE OUTPUT—The HI and LO outputs are the connections for the internal voltage source. This source can be used as a stand-alone source or in conjunction with the electrometer section to make resistance measurements as high as $10^{16}\Omega$.

EXTERNAL TRIGGER INPUT—This BNC connector can be used to apply external trigger pulses to the Model 617 to trigger the instrument to take one or more readings, depending on the selected trigger mode.

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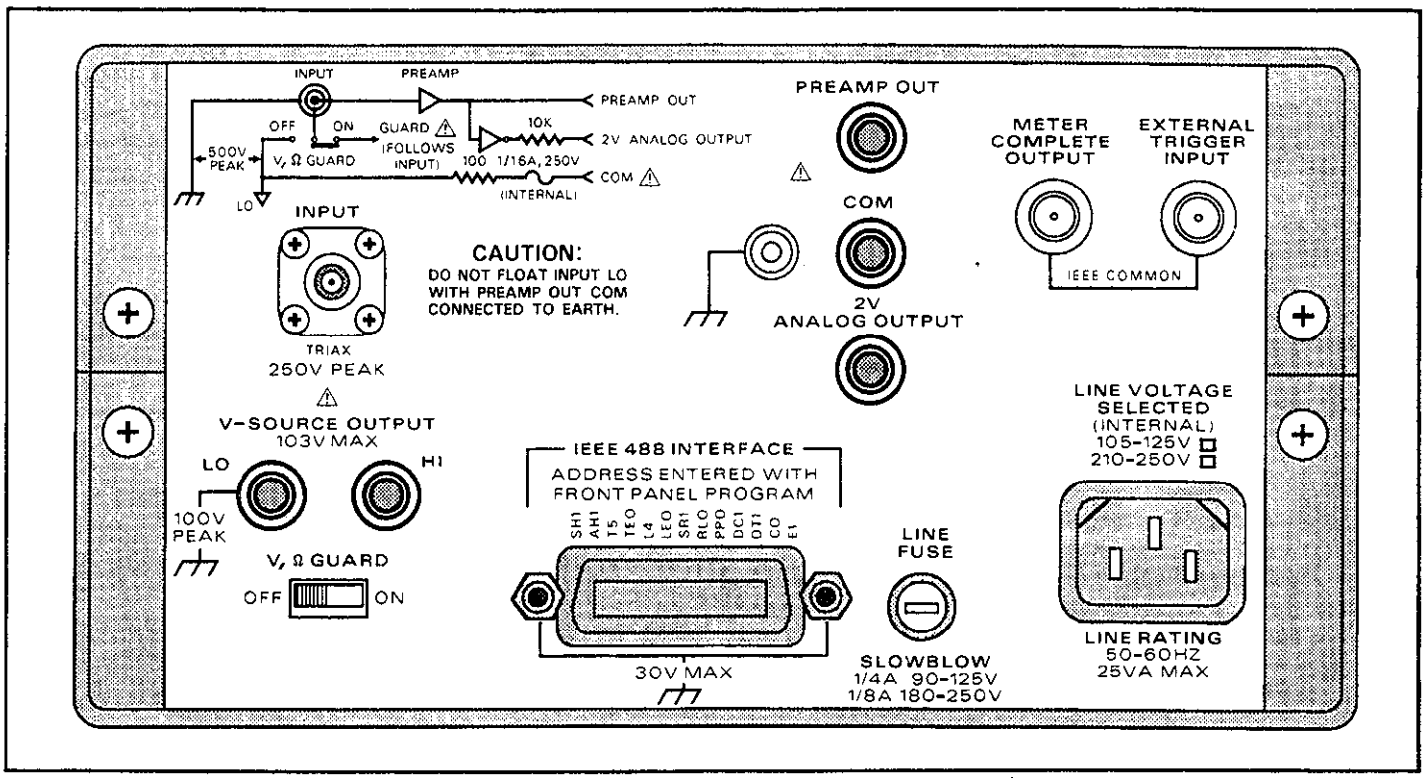


Figure 2-2. Model 617 Rear Panel

METER COMPLETE OUTPUT—This BNC connector provides an output pulse when the Model 617 has completed a reading; it is useful for triggering other instrumentation.

Chassis Ground—This jack is a 5-way binding post that is connected to instrument chassis ground. It is intended for use in situations requiring an accessible chassis ground terminal.

A shorting link is supplied and connected to the CHASSIS GROUND terminal.

2.6.2 V, Ω GUARD Switch

The Model 617 has provisions for connecting a guard to the inner shield of the input cable. Guarding is useful in the volts and ohms modes to speed up response time and minimize the effects of leakage resistance. Note that guarded operation is not recommended in amps or coulombs. The V, Ω GUARD switch allows easy selection of the guarded mode of operation. See paragraph 2.7.4 for more information on guarded operation.

2.6.3 Line Fuse

The LINE FUSE, which is accessible on the rear panel, provides protection for the AC power line output. For information on replacing this fuse, refer to Section 7.

2.7 BASIC MEASUREMENT TECHNIQUES

The paragraphs below describe the basic procedures for using the Model 617 to make voltage, resistance, charge, and current measurements.

2.7.1 Warm Up Period

The Model 617 is useable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least two hours to achieve rated accuracy.

NOTE

While rated accuracy is achieved after the two hour warm up period, input bias current may require additional time to come to its optimum level. Allow two hours for input bias current to settle to less than 10fA and eight hours to less than 5fA. It is preferable in sensitive applications to leave the unit on continuously.

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2.7.2 Input Connections

The rear panel INPUT connector is a Teflon-insulated receptacle intended for all input signals to the Model 617. As shown in Figure 2-3, the center terminal is high, the inner ring or shield is low, and the outer shield is connected to instrument chassis ground. In the guarded mode, the inner shield is driven at guard potential, while the outer shield is chassis ground.

NOTE

The input connector must be kept clean to maintain high input impedance.

The supplied Model 6011 input cable is designed to mate with the input connector. The other end of the Model 6011 is terminated with three alligator clips. Input high is color coded in red, input low is colored black, and chassis ground is color coded in green. Keep in mind that these connections are for the unguarded mode. In the guarded mode, red is high, black is guard, and green is chassis ground. The COM binding post provides a connection to input low through 100Ω for use in the guarded mode.

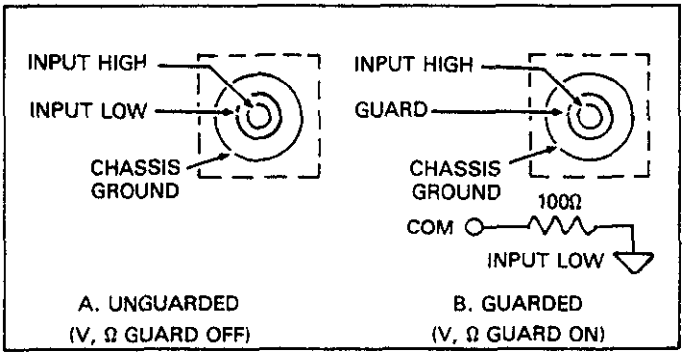


Figure 2-3. Input Connector Configuration

NOTE

It is recommended that zero check be enabled when connecting or disconnecting input signals.

WARNING

The maximum common-mode input voltage (the voltage between input low and chassis ground) is 500V peak. Exceeding this value may create a shock hazard.

CAUTION

Connecting PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth while floating input may damage the instrument.

CAUTION

The maximum voltage between input high and input low is 250V rms, DC to 60Hz sine wave (10 seconds maximum in mA ranges). Exceeding this value may cause damage to the instrument.

2.7.3 Making Voltage Measurements

The Model 617 can be used to measure voltages in the range of $\pm 10\mu V$ to $\pm 200V$. In principle, the instrument operates much like an ordinary DMM, but its special characteristics allow it to make measurements in cases where an ordinary DMM would be unable to perform well. In particular, the very high input resistance of $200T\Omega$ ($2 \times 10^{14}\Omega$) allows it to accurately measure voltage sources with high internal resistances. In contrast, an ordinary DMM may have an input resistance of only $10M\Omega$, resulting in inaccurate measurements because of instrument loading.

Use the procedure below to make voltage measurements.

1. Turn on instrument power and allow it to warm up for two hours to reach rated accuracy.
2. Check to see that the voltage function is selected by pressing the VOLTS button. Use the autorange mode, or select the desired range with the ranging pushbuttons.
3. To achieve specified accuracy, especially on the lower ranges, it is recommended that you zero the instrument. To do so, first enable zero check and then press the ZERO CORRECT button. Correcting zero in the lowest range of any function will correct all ranges because of internal scaling.

NOTE

The input circuit configuration changes with zero check enabled. See paragraph 2.11.1.

4. Connect the Model 6011 triaxial input cable or other similar cable to the rear panel INPUT jack on the instrument. For sources with high output resistance, the cable should be kept as short as possible to minimize cable capacitance.
5. If response time and leakage resistance are considerations, place the instrument in the guarded mode as described in the next paragraph.
6. Connect the other end of the cable to the voltage to be measured, as shown in Figure 2-4. Disable zero check.
7. The reading may be obtained directly from the display. The exponent can be placed either in the alpha or numeric mode, as described in paragraph 2.5.

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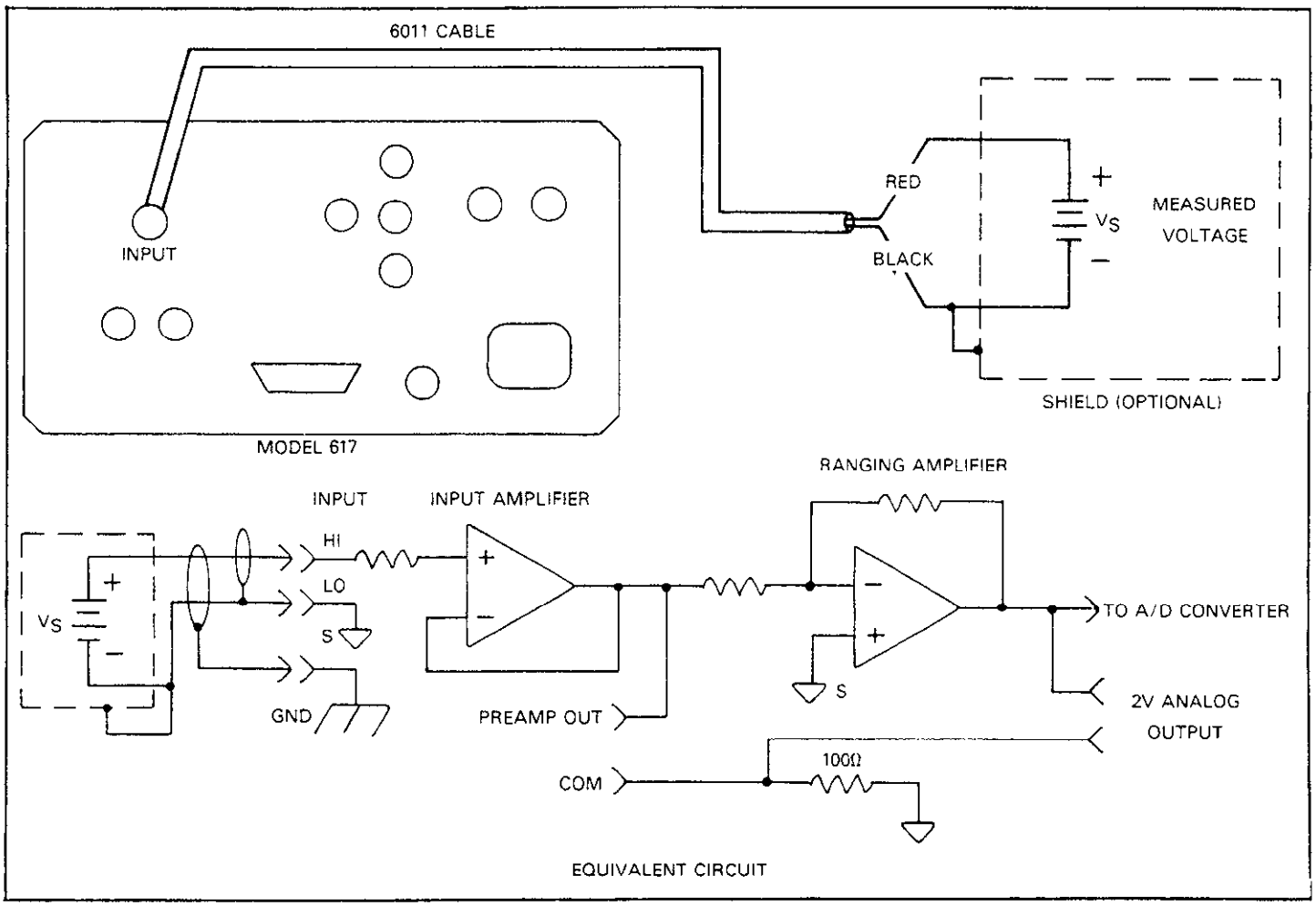


Figure 2-4. Connections for Voltage Measurements

Voltage Measurement Considerations: Two primary considerations come to mind when making voltage measurements, especially for voltage sources with high output resistances. For one thing, the loading effects of the measuring instrument come into play at the high resistance levels involved. Secondly, the distributed capacitance of the source, the input cable, and the input circuit of the instrument itself come into play when making these measurements.

To see how meter loading can affect accuracy, refer to Figure 2-5. In this figure there is a voltage source with a value E_S and an output R_S connected to the input of the electrometer, which has its input resistance represented by R_{IN}. The percent error due to loading can be calculated as follows:

$$\% \text{ ERROR} = \frac{100\ R_S}{R_S + R_{IN}}$$

Thus, to keep the error under 0.1%, the input resistance must be about 1000 times the value of the source resistance, R.

At very high resistance levels, the very large time contants created by even a minimal amount of capacitance can slow down response time considerably. For example, measuring a source with an internal resistance of 100GΩ would result in an RC time constant of one second when measured through a cable with a nominal capacitance of 10pF. If 1% accuracy is required, a single measurement would require at least five seconds.

Basically, there are two ways to minimize this problem: (1) keep the input cable as short as possible, and (2) use guarding. With the first method, there is a limit as to how short the cable can be. Using guarding can reduce these effects by up to a factor of 1000. The Model 617 has a rear panel switch to allow guarding to be easily applied to the input circuit; see the next paragraph for details.

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At low signal levels, noise may affect accuracy. Shielding of the unknown voltage can reduce noise effects substantially. When using shielding, the shield should be connected to input low.

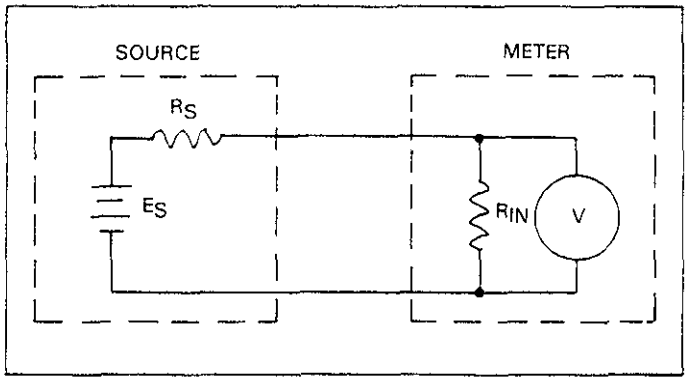


Figure 2-5. Meter Loading Considerations

2.7.4 Guarded Operation

Guarding consists of using a conductor supplied by a low impedance source to totally surround the leads carrying a high-impedance signal. The output of this low-impedance source is kept at the same potential as the signal itself, resulting in drastically reduced leakage currents.

To approach the concept of guarding, let us first review the unguarded circuit shown in Figure 2-6. The measured signal is represented by the voltage source E_S and the source resistance R_S. Cable leakage impedance is represented by Z_L . The source resistance and leakage impedance form a voltage divider that attenuates the source voltage as follows:

$$E_O = \frac{Z_L E_S}{Z_L + R_S}$$

Thus, to keep the error due to leakage resistance under 0.1%, the leakage resistance must be at least 1000 times the source resistance value.

Guarding the circuit miminizes these effects by driving the shield at signal potential, as shown in Figure 2-7. Here, a unity gain amplifier with a high input impedance and low output impedance is used. The input of the amplifier is connected to the signal, while the output is used to drive the shield. Since the amplifier has unity gain, the potential across Z_L is essentially zero, so no leakage current flows. Leakage between the cable shield and ground may be considerable, but it is of no consequence since that current is supplied by the low impedance source, rather than by the signal itself.

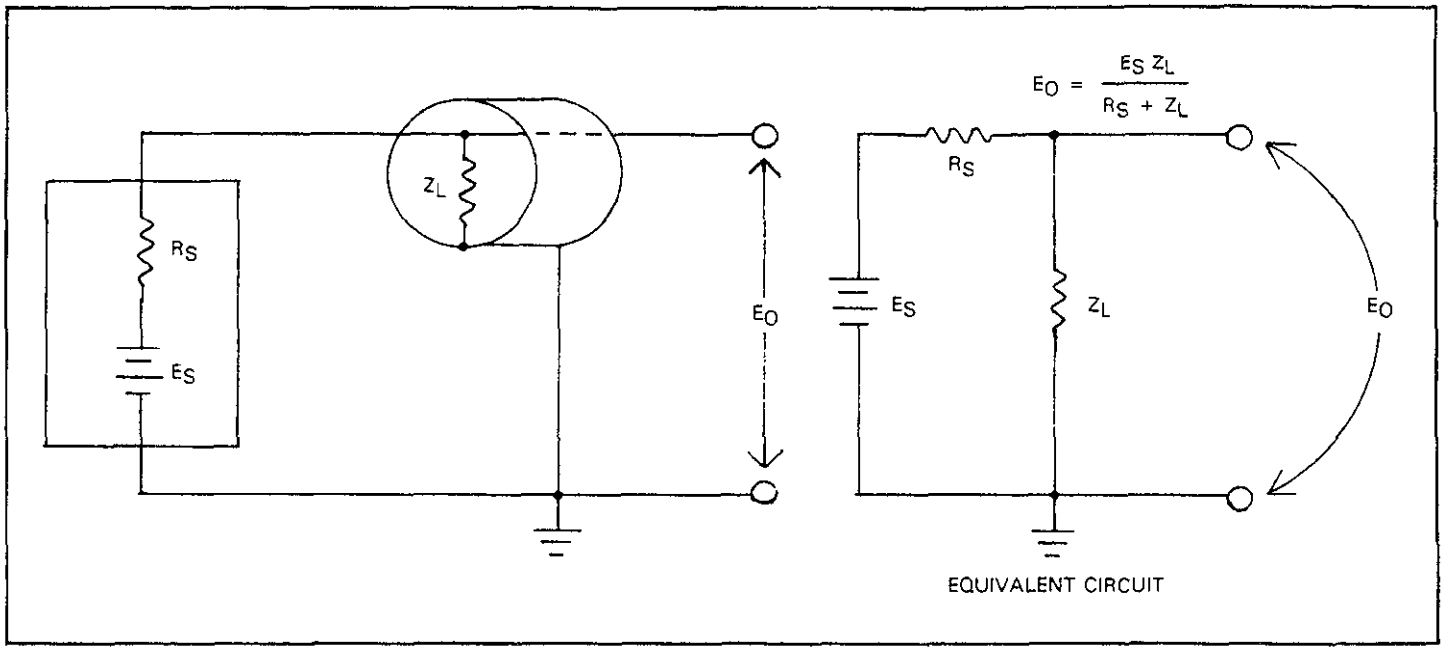


Figure 2-6. Unguarded Circuit

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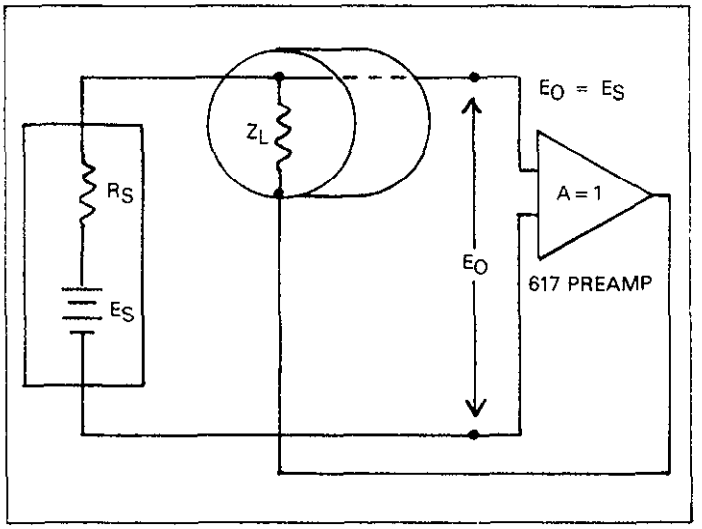


Figure 2-7. Guarded Circuit

When the rear panel V, Ω GUARD switch is placed in the ON position, guard potential is placed on the inner shield of the triaxial cable. The other shield remains at chassis ground. Thus, it is necessary to use the COM terminal for low signal connections, as shown in Figure 2-8. For very critical measurements, a shielded, guarded enclosure should be used.

WARNING

Hazardous voltage (up to 300V) may be present on the inner shield when V, Ω GUARD is on, depending on the input signal. A safety shield, connected to chassis ground is recommended when making voltage measurements over 30V or guarded resistance measurements.

NOTE

The use of guarding is not recommended in amps or coulombs.

The PREAMP OUT terminal may be used for guarding in the volts and ohms modes in a similar manner. In this mode, the preamplifier acts as a unity gain amplifier with low output impedance.

WARNING

Hazardous voltage (up to 300V) may be present at the PREAMP OUT terminal, depending on the input signal.

2.7.5 Making Current Measurements

The Model 617 can resolve currents as low as 0.1 fA (10^{-16}A), and measure as high as 20mA in 11 ranges. The Model 617 exhibits low input voltage burden and extremely low input offset current. The low voltage burden is achieved because the Model 617 measures current as a feedback type picoammeter, rather than the shunt method used by many DMMs.

NOTE

After measuring high voltage in volts, or following an overload condition in ohms, it may take a number of minutes for input current to drop to within specified limits. Input current can be verified by placing the protection cap on the INPUT jack and then connecting a jumper between the COM and chassis ground terminals. With the instrument on the 2pA range and zero check disabled, allow the reading to settle until the instrument is within specifications.

NOTE

Safe operation and good measurement practice dictates the use of an external resistor when necessary to limit currents to less than 30mA.

To measure current with the Model 617, use the following procedure.

1. Turn on the power and allow the instrument to warm up for at least two hours to obtain rated accuracy.
2. Select the current mode by pressing the AMPS button on the front panel. Set V, Ω GUARD to OFF.
3. To achieve rated accuracy, select the 2pA range, zero the instrument by enabling zero check and then pressing the ZERO CORRECT button. Select the desired range, or use autoranging if desired.
4. Connect the Model 6011 or other similar cable to the rear panel INPUT jack. Connect the other end of the circuit to be measured as shown in Figure 2-9. Shielding will be required for low-level measurements. Connect the shield to input low.
5. Disable zero check.
6. Read the current value directly from the display. The exponent may be placed either in the alpha or numeric modes, as described in paragraph 2.5.

Current Measurement Considerations: At very low levels (in the picoampere range), noise currents generated in the cable or from other sources can affect measurements. Currents generated by triboelectric effects are a primary cause of noise currents generated in connecting cables. These currents are generated by charges created at the junction between a conductor and an insulator because of friction. Coaxial and triaxial cables are especially prone to such noise currents, which are generated by cable flexing. To minimize these effects, the cable should be tied down firmly to minimize any flexing. Also, special low-noise cable, constructed with graphite between the shield and insulator, is available to minimize these effects. However, even with low-noise cables, several tens of femtoamps of noise currents can be generated by cable movement.

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Voltage burden is frequently a consideration when making current measurements. Ideally, the input voltage burden should be zero in order for the instrument to have absolutely no effect on the circuit it is measuring. If the voltage burden is too high, its effects can degrade measurement accuracy considerably.

To see how voltage burden can upset measurement accuracy, refer to Figure 2-10. A source, represented by E_S with an output resistance R_S is shown connected to the input of a picoammeter. The voltage burden is represented by a constant voltage source at the input as E_{IN}. If E_{IN} were zero, the current as seen by the meter would simply be:

$$I = \frac{E_S}{R_S}$$

However, if E_{IN} has a non-zero value, the current now becomes:

$$I \doteq \frac{E_S - E_{IN}}{R_S}$$

Additional considerations include source resistance and capacitance, as discussed in paragraph 2.14.

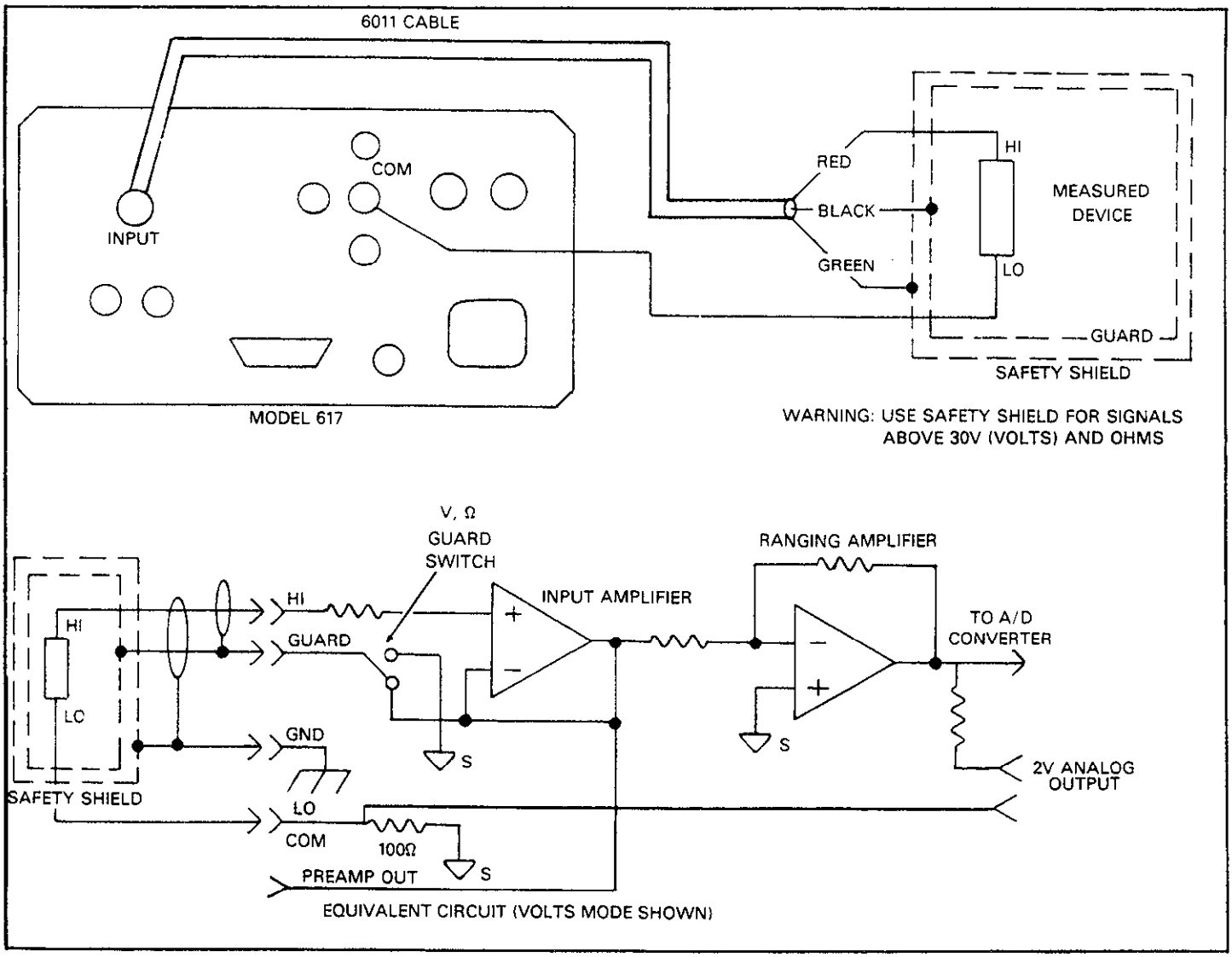


Figure 2-8. Guarded Input Connections

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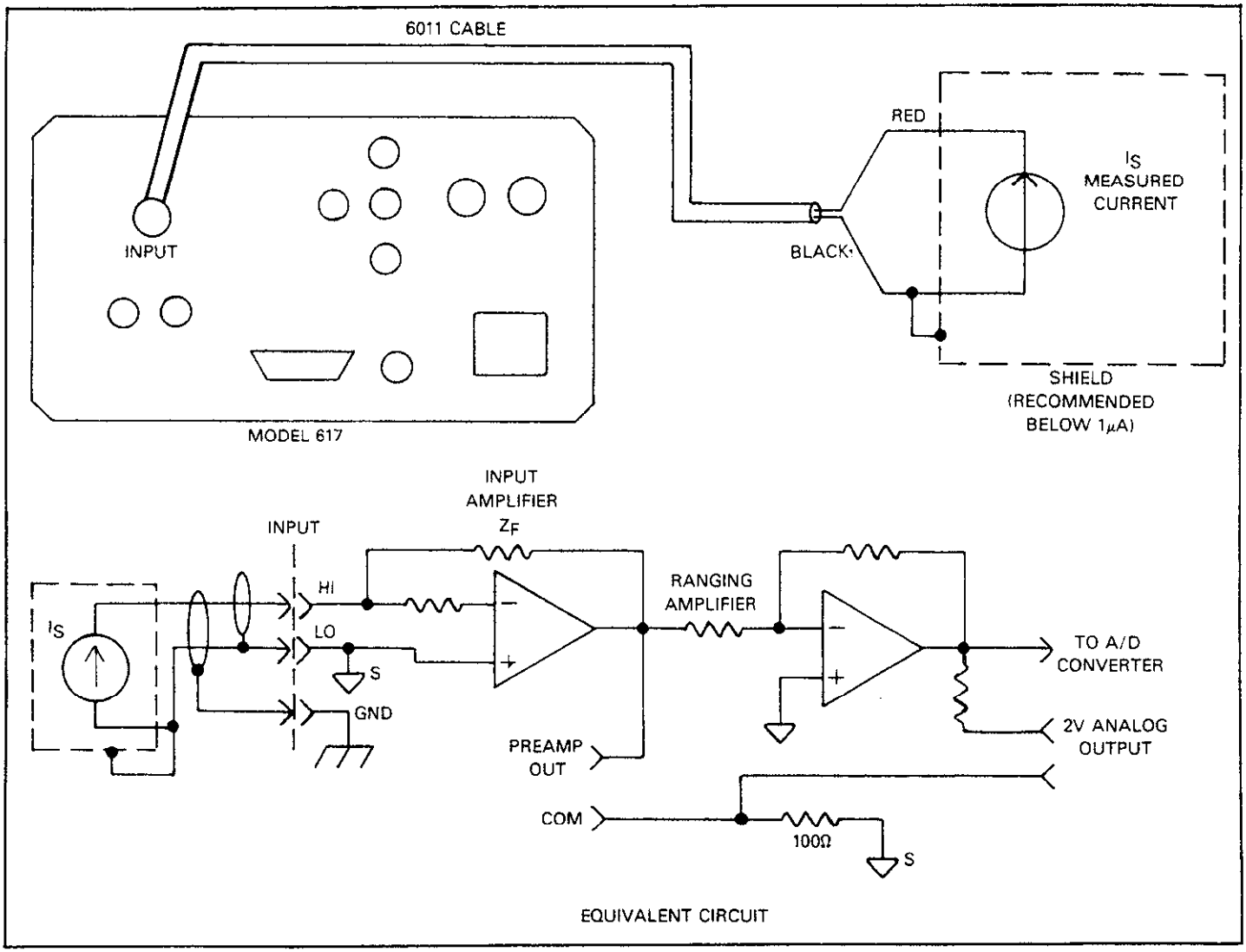


Figure 2-9. Current Measurements

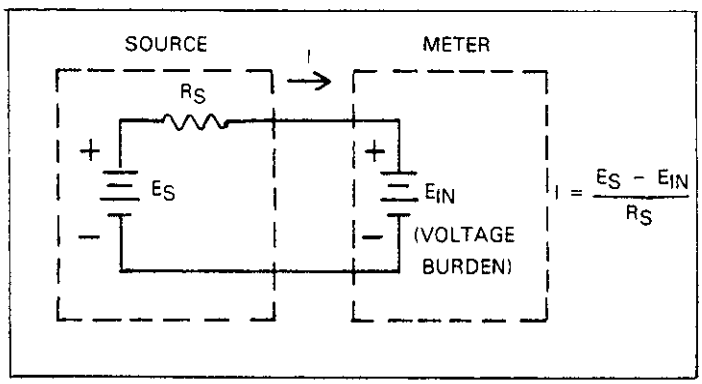


Figure 2-10. Voltage Burden Considerations

2.7.6 Making Charge Measurements

The Model 617 is equipped with three coulombs ranges to resolve charges as low as 10fC (10^{-14}C) and measure as high as 20nC (20×10^{-9}C). When the instrument is placed in one of the coulombs ranges, an accurately known capacitor is placed in the feedback loop of the amplifier so that the voltage developed is proportional to the integral of the input current in accordance with the formula: $V = \frac{1}{C} \int idt$. The voltage is scaled and displayed as charge.

NOTE

After measuring high voltages in volts, or following an overload condition in ohms, it may

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take a number of minutes for the input current to drop within specified limits. Input current can be verified by placing the protection cap on the INPUT jack and then connecting a jumper between the COM and chassis ground terminals. With the instrument on the 2pA range and zero check disabled, allow the reading to settle until the instrument is within specifications.

Use the following procedure to measure charge with the Model 617.

1. Turn on the power and allow a two-hour warm up period for rated accuracy.
2. Place the instrument in the coulombs mode by pressing the COUL button. Set V, Ω GUARD to OFF.
3. To achieve rated accuracy, place the instrument on the 200pC range and zero the instrument by enabling zero check and then pressing the ZERO CORRECT button.
4. Select the desired range, or use autoranging, if desired.
5. Disable zero check. A small amount of zero check hop (sudden change in the reading) may be observed when zero check is disabled. If desired, enable suppress to null out any zero check hop, which typically will be in the 10-25 count range.
6. Connect the Model 6011 cable to the INPUT jack. Connect the other end of the cable to the circuit being measured, as shown in Figure 2-11. For low-level measurements, shielding may be required. Note: Do not connect the circuit to the instrument with zero check enabled.
7. Read the charge value from the display. The exponent may be placed either in the alpha or numeric modes as described in paragraph 2.5.

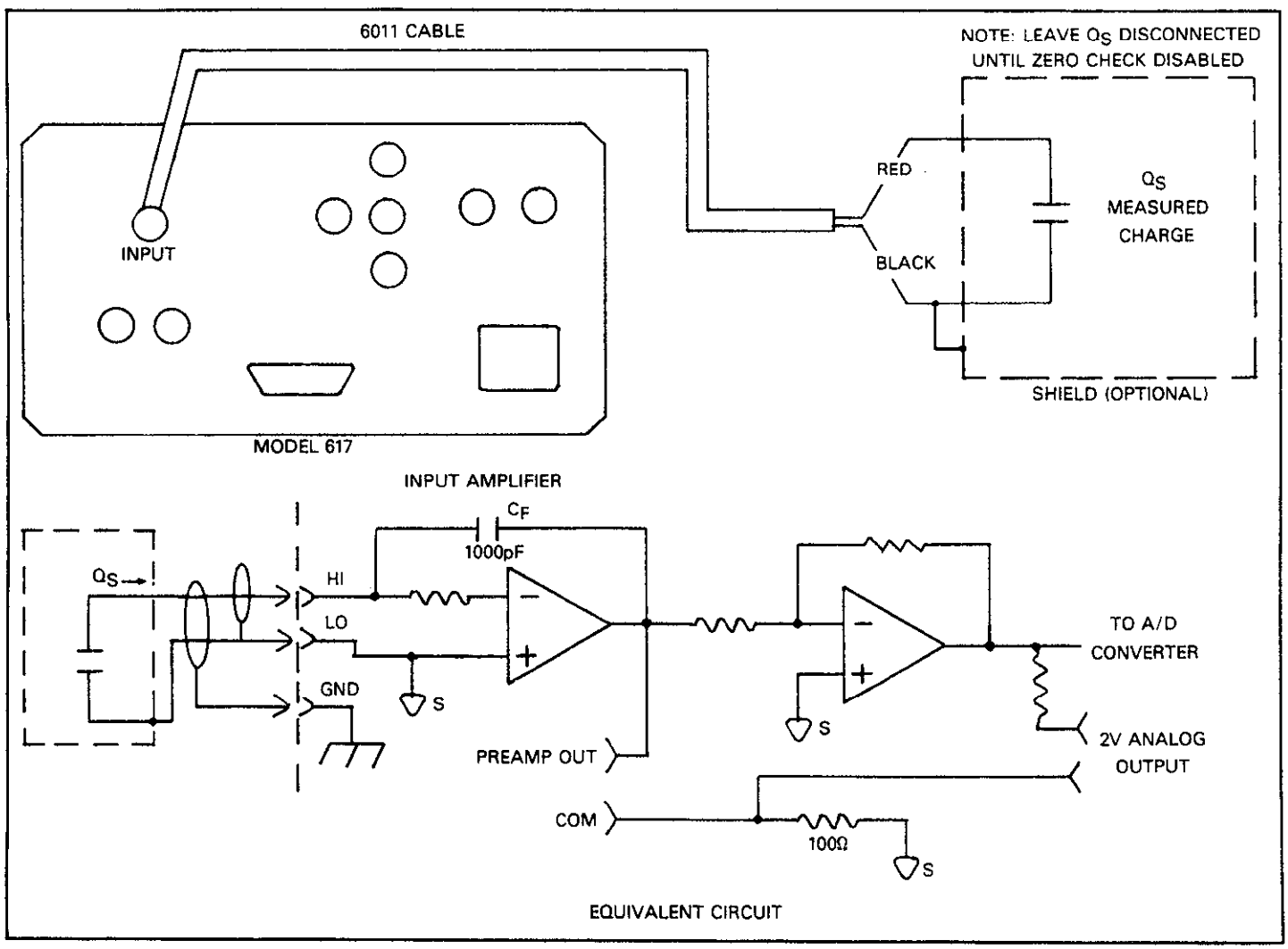


Figure 2-11. Coulombs Connections

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Note that the coulombs function can also be used to measure current. The advantage of doing so is that noise in the measurement is substantially reduced because of the integrating process. To measure current using the coulombs function, proceed as follows:

1. Place the instrument in the coulombs function and select the desired range, or use autoranging, if desired.
2. Enable zero check and connect the current to be measured to the INPUT jack (see Figure 2-9).
3. Disable zero check and note the charge measurement at the end of a specific interval of time (for example, 10 seconds).
4. To determine the current, simply divide the measured charge by the time in seconds. For example, if a charge of 12nC is seen after a 10-second interval, the current is 12nC/10 = 1.2nA. (Using Data Store at a 10 second rate can ease data taking).
5. As an alternative to the above procedure, connect a chart recorder to the 2V ANALOG OUTPUT (paragraph 2.9) and graph the measured charge. Since the current is given by $I = dQ/dt$, the current at any point is equal to the slope of the graph at that point, after applying the appropriate scaling factor (100pC/V, 200pC range; 1nC/V, 2nC range; 10nC/V, 20nC range).

CAUTION
Connecting PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth while floating input may damage the instrument.

Charge Measurement Considerations: A primary consideration when making charge measurements is the input offset current of the integrating amplifier. Any such current is integrated along with the input signal and reflected in the final reading. The Model 617 has a maximum input offset current of 5×10^{-15}A at 23°C. This value doubles every 10°C. This input offset current translates into a charge of 5×10^{-15}C per second at a temperature of 23°C. This value must be subtracted from the final reading to obtain the correct value.

When using an external voltage source, the input current should be limited to less than 1mA by placing a resistor in series with the high input lead. The value of this resistor should be at least: R=1000V (in ohms) where V is the voltage across the capacitor, or the compliance of the current being integrated.

2.7.7 Resistance Measurements

The Model 617 can make resistance measurements using two different methods: the constant current method and the constant voltage method. The constant voltage method, which is discussed in paragraph 2.8, uses the built in voltage source. With the constant current method discussed here, the instrument can resolve resistances as low as 0.1Ω and measure as high as 200GΩ.

To measure resistance with the Model 617, use the following procedure:

1. Turn on the power and allow a two-hour warm-up period for rated accuracy.
2. Press the OHMS button to place the instrument in the correct mode.
3. For maximum accuracy, place the instrument on the 2kΩ range and zero the instrument by enabling zero check and then pressing the ZERO CORRECT button.
4. Select the desired range, or use autoranging, if desired.
5. Connect the Model 6011 or similar cable to the INPUT jack. Keep the cable as short as possible to minimize the effects of cable capacitance. Connect the other end of the cable to the resistance to be measured, as shown in Figure 2-12. For measurements above 1GΩ, it is recommended that you use guarded connections, as described in paragraph 2.7.4.
6. Disable zero check.
7. Take the reading from the display. The exponent may be placed in either the alpha or numeric modes, as described in paragraph 2.5.

Resistance Measurement Considerations: When measuring high resistance values, there are two primary factors that can affect measurement accuracy and speed. Any leakage resistance in the connecting cable or test fixture can decrease the actual resistance seen by the instrument. Also, capacitance of the cable or input circuit can slow down the response time considerably.

These two problems can be minimized by using guarding, especially when measuring resistances above 1GΩ. Guarding is further discussed in paragraph 2.7.4. Noise pickup can also be a problem, in which case the resistor must be shielded. Connect the shield to input low.

At low resistances, lead resistance can be a consideration. Cancel the effects of lead resistance by shorting the input leads and enabling suppress with zero check disabled. Leave suppress enabled for subsequent measurements.

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2.7.8 Using the Ohms Function As A Current Source

The Model 617 ohms function may also be used to generate currents in decade values between 1nA and 100μA. To use the instrument in this manner, simply connect the Model 6011 cable to the INPUT jack and connect the red and black alligator clips to the circuit under test. Select the resistance range in accordance with the desired current (see Table 2-4). Note that current flows from input high through input low. The test voltage is less than 2V for all ranges 2GΩ and less, except when an overload occurs, in which case the compliance is 300V.

Table 2-4. Ohms Function Current Output Values

Ranges	Output Current (±1.5%)
2kΩ, 20kΩ	100μA
200 kΩ	10μA
2MΩ	1μA
20MΩ	100nA
200MΩ	10nA
2GΩ, 20GΩ, 200GΩ	1nA

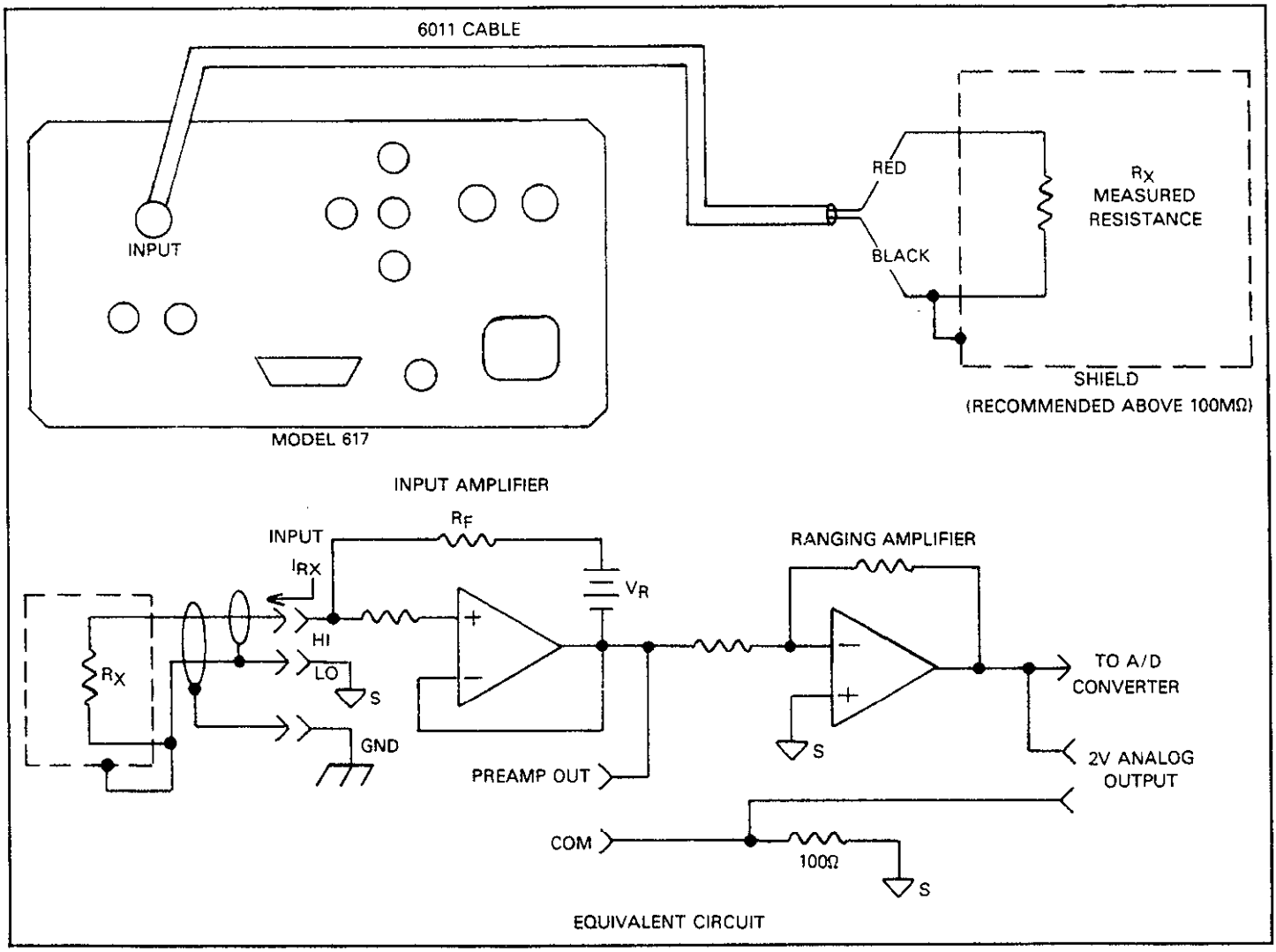


Figure 2-12. Resistance Measurement Connections

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2.8 USING THE VOLTAGE SOURCE

The Model 617 has a built-in voltage source that can be used to make V/I resistance measurements. The voltage source can be adjusted between −102.35V and +102.4V in 50mV increments, and has a maximum output current of 2mA. The following paragraphs describe the basic procedure for using the voltage source as well as the method for making V/I resistance measurements.

2.8.1 Basic Operating Procedure

Use the following procedure for connecting the voltage source and adjusting its output value:

1. Connect the circuit under test to the V-SOURCE OUTPUT HI and LO binding posts, as shown in Figure 2-13. R_L represents the resistive load of the circuit under test. Note that R_L has a minimum value of 50kΩ at an output voltage of 100V. This value is based on the 2mA current limit of the voltage source.

WARNING
The maximum common-mode voltage (voltage between SOURCE LO and chassis ground) is ±100V. Exceeding this value may create a shock hazard.

2. Press the DISPLAY button to observe the voltage source value.
3. Press either of the V-SOURCE ADJUST buttons repeatedly to increment or decrement the source in 50mV increments, as required. The value may be scrolled simply by holding the button in. The scrolling rate can be increased by pressing SHIFT before pressing the appropriate ADJUST button. The actual maximum and minimum values are +102.4V and −102.35V.
4. Press OPERATE to turn the source output on. The LED adjacent to this button will illuminate when the output is turned on. The OPERATE LED will flash if the 2mA current limit is exceeded.

WARNING
Dangerous voltage may be present on the source terminals when the output is enabled.

5. To turn the source output off, simply press the OPERATE button a second time. The source output will then be programmed to 00.00V.

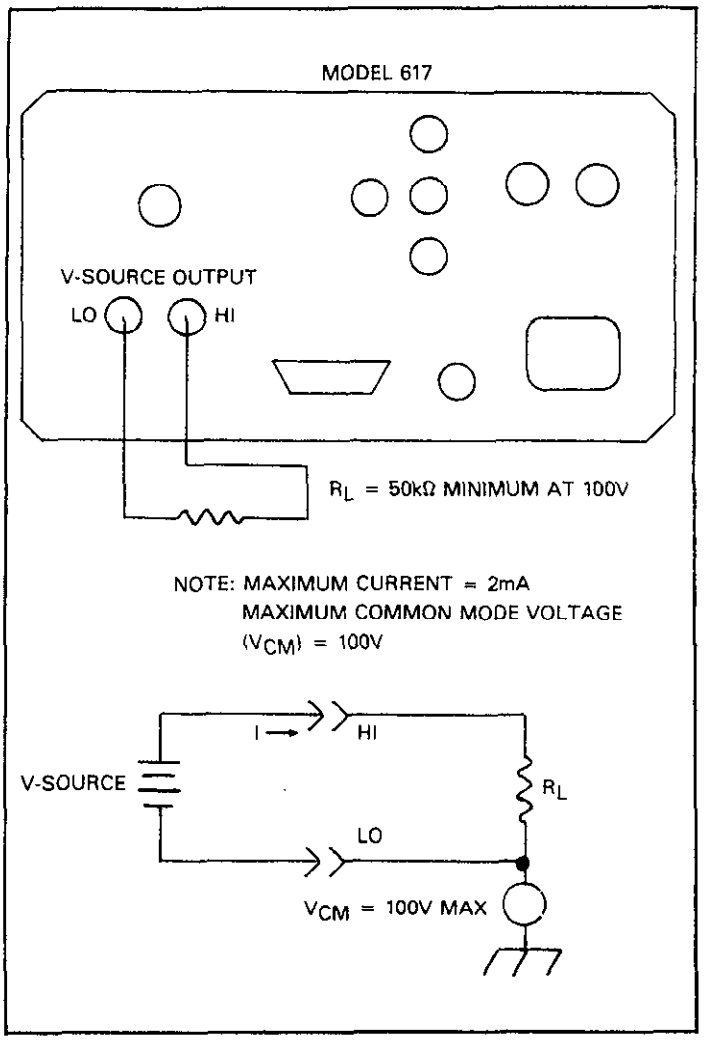


Figure 2-13. Voltage Source Connections

2.8.2 V/I Resistance Measurements

The voltage source can be used in conjunction with the electrometer section of the Model 617 to measure resistances as high as $10^{16}\Omega$. In this mode, the measured resistance is automatically calculated from the applied voltage and the measured current in accordance with the familiar formula: R = V/I. In V/I ohms a flashing AMPS LED indicates a current overload. Display resolution depends on the selected current range. The suppress function acts on the displayed value. If suppress is enabled in the amps function the displayed current is suppressed. If suppress is enabled in the V/I function the displayed resistance is suppressed. To make V/I measurements while suppressing current, enable the suppress mode while in amps and then enable the V/I mode. In this case the SUPPRESS LED remains ON and the displayed resistance is calculated from the suppressed current. If the suppress mode is enabled while in the V/I mode and AMPS is pressed, suppress is cancelled but is reapplied when the V/I mode is reentered.

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Use the following procedure to measure resistance with this mode:

1. Turn on the instrument and allow it to warm up for one hour to obtain rated accuracy.
2. Place the instrument in the amps mode by pressing AMPS.
3. For maximum accuracy, select the 2pA range and zero correct the instrument by enabling zero check and then zero correct in that order.
4. Select the desired range or use autoranging, if desired.
5. Connect the voltage source and INPUT jack to the measured resistance, as shown in Figure 2-14. Use the Model 6011 or other similar triaxial cable to make the input connections.
6. Turn on the source output by pressing the OPERATE button.
7. Press the DISPLAY button to return the display to the meter mode.
8. Disable zero check. The meter will now display the current being sourced through the resistor under test by the voltage source. To measure from a baseline current, such as fixture leakage, enable suppress while in amps.
9. To display the resistance being measured, press SHIFT and then OHMS in that order. The V/I light will turn on indicating that the V/I ohms mode is enabled. If a displayed resistance overload occurs, the usual "OL" display message will be indicated; however, if the input current exceeds the maximum input value for the selected amps range, the AMPS LED will flash, as previously indicated. Note that the display can be placed in either the alpha or numeric exponent mode as discussed in paragraph 2.5.
10. To measure from a baseline resistance enable suppress while in V/I.

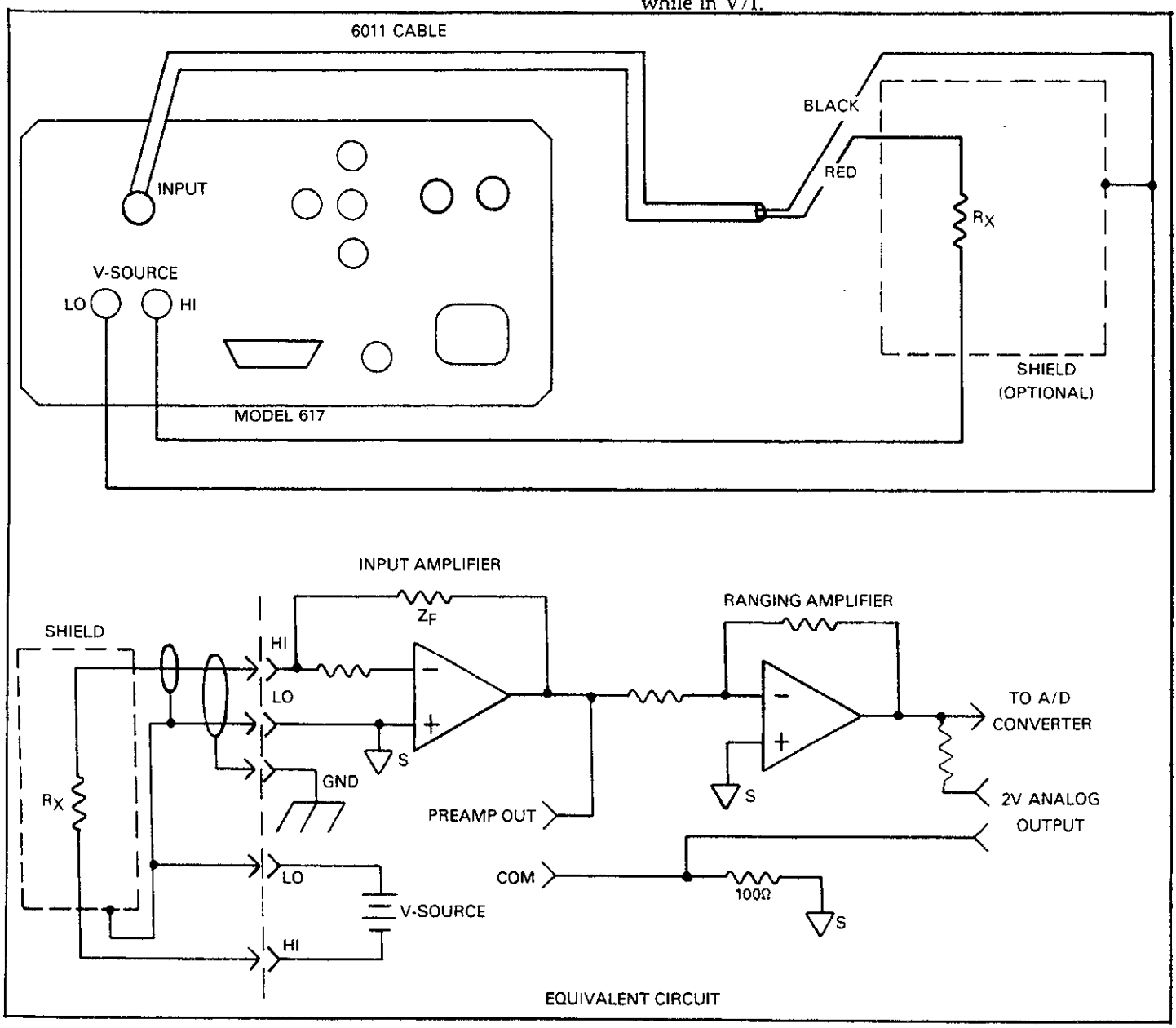


Figure 2-14. V/I Resistance Measurement Connections

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V/I Resistance Measurement Considerations: The main advantage of using the constant voltage method for resistance measurements is that the effects of leakage resistance and distributed capacitance are minimized. Because of these factors, the resistance range of the instrument can be greatly increased, in the case of the Model 617, to $10^{16}\Omega$. However, there are certain characteristics pertaining to high resistance measurements that require discussion.

A primary consideration when using this mode is to match the voltage and current ranges to optimize accuracy. In most cases, it is best use the maximum voltage value possible (except as indicated below) and set the current range accordingly. As with other Model 617 measurements, the instrument should be placed on the most sensitive range possible without overranging the electrometer section. Doing so will optimize the measurement for resolution and accuracy. Autoranging can facilitate range selection.

At very high resistance values, the corresponding current, as seen by the instrument, will be extremely low. Thus, any current generated by the triaxial input cable will be reflected in the final measurement. To minimize such problems, use low-noise graphite triaxial cable, (such as the Model 6011). Tie down the cable to avoid any triboelectric currents that might be generated by cabling flexing. In many situations, shielding of the circuit under test will also be required to minimize noise pickup.

Although V/I resistance measurements are much less susceptible to the effects of leakage resistance than resistance measurements made with the constant current method, there are some cases where leakage resistance could affect V/I resistance measurements. For example, test fixture leakage paths may appear in parallel with the device being measured, introducing errors in the measurement. As with other Model 617 high impedance measurements, these errors can be minimized by using proper insulating material (such as Teflon) in fixture terminal connections.

Any leakage current through cables and test fixtures can be minimized if care is taken. To cancel these effects, set up the measurement exactly as desired, but leave the resistor under test disconnected. Program the voltage source to the desired value and turn on its output. With the instrument in the amps mode, enable suppress to null the leakage current. Turn off the source, connect the resistor, and re-enable the voltage source. Place the instrument in the V/I ohms mode and proceed with the measurement.

High megohm resistors are somewhat curious devices, often exhibiting characteristics somewhere between those of an insulator and a normal resistor. Because of these unique traits, the measured value of such a resistor will often vary with applied voltage.

Such variation in resistance is known as the voltage coefficient. The Model 617 can be used to characterize such resistance changes by measuring the resistance with a number of different applied voltages. Once the variations are known, the voltage coefficient of the resistor being tested can be calculated. The method for determining the voltage coefficient of these resistors is discussed in Section 4.

2.9 ANALOG OUTPUTS

The Model 617 has two analog outputs on the rear panel. The 2V ANALOG OUTPUT provides a scaled 0-2V output with a value of 2V corresponding to full range input. The PREAMP OUT is especially useful in situations requiring buffering. These two analog outputs are discussed the the following paragraphs.

WARNING

When floating Input Low above 30V from earth ground, hazardous voltage will be present at the analog outputs. Hazardous voltage may also be present when measuring in ohms, or when the input voltage exceeds 30V in the volts mode.

CAUTION

Connecting PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth while floating input may damage the instrument.

2.9.1 2V Analog Output

The 2V ANALOG OUTPUT provides a scaled 0-2V output that is inverting in the volts and ohms modes. Connections for using this output are shown in Figure 2-15. For a full range input, the output will be 2V; typical examples are listed in Table 2-5. The 2V ANALOG OUTPUT is not corrected during calibration. Gain errors of up to 3% may appear at this output, depending on function and range selection.

Note that the output impedance is $10k\Omega$; to minimize the effects of loading, the input impedance of the device connected to the 2V ANALOG OUTPUT should be as high as possible. For example, with a device with an input impedance of $10M\Omega$, the error due to loading will be approximately 0.1%.

2.9.2 Preamp Out

The PREAMP OUT of the Model 617 follows the signal amplitude applied to the INPUT terminal. Some possible uses for the preamp output include buffering of the input signal, as

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well as for guarding in the volts and ohms modes. Connections and equivalent circuits for the preamp output are shown in Figure 2-16. Full range outputs for various functions and ranges are listed in Table 2-6. The PREAMP OUTPUT is not corrected during calibration. Gain errors of up to 3% may appear at this output, depending on function and range selection. For all volts ranges, PREAMP OUTPUT accuracy is typically 5ppm.

Table 2-5. Typical 2V Analog Output Values

Range	Applied Signal	2V Analog Output Value
20 pA	10.4 pA	1.04V
2 μA	1.65μA	1.65V
200mV	140mV	1.4 V
200 V	35 V	0.35V
200 kΩ	175 kΩ	1.75V
20GΩ	9.5GΩ	0.95V
200 pC	125 pC	1.25V
20 nC	19 nC	1.9 V

Table 2-6. Full Range PREAMP OUT Values

Function	Range	Full Range Value
Volts	200mV	200mV
	2 V	2 V
	20 V	20 V
	200 V	200 V
Amps	2pA, 2nA, 2μA, 2mA,	200mV
	20pA, 20nA, 20μA, 20mA	2 V
	200pA, 200nA, 200μA	20 V
Ohms*	2 kΩ	200mV
	20kΩ-2GΩ	2 V
	20GΩ	20 V
	200GΩ	200 V
Coulombs	200pC	200mV
	2nC	2 V
	20nC	20 V

*WARNING: Open circuit voltage of 300V present at PREAMP OUT in Ohms.

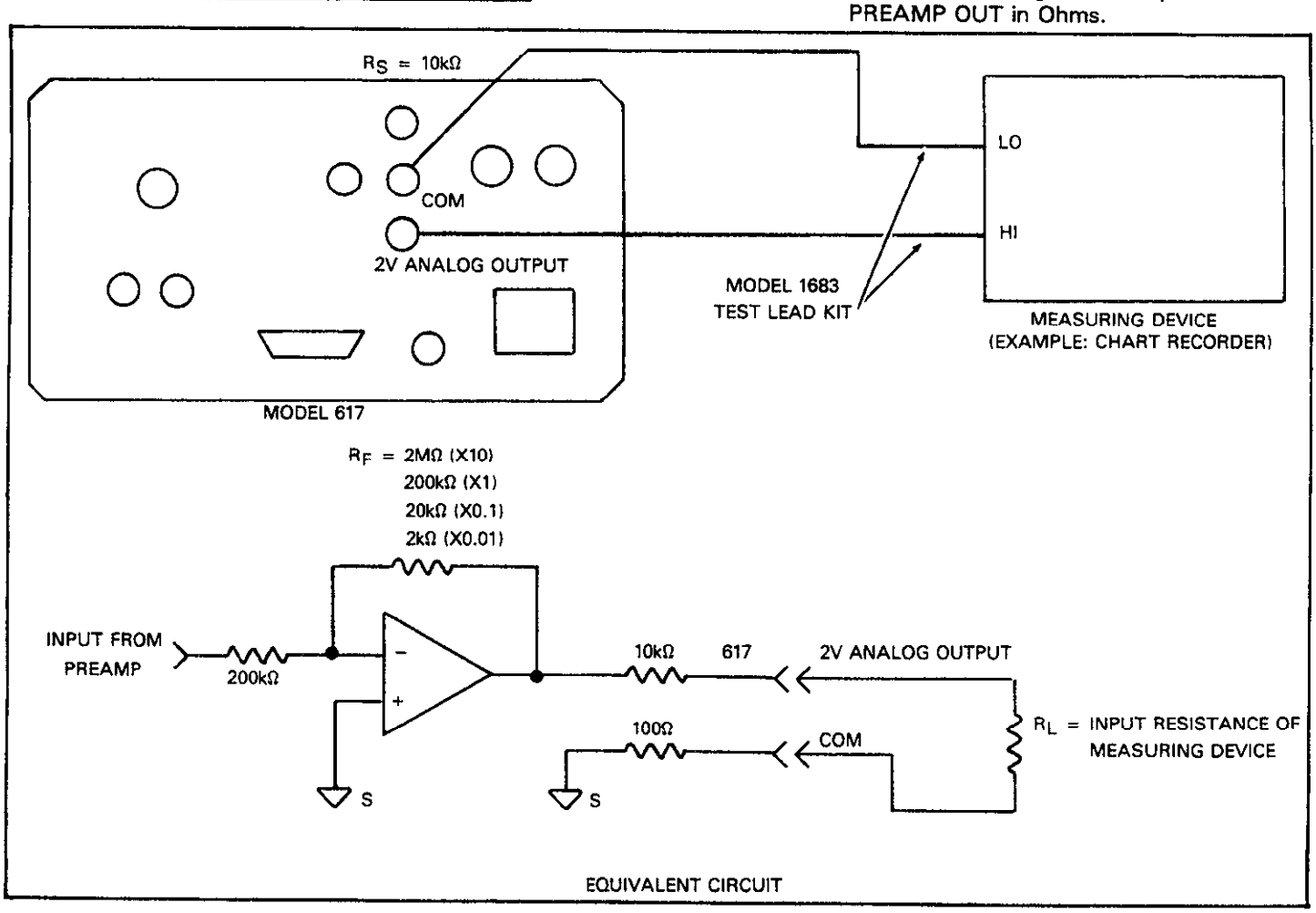


Figure 2-15. Typical 2V Analog Output Connections

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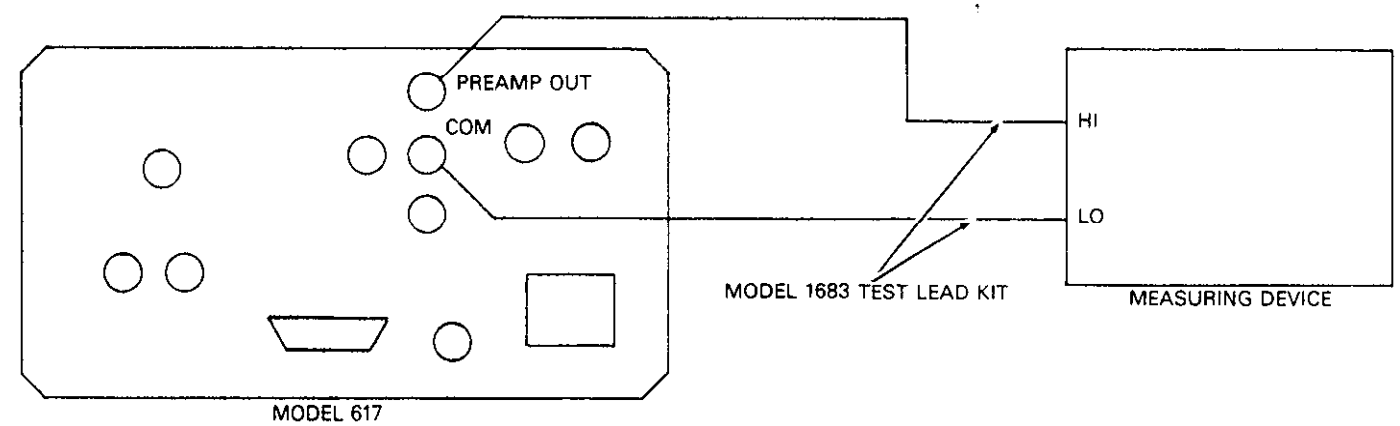
WARNING

High voltage may be present between the PREAMP OUT and COM terminals depending on the input signal (see Table 2-6).

CAUTION

Connecting PREAMP OUT, COM, or 2V ANALOG OUTPUT to earth while floating input may damage the instrument.

Note that the output resistance is 100Ω. The output resistance appears between Input Low and Analog Output Low to keep the resistor out of the loop when using external feedback elements. To keep loading errors under 0.1%, the device connected to the PREAMP OUT should have a minimum input impedance of 100kΩ.



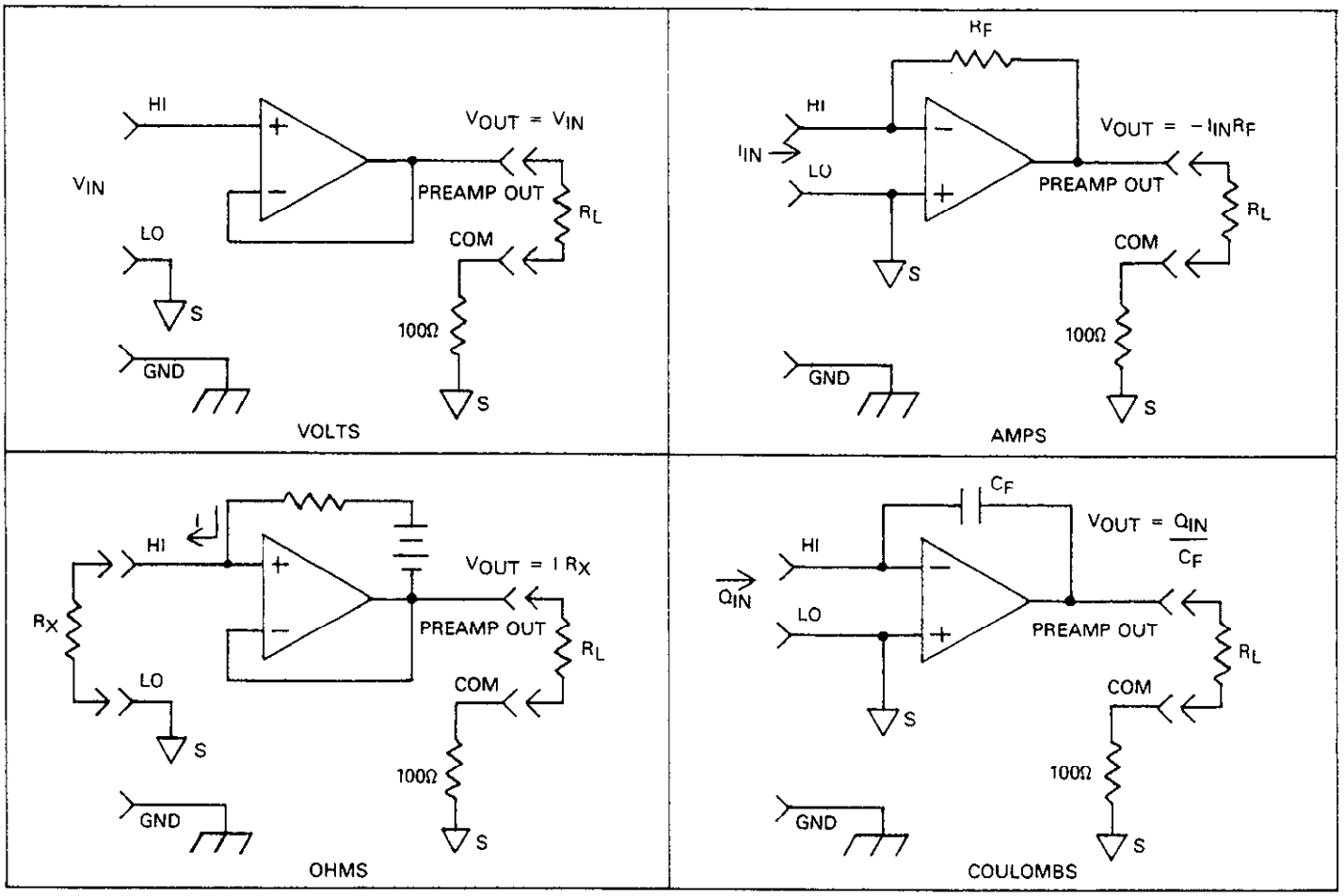


Figure 2-16. Typical Preamp Out Connections

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2.10 USING EXTERNAL FEEDBACK

External feedback provides a means to extend the capabilities of the Model 617 Electrometer to such uses as logarithmic currents, non-decade current ranges, as well as non-standard coulombs ranges. The following paragraphs discuss the basic electrometer input circuitry and methods to implement these functions.

2.10.1 Electrometer Input Circuitry

A simplified diagram of the electrometer input in the amps mode is shown in Figure 2-17. An input current applied to the inverting (−) input of the op amp is nulled by a current fed back through the internal feedback network made up of R_{FB} and C_{FB}. Because the output of the op amp appears at the PREAMP OUT, this internal network can be replaced by an external network connected between the preamp output and Input HI connections. When using external feedback, the following factors must be taken into account:

1. The maximum current value that can be supplied by the preamp output is 20mA in amps (1mA in V/Ω).
2. The input impedance in the external feedback mode is given by the relationship $Z_{IN} = Z_{FB}/A_V$, where Z_{FB} is the impedance of the external feedback network, and A_V is the open-loop gain of the electrometer (typically greater than 10^6). Note that the input impedance is $Z_{IN} = 10M\Omega \parallel Z_{FB}$ when zero check is enabled.
3. The voltage at the PREAMP OUT terminal is given by the formula:
   $V = -IR_{FB}$, where R_{FB} is the value of the feedback resistance.
4. Any feedback elements should be housed in a suitable shielded enclosure. Insulators connected to Input HI should be made of Teflon or other high quality insulating material and should be thoroughly cleaned to maintain the high input impedance and low input current of the Model 617. If these insulators become contaminated, they can be scrubbed with methanol and then dried with clean, pressurized air.

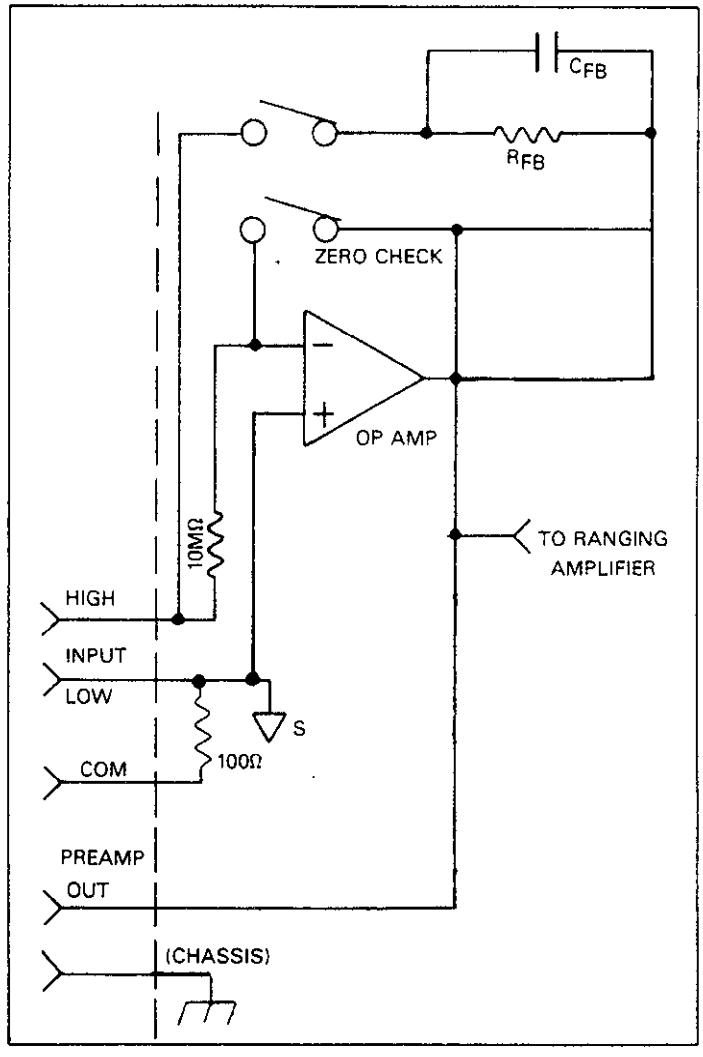
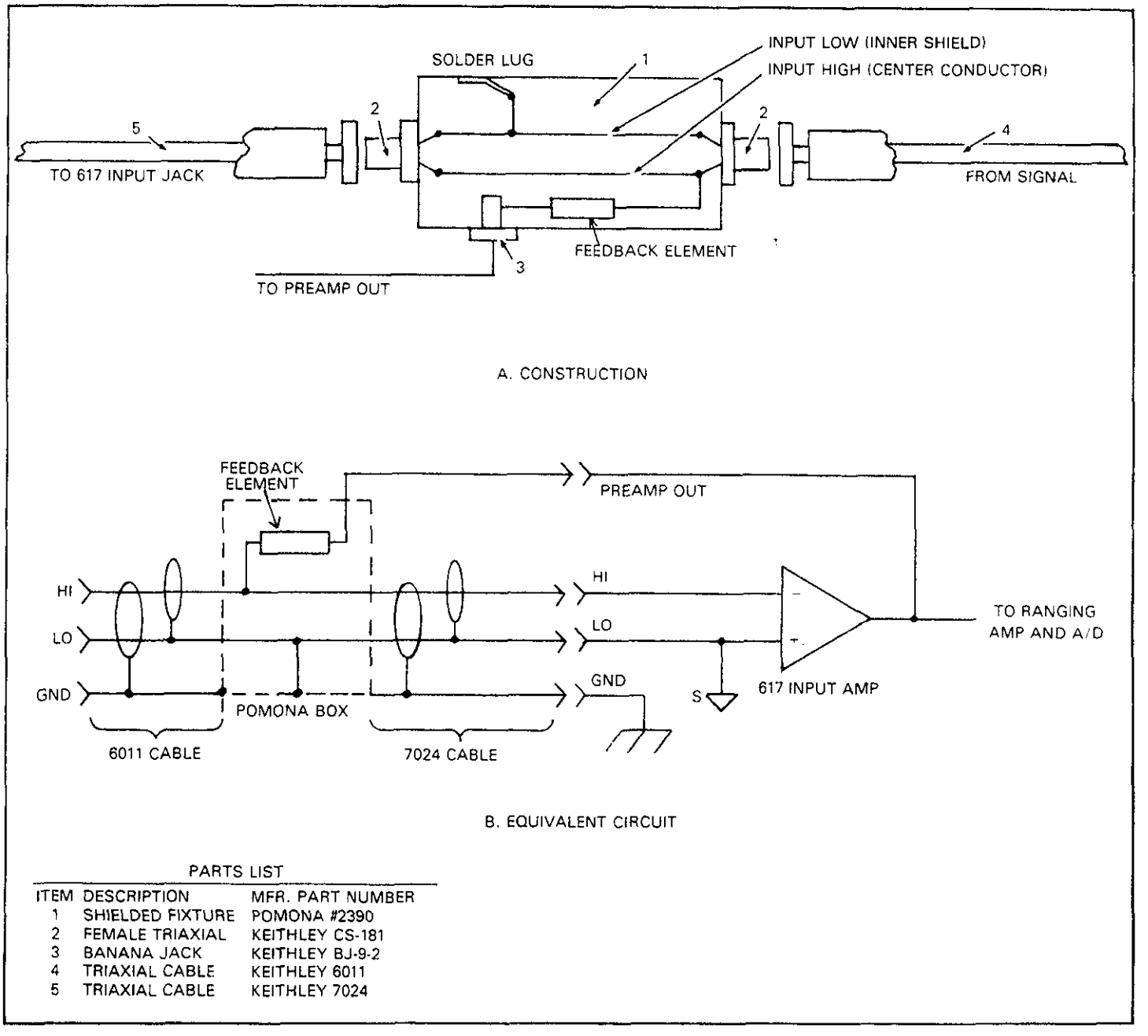


Figure 2-17. Electrometer Input Circuitry (Amps Mode)

2.10.2 Shielded Fixture Construction

Since shielding is so critical for proper operation of external feedback, it is recommended that the shielded fixture shown in Figure 2-18 be used to house the feedback element. The fixture is constructed of a Pomona #2390 shielded fixture modified with the standard BNC connectors replaced with triaxial female connectors. For convenience, a banana jack can be mounted on the box to make the necessary PREAMP OUT connection. Alternately, a wire could be run through a rubber grommet mounted in a hole in the side of the box. Note that input low is connected to chassis ground within the shielded box. This connection can be made by using a small solder lug secured with a screw.

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PARTS LIST

ITEM	DESCRIPTION	MFR. PART NUMBER
1	SHIELDED FIXTURE	POMONA #2390
2	FEMALE TRIAXIAL	KEITHLEY CS-181
3	BANANA JACK	KEITHLEY BJ-9-2
4	TRIAXIAL CABLE	KEITHLEY 6011
5	TRIAXIAL CABLE	KEITHLEY 7024

Figure 2-18. Shielded Fixture Construction

2.10.3 External Feedback Procedure

Use the following procedure to operate the Model 617 in the external feedback mode.

1. Connect the feedback element between the PREAMP OUT terminal and the Input High terminal.
2. Place the instrument in the external feedback mode by pressing the SHIFT then VOLTS buttons in that order. The AMPS and VOLTS indicators will illuminate simultaneously in the external feedback mode.
3. The display will show the voltage measured at the output of the input preamplifier (PREAMP OUT). However, the "V" exponent will not appear as in the volts mode. For example, with a 150mV output the display will show:

   150.00 m

4. External feedback may be temporarily digitally calibrated as outlined in paragraph 7.4.16.
5. The external feedback mode may be cancelled by pressing one of the four functions keys (VOLTS, OHMS, COUL, or AMPS), or by pressing SHIFT OHMS to enter V/I OHMS.

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2.10.4 Non-standard Coulombs Ranges

In its standard form, the Model 617 has three coulombs ranges allowing it to measure charge between 10fC and 20nC. Different charge measurement ranges can be used by placing an external feedback capacitor between the PREAMP OUT and Input HI and then placing the instrument in the external feedback mode.

Charge is related to capacitance and voltage by the formula: $Q = CV$, where Q is the charge, C is the capacitance, and V is the voltage. The Model 617 display will read charge directly in units determined by the value of C. For example, a 1μF capacitor will result in a displayed reading of 1μC/V.

In practice, the feedback capacitor should be greater than 100pF for feedback stability and of suitable dielectric material to ensure low leakage and low dielectric absorption. Polystyrene, polypropylene and Teflon dielectric capacitors are examples of capacitor types with these desirable characteristics. The capacitor should be mounted in a shielded fixture like the one in Figure 2-18.

To discharge the external feedback capacitor, enable zero check. The discharge time constant will be given by: $\tau = (10M\Omega)\ (C_{FB})$.

2.10.5 Logarithmic Currents

The use of a diode junction in the external feedback path permits a logarithmic current-to-voltage conversion. This relationship for a junction diode is given by the equation:

$$V = mkT/q\ \ln(I/I_o) + IR_B$$

where q = unit charge (1.6022×10^{-19}), k = Boltzmann's constant (1.3806×10^{-23}), and T = temperature (°K).

The limitations in this equation center on the factors I_o, m and R_B. I_o is the extrapolated current for V_o. An empirical proportional constant, m, accounts for the different character current conduction (recombination and diffusion mechanisms) within the junction, typically varying between 1 and 2. Finally, R_B constitutes the ohmic bulk resistance of the diode junction material. I_o and R_B limit the usefulness of the junction diode at low and high currents, respectively. The factor m introduces non-linearities between those two extremes. Because of these limitations, most diodes have a limited range of logarithmic behavior.

A solution to these constraints is to use a transistor configured as a "transdiode" in the feedback path, as shown in Figure 2-19. Analyzing the transistor in this configuration leads to the relationship:

$$V = kT/q[\ln I/I_0 - \ln(h_{FE}/(1 + h_{FE}))]$$

where h_{FE} is the current gain of the transistor.

From this equation, proper selection of Q_1 would require a device with high current gain (h_{FE}), which is maintained over a wide range of emitter currents. Suitable devices for this application include Analog Devices AD812 and Precision Monolithics MAT-01. Use the enclosure in Figure 2-18 to shield the device.

Frequency compensation/stabilization is accomplished by adding a feedback capacitor, C_{FB}. The value of this capacitor depends on the particular transistor being used and the maximum current level expected. Compensation at maximum current is required because the dynamic impedance will be minimum at this point. It should be noted that the response speed at lower currents will be compromised due to the increasing dynamic impedance, which is given by the following formula:

$$Z = \frac{dV}{dI} = KT/qI = 0.026/I\ (@\ 25°C)$$

Using the above transistors, a minimum RC time constant of 100μsec at maximum input current would be used. At I_{IN} (max) of 100μA, this value would correspond to 0.4μF. Note that at 100nA, this value would increase the RC response time constant to 100msec. A minimum capacitance of 100pF is recommended.

Although the input signal to this particular circuit is assumed to be a current, conversion to voltage input could be performed by placing a shunt resistor across the input. However, the nominal voltage burden of 1mV must be considered as an error signal that must be taken into account.

Further processing of the current response can be achieved by using suppress. For example, suppress could be enabled with a reference input current applied. For all subsequent currents, the natural logarithm of the ratio of the measured current to the suppressed current would then be displayed:

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$$V_{DISP} = V_{READ} - V_{SUPPRESS}\ kT/q\ (\ln I_{READ}/I_o - \ln I_{SUPPRESS}/I_o)$$

$$= kT/q\left(\ln\left(\frac{I_{READ}}{I_{SUPPRESS}}\right)\right)$$

$$= 0.026/I\left(\ln\left(\frac{I_{READ}}{I_{SUPPRESS}}\right)\right) @ 25°C$$

NOTE

The circuit topology of Figure 2-19 works for positive input currents only. For bipolar input signals, an external offset bias must be applied or use a PNP at QL.

2.10.6 Non-Decade Current Gains

The Model 617 electrometer input uses internal decade resistance feedback networks for the current ranges. In some applications, non-decade current gains may be desirable. As shown in Figure 2-20, an external feedback resistor, R_{FB}, can be used to serve this purpose. Limitations on the magnitude of the feedback current require that the value of R_{FB} be greater than 10kΩ.

Note that external feedback can be temporarily calibrated ±12% using the calibration program with the calibration jumper in the disable position. See Section 7.

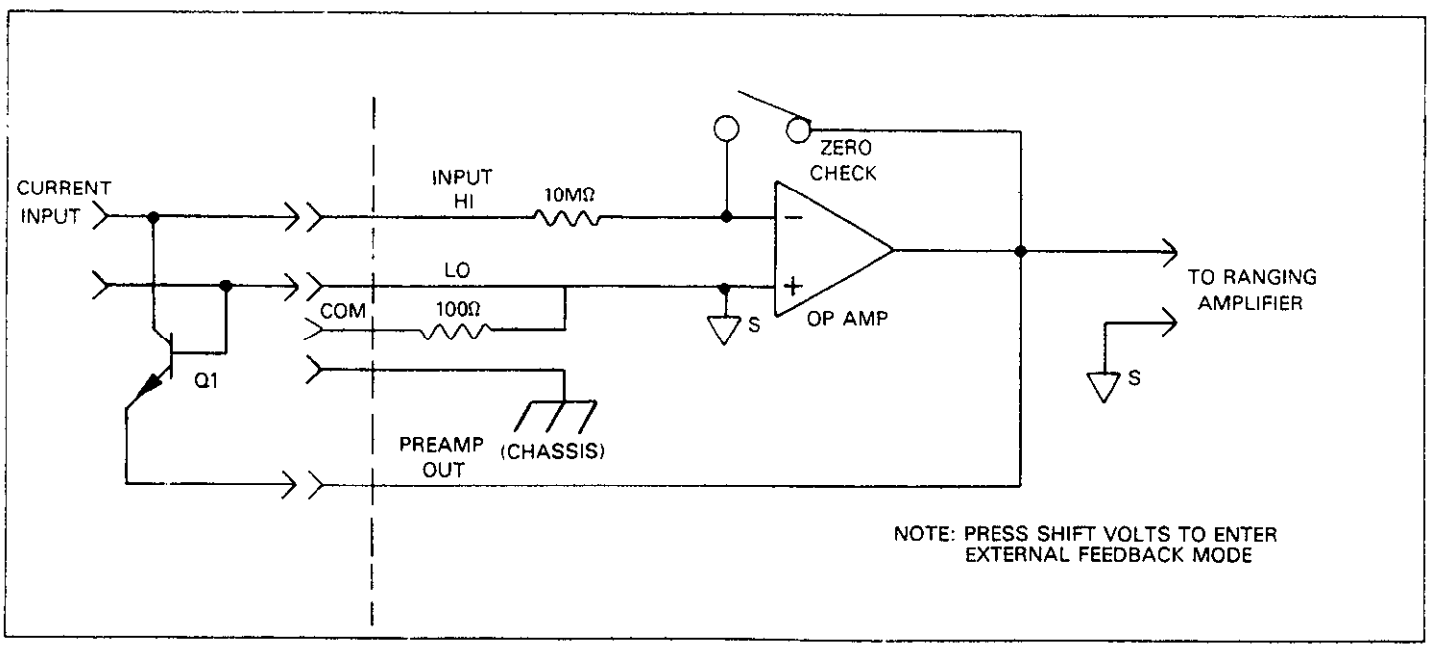


Figure 2-19. "Transdiode" Logarithmic Current Configuration

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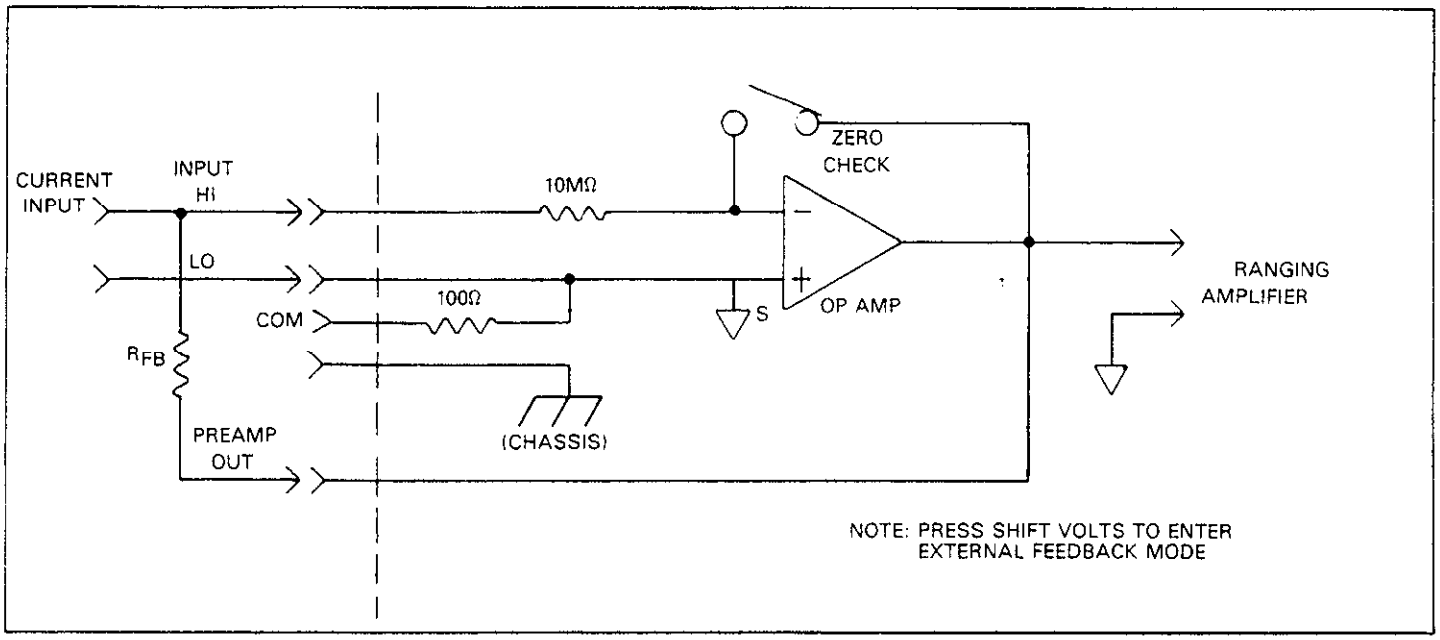


Figure 2-20. Non-Decade Current Gains

2.11 USING ZERO CORRECT AND BASELINE SUPPRESSION

The Model 617 has zero correction and baseline suppression modes that allow the cancellation of any internal offsets, or the storage of a baseline value that can be subtracted from subsequent readings.

2.11.1 Zero Correct and Zero Check

The ZERO CORRECT and ZERO CHECK buttons work together to cancel any internal offsets that might upset accuracy. Note that the specifications listed for the instrument at the front of this manual assume that the instrument has been zeroed. Use the following procedure to zero the instrument. Note that the zero should be corrected on the range to be used, or on the lowest range of the function being used.

1. With the zero correct mode off, press the ZERO CHECK button. Be sure ZERO CHECK light is on. In this mode, the input signal is disconnected from the input amplifier and the input circuit is configured as shown in Figure 2-21. The internal preamplifier is configured to measure its own offset when zero check is enabled.
2. Press the ZERO CORRECT button to zero the instrument. Note that if zero check is not enabled, the zeroing process will not take place. The previously stored zero parameter will be used instead.
3. To take readings, press ZERO CHECK to disable the zero check mode.
4. Readings can now be taken in the normal manner. Note that the instrument will remain zeroed even if the instrument is upranged.
5. For maximum accuracy, the zero correction process should be repeated every 24 hours when the ambient temperature changes by more than 1°C, or when the function is changed.

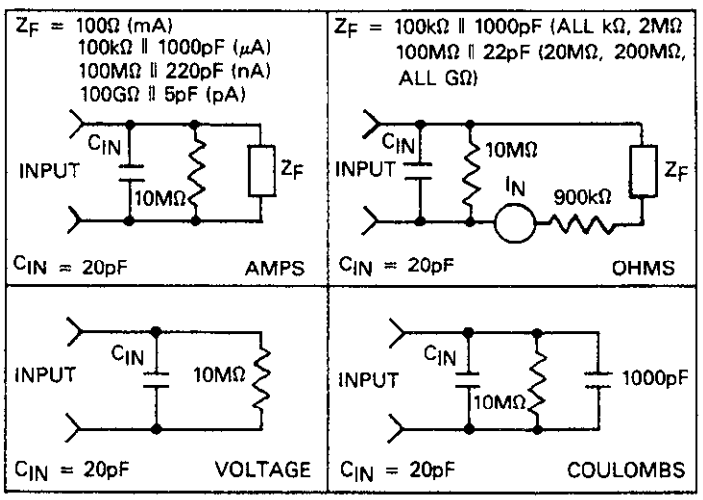


Figure 2-21. Equivalent Input Impedance with Zero Check Enabled

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NOTES:

1. Leave zero check enabled when connecting or disconnecting input signals, or when changing functions.
2. In V/I ohms, the display will go blank if zero check is enabled.
3. Zero will automatically be scaled when the instrument is moved uprange.
4. Do not move the instrument down range after zero-correcting the instrument. Re-zero the instrument after moving downrange.

2.11.2 Using Suppression

The suppression mode allows a stored offset value to be subtracted from subsequent readings. When the SUPPRESS button is pressed, the instrument will trigger a conversion and internally store the displayed value as a baseline. The SUPPRESS LED will illuminate. All subsequent readings will be the difference between the suppressed value and the actual signal level.

The baseline maintains its absolute value regardless of range. For example, if a 1V signal is suppressed on the 2V range, it will remain at 1V on the 20V and 200V ranges. Only one reading for the presently selected function can be supressed; the value will be lost if the function is changed except when in the V/I ohms mode. The instrument can be toggled between V/I ohms and amps without loosing the stored value.

The suppressed readings can be as small as the resolution of the instrument will allow, or as large as full range. Some typical examples include:

Suppressed Reading	Applied Signal	Displayed Value
+10.500 V	+18.600 V	+8.100 V
+2.556 nA	+1.8000 nA	−0.7560 nA
−12.600mA	+4.500mA	+17.100mA

To use suppression, perform the following steps:

1. Cancel suppress if presently enabled.
2. Select a range and function that is consistent with the anticipated mesurement. If current is to be suppressed in V/I ohms, select amps first.
3. Connect the signal to be supressed to the instrument input.

WARNING

The voltage on the input terminals may be larger than the displayed value. For example, if a 150VDC baseline is stored, an applied voltage of +175V will result in a displayed value of only +25V.

4. Press the SUPPRESS button. The triggered reading will be stored at that point. (If suppressing current in V/I ohms, press SHIFT OHMS).
5. Disconnect the supressed signal from the input and connect the signal to be measured in its place. Subsequent readings will be the difference between the supressed value and the applied signal.
6. To return the instrument to the normal mode, press the SUPPRESS button. The SUPPRESS Light will go off and the instrument will be taken out of the suppression mode. The previously stored suppressed value will be cancelled.

NOTES:

1. Using suppress reduces the dynamic range of the measurement. For example, if the suppressed value is −100mV on the 200mV range, an input voltage of 100mV or more would overrange the instrument even though input voltages up to 199.99mV are normally within the capabilities of the 200mV range. If the instrument is in the autorange mode, it will move up range, if necessary.
2. Setting the range lower than the suppressed value will overrange the display; the instrument will display the "OL" message under these conditions.
3. To store a new baseline, suppress must first be disabled and the enabled once again. The new value will be stored with the first triggered conversion.
4. Do not move the instrument down range when using suppress
5. If the instrument is in the V/I ohms when suppress is enabled, the displayed resistance value will be supressed (supression will be cancelled temporarily by going to amps).
6. To suppress the current in V/I ohms, enter amps and then enable suppress. Enter V/I ohms in the usual manner.

2.12 DATA STORAGE

The Model 617 has an internal 100-point data store mode that can be used to log a series of readings. The fill rate of the data store can be set to specific intervals by a parameter that is entered when the storage mode is first enabled. Alternatively, a special one-shot trigger mode can be used to control the fill rate from the front panel. Once data is stored, readings can be easily recalled from the front panel.

Minimum and maximum values can also be retained for future recall. As long as data store is enabled, maximum and minimum values are updated with each conversion.

Enter the data storage mode as follows:

1. Press and hold the DATA STORE ON/OFF button. The instrument will then scroll through the various reading rates that are listed in Table 2-7. In addition to the continuous rate, which stores readings at the conversion rate, five additional intervals from one reading per second to

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one reading per hour are available. A special trigger mode allows you to control the interval with the TRIG button. During the rate selection process, the display will appear as follows:

r=3

In this example, the rate parameter is 3, indicating a 1 rdg/min interval.

Table 2-7. Data Store Reading Rates

r Value	Rate
0	Conversion Rate (every 360msec)
1	1 Reading Per Second
2	1 Reading Every 10 Seconds
3	1 Reading Per Minute
4	1 Reading Every 10 Minutes
5	1 Reading Per Hour
6	Front Panel Trigger Mode

2. To select the desired interval, simply release the ON/OFF button when the desired rate appears in the display. The Model 617 will then begin storing readings at the selected rate. If you selected the triggered mode, one reading will be stored in memory each time the front panel TRIG button is pushed.

   For rapid starts, the rate can be pre-selected by pressing ON/OFF, releasing the button when the selected rate is displayed, and then turning off data store. Storage will then begin at the pre-selected rate the next time the ON/OFF button is pressed.
3. When data store memory is full (after all 100 readings have been stored), the instrument will stop logging data, and the DATA LED will flash to indicate that memory is full.
4. Readings can be recalled any time (even if the instrument is still logging) by pressing and holding the RECALL button. Holding the RECALL button in causes the data pointer to be displayed. Releasing the RECALL button causes the corresponding data to be displayed. The first data point to be displayed will be the last reading stored. For example, if reading #65 was the last point, the display will show:

   n=65

5. The second and third points will be the high and low data points. For example, for the high value, the display will show:

   n=HI

   Similarly, the display will show the following for the low data point:

   n=Lo

6. Following these three points, the remaining data points will be displayed, beginning with the first one stored. The data pointer will increment from 1 to the maximum point stored. For example, the tenth reading appears as:

   n=10

7. To continue recalling readings, use the RECALL button to scroll the data pointer. Scrolling becomes more rapid if the RECALL button is held in. Release the button when the desired data point is displayed.
8. The recall mode can be cancelled simply by pressing SHIFT RECALL. The instrument will then return to the normal display mode. As long as data store is not disabled and then re-enabled, readings are retained within memory. You can return to the recall mode at any time to review data.
9. To cancel data store operation, press the ON/OFF button. The ON/OFF LED will turn off, indicating that data store is disabled. Data is retained until data store is enabled once again. Thus, you can still recall data even after data store is turned off.

Data Store Operating Notes:

1. Data logging continues at the selected rate during the recall until all 100 locations have been filled. Logging stops when all 100 locations are full, as indicated by the flashing DATA indicator.
2. The data store trigger mode should not be confused with the front panel trigger mode. The data store trigger mode is enabled by entering the special trigger parameter (r=6) at the beginning of the data storage process, while the front panel trigger mode is entered by pressing SHIFT TRIG.
3. If the instrument is placed in the front panel one-shot trigger mode, display readings will be triggered at the data store rate interval except when r=0. For example, if the instrument is set up for 10 minute intervals, one reading will be triggered and displayed every 10 minutes. When r=0, a single reading is stored each time an appropriate trigger is received (for example, GET in the T3 trigger mode, as described in paragraph 3.10.14)
4. The data store rate can be used to control the data output rate in the IEEE-488 talk-only mode. To use the Model 617 in this manner, place the instrument in the talk only mode (see paragraph 3.7). Now enter the data storage mode and select the desired interval as described above. The instrument will then output readings over the IEEE-488 bus at the selected rate.
5. The storage rate in r=0 and r=1 may be affected if the instrument is in autorange and a range change occurs. Typically, it takes about 350msec per range change.

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Minimum/Maximum Operation:

Minimum/Maximum operation is essentially separate from data store except for the fact that both are enabled or disabled by the ON/OFF button. Thus, the minimum and maximum data points are continuously updated with each triggered conversion as long as the ON/OFF LED is on. Note that only range, not function, is indicated when reading maximum and minimum values. Maximum and minimum values can be obtained during the recall process, as indicated in step 4 above.

2.13 EXTERNAL TRIGGERING

The Model 617 has two external BNC connectors on the rear panel associated with instrument triggering. The EXTERNAL TRIGGER INPUT allows the instrument to be triggered by other devices, while METER COMPLETE OUTPUT allows the instrument to trigger other devices.

2.13.1 External Trigger

The Model 617 may be triggered on a continuous or one-shot basis. For each of these modes, the trigger stimulus will depend on the selected trigger mode, which is further described in paragraph 3.10. In a continuous trigger mode, the instrument takes a continuous series of readings. A trigger stimulus in continuous triggers a new reading. In a one-shot mode, only a single reading is taken each time the instrument is triggered.

The EXTERNAL TRIGGER INPUT requires a falling edge pulse at TTL logic levels, as shown in Figure 2-22. The low logic level should be between 0-0.8V, and the high level should be 2-5V. The minimum pulse width for reliable triggering is approximately 10μsec. Connections to the rear panel EXTERNAL TRIGGER INPUT jack should be made with a standard BNC connector. If the instrument is in the external trigger mode, it will be triggered to take readings while in either a continuous or one-shot mode when the negative-going edge of the external trigger pulse occurs.

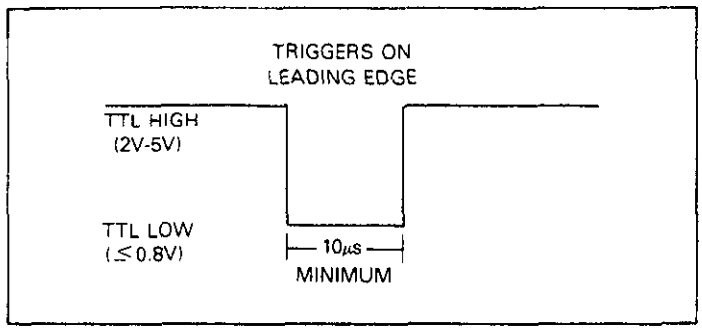


Figure 2-22. External Trigger Pulse Specifications

To use the external triggering, proceed as follows:

1. Connect the external trigger source to the rear panel BNC EXTERNAL TRIGGER INPUT connector. The shield (outer) part of the connector is connected to digital common. Since an internal pull-up resistor is used, a mechanical switch may be used. Note, however, that debouncing circuitry will probably be required to avoid improper triggering.

CAUTION
Do not exceed 30V between digital common and chassis ground, or instrument damage may occur.

2. Place the instrument in the one-shot trigger mode by pressing SHIFT and then TRIG in that order. The instrument will indicate that it is in the one-shot mode by illuminating the SGL indicator.
3. To trigger the instrument, apply a pulse to the External Trigger input. The instrument will process a single reading each time the pulse is applied. Note that the instrument may also be triggered by pressing TRIG.
4. To return the instrument to the continuous mode, press the SHIFT and TRIG buttons in sequence.

NOTES:

1. External triggering can be used to control the fill rate in the data store mode. See paragraph 2.12 for details.
2. The Model 617 must be in the appropriate trigger mode to respond to external triggering (the unit will be in this mode upon power-up). See paragraph 3.10.14 for details.
3. If a trigger overrun occurs (the instrument is triggered while processing a reading from a previous trigger), it will ignore the trigger and display the following:

t Err

2.13.2 Meter Complete

The Model 617 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible negative-going pulse with a minimum duration of 10μsec (see Figure 2-23) will appear at the METER COMPLETE OUTPUT jack each time the instrument completes a reading. To use the meter complete output, proceed as follows:

1. Connect the Model 617 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 617.

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CAUTION

Do not exceed 30V between the METER COMPLETE common (outer ring) and chassis ground or instrument damage may occur.

2. Select the desired function, range, trigger mode, and other operating parameters, as desired.
3. In a continuous trigger mode, the instrument will output pulses at the conversion rate; each pulse will occur after the Model 617 has completed a conversion.
4. In a one-shot trigger mode, the Model 617 will output a pulse once each time it is triggered after it completes the reading conversion.

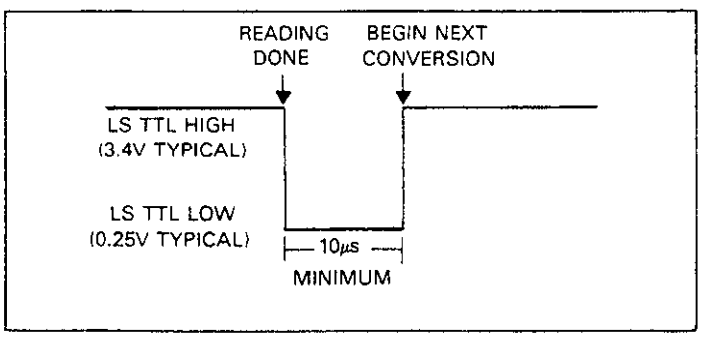


Figure 2-23. Meter Complete Pulse Specifications

2.13.3 Triggering Example

As an example of using both the external trigger input and the meter complete output, assume that the Model 617 is to be used in conjunction with a Keithley Model 705 Scanner to allow the Model 617 to measure a number of different signals, which are to be switched by the scanner. The Model 705 can switch up to 20 2-pole channels (20 single-pole channels with special cards such as the low-current card). In this manner, a single Model 617 could monitor up to 20 measurement points.

By connecting the triggering inputs of the two instruments together, a complete automatic measurement sequence could be performed. Data obtained from each measurement point could be stored by the data store mode of the Model 617. Alternatively, the Model 617 could be connected through the IEEE-488 bus to a printer, which would print out the data for each point as it is measured.

Once the Model 705 is programmed for its scan sequence, the measurement procedure is set to begin. When the Model 705 closes the selected channel, it triggers the Model 617 to take a reading. When the Model 617 finishes the reading, it triggers the Model 705 to scan to the next channel. The process repeats until all channels have been scanned.

To use the Model 617 with the Model 705, proceed as follows:

1. Connect the Model 617 to the Model 705 as shown in Figure 2-21. Use shielded cables with BNC connectors. The Model 617 METER COMPLETE OUTPUT jack should be connected to the Model 705 EXTERNAL TRIGGER INPUT jack. The Model 617 EXTERNAL TRIGGER INPUT should be connected to the Model 705 CHANNEL READY OUTPUT. Additional connections, which are not shown on the diagram, will also be necessary to apply signal inputs to the scanner cards, as well as for the signal lines between the scanner and the Model 617.
2. Place the Model 617 in the one-shot trigger mode by pressing the SHIFT and TRIG buttons, in that order.
3. Program the Model 705 scan parameters such as first and last channel as required. Place the instrument in the single scan mode.
4. Install the desired scanner cards and make the required input and output signal connections. See the Model 705 Instruction Manual for details.
5. If data storage is required, enter the data storage mode as described in paragraph 2.12.
6. Begin the measurement sequence by pressing the Model 705 START/STOP button. The Model 705 will close the first channel and trigger the Model 617 to take a reading. When the Model 617 completes the reading, it will trigger the Model 705 to go to the next channel. The process repeats until all programmed channels have been scanned.

2.14 MEASUREMENT CONSIDERATIONS

The Model 617 is a highly sensitive instrument that can measure extremely low signal levels. At these low signal levels, a number of factors can affect a measurement. Some considerations when making measurements with the Model 617 are discussed in the following paragraphs.

2.14.1 Ground Loops

Ground loops that occur in multiple-instrument test set-ups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure 2-25 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires, or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the ground leads can induce sufficient voltages to disturb sensitive measurements.

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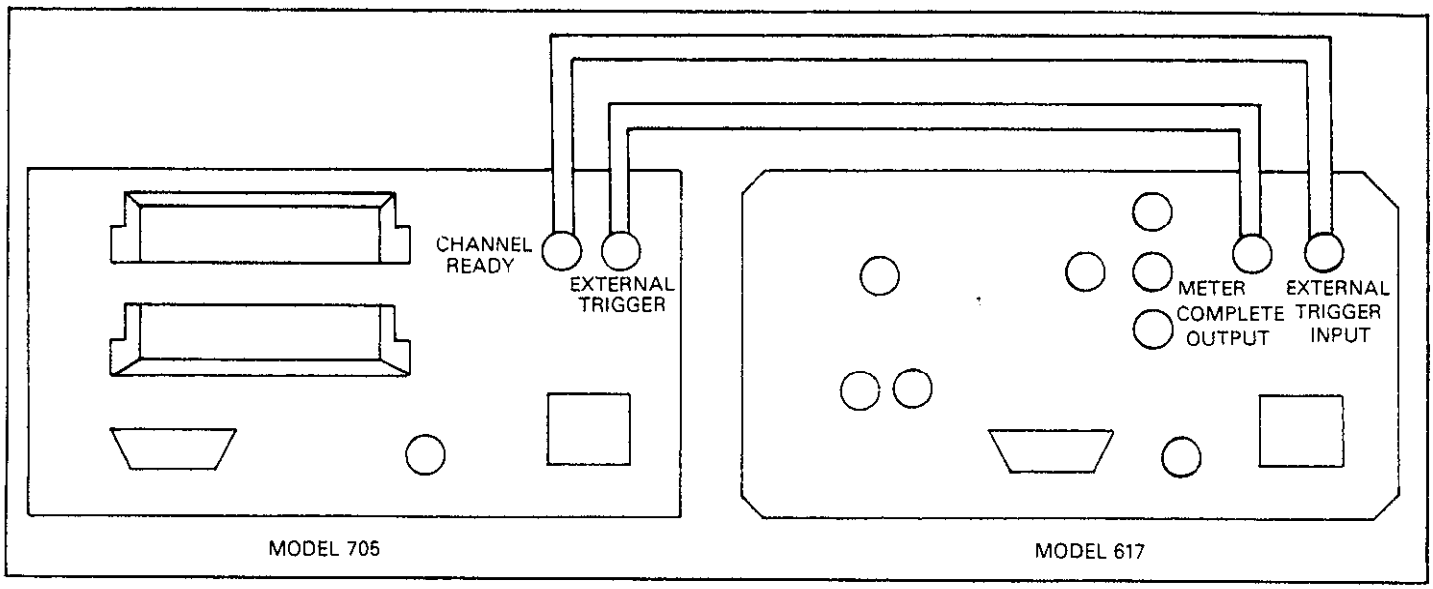


Figure 2-24. External Triggering Example

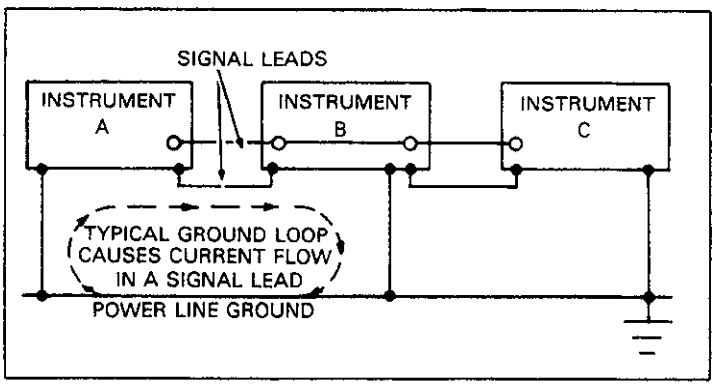


Figure 2-25. Multiple Ground Points Create a Ground Loop

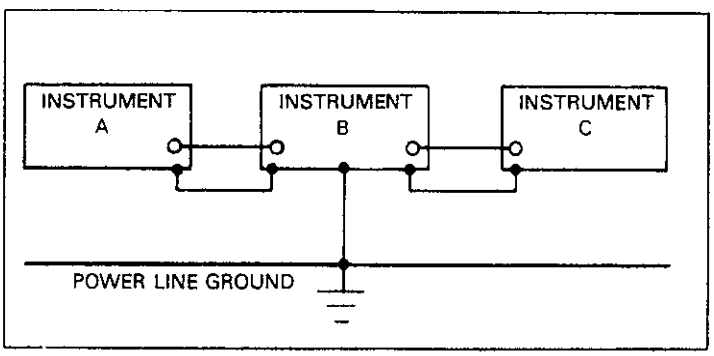


Figure 2-26. Eliminating Ground Loop

To prevent ground loops, instruments should be connected to ground at only a single point, as shown in Figure 2-26. Note that only a single instrument is connected directly to power line ground. Experimentation is the best way to determine an acceptable arrangement. For this purpose, measuring instruments should be placed on their lowest ranges. The configuration that results in the lowest noise signal is the one that should be used.

2.14.2 Electrostatic Interference

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, effects of such electrostatic action are not noticable because low impedance levels allow the induced charge to dissipate quickly. However, the high impedance levels of many Model 617 Electrometer measurements do not allow these charges to decay rapidly, and erroneous or unstable readings may result. These erroneous or unstable readings may be caused in the following ways:

1. DC electrostatic field can cause undetected errors or noise in the reading.
2. AC electrostatic fields can cause errors by driving the amplifier into saturation, or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in

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the reading. Pick up from AC fields can also be detected by observing the electrometer output on an oscilloscope. Line frequency signals on the output are an indication that electrostatic interference is present.

Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit, and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. If circuit low is floated above ground, observe safety precautions when touching the shield. Meshed screen or loosely braided cable could be inadequate for high impedances, or in strong fields. The Keithley Model 6104 Test Shield can provide shielding under many circumstances. Note, however, that shielding can increase capacitance in the measuring circuit, possibly slowing down response time.
2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen in the measurement.

2.14.3 Thermal EMFs

Thermal EMFs are small electric potentials generated by differences in temperature at the junction of two dissimilar metals. Low thermal connections should be used whenever thermal EMFs are known to be a problem. Crimped or cadmium soldered copper to copper connections are methods that can be used to minimize these effects.

2.14.4 RFI

Radio Frequency Interference (RFI) is a general term frequently used to describe electromagnetic interference over a wide range of frequencies across the spectrum. RFI can be especially troublesome at low signal levels, but it may also affect higher level measurements in extreme cases.

RFI can be caused by steady-state sources such as TV or radio broadcast signals, or it can result from impulse sources, as in the case of arcing in high voltage environments. In either case, the effect on instrument performance can be considerable, if enough of the unwanted signal is present. The effects of RFI can often be seen as an unusually large offset, or, in the case of impulse sources, sudden, erratic variations in the displayed reading.

RFI can be minimized by taking one or more of several precautions when operating the Model 617 in such environments. The most obvious method is to keep the instrument and experiment as far away from the RFI source as possible. Shielding the instrument, experiment, and test leads will often reduce RFI to an acceptable level. In extreme cases, a specially constructed screen room may be necessary to sufficiently attenuate the troublesome signal.

If all else fails, external filtering of the input signal path may be required. In some cases, a simple one-pole filter may be sufficient. In more difficult situations, multiple-pole notch or band-stop filters, tuned to the offending frequency range, may be required. Keep in mind, however, that such filtering may have other detrimental effects (such as increased response time) on the measurement.

2.14.5 Leakage Resistance Effects

At normal resistance levels, the effects of leakage resistance are seldom seen because any leakage resistance present is generally much higher than the resistance levels encountered in the circuit under test. At the high resistance levels of many Model 617 measurements, however, leakage resistance can have a detrimental effect on the measurement. Such leakage resistance can occur in the circuit under test (on PC boards, for example), in the connecting cable, or even at the electrometer input itelf, especially if the input connector is not kept clean.

To see how leakage resistance can affect measurement accuracy, let us review the equivalent circuit in Figure 2-27. E_S and R_S are the source voltage and source resistance respectively. The leakage resistance is represented by R_L, while the voltage, as seen by the electrometer, is V_M.

R_S and R_L form a voltage divider that attenuates the input signal in accordance with the formula:

$$V_M = \frac{E_S R_L}{R_S + R_L}$$

Thus, if R_L has a value of 100GΩ and R_S is 10GΩ, the actual voltage measured by the electrometer with a 10V source would be:

$$V_M = \frac{10 \times 100G\Omega}{10G\Omega + 100G\Omega}$$

$$V_M = 9.09V$$

Thus, we see that the effects of leakage resistance can be substantial, resulting in an error of almost 10% in this case.

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Certain steps can be taken to ensure that the effects of leakage resistance are mimimal. The most obvious remedy to ensure that the leakage resistance itself is as high as possible. Use only good quality triaxial cable for signal connections, and make sure that the circuit under test and connectors are kept free of contamination.

Even with these steps, however, there is a limit as to how high the leakage resistance can be. In those cases, guarded input connections should be used, as described in paragraph 2.7.4.

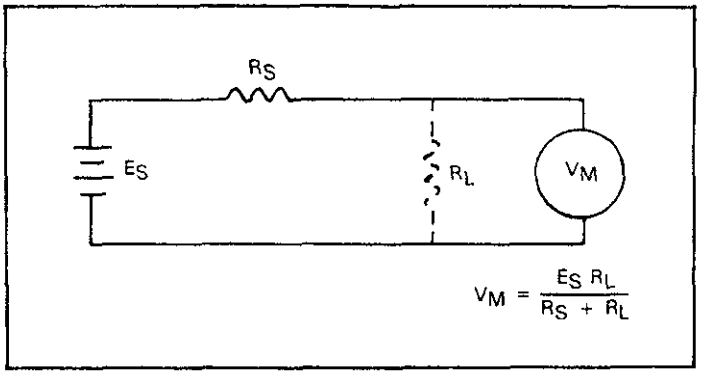


Figure 2-27. Leakage Resistance Effects

2.14.6 Input Capacitance Effects

Virtually any circuit has at least some small amount of distributed capacitance that can slow down the response time of high-impedance measurements. Even if the circuit itelf has minimal capacitance, cable or instrument input capacitance effects can be noticable.

As an example, assume that the Model 617 is being used to measure the value of a high-impedance voltage source, as shown in Figure 2-28. The source and source resistance are represented by E_S and R_S, the input capacitance is C_{IN}, and the voltage measured by the electrometer is V_M.

When E_S is first applied, the voltage across the capacitance (and thus, at the electrometer input) does not instantaneously rise to its final value. Instead, the capacitance charges exponentially in accordance with the following formula:

$$V_M = E_S (1 - e^{\frac{-t}{RC}})$$

Note that R_S is given in megohms, C is in microfarads, while t is in seconds.

Because of the charging of C_{IN}, the electrometer follows the exponential curve shown in Figure 2-28B. At the end of one time constant (R_SC_{IN}), the voltage will reach approximately 63% of its final value. At the end of two time constants ($2R_SC$), the voltage will reach about 86% of its final value, and so on. Generally, at least five time constants should be allowed for better than 1% accuracy.

The amount of time that must be allowed will, of course, depend on the relative values of R_S, and C_{IN}. For example, when measuring a voltage with a source resistance of 10GΩ with an input capacitance of 100pF, a time constant of 1 second results. Thus, at least five seconds must be allowed to achieve a better than 1% accuracy figure. Table 2-8 summarizes voltage values and percentage error values for ten different time constants ($\tau = R_SC_{IN}$).

The most obvious method to minimize the slowing effects of input capacitance is to minimize the amount of capacitance in the circuit. Using low capacitance cable and keeping the cable as short as possible are two ways to do so. However, there is a limit to the amount of capacitance reduction that can be achieved. In those cases, especially where high impedance levels are involved, guarded operation (see paragraph 2.7.4) may be necessary.

While input capacitance does increase rise-time, it can help to filter out some noise present at the input by effectively reducing electrometer bandwidth. If we assume that all input capacitance is lumped into a single element, the half-power (−3dB) point of the circuit in Figure 2-28 will be:

$$f_{-3dB} = \frac{1}{2\pi R_S C_{IN}}$$

Thus, if R_S has a value of 10MΩ, and C_{IN} has a value of 100pF, the half-power point will be 159Hz.

$$f_{-3dB}$$

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Table 2-8. Voltage and Percent Error For Various Time Constants

Time*	V_M	% Error
τ	0.632 E_S	36 %
2τ	0.86 E_S	14 %
3τ	0.95 E_S	5 %
4τ	0.982 E_S	1.8 %
5τ	0.993 E_S	0.674%
6τ	0.9975 E_S	0.25 %
7τ	0.999 E_S	0.09 %
8τ	0.99966E_S	0.033%
9τ	0.9999 E_S	0.012%
10τ	0.99995E_S	0.005%

*$\tau = R_S C_{IN}$

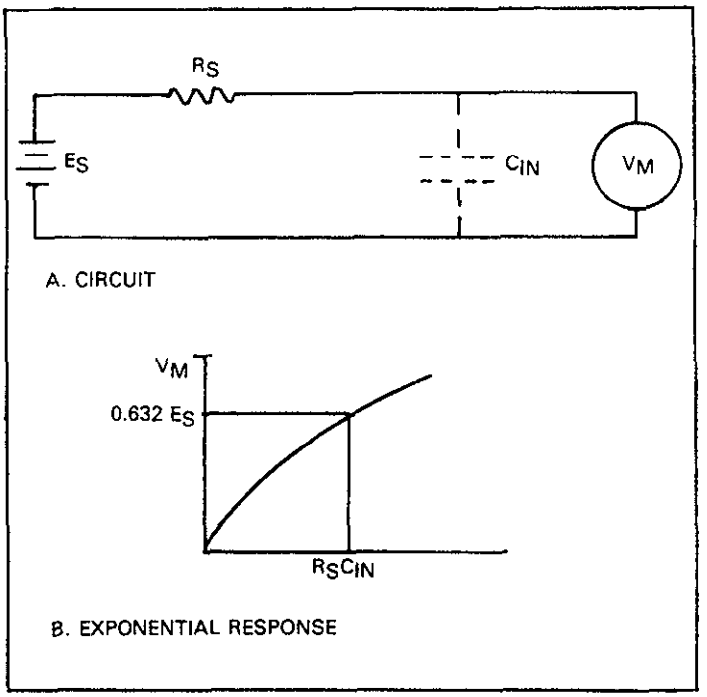


Figure 2-28. Input Capacitance Effects

2.14.7 Source Resistance

As shown in Table 2-9, a minimum value of source resistance is recommended for each AMPS range. The reason for this can be understood by examining Figure 2-29. Considering effects on low frequency noise and drift, C_S and C_F can momentarily be ignored.

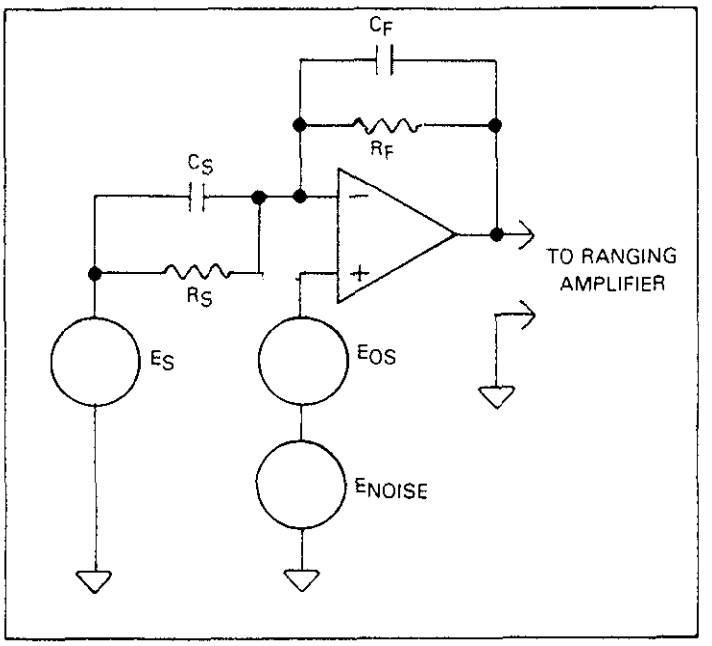


Figure 2-29. Simplified Model for Source Resistance and Source Capacitance Effects

Table 2-9. Minimum Recommended Source Resistance Values in Amps

Range	Minimum Source Resistance
All pA	100GΩ
All nA	100MΩ
All μA	100 kΩ
All mA	100 Ω

Input amplifier noise and drift appearing at the output can be calculated as follows:

Equation 1.

$$\text{Output } E_{noise} = \text{Input } E_{noise} \times \left(1 + \frac{R_F}{R_S}\right)$$

Thus it is clear that as long as $R_S >> R_F$, Output E_{noise} = Input E_{noise}. When $R_F = R_S$, output $E_{noise} = 2 \times$ Input E_{noise}.

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The same applies for E_{OS}. The Model 617 will typically show insignificant degradation in displayed performance with the noise gain of 2 resulting from allowing $R_S = R_{FB}$. Typical amplifier input E_{noise} is about 9μV p-p in a bandwidth of 0.1-10Hz. Amplifier E_{OS} can be nulled by using suppress. The temperature coefficient of E_{OS} is $< 30\mu V/°C$. These numbers can be used with Equation (1) to determine expected displayed noise/drift given any source resistance. Note also that the values given in Table 2-9 for minimum source resistance also represent the value of R_F on that range.

2.14.8 Source Capacitance

In amps, the Model 617 is designed to accommodate up to 10,000pF input capacitance (C_S). This limit will preclude problems in most test setups and allow extremely long input cable lengths without inducing instability or oscillations.

Increasing capacitance beyond this level may increase noise and induce instrument instability. The noise gain of the measurement circuit can be found from:

Equation 2.

$$\text{Output } E_n = \text{Input } E_n \times \left(1 + \frac{Z_F}{Z_S}\right)$$

where $Z_F =$

$$\frac{R_F}{\sqrt{(2\pi\, fR_FC_F)^2+1}}$$

and $Z_S =$

$$\frac{R_S}{\sqrt{(2\pi\, fR_SC_S)^2+1}}$$

Clearly as f -- 0 equation (2) reduces to equation (1).

Refer to Table 2-11 for equivalent voltage sensitivity of 617 amps ranges.

The frequency range of interest is 0.1 to 10Hz which is the noise bandwidth of the A/D converter. The value of C_F is 5pF for pA ranges, 22pF for nA ranges and 1000pF for μA ranges.

In general, as C_S becomes larger, the noise gain becomes larger. An application where C_S may be greater than 10,000pF is leakage measurement of capacitors. In this case Input E_n must include the effects of the voltage source (E_S) used to bias the capacitor (any noise in the source voltage will increase the input noise).

When measuring leakage currents on capacitors larger than 10,000pF, stability and noise performance can be maintained by adding a resistor in series with the capacitor under test. The value of this resistor should be around 1MΩ. For large capacitor values ($> 1\mu F$), the value of the series limiting resistor can be made lower in order to improve settling times; however, values below 10kΩ are not generally recommended.

This resistor is not critical in terms of tolerance or stability. Any carbon composition resistor will prove adequate.

2.15 ENGINEERING UNITS CONVERSION

The Model 617 is a highly sensitive instrument with wide-ranging measurement capabilities. In the amps mode, for example, the unit can detect currents as low as 0.1fA (10^{-16}A). At the other extreme, resistances in the 10PΩ ($10^{16}\Omega$) range can be measured. The instrument can display its reading either in engineering units (such a mA) or in scientific notation (such as 10^{-3}A). Table 2-10 lists engineering units and their equivalent scientific notation values.

Table 2-10. Engineering Units Conversion

Symbol	Prefix	Exponent
f	femto-	10^{-15}
p	pico-	10^{-12}
n	nano-	10^{-9}
μ	micro-	10^{-6}
m	milli-	10^{-3}
k	kilo-	10^{3}
M	mega-	10^{6}
G	giga-	10^{9}
T	tera-	10^{12}
P	peta-	10^{15}

Table 2-11. Equivalent Voltage Sensitivity of 617 Amps Ranges

Range	Equivalent Voltage Sensitivity (μV/count)
2pA, 2nA, 2μA 2mA	10μV
20pA, 20nA, 20μA 20mA	100μV
200pA, 200nA, 200μA	1mV

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SECTION 3
IEEE-488 PROGRAMMING

3.1 INTRODUCTION

The IEEE-488 bus is an instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975 and given the IEEE-488 designation. In 1978, standards were upgraded into the IEEE-488-1978 standards. The Model 617 conforms to these IEEE-488-1978 standards.

This section contains general bus information as well as the necessary programming information and is divided into the following sections:

1. Introductory information pertaining to the IEEE-488 bus in general is located in paragraphs 3.2 through 3.6.
2. Information necessary to connect the Model 617 to the IEEE-488 bus is contained in paragraphs 3.7 and 3.8.
3. General bus command programming is covered in paragraph 3.9.
4. Device-dependent command programming is described in paragraph 3.10. These are the most important commands associated with the Model 617 as they control most of the instrument functions.
5. Additional information necessary to use the Model 617 over the IEEE-488 bus is located in the remaining paragraphs.

3.2 BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical configuration for controlled operation is shown in Figure 3-1. The typical system will have at least one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

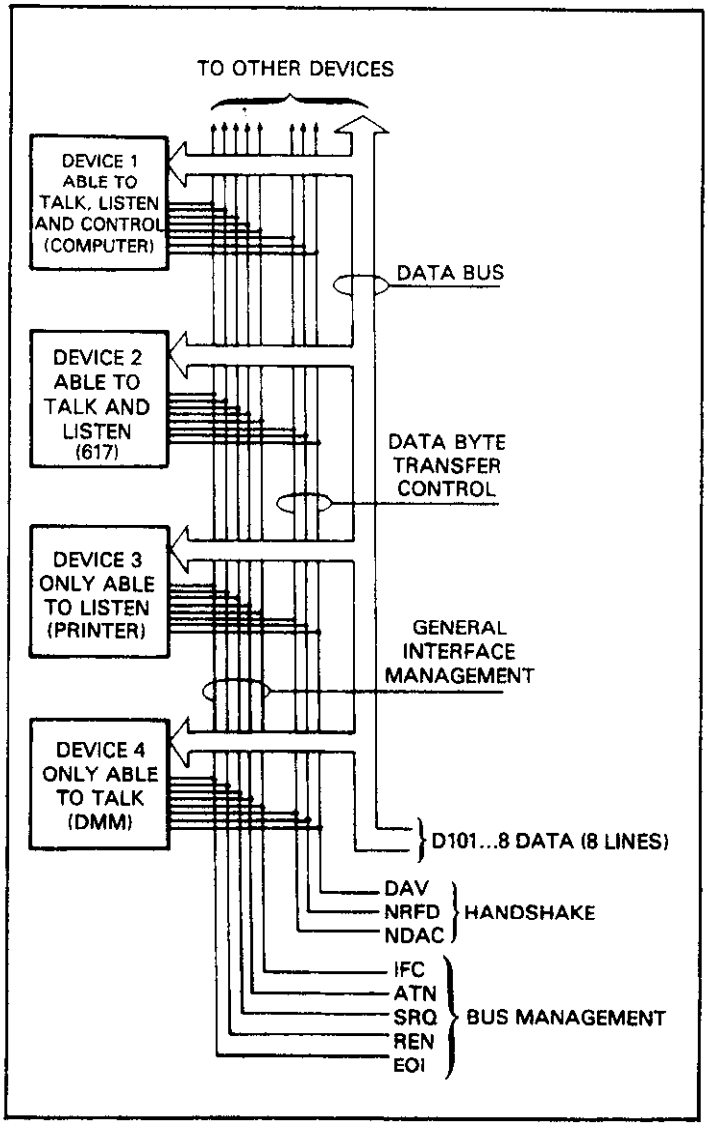


Figure 3-1. IEEE Bus Configuration

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), while a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener.

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There are two categories of controllers: system controller, and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more that one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is 27 ($1B), the actual listen address is $3B ($3B = $1B + $20). In a similar manner, the talk address is obtained by ORing the primary address value with $40. With the present example, the talk address derived from a primary address of 27 decimal would be $5B ($5B = $1B + $40)

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however, that many devices do not use secondary addressing.

Once the device is properly addressed, appropriate bus transactions are set to take place. For example, if an instrument is addressed to talk, it will usually place its data byte on the bus one byte at a time. The listening device (frequently the controller) will then read this information.

3.3 IEEE-488 BUS LINES

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines, and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and bus operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the purpose of these lines, which are shown in Figure 3-1.

3.3.1 Data Lines

The IEEE-488 bus uses eight data lines that allow data to be transmitted and received in a bit-parallel, byte serial manner. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining lines, low is considered to be true.

3.3.2 Bus Management Lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands that are described in paragraph. 3.4.1.

ATN (Attention)—The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear)—As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable)—The REN line is used to place instrument on the bus in the remote mode.

EOI (End or Identify)—The EOI line is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request)—This line is used by devices when they require service from the controller.

3.3.3 Handshake Lines

The bus uses handshake lines that operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (Data Valid)—The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

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NRFD (Not Ready For Data)—The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device.

The complete handshake sequence for one data byte in shown in Figure 3-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

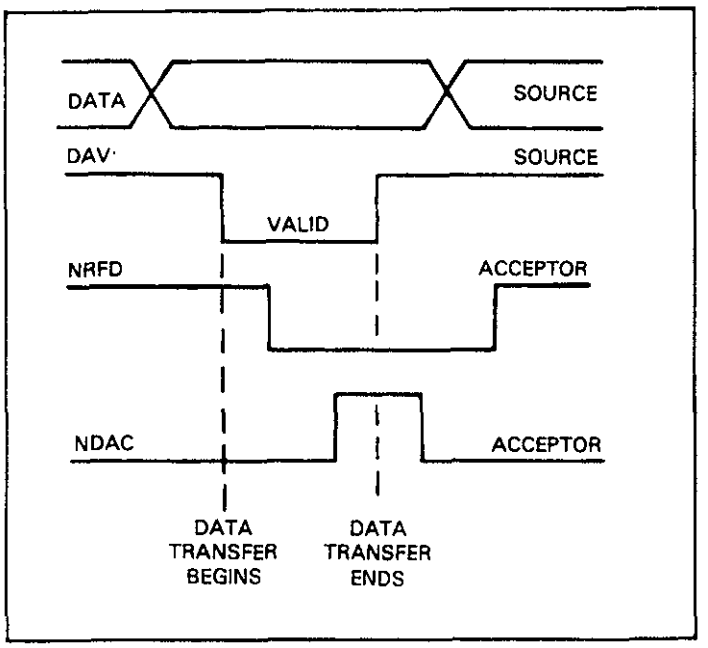


Figure 3-2. IEEE Handshake Sequence

Once NDAC goes high, the source then sets DAV high to indicate that the data byte is no longer valid. NDAC is returned to its low state, and NRFD is released by each device at its own rate, until NRFD goes high when the slowest device is ready, and the bus is set to repeat the preocess with the next data byte.

The sequence just described is used to transfer data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses, or commands as described in the following paragraph.

3.4 BUS COMMANDS

While hardware aspects of the bus are essential, the interface would have minimal capabilities without appropriate commands to control communications among the various devices on the bus. This paragraph briefly describes the purposes of the various device commands, which are grouped into the following three general categories:

Uniline Commands—Sent by setting the corresponding bus line true.

Multiline Commands—General bus commands which are sent over the data lines with ATN true (low).

Device-dependent Commands—Special commands whose meanings depend on device configuration; sent over the data lines with ATN high (false).

These bus commands and their general purposes are summarized in Table 3-1.

3.4.1 Uniline Commands

ATN, IFC, and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable)—REN is sent to set up instruments on the bus for remote operation. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End or Identify)—EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

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IFC (Interface Clear)—IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request)—SRQ is asserted by a device when it requires service from a controller.

3.4.2 Universal Commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the command is transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out their front panel controls.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device has requested service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

3.4.3 Addressed Commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands:

SDC (Selective Device Clear)—The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local)—The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger)—The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Table 3-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Set up for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears Interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out front panel controls.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Poll Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Sends go to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent**		High	Programs Model 617 for various modes.

*Don't Care.
**See paragraph 3.10 for complete description.

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3.4.4 Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by the UNT command.

3.4.5 Device-Dependent Commands

The meaning of the device-dependent commands will depend on the configuration of the instrument. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function. For example, the command sequence F0X is used to place the Model 617 in the volts mode. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

3.5 COMMAND CODES

Each multiline command is given a unique code that that is transmitted over the bus as 7 bit ASCII data. This section briefly explains the code groups, which are summarized in Figure 3-3.

Addressed Command Group (ACG)—Addressed commands and corresponding ASCII codes are listed in columns 0(A) and 0(B).

Universal Command Group (UCG)—Universal commands and values are listed in columns 1(A) and 1(B).

Listen Address Group (LAG)—Columns 2(A) through 3(B) list codes for commands in this address group. For example, if the primary address of the instrument is 27, the LAG byte will be an ASCII left bracket.

Talk Address Group (TAG)—TAG primary address values and corresponding ASCII characters are listed in columns 4(A) through 5(B).

The preceding address groups are combined together to form the Primary Command Group (PCG). The bus also has another group of commands, called the Secondary Command Group (SCG). These are listed in Figure 3-3 for informational purposes only; the Model 617 does not have secondary addressing capabilities.

Note that these commands are normally transmitted with the 7 bit code listed in Figure 3-3. For many devices, the condition of DIO8 is unimportant. However, many devices may require that DIO8 has a value of logic 0 (high) to properly send commands.

Hexadecimal and decimal values for each of the commands or command groups are listed in Table 3-2. Each value assumes that DIO8 has a value of 0.

Table 3-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
UNL	3F	63
UNT	5F	95

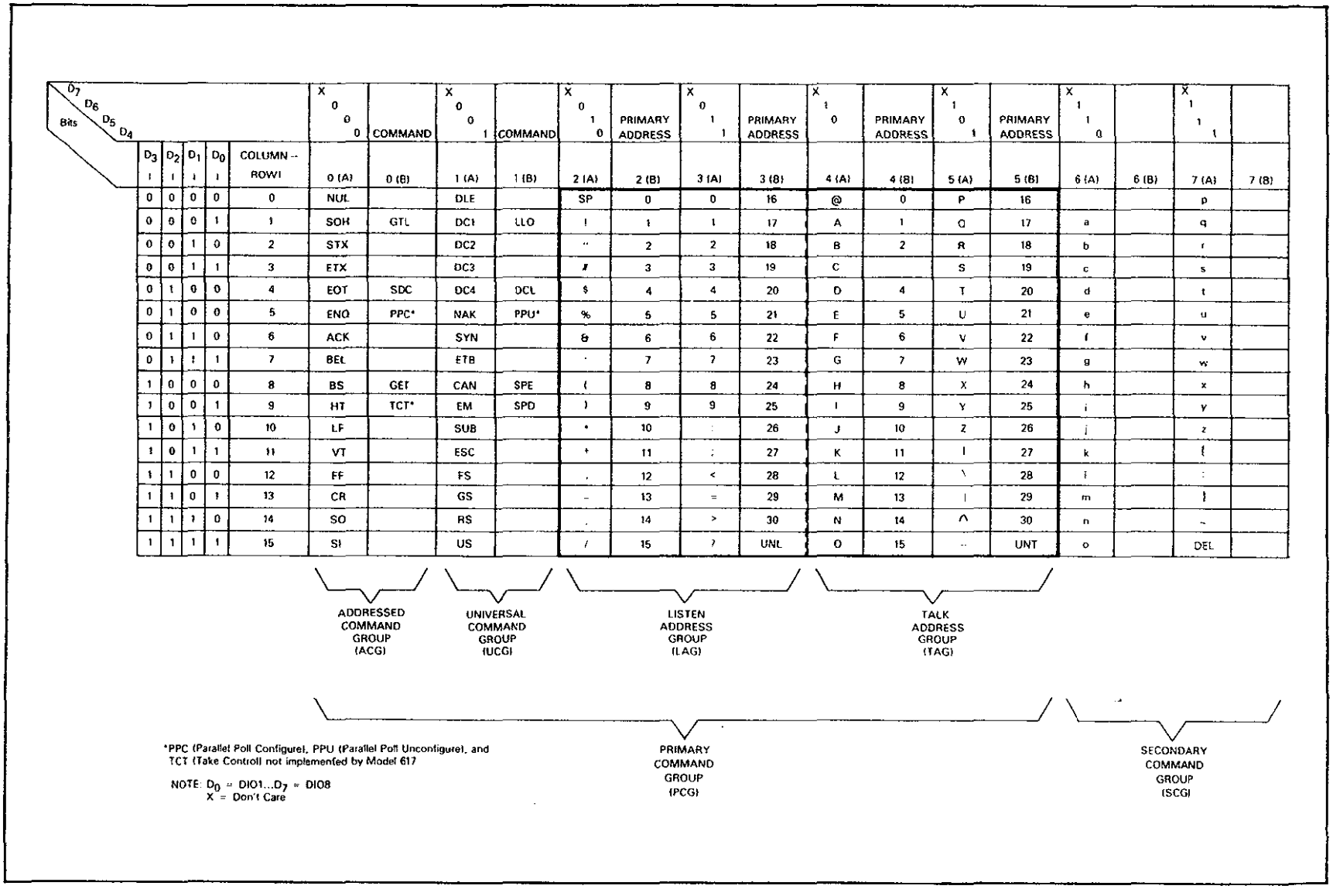
3.6 COMMAND SEQUENCES

The proper command sequence must be sent to the instrument before it will respond as intended. Universal commands, such as LLO and DCL, require only that ATN be set low when sending the command. Other commands require that the instrument be properly addressed to listen first. This section briefy describes the bus sequence for several types of commands.

3.6.1 Addressed Command Sequence

Before a device will respond to one of these commands, it must receive a LAG command derived from its primary address. Table 3-3 shows a typical sequence for the SDC command; the example assumes that a primary address of 27 is being used.

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Bits D_7 D_6 D_5 D_4					X 0 0 0 0		X 0 0 0 1		X 0 0 1 0		X 0 0 1 1		X 0 1 0 0		X 0 1 0 1		X 0 1 1 0			X 0 1 1 1	
D_3	D_2	D_1	D_0	COLUMN → ROW↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3 (B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	0	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	_	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SCG)

*PPC (Parallel Poll Configure), PPU (Parallel Poll Unconfigure), and TCT (Take Control) not implemented by Model 617

NOTE: D_0 = DIO1...D_7 = DIO8
X = Don't Care

Figure 3-3. Command Groups

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Note that an UNL command is generally sent before the LAG, SDC sequence. This is usually done to remove all other listeners from the bus so that the desired device responds to the command.

Table 3-3. Typical Addressed Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	[	3B	59
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 27.

3.6.2 Universal Command Sequence

Universal commands are sent by setting ATN low and then placing the command byte on the data bus. ATN would then remain low during the period the command is transmitted. For example, if the LLO command were to be sent, both ATN and LLO would be asserted simultaneously.

3.6.3 Device-Dependent Command Sequence

Device-dependent commands are transmitted with ATN false. However, a device must be addressed to listen before these commands are transmitted. Table 3-4 shows the byte sequence for a typical Model 617 command (F0X), which sets the instrument for the volts mode of operation.

Table 3-4. Typical Device-Dependent Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	[	3B	59
3	Data	Set high	F	46	70
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 27.

3.7 HARDWARE CONSIDERATIONS

Before the Model 617 can be operated over the IEEE-488 bus, it must first be connected to the bus with a suitable cable. Also, the primary address must be programmed to the correct value, as described in the following paragraphs.

3.7.1 Typical Controlled Systems

System configurations are many and varied and will depend on the application. To obtain as much versatility as possible, the IEEE-488 bus was designed so that additional instrumentation could be easily added. Because of this versatility, system complexity can range from the very simple to extremely complex.

Figure 3-4 shows two possible system configurations. Figure 3-4(a) shows the simplest possible controlled system. The controller is used to send commands to the instrument, which sends data back to the controller.

The system in Figure 3-4(b) is somewhat more complex in that additional instruments are used. Depending on programming, all data may be routed through the controller, or it may be sent directly from one instrument to another.

In very complex applications, a larger computer could be used. Tape drives or disks could be used to store any data generated by the instruments.

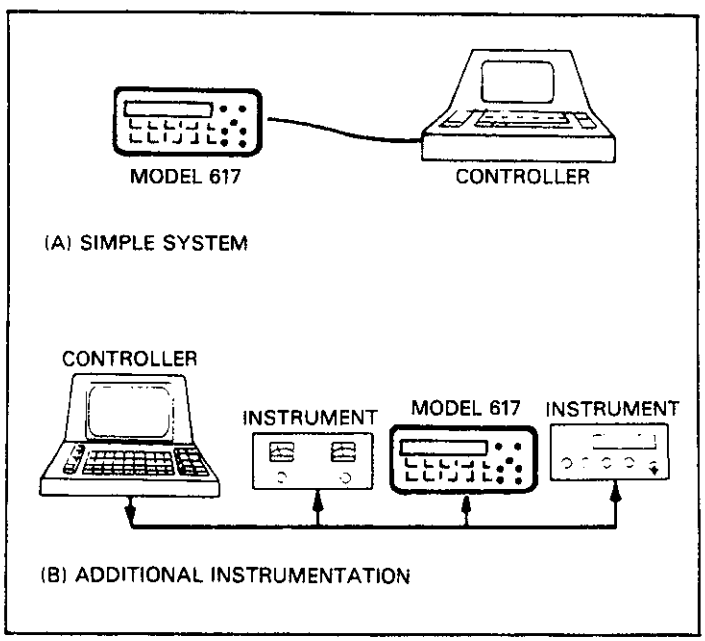


Figure 3-4. System Types

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3.7.2 Bus Connections

The Model 617 is to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 3-5. The connector is designed to be stacked to allow a number of parallel connections. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, as identified by dark colored screws. Earlier versions had different screws, which are silver colored. Do not attempt to use these type of connectors with the Model 617, which is designed for metric threads.

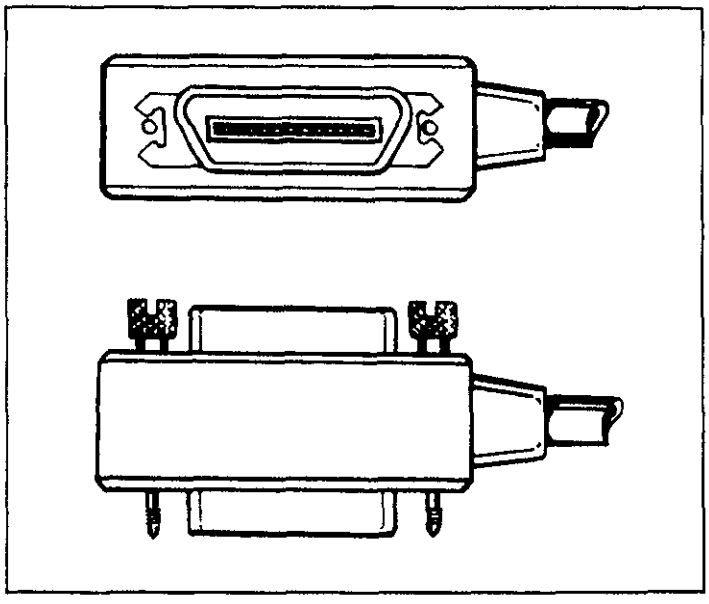


Figure 3-5. IEEE-488 Connector

A typical connecting scheme for the bus is shown in Figure 3-6. Each cable normally has the standard connector on each end. These connectors are designed to be stacked to allow a number of parallel connections on one instrument.

NOTE

To avoid possible damage, it is recommended that you stack no more than three connectors on any one instrument.

Connect the Model 617 to the cable as follows:

1. Line up the connector on the cable with the connector on the rear panel of the instrument. See Figure 3-7 for connector location.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make sure the other end of the cable is properly connected to the controller. Some controllers have an IEEE-488 type connector, while others do not. Consult the instruction manual for your controller for the proper connecting method.

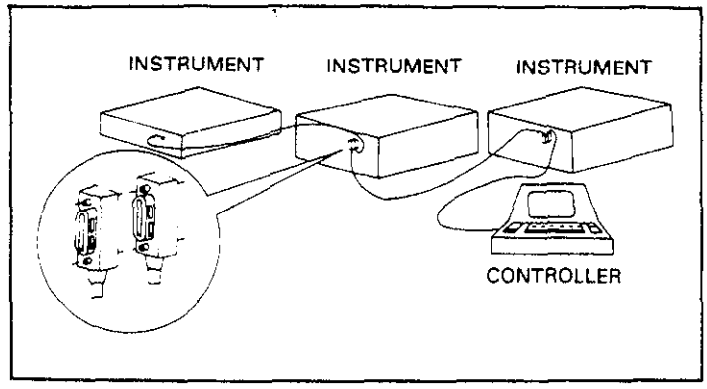


Figure 3-6. IEEE-488 Connections

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is limited to 20 meters, or 2 meters times the number of devices, which ever is less. Failure to heed these limits may result in erratic bus operation.

Custom cables may be constructed by using the information in Table 3-5 and Figure 3-8. Table 3-5 lists the contact assignments for the various bus lines, while Figure 3-8 shows contact assignments.

CAUTION

The voltage between IEEE-488 common and chassis ground must not exceed 30V or instrument damage may occur.

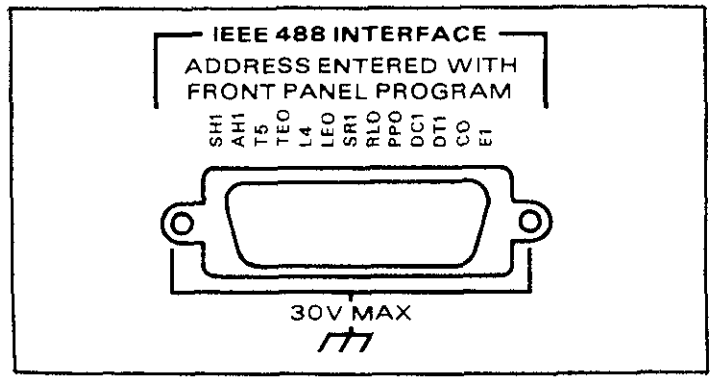


Figure 3-7. 617 Rear Panel IEEE Connector

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Table 3-5. IEEE Contact Designations

Contact Number	IEEE-488 Designation	Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Number in parenthesis refer to signal ground return of referenced contact number. EOI and REN signal lines return on contact 24.

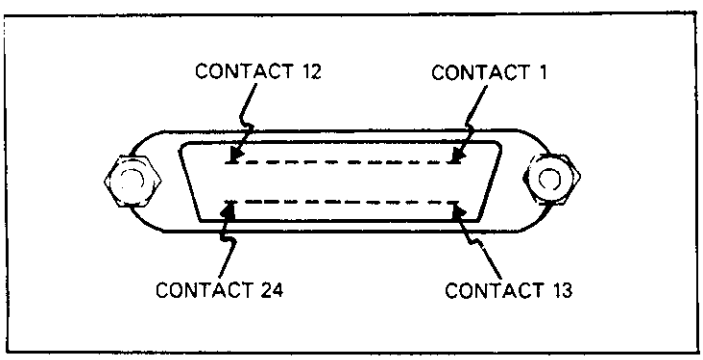


Figure 3-8. Contact Assignments

3.7.3 Primary Address Programming

The Model 617 must receive a listen command before is will respond to addressed commands. Similarly, the unit must receive a talk command before it will transmit its data. The Model 617 is shipped from the factory with a programmed primary address of 27. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples included in this manual assume that address.

The primary address may be set to any value between 0 and 30 as long as address conflicts with other instruments are avoided. Note that controllers are also given a primary address, so you must be careful not to use that address either. Most frequently, controller addresses are set to 0 or 21, but you should consult the controller's instruction manual for details. Whatever primary address you choose, you must make certain that it corresponds with the value specified as part of the controller's programming language.

To check the present primary address, or to change to a new one, use the following sequence:

1. Press the PROGRAM SELECT button repeatedly until the following message is displayed:

   IEEE 27

2. This message indicates that the IEEE address program is selected, along with the presently programmed value (in this case, the default value of 27 is being displayed).
3. Using one of the V-SOURCE ADJUST buttons, scroll the displayed address to the desired value (the display will show special values for the talk-only mode, as described in the next paragraph).
4. Exit the program by pressing SHIFT then SELECT EXIT. The new address is now in effect, and it will remain programmed even if the power is turned off.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution will probably result in erratic bus operation.

3.7.4 Talk-Only Mode

The Model 617 may be placed into the talk-only mode and be used with a listen-only device such as a printer. When in this mode, the instrument will ignore commands given over the bus and merely output data as requested by the listening

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device. When the instrument is in the talk-only mode, the front panel TALK LED will turn on.

The instrument can be placed in the talk-only mode by entering one of the following parameters in the primary address program:

40 Talk only mode with prefix on data string (Example: NDCV—1.2345E—01

41 Talk only mode without prefix on data string (Example: —1.2345E—01

To place the instrument in the talk-only mode, perform the following steps:

1. Press the PROGRAM SELECT button so that the following message is displayed:

   IEEE 27

2. Press the up arrow V-SOURCE ADJUST button repeatedly until the desired talk-only parameter (40 or 41) is shown.
3. To exit the program, press SHIFT then SELECT EXIT. The unit is now programmed for the talk-only mode, and it will remain programmed in this manner even if the power is turned off.

The data output rate in the talk-only mode can be selected as follows:

1. Press and hold the DATA STORE ON/OFF button until the desired rate is displayed, as indicated below.

Displayed r Value	Data Output Rate
r=0	Conversion Rate (Every 360msec)
r=1	One reading per second
r=2	One reading every 10 seconds
r=3	One reading per minute
r=4	One reading every 10 minutes
r=5	One reading per hour
r=6	On reading each time TRIG is pressed

2. Press the PROGRAM SELECT button until the IEEE program message is displayed and then release the button. Select the desired IEEE-488 talk-only parameter (40 or 41) using an ADJUST button.
3. Press SELECT EXIT to return to normal operation. The instrument will then enter the talk-only mode and output readings over the IEEE-488 bus at selected intervals.

3.8 SOFTWARE CONSIDERATIONS

There are a number of IEEE-488 controllers available, each of which has its own programming language. Also, different instruments have differing capabilities. In this section, we will discuss programming languages for two typical controllers: the HP-85, and the IBM-PC interfaced to the bus through a Keithley Model 8573 IEEE-488 interface. In addition, interface functions codes that define Model 617 capabilities will be discussed.

3.8.1 Controller Handler Software

Before a specific controller can be used over the IEEE-488 bus, it must have IEEE-488 handler software installed. With some controllers, the software is located in ROM, and no software initialization is required on the part of the user. With other controllers, software must be loaded from disk or tape and be properly initialized. With the HP-85, for example, an additional I/O ROM that handles interface functions must be installed. With the Keithley Model 8573 interface for the IBM-PC, software must be installed and configured from a diskette.

Other small computers that can be used as IEEE-488 controllers may have limited capabilities. With some, interface programming functions may depend on the interface being used. Often little software "tricks" are required to obtain the desired results.

From the preceding discussion, the message is clear: make sure the proper software is being used with the interface. Often, the user may incorrectly suspect that the hardware is causing a problem when it was the software all along.

3.8.2 Interface BASIC Programming Statements

Many of the programming instructions covered in this section use examples written with Hewlett Packard Model 85 BASIC and Model 8573 Interface statements. These computers and interfaces were chosen for these examples because of their versatility in controlling the IEEE-488 bus. This section covers those HP-85 and Model 8573 statements that are essential to Model 617 operation.

A partial list of HP-85 and Model 8573 statements is shown in Table 3-6. HP-85 statements have a one or three digit argument that must be specified as part of the statement. The first

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digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address.

Those statements with a 3-digit argument listed in the table shown a primary address of 27 (the default primary address of the Model 617). For a different address, you would, of course, change the last two digits to the required value. For example, to send a GTL command to a device using a primary address of 22, the following statement would be used: LOCAL 722.

Some of the statements have two forms; the exact configuration depends on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command, while CLEAR 727 sends the SDC command to a device with a primary address of 27.

The Model 8573 statements, which are also listed in Table 3-6, take on a somewhat different form. Each of these statements uses the IBM BASIC CALL statement, with various variables passed as shown in the table. The command words, such as IBCLR (Interface Bus Clear) and IBSRE (Interface Bus Send Remote Enable), are, in fact, BASIC variables themselves, which must be initialized at the start of each BASIC program. In addition, you must remember not to use these keywords for any other purpose in your BASIC program.

Before using the Model 8573 examples throughout this section, you must configure the software by using the procedure below. Note that the binary handler file called GPIB.COM and the system configuration file called CONFIG.SYS must be present on the DOS boot disk, as described in the Model 8573 Instruction Manual.

1. Boot up your system in the usual manner and enter BASICA.
2. Place the Model 8573 software disk into the default drive and load the program called "DECL.BAS". Modify the program by changing the XXXXX values in lines 1 and 2 to 16000.
3. Add the following lines to the declaration file:
   7 NA$="GPIB0":CALL IBFIND(NA$,BRD0%)
   8 NA$="DEV0":CALL IBFIND(NA$,M617%)
   9 V%=27:CALL IBPAD(M617%,V%)
4. Now save the modified declaration file for future use. Remember that you must load and run this short program before using the Model 8573 programming examples throughout this section. Also, do not use the BASIC CLEAR or NEW commands after running this program.

Table 3-6. BASIC Statements Necessary to Send Bus Commands

Action	HP-85 Statement	Model 8573 Statement
Transmit string to device 27.	OUTPUT 727;A$	CALL IBWRT (M617%, CMD$)
Obtain string from device 27.	ENTER 727; A$	CALL IBRD (M617%, RD$)
Send GTL to device 27.	LOCAL 727	CALL IBLOC (M617%)
Send SDC to device 27.	CLEAR 727	CALL IBCLR (M617%)
Send DCL to all devices.	CLEAR 7	CMD$=CHR$ (&H14): CALL IBCMD (BRD0%, CMD$)
Send remote enable.	REMOTE 7	V%=1: CALL IBSRE (BRD0%, V%)
Cancel remote enable.	LOCAL 7	V%=0: CALL IBSRE (BRD0%, V%)
Serial poll device 27.	SPOLL (727)	CALL IBRSP (M617%, SB%)
Send local lockout.	LOCAL LOCKOUT 7	CMD$=CHR$ (&H11): CALL IBCMD (BRD0%, CMD$)
Send GET to device.	TRIGGER 727	CALL IBTRG (M617%)
Send IFC.	ABORTIO 7	CALL IBSIC (BRD0%)

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3.8.3 Interface Function Codes

The interface functions codes, which are part of the IEEE-488-1978 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 617 are listed in Table 3-7. These codes are also listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 617 capabilities as follows:

SH (Source Handshake Function)—SH1 defines the ability of the Model 617 to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function)—AH1 defines the ability of the Model 617 to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function)—The ability of the Model 617 to send data over the bus to other devices is provided by the T function. Model 617 talker capabilities exist only after the instrument has been addressed to talk, or when it has been placed in the talk-only mode.

L (Listener Function)—The ability for the Model 617 to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities of the Model 617 exist only after the instrument has been addressed to listen.

SR (Service Request Function)—The SR function defines the ability of the Model 617 to request service from the controller.

RL (Remote-Local Function)—The RL function defines the ability of the Model 617 to be placed in the remote or local modes.

PP (Parallel Poll Function)—The Model 617 does not have parallel polling capabilities.

DC (Device Clear Function)—The DC function defines the ability of the Model 617 to be cleared (initialized).

DT (Device Trigger Function)—The ability for the Model 617 to have its readings triggered is provided by the DT function.

C (Controller Function)—The Model 617 does not have controller capabilities.

TE (Extended Talker Function)—The Model 617 does not have extended talker capabilities.

LE (Extended Listener Function)—The Model 617 does not have extended listener capabilities.

E (Bus Driver Type)—The Model 617 has open-collector bus drivers.

Table 3-7. Model 617 Interface Function Codes

Code	Interface Function
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T5	Talker (Basic Talker, Serial Poll, Talk Only Mode, Unaddressed To Talk On LAG)
L4	Listener (Basic Listener, Unaddressed To Listen On TAG)
SR1	Service Request Capability
RL1	Remote/Local Capability
PP0	No Parallel Poll Capability
DC1	Device Clear Capability
DT1	Device Trigger Capability
C0	No Controller Capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker Capabilities
LE0	No Extended Listener Capabilities

3.8.4 IEEE Command Groups

Command groups supported by the Model 617 are listed in Table 3-8. Device dependent commands, which are covered in paragraph 3.10, are not included in this list.

3.9 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general meaning regardless of the instrument type. Commands supported by the Model 617 are listed in Table 3-9, which also lists both HP-85 and Model 8573 statements necessary to send each command. Note that commands requiring that a primary address be specified assume that the Model 617 primary address is set to 27 (its default address). If you are using Model 8573 programming examples, remember that the modified declaration file must be loaded and run first, as described in paragraph 3.8.2.

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Table 3-8. IEEE Command Groups

HANDSHAKE COMMAND GROUP
DAC = DATA ACCEPTED
RFD = READY FOR DATA
DAV = DATA VALID
UNIVERSAL COMMAND GROUP
ATN = ATTENTION
DCL = DEVICE CLEAR
IFC = INTERFACE CLEAR
LLO = LOCAL LOCKOUT
REN = REMOTE ENABLE
SPD = SERIAL POLL DISABLE
SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP
LISTEN: LAG = LISTEN ADDRESS GROUP
MLA = MY LISTEN ADDRESS
UNL = UNLISTEN
TALK: TAG = TALK ADDRESS GROUP
MTA = MY TALK ADDRESS
UNT = UNTALK
OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP
ACG = ADDRESSED COMMAND GROUP
GET = GROUP EXECUTE TRIGGER
GTL = GO TO LOCAL
SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP
RQS = REQUEST SERVICE
SRQ = SERIAL POLL REQUEST
STB = STATUS BYTE
EOI = END

3.9.1 REN (Remote Enable)

The remote enable command is sent to the Model 617 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true will not actually place the instrument in the remote mode. Instead the intrument must be addressed after setting REN true before it will go into remote.

To place the Model 617 in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 617 to listen.

HP-85 Programming Example—This sequence is automatically performed by the HP-85 when the following is typed into the keyboard.

```
REMOTE 727 (END LINE)
```

After the END LINE key is pressed, the Model 617 will be in the remote mode, as indicated by the REMOTE light. If not, check to see that the instrument is set to the proper primary address (27), and check to see that the bus connections are properly made.

Model 8573 Programming Example—To place the Model 617 into the remote mode, type the following lines into the computer.

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="X":CALL IBWRT(M617%,CMD$) (return)
```

Table 3-9. General Bus Commands and Associated BASIC Statements

Command	HP-85 Statement	Model 8573 Statement	Affect On Model 617
REN	REMOTE 7	V% = 1:CALL IBSRE (BRD0%, V%)	Goes into remote when next addressed.
IFC	ABORTIO 7	CALL IBSIC (BRD0%)	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	CMD$ = CHR$ (&H11): CALL IBCMD (M617%, CMD$)	Front panel controls locked out.
GTL	LOCAL 727	CALL IBLOC (M617%)	Cancel remote.
DCL	CLEAR 7	CMD$ = CHR$(&H14): CALL IBCMD (M617%, CMD$)	Returns to default conditions.
SDC	CLEAR 727	CALL IBCLR (M617%)	Returns to default conditions.
GET	TRIGGER 727	CALL IBTRG (M617%)	Triggers reading in T2 and T3 modes.
	LOCAL 7	V% = 0: CALL IBSRE (BRD0%, V%)	Cancel LLO

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The instrument will go into the remote mode when the return key is pressed the second time.

3.9.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 617 in the local, talker and listener idle states. The unit will respond to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

HP-85 Programming Example—Before demonstrating the IFC command, turn on the TALK indicator with the following statements:

```
REMOTE 727 (END LINE)
ENTER 727;A$ (END LINE)
```

At this point, the REMOTE and TALK lights should be on. The IFC command can be sent by typing in the following statement into the HP-85:

```
ABORTIO 7 (END LINE)
```

After the END LINE key is pressed, the REMOTE and TALK lights will turn off, indicating that the instrument has gone into the talker idle state.

Model 8573 Programming Example—Place the instrument in the remote and talker active states with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$=CHR$(&H5B):CALL  IBCMD(BRD0%,CMD$)
(return)
```

After the return key is pressed the second time, the instrument should be in the remote and talker active states, as indicated by the respective indicators.

To send IFC, enter the following statement into the IBM-PC:

```
CALL IBSIC(BRD0%) (return)
```

After the return key is pressed, the instrument will return to the local and talker idle states.

3.9.3 LLO (Local Lockout)

The LLO command is used to remove the instrument from the local operating mode. After the unit receives LLO, all its front panel controls except POWER will be inoperative. REN must be true for the instrument to respond to LLO. REN must be set false to cancel LLO.

To send the LLO command, the controller must perform the following steps:

1. Set ATN true.
2. Place the LLO command on the data bus.

HP-85 Programming Example—The LLO command is sent by using the following HP-85 statement:

```
REMOTE 7 (END LINE)
LOCAL LOCKOUT 7 (END LINE)
```

After the second statement is entered, the instrument's front panel controls will be locked out.

Model 8573 Programming Example—To send the LLO command from the IBM-PC, type in the following statement:

```
V%=1: CALL IBSRE (BRD0%, V%) (RETURN)
CMD$=CHR$(&H11):CALL  IBCMD$(BRD0%,CMD$)
(return)
```

After the return key is pressed, Model 617 front panel controls will be locked out.

3.9.4 GTL (Go To Local) and Local

The GTL command is used to take the instrument out of the remote mode. With some instruments, GTL may also cancel LLO. With the Model 617, however, REN must first be placed false before LLO will be cancelled.

To send GTL, the controller must perform the following sequence.

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1. Set ATN true.
2. Address the Model 617 to listen.
3. Place the GTL command on the bus.

HP-85 Programming Example—Place the instrument in the remote mode with the following statement:

REMOTE 727 (END LINE)

Now send GTL with the following statement:

LOCAL 727 (END LINE)

When the END LINE key is pressed, the front panel REMOTE indicator goes off, and the instrument goes into the local mode. To cancel LLO, send the following:

LOCAL 7 (END LINE)

Model 8573 Programming Example—Place the instrument in the remote mode with the following statements:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="X":CALL IBWRT(M617%,CMD$) (return)

Now send GTL with the following statement:

CALL IBLOC(M617%) (return)

After return is pressed, the REMOTE indicator turns off, and the instrument goes into the local mode. To cancel LLO, send the following:

V%=0: CALL IBSRE (M617%, V%) (return)

3.9.5 DCL (Device Clear)

The DCL command may be used to clear the Model 617 and return it to its power-up default conditions. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 617 receives a DCL command, it will return to the default conditions listed in Table 3-10.

To send the DCL command, the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command byte on the data bus.

HP-85 Programming Example—Place the instrument in the amps mode and cancel autorange with the front panel controls. Now enter the following statement into the HP-85 keyboard:

CLEAR 7 (END LINE)

When the END LINE key is pressed, the instrument returns to the default conditions listed in Table 3-10.

Model 8573 Programming Example—Place the unit in the amps function, and cancel autorange with the front panel controls. Now enter the following statement into the IBM computer:

CMD$=CHR$(&H14):CALL IBCMD(BRD0%,CMD$)
(return)

When the return key is pressed, the instrument returns to the default conditions listed in Table 3-10.

3.9.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only a single, selected instrument instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 617 receives the SDC command, it will return to the power-up default conditions listed in Table 3-10.

Table 3-10. Default Conditions*

Mode	Default Value	Status
Function	F0	Volts
Range	R0	Autorange
Zero Check	C1	Enabled
Zero Correct	Z0	Disabled
Suppression	N0	Disabled
Trigger	T6	Continuous External
Voltage Source Operate	O0	Output off
Read Mode	B0	Electrometer
Data Format	G0	Prefix, no suffix
Display	D0	Electrometer
Data Store	Q7	Disabled
SRQ Mode	M00	Disabled
EOI and Bus Hold-off	K0	Both Enabled
Terminator	Y(CR LF)(=:)	CR LF

*(Status Upon Power-Up or After DCL or SDC)
Obtained with U0 command

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To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 617 to listen.
3. Place the SDC command on the data bus.

HP-85 Programming Example—Using the front panel controls, place the instrument in the amps mode and cancel autorange. Enter the following statement into the HP-85:

CLEAR 727 (END LINE)

After END LINE is pressed, the instrument returns to the power up default conditions listed in Table 3-10.

Model 8573 Programming Example—Place the instrument in the amps function and cancel autorange with the front panel controls. Now enter the following statement into the IBM-PC:

CALL IBCLR(M617%) (return)

After the return key is pressed, the instrument returns to the default conditions listed in Table 3-10.

3.9.7 GET (Group Execute Trigger)

GET may be be used to trigger the Model 617 to take readings if the instrument is placed in the appropriate trigger mode (more information on trigger modes may be found in paragraph 3.10.14).

To send GET, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 617 to listen.
3. Place the GET command byte on the data bus.

HP-85 Programming Example—Type in the following statements into the HP-85 keyboard to place the instrument in remote and enable the correct trigger mode for this demonstration:

REMOTE 727 (END LINE)
OUTPUT 727; "T3X" (END LINE)

Now send the GET command with the following statement:

TRIGGER 727 (END LINE)

When the END LINE key is pressed, the instrument will process a single reading.

Model 8573 Programming Example—Type in the following statements to make sure the instrument is in the remote and correct trigger modes for purposes of this demonstration:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="T3X":CALL IBWRT(M617%,CMD$)(return)

Now send GET to the instrument with the following statement:

CALL IBTRG(M617%) (return)

When the return key is pressed, the instrument will process a single reading.

3.9.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 617 status byte. The status byte contains important information about internal functions, as described in paragraph 3.10.15. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 617.

The serial polling sequence is conducted as follows:

1. The controller sets ATN true.
2. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll mode and waiting to be addressed.
3. The Model 617 is then addressed to talk.
4. The controller sets ATN false.
5. The instrument then places its status byte on the data bus, at which point it is read by the controller.
6. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

Once instruments are in the serial poll mode, steps 3 through 5 above can be repeated by sending the correct talk address for each instrument. ATN must be true when the address is transmitted and false when the status byte is read.

HP-85 Programming Example—The HP-85 SPOLL statement automatically performs the sequence just described. To demonstrate serial polling, type in the following statements into the HP-85:

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```
REMOTE 727 (END LINE)
S=SPOLL(727) (END LINE)
DISP S (END LINE)
```

When the END LINE key is pressed the second time, the computer conducts the serial polling sequence. The decimal value of the status byte is then displayed on the computer CRT when the END LINE key is pressed the third time. More information on the status byte may be found in paragraph 3.10.15.

Model 8573 Programming Example—Use the following sequence to serial poll the instrument and display the decimal value of the status byte on the computer CRT:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CALL IBRSP(M617%,SB%) (return)
PRINT SB% (return)
```

When the return key is pressed the second time, the serial polling sequence is conducted. The status byte value is displayed when the return key is pressed the third time.

3.10 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 617 to control various operating modes such as function, range, trigger mode, and data format. Each command is made up of a single ASCII letter followed by a number representing an option of that command. For example, a command to control the measuring function (Volts, Ohms, Amps, Coul) is programmed by sending an ASCII "F" followed by a number representing the function option. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

A number of commands may be grouped together in one string. A command string is usually terminated with an ASCII "X" character, which tells the instrument to execute the command string. Commands sent without the execute character will not be executed at that time, but they will be retained within an internal command buffer for execution at the time the X character is received. If any errors occur, the instrument will display appropriate front panel error messages and generate an SRQ if programmed to do so.

Commands that affect the electrometer section (F, R, C, Z, N, T, and A) will trigger a reading when the command is executed. These bus commands affect the Model 617 much like the front panel controls. Note that commands are not necessarily executed in the order received; instead, they will be executed in the same order as they appear in the status word:

Function (F); Range (R); Zero Check (C); Zero Correct (Z); Suppress (N); Trigger (T); Voltage Source Operate (O): Read Mode (B); Display Mode (D); Data Storage (Q); SRQ Mode (M); EOI and Bus Hold-off (K); and Terminator (Y). Thus to force a particular command sequence, you would follow each command with the execute character, as in the example string, C1XZ1XCOX, which can be used to zero correct the instrument.

These programming aspects are covered at the end of this paragraph.

Device-dependent commands can be sent either one at a time, or in groups of several commands within a single string. Some examples of valid command strings include:

F0X Single command string.
F0K1D0R0X Multiple command string.
T6 X Spaces are ignored.

Typical invalid command strings include:

H1X Invalid command, as H is not one of the instrument commands.
F9X Invalid command option because 9 is not an option of the F command.

If an illegal command (IDDC), illegal command option (IDDCO), is sent, or if a command string is sent with REN false, the string will be ignored.

Device-dependent commands that control the Model 617 are listed in Table 3-11. These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands with both the HP-85 and the IBM-PC/8573.

NOTE
Programming examples assume that the Model 617 is at its factory default value of 27.

In order to send a device-dependent command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 617 to listen.
3. Set ATN false.
4. Send the command string over the bus one byte at a time.

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NOTE

REN must be true when sending device-dependent commands to the instrument, or it will ignore the command and display a bus error message.

General HP-85 Programming Example—Device-dependent commands may be sent from the HP-85 with the following statement:

```
OUTPUT 727; A$
```

A$ in this case contains the ASCII characters representing the command string.

General Model 8573 Programming Example—Use the following general syntax to send device-dependent commands from the IBM-PC:

```
CALL IBWRT(M617%,CMD$)
```

Again, CMD$ contains the command letters to program the instrument. Remember that the modified declaration file must be loaded and run before using any of the programming examples.

3.10.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 617 to execute other device-dependent commands such as F (function) or R (range). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain circumstances where it is desirable to send a command string at one time, and then send the execute character later on. Command strings sent without the execute character will be stored within an internal command buffer for later execution. When the X character is finally transmitted, the stored commands will be executed, assuming that all commands in the previous string were valid.

HP-85 Programming Example—Enter the following statements into the HP-85 keyboard:

```
REMOTE 727 (END LINE)
OUTPUT 727;"X" (END LINE)
```

When the END LINE key is pressed the second time, the X character will be transmitted to the instrument. No mode changes will occur with this example because no other commands were sent. Note that the instrument remains in the listener active state after the command is transmitted.

Model 8573 Programming Example—Enter the following statements into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="X":CALL IBWRT(M617%,CMD$) (return)
```

When the return key is pressed the second time, the X character is transmitted to the instrument, although no mode changes occur because no other commands are transmitted. Note that the instrument remains in the listener idle state after the command is transmitted because IBWRT automatically sends UNT (Untalk) and UNL (Unlisten) at the end of the transmission sequence.

3.10.2 Function (F)

The function command allows you to select the type of measurement made by the Model 617. The parameter options associated with the function command set the instrument to measure voltage, current, resistance, charge, external feedback, or V/I ohms. When the instrument responds to a function command, it will be ready to take a reading once the front end is set up. The function may be programmed by sending one of the following commands:

F0=Volts
F1=Amps
F2=Ohms
F3=Coulombs
F4=External Feedback
F5=V/I Ohms

Upon power-up, or after the instrument receives a DCL or SDC command, the F0 (Volts) mode will be enabled.

HP-85 Programming Example—Place the instrument in the current function with the front panel AMPS button and enter the following statements into the HP-85 keyboard:

```
REMOTE 727 (END LINE)
OUTPUT 727;"F0X" (END LINE)
```

When END LINE is pressed the second time, the instrument changes to the volts mode, as indicated by the associated LED.

Model 8573 Programming Example—Place the instrument into the current mode with the front panel AMPS button. Now type the following statements into the computer keyboard:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="F0X":CALL IBWRT(M617%,CMD$) (return)
```

When the return key is pressed the second time, the instrument changes to the volts function.

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Table 3-11. Device-Dependent Command Summary

Mode	Command	Description	Paragraph
Execute	X	Execute other device-dependent commands.	3.10.1
Function	F0	Volts	3.10.2
	F1	Amps	
	F2	Ohms	
	F3	Coulombs	
	F4	External Feedback	
	F5	V/I Ohms	
Range		Volts Amps Ohms Coulombs External Feedback V/I Ohms	3.10.3
	R0	Auto Auto Auto Auto Auto Auto	
	R1	200mV 2 pA 2 kΩ 200 pC 200mV 200TΩ	
	R2	2 V 20 pA 20 kΩ 2 nC 2 V 20TΩ	
	R3	20 V 200 pA 200 kΩ 20 nC 20 V 2TΩ	
	R4	200 V 2 nA 2MΩ 20 nC 20 V 200GΩ	
	R5	200 V 20 nA 20MΩ 20 nC 20 V 20GΩ	
	R6	200 V 200 nA 200MΩ 20 nC 20 V 2GΩ	
	R7	200 V 2 μA 2GΩ 20 nC 20 V 200MΩ	
	R8	200 V 20 μA 20GΩ 20 nC 20 V 20MΩ	
	R9	200 V 200 μA 200GΩ 20 nC 20 V 2MΩ	
	R10	200 V 2mA 200GΩ 20 nC 20 V 200 kΩ	
	R11	200 V 20mA 200GΩ 20 nC 20 V 200 kΩ	
	R12	Cancel autoranging for all functions	
Zero Check	C0	Zero Check Off	3.10.4
	C1	Zero Check On	
Zero Correct	Z0	Zero Correct Disabled	3.10.4
	Z1	Zero Correct Enabled	
Baseline Suppression	N0	Suppression Disabled	3.10.5
	N1	Suppression Enabled	
Display Mode	D0	Electrometer	3.10.6
	D1	Voltage Source	
Reading Mode	B0	Electrometer	3.10.7
	B1	Buffer Reading	
	B2	Maximum Reading	
	B3	Minimum Reading	
	B4	Voltage Source	
Data Store	Q0	Conversion rate	3.10.8
	Q1	One Reading Per Second	
	Q2	One Reading Every 10 Seconds	
	Q3	One Reading Per Minute	
	Q4	One Reading Every 10 Minutes	
	Q5	One Reading Per Hour	
	Q6	Trigger Mode	
	Q7	Disabled	
Voltage Source Value	V+nnn.nn or V+n.nnnnE+n	Voltage Source Value: −102.35V to +102.4V, 50mV increments	3.10.9
Voltage Source Operate	O0	Source Output Off (0V)	3.10.10
	O1	Source Output On (Programmed Value)	
Calibration Value	A+nnn.nn or An.nnnE+n	Calibrate Function and Range	3.10.11
Store Calibration	L1	Store Calibration Constants in NVRAM	3.10.12

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Table 3-11. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Data Format	G0	Reading with Prefix (NDCV −1.23456E+00)	3.10.13
	G1	Reading without Prefix (−1.23456E+00)	
	G2	Reading with Prefix and Buffer Suffix (if in B1) (NDCV−1.23456E+00, 012)	
Trigger Mode	T0	Continuous, Trigger by Talk	3.10.14
	T1	One-Shot, Trigger by Talk	
	T2	Continuous, Trigger by GET	
	T3	One-Shot, Trigger by GET	
	T4	Continuous, Trigger by X	
	T5	One-Shot, Trigger by X	
	T6	Continuous, Trigger by External Trigger	
	T7	One-Shot, Trigger by External Trigger	
SRQ	M0	Disable SRQ	3.10.15
	M1	Reading Overflow	
	M2	Buffer Full	
	M8	Reading Done	
	M16	Ready	
	M32	Error	
EOI and Bus Hold Off	K0	Enable EOI and Bus Hold-off On X	3.10.16
	K1	Disable EOI, Enable Bus Hold-off On X	
	K2	Enable EOI, Disable Bus Hold-off On X	
	K3	Disable both EOI and Bus Hold-off On X	
Terminator	Y(LF CR)	Terminator = LF CR	3.10.17
	Y(CR LF)	Terminator = CR LF	
	Y(ASCII)	Terminator = ASCII Character	
	YX	No Terminator	
Status Word	U0	Send Status Format: 617 FRRCZNTOBGDQMMKYY	3.10.18
	U1	Error Conditions	
	U2	Data Conditions	

3.10.3 Range (R)

The range command gives the user control over the sensitivity of the instrument. This command, and its options, perform essentially the same functions as the front panel AUTO and up and down range buttons. Range command parameters and the respective ranges for each measuring function are summarized in Table 3-12. The instrument will be ready to take a reading after the range is set up when responding to a range command.

Upon power up, or after receiving a DCL or SDC command, the instrument will be in the R0 (autorange) mode.

HP-85 Programming Example—Make sure the instrument is in the autorange mode and then enter the following statements into the HP-85:

```
REMOTE 727 (END LINE)
OUTPUT 727;"R3X" (END LINE)
```

When the END LINE key is pressed the second time, the instrument cancels the autorange mode, and enters the R3 range instead.

Model 8573 Programming Example—Make sure the instrument is in the autorange mode. Now enter the following statements into the IBM-PC keyboard:

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V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="R3X":CALL IBWRT(M617%,CMD$) (return)

When the return key is pressed the second time, the instrument cancels the autorange mode and switches to the R3 range.

3.10.4 Zero Correct and Zero Check (Z and C)

The zero correct and zero check commands work together to cancel any internal offsets that might upset accuracy. If the instrument is placed in the zero correct mode with zero check enabled, it will store a new offset value to be used for subsequent readings. If the instrument is zero corrected with zero check disabled, the previously stored zero value will be used instead. Note that the specifications at the front of this manual assume that the instrument has been properly zeroed. Zero correct and zero check commands include:

C0=Zero check off
C1=Zero check on

Z0=Zero correct off
Z1=Zero correct on

The instrument will be ready on reading done (zero correct) or when the front end is set up (zero check). Upon power up, or after receiving a DCL or SDC command, the unit will be in the C1 and Z0 modes (zero check on and zero correct off).

Use the following procedure to zero the instrument:

1. With zero correct off, place the instrument in zero check by sending C1X.
2. Zero correct the instrument by sending Z1X.
3. Disable zero check by sending C0X. Readings can then be taken in the usual manner.

HP-85 Programming Example—Enter the following lines into the HP-85 computer:

REMOTE 727 (END LINE)
OUTPUT 727;"C1XZ1XC0X" (END LINE)

When END LINE is pressed the second time, the instrument is first placed in zero check, the unit is zero corrected, and the zero check mode is then disabled.

Model 8573 Programming Example—Enter the following statements into the IBM computer:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="C1XZ1XC0X":CALL IBWRT(M617%,CMD$) (return)

The zero check and zero correct sequence will be performed when the return key is pressed the second time.

Table 3-12. Range Command Summary

Command	Range					
	Volts	Amps	Ohms	Coulombs	External Feedback	V/I* Ohms
R0	Auto	Auto	Auto	Auto	Auto	Auto
R1	200mV	2 pA	2 kΩ	200pC	200mV	200TΩ
R2	2 V	20 pA	20 kΩ	2nC	2 V	20TΩ
R3	20 V	200 pA	200 kΩ	20nC	20 V	2TΩ
R4	200 V	2 nA	2MΩ	20nC	20 V	200GΩ
R5	200 V	20 nA	20MΩ	20nC	20 V	20GΩ
R6	200 V	200 nA	200MΩ	20nC	20 V	2GΩ
R7	200 V	2 μA	2GΩ	20nC	20 V	200MΩ
R8	200 V	20 μA	20GΩ	20nC	20 V	20MΩ
R9	200 V	200 μA	200GΩ	20nC	20 V	2MΩ
R10	200 V	2mA	200GΩ	20nC	20 V	200 kΩ
R11	200 V	20mA	200GΩ	20nC	20 V	200 kΩ
R12	Cancel Auto	Cancel Auto	Cancel Auto	Cancel Auto	Cancel Auto	Cancel Auto

*Full range value based on 100V/10,000 displayed counts of current.

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3.10.5 Baseline Suppression (N)

The baseline suppression mode allows a stored offset value to be subtracted from subsequent readings. When the suppression mode is enabled with the appropriate command, the instrument will internally store the baseline value with the next triggered conversion. All subsequent readings will be the difference between the stored baseline value and the actual signal level. For example, if 100mV is stored as a baseline, that value will be subtracted from the following readings. See paragraph 2.11.2 for a complete description.

To use baseline suppression, perform the following steps:

1. Cancel baseline suppression by sending N0X if already enabled.
2. Select a range and function consistent with the expected measurement.
3. Connect the signal to be used as a baseline to the instrument input.

WARNING

The voltage present on the input terminals may be larger than the displayed value. For example, if a 150VDC baseline is stored, an applied voltage of +175V will result in a displayed reading of only +25V

4. Enable baseline suppression by sending N1X over the bus. The baseline will be stored when the command is executed.
5. Disconnect the baseline signal from the instrument and connect the signal to be measured in its place. Subsequent readings will be the difference between the baseline and the applied signal.

NOTES:

1. Baseline suppression reduces the dynamic range of the measurement. For example, if the stored baseline value is 100mV on the 200mV range, an input voltage of 100mV or more would overrange the instrument even though voltages up to 199.99mV are normally within the capabilities of the 200mV range. If the instrument is in the autorange mode, it will move up range if necessary.
2. Setting the range lower than the stored baseline value will overrange the instrument.
3. Accurate control over when the baseline is actually stored may be achieved by placing the instrument in a one shot trigger mode. Once the desired baseline value is connected to the instrument, the baseline can be stored by sending N1X.
4. Function changes cancel baseline suppress. Refer to paragraph 2.11.2 for details concerning suppress.

HP-85 Programming Example—To enable baseline suppression, type in the following lines:

```
REMOTE 727 (END LINE)
OUTPUT 727;"N1X" (END LINE)
```

When the END LINE key is pressed the second time, the baseline suppression mode is enabled.

Model 8573 Programming Example—Type the following commands into the HP-85 keyboard in order to enable baseline suppression:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="N1X":CALL IBWRT(M617%,CMD$) (return)
```

The baseline suppression mode will be enabled when the return key is pressed the second time.

3.10.6 Display Mode (D)

The two parameters associated with the display mode command control whether the front panel display shows the electrometer reading or the voltage source value. Thus, this command performs essentially the same function as the front panel DISPLAY button. The two display command parameters are:

D0=Electrometer
D1=Voltage source

Upon power up, or after receiving a DCL or SDC command, the instrument will be in the D0 (electrometer) mode.

NOTE

When in the D1 mode, sending an electrometer command (F, R, C, Z, N, or T) will cause the instrument to revert to the D0 (electrometer) mode.

To program the desired display mode over the bus, you need only send the appropriate command string. For example, D1X would be transmitted to view the voltage source value on the display.

HP-85 Programming Example—Using the front panel DISPLAY button place the display in the electrometer mode. Now type in the following lines:

```
REMOTE 727 (END LINE)
OUTPUT 727;"D1X" (END LINE)
```


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When the END LINE key is pressed the second time, the display shows the voltage source value.

Model 8573 Programming Example—Momentarily power down the instrument and then enter the following lines into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="D1X":CALL IBWRT(M617%,CMD$) (return)
```

Note that the instrument changes from the electrometer display mode to the voltage source display mode when the return key is pressed the second time.

3.10.7 Reading Mode (B)

The reading mode command parameters allow the selection of the source of data that is transmitted over the IEEE-488 bus. Through this command, you have a choice of data from the electrometer, voltage source, data store reading, or minimum and maximum values. Note that the commands associated with data store are always available; however the suffix of the reading string will show 000 if data store is disabled, as in NDCV +1.2345E+00,000. Minimum/maximum values returned will be the last values stored, unless these parameters are requested after a DCL, in which case unuseable readings will be returned.

Parameters associated with the reading mode include:

B0=Electrometer
B1=Data store reading
B2=Maximum reading
B3=Minimum reading
B4=Voltage source value.

Upon power up, or after receiving a DCL or SDC command, the unit will be in the B0 (electrometer) mode.

When in B0, normal electrometer readings will be sent. In a continuous trigger mode, readings will be updated at the conversion rate (one reading every 360msec. In B1, readings will be taken from consecutive data store locations, beginning with the oldest reading and progressing to the newest reading until all readings currently stored have been read. Once all readings have been requested, the unit will cycle back and begin again. These readings may be accessed even if data store is still taking place.

While data store is enabled, the maximum (most positive) and minimum (most negative) readings may also be requested by sending the B2 or B3 commands. Note that the maximum and minimum values are updated at the maximum reading rate while data store is enabled. See paragraph 3.10.8 for a complete description of data storage.

The voltage source value is returned in a similar manner by sending B4X. Once the desired reading mode has been selected, the data string can be read by addressing the instrument to talk and reading the bytes in the string in the normal manner.

HP-85 Programming Example—Use the following sequence to read the voltage source value and display it on the computer CRT:

```
REMOTE 727 (END LINE)
OUTPUT 727;"B4X" (END LINE)
ENTER 727; A$ (END LINE)
DISP A$ (END LINE)
```

The second command above changes the reading mode to access the voltage source, while the third and fourth statements acquire the reading and display it on the CRT.

Model 8573 Programming Example—To display the voltage source value on the computer CRT, enter the following program statements into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="B4X":CALL IBWRT(M617%,CMD$) (return)
RD$=SPACE$(25):CALL IBRD(M617%,RD$) (return)
PRINT RD$ (return)
```

The second statement above programs the reading mode to access the voltage source value. The third statement addresses the instrument to talk and reads the data string from the instrument, while the fourth statement prints the data string on the computer CRT.

3.10.8 Data Store Mode

The data store commands enter the data storage mode and allow you to store up to 100 readings with internal memory of the Model 617. By entering an appropriate parameter, readings may be stored at one of six intervals between the conversion rate and one reading per hour. Either during or after the storage process, readings, including maximum and minimum values, may be recalled by using the B command as described in the last paragraph.

Once the unit has logged all 100 readings, the instrument will stop data storage until another Q command is sent to enable

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data store once again. Note that the instrument may be programmed to generate an SRQ when memory is full, as described in paragraph 3.10.15.

The available storage intervals include:

Q0=Conversion rate (one reading every 360msec)
Q1=One reading per second
Q2=One reading every 10 seconds
Q3=One reading per minute
Q4=One reading every 10 minutes
Q5=One reading per hour.
Q6=Trigger mode (TRIG button)
Q7=Data store disabled

In addition to the various rates, data store can be used at a rate determined by the TRIG button (Q6 mode). When in this mode, one reading will be stored in memory each time TRIG button is operated.

Upon power up, or after a DCL or SDC command, the data store will be disabled (Q7 mode.)

NOTES:
1. To use data store on a one-shot basis with other trigger stimuli, place the instrument in the Q0 mode and select the desired one-shot trigger mode (paragraph 3.10.14).
2. In Q0 and Q1, the storage rate may be decreased if the instrument is in autorange and a range change occurs.

HP-85 Programming Example—Enter the program below to enable data store operation and obtain and display 100 readings on the computer CRT:

PROGRAM	COMMENTS
10 DIM A$ [25]	
20 REMOTE 727	Send remote enable
30 OUTPUT 727;"Q0X"	Enable data store at conversion rate.
40 S=SPOLL(727)	Serial poll the 617.
50 IF NOT BIT(S,1) THEN 40	If not full, wait.
60 OUTPUT 727;"B1G2X"	Set read mode to data store.
70 FOR I = 1 TO 100	Loop 100 times.
80 ENTER 727;A$	Get a reading.
90 DISP A$	Display it.
100 NEXT I	Loop back and get next reading.
110 END	

After entering the program, press the HP-85 RUN key. The program will enable data store (line 30), wait for memory to fill (lines 40 and 50), turn on the data store output (line 60), and then request and display all 100 readings (lines 70-100).

Model 8573 Programming Example—To demonstrate data store operation, load the modified DECL.BAS file and enter the program lines below:

PROGRAM	COMMENTS
10 NA$="GPIB0":CALL IBFIND (NA$,BRD0%)	Find the board descriptor.
20 NA$="DEV0":CALL IBFIND (NA$,M617%)	Find the instrument descriptor.
30 V%=27:CALL IBPAD (M617%,V%)	Set primary address to 27.
40 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
50 CMD$="Q0X":CALL IBWRT (M617%,CMD$)	Enable data store at conversion rate.
60 CALL IBRSP(M617%,SB%)	Get status byte.
70 IF (SB% AND 2) = 0 THEN 60	If not full, wait.
80 CMD$="B1G2X":CALL IBWRT(M617%,CMD$)	Turn on data store.
90 FOR I = 1 TO 100	Loop 100 times.
100 RD$=SPACE$(25):CALL IBRD(M617%,RD$)	Get a reading.
110 PRINT RD$	Display the reading.
120 NEXT I	Go back and get another.
130 V%=0:CALL IBONL (BRD0%,V%)	Close the board file.
140 CALL IBONL(M617%,V%)	Close the instrument file.

Press the IBM F2 key to run the program. Data store is enabled (line 50), the program waits for memory to fill (lines 60 and 70), the output is turned on (line 80), and all 100 readings are then requested and displayed (lines 90-120).

3.10.9 Voltage Source Value (V)

The voltage source value command allows you to program the built-in voltage source of the Model 617 to between −102.35V and +102.4V in 50mV increments. Normally, the voltage source output is updated at the beginning of each electrometer conversion (every 160msec); however, you can force an immediate update by applying an appropriate trigger stimulus to force the start of a new conversion (see paragraph 3.10.14 for more information on triggering).

The voltage source value is programmed by sending the V

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command letter followed by a maximum of 5½ digits representing the voltage value. The unit will round off the programmed values to 50mV minimum increments. Either normal or scientific representation may be used as indicated below:

Vnnn.nn (normal convention)
Vn.nnnnE+n (scientific notation)

Upon power up or after a DCL or SDC, the source output will be programmed to 00.00V.

Some equivalent examples of these two conventions are shown below:

Normal	Scientific
V25	V2.5E+1
V99.1	V0.99E+2
V0.05	V50E−3
V−11	V−1.1E+1

Note that merely programming the source value does not apply the voltage to the voltage source output terminals. The output must be separately programmed on or off as described in the following paragraph.

HP-85 Programming Example—To program the voltage source to a value of −10V, press the front panel DISPLAY button to view the source value and enter the following statements into the computer:

```
REMOTE 727 (END LINE)
OUTPUT 727;"D1V−10X" (END LINE)
```

When the second statement is executed, the source value is programmed for a value of −10V.

Model 8573 Programming Example—Momentarily power down the instrument and then select the voltage source with the front panel DISPLAY button. Now enter the following statements into the IBM computer:

```
V%=1:CALL IBSRE (BRD0%,V%) (return)
CMD$="D1V−10X":CALL  IBWRT (M617%, CMD$)
(return)
```

The voltage source will be programmed to a value of −10V when the second statement is executed.

3.10.10 Voltage Source Operate (O)

The voltage source operate command performs essentially the same operations as the front panel OPERATE button. The parameters included with this command are:

O0=Source output off (Output =0V)
O1=Source output on (Output = programmed value)

Upon power up, or after receiving a DCL or SDC command, the instrument will be in the O0 (Source off) mode.

Keep in mind that the voltage source has a maximum current output of 2mA; the OPERATE LED will flash if this value is exceeded.

WARNING
Hazardous voltage may be present on the voltage source terminals, depending on the programmed value.

HP-85 Programming Example—Enter the following statements into the HP-85 to program and display the source and turn the output on:

```
REMOTE 727 (END LINE)
OUTPUT 727;"D1V6O1X" (END LINE)
```

When the command string is sent to the instrument, the display mode is changed to view the source value, the source voltage is programmed to +6V, and the source output is turned on.

Model 8573 Programming Example—Enter the following statements into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="D1V6O1X":CALL  IBWRT(M617%,CMD$)
(return)
```

When the command string is sent to the instrument, the display will change to the source mode, the source value will be programmed to a value of +6V, and the source output will be turned on.

3.10.11 Calibration Value (A)

One advanced feature of the Model 617 is its digital calibration capabilities. Instead of the more difficult method of ad-

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justing a number of potentiometers, the user need only apply an appropriate calibration signal and send the calibration value over the bus. The calibration command may take on either of the following forms:

Ann.nnn
An.nnnnE+n

Thus, the following two commands would be equivalent:

A19
A1.9E+1

In this example, the nominal value for the 20V range is being used. Note that only as many significant digits as necessary need be sent. In this case, the exact calibration point is assumed to be 19.000 even though only the first two digits were actually sent.

If the calibration value is outside the allowed range (±6% of nominal value), a number error will occur, as indicated by the following message:

n Err

Once all functions and ranges have been calibrated, permanent storage of calibration parameters must be performed, as described in paragraph 3.10.12.

NOTE

The proper calibration signal must be connected to the instrument before attempting calibration. See Section 7 for complete details on calibrating the instrument either from the front panel or over the bus.

HP-85 Programming Example—The following statements can be used to calibrate the instrument on the 200V range:

```
REMOTE 727 (END LINE)
OUTPUT 727;"A190X" (END LINE)
```

When the second statement is executed, calibration of the 200V range is performed, assuming that the correct calibration value is applied to the instrument.

Model 8573 Programming Example—Use the following statements to send the 200V range calibration value to the instrument:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="A190X":CALL IBWRT(M617%,CMD$) (return)
```

The calibration value is sent to the instrument when the second statement is executed.

3.10.12 Non-Volatile Memory Storage (L)

The Model 617 uses non-volatile (NV) RAM to store calibration parameters. Once the instrument has been calibrated, as described in the last paragraph, the NVRAM storage command should be sent to permanently store these parameters. This procedure is performed by sending the following sequence: L1X. NVRAM storage will take place when the instrument receives this command over the bus. Note that NVRAM storage may be disabled by changing the position of a calibration jumper, as described in Section 7. If the jumper is in the enabled position, all calibration must be properly done, or calibration of all functions and ranges will be affected.

NOTE

Do not perform the following programming examples unless actual NVRAM storage is desired. Unless proper calibrating parameters have been previously programmed, inadvertent use of this command could affect instrument accuracy.

HP-85 Programming Example—Use the following statements to perform NVRAM storage:

```
REMOTE 727 (END LINE)
OUTPUT 727;"L1X" (END LINE)
```

NVRAM storage will be performed when the second statement is executed.

Model 8573 Programming Example—Perform NVRAM storage with the following Model 8573 statements:

```
V%=1:CALL IBSRE(BRD0%,CMD$) (return)
CMD$="L1X":CALL IBWRT(M617%,CMD$) (return)
```

NVRAM storage is performed when the second statement is executed.

3.10.13 Data Format (G)

Through the use of the G command, the format of the data the instrument sends over the bus may be controlled as follows:

G0=Send reading with prefix. Example:NDCV−1.23456E+00

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G1=Send reading without prefix. Example: −1.23456E+00
G2=Send reading with prefix and suffix when in B1 (data store) mode. Example:
NDCV−1.23456E+00,023. In this example, memory location 23 is being accessed.

Upon power up, or after the instrument receives a DCL or SDC command, the instrument will be in the G0 mode.

Figure 3-9 further clarifies the general data format. Note that the prefix defines a normal or overflow reading as well as the measuring function. The mantissa is always 5½ digits, although the most significant digit will assume a value of 2 under overload conditions, except for a current overload in V/I ohms. In V/I ohms, all zeroes will be returned when a current overload condition occurs. Keep in mind that the B command affects the source of the data. See paragraph 3.10.7 for complete details.

If the B4 (voltage source) mode is enabled, the VSRC prefix will be sent.

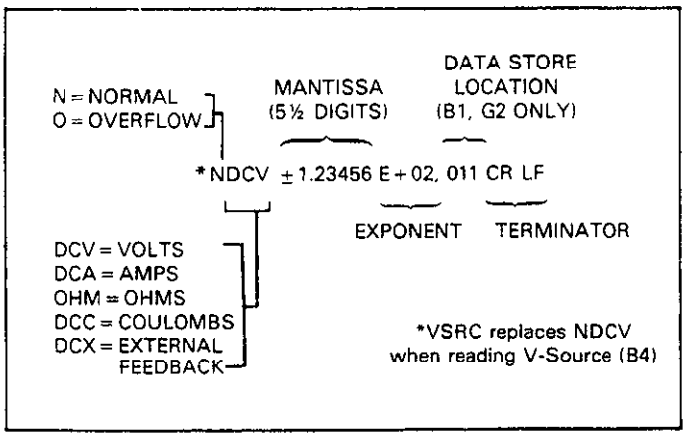


Figure 3-9. General Data Format

HP-85 Programming Example—To place the instrument in the G1 mode and obtain a reading, enter the following statements into the HP-85 keyboard:

REMOTE 727 (END LINE)
OUTPUT 727; "B0XG1X" (END LINE)
ENTER 727;A$ (END LINE)
DISP A$ (END LINE)

When the second statement is executed, the instrument will change to the G1 mode. The last two statements acquire data from the instrument and display the reading string on the CRT. Note that no prefix appears on the data string. The above procedure can be repeated with the G0 command to return to the normal prefix mode.

Model 8573 Programming Example—Type in the following statements to place the instrument in the G1 mode:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="B0XG1X":CALL IBWRT(M617%,CMD$) (return)
RD$=SPACE$(20):CALL IBRD(M617%,CMD$) (return)
PRINT RD$ (return)

When the second statement is executed, the instrument will be placed in the G1 mode. The last two lines obtain the data string from the instrument and display it on the CRT. Note that the prefix is absent from the data string. The instrument may be returned to the prefix mode by repeating the above procedure with the G0 command.

3.10.14 Trigger Mode (T)

Triggering provides a stimulus to begin a reading conversion within the instrument. Triggering may be done in two basic ways: in a continuous trigger mode, a single trigger stimulus is used to re-start a continuous series of readings. In a one-shot mode, a single reading will be processed each time the appropriate trigger simulus is given.

The Model 617 has eight trigger modes as follows:

T0=Continous Mode, Triggered by Talk
T1=One-shot Mode, Triggered by Talk
T2=Continous Mode, Triggered by GET
T3=One-shot Mode, Triggered by GET
T4=Continous Mode, Triggered by X
T5=One-shot Mode, Triggered by X
T6=Continous Mode, Triggered with External Trigger
T7=One-shot Mode, Triggered with External Trigger

Upon power up, or after the instrument receives a DCL or SDC command, the T6 (continous mode, external trigger) mode will be enabled.

The trigger modes are paired according to the type of stimulus that is used to trigger the instrument. In the T0 and T1 modes, triggering is performed by addressing the Model 617 to talk. In the T2 and T3 modes, the IEEE-488 multiline GET command performs the trigger function. The instrument execute (X) character provides the trigger stimulus in the T4 and T5 modes, while a trigger pulse applied to the rear panel EXTERNAL TRIGGER INPUT, triggers the instrument in the T6 and T7 modes.

NOTES:
1. A trigger stimulus will abort the present reading conversion and immediately begin another.

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2. The front panel TRIG button will trigger the instrument regardless of the selected trigger mode, unless LLO is in effect.
3. Serial polling usually addresses the instrument to talk. This talk command will trigger the instrument in the T0 and T1 modes.

HP-85 Programming Example—Place the instrument in the one-shot on talk mode with the following statements:

```
REMOTE 727 (END LINE)
OUTPUT 727;"T1X" (END LINE)
```

One reading can now be triggered and the resulting data obtained with the following statements:

```
ENTER 727;A$ (END LINE)
DISP A$ (END LINE)
```

In this example, the ENTER statement addresses the Model 617 to talk, at which point a single reading is triggered. When the reading has been processed (360msec later), it is sent out over to the bus to the computer, which then displays the result.

Model 8573 Programming Example—Place the instrument in the T1 mode with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="T1X":CALL IBWRT(M617%,CMD$) (return)
```

The instrument can now be addressed to talk to trigger a conversion, and the resulting data displayed with the following statements:

```
RD$=SPACE$(20):CALL IBRD(M617%,RD$) (return)
PRINT RD$ (return)
```

Each time the IBRD function is called, the instrument is addressed to talk, at which time it is triggered. When the conversion is complete (360msec later), the reading is sent out over the bus to the computer, which then displays the resulting data.

3.10.15 SRQ Mask (M) and Status Byte Format

The SRQ command controls which of a number of conditions within the Model 617 will cause the instrument to request service from the controller by asserting SRQ. Once an SRQ is generated, the status byte can be checked to determine if the Model 617 was the instrument that asserted SRQ, and, if so, what conditions caused it to do so. Note that additional data and error conditions can be checked by using the U1 and U2 commands, as described in paragraph 3.10.18.

The Model 617 can be programmed to generate an SRQ under one or more of the following conditions:

1. If an overrange condition occurs.
2. When the data store memory is full (100 readings).
3. If a reading is completed.
4. When the instrument is ready to accept bus commands.
5. If an error occurs. The nature of the error can then be determined with the U1 command, as described in paragraph 3.10.18 (use U1 to restore SRQ after an error occurs.)

Upon power up, or after a DCL or SDC command is received, SRQ is disabled.

SRQ Mask—The Model 617 uses an internal mask to determine which conditions will cause an SRQ to be generated. Figure 3-10 shows the general format of this mask, which is made up of eight bits. The SRQ has the same general format as the status byte (described below) except for the fact that bit 6 is not used in the SRQ mask.

SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit in the SRQ mask. Decimal values for the various bits are summarized in Table 3-13. Note that the instrument may be programmed for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under reading overflow and buffer full conditions, send M3X. To disable SRQ, send M0X. This command will clear all bits in the SRQ mask.

Table 3-13. SRQ (M) Command Parameters

Command	Conditions to Generate SRQ
M0	Disabled
M1	Reading Overflow
M2	Data Store Full
M8	Reading Done
M16	Ready
M32	Error

Status Byte Format—The status byte contains information relating to data and error conditions within the instrument. The general format of the status byte (which is obtained by using the serial polling sequence, as described in paragraph 3.9) is shown in Figure 3-9. Note that the various bits correspond to the bits in the SRQ mask as described above.

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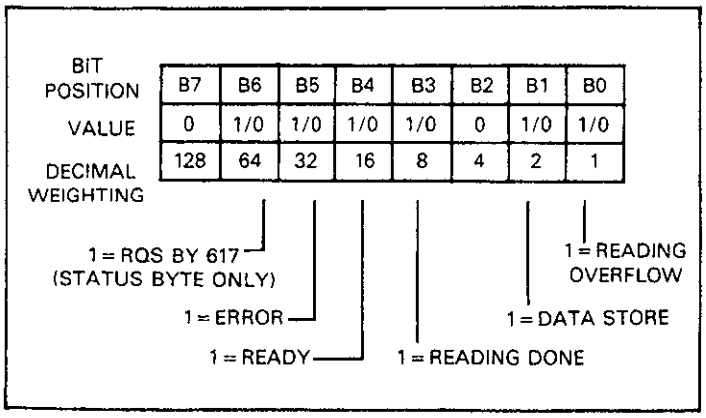


Figure 3-10. SRQ Mask and Status Byte Format

Bit 6 provides a means for you to determine if SRQ was asserted by the Model 617. If this bit is set, service was requested by the instrument. Bit 5 flags a Model 617 error condition, which can be further checked with the U1 command. If this bit is set, one of the following errors has occurred:

1. An illegal device dependent command (IDDC) or illegal device dependent command option (IDDCO) was transmitted.
2. The instrument was programmed when not in remote.
3. A trigger overrun has occurred (the instrument was triggered while processing a reading from a previous trigger).
4. A number error has occurred (calibration or voltage source values were out of limits).

Keep in mind that you can program the instrument to assert SRQ under any of these conditions simply by setting bit 5 in the SRQ mask (M32X). Paragraph 3.10.18 describes how to use the U1 command to obtain information on the type of error from the instrument. The U1 command is used to clear the error bit and restore operation of SRQ on error after the error byte is read.

The bits in the status (serial poll) byte have the following meanings:

Reading Overflow (Bit 0)—Set when an overrange input is applied to the instrument (except when a current overload occurs in V/I ohms). Cleared when a non-overflowed reading is available.

Data Store Full (Bit 1)—Set when all 100 readings in data store have been taken. Cleared by reading a stored reading over the bus (B1X).

Reading Done (Bit 3)—Set when the Model 617 has completed the present reading conversion. Cleared by requesting a reading over the bus.

Ready (Bit4)—Set when the instrument has processed all previously received commands and is ready to accept additional commands over the bus.

Error (Bit 5)—Set when an error condition occurs, as described above. Cleared by reading the error word with the U1 command.

RQS (Bit 6)—Set if the Model 617 has asserted SRQ.

Bits 2 and 7 are not used, and are always set to 0.

Note that the status byte should be read to clear the SRQ line once the instrument has generated an SRQ. All bits in the status byte will be latched when the SRQ is generated. Bit 6 (RQS) will be cleared when the status byte is read.

Even with SRQ disabled, the status byte can be read to determine appropriate instrument conditions. In this case, bits 0, 1, 3, and 4 will be continuously updated to reflect current instrument status; however, bit 5 (the error bit) will latch and remain so until the U1 status word (paragraph 3.10.18) is read, even if no SRQ occurs.

HP-85 Programming Example—Enter the following program into the HP-85:

PROGRAM	COMMENTS
10 REMOTE 717 @ CLEAR 7	Set up for remote operation, clear instrument.
20 OUTPUT 727;"M32X"	Program for SRQ on error.
30 OUTPUT 727;"K5X"	Attempt to program illegal option.
40 S=SPOLL(727)	Serial poll the instrument.
50 DISP"B7 B6 B5 B4 B3 B2 B1 B0"	Identify the bits.
60 FOR I=7 TO 0 STEP −1	Loop eight times.
70 DISP BIT (S,I);	Display each bit position.
80 NEXT I	
90 DISP	
100 END	

Once the program is entered and checked for errors, press the HP-85 RUN key. The computer first places the instrument in remote (line 10) and then programs the SRQ mode of the instrument (line 20). Line 30 then attempts to program an illegal command option, at which point the instrument generates an SRQ and sets the bus error bit in its status byte. The computer then serial polls the instrument (line 40), and then displays the status byte bits in proper order on the CRT. In this example, the SRQ (B6) and error (B5) bits are set because of the attempt to program an illegal command option (K5). Other bits may also be set depending on instrument status.

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Model 8573 Programming Example—Load the modified DECL.BAS file into the IBM computer (see the Model 8573 Instruction Manual) and add the lines below:

PROGRAM	COMMENTS
10 NA$="GPIB0" :CALL IBFIND (NA$,BRD0%)	Find the board descriptor.
20 NA$= "DEV0" :CALL IBFIND (NA$,M617%)	Find the instrument descriptor.
30 V%=27:CALL IBPAD (M617%,V%)	Set primary address to 27.
40 V%=1:CALL IBSRE (BRD0%,V%):CALL IBCLR(M617%)	Send remote enable, clear instrument.
50 CMD$="M32X":CALL IBWRT(M617%,CMD$)	Program for SRQ on error.
60 CMD$="K5X":CALL IBWRT (M617%,CMD$)	Attempt to program illegal option.
70 PRINT"B7 B6 B5 B4 B3 B2 B1 B0"	Identify the bits.
80 MASK%=128	Define bit mask.
90 CALL IBRSP(M617%,SB%)	Serial poll the instrument.
100 FOR I =1 TO 8	Loop eight times.
110 IF (SB% AND MASK%)=0 THEN PRINT "0"; ELSE PRINT "1 ";	Mask off the bits and display them.
120 MASK%=MASK%/2	
130 NEXT I	
140 PRINT	
150 V%=0:CALL IBONL(BRD0%,V%)	Close the board file.
160 CALL IBONL(M617%,V%)	Close the instrument file.

To run the program press the F2 function key. After placing the instrument in remote (line 40), the program then sets the SRQ mode (line 50). An attempt is made to program an illegal command option (line 60), at which point the instrument generates an SRQ and sets the error and RQS bits in its status byte. Other bits may also be set depending on instrument status. Lines 70-90 display the bit positions, set the mask value to the most significant bit, and serial poll the instrument. Since the status byte is in decimal form, lines 100-130 are used to generate the binary equivalent of the status byte value.

3.10.16 EOI and Bus Hold-off Modes (K)

The K command allows control over whether or not the instrument sends the EOI command at the end of its data string, and whether or not bus activity is held off (through the NRFD line) until all commands sent to the instrument are internally processed once the instrument receives the X character. K command options include:

K0=Send EOI with last byte; hold off bus until commands processed on X
K1=Do not send EOI with last byte; hold off bus until commands processed on X
K2=Send EOI with last byte; do not hold off bus on X
K3=Send no EOI with last byte; do not hold off bus on X

Upon power up, or after the instrument receives a DCL or SDC command, the K0 mode is enabled.

The EOI line on the IEEE-488 bus provides a method to positively identify the last byte in a multi-byte transfer sequence. Keep in mind that some controllers rely on EOI to terminate their input sequences. In this case, suppressing EOI with the K command may cause the controller input sequence to hang unless other terminator sequences are used.

The bus hold off mode allows the instrument to temporarily hold up bus operation when it receives the X character until it processes all commands sent in the command string. The purpose of the hold off is to ensure that the front end FETs and relays are properly configured before taking a reading. Keep in mind that all bus operation will cease--not just activity associated with the Model 617. The advantage of this mode is that no bus commands will be missed while the instrument is processing commands previously received.

The hold off period depends on the commands being processed. Table 3-14 lists hold off times for a number of different commands. Since a NRFD hold off is employed, the handshake sequence for the X character is completed.

HP-85 Programming Example—To program the instrument for the K2 mode, enter the following statements into the HP-85:

```
REMOTE 727 (END LINE)
OUTPUT 727;"K2X" (END LINE)
```

When the second statement is executed, the instrument will be placed in the K2 mode. In this mode, EOI will still be transmitted at the end of the data string, but the bus hold-off mode will be disabled.

Model 8573 Programming Example—To place the instrument in the K2 mode, enter the following statements into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="K2X":CALL IBWRT(M617%,CMD$) (return)
```

The Model 617 will be placed in the K2 mode when the second statement is executed. The EOI mode will be enabled, but the bus hold off will be disabled.

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Table 3-14. Bus Hold-off Times

Commands	Bus Held Off On X Until:
L	NVRAM Storage Completed (13msec)
F, R, C	617 Front End Configured (20msec)
Z, N	Value Taken (360msec)
All Others	When X is recognized

Note: NRFD will be held off until each byte is recognized (1-60msec in continuous trigger mode; 1msec in one-shot trigger mode).

3.10.17 Terminator (Y)

The terminator sequence that marks the end of the instrument's data string or status word can be programmed by sending the Y command followed by an appropriate ASCII character. The default terminator sequence is the commonly used carriage return, line feed (CR LF) sequence (CR=ASCII 13; LF=ASCII 10). The terminator will assume this default value upon power up, or after the instrument receives a DCL or SDC command.

The terminator sequence may be changed by sending the desired one or two characters after the Y command. However, the capital letters (A-Z) cannot be used as terminators.

Special command sequences will program the instrument as follows:

1. Y(LF)(CR)X = (LF CR) (two terminator characters)
2. Y(CR)(LF)X = (CR LF) (two terminator characters)
3. YX = (no terminator)

HP-85 Programming Example—To reverse the default (CR LF) terminator sequence, type the following lines into the computer:

```
REMOTE 727 (END LINE)
OUTPUT 727;"Y";CHR$(10);CHR$(13);"X" (END LINE)
```

When the second statement is executed, the normal terminator sequence will be reversed; the instrument will terminate each data string or status word with a (LF CR) sequence.

Model 8573 Programming Example—Use the following statements to reverse the default terminator sequence:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="Y"+CHR$(10)+CHR$(13)+"X":CALL
IBWRT(M617%,CMD$) (return)
```

The terminator sequence will be reversed when the second statement is executed.

3.10.18 Status (U)

The status command allows access to information concerning instrument operating modes that are controlled by other device-dependent commands such as F (function) and R (range). Additional parameters of the status command allow data and error conditions to be accessed. Status commands include:

U0=Send status word.
U1=Send instrument error conditions.
U2=Send instrument data conditions.

When the command sequence U0X is transmitted, the instrument will transmit the status word instead of its normal data string the next time it is addressed to talk. The status word will be transmitted only once each time the U0 command is given. To make sure that correct status is transmitted, the status word should be requested as soon as possible after the command is transmitted.

The format of U0 status is shown in Figure 3-11. Note that the letters correspond to modes programmed by the respective device-dependent commands. The default values in the status word (upon power up or after a DCL or SDC command) are also shown in Figure 3-11.

Note that all returned values except for those associated with the terminator correspond to the programmed numeric values. For example, if the instrument is presently in the R3 range, the second (R) byte in the status word will correspond to an ASCII 3. The returned terminator characters are derived by ORing the actual terminator byte values with $30. For example, a CR character has a decimal value of 13, which equals $0D in hexadecimal notation. ORing this value with $30 yields $3D, or 61_{10}, which prints out as an ASCII equal sign (=). This terminator conversion step is necessary to convert the standard terminators into displayable form, as they will not normally print out on a computer CRT.

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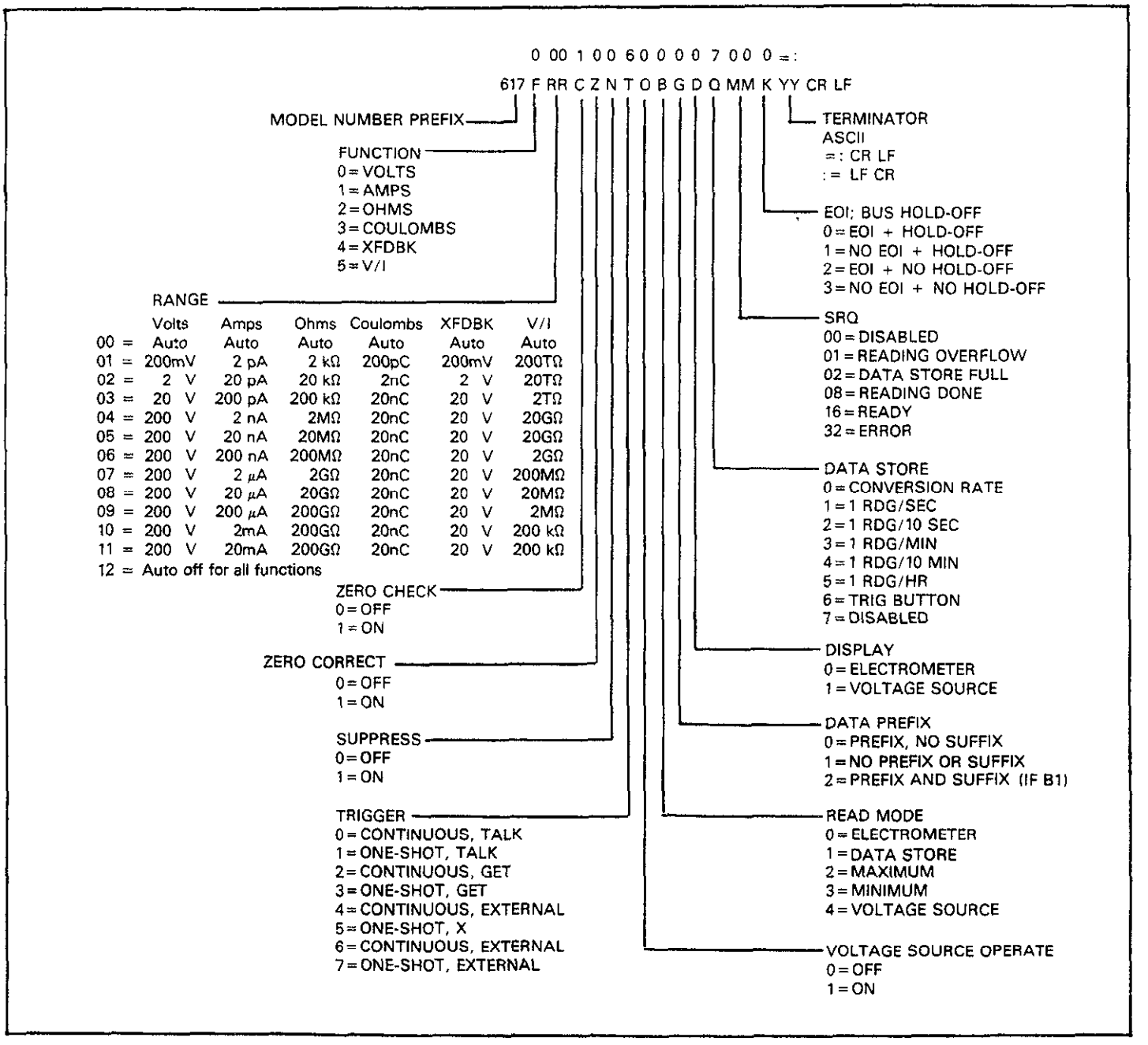


Figure 3-11. U0 Status Word and Default Values

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The U1 command allows access to Model 617 error conditions in a similar manner. Once the sequence U1X is sent, the instrument will transmit the error conditions with the format shown in Figure 3-12 the next time it is addressed to talk in the normal manner. The error condition word will be sent only once each time the U1 command is transmitted. Note that the error condition word is actually a string of ASCII characters representing binary bit positions. An error condition is also flagged in the status (serial poll) byte, and the instrument can be programmed to generate an SRQ when an error condition occurs. See paragraph 3.10.15. Note that all bits in the error condition word and the status byte error bit will be cleared when the word is read. In addition, SRQ operation will be restored after an error condition by reading U1.

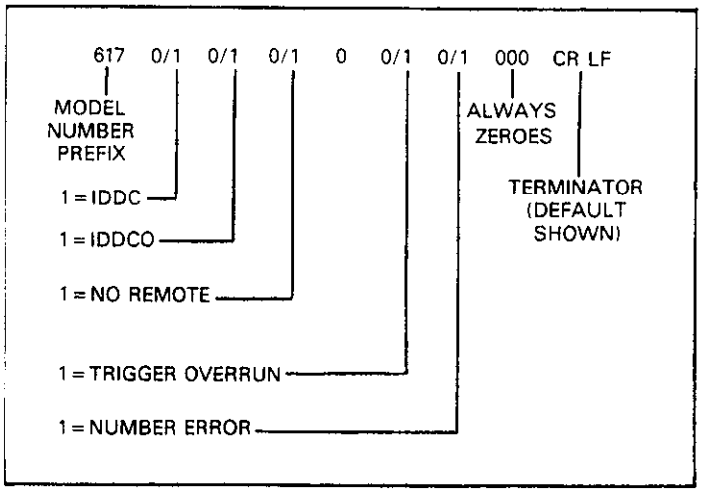


Figure 3-12. U1 Status (Error Condition) Format

The various bits in the error condition word are described as follows:

IDDC—Set when an illegal device dependent command (IDDC) such as H1X is received ("H" is illegal).

IDDCO—Set when an illegal device-dependent command option (IDDCO) such as T9X is received ("9" is illegal).

No Remote—Set when a programming command is received when REN is false.

NOTE

The complete command string will be ignored if an IDDC, IDDCO or no remote error occurs.

Trigger Overrun—Set when a trigger is received when the instrument is still processing a reading from a previous trigger.

Number Error—Set when an out of range calibration or voltage source value is received.

In a similar manner, the U2X sequence allows access to instrument data conditions. When this command is transmitted, the instrument will transmit the data condition word shown in Figure 3-13 the next time it is addressed to talk. This information will be transmitted only once each time the command is received. As with the U1 error word, the U2 word is made up of ASCII characters representing binary values. Unlike the U1 error word, however, the U2 data condition word will not be cleared when read; thus, instrument status in the U2 word is always current.

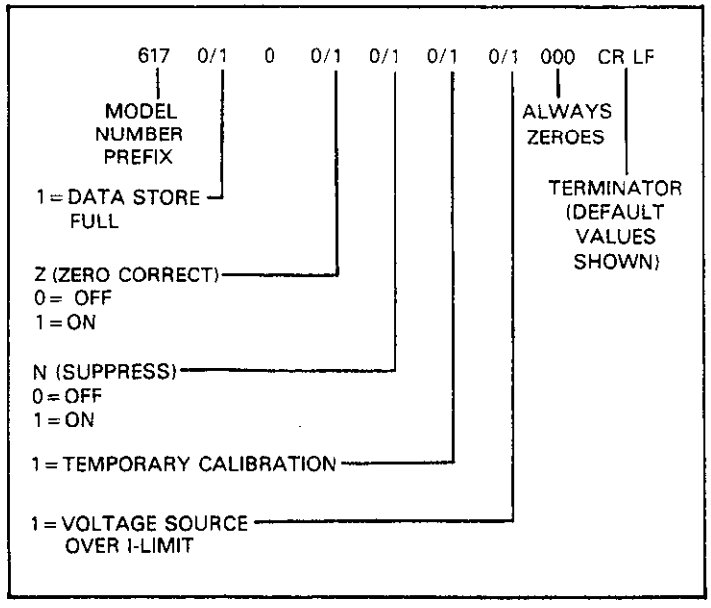


Figure 3-13. U2 Status (Data Condition) Format

The various bits in the data condition word include:

Data Store Full—Set when all 100 readings have been stored in the data store memory.

Z and N—Represents the same information as the corresponding zero correct (Z) and suppress (N) bytes in the U0 status word.

Temporary Calibration—Set when new calibration parameters not yet stored in NVRAM have been received, or if power-up recall of NVRAM data was in error. Cleared when NVRAM storage is performed.

Voltage Source I-limit—Set when the 2mA current limit of the voltage source has been exceeded.

HP-85 Programming Example—Enter the following program into the computer to obtain and display instrument status, the error condition word, and the data condition word.

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```
10 REMOTE 727                          Send remote enable.
20 DIM A$ [25]
30 OUTPUT 727;"U0X"                    Send U0 command.
40 DISP"mdlFRRCZNTOBGD                 Display U0 word values.
   QMMKYY"
50 ENTER 727;A$                        Obtain U0 status from in-
                                       strument.
60 DISP A$                             Display U0 status word.
70 OUTPUT 727;"U1X"                    Send U1 command.
80 ENTER 727;A$                        Get error condition
                                       word.
90 DISP A$                             Display error condition
                                       word.
100 OUTPUT 727;"U2X"                   Send U2 command.
110 ENTER 727;A$                       Get data condition word.
120 DISP A$                            Display data condition
                                       word.
130 ENTER 727;A$                       Get normal reading.
140 DISP A$                            Display normal reading.
150 END
```

After entering the program, run it by pressing the HP-85 RUN key. The program will place the unit in remote (line 10), send the U0 command (line 30), and then obtain and display the status word (lines 50 and 60). The U1 command is then transmitted (line 70), and the error condition word is then obtained and displayed (lines 80 and 90). Line 100 sends the U2 command, and the data condition word is then obtained and displayed (lines 110 and 120). To show that status is transmitted only once, a normal reading is then requested and displayed (lines 130 and 140).

Model 8573 Programming Example—Obtain and display instrument status, the error condition word, and the data condition word as follows: load the modified DECL.BAS file from disk (see the Model 8573 Instruction Manual) and add the lines from the program below:

```
10 NA$= "GPIB0":CALL IBFIND            Find the board
   (NA$,BRD0%)                         descriptor.
20 NA$="DEV0":CALL IBFIND              Find the instrument
   (NA$,M617%)                         descriptor.
30 V%=27:CALL IBPAD                    Set primary address
   (M617%,V%)                          to 27.
40 V%=1:CALL IBSRE                     Send remote enable.
   (BRD0%,V%)
50 CMD$="U0X":CALL IBWRT               Send U0 command.
   (M617%,CMD$)
60 PRINT"mdlFRRCZNTOBGD                Identify word bytes.
   QMMKYY"
70 RD$=SPACE$(25):CALL IBRD            Get status word
   (M617%,RD$)                         from instrument.
80 PRINT RD$                           Display status word.
90 CMD$="U1X":CALL IBWRT               Send U1 command.
   (M617%,CMD$)
100 RD$=SPACE$(25):CALL IBRD           Get error condition
   (M617%,RD$)                         word.
110 PRINT RD$                          Display error condi-
                                       tion word.
120 CMD$="U2X":CALL IBWRT              Send U2 command.
   (M617%,CMD$)
130 RD$=SPACE$(25):CALL IBRD           Get data condition
   (M617%,RD$)                         word.
140 PRINT RD$                          Display data condi-
                                       tion word.
150 RD$=SPACE$(25):CALL IBRD           Get normal reading.
   (M617%,RD$)
160 PRINT RD$                          Display normal
                                       reading.
170 V%=0:CALL IBONL                    Close the board file.
   (BRD0%,V%)
180 CALL IBONL (M617%,V%)              Close the instrument
                                       file.
```

Press the computer F2 function key to run the program. The instrument is placed in remote (line 40), programmed to access the U0 status word (line 50), and that status word is then obtained and displayed (lines 70 and 80). The U1 command is then transmitted (line 90), and the error condition word is then obtained and displayed (lines 100 and 110). Line 120 then sends the U2 command, and the data condition word is obtained and displayed in lines 130 and 140. To show that status is transmitted only once, a normal reading is then requested and displayed (lines 150 and 160).

3.11 Front Panel Messages

The Model 617 has a number of front panel messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that occur when sending device-dependent commands to the instrument.

The following paragraphs describe the front panel error messages associated with IEEE-488 programming.

3.11.1 Bus Error

A bus error will occur if the instrument receives a device dependent command when it is not in remote, or if an illegal device-dependent command (IDDC) or illegal device dependent command option (IDDCO) is sent to the instrument. Under these conditions, the complete command string will be rejected and the following message will be displayed:

b Err

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In addition, the error bit and pertinent bits in the U1 word will be set (paragraph 3.10.15 and 3.10.18) and the instrument can be programmed to generate an SRQ under these conditions (paragraph 3.10.15).

A no remote error can occur when a command is sent to the instrument when the REN line is false. Note that the state of REN is only tested when the X character is received. An IDDC error can occur when an invalid command such as H1X is transmitted (this command is invalid because the instrument has no command associated with that letter). Similarly, an IDDCO error occurs when an invalid option is sent with a valid command. For example, the command T9X has an invalid option because instrument has no such trigger mode.

HP-85 Programming Example—To demonstrate a bus error, send an IDDC with the following statements:

```
REMOTE 727 (END LINE)
OUTPUT 717;"H1X" (END LINE)
```

When the second statement is executed, the bus error message appears on the display for about one second.

Model 8573 Programming Example—Type in the following statements to demonstrate a bus error by sending an IDDCO:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="H1X":CALL IBWRT(M617%,CMD$) (return)
```

The bus error message will be displayed for about one second when the second statement is executed.

3.11.2 Number Error

A number error occurs when an out of range value is sent to the instrument when programming the voltage source, or when sending calibration values over the bus. Under these conditions, the instrument will display the following error message:

```
n Err
```

The command string will be accepted, but calibration or voltage values will remain unchanged.

HP-85 Programming Example—Enter the following lines to display a number error:

```
REMOTE 727 (END LINE)
OUTPUT 727;"D1V125X" (END LINE)
```

When the second statement is executed, the instrument will display the number error message for about one second. This error occurs with this example because an attempt is made to program a voltage value of 125V, which is outside the range of the voltage source ($-102.35V \leq V \leq +102.4V$).

Model 8573 Programming Example—To display the number error, enter the following lines into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="D1V125X":CALL IBWRT(M617%,CMD$)
(return)
```

The number error message will be displayed for about one second when the second statement is executed. The number error occurs with this example because of the attempt to program a voltage of 125V, which is above the range of the voltage source ($-102.35V \leq V \leq +102.4V$).

3.11.3 Trigger Overrun Error

A trigger overrun error occurs when the instrument receives a trigger while it is still processing a reading from a previous trigger. Note that only the overrun triggers are ignored and will have no effect on the instrument except to generate the message below. When a trigger overrun occurs, the following front panel message will be displayed for approximately one second:

```
t Err
```

HP-85 Programming Example—To demonstrate a trigger overrun error, enter the following statements into the HP-85 keyboard:

```
REMOTE 727 (END LINE)
OUTPUT 727;"T3X" (END LINE)
TRIGGER 727@TRIGGER 727 (END LINE)
```

Note that the trigger overrun message is displayed with the third line above is executed.

Model 8573 Programing Example—Enter the following statements into the computer to demonstrate the trigger overrun message:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="T3X":CALL IBWRT(M617%,CMD$) (return)
CALL IBTRG(M617%):CALL IBTRG(M617%) (return)
```

The trigger overrun error message will be displayed when the third line above is executed.

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Table 3-15. Trigger to Reading-Ready Times

Configuration	Time (msec)	Error (% of Step Input)
220V, 20V, 2V	365	.01
200mV	780	.10
20mA, 200μA, 20μA, 200nA, 20nA	365	.01
200pA, 20pA	365	55 (2)
2mA, 2μA, 2nA	780	.10
2pA	780	25 (2)
20nC, 2nC	365	.01
200pC	780	.10
20kΩ-200GΩ	365	.01
2kΩ	780	.10

Notes:
1. Conditions: Input is on range, HP-85 controller.
2. Preamp settling time (to 12%) is 2 seconds on preamp ranges (2, 20, 200pA), and must be taken into account by the user.
3. Volt time/error also apply to external feedback.
4. V/I time/error is the same as the applicable current range.

3.12 Bus Data Transmission Times

A primary consideration is the length of time it takes to obtain a reading once the instrument is triggered to make a conversion. The length of time will vary somewhat depending on the selected function and trigger mode. Table 3-15 gives typical times

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SECTION 4
APPLICATIONS

4.1 INTRODUCTION

Applications for the Model 617 are many and varied and will depend on the user's needs. Basically, the Model 617 can be used to make many of the same measurements in the range of ordinary DMMs; however, special characteristics such as high input resistance and high sensitivity give the instrument much better capabilities than those of the ordinary DMM.

For example, the typical input resistance for an ordinary DMM is on the order of 10MΩ. In contrast, the Model 617 has an input resistance of greater than 200TΩ ($2 \times 10^{14}\Omega$). The Model 617 can detect currents as low as 0.1fA (10^{-16}A), while a typical DMM might be limited to current measurements in the μA range.

In this section, then, we will discuss some possible applications for the Model 617 Electrometer. Keep in mind that these examples are only representative of what is possible with this highly sophisticated instrument, and by no means exhaust the possible uses for the unit.

4.2 INSULATION RESISTANCE MEASUREMENTS

At the moderate impedance levels of many circuits, insulation resistance is seldom a consideration, as it is generally many orders of magnitude above the highest impedance encountered in the remainder of the circuit. At very high impedance levels, however, insulation resistance can be a consideration, since it can lower effective circuit impedance considerably. Since typical insulation resistances run in the range of $10^{10}-10^{16}\Omega$, their values lie above the measurement range of ordinary instruments. The high resistance measurement range of the Model 617, however, gives it capabilities to measure such high resistances.

A typical test configuration for making insulation resistance measurements is shown in Figure 4-1. In this case, the constant current method is used. Using this method, insulation resistances up to 200GΩ can be measured. As the term implies, the test current through the unknown resistance is kept constant. The voltage developed across the test resistance will, of course, depend on the value of the insulation resistance. The Model 617 measures the generated voltage and calculates the resistance value accordingly. The low compliance voltage of the Model 617 (< 2V on 2GΩ range and lower, except <300V during overload) keeps error due to voltage coefficient small.

For resistance measurements above $10^{8}\Omega$, or for cables longer than three feet, guarded measurements are recommended, as shown in Figure 4-2. In this case, the rear panel V, Ω GUARD switch is used to internally apply a guard signal to the inner shield on the connecting cable. The guard is carried through to the inner shield of the test fixture. The inner shield must be insulated from the outer shield, which is a safety shield. Incidentally, a shielded fixture is recommended for both unguarded and guarded configurations for measurements above $10^{7}\Omega$ if stable readings are to be expected (in the unguarded mode, the shield should be connected to input low).

With the constant current method just discussed, the Model 617 can make measurements as high as 200GΩ. However, the insulation resistance of such materials as polyethylene may lie above this range. By using the Model 617 to make resistance measurements in the constant-voltage mode, measurement range can be extended up to $10^{16}\Omega$. Also, for a given resistance range, the V/I mode will be faster.

A typical configuration for using the Model 617 in this manner is shown in Figure 4-3. Here, the built in voltage source of the instrument is used to force a current, I, through the unknown resistance, R. The insulation resistance is then automatically calculated by the Model 617 as follows:

$$R = \frac{V}{I}$$

where I is the current through the resistance as measured by the instrument, and V is the programmed voltage.

Note that COM is connected to input LO thru 100Ω and appears in series with the resistor under test. This resistance is below the resolution of the instrument on ranges above 2MΩ.

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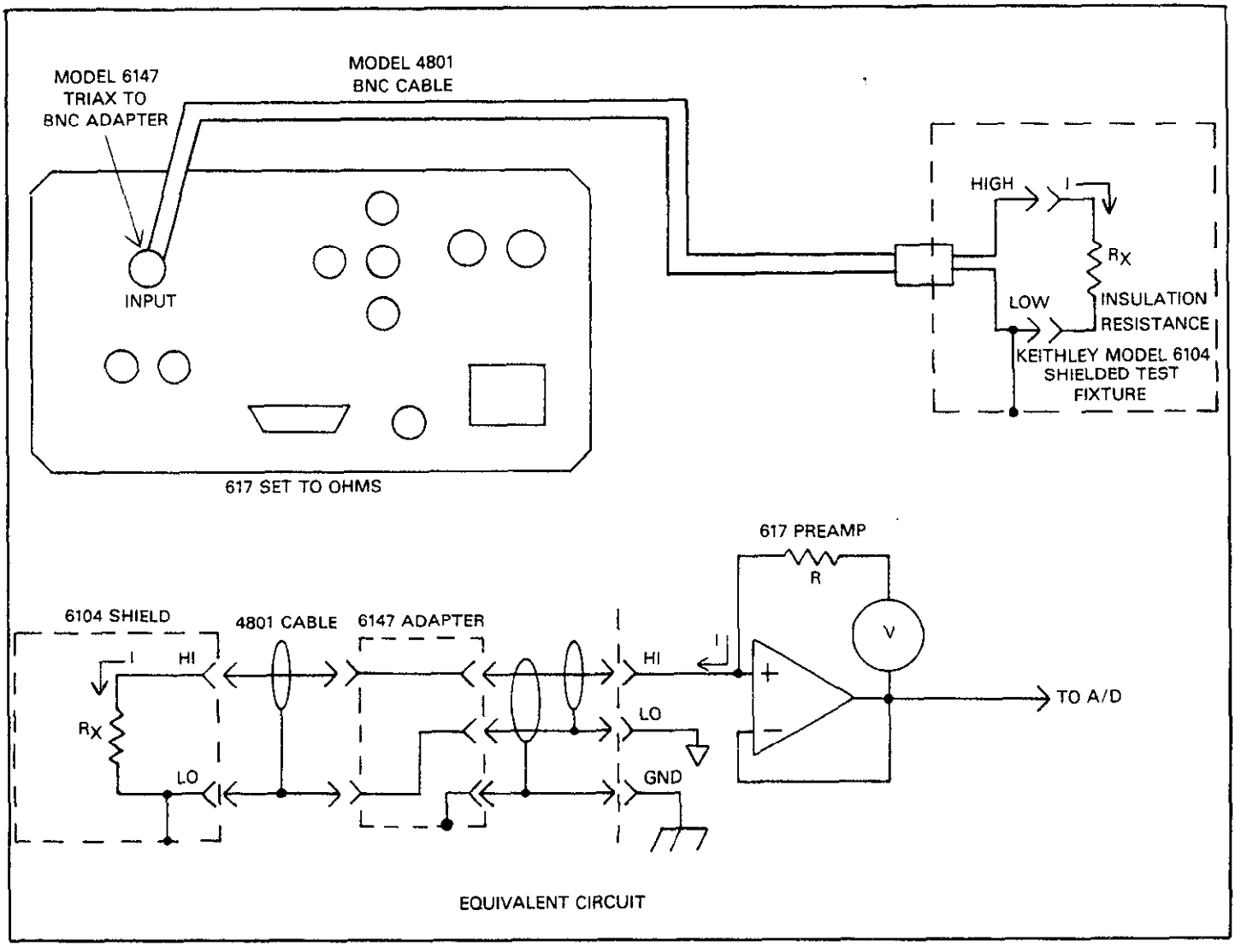


Figure 4-1. Insulation Resistance Measurement (Unguarded)

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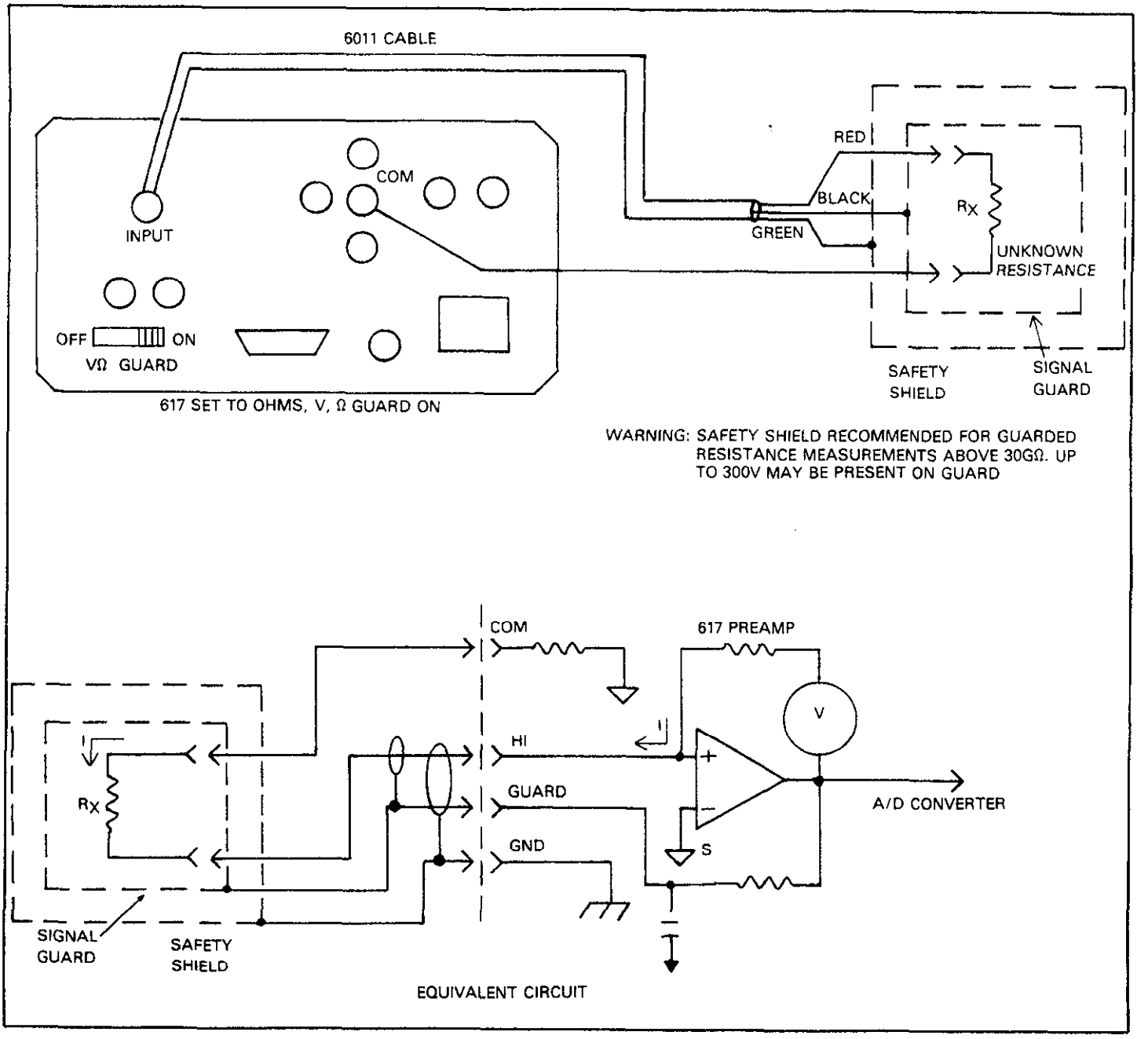


Figure 4-2. Insulation Resistance Measurement (Guarded)

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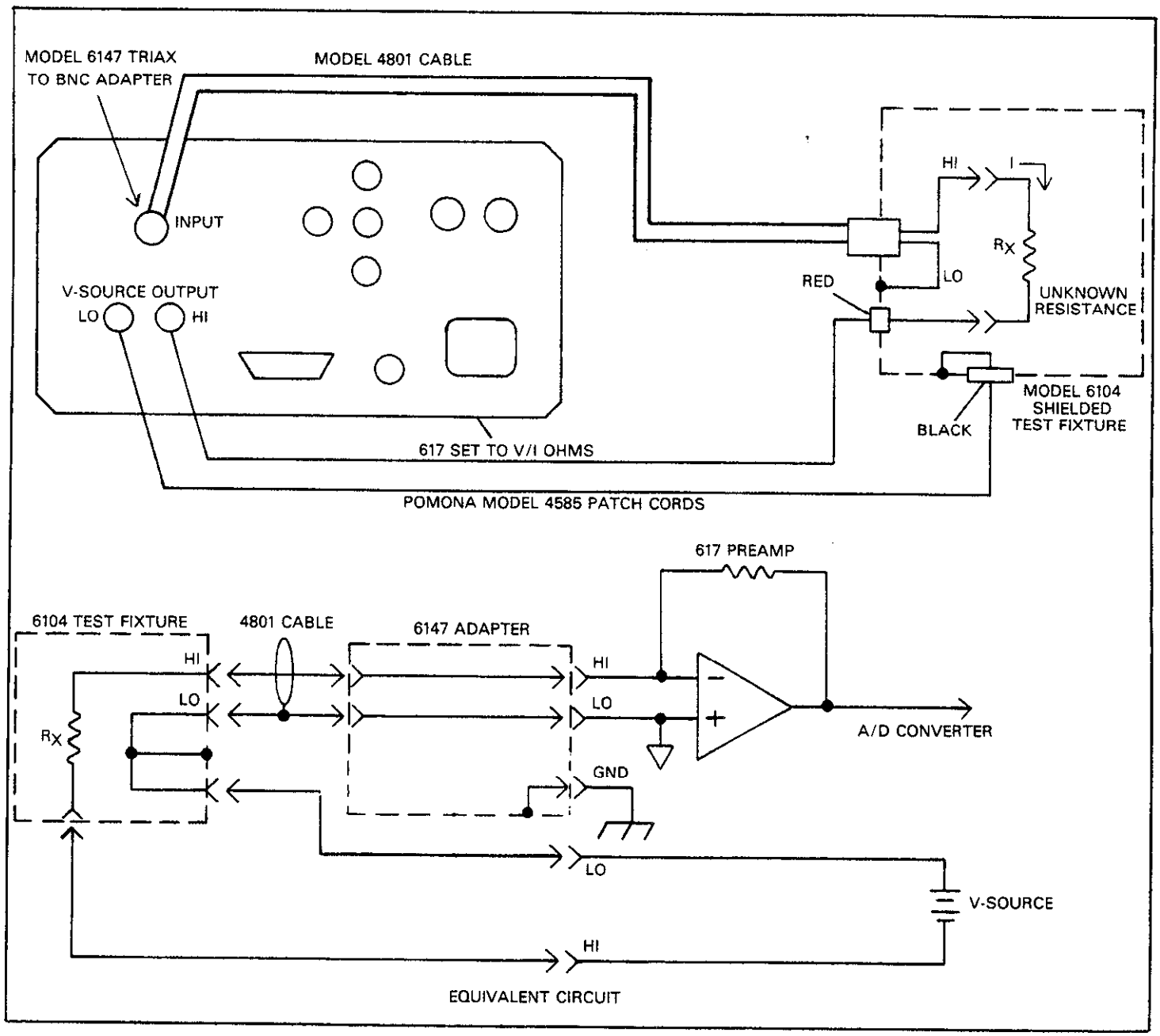


Figure 4-3. Insulation Resistance Measurement Using V/I Ohms Mode

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For example, assume that the applied voltage is 100V, and the measured current is 1pA. The resistance is calculated as follows:

$$R = \frac{V}{I} = \frac{100}{1pA} = 10^{14}\Omega$$

Since the user has fine control over the internal voltage source (−102.35V to +102.4V in 50mV steps), the resistance at a given applied voltage can be easily determined. Such control can give rise to voltage coefficient studies, as described later in this section.

In addition to the measurement of insulation resistances, this basic method can be used to measure unwanted leakage resistances. For example, leakage resistance between PC board traces and connectors can be made with either of the two methods above, depending on the resistance values involved.

4.3 HIGH IMPEDANCE VOLTMETER

The input resistance of the Model 617 in the volts mode is greater than 200TΩ. Because of this high value, the Model 617 can be used to make voltage measurements in high impedance circuits with a minimum of loading effects on the circuit.

Consider the situation where a circuit designer must measure the gate-to-source voltage of a precision JFET amplifier that has a gate impedance of 100MΩ. Further assume that the required accuracy of this measurement is 1%.

The set-up for this measurement is shown in Figure 4-4. The gate-source voltage is represented by V_{GS}, while the effective gate impedance is represented as R_S. The input resistance of the voltmeter is given as R_{IN}.

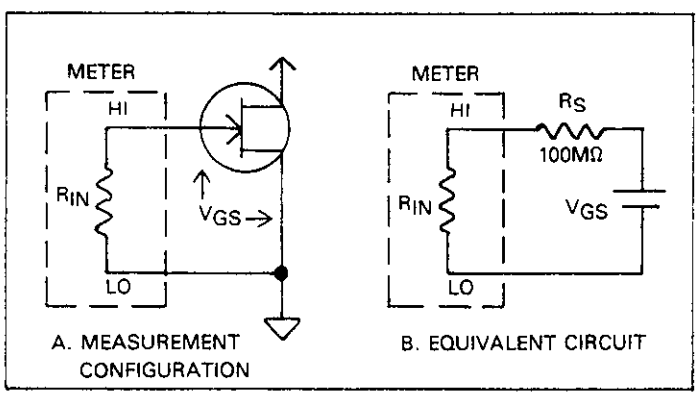


Figure 4-4. Measuring High Impedance Gate-Source Voltage

The percent error due to voltmeter loading in this circuit can be given as:

$$\% \text{ ERROR} = \frac{R_S}{R_S + R_{IN}} \times 100\%.$$

Suppose, for example, a typical DMM with a 10MΩ input resistance were used to make this measurement. The error because of meter loading would be:

$$\% \text{ ERROR} = \frac{100M\Omega}{100M\Omega + 10M\Omega} \times 100\% = 91\% \text{ error}$$

Even if a DMM with an input resistance of 10⁹Ω were used, the error would still be:

$$\% \text{ ERROR} = \frac{100M\Omega}{100M\Omega + 1G\Omega} \times 100\% = 9.1\% \text{ error}$$

Such a large error would not be tolerable in this case because of the 1% accuracy requirement. However, since the Model 617 has an input resistance of 200TΩ, its error in this example would be:

$$\%\text{ERROR} = \frac{100M\Omega}{100M\Omega + 200T\Omega} \times 100\% = 0.00005\% \text{ error}$$

which would be dominated by the instrument's specified accuracy.

Thus, the input impedance of the Model 617 would be more than adequate for this situation, because the error due to meter loading is substantially better than the required 1% value stated earlier. In addition, the 4½ digit resolution of the instrument allows the designer sufficient precision to make use of the high input impedance.

4.4 LOW-LEVEL LEAKAGE CURRENT MEASUREMENTS

Many devices exhibit low-level leakage currents that may require measurement. Typically, such leakage currents might lie in the nA (10^{-9}A), pA (10^{-12}A) or even the fA (10^{-15}A) range. The Model 617 is an ideal instrument for such current measurements because it can detect currents as low as 0.1fA.

An example of a situation requiring low current measurement is shown in Figure 4-5. In this example, the gate leakage current of a JFET is to be measured. Although the device manu-

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facturer may specify the current value, it is often desirable to verify the specification for a particular sample of the device. Then too, the specified leakage current might be at a higher voltage than required. For example, the specified leakage current might be 1nA with an applied voltage of 25V, while that figure might be much less at an operating value of 10V.

An added bonus of using the Model 617 in this situation is that the instrument has a built in voltage source. Thus, the voltage source could be programmed to the desired value or values, and the leakage current could be measured for each voltage. In this manner, leakage current characterization studies could be performed with only a single measuring instrument, rather than requiring a separate voltage source.

As shown in Figure 4-5, a shielded test fixture such as the Keithley Model 6104 should be used to keep the measurement quiet and stable. A good quality low-noise cable, such as the Model 4801 connected through a Model 6147 adapter should be used to connect the current input to the instrument.

Forward and reverse diode currents could be measured in a similar manner. The forward leakage current (measured with

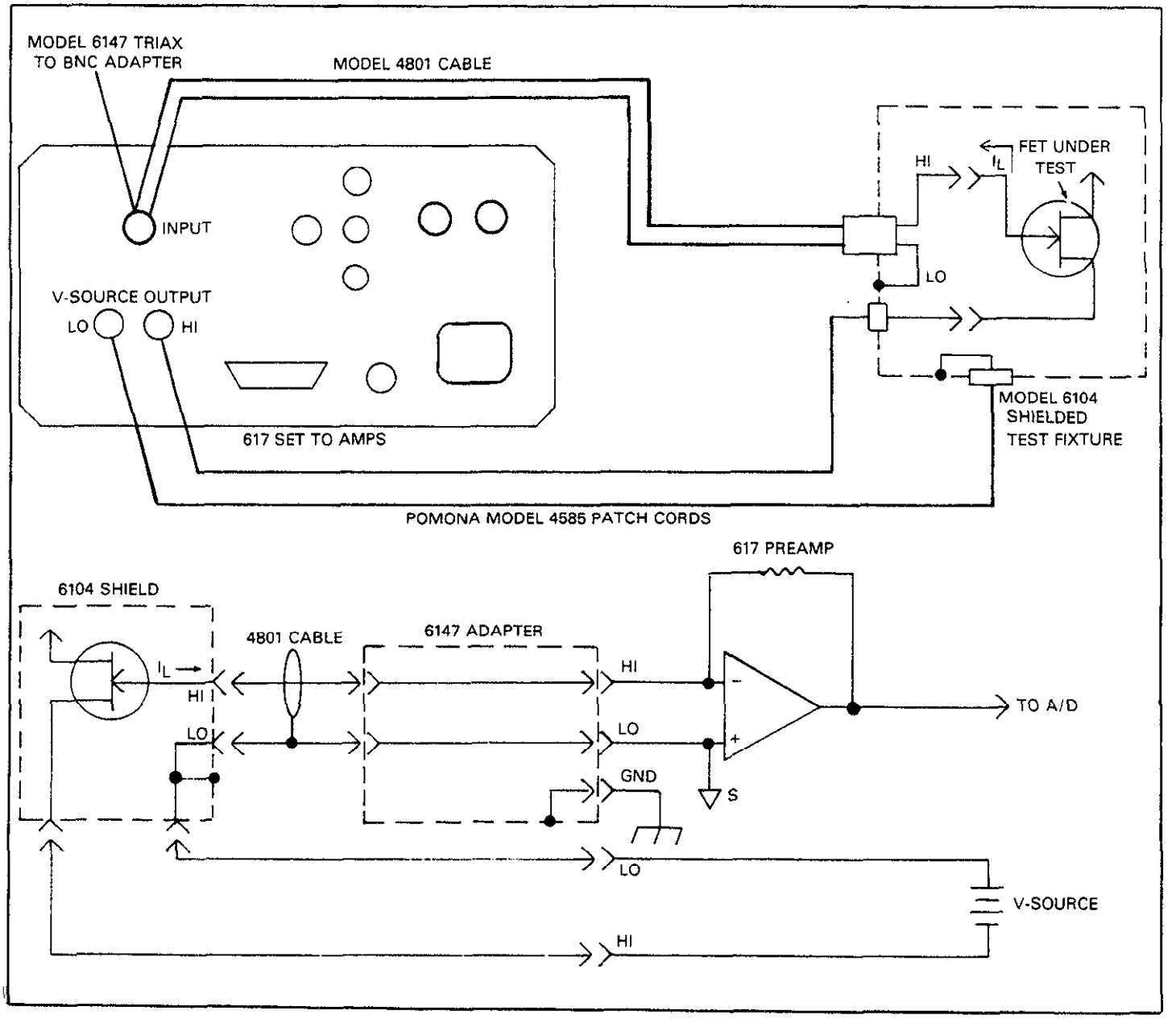


Figure 4-5. Leakage Current Measurement

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the built-in voltage source set to less than 0.6V) can be measured using the Model 617 without regard to input voltage burden. High capacitance diodes such as zener devices will present no problem, since the Model 617 is unaffected by stray capacitance up to 0.01μF.

4.5 DIODE CHARACTERIZATION

When the Model 617 is placed in the ohms mode, constant current values between 1nA and 100μA are available at the INPUT jack high and low terminals, as shown in Table 4-1. (Input high sources the current). These currents can be used to plot the I-V (current-voltage) characteristics over a substantial range.

Table 4-1. Diode Currents and Voltages

Range	Diode Current	Diode Voltage (V)*
2kΩ, 20kΩ	100μA	$V = (100 \times 10^{-6})$ (R)
200 kΩ	10μA	$V = (10 \times 10^{-6})$ (R)
2MΩ	1μA	$V = (1 \times 10^{-6})$ (R)
20MΩ	100nA	$V = (100 \times 10^{-9})$ (R)
200MΩ	10nA	$V = (10 \times 10^{-9})$ (R)
2GΩ, 20GΩ, 200GΩ	1nA	$V = (1 \times 10^{-9})$ (R)

*R = displayed resistance.

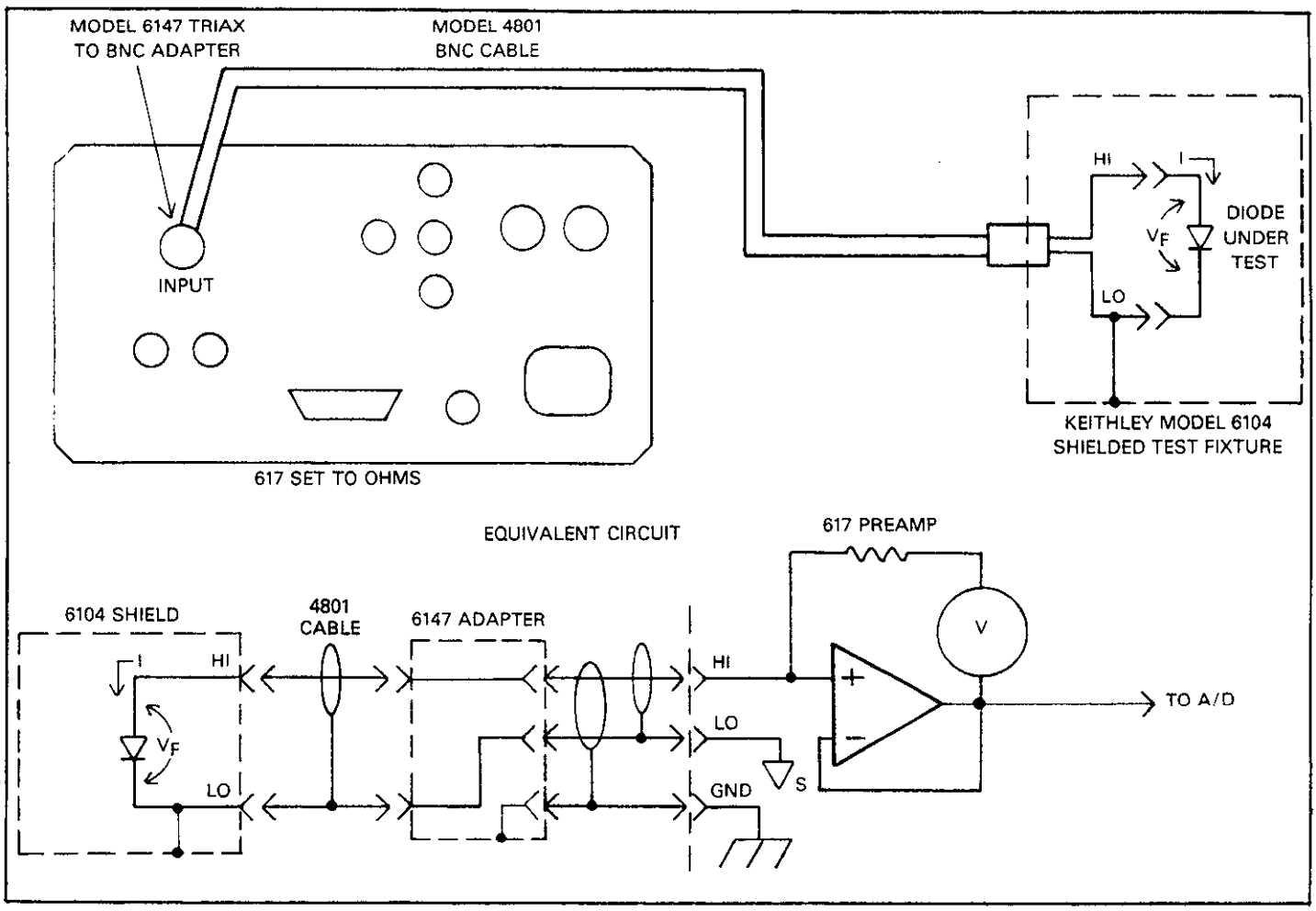


Figure 4-6. Diode Characterization

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Figure 4-6 shows the basic circuit configuration for using the Model 617 in this manner. A decade current, I, is forced through the diode under test. The current will develop a forward voltage drop, V_F, across the diode. The voltage across the diode can be calculated by multiplying the displayed resistance by the test current (see Table 4-4). For example, assume that a resistance reading of 50kΩ is measured with the instrument on the 200kΩ range. The voltage across the diode is: $10\mu A \times 50k\Omega = 0.5V$.

Figure 4-7 shows several examples for typical diodes. The curves were drawn from data obtained in the manner just described.

WARNING
Up to 300V may be present between the high and low terminals in ohms.

4.6 CAPACITOR LEAKAGE MEASUREMENTS

An important parameter associated with capacitors is their leakage currents. Once the leakage current is known, the insulation resistance can be calculated. Ideally, a capacitor should have no leakage current, and thus infinite leakage resistance. However, capacitors, like all practical devices, are not ideal, so these parameters can become important, especially to circuit design and component engineers. The amount of leakage current in a given capacitor depends on its dielectric as well as the applied voltage. Ceramic dielectric capacitors typically have leakage currents in the nA to pA range, while polystyrene and polyester dielectric devices exhibit much lower leakage currents--generally in the fA range. (These values are for test voltages in the 100V range).

The basic configuration for this test is shown in Figure 4-8. The Model 617 voltage source is used to impress a voltage across the capacitor, C. The resulting leakage current is then measured by the electrometer section of the Model 617.

The resistor R is necessary to limit current to a safe value in case the capacitor is shorted, and it also helps to reduce noise. Typically a value of about 1MΩ should be used, although that value can be decreased for larger capacitor values. However, values under 10kΩ are not recommended. Refer to paragraph 2.14.8.

At the start of the test, the Model 617 should be placed in the amps mode and on the 20mA range. The voltage source is then programmed to the desired voltage, and the output turned on. Once the required soak time has passed, the instrument can be placed on the proper current range to make the current measurement. The soak time is the period necessary to fully charge the capacitor, typically 10RC. Once the test is completed, the voltage source should be turned off to allow the capacitor to discharge.

The leakage current can be directly read from the Model 617 display during the test procedure. If the leakage resistance value is required instead, the instrument can be placed in the V/I ohms mode, and the instrument will directly display the leakage resistance value, with no calculations necessary on the part of the user.

This basic procedure could be used to test a number of capacitors on an automated basis. A test fixture that holds a number of capacitors could be constructed, and a Keithley Model 705 or Model 706 Scanner could be used to select among the various devices to be tested. For a higher degree of automation, both the scanner and the Model 617 could be controlled from a computer via the IEEE-488 bus. In this way, measurements that would otherwise be tedious and time consuming could be conducted on a more routine basis.

4.7 CAPACITANCE MEASUREMENT

The coulombs function of the Model 617 provides a quick and easy method of measuring capacitance values of capacitors, cables, and connectors. It is especially useful in cases of cables and connectors because of the very small values of charge that can be measured.

The basic method involves using the voltage source to apply a step voltage across the capacitor, as shown in Figure 4-9. Since charge is to be measured, the Model 617 should be in the coulombs function to make the measurement. Just prior to turning on the voltage source, zero check should be disabled and the charge suppressed. Then, turn on the voltage source and note the final charge value.

The capacitance can then be computed as follows:

$$C = \frac{\Delta Q}{\Delta V}$$

where:

$\Delta Q = Q_2$ (final charge) $- Q_1$ (initial charge assumed to be 0)

$\Delta V = V_2$ (step voltage) $- V_1$ (initial voltage, assumed to be 0)

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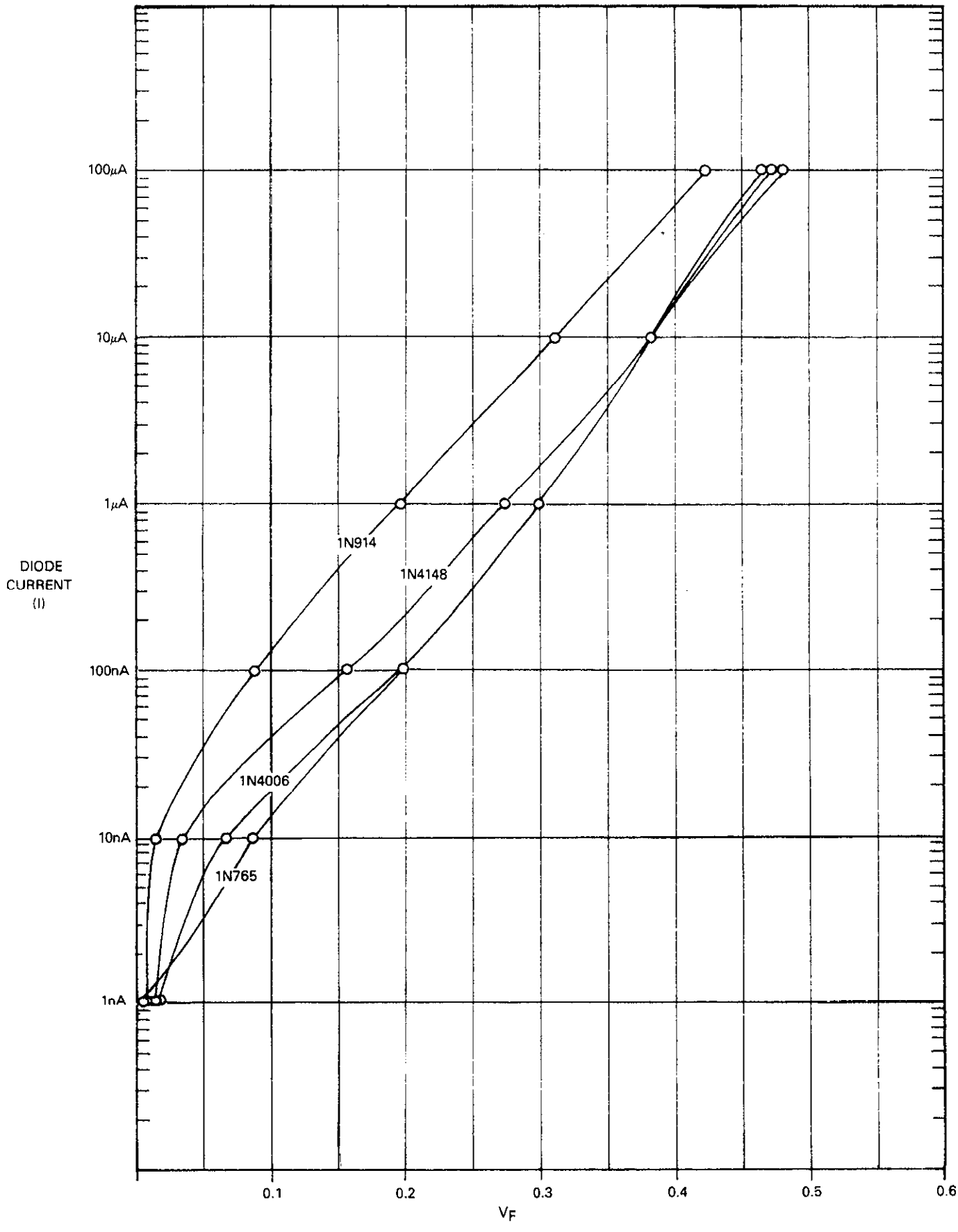


Figure 4-7. Diode Curves

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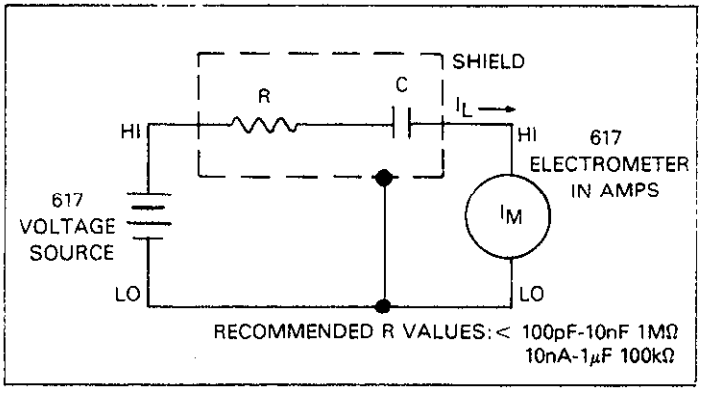


Figure 4-8. Capacitor Leakage Tests

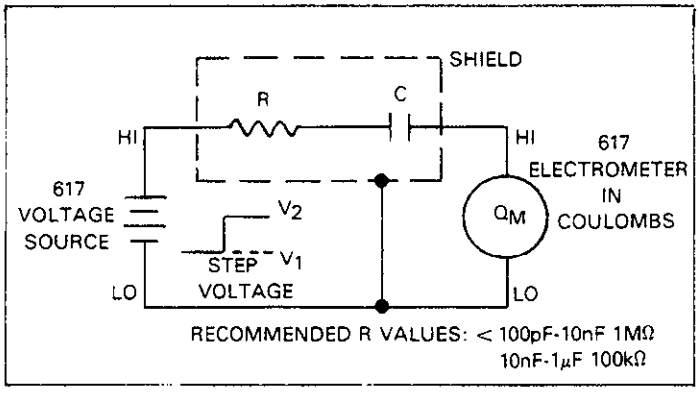


Figure 4-9. Capacitor Measurement

As an example of the above procedure, assume that an unknown capacitor is to be measured. If the step voltage is 100V, and a ΔQ value of 2nC is obtained, the capacitance value is:

$$C = \frac{2nC}{100V} = 20pF$$

4.8 VOLTAGE COEFFICIENTS OF HIGH-MEGOHM RESISTORS

High megohm resistors (above $10^9\Omega$) often exhibit a change in resistance with applied voltage. This resistance change is characterized as the voltage coefficient. The Model 617 is an ideal instrument to obtain data to determine the voltage coefficient because of its built-in variable voltage source and its highly sensitive picoammeter section.

The basic configuration for making voltage coefficient measurements is shown in Figure 4-10. The voltage, V_S, is applied to the resistor under test by the voltage source of the instrument. The current is measured by the electrometer input of the instrument. The resulting current can then be used to calculate the resistance. If the instrument is in the V/I ohms mode, the resistance will be calculated automatically.

Two resistance readings at two different voltage values will be required to calculate the voltage coefficient. The voltage coefficient in %/V can then be calculated as follows:

$$\text{Voltage Coefficient (\%/V)} = \frac{100\,(R_2 - R_1)}{R_1(\Delta V)}$$

where:
R_1 is the resistance with the first applied voltage.
R_2 is the resistance with the second applied voltage.
ΔV is the difference between the two applied voltages.

As an example, assume that the following values are obtained:

$R_1 = 1.01 \times 10^{10}\Omega$
$R_2 = 1 \times 10^{10}\Omega$
$\Delta V = 5V$

The resulting voltage coefficient is:

$$\text{Voltage coefficient (\%/V)} = \frac{100(1 \times 10^8)}{1 \times 10^{10}(5)} = 0.2\%/V$$

Note that the voltage coefficient of a particular device may apply only across the selected voltage range, and may, in fact, vary with different voltage increments in the same approximate range.

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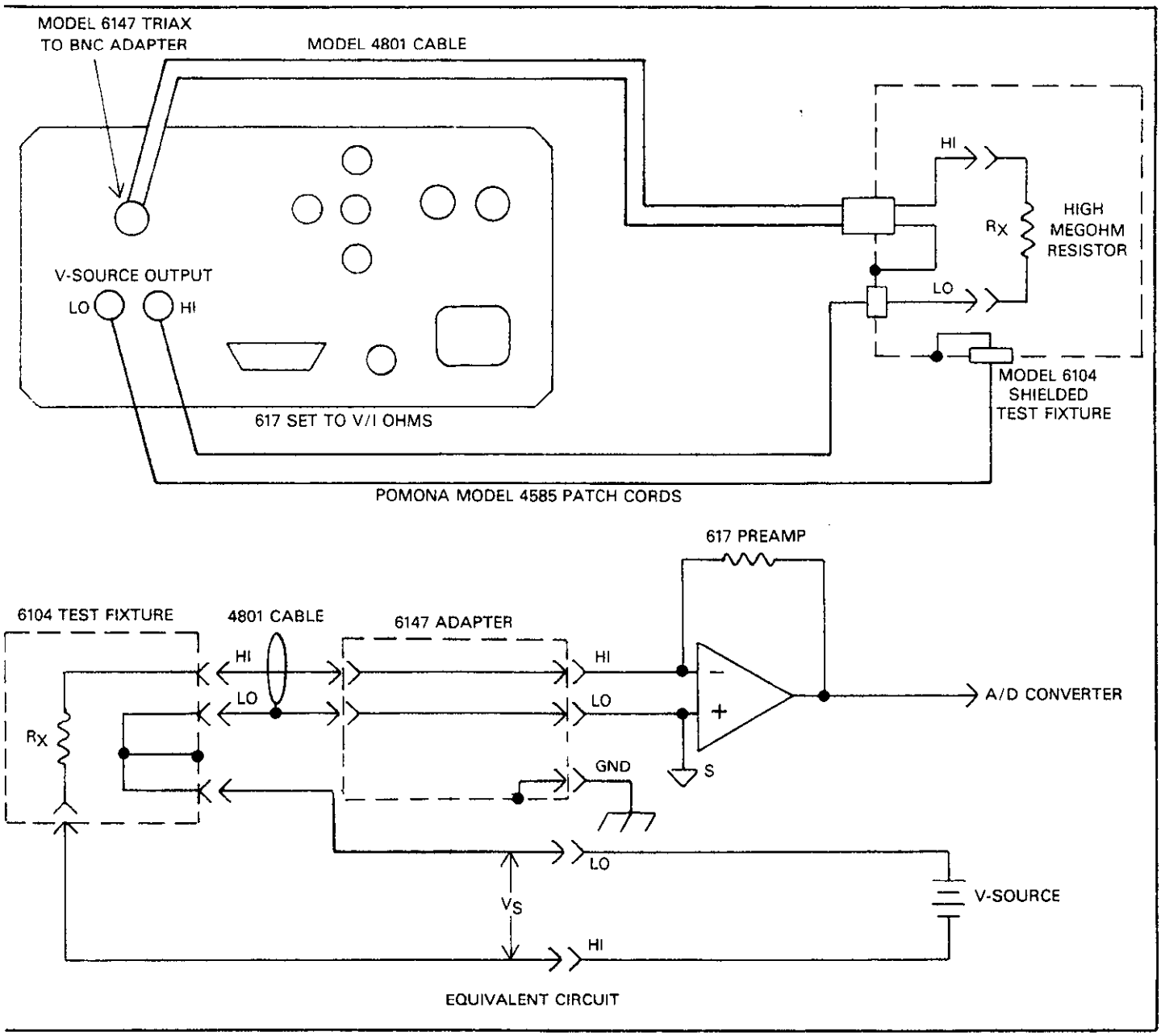


Figure 4-10. Configuration for Voltage Coefficient Studies

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4.9 STATIC CHARGE DETECTION

Electrostatic charge is a deficiency or excess of electrons on an ungrounded surface. Such charges are usually generated on poor conductors of electricity such as plastics, synthetic fibers, and paper during handling or processing of these materials. Once these charges accumulate, they do not dissipate readily because of the excellent insulating characteristics of the materials involved.

Static charge build-up can be a problem with integrated circuits, especially with those of the CMOS variety. While these devices, which operate at high impedance levels, often have static protection built in, it is best to properly protect them during transit or storage. For that reason, such ICs are usually shipped and stored in anti-static tubes.

A primary consideration, then, is the degree of static protection afforded by the anti-static tube. A comparison among various tubes can be set up to test the variations in charge build-up as a particular IC slides the length of the tube. The charge value will, of course, be measured by the Model 617 being operated in the coulombs function.

To perform this test, a test fixture called a Faraday cup will be necessary. Such a fixture can be easily constructed from two cans, as shown in Figure 4-11. For example, the outer can could be the ubiquitous one-gallon paint can, while the inner cylinder could be one of slightly smaller diameter, such as a quart paint can. The two cans must be insulated from one another. Although the type of insulator is not all that critical, ceramic or Teflon insulators can be used.

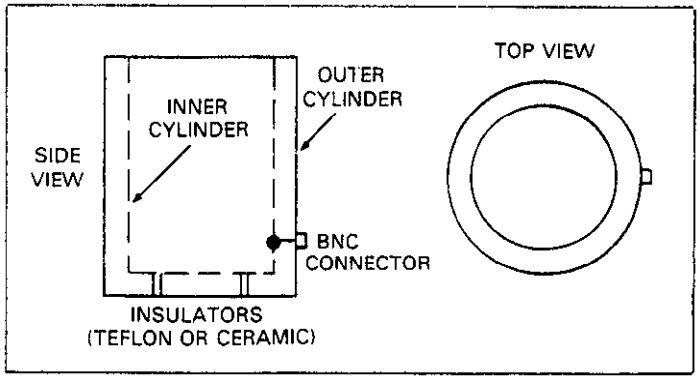


Figure 4-11. Faraday Cup Construction

For convenience, a BNC connector could be mounted on the outside can. The outer, or shield connection will, of course, be connected to the outer can, while the inner conductor should be connected to the inner can.

To perform the test, connect the Model 617 to the Faraday cup using a suitable shielded cable, such as Model 4801 BNC cable. A Model 6147 triax-to-BNC adapter will be required to make the connection. With the instrument in the coulombs mode, place a typical IC in the tube to be tested; allow it to slide the full length of the tube and fall into the Faraday cup. The amount of charge built up during the test will then be registered on the Model 617.

The test can be repeated with other tubes, as required. In order for the test to be valid, all tubes should be the same length, and the same IC should be used in every case. The tube that generates the smallest static charge as seen on the electrometer is the one with the best anti-static characteristics. The amount of charge seen during this test will depend on many factors, including the type of tube material, tube length, the IC used, as well as the relative humidity. Typical values might be in the 0.5-1nC range for a good anti-static tube, while one without anti-static protection might generate 10 times that amount.

4.10 USING THE MODEL 617 WITH EXTERNAL VOLTAGE SOURCES

The internal voltage source of the Model 617 should be more than adequate for most measuring situations. However, there may be a few applications where a voltage higher than the nominal ±100V value is required. For example, it may be desirable to increase the measurement range of the V/I ohms mode. In another instance, voltage coefficient studies at high voltages may required. These functions can be performed with the Model 617 if an external high voltage source is used.

Accuracy of the V/I ohms mode will depend largely on the relative current seen by the instrument. For best accuracy in this mode, it is best to choose a range that will result in a current that is equal to a large percentage of the full range value. On the 200TΩ V/I range, for example, a full range resistance measurement will result in a current of 0.5pA, assuming a voltage of 100V is being used. For resistances above 200TΩ, the current seen by the instrument will be less than 0.5pA. For very high resistance values (above 2PΩ), the current will be very small indeed, and accuracy will be reduced.

Figure 4-12 shows a test set-up using the Model 617 along with an external supply to make V/I resistance measurements. The basic set-up is much like that used when making V/I measurements with the Model 617 voltage source: the resistance under test is connected in series with the electrometer input lead. The voltage supplied by the external supply forces a current, which is read by the electrometer, through the resistor. The current and voltage values are then used to calculate the resistance.

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CAUTION

The maximum voltage between input high and input low is 250V (10sec maximum on mA ranges). Exceeding this value may damage the instrument.

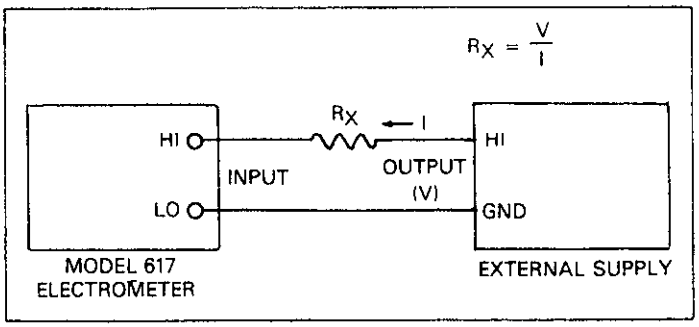


Figure 4-12. Using the Model 617 with an External High Voltage Source

Since an external voltage source is used, resistance values cannot be automatically calculated by the Model 617. You can, however, simplify these calculations by maintaining a known ratio between the external value and the programmed voltage of the Model 617. For example, assume that an external voltage of 200V is used. If you programmed the Model 617 voltage source to 20V, you could easily determine the actual resistance by noting the displayed value and moving the decimal point one place to the right.

The same general considerations apply to making voltage coefficient studies at voltages higher than 100V. The basic configuration shown in Figure 4-12 would be used. As discussed in paragraph 4.8, the resistance would be measured at two different voltages, and the resulting voltage coefficient could then be calculated. As long as a known ratio is maintained between the external high voltage and the programmed voltage of the Model 617, resistance calculations would be relatively simple.

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SECTION 5
PERFORMANCE VERIFICATION

5.1 INTRODUCTION

The procedures outlined in this section may be used to verify that the instrument is operating within the limits stated in the specifications at the front of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

NOTE

If the instrument is still under warranty (less than 1 year from the date of shipment), and its performance falls outside the specified range, contact your Keithley representative or the factory to determine the correct course of action.

5.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at 18—28°C (65—82°F) and at less than 70% relative humidity unless otherwise noted.

5.3 INITIAL CONDITIONS

The Model 617 must be turned on and allowed to warm up for at least two hours before beginning the verification procedures. If the instrument has been subject to extremes of temperature (outside the range specified in paragraph 5.2), additional time should be allowed for internal temperatures to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

NOTE

While rated accuracy is achieved after the two hour warm up period, input bias current may require additional time to come to its optimum level. Allow two hours for input bias current to settle to less than 10fA and eight hours to less than 5fA. It is preferable in sensitive applications to leave the unit on continuously.

5.4 RECOMMENDED TEST EQUIPMENT

Table 5-1 lists all test equipment required for verification. Alternate equipment may be used as long as the substitute equipment has specifications at least as good as those listed in the table.

NOTE

The verification limits in this section do not include test equipment tolerance.

A shielded test fixture will be necessary for some of the amps, ohms and coulombs verification procedures. Construction of

Table 5-1. Recommended Test Equipment for Performance Verification

Description	Specifications	Manufacturer and Model
DC Calibrator	0.19V, 1.9V, 19V, 190V, 0.002%	Fluke; 343A
5½ Digit DMM	0.015% DC Accuracy	Keithley; 197
Teraohmmeter	100MΩ, ±0.035%	Guildline; 9520
	1GΩ, ±0.05%	
	10GΩ, ±0.07%	
	100GΩ, ±0.08%	
Resistor	100MΩ, ±1%	Keithley; R-289-100M
Resistor	1GΩ, ±2%	Keithley; R-289-1G
Resistor	10GΩ, ±2%	Keithley; R-319-10G
Resistor	100GΩ, ±2%	Keithley; R-319-100G
Decade Resistor	10Ω-10MΩ, ±.03%	ESI; DB-62
Standard Capacitor	1000pF, ±0.1%	Hewlett-Packard; 16384A
Shielded Test Box	See Figure 5-1	

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this shield is noted in Figure 5-1. Note that the jumper configuration will depend on whether the amps or ohms mode is being calibrated.

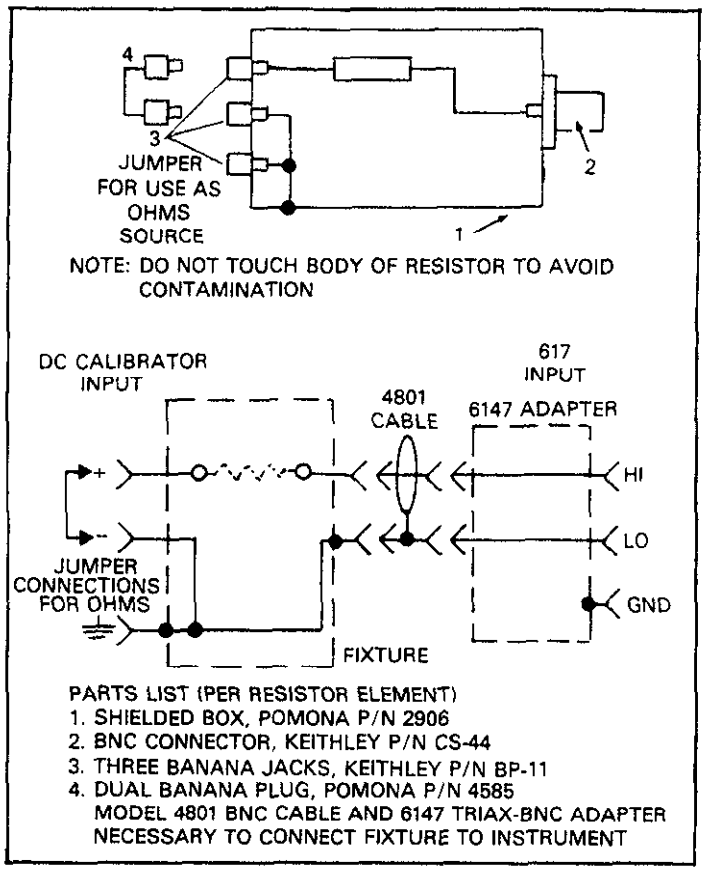


Figure 5-1. Test Fixture Construction

5.5 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying instrument accuracy with each of the four measuring functions: volts, ohms, amps and coulombs. In addition, a procedure to verify accuracy of the internal voltage source is also included. These procedures are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications, refer to Section 7 for calibration procedures, unless the unit is still under warranty.

WARNING

The maximum common-mode voltage (voltage between input low and chassis ground) is 500V. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

CAUTION

The maximum voltage between the high and low input terminals is 250V (10 seconds maximum on the mA ranges). Instrument damage may occur if this value is exceeded.

NOTE

Verify the electrometer section in the order listed: input current, amps, coulombs, volts and ohms. Input current may remain high for several minutes following measurement of high volts or ohms. Place the V, Ω GUARD switch in the OFF position, unless otherwise noted.

5.5.1 Input Current Verification

Perform input current verification as follows:

NOTE

The following procedure must be performed at an ambient temperature of 23°C ±1°C.

1. Disconnect all cables from the Model 617 input.
2. Place the input cap supplied with the instrument on the INPUT connector.
3. Select the amps function, 2pA range, enable zero check, and then enable zero correct.
4. Connect a jumper between the rear panel COM and chassis ground terminals.
5. Disable zero check and allow the reading to stabilize (typically one minute).
6. Verify that the reading is 66 counts or less. Enable zero check.
7. Remove the jumper connected between the COM and chassis ground connectors.

5.5.2 Amps Verification

Perform amps verification as follows:

1. Enable zero check and select the amps mode.
2. Select the 20mA range and make sure autorange is disabled.

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3. Connect the DC calibrator and decade resistance box to the instrument as shown in Figure 5-2.
4. With zero check still enabled, verify that the display reads 0.000 ±1 count. If not, enable zero correct.
5. Apply the correct input by setting the DC calibrator and decade box to the values listed in Table 5-2.
6. Disable zero check. Check to see that the reading is within the limits listed in the table.
8. Repeat the procedure for the 200nA-2mA ranges, as listed in Table 5-2. Be sure to set both the decade box and DC calibrator to the values listed.
9. Using the teraohmmeter, measure the actual value of the 100MΩ resistor and record its value in the appropriate space in the table.

NOTE

Do not touch the body of the resistor to avoid contamination which could give erroneous results.

10. Calculate the actual calibrator voltage by multiplying the measured resistor value by the calibration current for that range. For example, if the actual resistance is 99MΩ, the required calibrator voltage is $V = (99 \times 10^6)(19 \times 10^{-9}) = 1.881V$. Write the calculated value in Table 5-2.
11. Set the calibrator voltage to the exact value obtained in step 10.
12. Place the instrument on the 20nA range and enable zero check. Verify that the display shows 0.000 ±1 count. If not, enable zero correct.
13. Mount the 100MΩ resistor in the shielded fixture (construction is covered in Figure 5-1) and connect the fixture to the instrument, as shown in Figure 5-3.

NOTE

Disconnect floating sources when using this configuration.

14. Disable zero check and verify that the reading is within the limits given in Table 5-2. Enable zero check.
15. Repeat steps 9 through 14 for the 2nA-2pA ranges. For each range, measure the actual resistor value and calculate the calibration voltage using that value along with the required calibration current.

5.5.3 Coulombs Verification

To confirm coulombs operation, proceed as follows:

1. Enable zero check and set the DC calibrator output to 00.000.
2. Connect the 1000pF capacitor, the calibrator, and the Model 617 together, as shown in Figure 5-4.

NOTE

Disconnect floating sources when using this configuration.

3. Place the instrument in the coulombs mode and select the 2nC range. Enable zero correct.
4. Disable zero check, enable suppress, and set the DC calibrator output to 1.0000V.
5. Verify that the display reads between 0.995 and 1.005nC.
6. Enable zero check and set the calibrator output to 0.0000V.

Table 5-2. Limits for Amps Verification

Range	Verification Current	DC Calibrator* Voltage	Resistance Value*	Allowable Reading (18°—28°C)
20mA	19mA	19.000V	1 kΩ	18.970 to 19.030mA
2mA	1.9mA	19.000V	10 kΩ	1.8967 to 1.9033mA
200 μA	190μA	19.000V	100 kΩ	189.70 to 190.30μA
20 μA	19 μA	19.000V	1MΩ	18.970 to 19.030μA
2 μA	1.9 μA	19.000V	10MΩ	1.8967 to 1.9033μA
200 nA	190 nA	1.900V	10MΩ	189.51 to 190.49nA
20 nA	19nA	(1.9V) _____	(100MΩ) _____	18.951 to 19.049nA
2 nA	1.9 nA	(1.9V) _____	(1GΩ) _____	1.8947 to 1.9053nA
200 pA	190 pA	(1.9V) _____	(10GΩ) _____	186.95 to 193.05pA
20 pA	19 pA	(1.9V) _____	(100GΩ) _____	18.689 to 19.311pA
2 pA	1.9 pA	(0.19V) _____	(100GΩ) _____	1.8630to 1.9370pA

*Values in parenthesis are nominal values. See text for methods to determine these values.

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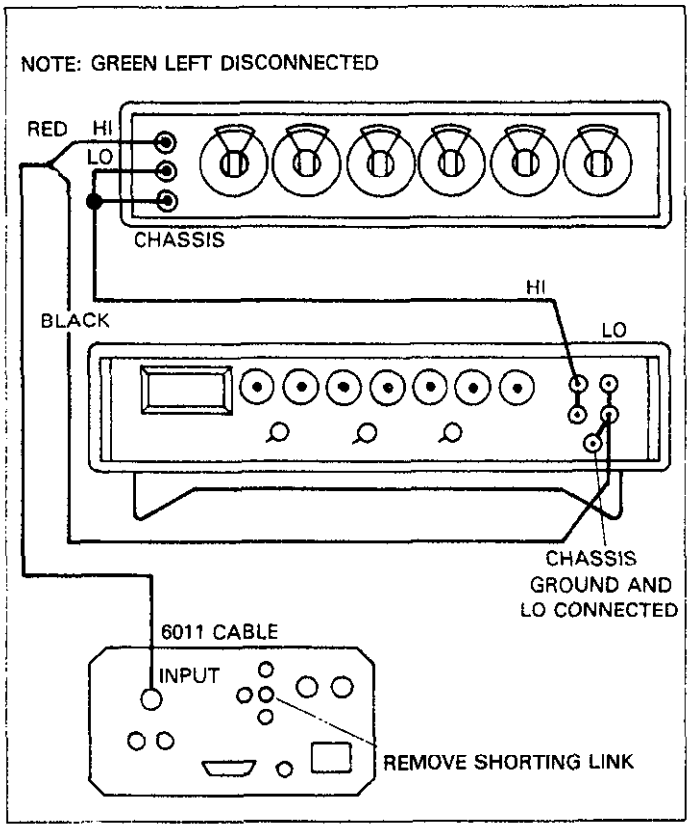


Figure 5-2. Connections for Amps Verification (200nA to 20mA Ranges)

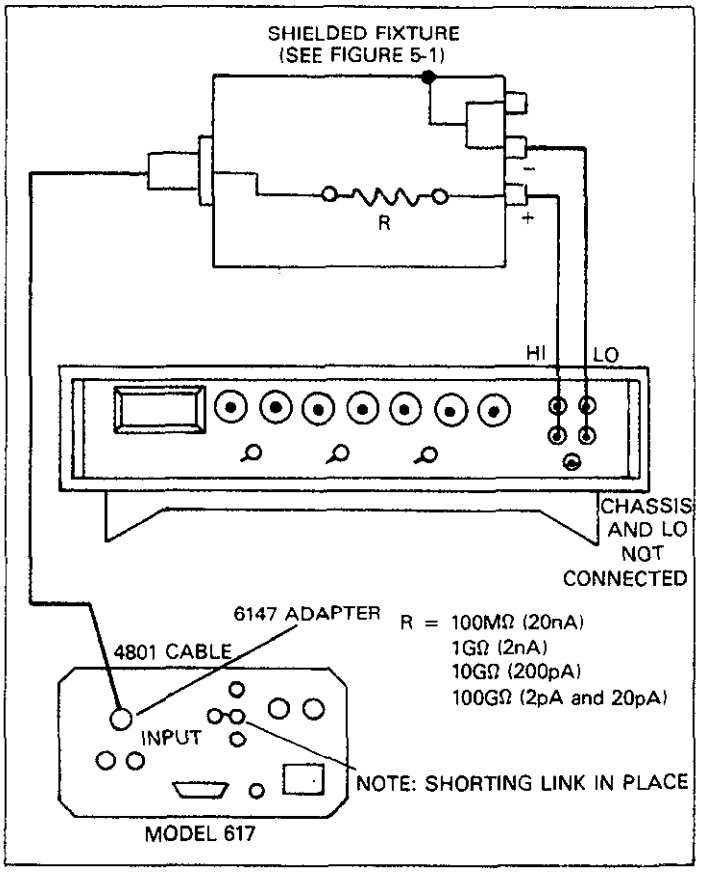


Figure 5-3. Connections for Amps Verification (2pA to 20nA Ranges)

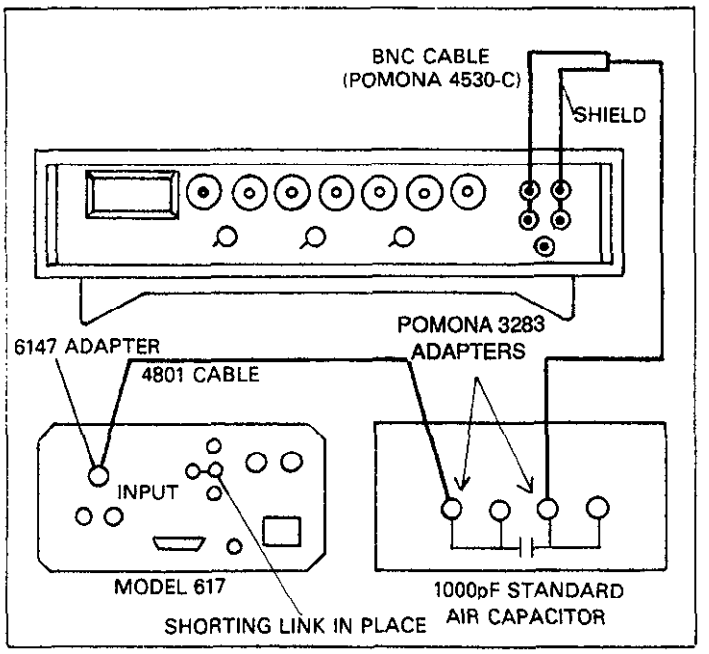


Figure 5-4. Connections for Coulombs Verifications

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5.5.4 Volts Verification

NOTE

Current and charge verification must be performed before volts verification.

Verify the volts function as follows:

1. Enable zero check and select the volts functions with the associated front panel buttons.
2. Select the 200mV range and enable zero correct. Check to see that the display shows 000.00 ±1 count. If not, enable zero correct.
3. Connect the signal source to the instrument, as shown in Figure 5-5. Set the calibrator output to 190mV, as indicated in Table 5-3.
4. Disable zero check and verify that the reading is within the limits listed in Table 5-3.

Table 5-3. Limits for Volts Verification

Range	Applied Calibrator Input	Allowable Reading (18° – 28°C)
200mV	190.000mV	189.87 to 190.13mV
2 V	1.90000 V	1.8990 to 1.9010 V
20 V	19.0000 V	18.990 to 19.010 V
200 V	190.000 V	189.86 to 190.14 V

5. Repeat the procedure for the 2V, 20V, and 200V ranges by applying the respective inputs listed in Table 5-3. Check to see that the reading for each range is within the limits listed in the table.
6. Repeat the procedure for each of the ranges with negative voltages.

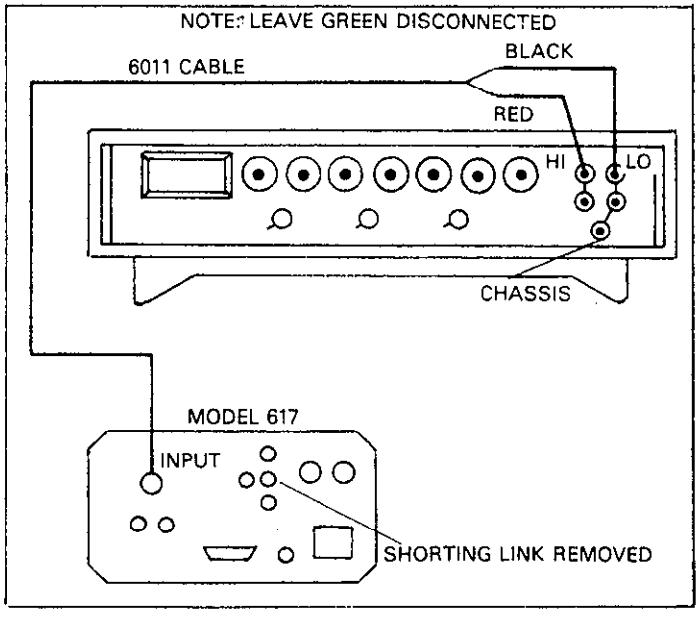


Figure 5-5. Connections for Volts Verification

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5.5.5 Ohms Verification (2kΩ-20MΩ Ranges)

Perform ohms verification for the 2kΩ-20MΩ ranges as follows:

NOTE

Charge and current verification must be performed before resistance verification.

1. Place the instrument in the ohms mode, select the 2kΩ range, and enable zero check.
2. Verify that the display shows .0000 ±1 count. If not, enable zero correct.
3. Short the input leads, disable zero check, and enable suppress.
4. Connect the decade resistance box to the Model 617, as shown in Figure 5-6.
5. Set the decade resistance box to a value of 1.900kΩ and disable zero check.
6. Verify that the reading is within the limits stated in Table 5-4. Enable zero check.
7. Select the remaining ranges and repeat steps 5 and 6 for each range.

Table 5-4. Limits for Ohms Verification (2kΩ-20MΩ Ranges)

Range	Input	Allowable Reading (18° –28°C)
2 kΩ	1.900 kΩ	1.8958 to 1.9042 kΩ
20 kΩ	19.00 kΩ	18.971 to 19.029 kΩ
200 kΩ	190.0 kΩ	189.52 to 190.48 kΩ
2MΩ	1.900MΩ	1.8952 to 1.9048MΩ
20MΩ	10.00MΩ	9.974 to 10.026MΩ

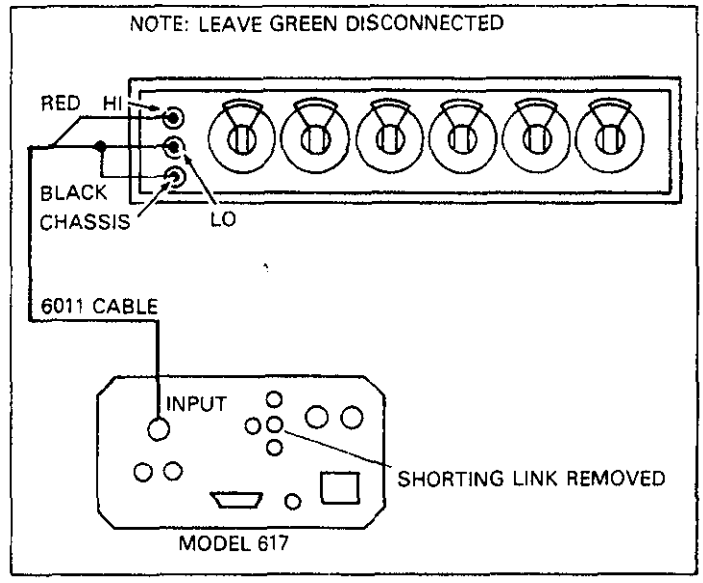


Figure 5-6. Corrections for Ohms Verification (2kΩ-20MΩ Ranges)

5.5.6 Ohms Verification (200MΩ and GΩ Ranges)

Accuracy of the 200MΩ, 2GΩ, 20GΩ and 200GΩ ranges may be verified as follows:

1. Accurately measure the 100MΩ , 1GΩ and 10GΩ resistors with the teraohmmeter (or obtain the values from Table 5-2) and record the values in Table 5-5. Calculate the allowable tolerances for each range by determining the percent value and adding or subtracting from the actual value.
2. Place the instrument in the ohms mode and select the 200MΩ, range. Enable zero check and verify that the display shows 00.00 ± 1 count. If not, enable zero correct.

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3. Place the 100MΩ resistor in the shielded fixture and connect the fixture to the instrument as shown in Figure 5-7. Note that the fixture is modified from the original configuration so that one side of the resistor is connected to the rear panel COM terminal.
4. Place the V, Ω GUARD switch in the ON position.

WARNING

Up to 300V may be present on the test fixture when using guarded operation. Enable zero check and disconnect the fixture from the instrument before installing or removing test resistors.

NOTE

Do not touch the body of the test resistors, as the resulting contamination could give erroneous results.

5. Disable zero check and verify that the resistance value is within the tolerance calculated in step 1.
6. Repeat the above procedure for the 2GΩ and 20GΩ ranges using the 1GΩ and 10GΩ resistors, and verify that the instrument is within specified limits.
7. Enable zero check and disconnect the test fixture from the instrument.

A 100GΩ standardized resistor is necessary to check the 200GΩ range. This test verifies that the input impedance of the unit is greater than 200TΩ. Proceed as follows:

1. Place the instrument in the volts mode, select the 20V range, and enable zero check. Verify the display shows 0.000 ±1 count. If not, enable zero correct.
2. Place the V, Ω GUARD switch in the ON position.
3. Connect the DC calibrator to the Model 617 (use the configuration in Figure 5-8, but with a short in place of the resistor). Set the calibrator output to 19.000V. Disable zero check and note the reading.
4. Enable zero check and place the 100GΩ resistor in the shielded test fixture as shown in Figure 5-8.

WARNING

Up to 300V may be present on the shielded fixture in the guarded mode.

5. Disable zero check. Wait a few seconds before noting the reading to allow the reading to settle.
6. Compare the reading obtained in step 5 with that noted in step 3. The two readings should be within 10 counts (10mV) of one another.

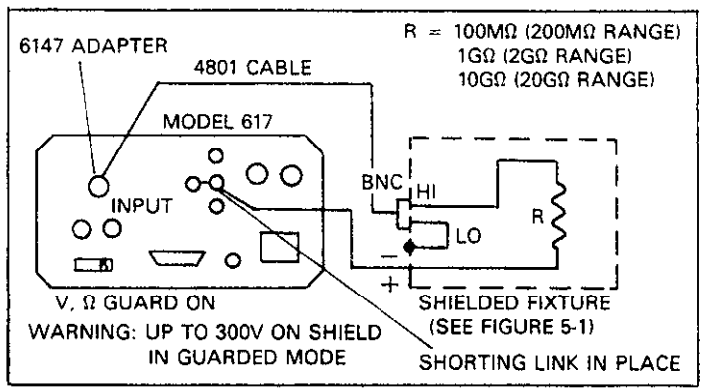


Figure 5-7. Connections for Ohms Verification (200MΩ, 2GΩ and 20GΩ Ranges)

Table 5-5. Limits for Ohms Verification (200MΩ, 2GΩ and 20GΩ Ranges)

Range	Nominal Resistance	Measured* Resistance (R_M)	Percent Tolerance (T) (18° −28°C)	Allowable Reading**
200MΩ	100MΩ	_____	±0.305%	_____
2GΩ	1GΩ	_____	±1.505%	_____
20GΩ	10GΩ	_____	±1.505%	_____

*From Table 5-2.

**Allowable Reading = $R_M \pm ((T \times R_M)/100)$.

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5.5.7 Voltage Source Verification

Use the following procedure to verify that the Model 617 voltage source is within tolerance:

WARNING
Dangerous voltage may be present on the voltage source output terminals when the voltage source output is enabled.

1. Connect the DMM (see Table 5-1) to the voltage source output terminals, as shown in Figure 5-9.
2. Select an appropriate DCV range on the DMM. Alternately, place the DMM in the autorange mode, if desired.
3. Press the DISPLAY button to view the voltage source value and turn on its output by pressing the OPERATE button.
4. Using the ADJUST buttons, set the voltage source output to 00.00V.

Table 5-6. Voltage Source Verification Limits

Programmed Voltage	Allowable DMM Reading (18°C – 28°C)
00.00V	– 0.050 to + 0.050V
01.00V	0.948 to 1.052V
10.00V	9.93 to 10.07V
25.00V	24.90 to 25.10V
50.00V	49.85 to 50.15V
100.00V	99.75 to 100.25V

5. Verify that the voltage source value is within the limits stated in Table 5-6.
6. Repeat steps 4 and 5 above with the remaining voltages listed in the table.
7. Repeat the procedure for negative voltages of the same amplitude listed in the table.

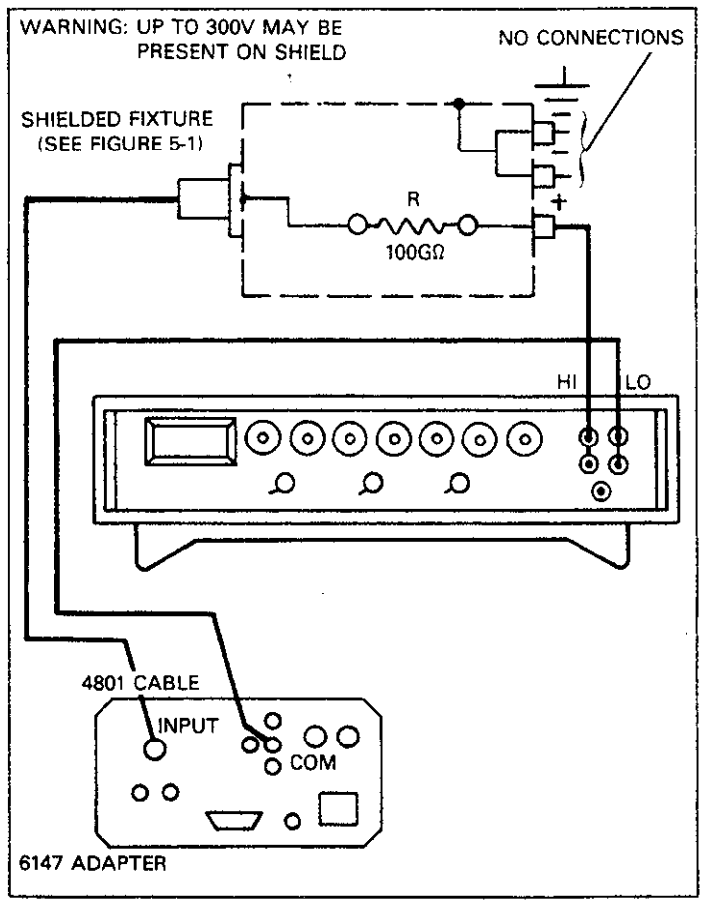


Figure 5-8. Input Impedance Verification

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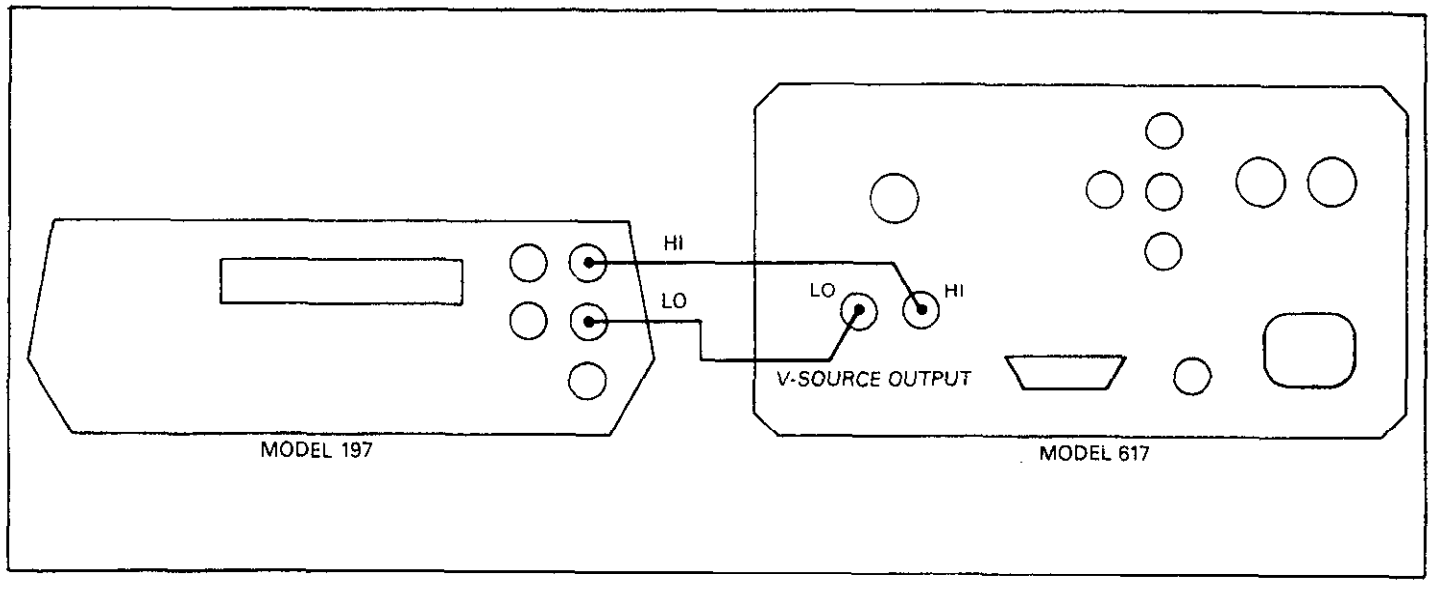


Figure 5-9. Connections for Voltage Source Verification

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SECTION 6
THEORY OF OPERATION

6.1 INTRODUCTION

This section contains an overall functional description of the Model 617 in block diagram form as well as details of the various sections of the instrument. Information concerning the electrometer section, mother board circuitry, IEEE-488 interface, power supplies, and display circuitry is included.

Information is arranged to provide a description of each of the functional blocks within the instrument. Many of these descriptions include simplified schematics and block diagrams. Detailed schematic diagrams and component layout drawings for the various circuit boards are located at the end of Section 8.

6.2 OVERALL FUNCTIONAL DESCRIPTION

A simplified block diagram of the Model 617 is shown in Figure 6-1. The instrument may be divided into four discrete sections: analog, digital, voltage source, and power supplies. The analog, digital, and voltage source sections are electrically isolated from one another by using opto-isolators for control and communications. Separate power supplies for the various analog sections, digital section, and the voltage source ensure proper isolation. Because of these isolation techniques, the analog low connection may be floated up to ±500V above chassis ground, while voltage source common may be floated up to ±100V ground, and digital common may be floated up to ±30V above ground.

The analog section consists of the input stage, output stage, ranging amplifier, A/D converter, feedback and switching elements. The input stage is a propietary FET amplifier designed for high input impedance (200TΩ) and low input offset current (less than 5fA). The output stage provides further amplification, thus allowing the preamp output to go as high as ±210V, depending on the selected range and function. Further control of the input and output stages are provided by the feedback and switching elements, which set gain and transfer function according to the selected range and function. In addition, zero check and zero correct provide a convenient means to zero the instrument, allowing cancellation of internal offsets.

The ranging amplifier conditions the output stage signal into a 0-2V signal for the A/D converter. The A/D converter uses both charge balance and single-slope conversion techniques.

The heart of the digital section is the 146805E2 CMOS processor that supervises the entire operation of the instrument. Additional digital circuits include the display made up of a 4½ digit mantissa and a 2-digit alpha or numeric exponent, the IEEE-488 interface, and the front panel switch matrix. The switch matrix decodes front panel switch closure information that controls instrument operation from the front panel.

The voltage source is a fully programmable, isolated unit that is also controlled by the microprocessor. An internal 12 bit D/A converter transforms the digital control information into analog voltages that set the voltage output to a maximum of +102.4V, −102.35V with 50mV resolution.

Because of the diversity of circuitry within the Model 617, a number of power supply voltages are required. The voltage source requires both ±15V and ±110V supplies, while the analog section requires ±5V (input stage) and ±210V and ±24V supplies (output stage). Additional supplies include a separate +5V and −9.1V supply for A/D circuits, and a separate +5V supply for digital circuitry. In order to ensure proper isolation, two separate power transformers are used: one for the digital and voltage source power supplies, and the other for analog power supplies.

6.3 INPUT PREAMPLIFIER

The input preamplifier provides the high input impedance and high output voltage capability necessary for the volts and ohms functions, and the low input impedance and high current output capability needed for the amps and coulombs functions.

A simplified block diagram of the input preamplifier is shown in Figure 6-2. The circuit is essentially made up of three sections: an input stage, which provides the necessary input impedance functions, a gain stage, which provides the needed amplification, and an output stage, which supplies the required voltage or current drive capability. Additional feedback and switching elements configure the amplifier according to the selected measuring function.

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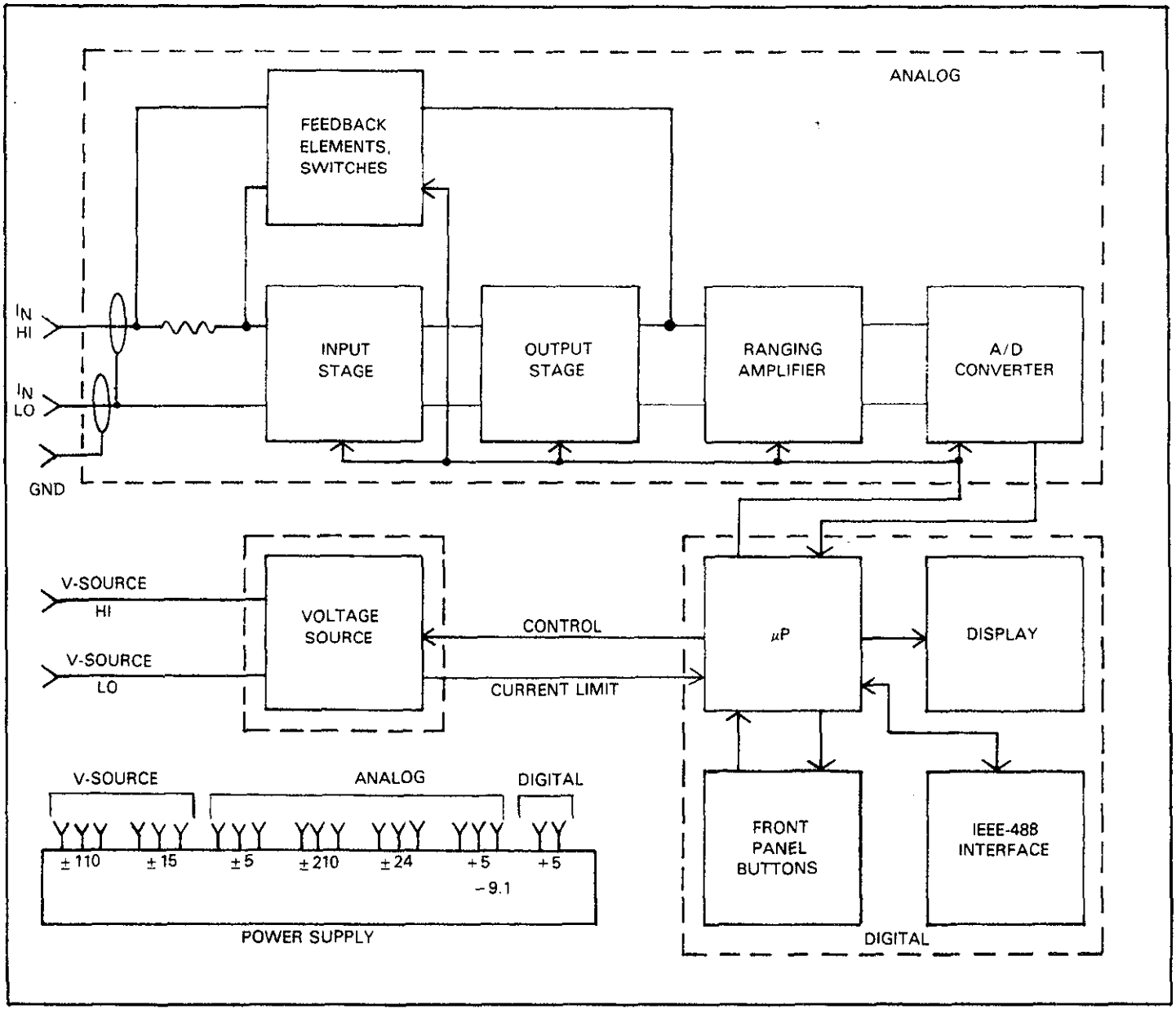


Figure 6-1. Overall Block Diagram

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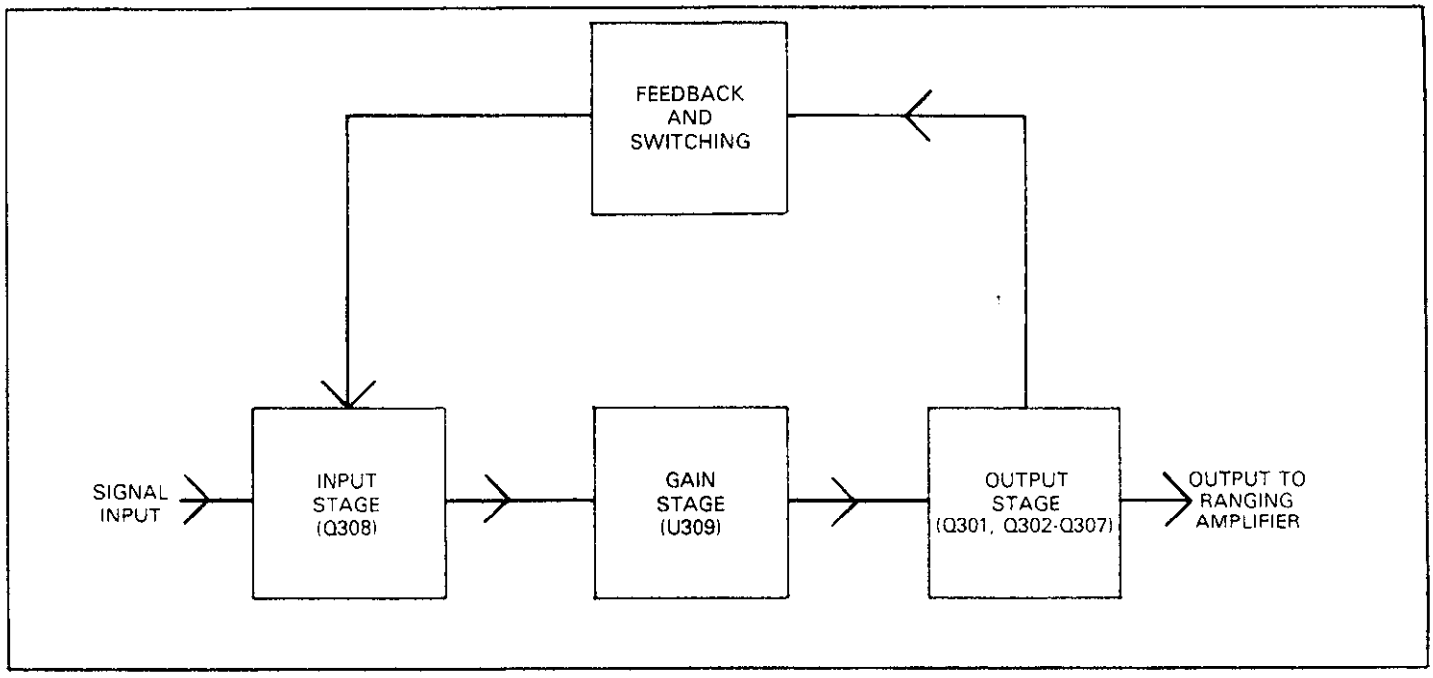


Figure 6-2. Basic Configuration of Electrometer Preamplifier

The exact configuration of the input preamplifier will depend on the measuring function. Figure 6-3 shows circuit configuration for the four measuring functions. In the volts function, the circuit is set up as a high-input impedance ($2 \times 10^{14}\Omega$), unity gain, non-inverting buffer amplifier. In the ohms function, a bootstrapped reference is placed in series with a range resistor (R_F) drives a constant current through the measured resistance (R_X). The reference has a value of 10V, 1V or 0.1V, depending on the selected range. The voltage developed across the unknown resistance is proportional to its value.

In the amps and coulombs modes, the circuit is configured as a feedback type current-to-voltage converter. In the amps mode, the feedback element is a resistor, with the value dependent on the selected range. In the coulombs mode, the feedback element is a capacitor.

6.3.1 Input Stage

A simplified schematic of the input stage is shown in Figure 6-4. The primary purpose of this stage is to provide low leakage characteristics of the input preamplifier.

Stage operation centers around a dual JFET, Q308. Resistors R314, R342, R351 and R352 provide a means to balance the circuit with help of jumper W303. Depending on circuit offset, jumper W303 should be placed in one of three positions: A, B or C.

Signal input is applied to the gate of the left JFET section through R334. The characteristics of the right JFET section remain constant since its V_{GS} voltage stays constant. Because of the variation in the characteristics of Q308A, the current through R335 varies, developing a proportional output signal that is applied to the next stage.

6.3.2 Gain Stage

Input preamplifier gain is provided by a single IC operational amplifier, U309, as shown in Figure 6-5. The input signal from the input stage is applied to the inverting and noninverting terminals of the op amp, while the output from the IC is applied to the output stage. The feedback capacitor, C319, is one of several components that provides stability by limiting the bandwidth of the amplifier.

6.3.3 Output Stage

The output stage takes on one of two configurations, depending on the selected function. In the volts and ohms modes, the output is optimized for voltages as high as ±210V, while a different configuration (one necessary for high current) is used in amps and coulombs.

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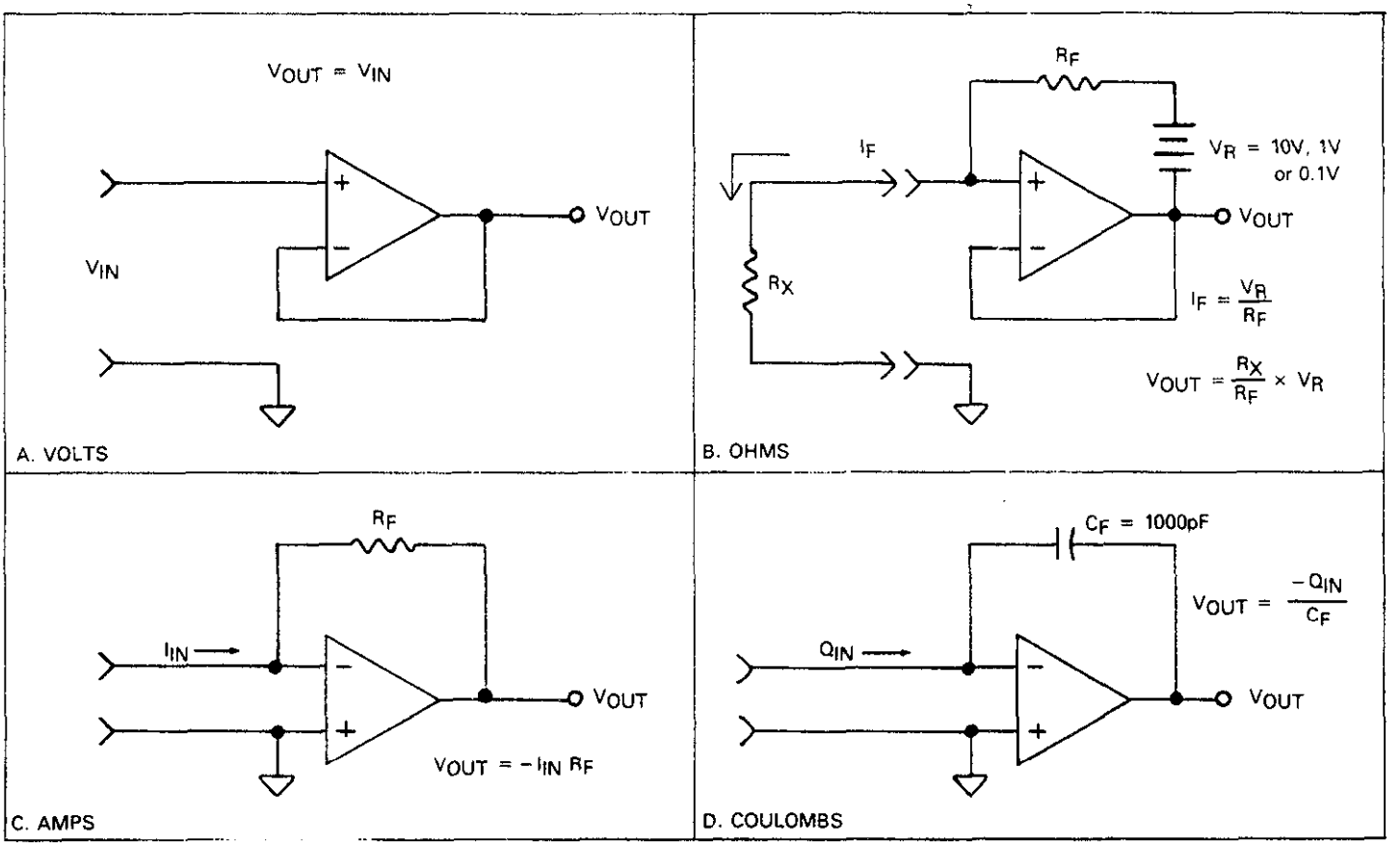


Figure 6-3. Electrometer Preamplifier Configuration

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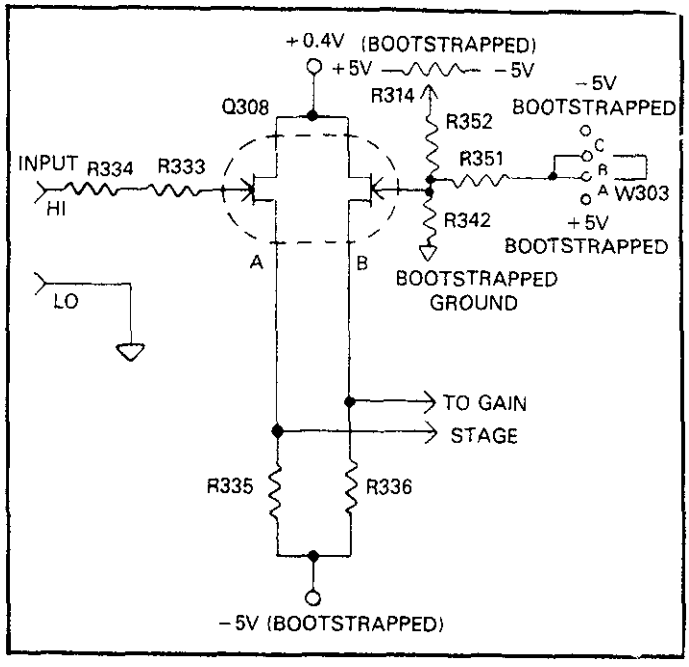


Figure 6-4. Simplified Schematic of Input Stage

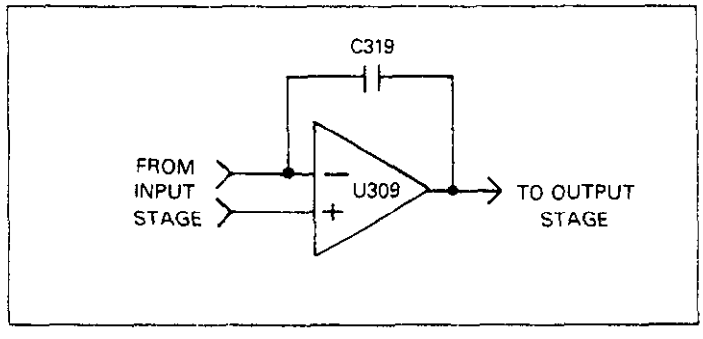


Figure 6-5. Gain Stage

A simplified diagram of the output stage in the volts and ohms modes is shown in Figure 6-6. Four transistors, Q301, Q303, Q304, and Q305 are used in this configuration. Each transistor pair is used for one-half the output voltage swing. Q301 and Q304 are used for the positive half, while Q303 and Q305 are used for the negative half. Because of the ±210V voltage swing requirement, ±210V supplies are used. Each transistor pair is operated in series to provide the necessary device breakdown voltage and power rating.

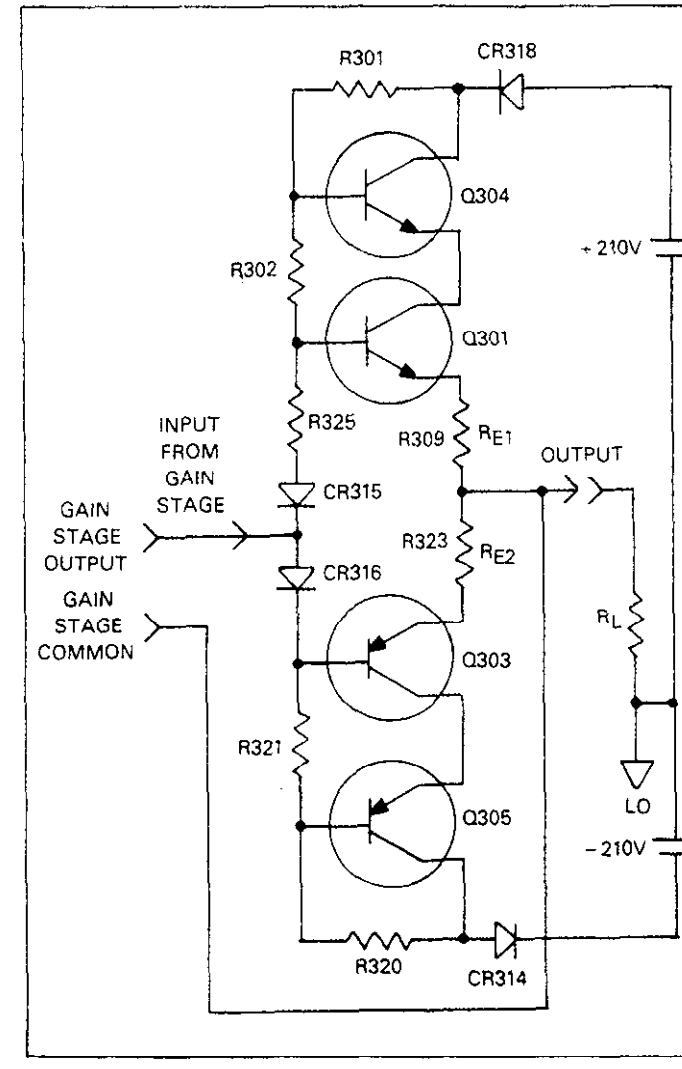


Figure 6-6. Output Stage Configuration (Volts and Ohms)

Circuit biasing components include R301, R302, R320, R321, R325, CR315, and CR316. Meanwhile, CR318 and CR314 provide protection for the 210V supplies in case a high external voltage is applied to the PREAMP OUT terminal.

Output voltage V from the gain stage causes a current to flow through the emitter resistor R_{E1}, which is approximately equal to V_{IN}/R_E. This same current flows through the load resistor, R_L which produces a buffered output voltage of V_{IN} and is non-inverting.

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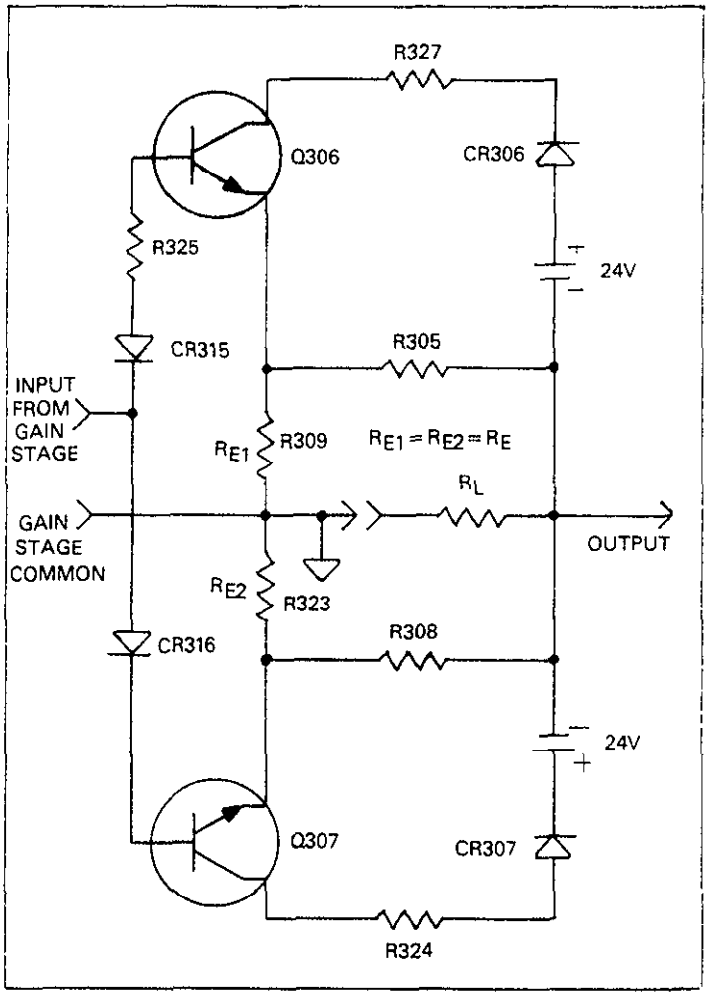


Figure 6-7. Output Stage Configuration (Amps and Coulombs)

Output stage configuration for the amps and coulombs functions is shown in Figure 6-7. Q306 and Q307 are the active devices for this configuration. Since the power supply voltages are much lower (±24V), only a single pair of transistors is required. As with the high voltage configuration, signal input is applied through the two diodes to the bases of the transistors. This input causes a current, V/R_E to flow through R309 and R323. This current develops an output voltage $-V(R_L/R_E)$. R327 and R324 limit power dissipation at high current outputs for Q306 and Q307 respectively. CR306 and CR307 provide protection for the 24V supplies in case a high external voltage is applied to the PREAMP OUT terminal. R305 and R308 provide protection for the output stage in this same situation. Note that the output stage provides an inversion in amps and coulombs, while in volts and ohms it does not.

6.3.4 Ohms Voltage Source

In the constant-current ohms mode, a bootstrapped voltage source is connected in series with a range resistor to force a constant current through the resistance being measured. A simplified schematic diagram of this source is shown in Figure 6-8.

The source itself is made up of U304 and associated components. VR301 provides the voltage reference, while VR304 is a clamping diode to protect the circuit in case of line over voltage. R347 limits power dissipation in Q302. The current through the reference is produced by the 10V output through R315. R316, R313 and R317 divide the output to provide feedback for U304. R313 and VR301 are selected at the factory to provide an accurate 10V output. The actual

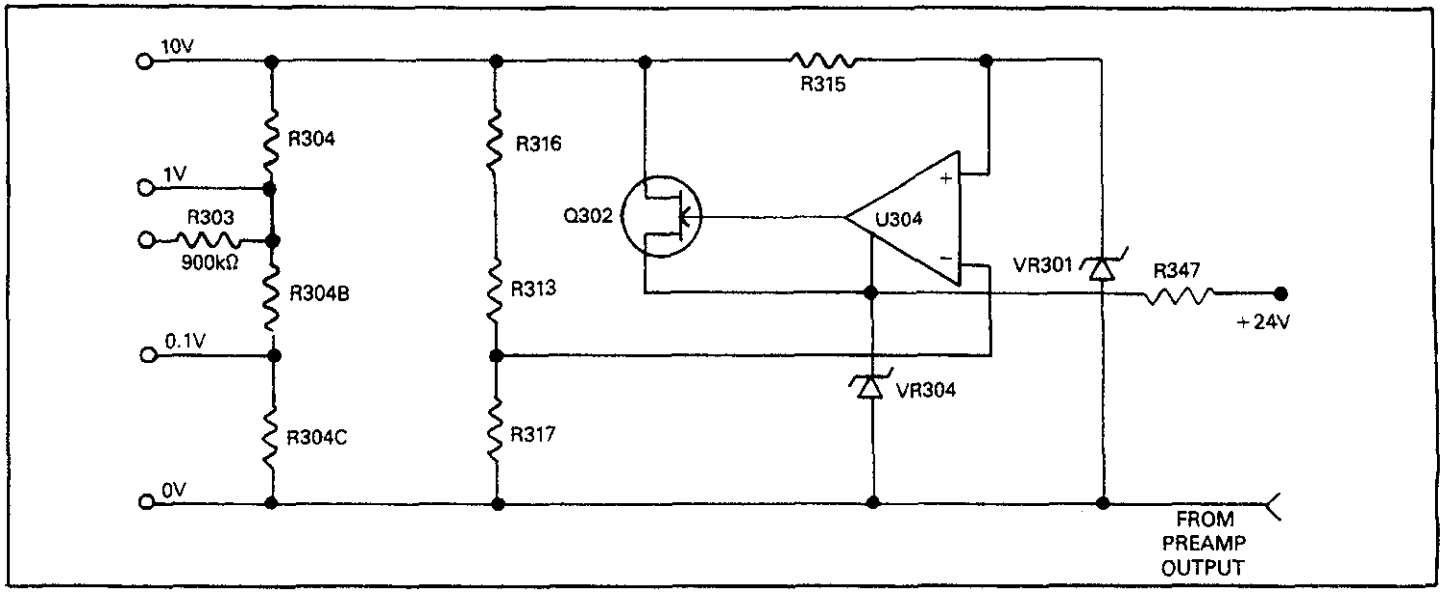


Figure 6-8. Ohms Voltage Source Simplified Schematic

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souce output is 10V, but this value is divided to 1V and 0.1V by a voltage divider made up of elements of R304. Q302 buffers the output of U304 since R304 will draw 10mA. Only a single voltage source value is used for a given range, with the value being selected by the appropriate relay contacts. For the 2MΩ range, however, all relay contacts are open and a 1μA current is sourced through the precision 900kΩ resistor R303 and feedback element R322.

6.3.5 Zero Check

The zero check mode provides a means for determining and cancelling offsets internal to the instrument. The exact configuration of the zero check circuitry will depend on the selected function.

A simplified schematic of the zero check circuitry for volts and ohms functions is shown in Figure 6-9. When zero check is enabled, K307 is energized, providing a path to signal common through the normally closed contacts of K301. A 10MΩ resistor, R334, is placed across the electrometer input when zero check is enabled, while the preamp input is shorted to input low.

In amps and coulombs, contacts on K301 connect the inverting input and the output of the op amp together. This configuration gives the circuit unity gain, allowing any input offset voltage to appear at the output. Note that when zero check is enabled, the input impedance is the combined impedance of the feedback element in parallel with R334, which has a value of 10MΩ (see Figure 6-10).

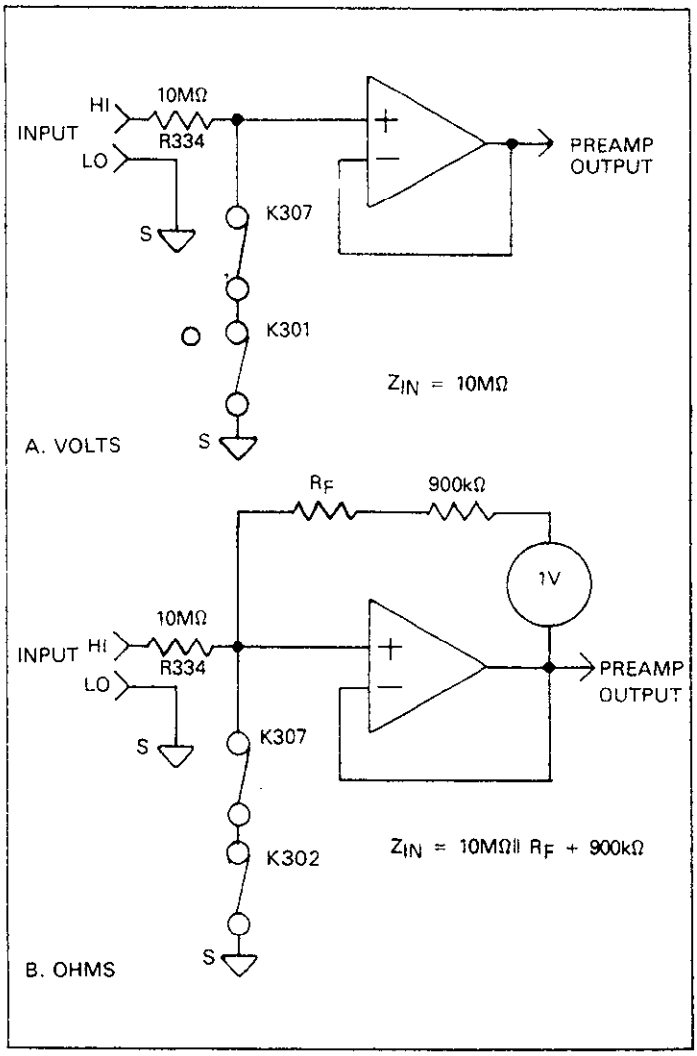


Figure 6-9. Zero Check Configuration (Volts and Ohms)

6.4 ADDITIONAL SIGNAL CONDITIONING

Before the signal can be applied to the A/D converter for digitization, it must be further scaled as described in the following paragraphs.

6.4.1 Ranging Amplifier

The ranging amplifier provides inverting gain values of X10, X1, X0.1, or X0.01. The actual gain value will depend on the selected range and function.

A simplified schematic of the ranging amplifier is shown in Figure 6-11. The ranging amplifier itself is U130, while gain is set by feedback resistors R142, R143, R144, R145 and input resistor R128. The gain is modified by switching these resistors in and out of the circuit with FETs.

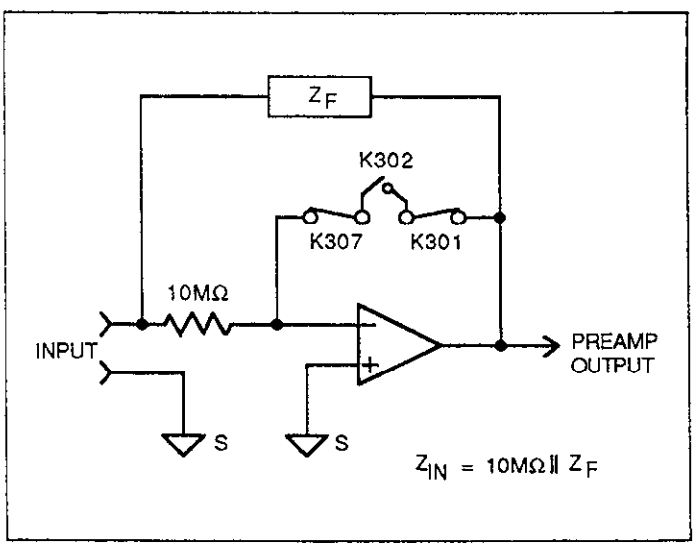


Figure 6-10. Zero Check Configuration (Amps and Coulombs)

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The gain of the ranging amplifier is determined by the following formula:

$$A_V = \frac{-R_F}{R128}$$

(Note that R_F = R142 in parallel with R143, R145 or R146, depending on which is selected).

For example, for X10 gain, the selected feedback resistor R_F if 142, yielding a gain of:

$$A_V = \frac{-2M\Omega}{200k\Omega} = -10$$

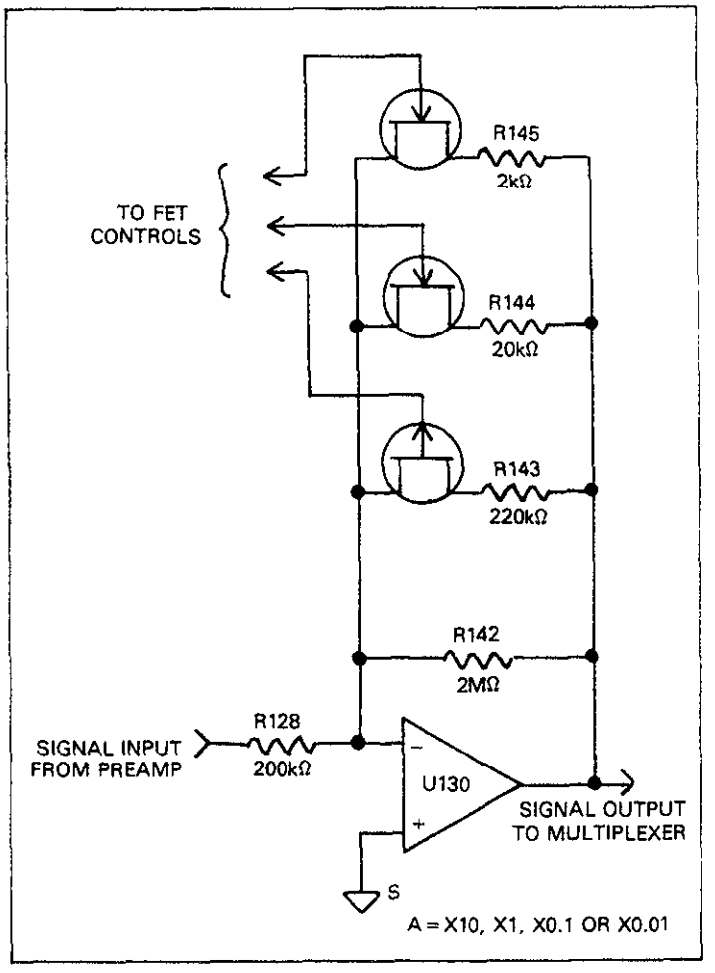


Figure 6-11. Simplified Schematic of Ranging Amplifier

6.4.2 Multiplexer and Buffer Amplifier

The multiplexer selects among the three signals that are part of the Model 617 measurement cycle. During the common phase, the multiplexer selects signal common. During the reference phase, the −2V reference voltage is selected, while the signal from the ranging amplifier is selected during the signal phase.

Figure 6-12 shows a simplified schematic of the multiplexer and buffer amplifier. U145 is the multiplexer IC, which contains CMOS devices that act as analog switches to select among the three input signals. The multiplexer IC is controlled by digital signals that are generated by the microprocessor.

Figure 6-13 shows the general signal switching phases for the three signals. During each phase, an integration is performed by the A/D converter, and the resulting data is then used by the microprocessor to calculate the final reading.

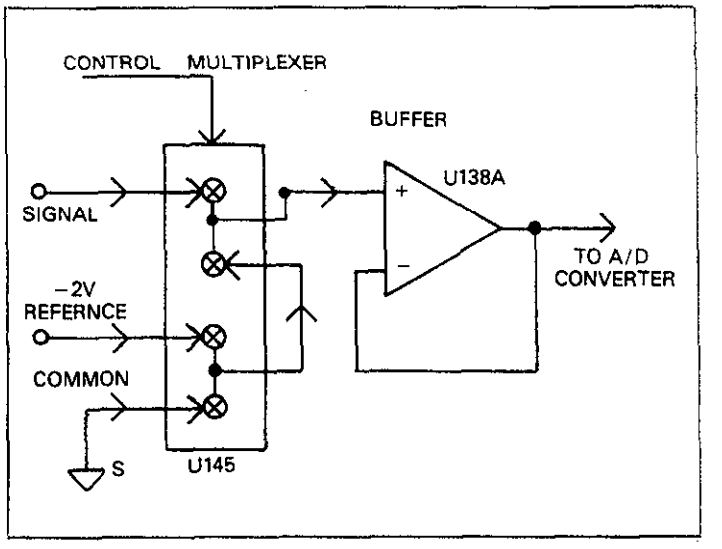


Figure 6-12. Multiplexer and Buffer

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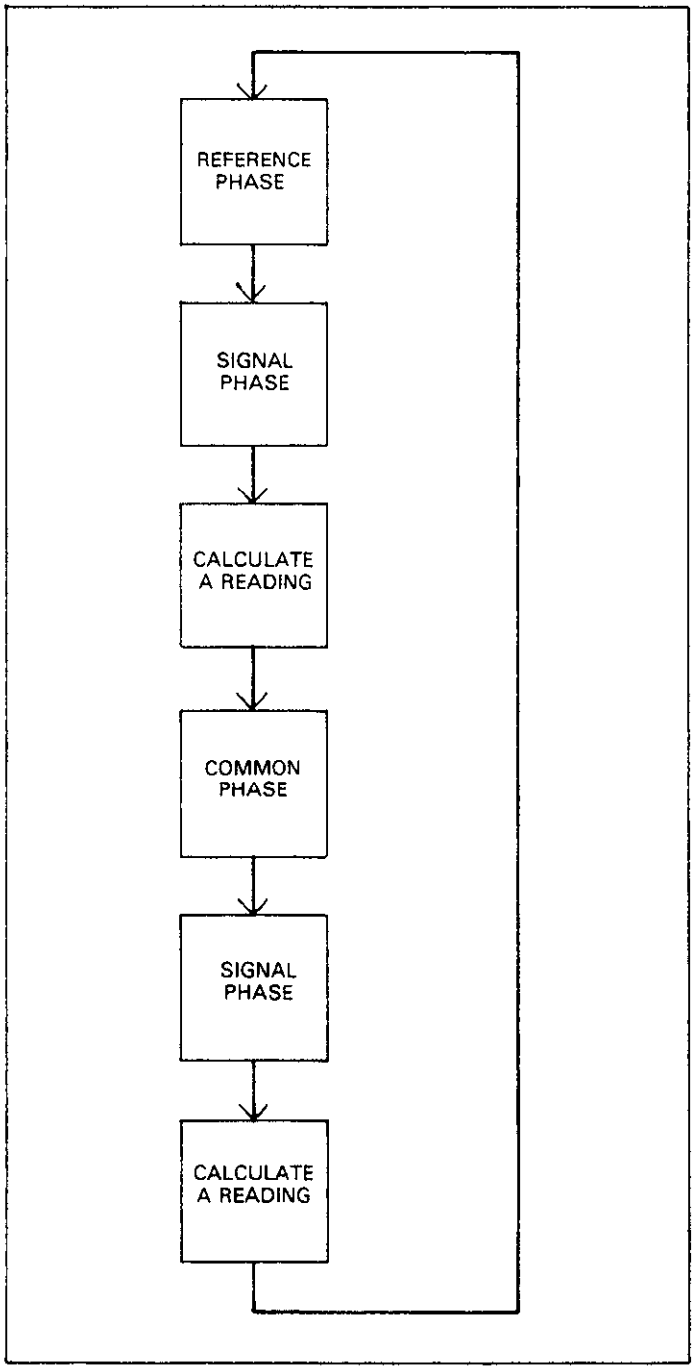


Figure 6-13 Multiplexer Phases

6.4.3 -2V Reference Source

Model 617 measurements are based on comparing the unknown signal with an internal −2V reference voltage source. During each measurement cycle, the unknown signal is sampled and then compared with signal common and the −2V reference values.

Figure 6-14 shows a simplified diagram of the −2V reference source. VR102 provides a highly stable −6.3V reference, while U139 and elements of R153 provide a constant current to minimize zener voltage variations. R146A and R146B divide down the −6.3V value to the final −2V reference voltage. The output of U139 (−7V) is used as bias for the A/D converter, and as a negative supply for various other components.

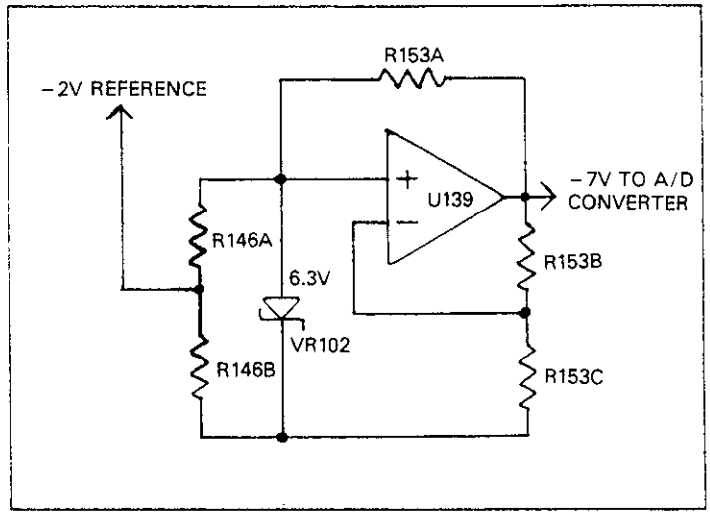


Figure 6-14. -2V Reference Source

6.5 A/D CONVERTER

The Model 617 uses an A/D converter that utilizes both constant-frequency charge balance and single-slope techniques. This combination gives the instrument both high accuracy and relatively fast conversion times.

A simplified schematic of the A/D converter is shown in Figure 6-15, along with an associated integrator waveform.

The charge balance phase begins when the input ENABLE/-DISABLE line is set high. This action occurs at the end of a software generated delay period that allows the signal to settle following signal selection. Once the input is enabled, the signal from the buffer amplifier is added to the level shift current applied through R153H. In this manner, the ±2V bipolar signal from the buffer amplifier is converted to a unipolar signal that can be integrated.

The integrator is made up of U138B and C128. When the input to the integrator is applied, the integrator output ramps up until its voltage is slightly higher than the voltage applied to the inverting input of the charge balance comparator

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(U137B). When the Q4 output of the clock generator (U127) goes high; the output of U135B is low, the $\overline{Q1}$ output of U126A will go high. This action injects the charge balance current into the integrator input. Since the charge balance current is much larger than the sum of the input and level shift currents, the integrator output now ramps in the negative direction. The integrator output will continue to ramp in the negative direction until the output of U135A goes low. Note that the Q3, Q4, and Q5 outputs of U127 must all be high for the output of U135A to go low.

The output of U136C is gated with the Q2 output of the clock generator by U135C. Each time Q2 goes high while the U136C output is high, a pulse is fed to the microprocessor. The MPU then counts the total number of pulses that occur during the charge balance phase.

The charge balance phase lasts for 100msec. At the end of this period, the output of the integrator is resting at some positive voltage. Since the integrator output is connected to the non-inverting input of the single-slope comparator (U137A), the single-slope comparator output remains high until the integrator output ramps in the negative direction.

During the single-slope phase, Q108 is turned off to disconnect the input and charge balance currents from the integrator input. In place of these two currents, the single-slope current (I_{SS}) is injected into the integrator input. This current is developed by connecting one end of R149H to +5V through U136B. As long as the integrator output remains positive, the Q2 pulses from U127 are transmitted to the microprocessor, where they are counted to be used in the final reading. Once the single-slope comparator output goes low, the Q2 pulses are turned off by U135C.

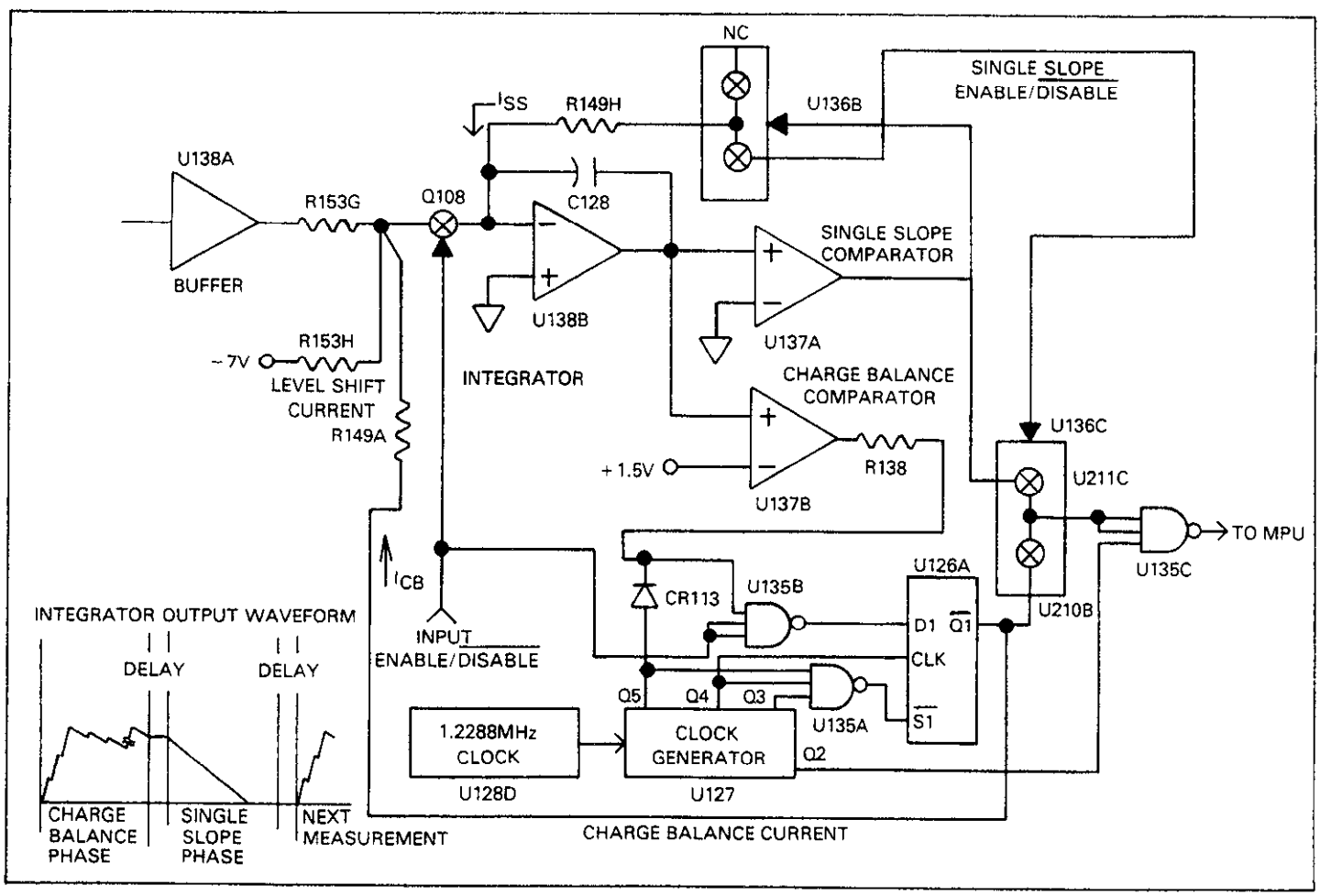


Figure 6-15. A/D Converter

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6.6 DIGITAL CIRCUITRY

Model 617 operation is controlled by the internal microcomputer and associated software. The following paragraphs briefly describe the various aspects of the digital circuitry. Descriptions are keyed to the digital circuitry schematic (drawing number 617-106, page 2) located at the end of Section 8.

6.6.1 Microcomputer

Microcomputer operation centers around the 8 bit 146805 CMOS microprocessor, U109. This device utilizes an 8 bit data bus and incorporates a multiplexed data/address bus for the lower eight bits of the 12 bit address bus. The 146805 has 112 bytes of on-chip memory, two 8 bit I/O ports, and is capable of directly addressing 8K bytes of memory. The MPU has direct control over the display, front panel switches, analog-to-digital converter, the voltage source, the IEEE-488 bus, as well as the Meter Complete output and the External Trigger Input.

Microprocessor timing is performed by Y101, a 3.2768MHz crystal. The signal is internally divided by five to obtain a bus operating frequency of 655.36kHz. This signal is present at the AS terminal of the processor, and is used as a control signal to strobe the lower ordered eight bits of the address into the address latch, U108. A 655.36kHz signal is also present at the DS terminal to act as a system clock.

6.6.2 Memory Elements

Software for the Model 617 is stored in U106, a 27128 16K X 8 PROM. Temporary storage is afforded by U107, a 6116 2K X 8 RAM IC. The MPU uses the RAM for temporary storage, as well as for data store readings. Calibration constants, the display mode, and the IEEE-488 primary address are stored in the NVRAM, U104. During the power-up cycle, NVRAM data is transferred to normal RAM to allow easier access during operation. While data transmission to the ROM and RAM are done in parallel, NVRAM data transmission is performed serially.

6.6.3 Device Selection

The 146805 processor can directly address only 8K bytes of memory. The Model 617 requires greater addressing capability, as 16K of ROM, 2K of RAM, and other memory space requirements are present in the system. To get around this problem, device selection circuitry is incorporated with the microcomputer.

Device selection is performed by elements of U111, U112, U117, and U118. MPU lines used are part of the selection process include the A10-A12 address lines, the PB6 line, the PB7 line, and the DS line. Signals generated by this circuitry include a line which controls the ROM chip select, a signal line that controls the RAM chip select, and circuitry which enables the display control and IEEE-488 bus circuits. Additional device selection signals include the memory paging signals. Two signals divide the 16K ROM area into 4K pages, while the a third signal divides the 2K RAM area into two 1K pages.

Because of the paging scheme employed, several devices can occupy a given address within the microprocessor's addressing space. Table 6-1 gives the general address range for each device.

Table 6-1. Memory Mapping

Device	Address Range
RAM (U107)	$0000-$03FF
ROM (U106)	$0800-$1FFF
Display Control (U110)	$0412
Display Control (U116)	$040A
IEEE-488 Bus (U113)	$0418-$041F

6.6.4 IEEE-488 Bus

The Model 617 has a standard IEEE-488 interface that allows the instrument to be programmed from a system controller. Commands can be sent over the bus to the instrument, and data can be requested from the instrument as well.

The IEEE-488 interface is made up of U113, U119, and U120. U113 is a 9914 GPIA (General Purpose Interface Adapter), while U119 and U120 are 75160 and 75161 interface bus drivers.

The 9914 GPIA simplifies MPU interfacing to the IEEE-488 bus because many control sequences take place automatically. For example, when the MPU writes to the GPIA data output register, the handshake sequence is performed automatically. Without the GPIA chip, complex MPU routines would otherwise be required.

On the MPU side of the GPIA, data transmission is handled much like any other data bus transaction. MPU data access is performed through the D0-D7 lines, while the RS0-RS2 lines, (which are connected to the three least significant address lines) serve to select among the 14 internal registers (seven read, seven write) of the IC. Chip selection is performed by the CS line.

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The output of the 9914 IC is in standard IEEE-488 format; the eight data lines (DIO1-DIO8), the three handshake lines (DAV, NRFD, NDAC), and the five management lines (ATN, REN, IFC, SRQ, and EOI) are all active low with approximately zero volts representing a logic one. The two IEEE-488 bus drivers, U119 and U120, are necessary to bring the drive capability of the interface up to the requirements of the IEEE-488 standard, which included provisions for up to 15 devices to be connected to the bus at one time. The outputs of the bus drivers are connected to J1010, which is a standard IEEE-488 connector.

6.6.5 Input/Output Circuitry

Additional MPU functions include the control of the Meter Complete and External Trigger Input, analog-to-digital converter control, and voltage source control.

At the end of its conversion cycle, the Model 617 sends a pulse out the Meter Complete jack on the rear panel. This function is performed by the PB2 line of the MPU through U102A configured as a buffer/inverter. Diodes CR104 and CR105 and resistor R102 protect the circuit output.

U102D, U105B, and associated components process the incoming trigger signal. U102D buffers and inverts the signal, while U105B latches the trigger pulse. The pulse is then read by the MPU through PA6. PB1 is used to reset the trigger latch once the pulse is read. Note that PB1 is also used to read the status of the calibration jumper (W101) during the calibration program.

As with the Meter Complete output, protection of the External Trigger input is necessary to protect the device from overvoltage inputs. External Trigger protection components include R101, CR102, and CR103.

A/D control information is fed out the PB3 and PB5 terminals through U102B. A pulse width modulation scheme is used with 18 and 50μsec pulses representing logic 0 and logic 1 respectively. A 200μsec pulse is used to strobe data into the A/D and serial-parallel control circuits. Note that this information is used to control the A/D converter as well as to control the input preamplifier (through relays), set the ranging amplifier gain, and to control the three phases of the measurement cycle. Isolation is provided by opto-isolator U122. Because of this isolation scheme, input signal common can be floated up to $\pm$500V above chassis ground while digital common remains within $\pm$30V of ground.

In a similar fashion, A/D data is routed in from the A/D converter through opto-isolator U121. The MPU reads this data through the TIMER terminal. As data pulses come in, an internal 8-bit timer is incremented until 256 counts have occurred. When all counts have been taken, an internal interrupt is generated, which causes to MPU to read the timer data. A separate software counter is then decremented, and the process repeats. Because of this data input scheme, MPU time necessary to read the A/D converter data is minimized, and the processor can concentrate on other important tasks.

The voltage source is controlled in a manner similar to that used to control the A/D converter. Control information is transmitted out the PB3 and PB4 terminals of the MPU through U102C. Once again, a pulse width modulation scheme is used to transmit the 12 bit data necessary to control the DAC in the voltage source section. 100V isolation is afforded by opto-isolator U124 located in the voltage source section.

Data transmission is controlled by a 81.92kHz clock. This clock is generated by U103 by dividing down the 655.36kHz system clock. The clock signal is transmitted through R105D through isolator U123, which is located in the voltage source section.

Voltage source overload data is fed in through opto-isolator U125 to the PA7 terminal of the MPU. When the 2mA current limit of the voltage source is exceeded, PA7 goes high. The necessary software routine is used to flash the OPERATE LED, indicating to the operator that an overload has occurred.

6.6.6 Display Circuitry

Display circuitry includes those elements necessary to control the seven and 14 segment readouts, the front panel annunciator LEDs, and to read the front panel switches. The display circuitry schematic may be found on drawing number 617-116 located at the end of Section 8.

The display circuitry consists of the LED readouts (DS201-DS206), the LED annunciators (DS207-DS224), the segment drivers (U201 and U202), and the digit select circuitry (U204, U201, and U203). DS202-DS205 are standard 7-segment units, while DS206 is a dual 14-segment display.

The display is updated at 1.56msec intervals. Timing for this process is performed by a 640Hz clock which controls the segment latches, U110 and U116, located on the mother board. Each time an interrupt is generated, the MPU writes segment data for two digits to the segment latches. The two latches outputs are then enabled in sequence by the 640Hz clock.

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When a latch output is enabled, segments in the selected digit are turned on.

Digit selection is performed by data from the PA3, PA4, and PA5 outputs of the MPU to control U203. A single U203 output, corresponding to the selected digit, will go low when the correct data appears on its inputs. For example, if 010_2 appears on the inputs of U203, DS201 will be turned on.

Selection of the display annunciators is performed in a similar manner. The data stored in the corresponding segment latches will then turn on the appropriate annunciator LEDs.

Front panel switches are read in a somewhat similar manner by using a row-column matrix along with U206. To select a particular row, data is transmitted out the MPU PA3, PA4, and PA5 lines to U206. This action selects one of the rows by placing the corresponding output of U206 high. Matrix columns are then read by reading data in through PA0, PA1, and PA2, of the MPU. If a particular switch contact is closed, the data bit will be high; if the switch is open, the data bit will be low.

6.7 VOLTAGE SOURCE

The voltage source circuitry, which is located on schematic number 617-106, page 1, consists of serial-to-parallel data conversion circuitry, the DAC (Digital-to-Analog Converter), analog circuitry, current limit circuitry, and protection circuitry.

Incoming clock and data signals are fed in through opto-isolators U123 and U124 respectively. The 88.92kHz clock is further divided down by U132. The pulse width modulated serial data controls the reset pin of U132. The Q2 and Q3 outputs of the divider are used to control the data and strobe inputs of the serial-to-parallel converter ICs, U131 and U140.

Control information consists of 12 bit words. As the bits come in, they are fed into the DATA input of U131 and U140 in serial form. After all bits are shifted in, data is strobed into the outputs of U131 and U140.

The resulting 12 bit data is then applied to the digital inputs of U141, a 12 bit DAC (Digital-to-Analog Converter). This IC converts the digital information into an analog current output. The current output of U141 is then converted into a ±10V full scale signal by U142A and U142B. The circuit is configured so that +10V will appear at the output of U142B when all ones appear on the digital inputs of the DAC. Conversely, −10V will appear at the output of U142B when all zeroes appear on the digital inputs of the DAC.

The voltage source output stage is made up of U143, Q101, Q102, Q111, Q112 and associated components. This circuit is essentially an operational amplifier with a gain of −10. U143 provides the circuit gain, while the transistors provide the necessary output capability. Transistors Q111 and Q112 and resistors R123, R124, R126 and R127 form a complementary common emitter amplifier. Current limiting is accomplished via Q101, Q102 and sensing resistors R124 and R126. Current limit threshold detection is performed by comparators U144A and U144B. As shown in Figure 6-16, U143 along with the output stage form a compound op amp which is connected to R157 and R159 in an inverting X10 gain configuration. Compliance at the output is ±110V.

The accurate reference voltage needed by the DAC is provided by U134, VR101, and associated components. VR101 provides a stable 6.3V reference voltage, while U134 is a constant current source that keeps zener voltage variations to a minimum. The output of the reference source is also used by the protection circuit to keep erroneous voltages from appearing at the voltage source output terminals.

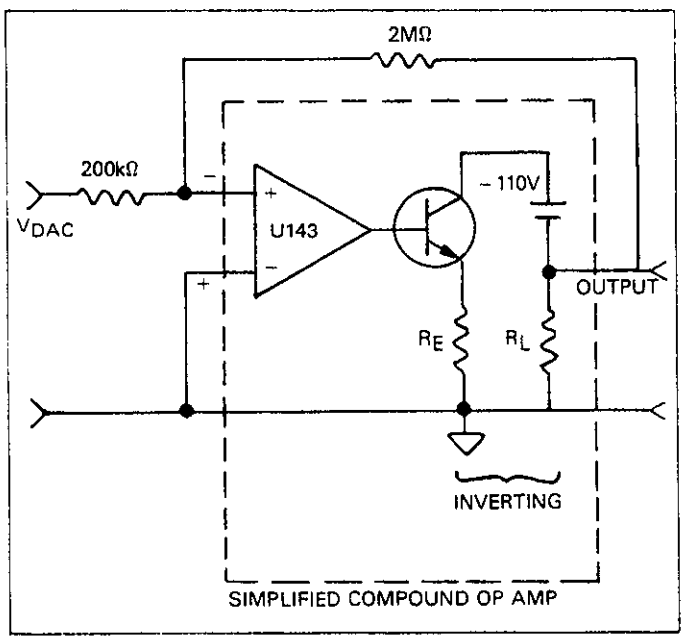


Figure 6-16. Simplified Schematic of Voltage Source Output Stage

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The protection circuit is made up of CR116, U144C, K101, and associated resistors. The purpose of these components is to make sure that erroneous and possible dangerous voltages do not appear at the voltage source output during power up. For example, if the Model 617 power is briefy turned off and then back on, the voltage source output might otherwise be at some undetermined value because of random data appearing on the DAC inputs. The protection circuit eliminates this potential problem by briefly opening up the contacts of K101 under these circumstances.

6.8 POWER SUPPLIES

The Model 617 has numerous power supplies which are used to power the analog, digital, and voltage source circuits. Diagrams of these supplies may be found on drawing numbers 617-106, page 1 and 617-166.

The power supplies are essentially divided into two groups: one group powers the digital and voltage source circuits, while a second group of supplies is used to power the input circuits. Each group of supplies has its own power supply transformer. This configuration is used to maintain proper isolation between the voltage source and digital circuits, and sensitive analog circuitry.

AC power is applied to J1011, which is the power connector located on the rear panel of the instrument. S101 is the POWER switch located on the front panel, while S102 is the line voltage selection switch. When S102 is in the 115V position, the primary windings are connected in parallel; when S102 is in the 230V position, the T101 windings are placed in series.

T101 has three secondary windings, which are used to supply the ±110V, ±15V, and +5V supplies. The ±110V and ±15V sources supply the voltage source, and the +5V supply is used for the digital circuitry.

The ±110V supplies consist of half-wave rectifier diodes (CR108 and CR107) and filter capacitors (C109 and C110). Each of the ±15V supplies has a similar half-wave rectification scheme (CR101 and C103 for the −15V supply, CR109 and C108 for the +15V supply). Regulation for these supplies is performed by U114 and U115, which are IC regulators.

The third winding of T101 supplies the +5V source that is used to power the digital circuits. Rectification is done by elements of CR110, while filtering is performed by C101. The supply voltage is regulated by U101, which is a standard 7805 IC regulator.

The same secondary of T101 that supplies the +5V digital source also supplies power to the primary of the electrometer section power transformer, T301. This transformer supplies power to all the DC supplies that power the analog circuits.

The ±210V supplies, which are used to power the preamplifier output circuit, are generated by one secondary winding of T301 and two voltage-doubling circuits. CR301, CR303, C301, and C304 perform the rectifier and filtering functions for the +210V supply, while CR302, CR304, C302, and C303 are similar components in the −210V supply. The ±210V supplies are not regulated and are referenced to analog and signal common.

Another secondary winding on T301 feeds power to components that generate the +5V analog and −9V analog supplies. The +5V supply is used to power the ranging amplifier, A/D converter and other components (such as U301) located in the analog section, while the −9V supply powers the −2V reference source. +5V supply components include CR311, which rectifies AC input, C305 for filtering, and Q309, VR302, and U306 for regulation. Elements of CR311 also provide rectification for the −9V supply, while C306 filters, and VR303 regulates the output voltage. Both of these supplies are referenced to analog and signal common.

The ±5V sources supply power to much of the input preamplifier section. These two supplies, which are referenced to bootstrap common, utilize half-wave rectification and IC regulators. CR320, C316, and U308 are associated with the +5V supply, and CR319, C315, and U307 perform similar functions for the −5V supply. R344 and R345 are intended to trim the −5V supply voltage to a precise value.

The ±24V sources supply power to the preamp output stage when the circuit is configured for amps or coulombs. Each supply is a simple half-wave rectifier, filter capacitor pair, with CR323 and C317 supplying +24V, and CR322 and C311 performing the same functions in the −24V supply. Both these supplies are referenced to the preamplifier output.

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SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 617. Fuse replacement and line voltage selection procedures are also included.

WARNING

The procedures included in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps in this section may expose you to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

7.2 LINE VOLTAGE SELECTION

The Model 617 may be operated from either 105-125V or 210-250V 50 or 60Hz power sources. A special transformer may be installed for 90-110V and 195-235V ranges. The instrument was shipped from the factory set for an operating voltage marked on the rear panel. To change the line voltage, proceed as follows:

WARNING

Disconnect the Model 617 from the power line and all other sources before removing the top cover.

1. Remove the screws securing the top cover to the rear panel and carefully lift the cover away from the instrument.
2. Locate the line voltage switch adjacent to the POWER switch on the mother board. Place the switch in the correct position, as outlined in Table 7-1.
3. Install a fuse consistent with the operating voltage, as described in paragraph 7.3.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

4. Mark the selected line voltage on the rear panel for future reference (to avoid confusion, erase the old mark).
5. Replace the top cover and connect the instrument to the power line.

Table 7-1. Line Voltage Selection (50-60Hz)

Line Voltage	Voltage Selection Switch Position
105-125V	115V
210-250V	230V
90-110V*	115V
195-235V*	230V

*Requires special power transformer.

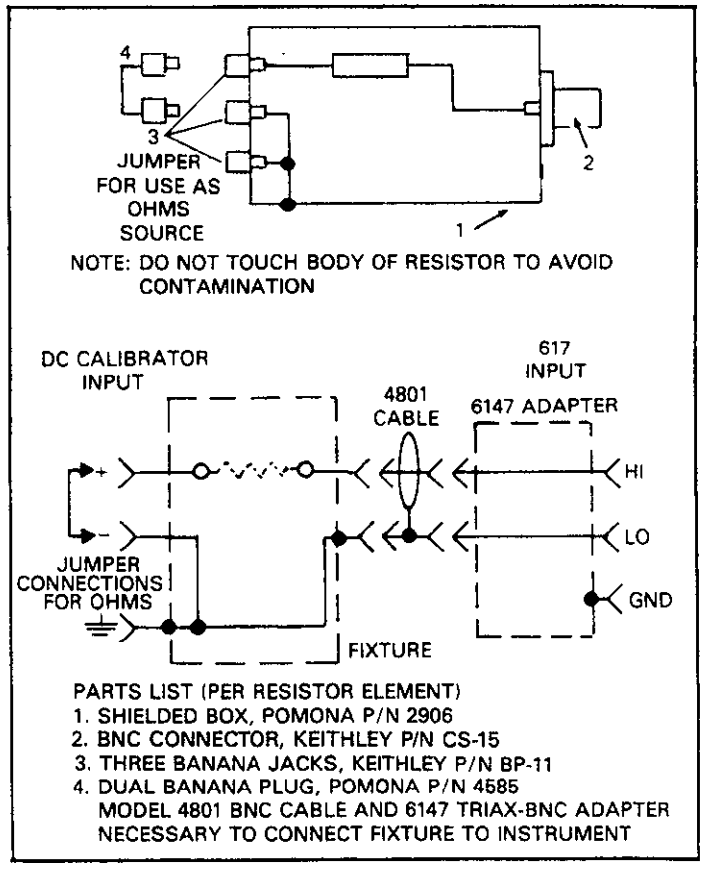


Figure 7-1. Test Fixture Construction

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7.3 FUSE REPLACEMENT

7.3.1 Line Fuse

A rear panel fuse protects the power line input of the instrument. Use the following procedure to replace the line fuse:

WARNING
Disconnect the instrument from the power line and other equipment before replacing the fuse.

1. With the power off, place the end of a flat-blade screwdriver into the slot in the rear panel LINE FUSE holder. Push in gently and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder and its internal spring will push the fuse and carrier out of the holder.
2. Remove the fuse and replace it with the type recommended in Table 7-2.

CAUTION
Do not use a fuse with a higher current rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

3. Install the new fuse and the fuse carrier into the holder by reversing the above procedure.

Table 7-2. Line Fuse Selection

Line Voltage	Fuse Type	Keithley Part No.
90-125V	1/4A, 250V, 3AG, Slo Blo	FU-17
195-250V	1/8A, 250V, 3AG, Slo Blo	FU-20

7.3.2 COM Fuse

The COM fuse (F102), which is located internally, protects the instrument from damage in situations where COM is inadvertently connected to earth ground with input LO floating. Use the following procedure to replace this fuse.

WARNING
Disconnect the line cord and all test leads and cables from the instrument before removing the top cover.

1. Remove the screws that secure the top cover to the instrument, then remove the cover.
2. Pry the COM fuse free of its holder using a screwdriver. The fuse holder is mounted on the inside of the rear panel.
3. Replace the fuse only with the following type: 1/16A, 250V, BUSS #AGC-1/16, Keithley Part No. FU-86-1.

CAUTION
Replace the fuse only with the recommended type. Installing a fuse with a larger rating may result in instrument damage.

4. Install the top cover and secure it with the screws removed earlier.

7.4 CALIBRATION

An advanced feature of the Model 617 is its digital calibration capabilities. Instead of the more conventional time-consuming method of adjusting numerous calibration potentiometers, the technician need only apply an appropriate calibration signal and digitally calibrate the instrument, either from the front panel, or over the IEEE-488 bus.

Some of the calibration procedures will require a shielded test fixture. Construction of this fixture is detailed in Figure 7-1. The fixture should be used wherever a shielded enclosure is called for at various places in the procedure.

Calibration should be performed every 12 months, or if the performance verification procedures in Section 5 show that the instrument is out of specification. If any of the calibration procedures cannot be performed properly, refer to the troubleshooting information in this section.

NOTE
Place the V, Ω GUARD switch in the OFF position unless otherwise noted.

7.4.1 Recommended Calibration Equipment

Table 7-3 lists recommended calibration equipment. Alternate equipment may be used as long as equipment accuracy is at least as good as the specifications listed in the table.

7.4.2 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%.

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Table 7-3. Recommended Calibration Equipment

Description	Specifications	Manufacturer	Model
DC Voltage Calibrator	.19V, 1.9V, 19V, 190V, ±0.002%	Fluke	343A
5½ digit DMM	0.015% DC accuracy	Keithley	197
Terohmmeter	100MΩ, ±0.035%	Guildline	9520
	1GΩ, ±0.07%		
	100GΩ, ±0.08%		
Resistor	100MΩ, ±1%	Keithley	R289-100M
Resistor	1GΩ, ±2%	Keithley	R289-1G
Resistor	100GΩ, ±2%	Keithley	R319-100G
Decade Resistor	10Ω-10MΩ, ±0.03%	ESI	DB-62
Standard Capacitor	1000pF, ±0.1%	Hewlett-Packard	16384A
Shielded Test Fixture (Figure 7-1)			
BNC Female-Female Adapter		Pomona	3823
BNC Cable		Pomona	4530-C
BNC Cable		Keithley	4801
Triax-BNC Adapter		Keithley	6147

7.4.3 Warm-Up Period

Turn on the instrument power and allow it to warm up for at least two hours before beginning the calibration procedure. If the instrument has been subjected to extremes of temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

NOTE

While rated accuracy is achieved after the two hour warm up period, input bias current may require additional time to come to its optimum level. Allow two hours for input bias current to settle to less than 10fA and eight hours to less than 5fA. It is preferable in sensitive applications to leave the unit on continuously.

7.4.4 Calibration Jumper

A jumper, located on the mother board, allows the disabling or enabling of front panel and IEEE-488 bus calibration. When the jumper is in the disabling position, permanent (NVRAM) storage of calibration constants will not take place. However, temporary calibration values may be entered and used even if NVRAM calibration storage is disabled. Note, however, that any calibration parameters will be lost once the power is turned off unless they are stored in NVRAM.

The calibration jumper location and the disabled/enabled positions are indicated in Figure 7-2. Note that the jumper is in the disabled position as shipped from the factory.

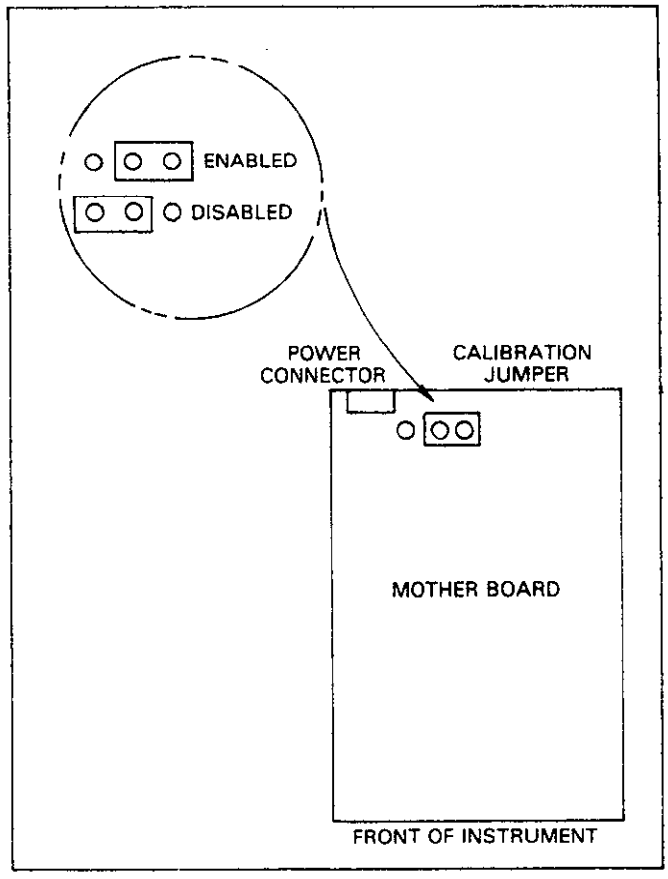


Figure 7-2. Calibration Jumper Location

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7.4.5 Front Panel Calibration

Use the basic procedure below for each of the calibration points listed in the following paragraphs. Zero correction must be performed on the range being calibrated.

1. Turn off the instrument for at least three seconds if it is presently turned on.
2. Press and hold the PROGRAM SELECT button and then turn on power.
3. The instrument powers up as normal, but the CAL program is accessible in the program menu.
4. Select the function and range to be calibrated (volts, amps, ohms, or coulombs).
5. Enable zero check and zero correct the instrument by enabling zero correct.
6. Connect the calibration signal to the instrument. Disable zero check.
7. Enter the front panel calibration program by pressing PROGRAM SELECT repeatedly until the following message is displayed:

CAL

8. Note that the decimal points in the exponent digits indicate that the instrument is in the calibration mode.
9. Use the voltage source arrow buttons to set the calibration value, as seen on the display, to agree with the actual calibration signal. For example, with a 1.9V calibration point, the display should be adjusted for a reading of 1.9000V.
10. Select the next range and function to be calibrated and repeat step 9. For maximum accuracy, the instrument must be zero corrected for each range and function.
11. Once all points have been calibrated, press PROGRAM SELECT to exit the calibration program. Assuming that the calibration jumper is in place (paragraph 7.4.4), calibration constants will be stored in NVRAM, and the following message will be displayed:

Stor

Also, constants for uncalibrated ranges are derived at this point.

12. If the calibration jumper is in the disabled position, NVRAM storage will not take place, and the following message will be displayed:

Out

Only changed constants are affected under these conditions.

Note, however, that the new calibration values will be used by the instrument until the power is turned off even if NVRAM storage does not take place.

7.4.6 IEEE-488 Bus Calibration

IEEE-488 bus calibration is performed in a manner similar to front panel calibration, except that calibration constants are transmitted over the bus instead of being entered from the front panel. Also, a separate command is included to perform NVRAM storage. By combining appropriate IEEE-488 compatible calibration equipment with a suitable test program, calibration of the Model 617 could be performed on an automated basis.

Use the following basic procedure when calibrating the Model 617 over the IEEE-488 bus.

1. Program the desired range and function over the bus. For example, to select the 200V range and volts function, send F0R4X.
2. Zero correct the instrument by sending C1XZ1X.
3. Apply the calibration signal to the input jack. Disable zero check by sending C0X.
4. Send the required calibration value preceded by the A command letter. For example, to calibrate the 200V range at the 190V calibration point, send A190X.
5. Repeat steps 1-4 for the remaining ranges and functions. For maximum accuracy, zero correct the instrument for each range and function.
6. After all points have been calibrated, send L1X to store calibration constants in NVRAM.

NOTE

NVRAM storage will not take place if the calibration jumper is in the disabled position. See paragraph 7.4.4 for details.

HP-85 Programming Example—The simple program below will allow you send the desired calibration command string to the Model 617. The program assumes that the instrument primary address is at its default value of 27.

PROGRAM	COMMENTS
10 REMOTE 727	Send remote enable.
20 DISP "CALIBRATION COMMAND"	Prompt for command.
30 INPUT A$	Input command string from keyboard.
40 OUTPUT 727;A$	Send command string to 617.
50 GOTO 20	Repeat.
60 END	

To run the program, press the HP-85 RUN key. At the command prompt, type in the desired calibration command and press return. For example, to perform NVRAM storage, type in L1X and press return.

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Model 8573 Programming Example—Use the program below to send calibration commands to the Model 617 from an IBM computer equipped with a Keithley Model 8573 IEEE-488 interface. The lines below are to be added to the DECL.BAS program, as described in the Model 8573 Instruction Manual.

PROGRAM	COMMENTS
10 NA$="GPIB0":CALL IBFIND (NA$,BRD0%)	Find board descriptor.
20 NA$="DEV0":CALL IBFIND (NA$,M617%)	Find instrument descriptor.
30 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
40 V%=27:CALL IBPAD (M617%,V%)	Set primary address to 27.
50 INPUT "CALIBRATION COM MAND";A$	Input command string.
60 IF A$="EXIT" THEN 90	Check if program is to be halted.
70 CALL IBWRT(M617%,A$)	Send command string to instrument.
80 GOTO 50	Repeat.
90 V%=0:CALL IBONL (BRD0%,V%)	Close the board file.
100 CALL IBONL(M617%,V%)	Close the instrument file.

After entering the program, run it by pressing the F2 function key on the computer. At the command prompt, type in the desired calibration command and press the return key. For example, type in L1X to perform NVRAM storage. To exit the program cleanly, type in EXIT and press the return key at the command prompt.

7.4.7 Calibration Sequence

Model 617 calibration must be performed in the the order given in the following paragraphs, with the exception of voltage source calibration, which can be done at any time. The basic sequence is:

1. Input offset adjustment (paragraph 7.4.8)
2. Input current adjustment (paragraph 7.4.9)
3. Amps calibration (paragraph 7.4.11)
4. Coulombs calibration (paragraph 7.4.12)
5. Volts calibration (paragraph 7.4.13)
6. Ohms calibration (paragraph 7.4.14)

In addition to the above sequence, the ranges for each function must be calibrated in the order given. Note that you should never calibrate a range using a suppress or zero correct value taken on a different range.

NOTE

Several minutes must be allowed for the input current to settle to within specified limits following high voltage or ohms measurements.

7.4.8 Input Offset Adjustment

Use the following procedure to null out any small offset in the input amplifier. Input offset adjustment is particularly critical if input voltage burden is a consideration since any offset will increase the voltage burden, as seen by the input signal.

1. Disconnect all input signals from the instrument.
2. Remove the two screws securing the top cover and remove the cover from the instrument.
3. Select the amps function and place the instrument on the 2pA range.
4. Enable zero check, but leave zero correct disabled.
5. Locate the offset adjustment potentiometer (R314) on the electrometer board (see Figure 7-3). The pot is accessible through a small hole in the shield closest to the rear of the instrument.
6. Adjust R314 for a reading of 0.0000 ±1 count on the display.
7. Replace the top cover unless the input current adjustment (below) is to be performed.

7.4.9 Input Current Adjustment

Use the following procedure to null out any input current present in the input stage. The input current will then be automatically temperature compensated to reduce the effects of high ambient temperature. Low input current is particularly important when making very low current or charge measurements, or when high input impedance is critical in volts and ohms. Proceed as follows:

1. Disconnect all input signals from the instrument. Place the protection cap (CAP-18) on the INPUT connector.
2. Remove the two screws securing the top cover and remove it from the instrument.
3. Select the amps function and place the instrument on the 2pA range.
4. Enable zero check and zero correct in that order.
5. Disconnect floating sources and connect a jumper wire between the COM and chassis ground binding posts. Disable zero check, but leave zero correct enabled.
6. Wait several minutes until the display on the reading settles down; about 15 counts (1.5fA) p-p of noise is normal.
7. Locate the input current potentiometer R348 on the electrometer board. It is accessible through a small hole in the shield. See Figure 7-3.

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8. Carefully adjust R348 for a reading of 0.0000 ±15 counts on the display. Iterative adjustment may be necessary.
9. Replace the top cover and secure it with the two screws removed earlier.

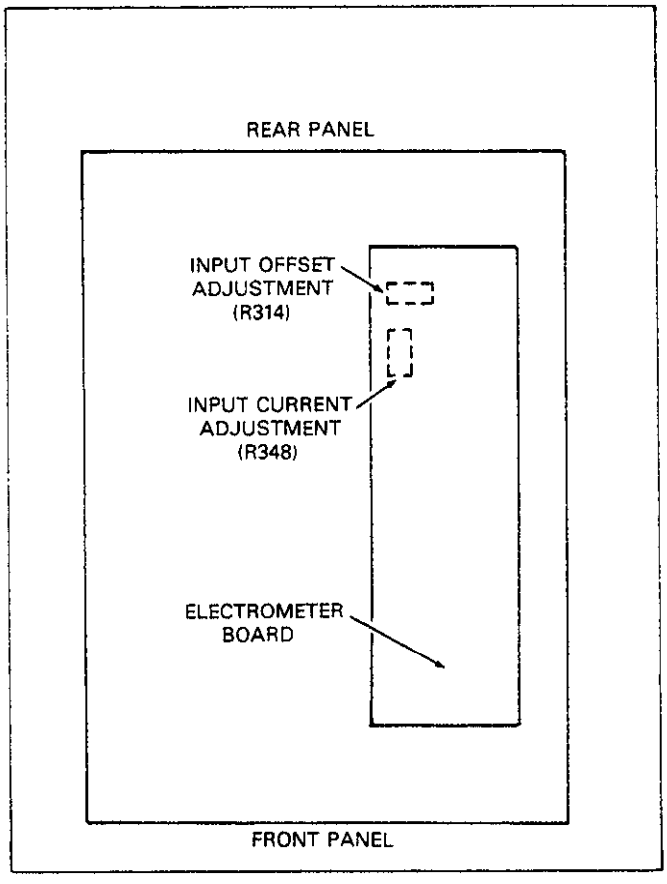


Figure 7-3. Input Offset Adjustment Locations

7.4.10 Permanent Storage of Calibration Parameters

The procedures given in the following paragraphs will temporarily store calibration constants in internal RAM memory. For calibration to be permanent, you must perform NVRAM storage once all calibration procedures have been performed. If you are calibrating the instrument from the front panel, simply press SELECT EXIT to leave the calibration program. From the IEEE-488 bus, simply send the following command: L1X. Note that this storage procedure need be performed only once after all calibration parameters have been entered. Keep in mind that the calibration jumper must be in the correct position, as described in paragraph 7.4.4.

7.4.11 Amps Calibration

Calibration of the amps function should be performed in the following order: 200pA, 20nA, 20μA and 20mA ranges. Once these ranges are calibrated, the remaining ranges are automatically calibrated.

Proceed as follows:

1. Using the teraohmmeter, accurately measure the value of the 100GΩ resistor. Record the value in the first line of Table 7-4. Using this value, calculate the calibration voltage as follows: E=I × R, where I is the nominal calibration current (190pA), and R is the measured resistance value. For example, if the actual resistance value is 101GΩ, the calibration voltage value would be 19.19V.

NOTE
Do not touch the body of the resistor to avoid contamination that could give erroneous results.

2. Connect the DC calibrator and 100GΩ resistor to the Model 617, as shown in Figure 7-4. Note that the resistor is to be placed in a shielded enclosure, as shown on the diagram. (See Figure 7-1 for recommended shield).
3. Place the instrument in the amps mode and select the 200pA range.
4. Zero correct the instrument by enabling zero check and zero correct in that order.
5. Set the calibrator voltage to the exact value obtained in step 1. Disable zero check.
6. Either from the front panel or over the IEEE-488 bus set the Model 617 calibration constant to exactly 190.00pA.
7. Reduce the calibrator voltage to zero and enable zero check.
8. Disconnect the resistor/shield fixture from the instrument and connect the decade resistance box in its place, as shown in Figure 7-5.
9. Select the 20nA range and zero correct the instrument by disabling zero correct. With zero check enabled, enable zero correct once again.
10. Set the decade box and calibrator to the values listed in the second line of Table 7-4. Disable zero check.
11. Set the Model 617 calibration constant to exactly 19.000nA, either with the front panel calibration program, or over the IEEE-488 bus.
12. Repeat steps 9 through 11 for the 20μA and 20mA ranges, as listed in the table. For maximum accuracy, zero correct the instrument after each range is selected.

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Table 7-4. Amps Calibration

617 Range	Calibration Current	Resistor Value*	Calibrator Value	617 Display Value	IEEE-488 Bus Command
200pA	190.00 pA	_____**	_____**	190.00 pA	A190E-12X
20 nA	19.00 nA	10.00MΩ	0.19000V	19.000 nA	A19E-9X
20 μA	19.00 μA	1.000MΩ	19.0000V	19.000 μA	A19E-6X
20mA	19.000mA	1000.0 Ω	19.0000V	19.000mA	A19E-3X

*Use 100GΩ resistor for 200pA range; decade box for other ranges.
**Values to be determined using procedure outlined in text.

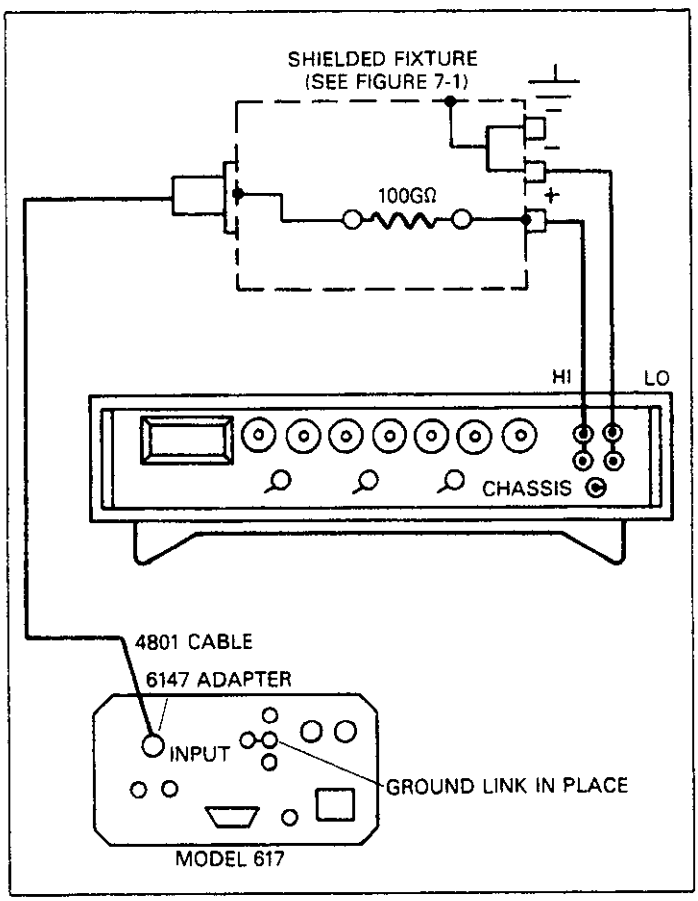


Figure 7-4. Connections For Amps Calibration (20pA)

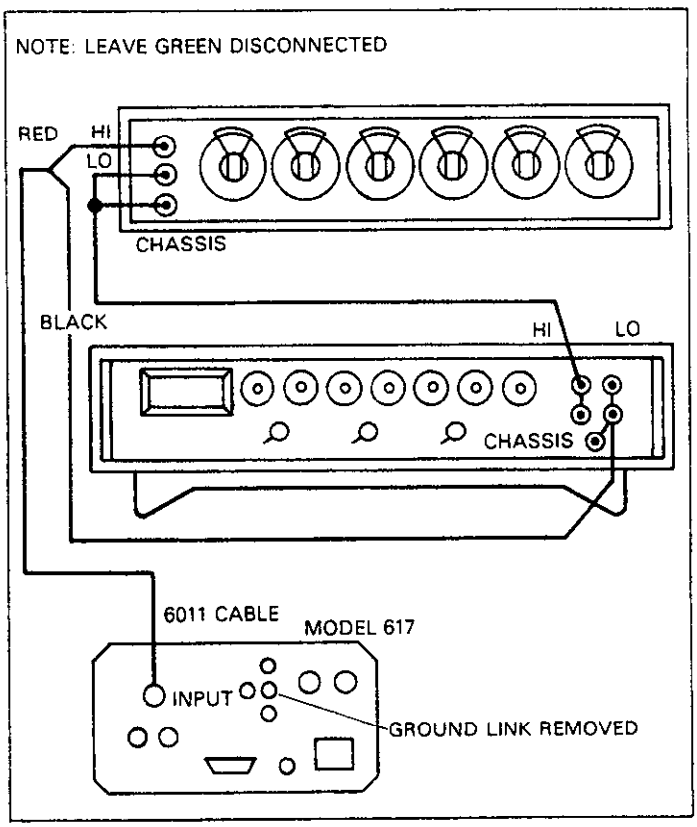


Figure 7-5. Connections For Amps Calibration (20nA, 20μA and 20mA Ranges)

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7.4.12 Coulombs Calibration

Use the following procedure to calibrate the 20nC range. Once this range is calibrated, the two remaining ranges are automatically calibrated.

1. Set the DC calibrator output to 0V and connect the calibrator and the 1000pF, 0.1% standard capacitor to the instrument, as shown in Figure 7-6.
2. Select the coulombs mode and select the 20nC range.
3. Zero correct the instrument by enabling zero check with zero correct disabled. Then, enable zero correct and disable zero check. Enable suppress to null the effects of zero check hop.
4. Set the DC calibrator to 19.000V.
5. Set the Model 617 calibration constant to 19.000nC, either with the front panel calibration program, or over the bus. The correct bus command value would be: A19E-9X.
6. Set the DC calibrator output to 0V and enable zero check.

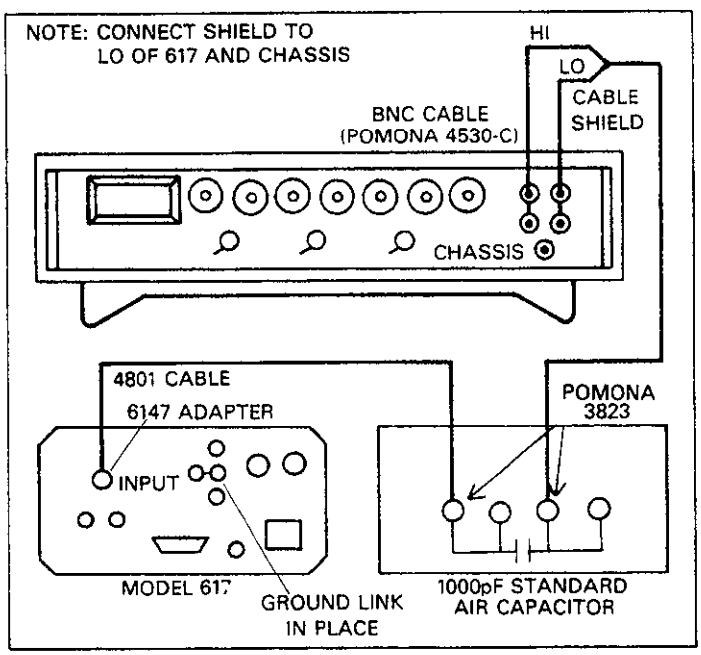


Figure 7-6. Connections for Coulombs Verification

7.4.13 Volts Calibration

Calibration of the volts function should be performed in the following order: 200mV, 2V, 20V and 200V ranges. Proceed as follows:

1. Select the volts function and place the instrument on the 200mV range.
2. Set the DC calibrator to 0V and connect it to the instrument, as shown in Figure 7-7.
3. Zero correct the instrument by enabling zero check and then zero correct in that order.
4. Disable zero check and set the calibrator output to 190.000mV.
5. Either from the front panel or over the IEEE-488 bus, set the calibration value to 190.00mV (see Table 7-6). From the front panel, enter the calibration program (paragraph 7.4.4) and use the voltage source arrow buttons to adjust the display for the correct value. Over the IEEE -488 bus, send the following command: A0.190X.
6. Repeat steps 3-5 for the remaining calibration points listed in Table 7-5. Zero correct the instrument before calibrating each range. To do so, select the range being calibrated and disable zero correct. Enable zero check and zero correct in that order. Disable zero check to calibrate the range in question.

Table 7-5. Volts Calibration

617 Range	DC Calibrator Value	617 Display Value	IEEE-488 Bus Command
200mV	190.000mV	190.00mV	A0.190X
2 V	1.90000 V	1.9000 V	A1.9X
20 V	19.0000 V	19.000 V	A19X
200 V	190.000 V	190.00 V	A190X

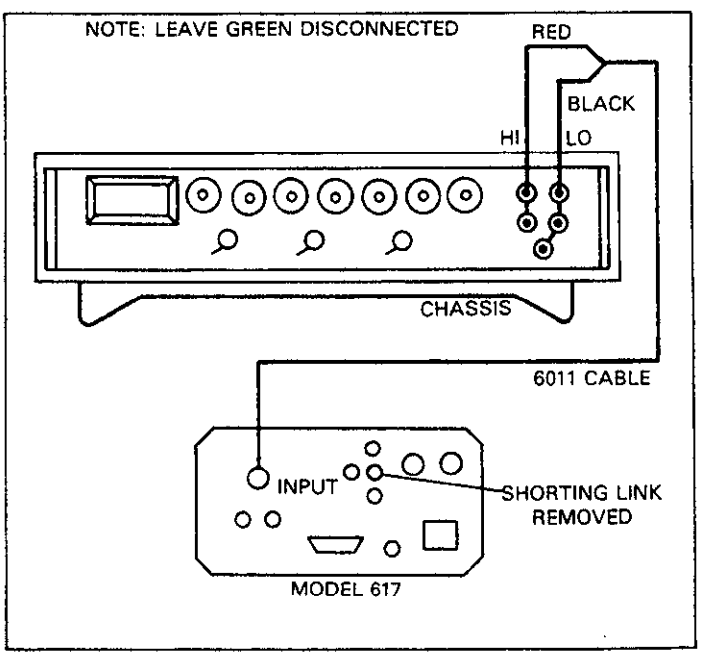


Figure 7-7. Connections for Volts Calibration

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7.4.14 Ohms Calibration

1. Using the teraohmmeter, measure the actual resistance values of the 1GΩ and 100MΩ resistors. Record these values in Table 7-6.

NOTE

Do not touch the body of these resistors to avoid contamination that could give erroneous results.

2. Connect the 1GΩ resistor to the Model 617, as shown in Figure 7-8. Use the shielded fixture in Figure 7-1. Enable zero check and place the V, Ω GUARD switch ON.

WARNING

Up to 300V may be present on the shielded fixture in the guarded mode.

3. Select the ohms function and place the instrument on the 2GΩ range.
4. Zero correct the instrument by enabling zero check and then zero correct in that order.
5. Disable zero check and allow sufficient time for the reading to settle. Set the Model 617 calibration value to the exact resistance obtained for the 1GΩ resistor in step 1. Either use the front panel calibration program, or send the calibration value over the bus. For example, if the resistor measured 1.012GΩ, the following command would be sent: A1.012E9X.
6. Enable zero check and disconnect the 1GΩ resistor from the instrument. Substitute the 100MΩ resistor in its place. The shielded enclosure should be retained.
7. Set the instrument to the 200MΩ range and disable zero check.
8. After allowing sufficient settling time, set the Model 617 calibration parameter to the exact resistance value obtained for the 100MΩ resistor in step 1. Again, use either the calibration program or send the value over the bus.
9. Enable zero check and place the V-Ω GUARD switch in the OFF position. Disconnect the 100MΩ resistor and shielded enclosure from the instrument. Substitute the decade resistance box in its place, as shown in Figure 7-9.
10. Select the 20MΩ range and set the decade box to the value listed in the table.
11. Zero correct the instrument. With zero check disabled, set the Model 617 calibration parameter to the required value.
12. Repeat steps 10 and 11 with the remaining ranges listed. Be sure to zero correct the instrument and set the decade box to the required value.

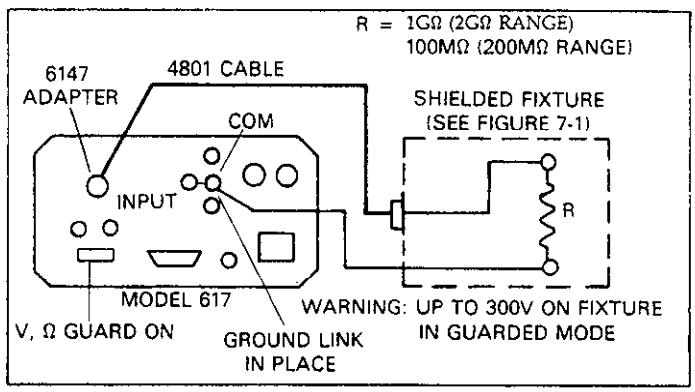


Figure 7-8. Connections for Ohms Calibration (2GΩ and 200MΩ Ranges)

Table 7-6. Ohms Calibration

617 Range	Nominal Calibration Resistance	Measured Calibration Resistance	617 Displayed Value	IEEE-488 Bus Command
2GΩ	1GΩ	_____	*	*
200MΩ	100MΩ	_____	*	*
20MΩ	10.000MΩ	**	10.000MΩ	A10E6X
2MΩ	1.900MΩ	**	1.9000MΩ	A1.9E-6X
200 kΩ	190.000 kΩ	**	190.00 kΩ	A190E3X
20 kΩ	19 kΩ	**	19.000 kΩ	A19E3X

*Use measured resistance values as calibration point.

**Measurement of decade resistance values not necessary due to inherent accuracy.

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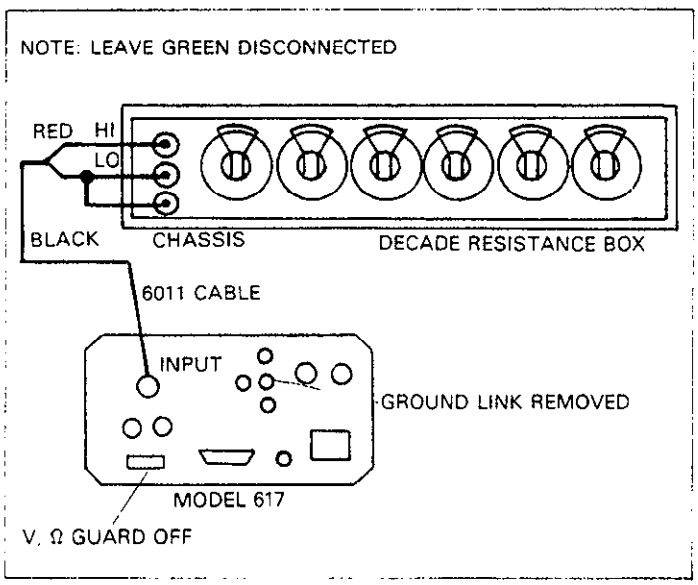


Figure 7-9. Connections for Ohms Calibration (20kΩ and 20MΩ Ranges)

7.4.15 Voltage Source Calibration

Use the following procedure to calibrate the voltage source. Since the voltage source is independent from the electrometer section, voltage source calibration can be performed at any time, separate from electrometer calibration.

WARNING
Hazardous voltage will be used in some of the following steps.

1. Connect the DMM to the voltage source output, as shown in Figure 7-10.
2. Either from the front panel, or over the IEEE-488 bus, program the voltage source to 0.00V. The correct bus command is: V0X.
3. Turn on the voltage source output by pressing the OPERATE button.
4. Place the DMM on the lowest DC voltage range possible without overranging the instrument and note the offset voltage value, including sign. 50mV or less should be seen.
5. Set the DMM to the 200V (or similar) range and program the voltage source output to 100.00V. The bus command to use is: V100X.
6. Adjust the voltage source gain adjustment (see Figure 7-9) so that the DMM reads a voltage of (100V ±offset ±10mV), using the offset value obtained in step 4.
7. Turn off the voltage source output and disconnect the DMM.

7.4.16 Additional Calibration Points

The electrometer calibration points discussed in the preceding paragraphs were chosen to optimize instrument accuracy without making the calibration procedure overly tedious and time consuming. As noted earlier, these calibration points are permanently stored in NVRAM when the correct storage sequence is performed.

Although this calibration method is more than adequate to allow the instrument to meet or exceed specifications, it should be pointed out that it is possible to temporarily calibrate those ranges not directly calibrated as part of the calibration procedure. With the calibration jumper in the disabled position, place the instrument in the desired function and select the range to be calibrated. Apply the necessary calibration signal and enter that value into the instrument's memory, either with the front panel calibration program, or over the IEEE-488 bus (The flashing exponent decimal points

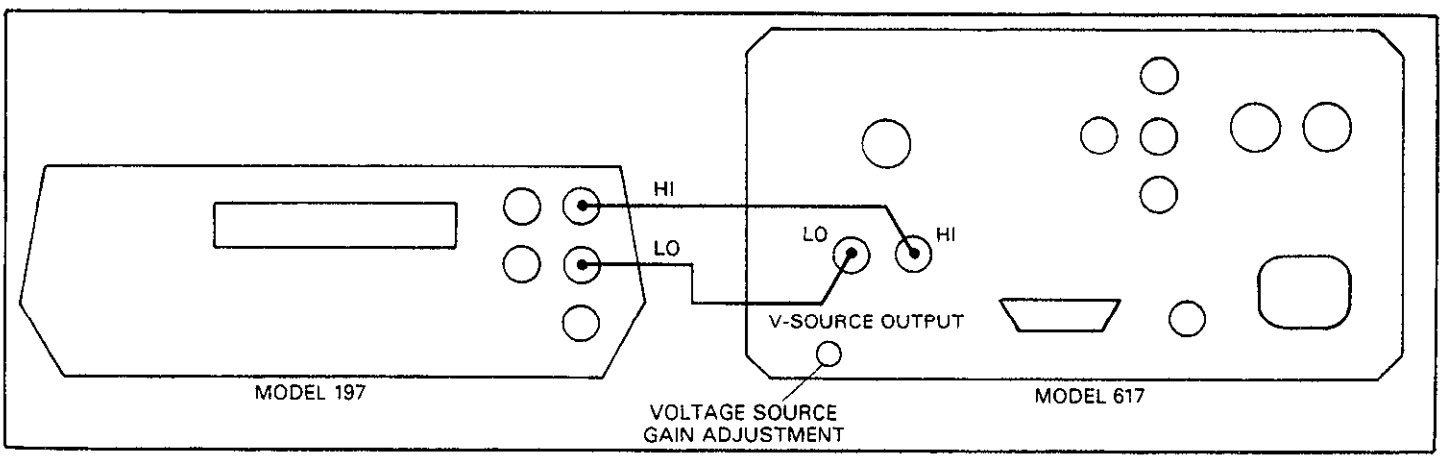


Figure 7-10. Connections for Voltage Source Calibration

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will indicate parameters have been entered). The nominal adjustment range is ±6% (±12% in external feedback). However, it is important to note that such calibration will be only temporary as these parameters will be lost when the power is turned off. Under these conditions, the instrument will revert to calibration constants previously stored in NVRAM the next time it is turned on. Note that the IEEE-488 DCL and SDC commands will also cancel temporary calibration constants.

As an example of this procedure, let us assume that you wish to temporarily calibrate the 2mA range–a range that is not part of the normal calibration sequence. The following basic procedure could be used to calibrate this range.

1. Select the amps mode and place the instrument on the 2mA range.
2. Zero correct the instrument by enabling zero check and then zero correct in that order.
3. Connect a suitable calibration signal to the instrument. Typically, calibration is done at 95% of full range, or 1.9000mA in this case.
4. Disable zero check and enter the front panel calibration program, as described in paragraph 7.4.4. The instrument will then display a reading that reflects its present calibration point for the selected range. The exact point can be set by using the voltage source adjust buttons to set the displayed value to exactly 1.9000mA.
5. After all points have been calibrated, exit the program by pressing SHIFT then SELECT.
6. If bus calibration is desired instead, send the calibration signal over the bus. In this case the command would be: A1.9E-3X.
7. Any non-standard calibration points will be only temporary, as stated earlier.

7.5 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices operate at very high impedance levels for low power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices, if they are not handled properly. Table 7-7 lists static-sensitive devices used in the Model 617. When handling these devices, use the precautions below to avoid damaging them.

1. The ICs listed in the table should be transported and handled only in containers specially designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder suckers.
6. Use only grounded tip soldering irons.
7. Once the device is installed on the PC board, it is normally adequately protected, and normal handling can resume.

Table 7-7. Static Sensitive Devices

Circuit Designation	Keithley Part Number
Q103	TF-139
Q104	TG-166
Q105	TG-128
Q106	617-600
Q107	TG-139
Q108	TG-128
Q113	TG-177
U102	IC-163
U103	IC-407
U105	IC-103
U106	LSI-56
U107	LSI-58
U108	IC-338
U109	LSI-60
U110	IC-338
U111	IC-351
U112	IC-143
U113	LSI-49
U116	IC-338
U117	IC-412
U118	IC-341
U126	IC-337
U127	IC-407
U128	IC-412
U129	IC-316
U131	IC-251
U132	IC-324
U133	IC-251
U135	IC-341
U136	IC-283
U138	IC-408
U139	IC-347
U140	IC-251
U141	IC-247
U142	IC-410
U145	IC-283
U203	IC-398
U206	IC-277
Q302	TG-128
Q308	617-602
Q310	TG-177
U301	IC-251
U302	IC-354
U303	IC-354

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7.6 DISASSEMBLY INSTRUCTIONS

If it is necessary to troubleshoot the instrument or replace a component, use the following disassembly procedure. An exploded view of the instrument may be found in Figure 7-11.

WARNING
Disconnect the line cord and any test leads from the instrument before disassembly.

1. Remove the top cover as follows:
   A. Remove the two screws that secure the top cover to the rear panel.
   B. Grasp the top cover at the rear and carefully pull up until the tabs at the front of the cover clear the front panel. The cover may then be pulled completely clear.
   C. To replace the top cover, reverse the above procedure. Be sure to install the tabs at the front of the cover before completely installing it.
2. Remove the electrometer board as follows:
   A. Remove the four screws that secure the top shield to the electrometer board.
   B. Carefully lift the shield clear of the board.
   C. Disconnect the input wires from the electrometer board.
   D. Disconnect the power transformer wires at the mother board end.
   E. Remove the three screws that secure the electrometer board to the standoffs adjacent to the power transformer.
   F. Carefully remove the electrometer board, taking care not to touch the PC board surfaces or any components. When the board is partially removed, disconnect the ribbon cable at the mother board end.
3. Remove the mother board as follows:
   A. Disconnect the display board ribbon cable near the front of the instrument.
   B. Remove the four screws securing the mother board shield and remove the shield from the board.
   Perform this step only on Rev A boards.
   C. Remove the standoffs, three spacers and the one additional screw that secure the mother board to the bottom case. Do not remove the three standoffs down the center of the board.
   D. Remove the two screws that secure the rear panel to the bottom case and remove the mother board and rear panel as a single unit.
4. The display board can now be removed as follows:
   A. Remove the two screws securing the display board to the front panel.
   B. Disconnect the DIP cable connected to the mother board.
   C. Remove the display board by lifting up and back until the tabs at the bottom of the case are clear and then lift the display board free.
5. The instrument can be re-assembled by reversing the above procedure. Make sure that all boards are properly seated and secured, and that all connections are properly made. To ensure proper operation, sheilds must be replaced and fastened securely.

WARNING
To ensure continued protection against safety hazards, power line ground (the green wire connected to the AC power receptacle) must be connected to the rear panel and mother board.

7.7 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for qualified personnel having a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment, as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician. Note that schematic diagrams and component layout drawings, which are an essential aid in troubleshooting, are located at the end of Section 8.

WARNING
The electrometer board shield is connected to the inner shield of the triaxial input, which is connected either to analog common (unguarded) or guard (guarded). Thus, the shield can float up to ±800V above chassis ground.

7.7.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 617 depends not only on the skill of the technician, but also relies on the use of accurate, reliable test equipment. Table 7-8 lists the minimum recommended equipment for troubleshooting the Model 617. Other equipment such as logic analyzers and capacitance meters could also be helpful, especially in difficult situations.

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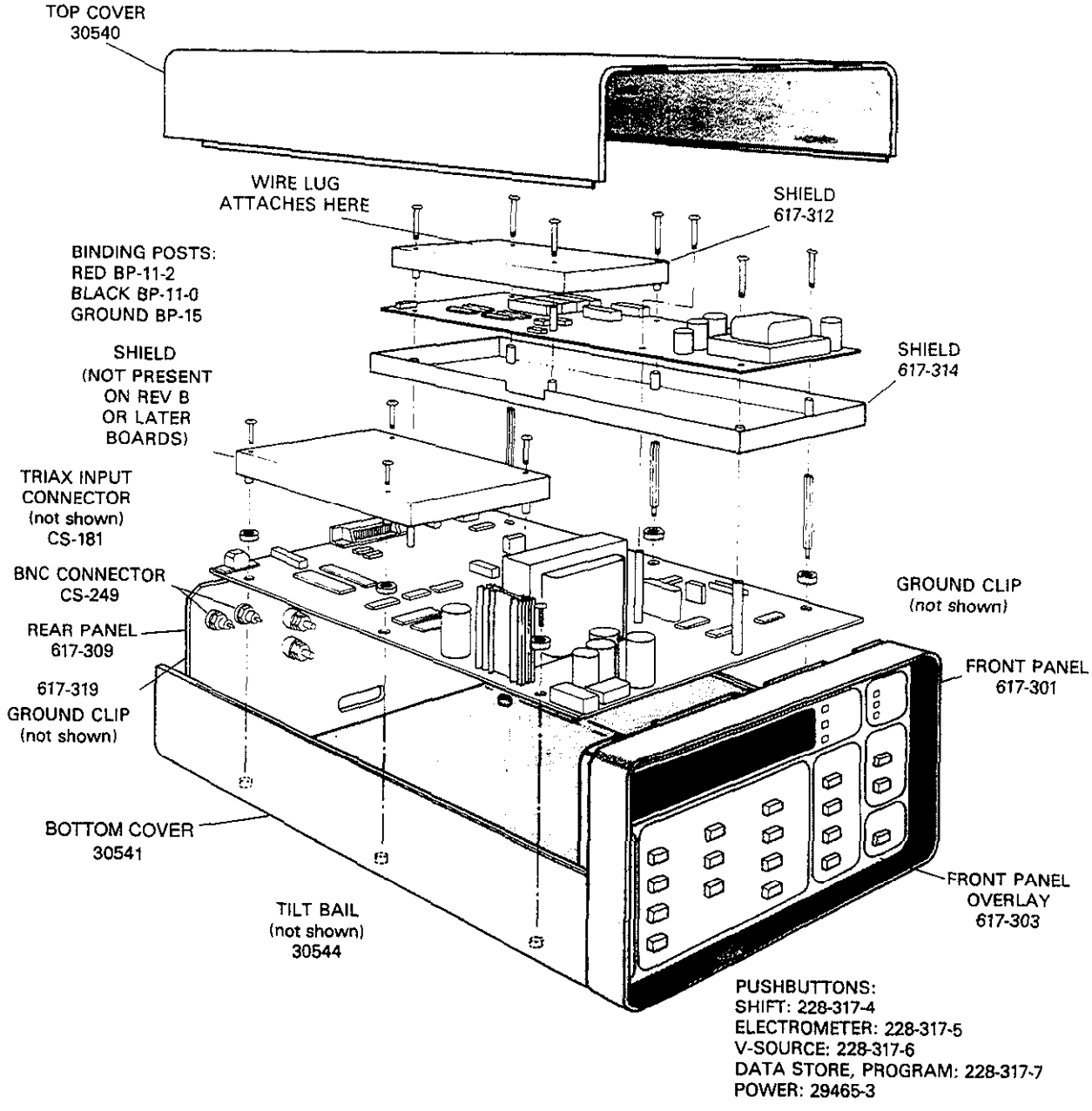


Figure 7-11. Model 617 Exploded View

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Table 7-8. Recommended Troubleshooting Equipment

Equipment	Use
DMM with 0.015% basic DC accuracy, 10MΩ input impedance (Keithley Model 197 or equivalent).	Power supply and DC voltage checks; analog signal tracing; continuity; static logic levels.
Dual-trace, triggered-sweep oscilloscope, DC-50MHz bandwidth.	Digital and analog waveform checks.

7.7.2 Power Up Self Test

Upon power up, the Model 617 will automatically test the RAM memory and check for proper calibration constants. If a RAM memory error occurs, the following message will remain on the display:

r.r.

The instrument will be completely inoperative. If this error occurs, it should be assumed that a problem exists within the instrument. The problem should be rectified before using the instrument.

If a calibration error occurs, the two exponent decimal points will flash. The instrument will be functional under these conditions, but calibration is not accurate. Use the calibration procedures in paragraph 7.4 of this section to calibrate the instrument. Note that this error may also indicate a defective NVRAM.

7.7.3 Self Diagnostic Program

The self diagnostic program can be used to test the front panel LEDs, access the software revision level, and enter a special mode to allow signal tracing through the instrument. Enter the diagnostic program as follows:

1. Turn off the instrument for at least three seconds if it is presently turned on.
2. Press and hold the TRIG button and then turn on power.
3. The instrument will then turn on all front panel LEDS and display segments. The instrument will remain in this configuration as long as the TRIG button is held in. The display should appear as follows:

   -1.8.8.8.8.8.8.

4. The software revision level will then be displayed when the TRIG button is released. A typical example is:

   E1

   Note that the revision level of your instrument may be different.
5. At this point, the instrument will enter the diagnostic mode that switches the instrument among the zero (common), calibration (reference), and signal phases of its measurement cycle. The unit can be cycled through these phases by repeatedly pressing the TRIG button. The decimal point will indicate the range. During the zero (common) phase, the display will appear as follows:

   P = 0

6. During the calibration (reference) phase, the display will show:

   P = C

7. Finally, the display will show the following message during the signal phase:

   P = S

8. To remove the instrument from the diagnostic mode, turn off the power.

During normal operation, the instrument cycles through these three phases in rapid succession. This cycle action makes it difficult to troubleshoot the instrument utilizing normal signal-tracing techniques. However, by using the diagnostic program to "freeze" the instrument on the appropriate phase, troubleshooting is greatly simplified. Table 7-9 summarizes phases, display messages, and signals applied to the A/D converter during each of the three phases.

7.7.4 Power Supply Checks

All power supply voltages should be checked first to make sure they are within the required limits. If the various operating voltages are not within the required limits, troubleshooting the remaining circuitry can be quite difficult.

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Table 7-9. Diagnostic Program Phases

Phase	Display Message	A/D Converter Input Signal
Zero (Common)	P = 0	Analog Common
Calibration (Reference)	P = C	−2V Reference
Signal	P = S	Output of Ranging Amplifier

Table 7-10 outlines the various power supply voltages that should be checked. In addition to the usual voltage checks, it is a good idea to check the various supplies with an oscilloscope to make sure that no noise or ringing is present.

WARNING

The electrometer board shield is connected to analog common, and can float up to ±800V above chassis ground, depending on the input signal.

7.7.5 Relay Configuration

Instrument functions are controlled by configuring the input amplifier with a number of relays. These relays are themselves controlled by serial-parallel converter ICs that decode control information from the microprocessor. Since each relay must assume a given state for proper operation, it is possible to verify input configuration switching by determining which relays are energized for every range and function.

Table 7-11 gives a summary of status for each of the twelve relays associated with the electrometer input section. You can verify proper relay operation for a given combination by selecting the range and function in question and then measuring the control voltage at the IC driver output. When a relay is energized (on), the voltage at the output will be high, while approximately 0V will be seen with the relay de-energized (off), except K302 and K303, which are energized when driven with 0V, and de-energized when driven to +5V.

7.7.6 Ranging Amplifier Gain Configuration

The ranging amplifier can have one of four gain values: X10, X1, X0.1, and X0.01. The actual value will depend on the selected range and function, as summarized in Table 7-12. This information can be used to determine if the ranging amplifier is working properly. To do so, select the desired range and function and apply an appropriate signal to the input of the electrometer. Measure the signal at the PREAMP and 2V ANALOG OUTPUT terminals and see if the correct scaling factor is applied.

For example, with the instrument on the 20V range an input signal of 19V could be applied. Assuming the input amplifier is operating properly, the voltage seen at the PREAMP OUT should also be 19V. The ranging amplifier should apply a gain of X0.1 in this case, so the voltage seen at the 2V ANALOG OUTPUT should be 1.9V. If the PREAMP OUT signal is correct, but the 2V ANALOG OUTPUT is not, the

Table 7-10. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S102 Line Switch	Set to 115 or 230 as required.	Line voltage selection.
2	F101 Line Fuse	Check for continuity.	Remove fuse to check.
3	Line Power	Plugged into live receptacle; power on.	
4	±110V supplies	+120V, −120V, ±15%	Referenced to ±110V common.
5	±15V V-Source Supplies	+15V, −15V, ±5%	Referenced to V-source common.
6	+5V Digital Supply	+5V, ±5%	Referenced to digital common.
7	±210V Supplies	+240V, −240V, ±13%	Referenced to analog common.
8	+5V Analog Supply	+5V, ±5%	Referenced to analog common.
9	−9.1V Supply	−9.1V, ±5%	Referenced to analog common.
10	±5V Bootstrap Supplies	+5V, −5V, ±5%	Referenced to bootstrap common.
11	±24V Supplies	+27.5V, −27.5V, ±15%	Referenced to preamp out.

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ranging amplifier or associated control circuits are not functioning properly.

7.7.7 A/D Converter and Display

Use the procedure listed in Table 7-13 to make sure the A/D converter and display circuits are operating properly. The operation of these circuits should be verified before attempting to troubleshoot the analog circuitry.

Table 7-11. Relay Configuration

Relay Function	Range	K309	K310	K308	K311	K312	K307	K303	K304	K305	K306	K301	K302
Volts	200mV											X	
	2 V											X	
	20 V											X	
	200 V											X	
Ohms	2 kΩ	X		X							X	X	
	20 kΩ	X		X							X	X	
	200 kΩ	X		X						X		X	
	2MΩ	X		X								X	
	20MΩ				X	X					X	X	
	200MΩ				X	X				X		X	
	2GΩ				X	X			X			X	
	20GΩ				X	X			X			X	
	200GΩ				X	X			X			X	
Amps	2 pA					X		X					X
	20 pA					X		X					X
	200 pA					X		X					X
	2 nA				X	X		X					X
	20 nA				X	X		X					X
	200 nA				X	X		X					X
	2 μA	X		X				X					X
	20 μA	X		X				X					X
	200 μA	X		X				X					X
	2mA		X					X					X
	20mA		X					X					X
Coulombs	200 pC	X						X					X
	2 nC	X						X					X
	20 nC	X						X					X
External Feedback	200mC							X					X
	2 V							X					X
	20 V							X					X
	Zero Check	*	*	*	*	*	X	*				*	*

X = Relay Energized.

* = These relays may also be energized depending on range and function.

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Table 7-12. Ranging Amplifier Gains

Function	Range	Gain
Volts	200mV	X10
	2 V	X1
	20 V	X0.1
	200 V	X0.01
Amps	2 pA	X10
	20 pA	X1
	200 pA	X0.1
	2 nA	X10
	20 nA	X1
	200 nA	X0.1
	2 μA	X10
	20 μA	X1
	200 μA	X0.1
	2mA	X10
	20mA	X1
Ohms	2 kΩ	X10
	20 kΩ	X1
	200 kΩ	X1
	2MΩ	X1
	20MΩ	X1
	200MΩ	X1
	2GΩ	X1
	20GΩ	X0.1
	200GΩ	X0.01
Coulombs	200pC	X10
	2nC	X1
	20nC	X0.1
External Feedback	200mV	X10
	2 V	X1
	20 V	X0.1

7.7.8 Input and Ranging Amplifiers

The input and ranging amplifiers condition the input signal, transforming it into a 0-2V DC voltage that is usable by the A/D converter. The exact conditioning process will depend on the selected range and function. With the voltage ranges, for example, the signal is merely attenuated (20V and 200V ranges) or amplified (200mV range), and inverted. For the amps function, the input signal must undergo current-voltage conversion.

The procedures outline in Tables 7-14 and 7-15 may be used as an aid in troubleshooting the input amplifier and ranging circuits. Note that the procedure in Table 7-15 assumes that the input amplifier is operating properly.

WARNING
Up to 300V may be present between PREAMP OUT and COM.

7.7.9 Digital Circuitry

Problems with the digital circuitry could cause erratic operation. Check the various components associated with the digital circuity, including the IEEE-488 interface, using the procedure given in Table 7-16.

7.7.10 Display Board

Check out the display board by using the procedure in Table 7-17.

7.7.11 Voltage Source

Check out the operation of the voltage source by using the procedure in Table 7-18. Note that the power supply voltage should be checked first to ensure proper operation of the voltage source.

7.8 INPUT STAGE BALANCING PROCEDURE

If the input FET (Q308) or associated bias resistors are replaced, the following procedure should be used to rebalance the circuit. This procedure may also be used if the offset adjustment potentiometer (R314) has insufficient range. The procedure involves checking the number of counts of offset with jumper W303 in position B.

Proceed as follows:

1. Remove the top cover and electrometer board shield as described in paragraph 7.6. Power should be off at this point.
2. Place jumper W303 in position B.
3. Select the volts mode and 200mV range. Do not use autoranging.
4. Enable zero check but leave zero correct disabled.
5. Set the input offset adjustment potentiometer (see Figure 7-3) fully clockwise as viewed from the screw end. The control is a muliturn potentiometer, so considerable adjustment may be required.
6. Note the number of counts shown on the display and compare the value to the ranges listed in Table 7-19. From this table, you can determine which position jumper

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W303 should be placed in. For example, if the display shows between −1200 and +200 counts, jumper W303 should be placed in position C.

7. Place the jumper in accordance with the results of step 6.
8. Replace the electrometer board shield.
9. Turn on the power and allow the instrument to warm up for one hour before performing the following adjustment.
10. Set the input offset potentiometer (R314) for a reading of 00.00 ±1 count on the display.
11. Replace the top cover when the procedure is complete.

7.9 HANDLING AND CLEANING PRECAUTIONS

When troubleshooting or otherwise working inside the instrument, care should be taken not to indiscriminately touch PC board traces and open wires to avoid contaminating them with body oils or other foreign matter. In particular, there are two areas within the Model 617 that have numerous high impedance nodes where contamination could cause degraded performance. These include the input amplifier area on the electrometer board and the ranging amplifier section location on the mother board.

The same general precautions apply when replacing parts in these areas. When unsoldering and soldering parts, be careful not to spread the flux around the board to adjacent areas. After replacing parts, or if contamination is suspected, use the following procedure to clean the affected area.

1. Using a squeeze bottle, carefully apply clean, uncontaminated methanol to the area to be cleaned. Use sufficient solution to throughly wet the circuit board.
2. Using a small, clean brush, wipe the area thoroughly until it is free of flux or contaminants. In some cases, it may be helpful to tilt the board at an angle and brush contaminants away from the affected area, allowing contaminated residue and methanol to run off the board.
3. Wash the area again with fresh, clean methanol.
4. Once the area is thoroughly cleaned, is should be dryed with pressurized dry, clean air or nitrogen. Do not use compressed air from an ordinary air compressor, as oil particles in the air could contaminate the circuit board.
5. After cleaning or parts replacement check to see that any components connected to the Teflon insulators are not physically touching the board or adjacent parts.

Table 7-13. A/D Converter Checks

Step	Item/Component	Required Condition	Remarks
1		Turn on power, select 2V range and short input.	All A/D checks referenced to analog common.
2	U127, pin 10	1.2288MHz gated clock	A/D Clock
3	U127, pin 7	307.2kHz gated clock	Synchronous clock for A/D
4	U127, pin 6	153.6kHz gated clock	Synchronous clock for A/D
5	U127, pin 5	76.8kHz gated clock	Synchronous clock for A/D
6	U127, pin 3	38.4kHz gated clock	Synchronous clock for A/D
7	U127, pin 1	300Hz gated clock	Synchronous clock for A/D
8	U135, pin 6	+5V to ≈ 0V pulse train 3μsec duration every 22μsec	Charge balance synchronization signal
9	U138, pin 7	Integrator ramp	
10	U137, pin 6	≈ 1.5V DC	Comparator reference
11	U137, pin 7	Variable pulse train 0V to +5V	Comparator output
12	U126, pin 6	Variable pulse train 0V to +5V	Reference current generator
13	U135, pin 8	Variable pulse train 0 to +5V	A/D Data Output
14	U136, pin 10	≈ 5msec positive going pulse	Control line for charge balance/ single slope
15	U126, pin 9	100msec positive going pulse	Integrator control line

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Table 7-14. Preamplifier Checks

Step	Item/Component	Required Condition	Remarks
1	COM fuse	Remove and check for continuity	Replace if open
2		Power on, 200mV DC range Zero check off	
3	Apply 190mV DC Input	190mV	Measure at PREAMP OUT and COM unless otherwise noted.
4	Apply 1.9V DC Input	1.9V	
5	Apply 19V DC Input	19V	
6	Apply 190V DC Input	190V	Remove before slecting amps
7		Select AMPS, 2mA range	
8	Apply 1.9mA Input	190mV	
9		Select 20mA range	
10	Apply 19mA Input	1.9V	
11		Select 200μA range	
12	Apply 190μA Input	19V	
13		Enable zero check, volts	
14		0V	Zero Correct, if necessary.
15		Select OHMS	
16	R304, pin 1	10V, ±0.1V	Referenced to PREAMP OUT
17	R304, pin 2	1V, ±0.01V	Referenced to PREAMP OUT
18	R304, pin 3	0.1V, ±0.001V	Referenced to PREAMP OUT

Table 7-15. Ranging Amplifier Checks

Step	Item/Component	Required Condition	Remarks
1		Power on, 200V DC range, ZERO CHECK off.	Measure between 2V ANALOG OUTPUT and COM.
2	Apply 190V DC to input.	1.9V	Check X0.01 Gain
3		Select 20V DC range.	
4	Apply 19V DC to input.	1.9V	Check X0.1 Gain
5		Select 2V DC range.	
6	Apply 1.9V DC to input.	1.9V	Check X1 Gain
7		Select 200mV DC range.	
8	Apply 190mV DC to input.	1.9V	Check X10 Gain

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Table 7-16. Digital Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1		Power on, 200VDC range.	Voltages referenced to digital common.
2	U109, pin 40	+5V, ±5%	+5V digital supply
3	U109, pin 2	500μsec negative pulse every 1.6msec	Interrupt clock
4	U109, pin 3	Stays low < 1sec on power on, then goes high (≅ 4V).	MPU Reset
5	U109, pin 4	655kHz clock	Data Strobe
6	U109, pin 6	655kHz clock	Address strobe
7	U109, pin 37	Variable pulse train.	A/D Data
8	U102, pin 6	Variable pulse train.	A/D Control
9	U102, pin 8	Variable pulse train.	Voltage supply control
10	U102, pin 3	Negative going pulse every 350msec.	Meter complete

Table 7-17. Display Board Checks

Step	Item/Component	Required Condition	Remarks
1		Power on, 200V DC range, zero check on.	Voltages referenced to digital common.
2	U201, pin 9	+5V, ±5%	+5V supply
3	U201, U202, pins 11-18	Variable pulses	Segment drivers
4	U204, pins 11-18 U205, pins 15-18	Variable pulses	Digit drivers
5	U209, pins 10-15	1msec negative going pulse every 10msec.	
6	P1016, pin 14	Depress COUL, R↓, ZERO CHECK, V↓, TRIG or DATA ON button.	Pulse present when button depressed.
7	P1016, pin 15	Depress AMPS, R↑, SHIFT, SUPPRESS, V↑ or RECALL button.	Pulse present when button depressed.
8	P1016, pin 16	Depress VOLTS, OHMS, AUTO, ZERO CORRECT, DISPLAY PROGRAM or OPERATE button	Pulse present when button pressed.

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Table 7-18. Voltage Source Checks

Step	Item/Component	Required Condition	Remarks
1		Power on, V-Source = 0V.	Voltages referenced to voltage source common except as noted.
2	U132, pin 9	82kHz clock	Voltage source clock.
3	U132, pin 15	Variable pulse train.	Voltage source data.
4		Program +102.4V output.	OPERATE on
5	U141, pins 4-15	All high (≅ 15V)	DAC Inputs
6		Program −102.35V output.	OPERATE on
7	U141, pins 4-15	All low (≅ 0V)	DAC Inputs
8	U141, pin 7	−10.235V	Current voltage converter.
9	V-SOURCE HI and LO Outputs	−102.35V	Voltage source output.
10		Program +102.4V output.	OPERATE ON
11	U142, pin 7	+10.24V	Current−voltage converter.
12	V-SOURCE HI and LO outputs	+102.4V	Voltage source output.
13		OPERATE off	
14	U141, pins 4-15	Pin 4 high, 5-15 low	DAC inputs when output at 0V.

Table 7-19. Input Stage Balancing

Number Counts W303 in position B and R314 Fully Clockwise	Positon of W303
1400 to 2800	A
200 to 1400	B
−1200 to 200	C

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SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 617 Electrometer. Also included is an exploded view drawing showing the general mechanical layout of the instrument along with part numbers.

8.2 ELECTRICAL PARTS LISTS

Electrical parts for the Model 617 mother board, electrometer board, and the display board are listed in Tables 8-2 through 8-4, respectively. Parts in each table are listed alphabetically in order of circuit designation.

8.3 MECHANICAL PARTS

Mechanical parts are shown in Figure 7-11. Part numbers are indicated on the diagram.

8.4 ORDERING INFORMATION

Keithley Instruments, Inc. maintains a complete inventory of all normal replacement parts. To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. When ordering parts, include the following information:

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Circuit designation, including schematic diagram and component layout numbers (if applicable).
5. Keithley Part Number

8.5 FACTORY SERVICE

If the instrument is to be returned to the factory for service, carefully pack the unit and include the following:

1. Complete the service form which follows this section and return it with the instrument.
2. Advise as to the warranty status of the instrument (see the inside front cover for warranty information).
3. Write the following on the shipping label: ATTENTION REPAIR DEPARTMENT.

8.6 COMPONENT LAYOUT DRAWINGS AND SCHEMATIC DIAGRAMS

Component layout drawings and schematic diagrams for the mother board, electrometer board, and the display board can be found immediately following the parts lists.

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Table 8-1. Mother Board, Parts List

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
C101	Capacitor, 4700μF, 16V Aluminum Electrolytic	1/B5	C1	C-313-4700
C102	Capacitor, 0.1μF, 50V, Ceramic Film	2/G5	D2	C-237-.1
C103	Capacitor, 10μF, 25V, Electrolytic	1/B5	B2	C-309-620
C104	Capcitor, 10μF, 25V, Aluminum Electrolytic	1/C5	C2	C-314-10
C105	Capacitor, 1μF, 50V, Ceramic Film	2/C2	F2	C-237-1
C106	Capacitor, 10μF, 20V, Tantalum	2/B1	F2	C-179-10
C107	Capacitor, 22pF, 1000V, Ceramic Disc	2/D3	F2	C-64-22p
C108	Capacitor, 620μF, 35V, Electrolytic	1/B5	B2	C-309-620
C109	Capacitor, 47μF	1/B4	B3	C-354-47
C110	Capacitor, 47μF	1/B4	B3	C-354-47
C111	Capacitor, 22pF, 1000V, Ceramic Disc	2/D4	F3	C-64-22p
C112	Capacitor, 0.1μF, 50V, Ceramic Film	2/G3	F3	C-237-.1
C113	Capacitor, 1μF, 50V, Ceramic Film	2/D1	C3	C-237-1
C114	Capacitor, 1μF, 50V, Ceramic Film	1/C5	B3	C-237-1
C115	Capacitor, 1μF, 50V, Ceramic Film	1/C5	B3	C-237-1
C116	Capacitor, 0.1μF, 50V, Ceramic Film	2/A4	D4	C-237-.1
C117	Capacitor, 0.1μF, 50V, Ceramic Film	2/H3	F4	C-237-.1
C118	Capacitor, 0.1μF, 50V, Ceramic Film	2/H1	F4	C-237-.1
C119	Capacitor, 0.1μF, 100V, Metallized Polyester	3/B3	D4	C-305-.1
C120	Capacitor, 0.01μF, 500V, Ceramic Disc	3/G1	D4	C-22-.01
C121	Capacitor, 33pF, 500V, Ceramic Disc	3/G3	C4	C-22-33p
C122	Capacitor, 150pF, 500V, Ceramic Disc	3/G3	C4	C-22-150p
C123	Capacitor, 0.1μF, 50V, Ceramic Film	3/F1	C4	C-237-.1
C124	Capacitor, 0.1μF, 100V, Metallized Polyester	3/B3	C4	C-305-.1
C125	Capacitor, 0.1μF, 50V, Ceramic Film	3/F3	B4	C-237-.1
C126	Capacitor, 0.1μF, 50V, Ceramic Film	3/F4	C4	C-237-.1
C127	Capacitor, 0.1μF, 50V, Ceramic Film	3/B3	D4	C-237-.1
C128	Capacitor, 0.01μF, 100V, Metalized Polypropylene	3/D4	C5	C-306-.01
C129	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D2	E4	C-314-10
C130	Capacitor, 0.47μF, 100V, Metalized Polyester	3/B3	D5	C-305-.047
C131	Capacitor, 22pF, 1000V, Ceramic Disc	1/B1	E5	C-64-22p
C132	Capacitor, 0.47μF, 50V, Ceramic Film	1/E4	E5	C-237-.47
C133	Capacitor, 33pF, 1000V, Ceramic Disc	3/F3	F5	C-64-33p
C134	Capacitor, 10μF, 25V, Aluminum Electrolytic	3/C4	C5	C-314-10
C135	Capacitor, 0.1μF, 16V, Ceramic Disc	1/F4	F5	C-22-.02
C136	Capacitor, 390pF, 500V, Polystyrene	1/F3	F5	C-138-390p
C137	Capacitor, 47μF, 25V, Aluminum Electrolytic	1/F5	F5	C-314-4.7μ
C138	Capacitor, 100V, .0047μF, Ceramic Disc			C-64-.0047
C139	Capacitor, .33μF, Polyester			C-344-.33
C140	Capacitor, .015μF, 500V, Ceramic Disc			C-22-.015
C141	Capacitor, 0.01μF, 500V, Ceramic Disc			C-22-.01
CR101	Diode, Silicon, 1N4006	1/B5	B1	RF-38
CR102	Diode, Silicon, 1N4148	2/A3	D1	RF-28
CR103	Diode, Silicon, 1N4148	2/A3	E1	RF-28
CR104	Diode, Silicon, 1N4148	2/B2	E1	RF-28
CR105	Diode, Silicon, 1N4148	2/B3	E1	RF-28
CR106	Diode, Silicon, 1N4148	2/B1	F1	RF-28
CR107	Diode, Silicon, 1N4006	1/B5	B2	RF-38
CR108	Diode, Silicon, 1N4006	1/B4	B2	RF-38
CR109	Diode, Silicon, 1N4006	1/B5	B2	RF-38
CR110	Bridge Silicon, 1A, 100PIV	1/B5	C2	RF-52
CR111	Diode, Silicon, 1N4148	1/F3	F4	RF-28
CR112	Diode, Silicon, 1N4148	1/F3	F4	RF-28
CR113	Diode, Silicon, 1N4148	3/E4	B4	RF-28

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Table 8-1. Mother Board, Parts List (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
CR114	Diode, Silicon, 1N4148	1/F4	F5	RF-28
CR115	Diode, Silicon, 1N4148	1/F3	F5	RF-28
CR116	Diode, Silicon, 1N4006	1/E4	B5	RF-38
F101	Line Fuse ¼A, 250V, 3AG, SLO-BLO (105-125V operation)	1/A4	G3	FU-17
F101	Line Fuse, 1/8A, 250V, 3AG, SLO-BLO (210-250V operation)	1/A4	G3	FU-20
F102	Fuse, 1/16A, 250V, AGC-1/16			FU-86-1
J1010	Connector, IEEE	2/H2	G4	CS-377
J1011	Connector		G2	CS-388
J1012	Not Used			
J1013	Connector	1/C6	C3	CS-288-3
J1014	Connector, 14 pin	3/A2	E4	CS-389-5
J1015	Connector		F2	CS-339-3
J1016	Connector	Sev	B3	SO-68
J1017	Pin, Contact		G5	24249A
J1018	Connector	3/A4	E4	CS-339-3
J1019	Connector		F4	CS-339-3
K101	Relay	1/F5	G4	RL-90
Q101	Transistor, Silicon NPN, 2N3904	1/F3	F4	TG-47
Q102	Transistor, Silicon PNP, 2N3906	1/F4	F4	TG-84
Q103	Transistor, N-Channel JFET	3/B3	D4	TG-139
Q104	Transistor, P-Channel JFET	3/B2	D4	TG-166
Q105	Transistor, N-Channel JFET	3/B2	D4	TG-128
Q106	Transistor, Selected	3/B2	D4	617-600
Q107	Transistor, N-CHannel JFET	3/B3	D4	TG-139
Q108	Transistor, N-Channel JFET	3/D4	C5	TG-128
Q109	Transistor, Silicon PNP, 2N3906	1/G3	F5	TG-84
Q110	Transistor, P-Channel JFET	3/C2	D5	TG-166
Q111	Transistor, NPN Silicon, Annular	1/F2	E5	TG-146
Q112	Transistor, PNP Silicon, Annular	1/F4	E5	TG-147
Q113	Transistor, N-Channel Enhancement Mode MOSFET	1/F4	F5	TG-177
R101	Resistor, 100Ω, 5%, ¼W, Composition	2/A3	D1	R-76-100
R102	Resistor, 100Ω, 5%, ¼W, Composition	2/B2	E1	R-76-100
R103	Resistor, 430Ω, 5%, ¼W, Composition	2/A4	E1	R-76-430
R104	Resistor, 10MΩ, 10%, ¼W, Composition	1/C6	C2	R-76-10M
R105	Resistor, Thick Film	Sev	E2	TF-183-1
R106	Resistor, 560Ω, 5%, ¼W, Composition	2/A5	E2	R-76-560
R107	Resistor, 30kΩ, 5%, ¼W, Composition	2/C1	F2	R-76-30k
R108	Resistor, Thick Film	Sev	E2	TF-179-1
R109	Resistor, Thick Film	Sev	F2	TF-179-1
R110	Resistor, 10MΩ, 10%, ¼W, Composition	1/C4	F2	R-76-10M
R111	Resistor, 200kΩ, 5%, ¼W, Composition	1/C4	B3	R-76-200k
R112	Resistor, 200kΩ, 5%, ¼W, Composition	1/C4	B3	R-76-200k
R113	Resistor, 100kΩ, 5%, ¼W, Composition	1/A6	F4	R-76-100k
R114	Resistor, 1kΩ, 5%, ¼W, Composition	3/G1	D4	R-76-1k
R115	Resistor, 5.1kΩ, 5%, ¼W, Composition	1/C1	E4	R-76-5.1k
R116	Resistor, 5.1kΩ, 5%, ¼W, Composition	1/D2	E4	R-76-5.1k
R117	Resistor, 100Ω, 5%, ¼W, Composition	3/A4	D4	R-76-100

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Table 8-1. Mother Board, Parts List (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
R118	Resistor, 100kΩ, 5%, ¼W, Composition		F4	R-76-100k
R119	Resistor, 10kΩ, 5%, ¼W, Composition	3/B3	D4	R-76-10k
R120	Resistor, 5.49kΩ, 1%, 1/8W, Composition	1/D4	E4	R-88-5.49k
R121	Resistor, 9.76kΩ, 1%, 1/8W, Composition	1/D5	E4	R-88-9.76k
R122	Resistor, 6.8kΩ, ¼W, Composition	1/F2	F4	R-76-6.8k
R123	Resistor, 470Ω, ¼W, Composition	1/G4	F4	R-76-470
R124	Resistor, 180Ω, 5%, ¼W, Composition	1/G3	F4	R-76-180
R125	Resistor, 100Ω, 5%, ¼W, Composition	1/F3	F4	R-76-100
R126	Resistor, 180Ω, 5%, ¼W, Composition	1/G3	F4	R-76-180
R127	Resistor, 470Ω, 5%, ¼W, Composition	1/G3	D4	R-76-470
R128	Resistor, 200kΩ, 0.1%, ¼W, Metal Film	3/B3	E4	R-264-200k
R129	Resistor, 1.87kΩ, 1%, 1/8W, Composition	1/D4	E4	R-88-1.87k
R130	Resistor, 100Ω, 1%, 1/8W, Composition	1/D4	E4	R-88-100
R131	Resistor, 15MΩ, 10%, ¼W, Composition	3/G2	C4	R-76-15M
R132	Resistor, 402kΩ, 1%, 1/8W, Composition	1/D4	E4	R-88-402k
R133	Resistor, 2.2kΩ, 5%, ¼W, Composition	3/G2	C4	R-76-2.2k
R134	Resistor, 1kΩ, 5%, ¼W, Composition	1/G4	F4	R-76-1k
R135	Resistor, 430Ω, 5%, ¼W, Composition	3/G3	C4	R-76-430
R136	Resistor, 6.8kΩ, 5%, ¼W, Composition	1/F4	F5	R-76-6.8k
R137	Resistor, 100kΩ, 5%, ¼W, Composition	1/G4	F5	R-76-100k
R138	Resistor, 22kΩ, 5%, ¼W, Composition	3/E4	B5	R-76-22k
R139	Resistor, 200kΩ, 5%, ¼W, Composition	1/G4	F5	R-76-200k
R140	Resistor, 100kΩ, 5%, ¼W, Composition	1/G2	F5	R-76-100k
R141	Resistor, Thick Film	Sev	F5	TF-102-2
R142	Resistor, 2MΩ, 0.9%, ¼W, Metal Film	3/B2	D5	R-321-2M
R143	Resistor, 220kΩ, 0.1%, ¼W, Metal Film	3/B2	D5	R-264-220k
R144	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	3/B2	D5	R-263-20k
R145	Resistor, 2kΩ, 0.1%, 1/10W, Metal Film	3/B2	D5	R-263-2k
R146	Resistor, Thick Film	Sev	C5	TF-150
R147	(Not Used)			
R148	(Not Used)			
R149	Resistor, Thick Film	Sev	C5	TF-172
R150	Resistor, 200kΩ, 5%, ¼W, Composition	3/C2	D5	R-76-200k
R151	Resistor, 20kΩ, ¼W, Composition	1/E4	E5	R-76-3.3k
R152	Resistor, 1kΩ, 5%, ¼W, Composition	1/E4	F5	R-76-1k
R153	Resistor, Thick Film	Sev	C5	TF-171
R154	Resistor, 47kΩ, 5%, ¼W, Composition	1/E4	E5	R-76-47k
R155	Potentiometer, 1kΩ	1/D5	G5	RP-111-1k
R156	Resistor, 5%, ¼W, Composition	1/B1	E5	R-76-10k
R157	Resistor Set, 10k, includes R158			R-332
R158	Resistor Set, 10k, includes R157			R-332
R159	Resistor, 200k, 0.1%, ¼W, Metal Film			R-264-200k
R160	Resistor, 2M, 0.1%, ¼W, Metal Film			R-321-2M
R161	Resistor, 10k, 5%, ¼W, Composition			R-76-10k
S101	Switch Line	1/A5	B1	SW-466
S102	Switch, Line Voltage Selection	1/A5	B2	SW-397
S103	Switch, SPDT Slide	3/A4	G5	SW-318
T101	Transformer, Power (90-110V, 180-220V)	1/A5	C3	TR-240*
T101	Transformer, Power (U.S and Europe version)	1/A5	C3	TR-239*
T102	Toroid			TR-214
U101	IC, Voltage Regulator, +5V, 7805	1/B5	C1	32469-2
U102	IC, Quad 2-Input NAND Gate, 74LS00	Sev	E1	IC-163
U103	IC, HC4040	2/E4	E1	IC-407

*Matched set with T301

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Table 8-1. Mother Board, Parts List (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
U104	IC, 16 × 16 Bit Serial NVRAM, X2443D	2/B2	F1	IC-353
U105	IC, CMOS Dual D Flip-Flop, 4013	2/B3	F2	IC-103
U106	IC, PROM, 27128	2/F5	D2	617-800-**
U107	IC, 2k × 8 Static CMOS RAM, 6116	2/F5	D2	LSI-58
U108	IC, Octal Tri-State Latch, 74HC373	2/D3	E2	IC-338
U109	IC, 8-Bit CMOS Microprocessor, 146805E2	2/C1	E2	LSI-60
U110	IC, Tri-State Octal Latch, 74HC373	2/F2	D3	IC-338
U111	IC, Quad 2-Input NAND Gate, 74HC00	2/D5	D3	IC-351
U112	IC, Triple 3-Input OR Gate, 4075	Sev	E3	IC-143
U113	IC, GPIB Adapter, 9914A	2/G2	E3	LSI-49
U114	IC, 15V, Voltage Regulator, LM320LZ-15	1/B5	B3	IC-253
U115	IC, Regulator, 78L15	1/C5	B3	IC-170
U116	IC, Tri-State Octal Latch, 74HC373	2/F3	D3	IC-338
U117	IC, Quad 2-Input NOR Gate, 74HC02	Sev	D3	IC-412
U118	IC, Triple 3-Input NAND Gate, 74HC10	Sev	E3	IC-341
U119	IC, Octal GPIB Transceiver, 75161A	2/H3	F3	IC-299
U120	IC, Octal GPIB Transceiver, 75160A	2/H2	F3	IC-298
U121	IC, Opto Coupler, HCPL-2601	2/A4	D4	IC-239
U122	IC, Opto Coupler, HCPL-2601	3/G1	D4	IC-239
U123	IC, Opto Coupler, HCPL-2200	1/E1	E4	IC-411
U124	IC, Opto Coupler, HCPL-2200	1/E2	E4	IC-411
U125	IC, Opto-Isolator, FCD-820	2/A5	F4	IC-82
U126	IC, Dual D Flip-Flop, 74HC74	3/F3	B4	IC-337
U127	IC, 74HC4040	3/E3	B4	IC-407
U128	IC, Quad 2-Input NOR Gate, 74HC02	Sev	C4	IC-412
U129	IC, CMOS Static Shift Register, CD4015AE	3/F2	C4	IC-136
U130	IC, Operational Amplifier, ICL7650	3/B3	D4	IC-316-
U131	IC, 8 Stage Shift-Store Register, MC14094	1/B3	E4	IC-251
U132	IC, 4520	1/B2	E4	IC-324
U133	IC, 8-Stage Shift-Store Register, MC14094	3/C2	C4	IC-251
U134	IC, Operational Amplifier, 741	1/B1	E5	IC-42
U135	IC, Triple 3-Input NAND Gate, 74HC10	Sev	C5	IC-341
U136	IC, Triple 2-Channel Multiplexer, CD4053BC	Sev	B5	IC-283
U137	IC, Dual Voltage Comparator, LM393	3/E4	B5	IC-343
U138	IC, Operational Amplifier, TLC272C	3/D4	C5	IC-408
U139	IC, Programmable Operational Amplifier, TLC271	3/B4	C5	IC-347
U140	IC, 8-Stage Shift-Store Register, MC14094	1/B3	E5	IC-251
U141	IC, 12-Bit DAC, AD7541JN	1/C3	E5	IC-247
U142	IC, Operational Amplifier, OP-14E	1/E3	E5	IC-423
U143	IC, Linear Op Amp, 308A	1/F3	F5	IC-203
U144	IC, Quad Comparator, LM339	Sev	F5	IC-219
U145	C, Triple 2-Channel Multiplexer, CD4053BC	3/C3	C5	IC-283
VR101	Regulator, Zener Diode, 6.35V, 400mW	1/D5	E4	DZ-58
VR102	Regulator, Zener Diode, 6.35V, 400mW	3/B4	C5	DZ-58
VR103	Regulator, Zener Diode, 5.1V, 400mV, IN751	3/C4	C5	DZ-59
W101	Jumper	2/B3	G2	CS-476
Y101	Crystal, 3.276800MHZ, ±0.25%	2/D3	F2	CR-21
Y102	Crystal, 1.2288MHz	3/G3	C4	CR-19

**Last two digits determined by software revision level. For example, if revision level is A1, order 617-800-A1.

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Table 8-2. Display Board, Parts List

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
C201	Capacitor, 10μF, 20V, Tantalum	A3	C2	C-179-10
DS201	Display, Digital "–1"	B2	B1	617-603
DS202	Display, 7-Segment, "8"	C2	C1	617-604
DS203	Display, 7-Segment, "8"	D2	C1	617-604
DS204	Display, 7-Segment, "8"	E2	C1	617-604
DS205	Display, 7-Segment, "8"	F2	C1	617-604
DS206	Display, Dual 14-Segment	G2	C1	DD-39
DS207	LED, Red	H1	D2	PL-71
DS208	LED, Red	H1	D1	PL-71
DS209	LED, Red	H2	D1	PL-71
DS210	LED, Red	H2	D2	PL-71
DS211	LED, Red	H2	D2	PL-71
DS212	LED, Red	H2	D2	PL-71
DS213	LED, Red	H2	D2	PL-71
DS214	LED, Yellow	H2	D3	PL-72
DS215	LED, Red	H3	C2	PL-71
DS216	LED, Red	H3	C2	PL-71
DS217	LED, Red	H3	C2	PL-71
DS218	LED, Red	H3	C2	PL-71
DS219	LED, Red	H4	C2	PL-71
DS220	LED, Yellow	H4	C2	PL-72
DS221	LED, Red	H4	D1	PL-71
DS222	LED, Red	H5	D2	PL-71
DS223	LED, Red	H5	D2	PL-71
DS224	LED, Red	H5	D2	PL-71
P1016	Cable, Ribbon	A1	C3	CA-30-1
R201	Resistor, Thick Film	B1	D2	TF-141
R202	Resistor, Thick Film	B2	D2	TF-141
S201	Switch, Pushbutton	D4	C2	SW-435
S202	Switch, Pushbutton	D4	C2	SW-435
S203	Switch, PUshbutton	D4	C2	SW-435
S204	Switch, Pushbutton	D4	C2	SW-435
S205	Switch, Pushbutton	D4	C2	SW-435
S206	Switch, Pushbutton	D4	C2	SW-435
S207	Switch, Pushbutton	D4	C2	SW-435
S208	Switch, Pushbutton	D4	B2	SW-435
S209	Switch, Pushbutton	D4	D2	SW-435
S210	Switch, Pushbutton	D5	D2	SW-435
S211	Switch, Pushbutton	D5	D2	SW-435
S212	Switch, Pushbutton	D5	D2	SW-435
S213	Switch, Pushbutton	D5	D2	SW-435
S214	Switch, Pushbutton	D5	D2	SW-435
S215	Switch, Pushbutton	D5	D2	SW-435
S216	Switch, Pushbutton	D5	D2	SW-435
S217	Switch, Pushbutton	D5	D2	SW-435
S218	Switch, Pushbutton	D5	D2	SW-435
S219	Switch, Pushbutton	D5	D2	SW-435
U201	IC, UDN2585A	A1	D2	IC-405
U202	IC, UDN2585A	A2	D2	IC-405
U203	IC, 3 to 8 Line Decoder, 74HCT138	B3	C2	IC-398
U204	IC, UDN2595A	D3	C2	IC-406
U205	IC, UDN2595A	E4	D2	IC-406
U206	IC, Analog Multiplexer, 4051	B5	B2	IC-277

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Table 8-3. Electrometer Board, Parts List

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
C301	Capacitor, 4.7μF, 350V, Aluminum Electrolytic	F3	B1	C-240-4.7
C302	Capacitor, 4.7μF, 350V, Aluminum Electrolytic	F3	C1	C-240-4.7
C303	Capacitor, 10μF, 350V, Aluminum Electrolytic	G3	C2	C-240-10
C304	Capacitor, 10μF, 350V, Aluminum Electrolytic	G3	B2	C-240-10
C305	Capacitor, 1500μF, 25V, Aluminum Electrolytic	G4	C2	C-314-1500
C306	Capacitor, 470μF, 16V, Aluminum Electrolytic	G4	B2	C-313-470
C307	Capacitor, 1000pF, 630V, Polystyrene	A2	E2	C-252-1000p
C308	Capacitor, 10pF, 1000V, Ceramic Disc	A4	F3	C-64-10p
C309	Capacitor, 10μF, 25V, Aluminum Electrolytic	H4	C2	C-314-10
C310	Capacitor, 10μF, 25V, Aluminum Electrolytic	H4	C2	C-314-10
C311	Capacitor, 470μF, 50V	G5	C3	C-276-470
C312	Capacitor, 5pF, 200V, Polystyrene	B2	E3	C-31-5p
C313	Capacitor, 10μF, 25V Aluminum Electrolytic	H4	C3	C-314-10
C314	Capacitor, 10μF, 25V, Aluminum Electrolytic	H4	C3	C-314-10
C315	Capacitor, 1000μF, 16V, Aluminum Electrolytic	G4	B3	C-313-1000
C316	Capacitor, 1000μF, 16V, Aluminum Electrolytic	G4	B3	C-313-1000
C317	Capacitor, 470μF, 50V	G5	C3	C-276-470
C318	Capacitor, 22pF, 500V, Polystyrene	B3	D3	C-138-22p
C319	Capacitor, 0.01μF, 500V, Ceramic Disc	C4	F3	C-22-.01
C320	Capacitor, 470pF, 1000V, Ceramic Disc	D4	G3	C-64-470p
C321	Capacitor, 0.02μF, 500V, Ceramic Disc	D4	D2	C-22-.02
C322	Capacitor, 390pF, 500V, Polystyrene	E3	E2	C-138-390
CR301	Diode, Silicon, 1A, 800PIV, 1N4006	F3	B1	RF-38
CR302	Diode, Silicon, 1A, 800PIV, 1N4006	F3	B1	RF-38
CR303	Diode, Silicon, 1A, 800PIV, 1N4006	G3	B1	RF-38
CR304	Diode, Silicon, 1A, 800PIV, 1N4006	G3	B1	RF-38
CR305	Diode, Silicon, 1A, 800PIV, 1N4006	C6	C3	RF-38
CR306	Diode, Silicon, 1A, 800PIV, 1N4006	D4	D2	RF-38
CR307	Diode, Silicon, 1A, 800PIV, 1N4006	D5	D3	RF-38
CR311	Bridge Rectifier, 1A, 100PIV	F4	B3	RF-52
CR314	Diode, Silicon, 1A, 800PIV, 1N4006	D6	C3	RF-38
CR315	Diode, Silicon, 1A, 800PIV, 1N4006	C5	D2	RF-28
CR316	Diode, Silicon, 1A, 800PIV, 1N4006	C5	D2	RF-28
CR317	Diode, Silicon, 1A, 800PIV, 1N4006	C4	C2	RF-38
CR318	Diode, Silicon, 1N4148	D3	C2	RF-38
CR319	Diode, Silicon, 1A, 800PIV, 1N4006	F4	B3	RF-38
CR320	Diode, Silicon, 1A, 800PIV, 1N4006	F4	B3	RF-38
CR321	Diode, Silicon, 1N4148	D2	D2	RF-28
CR322	Diode, Silicon, 1A, 800PIV, 1N4006	F5	B3	RF-38
CR323	Diode, Silicon, 1A, 800PIV, 1N4006	F5	B3	RF-38
K301	Relay, Electromechanical	E2	D2	RL-86
K302	Relay, Electromechanical	D2	D2	RL-86
K303	Relay, Reed	E2	F2	RL-44
K304	Relay, Reed	C2	F2	RL-44
K305	Relay, Reed	C2	F2	RL-44
K306	Relay, Reed	D2	F2	RL-44
K307	Relay, Reed	D2	F2	RL-70
K308	Relay, Reed	B2	E3	RL-70
K309	Relay, Reed	A2	E3	RL-70
K310	Relay, Reed	A2	E3	RL-70
K311	Relay, Reed	B2	E3	RL-70
K312	Relay, Reed	B2	E3	RL-70

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Table 8-3. Electrometer Board, Parts List (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
P1014	DIP Cable	F2	D1	CA-27-2
Q301	Transistor, NPN Silicon, Annular, MPS—U10	C4	D2	TG-146
Q302	Transistor, N-Channel J-FET	C3	F2	TG-128
Q303	Transistor, PNP Silicon, Annular, MPS-U60	C5	D3	TG-147
Q304	Transistor, NPN Silicon, Annular, MPS-U10	C3	D2	TG-146
Q305	Transistor, PNP Silicon, Annular, MPS-U60	C6	D3	TG-147
Q306	Transistor, NPN Silicon, Annular, MPS-U10	D4	D2	TG-146
Q307	Transistor, PNP Silicon, Annular, MPS-U60	D5	D3	TG-147
Q308	Transistor, Selected Dual JFET	B4	F3	617-606
Q309	Transistor, NPN Silicon, Annular, MPS-U60	G4	C3	TG-145
Q310	Transistor, PNP Silicon Annular, MPS-U60	E2	E2	TG-177
R301	Resistor, 330kΩ, 10%, ½W, Composition	C3	D2	R-1-330k
R302	Resistor, 330kΩ, 10%, ½W, Composition	C4	C2	R-1-330k
R303	Resistor, 900kΩ, 0.1%, 1/10W, Metal Film	B3	F2	R-283-900k
R304	Resistor, Thick Film	B3	F2	TF-191
R305	Resistor, 10kΩ, 5%, 5¼W	D4	D2	R-329-10k
R306	Resistor, 768Ω, 1%, 1/8W, Composition	C4	D2	R-88-768
R307	Resistor, 768Ω, 1%, 1/8W, Composition	C5	D3	R-88-768
R308	Resistor, 10kΩ, 5%, ½W	D5	D3	R-329-10k
R309	Resistor, 100Ω, 5%, ¼W, Composition	D4	D2	R-76-100
R310	Not Used			
R311	Resistor, 180Ω, 5%, ¼W, Composition	G4	C3	R-76-180
R312	Resistor, 100Ω, 0.1%, ½W, Metal Film	B4	E2	R-169-100
R313	Resistor, Selected	B3	F2	617-601
R314	Potentiometer, 10kΩ	C4	F2	RP-89-10k
R315	Resistor, 1.87kΩ, 1%, 1/8W, Composition	C3	F2	R-88-1.87k
R316	Resistor, 2.78kΩ, 0.1%, 1/10W, Metal Film	C3	F2	R-263-2.78k
R317	Resistor, 5.025kΩ, 0.1%, 1/10W, Metal Film	C3	F2	R-263-5.025k
R318	Resistor, 5.1kΩ, 5%, ¼W, Composition	C4	C2	R-76-5.1k
R319	Resistor, 2.2kΩ, 5%, ¼W, Composition	C4	C2	R-76-2.2k
R320	Resistor, 330kΩ 10%, ½W, Composition	C6	D3	R-1-330k
R321	Resistor, 330kΩ, 10%, ½W, Composition	C5	C3	R-1-330k
R322	Resistor, 100kΩ, 0.1%, ½W, Metal Film	B3	D3	R-169-100k
R323	Resistor, 100Ω, 5%, ¼W, Composition	D5	D3	R-76-100
R324	Resistor, 560Ω, 10%, ½W, Composition	D5	D3	R-1-560
R325	Resistor, 100Ω, 5%, ¼W, Composition	C4	D2	R-76-100
R326	Resistor, 47Ω, 5%, ¼W, Composition	D4	D3	R-76-47
R327	Resistor, 560Ω, 10%, ½W, Composition	D4	D2	R-1-560
R328	Resistor, 5.1kΩ, ¼W, Composition	C6	C3	R-76-5.1k
R329	Resistor, 2.2kΩ, 5%, ¼W, Composition	C5	C3	R-76-2.2k
R330	Resistor, 100GΩ, 2%, 1.5W	B3	E3	R-289-100G
R331	Resistor, 100MΩ, 1%, 1.5W	B3	D3	R-269-100M
R332	Resistor, 250GΩ, 5%, 1.5W	A5	F2	R-319-250G
R333	Resistor, 100kΩ, 5%, ¼W, Composition	A4	F2	R-76-100k
R334	Resistor, 10MΩ, 10%, ¼W, Composition	A5	F3	R-76-10M
R335	Resistor, Set, 220k, includes R336	B5	F3	R-322
R336	Resistor, Set, 220k, includes R335	B5	F3	R-322
R337	Resistor, 2.2kΩ, 5%, ¼W, Composition	A5	G2	R-76-2.2k
R338	Thermistor	B5	F2	RT-12
R339	Thermistor	B5	F2	RT-12
R340	Resistor, 4.87kΩ, 1%, 1/8W, Composition	B4	F3	R-88-4.87k

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Table 8-3. Electrometer Board, Parts List (Cont).

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
R341	Resistor, 402Ω, 1%, 1/8W, Composition	B4	F3	R-88-402
R342	Resistor, 40.2Ω, 1%, 1/8W, Composition	C4	F3	R-88-40.2
R344	Resistor, 715Ω, 1%, 1/8W, Composition	G4	B3	R-88-715
R345	Resistor, 243Ω, 1%, 1/8W, Composition	G4	B3	R-88-243
R346	Resistor, 270Ω, 5%, ¼W, Composition	G4	C2	R-76-270
R347	Resistor, 560Ω, 5%, ¼W, Composition	C3	D2	R-76-560
R348	Potentiometer, 10kΩ	A5	F1	RP-104-10k
R349	Resistor, 5.6kΩ, 5%, ¼W, Composition	B3	E2	R-76-5.6k
R350	Resistor, 150kΩ, 5%, ¼W, Composition	E2	D2	R-76-150k
R351	Resistor, 16.5kΩ, 1%, 1/8W, Composition	B5	G3	
R352	Resistor, 24.9kΩ, 1%, 1/8W, Composition	C5	G3	
R353	Resistor, 100kΩ 5%, ¼W, Composition			R-76-100k
R354	Resistor, 5.1kΩ, 5%, ¼W, Composition			R-76-5.1k
T301	Transformer, Power	F3	B2	TR-203
U301	IC, 8-Stage Shift Register, MC14094BCP	D1	E2	IC-251
U302	IC, Hex Inverter, 74HC04	Sev	E2	IC-354
U303	IC, Hex Inverter, 74HC04	Sev	E2	IC-354
U304	IC, Operational Amplifier, 741	C3	G2	IC-42
U305	Not Used			
U306	IC, Regulator, +5V, 7805	G4	C3	IC-93
U307	IC, Adjustable Regulator, LM337L	G4	B3	IC-345
U308	IC, Voltage Regulator +5V, 78L05A	G5	B3	IC-223
U309	IC, Low Noise Op Amp	C5	F3	IC-394
VR301	Regulator, selected with R213	D3	F2	617-601
VR302	Regulator, Zener Diode, 9.1V, 1W, 1N4739A	G4	C2	DZ-56
VR303	Regulator, Zener Diode, 9.1V, 1W, 1N4730A	G4	C2	DZ-56
VR304	Regulator, Zener Diode, 33V, 1W, 1N4752A	C3	E2	DZ-68
W303	Jumper	B5		CS-476

*T301 and T101 are supplied as a matched set. Order TR239 for 105-125, 210-250V operation, TR240 for 90-110V, 180-220V operation.

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Table 8-4. Mechanical Parts

Quantity	Description	Keithley Part No.
1	Bottom Cover	30541
4	Foot	FE-14
1	Shield, Bottom Cover	617-305
1	Top Cover	30540
1	Front Panel	617-301
1	Front Panel Overlay	617-303
2	Black Binding Post (J1003, J1007)	BP-11-0
3	Red Binding Post (J1002, J1004, J1006)	BP-11-2
1	Binding Post (J1005)	BP-15
2	BNC Connector (J1008, J1009)	CS-249
1	Triax Connector (J1001)	CS-181
1	Protective Cap	CAP-18
1	Ground Clip	617-319
1	Line Cord	CO-9
1	Pushbutton (Power)	29465-3
1	Pushbutton (Shift)	228-317-4
11	Pushbutton (Electrometer)	228-317-5
4	Pushbutton (V-Source)	228-317-6
3	Pushbutton (Data Store, Program)	228-317-7
1	Fuse Holder (for F102)	FH-27

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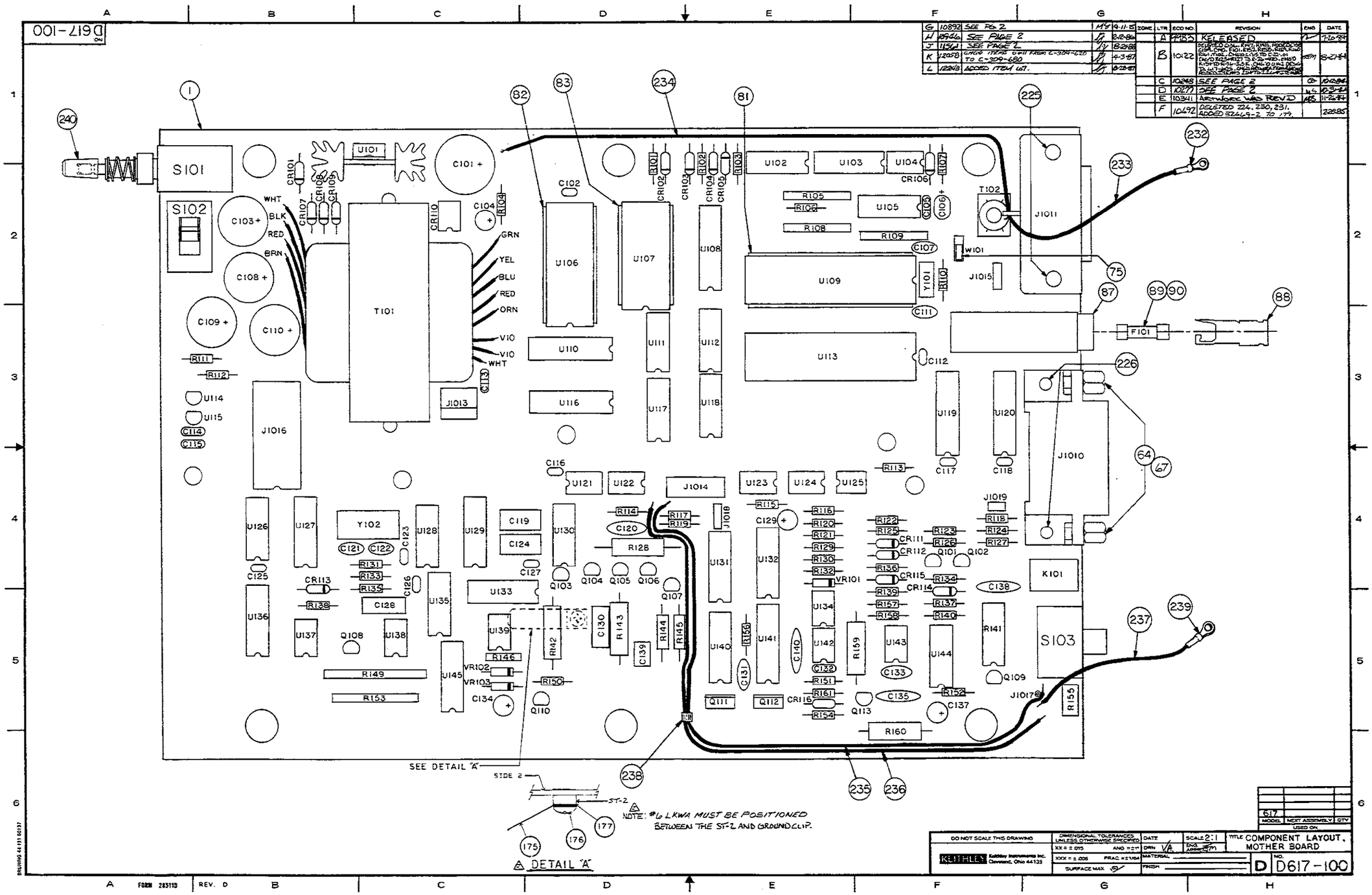


Figure 8-2. Mother Board, Component Location Drawing, Dwg. No. 617-100 (Sheet 1 of 2)

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D617-100

ZONE	LTR	ECO NO.	REVISION	ENG	DATE
	A	9984	RELEASED	VP	7-24-84
	B	10122	SEE PAGE 1 OF 2	KMH	8-27-84
	C	10248	ADDED C67-C80 TO ITEM 1 (U106) & CHG'D. U1106 WAS IC-410	JS	10-4-84
	D	10277	CHG'D ITEMS 235 & 237 FROM SC-68 (GLASS) TO SC-55 (GRN)	MS	10/31/84
	E	10341	See Pg 1	MS	11-26-84
	F	10492	DELETED R82, R86, R87, C60 and C61 FROM EC-23-30-32463-2		2-28-85
	G	10892	ITEM 173 WAS 72-209	MS	9-11-85
	H	10946	ITEM 170 WAS SW-436	JS	12-2-86
	J	11641	ADDED ITEMS 239-241 TO MOUNT DIP. ADDED WIRES TO PANEL PER GROUND CLIP.	JS	3-2-88
	K	12058	CHG'D ITEMS & QTY FROM C-309-680 TO C-309-680	JS	4-3-87
	L	12243	ADDED ITEM 67.	JS	8-28-87

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	STAKING	617-101	A1
2			
3			
4	C-313-4700	C101	C1
5	C-237-.1	C102	D2
6	C-309-680	C103	B2
7	C-314-10	C104	C2
8	C-237-.1	C105	F2
9	C-179-10	C106	F2
10	C-64-27p	C107	F2
11	C-309-680	C108	B2
12	C-354-47µ	C109	B3
13	"	C110	B3
14	C-64-22p	C111	F3
15	C-237-.1	C112	F3
16	C-237-.1	C113	C3
17	"	C114	B3
18	"	C115	B3
19	C-237-.1	C116	D4
20	"	C117	F4
21	"	C118	F4
22	C-305-.1	C119	D4
23	C-22-.01	C120	D4
24	C-22-33p	C121	C4
25	C-22-150p	C122	C4
26	C-237-.1	C123	C4
27	C-305-.1	C124	C4
28	C-237-.1	C125	B4
29	"	C126	C4
30	"	C127	D4
31	C-306-.01	C128	C5
32	C-314-10	C129	E4
33	C-305-.047	C130	D5
34	C-64-22p	C131	E5
35	C-237-.47	C132	E5
36	C-64-33p	C133	F5
37	C-314-10	C134	C5
38	C-22-.02	C135	E5
39			
40	C-314-47µ	C137	F5

ITEM	PART NO.	SCHEM. DESIG.	ZONE
41	C-64-.0047	C138	F4
42	C-344-.33	C139	D5
43	C-22-.015	C140	E5
44			
45			
46	KF-38	CR101	B1
47	KF-28	CR102	D1
48	"	CR103	E1
49	"	CR104	E1
50	"	CR105	E1
51	"	CR106	F1
52	KF-38	CR107	B2
53	"	CR108	B2
54	"	CR109	B2
55	RF-52	CR110	C2
56	RF-28	CR111	F4
57	"	CR112	F4
58	"	CR113	B4
59	"	CR114	F3
60	"	CR115	F5
61	KF-38	CR116	E5
62			
63			
64	CS-378	——	G4
65	CS-377	J1010	G4
66	CS-388	J1011	G2
67	4-40 SCREW	2 REQ'D	G4
68	CS-288-3	J1013	C3
69	CS-389-5	J1014	E4
70	CS-339-3	J1015	F2
71	SO-68	J1016	B3
72	24249A	J1017	G5
73	CS-339-3	J1018	E4
74	CS-389-2	J1019	F4
75	CS-339-3	——	G2
76	CS-476	J1101	G2
77			
78	CR-21	Y101	F2
79	CR-19	Y102	C4
80			

ITEM	PART NO.	SCHEM. DESIG.	ZONE
81	SO-84-40	——	E2
82	SO-69	——	D2
83	SO-68	——	D2
84			
85	RL-90	K101	G4
86			
87	FH-21	——	G3
88	FH-25	——	H3
89	FU-171	F101	G3
90	FU-201	F101	G3
91			
92	TG-47	Q101	F4
93	TG-84	Q102	F4
94	TG-139	Q103	D4
95	TG-1066	Q104	D4
96	TG-128	Q105	D4
97	617-4000	Q106	D4
98	TG-139	Q107	D4
99	TG-128	Q108	C5
100	TG-84	Q109	F5
101	TG-1066	Q110	D5
102	TG-146	Q111	E5
103	TG-147	Q112	E3
104	TG-177	Q113	F3
105			
106			
107			
108	R-76-100	R101	D1
109	"	R102	E1
110	R-76-430	R103	E1
111	R-76-10M	R104	C2
112	TF-183-1	R105	E2
113	R-76-360	R106	E2
114	R-76-30K	R107	F2
115	TF-179-1	R108	E2
116	"	R109	F2
117	R-76-10M	R110	F2
118	R-76-200K	R111	B3
119	"	R112	B3
120	R-76-100K	R113	F4

ITEM	PART NO	SCHEM. DESIG.	ZONE
121	R-76-1K	R114	D4
122	R-76-5.1K	R115	E4
123	"	R116	E4
124	R-76-100	R117	D4
125	R-76-100K	R118	F4
126	R-76-10K	R119	D4
127	R80-5.49K	R120	E4
128	R-80-9.76K	R121	E4
129	R-76-68K	R122	F4
130	R-76-470	R123	F4
131	R-76-180	R124	F4
132	R-76-100	R125	F4
133	R-76-180	R126	F4
134	R-76-470	R127	F4
135	R-248-200K	R128	D4
136	R-88-1.81K	R129	F4
137	R-88-100	R130	E4
138	R-76-15M	R131	C4
139	R-88-402K	R132	F4
140	R-76-2.2K	R133	C4
141	R-76-1K	R134	F4
142	R-76-430	R135	C4
143	R-76-68K	R136	F5
144	R-76-100K	R137	F5
145	R-76-22K	R138	B5
146	R-76-200K	R139	F5
147	R-76-100K	R140	F5
148	TF-102-2	R141	F5
149	R-321-2M	R142	D5
150	R-714-220K	R143	D5
151	R-263-20K	R144	D5
152	R-263-2K	R145	D5
153	TF-150	R146	C5
154			
155			
156	TF-172	R149	C5
157	R-76-200K	R150	D5
158	R-76-3.3K	R151	F5
159	R-76-1K	R152	F5
160	TF-171	R153	C5

ITEM	PART NO	SCHEM. DESIG.	ZONE
161	R-76-47K	R154	E5
162	RP-111-1K	R155	G5
163	R-76-10K	R156	E5
164	K-332	R157	F5
165	"	R158	F5
166	R-248-200K	R159	F5
167	K-321-2M	R160	F6
168	R-76-10K	R161	F5
169			
170	SW-446	S101	B1
171	SW-397	S102	B2
172	SW-318	S103	G5
173	TR-239	T101	C3
174	TR-214	T102	F2
175	197-314	——	D6
176	16-32-3/16 PPH	1 REQ'D	D5
177	6 LKWA	1 REQ'D	D5
178			
179	32469-2	U101	C1
180	IC-163	U102	E1
181	IC-407	U103	E1
182	IC-353	U104	F1
183	IC-103	U105	F2
184	22-88-00	U106	D2
185	LSI-58	U107	D2
186	IC-338	U108	E2
187	LSI-60	U109	E2
188	IC-338	U110	D3
189	IC-351	U111	D3
190	IC-143	U112	E3
191	LSI-49	U113	E3
192	IC-253	U114	B3
193	IC-170	U115	B3
194	IC-338	U116	D3
195	IC-412	U117	D3
196	IC-341	U118	E3
197	IC-299	U119	F3
198	IC-296	U120	F3
199	IC-239	U121	D4
200	"	U122	D4

ITEM	PART NO.	SCHEM. DESIG.	ZONE
201	IC-411	U123	E4
202	"	U124	E4
203	IC-82	U125	F4
204	IC-337	U126	B4
205	IC-407	U127	B4
206	IC-412	U128	C4
207	IC-136	U129	C4
208	IC-316	U130	D4
209	IC-251	U131	E4
210	IC-324	U132	E4
211	IC-251	U133	C4
212	IC-42	U134	E5
213	IC-341	U135	C5
214	IC-283	U136	B5
215	IC-343	U137	B5
216	IC-408	U138	C5
217	IC-347	U139	C5
218	IC-251	U140	E5
219	IC-247	U141	E5
220	IC-423	U142	E5
221	IC-203	U143	F5
222	IC-219	U144	F5
223	IC-283	U145	C5
224			
225			
226			
227	DZ-58	VR101	E4
228	"	VR102	C5
229	DZ-59	VR103	C5
230			
231			
232	LU-88	VD	
233	SC-73-5	LENGTH TO SUIT	F6
234	"	"	F6
235	SC-55	LENGTH TO SUIT	GRN.
236	"	"	"
237	SC-68	"	BLK.
238	CC-38-4	——	D6
239	LU-99-3	VD	
240	29645-3	——	A1

617			
MODEL	NEXT ASSEMBLY	QTY.	
USED ON			

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .015, ANG. ± 2°, XXX ± .005, FRAC. ± 1/64, SURFACE MAX 63

DATE

SCALE 2:1

DRN V.A.

CHK'D

MATERIAL

FINISH

KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139

TITLE COMPONENT LAYOUT, MOTHER BOARD

SIZE D NO. D617-100

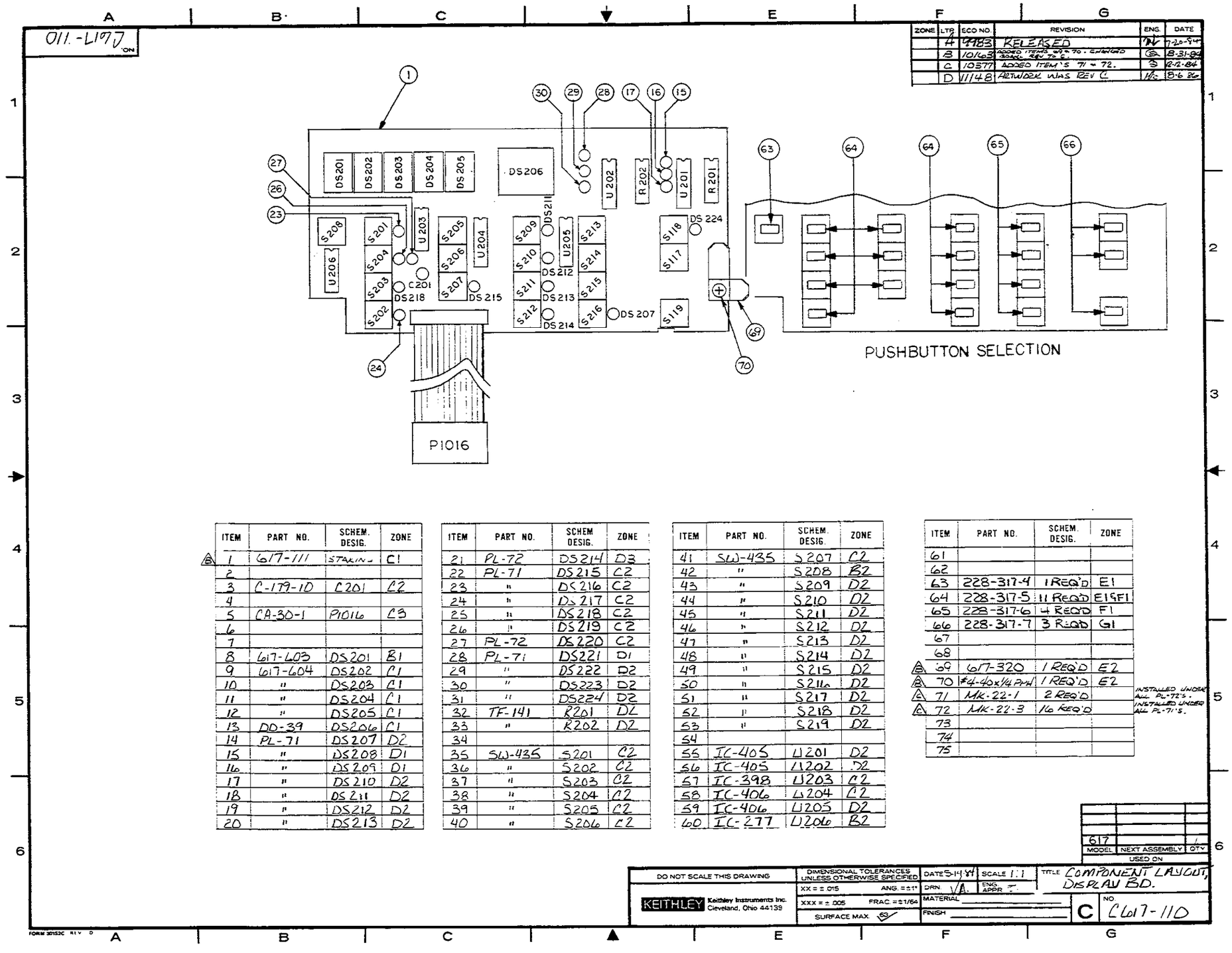
BRUSHING 44 131 60137

FORM 285110 REV. D

Figure 8-2. Mother Board, Component Location Drawing, Dwg. No. 617-100 (Sheet 2 of 2)

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ITEM	PART NO.	SCHEM. DESIG.	ZONE
A 1	617-111	STAKING	C1
2			
3	C-179-10	C201	C2
4			
5	CA-30-1	P1016	C3
6			
7			
8	617-603	DS201	B1
9	617-604	DS202	C1
10	"	DS203	C1
11	"	DS204	C1
12	"	DS205	C1
13	DD-39	DS206	C1
14	PL-71	DS207	D2
15	"	DS208	D1
16	"	DS209	D1
17	"	DS210	D2
18	"	DS211	D2
19	"	DS212	D2
20	"	DS213	D2

ITEM	PART NO.	SCHEM. DESIG.	ZONE
21	PL-72	DS214	D3
22	PL-71	DS215	C2
23	"	DS216	C2
24	"	DS217	C2
25	"	DS218	C2
26	"	DS219	C2
27	PL-72	DS220	C2
28	PL-71	DS221	D1
29	"	DS222	D2
30	"	DS223	D2
31	"	DS224	D2
32	TF-141	R201	D2
33	"	R202	D2
34			
35	SW-435	S201	C2
36	"	S202	C2
37	"	S203	C2
38	"	S204	C2
39	"	S205	C2
40	"	S206	C2

ITEM	PART NO.	SCHEM. DESIG.	ZONE
41	SW-435	S207	C2
42	"	S208	B2
43	"	S209	D2
44	"	S210	D2
45	"	S211	D2
46	"	S212	D2
47	"	S213	D2
48	"	S214	D2
49	"	S215	D2
50	"	S216	D2
51	"	S217	D2
52	"	S218	D2
53	"	S219	D2
54			
55	IC-405	U201	D2
56	IC-405	U202	D2
57	IC-398	U203	C2
58	IC-406	U204	C2
59	IC-406	U205	D2
60	IC-277	U206	B2

ITEM	PART NO.	SCHEM. DESIG.	ZONE
61			
62			
63	228-317-4	1 REQ'D	E1
64	228-317-5	11 REQ'D	E1&F1
65	228-317-6	4 REQ'D	F1
66	228-317-7	3 REQ'D	G1
67			
68			
A 69	617-320	1 REQ'D	E2
A 70	#4-40x1/4 PHH	1 REQ'D	E2
A 71	MK-22-1	2 REQ'D	
A 72	MK-22-3	16 REQ'D	
73			
74			
75			

A 71 & 72 INSTALLED UNDER ALL PL-72's. INSTALLED UNDER ALL PL-71's.

617 | MODEL | NEXT ASSEMBLY | QTY
USED ON

DO NOT SCALE THIS DRAWING
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .015 ANG. = ±1° | XXX = ± .005 FRAC. = ±1/64 | SURFACE MAX. 63
DATE 5-14-84 | SCALE 1:1 | DRN. | ENG. APPR. | MATERIAL | FINISH
KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139
TITLE COMPONENT LAYOUT, DISPLAY BD.
NO. C 617-110
C

FORM 3015C REV D

Figure 8-3. Display Board, Component Location Drawing, Dwg. No. 617-110

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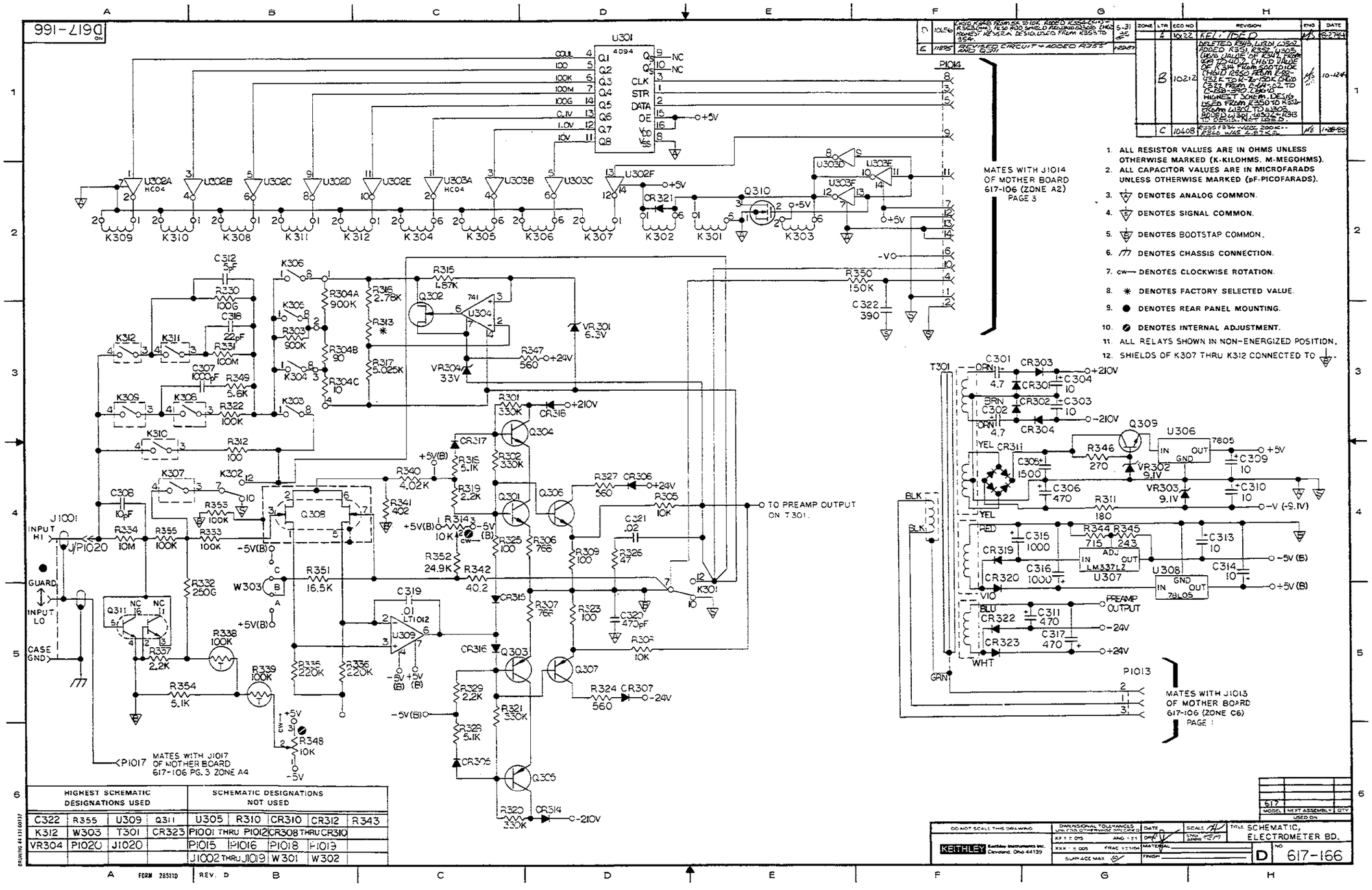


Figure 8-4. Electrometer Board, Schematic Diagram, Dwg. No. 617-166

D617-106

VOLTAGE SOURCE

ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	10122	RELEASED		6-23-86
	B	10737	ADDED CMT (P22-C4)		10/15/86
	C	11278	R157 150Ω WERE 10K		5-7-87
	D	11394	SEE PAGE 2		2-2-87
	E	12058	CHGD C103+C108 VALUE FROM 820 TO 680		4/3/87
	F	12282	SEE PAGE 3.		7-7-88

U132 4520 — C131 22pF, R156 10K, R115 5.1K, +15V, 82 KHZ

U123 HCPL2200 — TO PAGE 2 (ZONE A6) J, K

U124 HCPL2200 — R116 5.1K, C129 10 — TO PAGE 2 (ZONE A5) E, F

U131 4094 — U140 4094 — U141 AD7541

P1012, J/P1011, T102

MAIN POWER SUPPLY

S101 ON/OFF, F101 8A, T101, S102 115V 230V, WHT, RED, BLK, GRN, BLU, ORN, YEL, VIO

CR107 CR108 CR109 CR110 CR101 — C109 47, C110 47, C103 680, C108 680, C101 4700, C104 10, C114 1.0, C115 1.0

U114 LM320LZ-15, U115 LM78L15, U101 7805

R111 200K, R112 200K, R104 10M

±110V COM, −110V, +110V, −15V, +15V, 15VAC, +5V

J1013 — 2 COM, 1 AC, 3 AC — MATES WITH P1013 OF ELECTOMETER BD. 617-166 (ZONE G5)

U142B, U142A, U144B, U144A, U144C, U143 LM308A, U134 741

R157 5K, R158 617-605, R141C 10K, R130 100, R132 402K, R129 1.87K, R120 5.49K, R155 1K, R121 9.76K, VR101 6.3V CW, +6.3V

R159 200K, R160 2M, C140 .015, C133 33pF, C135 .02, R151 3.3K

R122 6.8K, Q111, R140 100K, R141A 10K, R141B 10K, Q109, CR115, R125 100, R127 470, Q101, CR111, R124 180, CR112, Q102, R126 180, R123 470, CR114, Q112, R137 100K, R134 1K — TO PAGE 2 (ZONE A5) G, H

R118 100K, C138 .0047, C141 .01, K101, J/P1019, J1007 LO, J1006 HI — V-SOURCE OUTPUT

CR116, R161 10K, R154 47K, C132 .47, R139 200K, Q113, R152 1K, C137 4.7, K101, R136 6.8K, −15V, −110V

HIGHEST SCHEMATIC DESIGNATIONS USED			
C141	Y102	R161	VR103
CR116	K101	S103	P1019
J1019	F102	T102	
W101	Q113	U145	

SCHEMATIC DESIGNATIONS NOT USED			
C136	R147	R148	J1012
P1002 THRU P1010			

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
3. ALL PUSHBUTTON SWITCHES ARE SHOWN IN THE PUSHBUTTON OUT POSITION.
4. DENOTES ANALOG COMMON.
5. DENOTES DIGITAL COMMON.
6. DENOTES SIGNAL COMMON.
7. DENOTES VOLTAGE SOURCE COMMON.
8. DENOTES CHASSIS CONNECTION.
9. DENOTES MAINFRAME GROUND SCREW.
10. CW DENOTES CLOCKWISE ROTATION.
11. DENOTES REAR PANEL ADJUSTMENT.
12. DENOTES FRONT PANEL CONTROL.
13. DENOTES REAR PANEL MOUNTING.
14. DENOTES INTERNAL ADJUSTMENT.

617 MODEL | NEXT ASSEMBLY | QTY | USED ON

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KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139

TITLE SCHEMATIC, MOTHER BOARD

D NO 617-106

FORM 28511D REV. D

Figure 8-5. Mother Board, Schematic Diagram, Dwg. No. 617-106 (Sheet 1 of 3)

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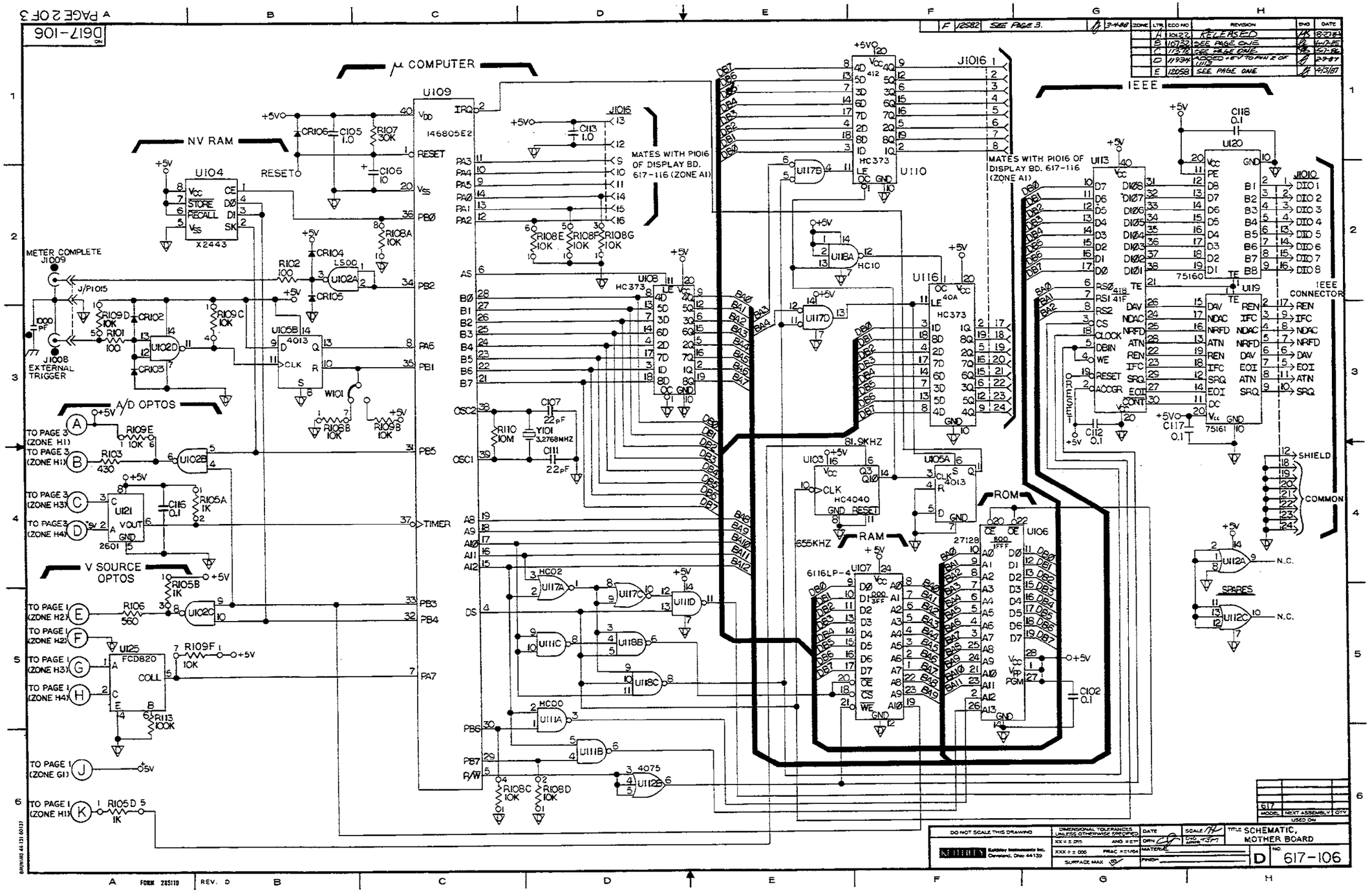


Figure 8-5. Mother Board, Schematic Diagram, Dwg. No. 617-106 (Sheet 2 of 3)

8-23/8-24

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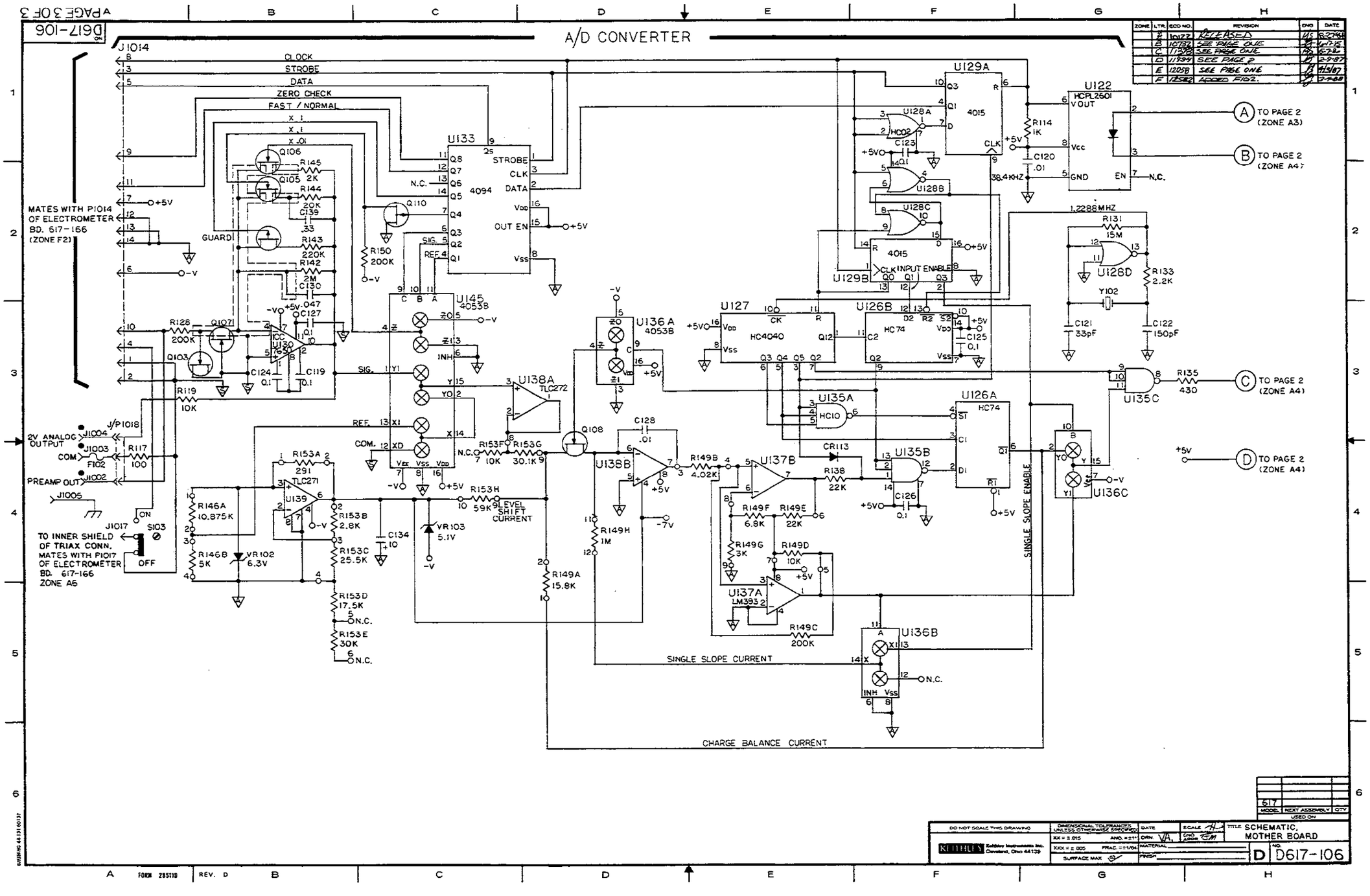


Figure 8-5. Mother Board, Schematic Diagram, Dwg. No. 617-106 (Sheet 3 of 3)

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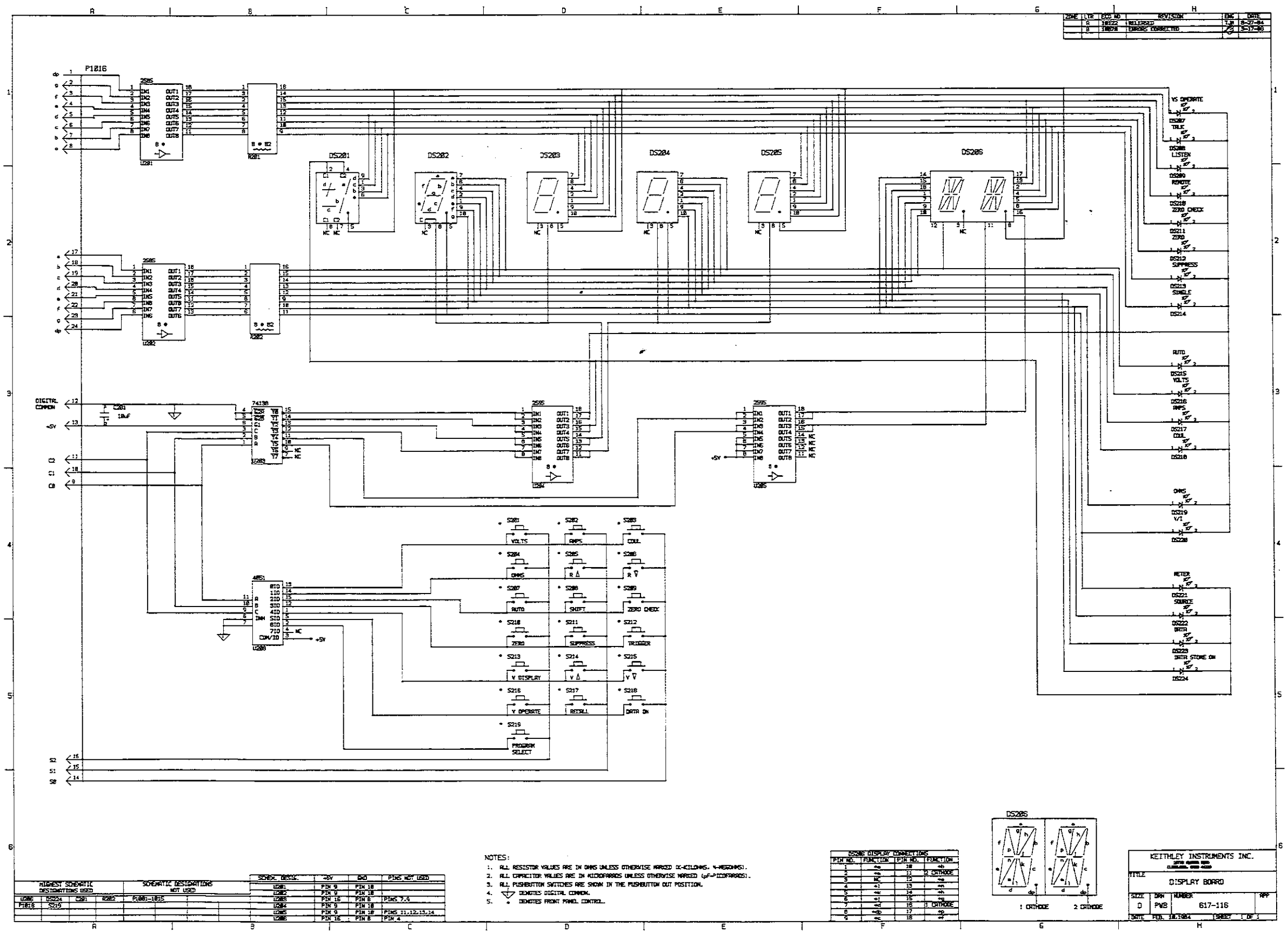
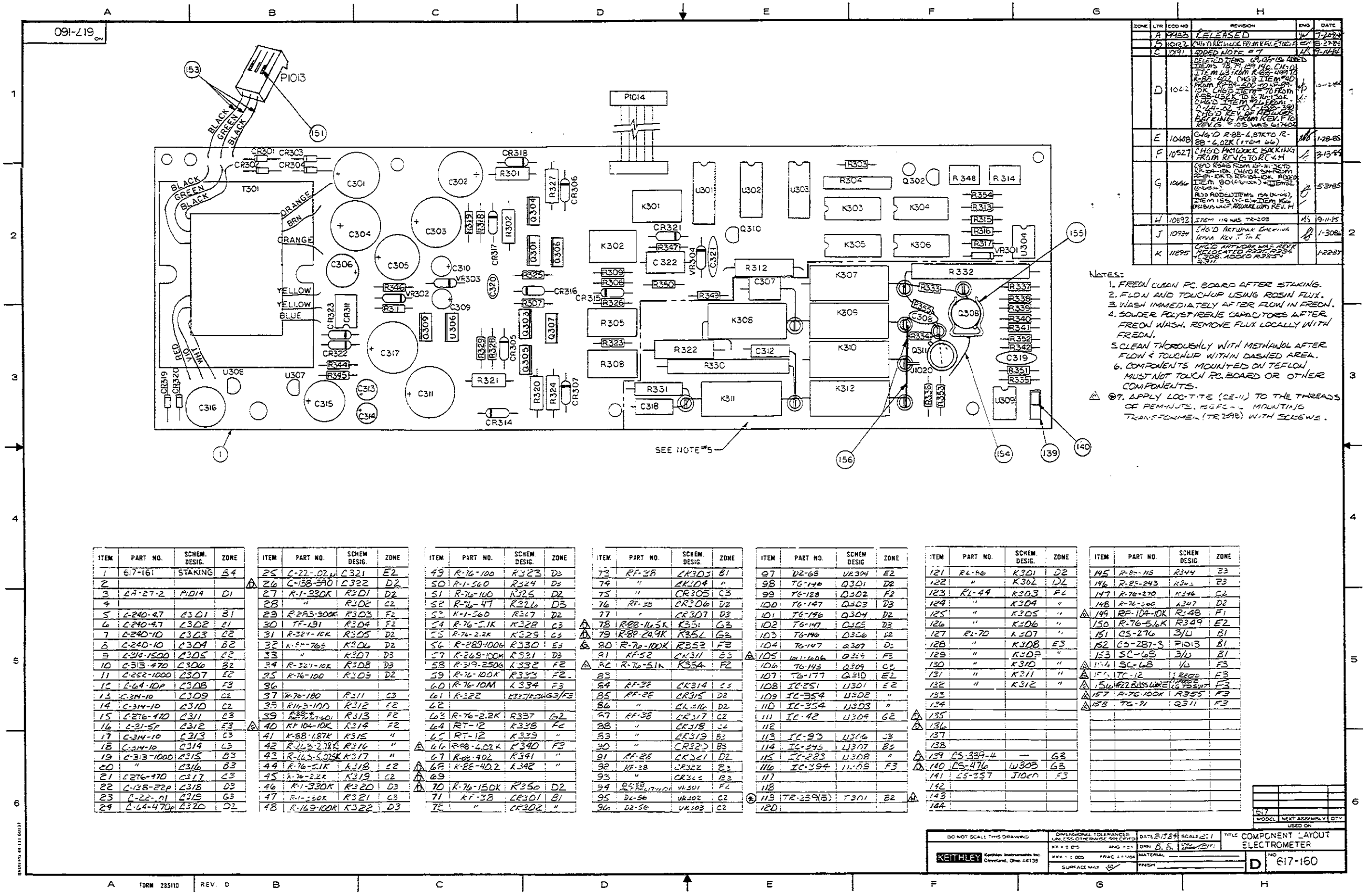


Figure 8-6. Display Board, Schematic Diagram, Dwg. No. 617-116

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ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	617-161	STAKING	B4
2			
3	EA-27-2	P1D14	D1
4			
5	C-240-4.7	C301	B1
6	C-240-4.7	C302	B1
7	C-240-10	C303	B2
8	C-240-10	C304	B2
9	C-314-1500	C305	B2
10	C-313-470	C306	B2
11	C-252-1000	C307	E2
12	C-64-10P	C308	F3
13	C-314-10	C309	C2
14	C-314-10	C310	C2
15	C-276-470	C311	C3
16	C-31-5P	C312	F3
17	C-314-10	C313	C3
18	C-314-10	C314	C3
19	C-313-1000	C315	B3
20	"	C316	B3
21	C-276-470	C317	C3
22	C-138-22P	C318	D2
23	C-22-.01	C319	G3
24	C-64-470P	C320	D2
25	C-22-.02μ	C321	E2
26	C-138-390	C322	D2
27	R-1-330K	R301	D2
28	"	R302	C2
29	R-285-900K	R303	F2
30	TF-131	R304	F2
31	R-327-10K	R305	D2
32	R-88-76.8	R306	D2
33	"	R307	D3
34	R-327-10K	R308	D3
35	R-76-100	R309	D2
36			
37	R-76-180	R311	C3
38	R11-3-100	R312	F2
39	R-88-4.87K	R313	F2
40	RT-104-10K	R314	F2
41	R-88-1.87K	R315	"
42	R-165-2.74K	R316	"
43	R-165-5.025K	R317	"
44	R-76-5.1K	R318	E2
45	R-76-2.2K	R319	C2
46	R-1-330K	R320	D3
47	R-1-330K	R321	C3
48	R-169-100K	R322	D3
49	R-76-100	R323	D2
50	R-1-560	R324	D2
51	R-76-100	R325	D2
52	R-76-47	R326	D3
53	R-1-560	R327	D2
54	R-76-5.1K	R328	C3
55	R-76-2.2K	R329	C3
56	R-289-100K	R330	E3
57	R-269-100M	R331	D3
58	R-319-2506	R332	F2
59	R-76-100K	R333	F2
60	R-76-10M	R334	F3
61	R-322	R335/R336/R337/R338	G3/F3
62			
63	R-76-2.2K	R337	G2
64	RT-12	R338	F2
65	RT-12	R339	"
66	R-88-4.02K	R340	F3
67	R-88-402	R341	"
68	R-88-402	R342	"
69			
70	R-76-150K	R350	D2
71	RT-38	CR301	B1
72	"	CR302	"
73	RF-38	CR303	B1
74	"	CR304	"
75	"	CR305	C3
76	RF-38	CR306	D2
77	"	CR307	D3
78	R88-16.5K	R351	G3
79	R88-24.9K	R352	G3
80	R-76-100K	R353	F2
81	RF-52	CR311	B3
82	R-76-5.1K	R354	F2
83			
84	RF-38	CR314	C3
85	RF-38	CR315	D2
86	"	CR316	D2
87	RF-38	CR317	C2
88	"	CR318	C2
89	"	CR319	B2
90	"	CR320	B3
91	RF-38	CR321	D2
92	HE-38	CR322	B2
93	"	CR323	B2
94	DELETED		
95	D2-56	VR302	C2
96	D2-56	VR303	C2
97	D2-68	VR304	E2
98	TG-140	Q301	D2
99	TG-128	Q302	F2
100	TG-147	Q303	D3
101	TG-196	Q304	D2
102	TG-147	Q305	D3
103	TG-140	Q306	E2
104	TG-147	Q307	D2
105	TG-146	Q309	F3
106	TG-145	Q310	C2
107	TG-177	Q311	E2
108	IC-251	U301	E2
109	IC-354	U302	"
110	IC-354	U303	"
111	IC-92	U309	G2
112			
113	IC-93	U306	B3
114	IC-245	U307	B3
115	IC-223	U308	"
116	IC-394	U1020	F3
117			
118			
119	TR-239(B)	T301	B2
120			
121	RL-96	K301	D2
122	"	K302	D2
123	RL-49	K303	F2
124	"	K304	"
125	"	K305	"
126	"	K306	"
127	RL-70	K307	"
128	"	K308	E3
129	"	K309	"
130	"	K310	"
131	"	K311	"
132	"	K312	"
133			
134			
135			
136			
137			
138			
139	CS-339-4	—	G3
140	CS-476	U303	G3
141	CS-357	J1060	F3
142			
143			
144			
145	R-84-115	R344	B3
146	R-84-243	R345	B3
147	R-76-270	R346	C2
148	R-76-200	R347	D2
149	RP-104-10K	R348	F1
150	R-76-5.6K	R349	E2
151	CS-276	3/4	B1
152	CS-287-3	P1D13	B1
153	SC-68	3/4	B1
154	SC-68	1/4	F3
155	ITC-12	1.25CCT	E3
156	4422 BLISS WIRE	0.75SHT	F3
157	R-76-100K	R355	F3
158	TG-91	Q311	F3

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DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .05 ANG ± 1° | XXX ± .005 FRAC ± 1/64 | SURFACE MAX 63
DATE 2-1-84 | SCALE 2:1 | DRN B.S. | MATERIAL | FINISH
TITLE COMPONENT LAYOUT ELECTROMETER
SIZE D | NO 617-160
617 | MODEL | NEXT ASSEMBLY | QTY USED ON

FORM 285110 REV. D

Figure 8-1. Electrometer Board, Component Location Drawing, Dwg. No. 617-160

PERFORMANCE VERIFICATION USING MODEL 263 CALIBRATOR/SOURCE

INTRODUCTION

Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

NOTE

If the instrument is still under warranty (less than 1 year from the date of shipment), and its performance falls outside the specified range, contact your Keithley representative or the factory to determine the correct course of action.

ENVIRONMENTAL CONDITIONS

All measurements should be made at 18 -28°C (65 -82°F) and at less than 70% relative humidity unless otherwise noted.

INITIAL CONDITIONS

The Models 617 and 263 must be turned on and allowed to warm up for at least one hour before beginning the verification procedures. If the instruments have been subject to extremes of temperature, additional time should be allowed for internal temperatures to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

TEST EQUIPMENT

Along with the Model 263 Calibrator/Source, the following equipment is needed to verify all functions of the Model 617. Alternate equipment may be used as long as their specifications are at least as good as the specifications in parenthesis.

- Fluke 343A DC Calibrator (190V; 0.002%)
- Keithley 196 DMM (0.015%)

VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying instrument accuracy with each of the four measuring functions: volts, ohms, amps, and coulombs. In addition, a procedure to verify accuracy of the internal voltage source is also included. These procedures are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications, refer to Section 7 for calibration procedures, unless the unit is still under warranty..

WARNING

The maximum common-mode voltage (voltage between input low and chassis ground) is 500V. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose you to dangerous voltage. Use standard safety precautions when such dangerous voltages are encountered.

CAUTION

The maximum voltage between the high and low input terminals is 250V (10 seconds maximum on the mA ranges). Instrument damage may occur if this value is exceeded.

NOTE

Verify the electrometer section in the order listed: input current, amps, coulombs, volts and ohms. Input current may remain high for several minutes following measurement of high volts or ohms. Place the V, Ω GUARD switch in the OFF position, unless otherwise noted.

Input Current Verification

Perform input current verification as follows:

NOTE

The following procedure must be performed at an ambient temperature of 23°C ±1°C.

1. Disconnect all cables from the Model 617 input.
2. Place the input cap supplied with the instrument on the INPUT connector.
3. Select the amps function, 2pA range, enable zero check, and then enable zero correct.
4. Connect a jumper between the rear panel COM and chassis ground terminals.
5. Disable zero check and allow one minute for the reading to stabilize.

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6. Verify that the reading is 50 counts or less. Enable zero check.
7. Remove the jumper connected between the COM and chassis ground connectors.

Amps Verification

Connect the Model 617 to the Model 263 as shown in Figure 1 and perform amps verification as follows:

1. On the Model 617, enable zero check and select the 20mA range. Do not use autorange.
2. Check that the display reads 0.000 ±1 count. If not, enable zero correct.
3. Using the AMPS (active) current source, program the Model 263 to output 19.0000mA to the Model 617.
4. Disable zero check and verify that the reading on the Model 617 is within the limits in the table.
5. Using Table 1 as a guide, repeat steps 1 through 4 for the 2mA through 2nA current ranges.
6. Using the AMPS V/R (passive) current source, repeat steps 1 through 4 for the 200pA through 2pA ranges.

Coulombs Verification

Connect the Model 617 to the Model 263 as shown in Figure 1 and perform coulombs verification as follows:

1. Using the COUL (active) charge source of the Model 263, select the 2nC range.
2. Place the Model 263 in the coulombs function, and perform zero correction by enabling zero check and zero correct in that order.
3. Release zero check on the Model 617.
4. Program the Model 263 for 1.90000nC and press OPERATE to source charge to the Model 617.
5. Verify that the Model 617 reads between 1.8943 and 1.9057nC.

Table 1. Limits for Amps Verification

617 Range	263 Function	263 Output	Allowable Reading* (18°C to 28°C)
20mA	AMPS	19.0000mA	18.978 to 19.022
2mA	AMPS	1.90000mA	1.8973 to 1.9027
200 μA	AMPS	190.000 μA	189.76 to 190.24
20 μA	AMPS	19.0000 μA	18.976 to 19.024
2 μA	AMPS	1.90000 μA	1.8973 to 1.9027
200 nA	AMPS	190.000 nA	189.59 to 190.41
20 nA	AMPS	19.0000 nA	18.965 to 19.035
2 nA	AMPS	1.90000 nA	1.8962 to 1.9038
200 pA	AMPS V/R	190.000 pA	187.45 to 192.55
20 pA	AMPS V/R	19.0000 pA	18.770 to 19.230
2 pA	AMPS V/R	1.90000 pA	1.8811 to 1.9189

*Includes Model 263 Error

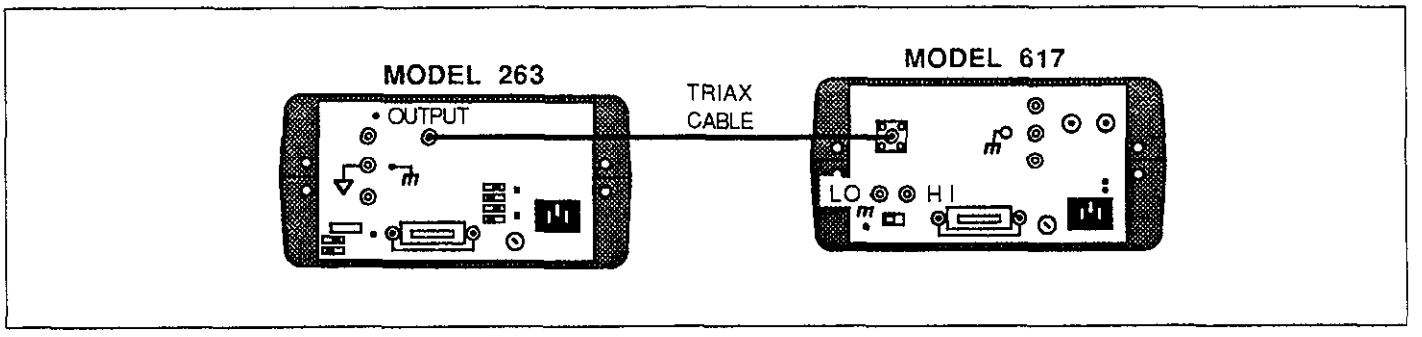


Figure 1. Amps Verification Setup

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Volts Verification

NOTE

Current and charge verification must be performed before volts verification.

Connect the Model 617 and 190V calibration source to the Model 263 as shown in Figure 2, and perform volts verification as follows:

1. On the Model 617, enable zero check and select the 200mV range.
2. Check to see that the display reads 000.00 ±1 count. If not, enable zero correct.
3. Program the Model 263 to output 190.000mV
4. Disable zero check and verify that the reading on the Model 617 is within the limits listed in Table 2.
5. Using Table 2 as a guide, repeat steps 1 through 4 for the 2V and 20V ranges.
6. Set the Model 617 to the 200V range.
7. Set the external calibration source to output 190.000V to the Model 263.
8. Source 190.000V to the Model 617 by pressing SHIFT VOLTS on the Model 263.
9. Verify that the reading on the Model 617 is within the limits listed in the table.
10. Enable zero check on the Model 263 and turn off the external calibration (190V) source.

Ohms Verification

Connect the Model 617 to the Model 263 as shown in Figure 3 and perform ohms verification as follows:

NOTE

Charge and current verification must be performed before resistance verification.

1. Set the Model 617 to the 2kΩ range.
2. Zero correct the Model 617 by enabling zero check and zero correct in that order.
3. Set the Model 263 to the 1kΩ range, and while in OPERATE, press ZERO to source zero ohms to the Model 617.
4. Release zero check on the Model 617 and allow the reading to settle.
5. On the Model 617, press SUPPRESS to cancel offset and test lead resistance.
6. On the Model 263, source the 1kΩ resistor to the Model 617. The actual value of the output resistance is displayed on the Model 263.
7. Record the reading on the Model 263 in Table 3.
8. Calculate the Model 617 reading limit using the formula in the table.
9. Verify that the reading on the Model 617 equals the Model 263 reading ± to calculated limit.
10. Referring to Table 3, repeat the basic procedure in steps 3 through 9 for the 20kΩ range.
11. For the remaining Model 617 ranges, repeat steps 6 through 9 by sourcing the appropriate resistances to the electrometer. Note that guard must be enabled on both the Models 617 and 263 when verifying the GΩ ranges. Also, note that COM of the Model 617 must be connected to COMMON of the Model 263 (see Figure 3).

Table 2. Limits for Volts Verification

617 Range	263 Output	Allowable Reading* (18°C to 28°C)
200mV	190.000 mV	189.91 to 190.09
2 V	1.90000 V	1.8993 to 1.9007
20 V	19.0000 V	18.993 to 19.007
200 V	190.000 V	189.86 to 190.14

*The 200mV, 2V and 20V ranges allowable readings include Model 263 error. The 200V range reading is based solely on Model 617 error.

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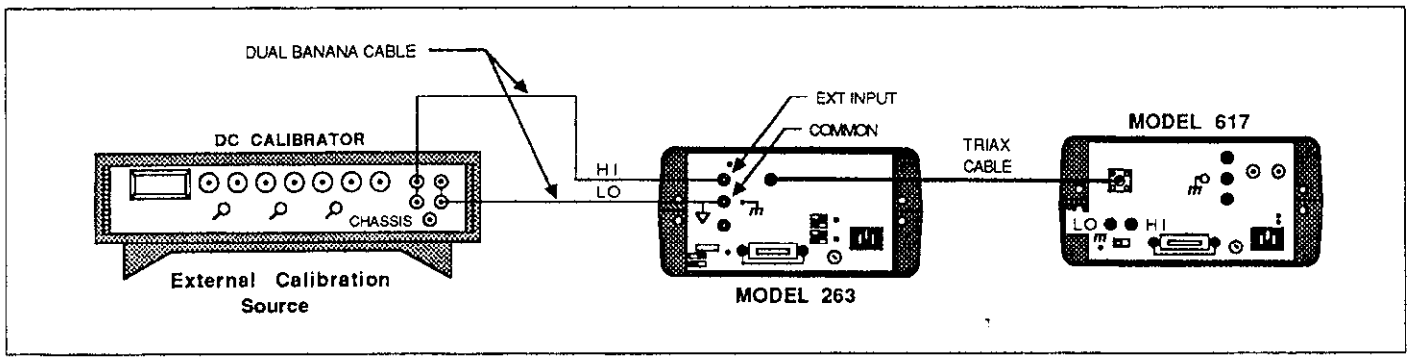


Figure 2. Volts Verification Setup

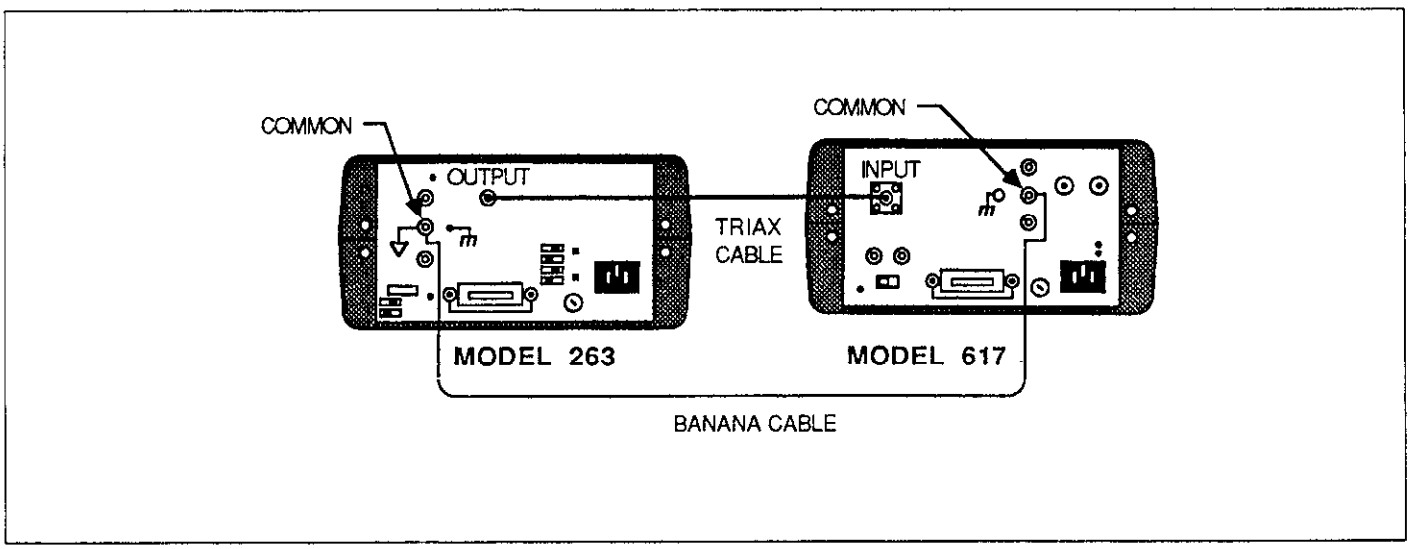


Figure 3. Ohms Verification Setup

Table 3. Limits for Ohms Verification

617 Range	263 Output (Nominal)	617 & 263 Guard	Calculated Limit: 263 Reading	Calculated Limit: Equipment Error*	Calculated Limit: Limit	Allowable 617 Reading (18°C to 28°C)
2 kΩ	1 kΩ	Off	(_____	× 0.16 %) + 0.0004 kΩ	= _____	263 Reading ± Limit
20 kΩ	10 kΩ	Off	(_____	× 0.13 %) + 0.001 kΩ	= _____	263 Reading ± Limit
200 kΩ	100 kΩ	Off	(_____	× 0.23 %) + 0.01 kΩ	= _____	263 Reading ± Limit
2MΩ	1MΩ	Off	(_____	× 0.225 %) + 0.0001MΩ	= _____	263 Reading ± Limit
20MΩ	10MΩ	Off	(_____	× 0.2125%) + 0.001 MΩ	= _____	263 Reading ± Limit
200MΩ	100MΩ	Off	(_____	× 0.23 %) + 0.01 MΩ	= _____	263 Reading ± Limit
2GΩ	1GΩ	On	(_____	× 1.4 %) + 0.0001GΩ	= _____	263 Reading ± Limit
20GΩ	10GΩ	On	(_____	× 1.275 %) + 0.001 GΩ	= _____	263 Reading ± Limit
200GΩ	100GΩ	On	(_____	× 1.1 %) + 0.01 GΩ	= _____	263 Reading ± Limit

*Includes Model 263 error.

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Voltage Source Verification

Use the following procedure to verify that the Model 617 voltage source is within tolerance:

WARNING
Dangerous voltage may be present on the voltage source output terminals when the voltage source output is enabled.

1. Connect the DMM to the voltage source output terminals, as shown in Figure 4.
2. Select an appropriate DCV range on the DMM. Alternately, place the DMM in the autorange mode, if desired.
3. Press the DISPLAY button to view the voltage source value and turn on its output by pressing the OPERATE button.
4. Using the ADJUST buttons, set the voltage source output to 00.00V.
5. Verify that the voltage source value is within the limits stated in Table 4.
6. Repeat steps 4 and 5 above with the remaining voltages listed in the table.
7. Repeat the procedure for negative voltages of the same amplitude listed in the table.

Input Impedance Verification

Perform this test to verify that the input impedance of the unit is greater than 200TΩ:

1. Connect the DC calibrator, Model 263 and the Model 617 as shown in Figure 5.
2. Place the Model 617 in the volts function, select the 20V range, and enable ZERO CHECK. Verify that the display shows 0.000V ±1 count. If not, enable ZERO CORRECT.
3. Enable GUARD on both the Models 617 and 263.
4. On the Model 263, select the 200GΩ range, and press ZERO to source zero ohms. Make sure the Model 263 is in OPERATE.
5. Set the DC calibrator to output 19.000V.
6. On the Model 617, disable ZERO CHECK and note the reading.
7. Enable ZERO CHECK on the Model 617, and press ZERO on the Model 263 to select the 100GΩ resistor.
8. Disable ZERO CHECK on the Model 617. After waiting a few seconds for settling, note reading on the Model 263.
9. Compare the reading obtained in step 8 with that noted in step 6. The two readings should be within 10 counts (10mV) of one another.

Table 4. Voltage Source Verification Limits

Programmed Voltage	Allowable DMM Reading (18°C -28°C)		
00.00V	− 0.050	to	+ 0.050V
01.00V	0.945	to	1.052V
10.00V	9.93	to	10.07 V
25.00V	24.90	to	25.10 V
50.00V	49.85	to	50.15 V
100.00V	99.75	to	100.25 V

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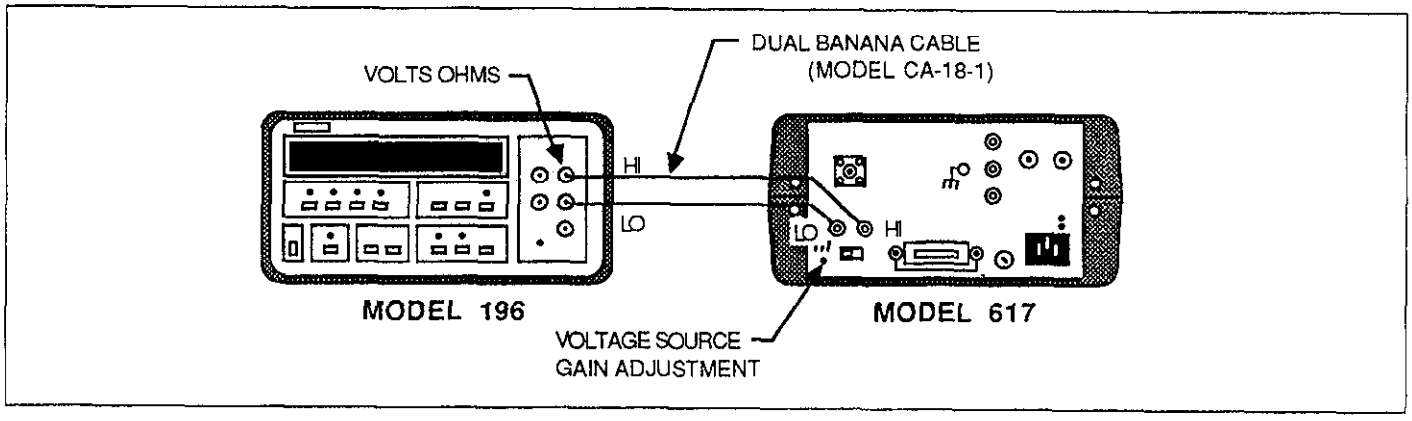


Figure 4. Voltage Source Verification Setup

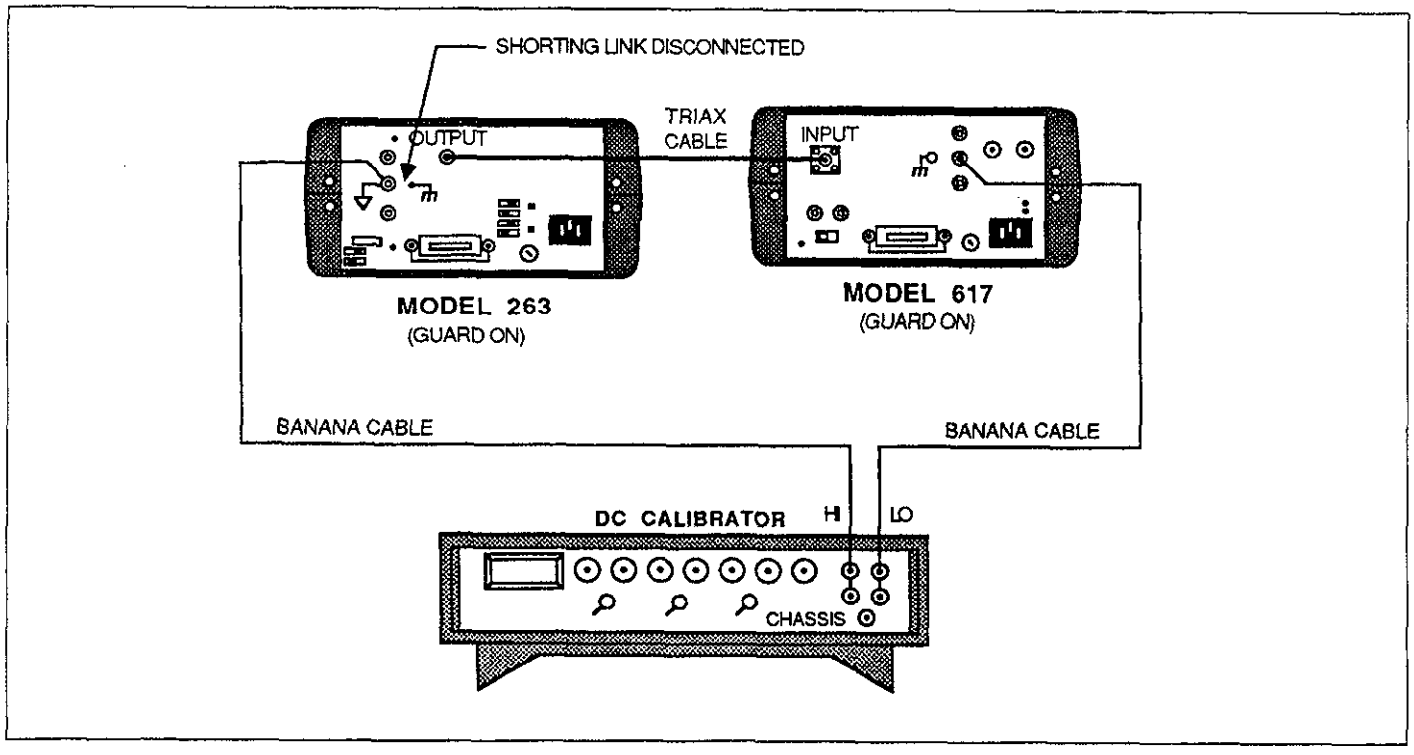


Figure 5. Input Impedance Verification Setup

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CALIBRATION USING MODEL 263 CALIBRATOR/SOURCE

INTRODUCTION

The following paragraphs provide detailed procedures to calibrate the Model 617 using the Model 263 Calibrator/Source. Most of the calibration procedures are digital in nature and can be done from the front panel or over the IEEE-488 bus.

To calibrate the instrument from the front panel, perform the following procedures, omitting paragraph "IEEE-488 Bus Digital Calibration". To calibrate the Model 617 over the IEEE-488 bus, perform the following procedures, omitting paragraph "Front Panel Digital Calibration".

Calibration Jumper

A jumper, located on the mother board, disables/enables front panel and IEEE-488 bus calibration. When the jumper is in the disabled position, permanent (NVRAM) storage of calibration constants will not take place. However, temporary calibration values may be entered and used even if NVRAM calibration storage is disabled. Note, however, that calibration parameters will be lost once power is turned off unless they are stored in NVRAM.

The calibration jumper location and the disabled/enabled positions are indicated in Figure 6.

WARNING

Turn off the instrument and disconnect the line cord before removing the top cover to reposition the calibration jumper.

Required Equipment

The following items (one of each) are necessary to calibrate the Model 617:

1. Keithley Model 263 Calibrator/Source.
2. Keithley Model 196 System DMM (±0.015%).*
3. Fluke Model 343A DC Voltage Calibrator (190V; ±0.002%).*
4. Triax-to-Triax cable (supplied with 263).
5. Keithley Model CA-18-1 Dual Banana-to-Banana cable.

NOTE: The following additional equipment will be necessary if calibration is to be performed over the IEEE-488 bus.

6. HP 85 Computer equipped with HP 82937 GPIB Interface and I/O ROM.
7. Keithley Model 7008 IEEE cable.

*Accuracy requirement of calibration equipment.

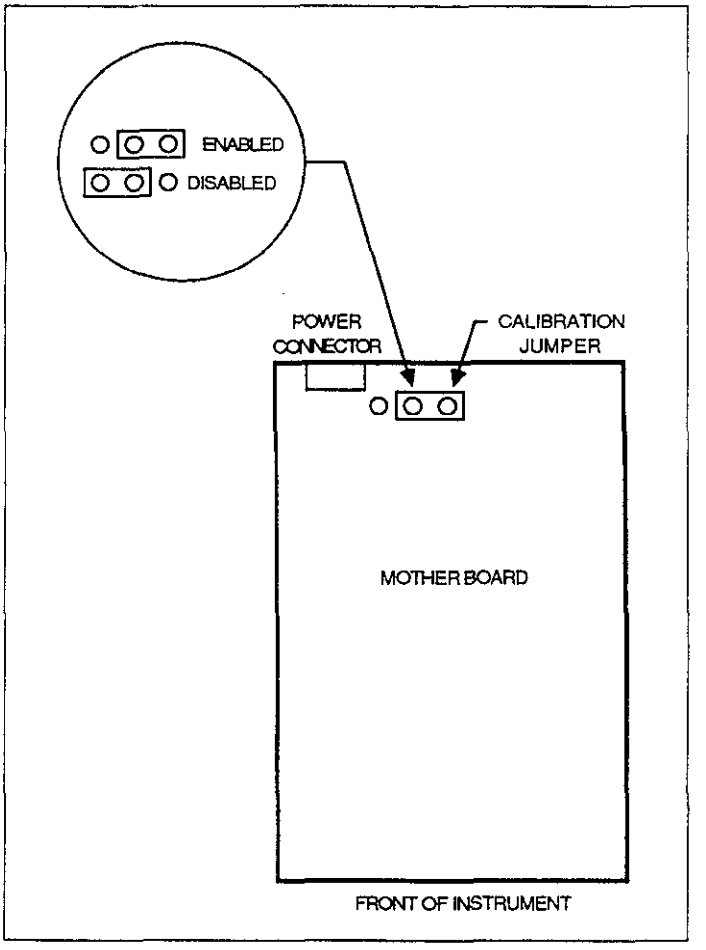


Figure 6. Calibration Jumper Location (Model 617)

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Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23 ±1°C and a relative humidity of less than 70%. With both the Models 617 and 263 on, allow them to warm up for one hour. If either instrument has been subjected to extreme temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

NOTE

While rated accuracy of the Model 617 is achieved after the two hour warm up period, input bias current may require additional time to come to its optimum level. Allow two hours for input bias current to settle to less than 10fA and eight hours to less than 5fA.

Calibration Sequence

Model 617 calibration must be performed in the order given in the following paragraphs, with the exception of the voltage source calibration, which can be done at any time. The basic sequence is:

Manual Adjustments:

1. Input offset adjustment
2. Input current adjustment
3. Voltage source calibration adjustments

Digital Calibration (Front Panel or IEEE-488 Bus):

4. Amps calibration
5. Coulombs calibration
6. Volts calibration
7. Ohms calibration

The voltage source is calibrated third since this is a manual adjustment. This allows the digital calibration procedures to be grouped together.

In addition to the above sequence, the ranges for each function must be calibrated in the order given. Note that you should never calibrate a range using a suppress or a zero correct value taken on a different range.

Manual Calibration Adjustments

After performing the following manual calibration adjustments, proceed to either front panel digital calibration or IEEE-488 Bus Digital Calibration.

A. Input Offset Adjustment

Perform the following steps to null out any small offset in the input amplifier:

1. Disconnect all input signals from the Model 617.
2. Remove the two screws securing the top cover and remove the cover from the instrument.
3. Select the amps function and place the instrument on the 2pA range.
4. Enable zero check, but leave zero correct disabled.
5. Locate the offset adjustment pot (R314) on the electrometer board (see Figure 7). The pot is accessible through a small hole in the shield closest to the rear of the instrument.
6. Adjust R314 for a reading of 0.0000 ±1 count on the display.
7. Replace the top cover unless the following input current adjustment is to be performed.

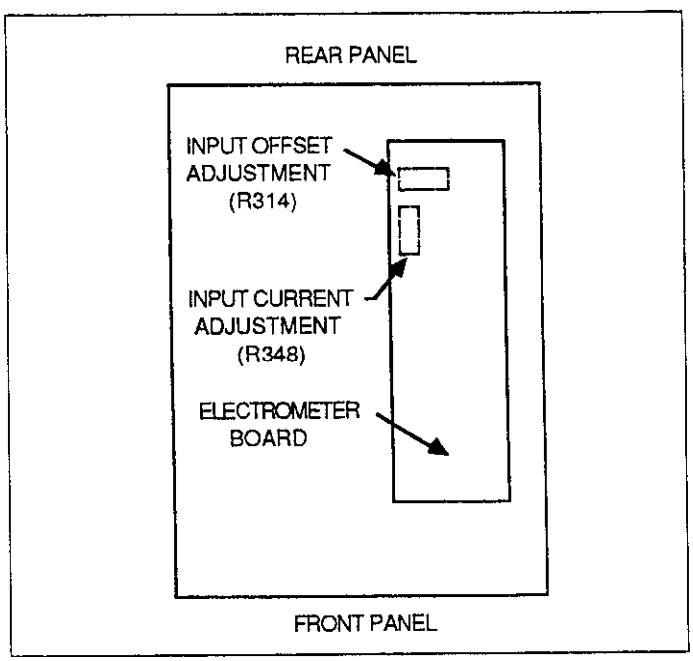


Figure 7. Input Offset Adjustment Locations (Model 617)

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B. Input Current Adjustment

Use the following procedure to null out any input current in the input stage:

1. Disconnect all input signals from the Model 617. Place the protection cap (CAP-18) on the INPUT connector.
2. Remove the two screws securing the top cover and remove it from the instrument.
3. Place the Model 617 in the amps function and the 2pA range.
4. Enable zero check and zero correct in that order.
5. Disconnect floating sources and connect a ground link between the COM and chassis ground binding posts. Disable zero check, but leave zero correct enabled.
6. Wait several minutes until the reading on the display settles down; about 15 counts (1.5fA) p-p of noise is normal.
7. Locate the input current pot R348 on the electrometer board. It is accessible through a small hole in the shield (see Figure 7).
8. Carefully adjust R348 for a reading of 0.0000 ±15 counts on the display. Iterative adjustment may be necessary.
9. Replace the top cover and secure it with the two screws removed earlier.

C. Voltage Source Calibration

Use the following procedure to calibrate the voltage source. Since the voltage source is independent from the electrometer section, voltage source calibration can be performed at any time.

WARNING
Hazardous voltage will be used in some of the following steps.

1. Connect the Model 196 DMM to the voltage source output as shown in Figure 8.
2. From the front panel, program the voltage source of the Model 617 to 0.00V.
3. Turn on the voltage source output by pressing the OPERATE button.
4. Place the Model 196 in autorange and note the offset voltage value. A reading of 50mV or less should be displayed.
5. Press ZERO on the Model 196 to cancel the offset.
6. Program the Model 617 to output 100.00V.
7. Adjust the voltage source gain adjustment (see Figure 8) so that the DMM reads a voltage of 100V ±10mV.
8. Turn off the voltage source output and disconnect the DMM.

Front Panel Digital Calibration

Perform the following procedures to digitally calibrate the Model 617 from the front panel.

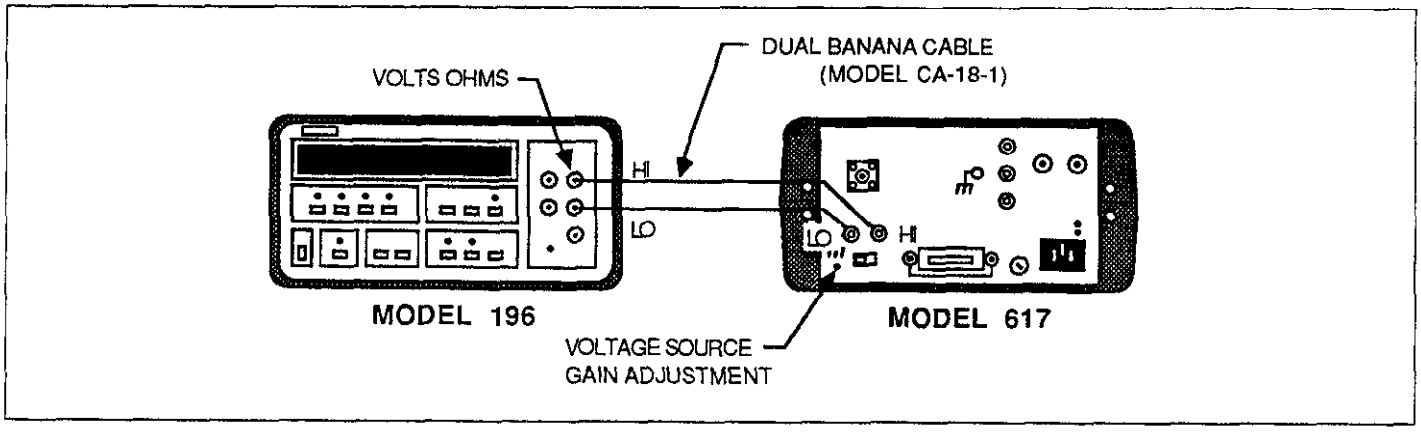


Figure 8. Connections for Model 617 Voltage Source Calibration

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Calibration Program

The Model 617 must be placed in the calibration program in order to perform the front panel digital calibration procedures. Select the calibration program as follows:

1. Turn off the instrument for at least three seconds if it is presently turned on.
2. Press and hold the PROGRAM SELECT button and then turn on the power.
3. The instrument powers up as normal, but the CAL program is accessible in the program menu.
4. Select the calibration program by pressing PROGRAM SELECT repeatedly until the following message is displayed briefly:

   CAL

5. A normal reading will now be displayed except that the exponent decimal points will be dislayed to indicate that the instrument is in the calibration mode.

With the instrument in the calibration mode, perform the following procedures to calibrate the Model 617 from the front panel.

Amps Calibration

Calibration of the amps function should be performed in the following order: 200pA, 20nA, 20μA, and 20mA ranges. Once these ranges are calibrated, the remaining ranges are automatically calibrated. Use the AMPS (active) function of the Model 263 to source current. Proceed as follows:

1. Connect the Model 263 Calibrator/Source to the Model 617 as shown in Figure 9.
2. Place the Model 617 in the amps function and select the 200pA range.
3. On the Model 617, enable zero check and zero correct in that order.
4. Program the Model 263 to output 00.000pA and release zero check on the Model 617.
5. After allowing the reading to settle for a few seconds, zero the display of the Model 617 by pressing SUPPRESS.
6. Program the Model 263 to output 190.000pA.
7. Adjust the display of the Model 617 to read 190.00pA using the ADJUST buttons of the Model 617.
8. Program the Model 263 to output 00.000pA by pressing ZERO on the Model 263.
9. On the Model 617, disable zero correct and suppress.
10. Using Table 5 as a guide, select the next electrometer range and calibrator range, and repeat the basic procedure in steps 3 through 9. Calibrate all the electrometer ranges listed in the table.

Table 5. Model 617 Amps Calibration

617 Range	263 Range	263 Output Current	617 Reading
200 pA	200 pA	190.000 pA	190.00 pA
20 nA	20 nA	19.0000nA	19.000nA
20 μA	20 μA	19.0000 μA	19.000 μA
20mA	20mA	19.0000mA	19.000mA

Coulombs Calibration

Use the following procedure to calibrate the 20nC range. Once this range is calibrated, the two remaining ranges are automatically calibrated.

1. Connect the Model 263 Calibrator/Source to the Model 617 as shown in Figure 9.
2. Place the Model 617 in the coulombs function and select the 20nC range.
3. While in standby, program the Model 263 to source 19.0000nC.
4. On the Model 617, enable zero check and then zero correct. Disable zero check and enable suppress to null the effects of zero check hop.
5. Press the OPERATE button on the Model 263. The calibrator will source for one second.
6. Adjust the display of the Model 617 for a reading of 19.000nC using the ADJUST buttons of the Model 617.
7. Repeat steps 4 through 6 until the reading on the Model 617 reads 19.000nC after OPERATE is pressed on the calibrator.
8. Place the Model 617 in zero check.

Volts Calibration

Calibration of the volts function should be performed in the following order: 200mV, 2V, 20V, and 200V ranges. The 200V range will require that an external 190V source be applied to the Model 263. Proceed as follows:

1. Connect the Model 263 to the Model 617 as shown in Figure 9.

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2. Place the Model 617 on the volts function and 200mV range.
3. Zero correct the Model 617 by enabling zero check and zero correct in that order.
4. Program the Model 263 to output 00.000mV and release zero check on the Model 617.
5. Zero the display of the Model 617 by pressing SUPPRESS.
6. Program the Model 263 to output 190.000mV.
7. Adjust the display of the Model 617 to read 190.00mV using the ADJUST buttons on the Model 617.
8. Program the Model 263 to output 00.000mV by pressing ZERO.
9. On the Model 617, disable zero correct and suppress.
10. Using Table 6 as a guide, repeat steps 3 through 9 for the 2V and 20V ranges.
11. With the Model 343A set to zero volts, connect it to the Model 263 as shown in Figure 10. Leave the Model 263 connected to the Model 617 as shown in Figure 9.
12. Select the 200V range and zero correct the Model 617 by enabling zero check and zero correct in that order.
13. Set the Model 343A to output 190.000V to the Model 263.
14. Release zero check on the Model 617, and program the Model 263 to output the external voltage source by pressing SHIFT VOLTS.
15. Adjust the display of the Model 617 to read 190.00V using the ADJUST buttons of the Model 617.
16. Place the Model 263 and the Model 343A in standby.
17. On the Model 617, disable zero correct.
18. Turn off the Model 343A and disconnect it from the Model 263.

Table 6. Model 617 Volts Calibration

617 Range	263 Output Voltage	External DC Calibrator Voltage	617 Reading
200mV	190.000 mV	—	190.00 mV
2 V	1.90000 V	—	1.9000 V
20 V	19.0000 V	—	19.000 V
200 V	EXT VOLTS	190.000 V	190.00 V

Ohms Calibration

Perform the following procedure to calibrate the ohms function of the Model 617:

1. Connect the Model 263 to the Model 617 as shown in Figure 8. Note that Model 263 COMMON must be connected to Model 617 COMMON.
2. Enable GUARD on the Model 263 and set the Model 617 guard switch to the "ON" position.
3. Place the Model 617 in the ohms function and 20GΩ range.
4. Zero correct the Model 617 by enabling zero check and zero correct in that order.
5. Program the Model 263 to output the 10GΩ resistor. The actual value of that resistor will be displayed by the Model 263.
6. Release zero check on the Model 617 and allow the resistor reading to settle.
7. Adjust the display, using the ADJUST buttons of the Model 617, to correspond to the reading on the Model 263.
8. Disable guard on the Model 263 and set the Model 617 guard switch to the "OFF" position.
9. Using Table 7 as a guide, repeat steps 4 through 7 for the 200MΩ, 2MΩ, and 200kΩ ranges.
10. Set the Model 617 to the 20kΩ range.
11. Zero correct the Model 617 by enabling zero check and zero correct in that order.
12. Set the Model 263 to the 10kΩ range and press ZERO to source zero ohms to the Model 617.
13. Release zero check on the Model 617. The reading on its display is test lead resistance and zero offset.
14. Enable suppress on the Model 617 to zero the display.
15. Press ZERO on the Model 263 to source 10kΩ to the Model 263. The actual value of that resistor will be displayed by the Model 263.
16. Adjust the displayed reading on the Model 617 to correspond to the reading on the Model 263.

Table 7. Model 617 Ohms Calibration

617 Range	617 Guard Switch	263 Guard	263 Calibration Resistance* (Nominal)	617 Reading
20GΩ	ON	Enabled	10GΩ	*
200MΩ	OFF	Disabled	100MΩ	*
2MΩ	OFF	Disabled	1MΩ	*
200kΩ	OFF	Disabled	100 kΩ	*
20kΩ	OFF	Disabled	10k Ω	*

*Actual calibration resistance value is displayed on the Model 263.

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Permanent Storage of Calibration Constants

The procedures given in the preceding paragraphs will temporarily store calibration constants in internal RAM memory and will be lost when the instrument is turned off. For calibration to be permanent, you must perform NVRAM storage. Once all points have been calibrated, press PROGRAM SELECT to exit the calibration program. Assuming that the calibration jumper is in the enable position, calibration constants will be stored in NVRAM, and the following message will be displayed briefly:

Stor

Also, constants for uncalibrated ranges are derived at this point.

If the calibration jumper is in the disable position, NVRAM storage will not take place, and the following message will be displayed briefly:

Out

Only changed constants are affected with uncalibrated ranges unaffected. The new calibration constants will be used by the instrument until power is turned off. Temporary calibration is denoted by the flashing exponent decimal points.

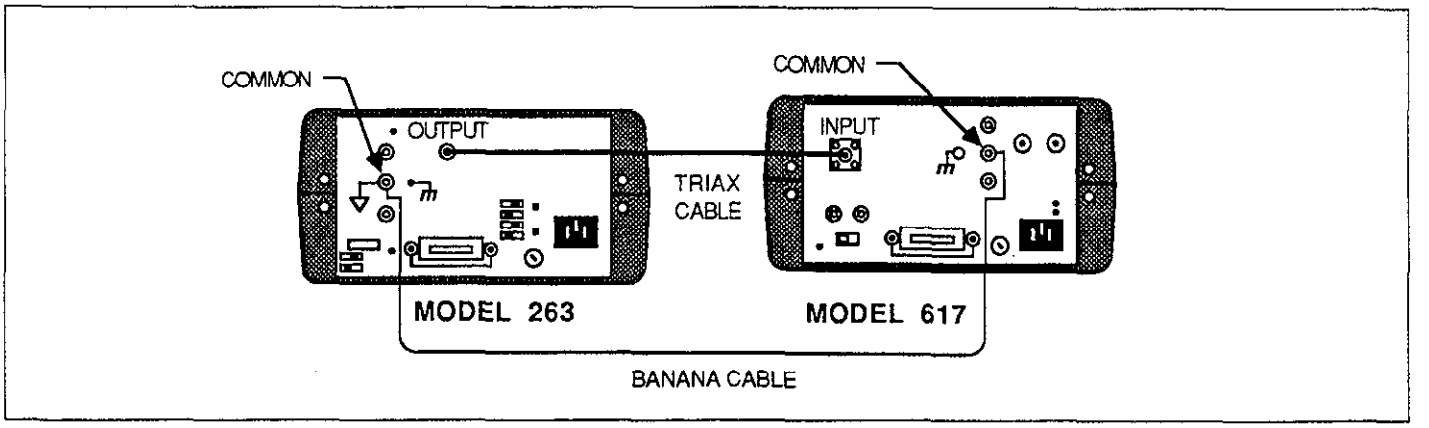


Figure 9. Connections for Model 617 Calibration

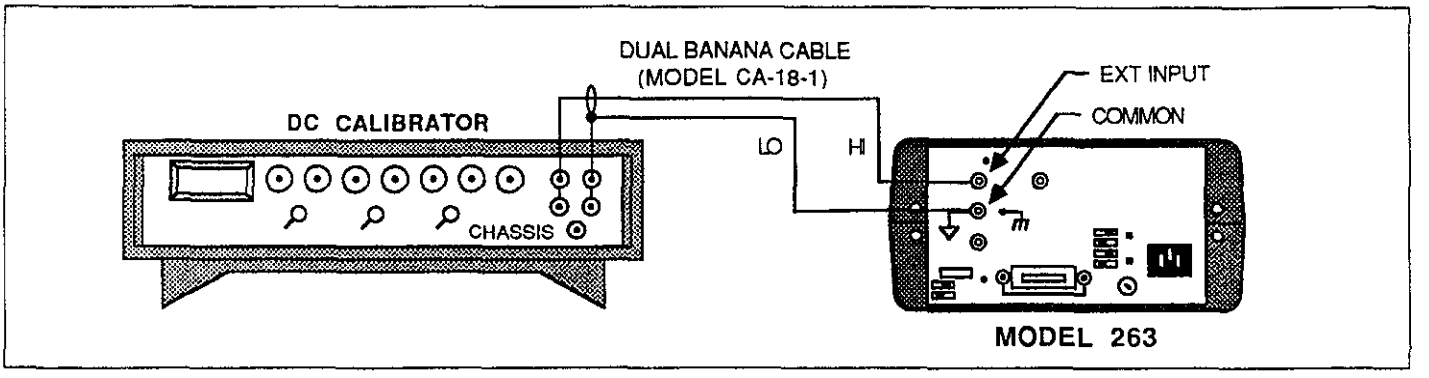


Figure 10. Connections for External Voltage Source

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IEEE-488 Bus Digital Calibration

After completing the manual calibration adjustments, perform the following procedure to digitally calibrate the Model 263 over the IEEE-488 bus.

1. Connect the Models 263 and 617 to the GPIB interface of the HP 85 computer.
2. Set the IEEE-488 address of the Model 263 to 8 and set the address of the Model 617 to 27.
3. Enter the calibration program into the HP 85 computer.
4. To calibrate the instrument, simply press the RUN key on the computer and follow the instructions on the CRT display.
5. After all functions are calibrated, the program will prompt for permanent storage of calibration constants in NVRAM (line 880). This provides the user the opportunity to stop at this point in order to avoid permanent calibration. The calibration constants will be lost when the instrument is turned off.
6. Storage of calibration constants into NVRAM is performed by line 940 of the program, and is indicated by the "Stor" message on the Model 617. If instead the message "out" is displayed, then the calibration jumper is in the disable position and calibration constants will be lost when the Model 617 is turned off.

```
10 CLEAR 727,708 @ CLEAR @ BEEP
20 DISP "CONNECT THE 263 TO THE 617 (FIG 8) AND THE EXT V-SOURCE (FIG 9)."
30 DISP "SET EXT V-SOURCE TO OUTPUT      190.000V TO 263." @ DISP
40 DISP "PRESS 'CONT' TO CONTINUE."
50 PAUSE
60 CLEAR
70 OUTPUT 708 ;"F1R3V190E-12X" ! 263; program for 190pA.
80 DATA 3,.00000000019,5,.000000019,8,.000019,11,.019
90 FOR I=1 TO 4
100 READ R
110 OUTPUT 727 ;"F1R";R;"X" ! 617; select I range.
120 OUTPUT 708 ;"R";R;"X" ! 263; select I range.
130 OUTPUT 708 ;"Z1O1X" ! 263; output 0A to 617.
140 WAIT 2000
150 OUTPUT 727 ;"Z1X" ! 617; zero correct display.
160 WAIT 1000
170 OUTPUT 727 ;"C0X" ! 617; disable zero check.
180 WAIT 5000
190 OUTPUT 727 ;"N1X" ! 617; zero display with suppress.
200 OUTPUT 708 ;"Z0X" ! 263; output programmed I to 617.
210 IF I>1 THEN 230
220 WAIT 15000
230 WAIT 3000
240 READ R
250 BEEP 2,200 @ OUTPUT 727 ;"A";R;"X" ! 617; send cal value.
260 WAIT 2000
270 OUTPUT 727 ;"N0Z0C1X" ! 617; disable suppress and zero correct, and enable z
280 NEXT I
290 OUTPUT 708 ;"O0X" ! 263; place in standby.
300 PRINT "AMPS RANGES CALIBRATED:"
310 PRINT "200pA, 20nA, 20uA, 20mA" @ PRINT
320 WAIT 2000 @ CLEAR
330 OUTPUT 727 ;"F3R3Z1X" ! 617; select 20nC range and zero correct display.
```

617 CALIBRATION PROGRAM

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```
340 OUTPUT 708 ;"F3R4V19E-9X" ! 263; program for 19nC.
350 OUTPUT 727 ;"C0X" ! 617; disable zero check.
360 WAIT 2000
370 OUTPUT 727 ;"N1X" ! 617; enable suppress.
380 OUTPUT 708 ;"O1X" ! 263; output 20nC to 617.
390 WAIT 2500
400 BEEP 2,200 @ OUTPUT 727 ;"A19E-9X" ! 617; send cal value.
410 WAIT 2000
420 PRINT "COUL RANGES CALIBRATED:"
430 PRINT "20nC" @ PRINT
440 OUTPUT 708 ;"F2R1V190E-3X" ! 263; program for 190mV.
450 DATA .19,1.9,19
460 FOR I=1 TO 3
470 OUTPUT 727 ;"C1Z0N0F0R";I;"X" ! 617; select volts range.
480 OUTPUT 708 ;"R";I;"Z1O1X" ! 263; select range, output 0V.
490 OUTPUT 727 ;"Z1XC0X" ! 617; enable z. cor. and disable z. chk.
500 OUTPUT 727 ;"N1X" ! 617; enable suppress.
510 OUTPUT 708 ;"Z0X" ! 263; output programmed voltage.
520 READ V
530 WAIT 2000 @ CLEAR
540 BEEP 2,200 @ OUTPUT 727 ;"A";V;"X" ! 617; send cal value.
550 WAIT 2000
560 NEXT I
570 OUTPUT 727 ;"Z0N0R4X" ! 617; select 200V range.
580 OUTPUT 708 ;"F5O1X" ! 263; source ext V to 617.
590 WAIT 2000
600 BEEP 2,200 @ OUTPUT 727 ;"A190X" ! 617; send cal value.
610 WAIT 2000
620 OUTPUT 727 ;"C1F2R8X" ! 617; select 20Gohm range.
630 PRINT "VOLTS RANGES CALIBRATED:"
640 PRINT "All" @ PRINT
650 OUTPUT 708 ;"F0R8W1X" ! 263; select 10Gohm range, guard on.
660 BEEP @ DISP "SET 617 GUARD SWITCH TO 'ON'    POSITION."
670 DISP @ DISP "PRESS 'CONT' TO CONTINUE."
680 PAUSE
690 FOR I=8 TO 2 STEP -1
700 IF I=8 THEN 770
710 IF I<7 THEN 770
720 CLEAR
730 BEEP @ DISP "SET 617 GUARD SWITCH TO 'OFF'   POSITION."
740 DISP @ DISP "PRESS 'CONT' TO CONTINUE."
750 PAUSE
760 CLEAR @ OUTPUT 708 ;"W0X" ! 263; disable guard.
770 OUTPUT 708 ;"R";I;"XZ1O1X" ! 263; output 0ohms to 617.
780 OUTPUT 727 ;"C1Z0N0R";I;"X" ! 617; select range.
790 OUTPUT 727 ;"Z1XC0XN1X" ! 617; zero display.
800 OUTPUT 708 ;"Z0X" ! 263; source programmed resistance.
```

617 CALIBRATION PROGRAM (Cont.)

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```
810 WAIT 7000
820 ENTER 708 ; A ! 263; send resistance reading.
830 BEEP 2,200 @ OUTPUT 727 ;"A";A;"X" ! 617;send cal value.
840 WAIT 3000
850 NEXT I
860 PRINT "OHMS RANGES CALIBRATED:"
870 PRINT "20Gohm, 2Gohm, 200Mohm, 20Mohm, 2Mohm, 200kohm, 20kohm"
880 BEEP @ DISP @ DISP "DO YOU WISH TO PERMANENTLY STORECAL CONSTANTS (Y/N)?"
890 INPUT B$
900 CLEAR @ IF B$="Y" THEN 940
910 DISP "CAL CONSTANTS NOT STORED." @ DISP
920 DISP "ALTERED RANGES TEMPORARILY CAL- IBRATED."
930 GOTO 970
940 OUTPUT 727 ;"L1X" ! 617; store cal constants.
950 DISP "IF JUMPER IN 'ENABLE' POSITION.."
960 DISP @ DISP "ALL FUNCTIONS/RANGES PERMANENTLYCALIBRATED."
970 END
```

617 CALIBRATION PROGRAM (Cont.)

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KEITHLEY

Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

- ❑ Intermittent
- ❑ IEEE failure
- ❑ Front panel operational
- ❑ Analog output follows display
- ❑ Obvious problem on power-up
- ❑ All ranges or functions are bad
- ❑ Particular range or function bad; specify _____
- ❑ Batteries and fuses are OK
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unstable
- ❑ Overload
- ❑ Unable to zero
- ❑ Will not read applied input

- ❑ Calibration only
- ❑ Data required
- ❑ Certificate of calibration required

(attach any additional sheets as necessary)

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

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

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APPENDIX A

This appendix contains complete procedures for calibrating the Model 617 using the Keithley Model 263 Calibrator/Source. Complete separate procedures are provided for performing digital calibration from either the front panel or over the IEEE-488 bus. Digital calibration over the bus is automated using a BASIC program run by the HP 85 computer.

Using the Model 263 to verify and calibrate the Model 617 simplifies the procedure and eliminates the need to build a test fixture.

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