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Model 642
Electrometer
Instruction Manual

Contains Operating and Servicing Information

KEITHLEY

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Model 642 Electrometer
Instruction Manual

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

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

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) measuring circuits are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that 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.

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Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a 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 in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean the instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument.

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SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The Model 642 is a direct reading MOSFET based Electrometer useful for sensitive measurement of voltage, current and charge. Voltage reading capabilities are 10 microvolts to 10 volts with 10^{16} ohms input resistance, typically shunted by less than 2 picofarads. Its current measurement range is 10^{-17} to 10^{-7} amperes with only a few hundred microvolts input voltage burden. Charge can be measured from 4 x 10^{-16} coulomb to 10^{-10} coulomb. Ranges and accuracies are listed in the Table of Specifications on Page 1-2. Some of The instrument features include:

a. 19,999 count resolution with a 4-1/2 digit LED display.

b. Two analog outputs which are provided on mainframe rear panel (1 volt per 10,000 counts and 1 volt per 100 counts of the digital display).

c. Mainframe front panel pushbuttons which permit selection of function and range, power off/on, variable or minimum damping and zero check.

d. A front panel zero knob used to compensate for input and amplifier offsets.

e. A range of available accessories that have been designed to permit full use of the Model 642 capabilities and to adapt it for rack mounting, operation on battery power and use with an isolated Digital BCD Interface or IEEE-488 Output.

1-3. WARRANTY INFORMATION.

1-4. The warranty is given on the inside front cover of this instruction manual. If there is a need to exercise the warranty, contact the Keithley representative in your area to determine the proper action to be taken. Keithley maintains service facilities in the United Kingdom and West Germany, as well as in the United States. Check the inside front cover of the instruction manual for addresses.

1-5. CHANGE NOTICES.

1-6. Improvements or changes to the instrument which occur after printing of the instruction manual will be explained on a change notice sheet attached to the inside back cover.

1-7. Safety Symbols.

1-8. Safety symbols used in this manual are as follows:

IMPORTANT

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

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

1-9. SPECIFICATIONS.

1-10. Detailed specifications for the Model 642 are given in Table 1-1, page 1-2.

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AS A DC AMMETER

CURRENT SETTING	MAXIMUM READING ON 0.1 RANGE	MAXIMUM READING ON 10 RANGE
10^{-8} A	0.19999 × 10^{-8} A	10.999 × 10^{-8} A
10^{-10}A	0.19999 × 10^{-10}A	10.999 × 10^{-10}A
10^{-11}A	0.19999 × 10^{-11}A	10.999 × 10^{-11}A
10^{-12}A	0.19999 × 10^{-12}A	10.999 × 10^{-12}A

CURRENT SETTING	25°C ±1°C 6-MONTH ACCURACY ±(%rdg + digits)	1% SETTLING TIME ON 10 RANGE AT 1V/10kCOUNT ANALOG OUTPUT, AT MINIMUM DAMPING
10^{-8}A	1% + 3d	40ms
10^{-9}A	1% + 3d	100ms
10^{-11}A	1.3% + 3d	400ms
10^{-12}A	1.5% + 6d	5 s

NOISE: 8 × 10^{-17}A rms (2 × 10^{-16}A p-p). Less than 15 self-generated alpha pulses per hour.

AS A DC VOLTMETER

RANGE	MAXIMUM READING	20°C to 30°C 6-MO. ACCURACY (Exclusive of Noise)	1% SETTLING TIME AT 1V/10k COUNT ANALOG OUTPUT
0.1V	0.19999	0.05% + 3 digits	3 sec.
1V	1.9999	0.05% + 1 digit	0.3 sec.
10V	10.999	0.05% + 1 digit	0.03 sec.

NOISE: Less than 20μV rms (100μV p-p).

ZERO STABILITY: 24 hours, ±3°C: ±180μV.

TEMPERATURE COEFFICIENT OUTSIDE OF ±3°C SPAN: ±(30μV + 0.5 digit)/°C.

INPUT RESISTANCE: Greater than or equal to 10^{10} Ω.

AS A COULOMBMETER

RANGES: 10^{-11} coulombs, 0.1, 1, or 10 ranges.

INPUT CURRENT (at 25°C ±1°C): Less than 5 × 10^{-17}A.

ACCURACY (at 25°C ±1°C for 6 months, exclusive of noise): ±(0.3% + 5 digits).

NOISE: 8 × 10^{-16} coulombs rms (4 × 10^{-15} coulombs p-p), 0.1 range. Less than 15 self-generated alpha pulses per hour.

CHARGE ERROR DUE TO ACTUATION OF ZERO CHECK: Typically less than 10^{-14} coulombs.

GENERAL

MAXIMUM INPUTS: Normal or Common Mode: 30V rms DC to 60Hz.

DISPLAY: Five 0.5 inch LED digits with decimal point and polarity indication.

CONVERSION PERIOD FOR DIGITAL DISPLAY: 400ms.

ANALOG OUTPUTS: Two analog outputs are provided on mainframe rear panel; 1V per 10,000 counts and 1V per 100 counts of the digital display.

POWER REQUIREMENTS:

90V to 110V
105V to 125V
180V to 220V
or 210V to 250V, 50Hz to 60Hz, 30VA max.

DIMENSIONS, WEIGHTS

MAINFRAME: 3½ in. half rack, overall bench size 100mm high × 217mm wide by 308mm deep (4″ × 8½″ × 12 ⅛″). Net weight 2.9kg (6 lb., 6 oz.).

REMOTE HEAD: 102mm high × 162mm wide × 165mm deep (4″ × 6⅜″ × 6½″), exclusive of connectors. Net weight 4.2kg 1 lb., 3 oz.).

INTERCONNECT CABLE: 4 ft. long. Net wt. 0.6kg (1 lb., 3 oz.).

ACCESSORY SUPPLIED: Four-foot remote head to mainframe interconnect cable.

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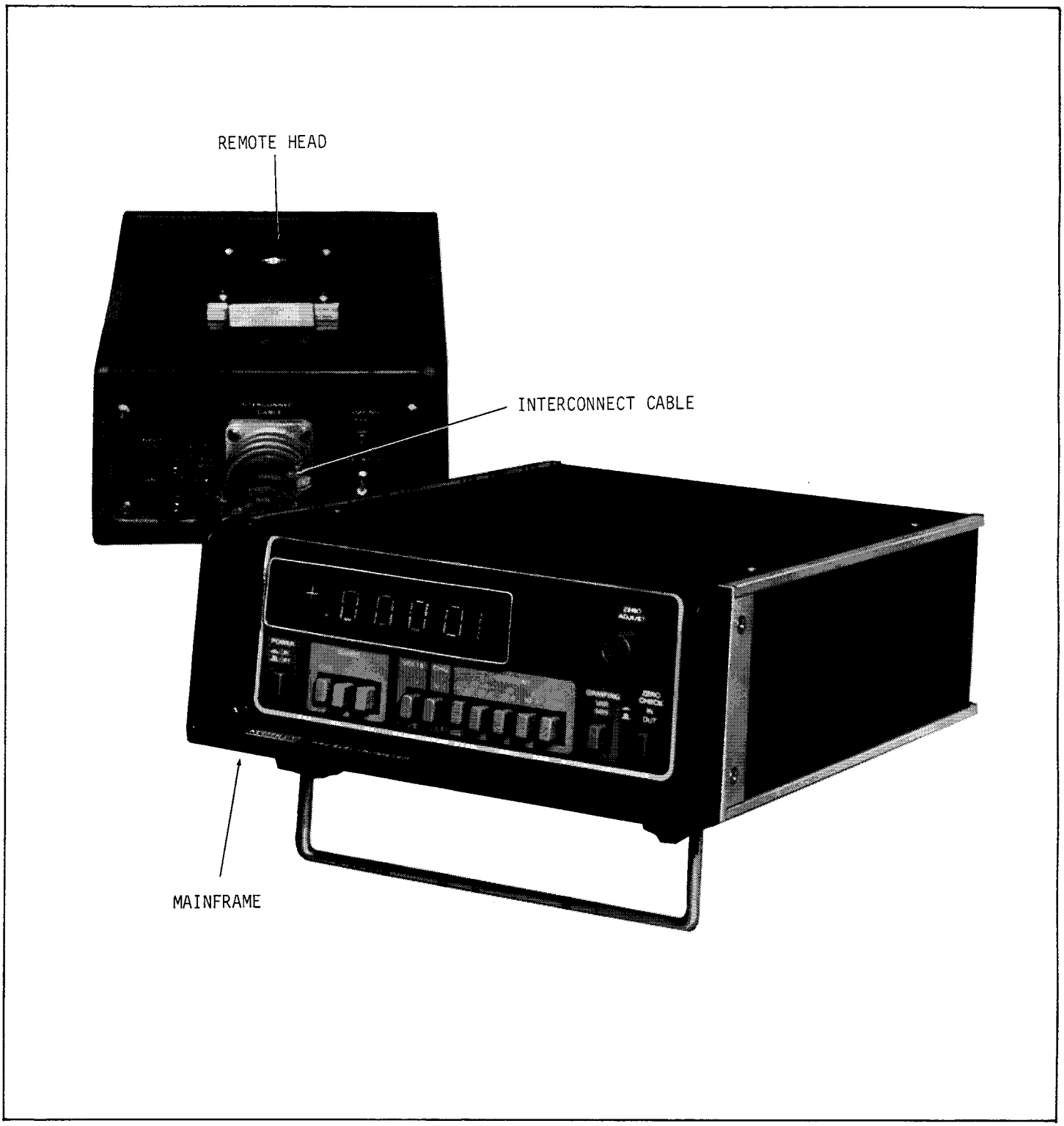
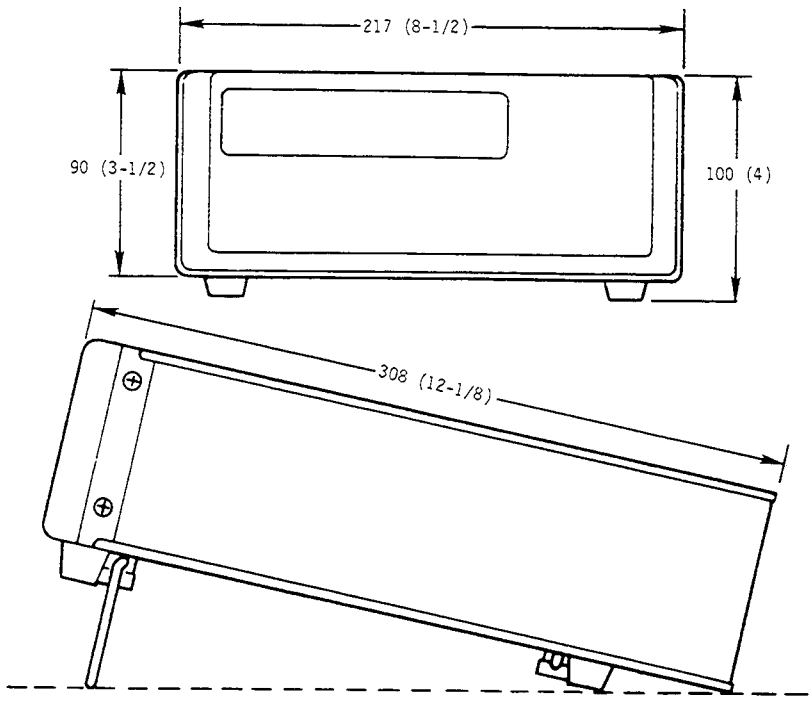


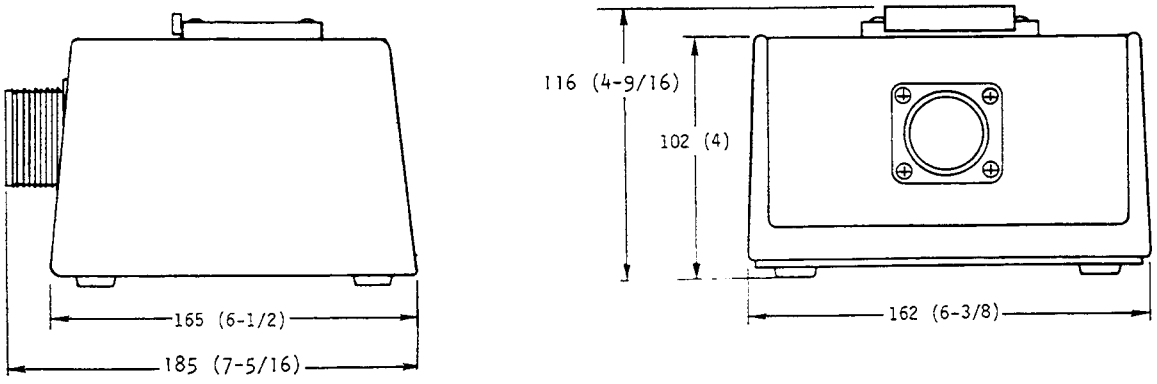
FIGURE 1-1. Model 642 Electrometer

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MAINFRAME

642-003-A



REMOTE HEAD

Dimensions in Millimeters (Inches).

642-004-A

FIGURE 1-2. Dimensional Data

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SECTION 2. OPERATION

2-1. GENERAL.

2-2. This section provides information needed for incoming inspection, preparation for use and operation of the Model 642.

2-3. UNPACKING AND INSPECTION.

2-4. The Model 642 was carefully inspected, both mechanically and electrically before shipment. Upon receiving the Model 642, unpack all items from the shipping container and check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. Retain and use the original packaging materials if reshipment is required. The following items are shipped with all Model 642 orders:

a. Model 642 Mainframe.

b. Remote Head Preamplifier.

c. Mainframe to Remote Head Interconnect Cable, Keithley Part Number 29815B.

d. Line Power Cord, Keithley Part Number CO-7.

e. Model 642 Instruction Manual.

f. Optional Accessories, as ordered.

2-5. PREPARATION FOR USE.

2-6. Preparation of the Model 642 for use consists of interconnecting the mainframe and remote head with the interconnection cable, configuring the Model 642 for operation on line power or battery power and rack mounting the mainframe if desired.

2-7. REMOTE HEAD TO MAINFRAME CONNECTIONS.

2-8. A cable assembly (Keithley Part Number 29815B) is provided with each Model 642 order to interconnect the remote head to the mainframe. The cable contains all of the necessary signal and control lines for interfacing the two units. The cable has a standard length of 4 feet (1.2 meters) and is equipped with connectors which mate with the INTERCONNECT receptacles on the mainframe and the remote head. If it is necessary to locate the remote head more than 4 feet away from the mainframe, an optional cable may be ordered in one of three available lengths - 10 ft., 50 ft., or 150 ft. See Models 6427-10, 6427-50 and 6427-150 described in Section 4.

NOTE

The INTERCONNECT bulkhead plug on the remote head is an environmental resistant connector, and as a result, the connector engagement will be very snug.

NOTE

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

2-9. OPERATION ON LINE POWER.

2-10. The Model 642 is provided with a detachable 3-wire line cord which mates with a third wire earth grounded receptacle. The line cord connects to the back of the mainframe. The instrument will operate on 4 voltage ranges of 60 or 50 Hertz AC power. The voltage ranges are selected by 2 slide switches located inside of the mainframe. Set up the Model 642 to operate on your input voltage as follows:



WARNING

Disconnect the line cord before removing the case cover.

a. Remove the four screws in the top cover to gain access to the inside of the mainframe.

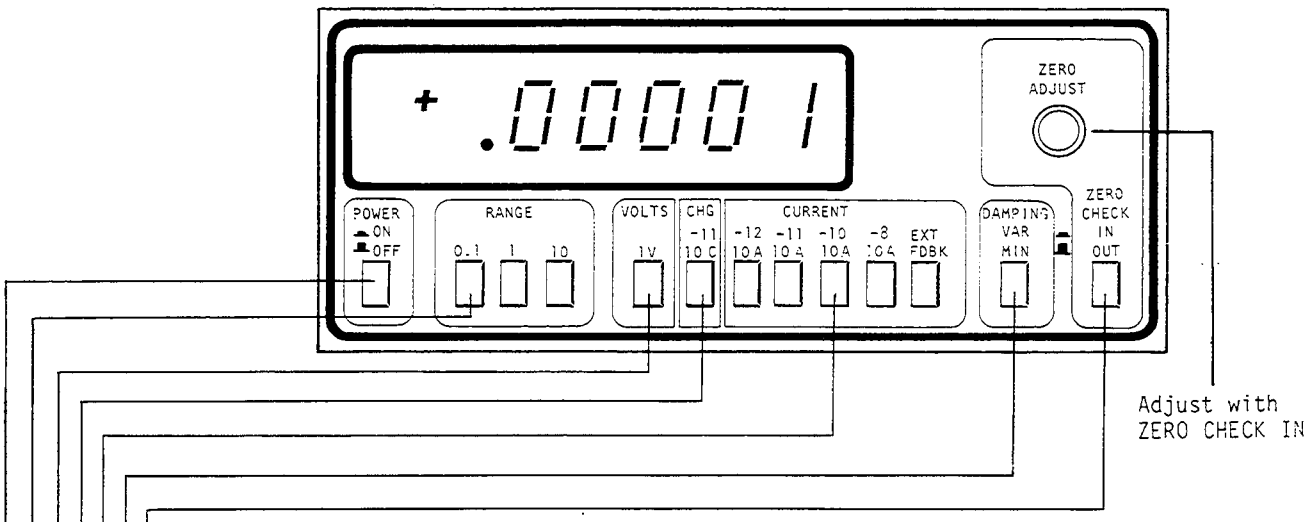
b. Set switch S306 and S307 as indicated in Table 2-1 for the applicable input line voltage.

c. Reinstall the mainframe top cover.

d. Remove the line fuse from its holder on the mainframe rear panel and verify that it has the correct current rating for the selected voltage. Install 1/4A for 90 to 125 volts or 1/8A for 180 to 250 volts.

e. Connect the line cord to its receptacle on the mainframe rear panel.

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ZERO CHECK: **IN:** Used for set-up and as a standby configuration. Shorts input across 100KΩ in volts. Shorts feedback elements in charge/amps mode.

OUT: Used for taking data only.

DAMPING: **VAR:** (VARIABLE) Speed is determined by DAMPING LEVEL adjustment on Remote Head.

MIN: Fastest speed is obtained (in most cases). Settling times are given in specifications.

CURRENT: Feedback resistance is the reciprocal of the current sensitivity selected. Custom feedback element may be connected from FEEDBACK to INPUT terminal and selected by depressing EXT FDBK. Input current is always read as display times selected sensitivity.

CHG (CHARGE): 20pF capacitor is the feedback element. Display always reads directly in 10^{-11} coulombs.

VOLTS: Non-inverting unity gain configuration is used. Display always reads directly in volts.

RANGE: Selects voltage sensitivity of display and mainframe analog outputs. Automatically positions decimal point in display.

POWER: Controls line or battery power to Model 642.

FIGURE 2-1. Summary of Mainframe Front Panel Controls.

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WARNING

Ground the mainframe to a properly earth grounded receptacle before operation. Failure to ground the mainframe can result in severe injury or death in the event of short circuit or malfunction. Also, connecting the line cord to a source having a higher voltage than that selected can damage the Model 642 circuitry.

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

TABLE 2-1
Line Power Selection

INPUT VOLTAGE	S306 115	S306 230	S307 HIGH	S307 LOW	LINE POWER FUSE F301
90 to 110	X			X	1/4 A
105 to 125	X		X		
180 to 220		X		X	1/8 A
210 to 250		X	X		

2-11. OPERATION ON BATTERY POWER.

2-12. An optional Model 6428 Battery Adapter is available which permits operation of the Model 642 from an external 12-volt automotive battery. Installation and use of this option is described in Section 4. Recommendations for standby power operation are also included.

2-13. RACK MOUNTING.

2-14. Two rack mounting its are available to mount the Model 642 mainframe into a NEMA standard 19-inch rack or cabinet. See Models 1007 and 2000 in Section 4.

2-15. OPERATING CONTROLS AND INPUT/OUTPUT CONNECTIONS.

2-16. Mainframe Front Panel Controls.

2-17. The mainframe front panel controls are shown in Figure 2-1. A brief description of the function and use of each control is also included in this illustration.

2-18. Analog Outputs.

2-19. Two analog outputs are provided on the mainframe rear panel (1 volt per 10,000 counts and 1 volt per 100 counts of the digital display). By using a common low, only 3 binding posts are needed to provide the two analog outputs. Both analog outputs have an output resistance of 1100 ohms (1 kilohm in the high and 100 ohms in the common). The polarity of both analog outputs is inverted on the voltage function. Discounting its output resistance, the 1 volt per 10,000 count analog output has the same accuracy as the displayed reading and is therefore useful to monitor or record the analog equivalent of the displayed reading. This analog output will have an output voltage between 0 and ±2 volts for any on-scale display. Its output voltage is clamped to a maximum of approximately ±5 volts when an input overload or overrange condition exists. Effectively, the 1 volt per 100 count analog output is the same as the 1 volt per 10,000 count output multiplied by approximately 100. The output voltage of the 1 volt per 100 count analog output is also limited to approximately ±5 volts, but clamping will begin at approximately 500 counts on the display. It should be noted that although both analog outputs are input protected from externally applied voltages by the resistors and ±5 volt clamps, applying an external voltage of greater than ±3 volts to the 1 volt per 10,000 counts analog output could result in an erroneous reading on the digital display.

2-20. A third analog output is provided at the remote head BNC FEEDBACK connector (see Figure 2-3). This is the highest performance analog output, providing the full capability of the remote head preamplifier. The dynamic range of this output is ±11V. It has low noise (2ppm rms) and the voltage linearity is typically within 5ppm (50μV in 10 volts). This output may be direct coupled to a V/F converter, which is often used to precisely digitize and integrate the signal. Also, resolution is more than adequate for a chart recorder. If automatic data gathering is necessary, the FEEDBACK output can also be connected to a digital multimeter with systems capability. A digital multimeter is available through KEITHLEY which has high accuracy and the capability of being interfaced with an IEEE Standard Interface Bus. See Model 6900 (6-1/2 digit) in Section 4 of this manual.

2-21. Remote Head Input Connections.

2-22. The remote head incorporates the provisions for connecting the parameter to be measured (source) to the Model 642. These provisions are described as follows:

a. Sapphire-insulated input connector. The input connector is shown in Figure 2-2. The connector consists of the input slide cover, the input high connection (center spring contact) and the cavity which accepts input adapters and serves as input low. The input high connection is insulated by optically polished sapphire to maintain an ultra high input resistance and an ultra low input current. The input slide cover performs several functions. When closed, it protects the sapphire insulator from becoming contaminated and it blocks light, RF pulses, and low level radiation from the input circuitry to prevent input offsets. When an input adapter is installed, it is held firmly in position by the input slide cover. It should be noted that the input slide cover, the input cavity and the remote head chassis are all at input low potential. The guard ring shown in the illustration is always maintained at the guard potential to reduce the effect of input capacitance. In DC voltage function, the guard ring is driven by the output of the preamplifier (head output) while in current and charge functions the guard ring is at input low. The guard ring is sometimes referred to as the input tube, see Schematic 29654E.

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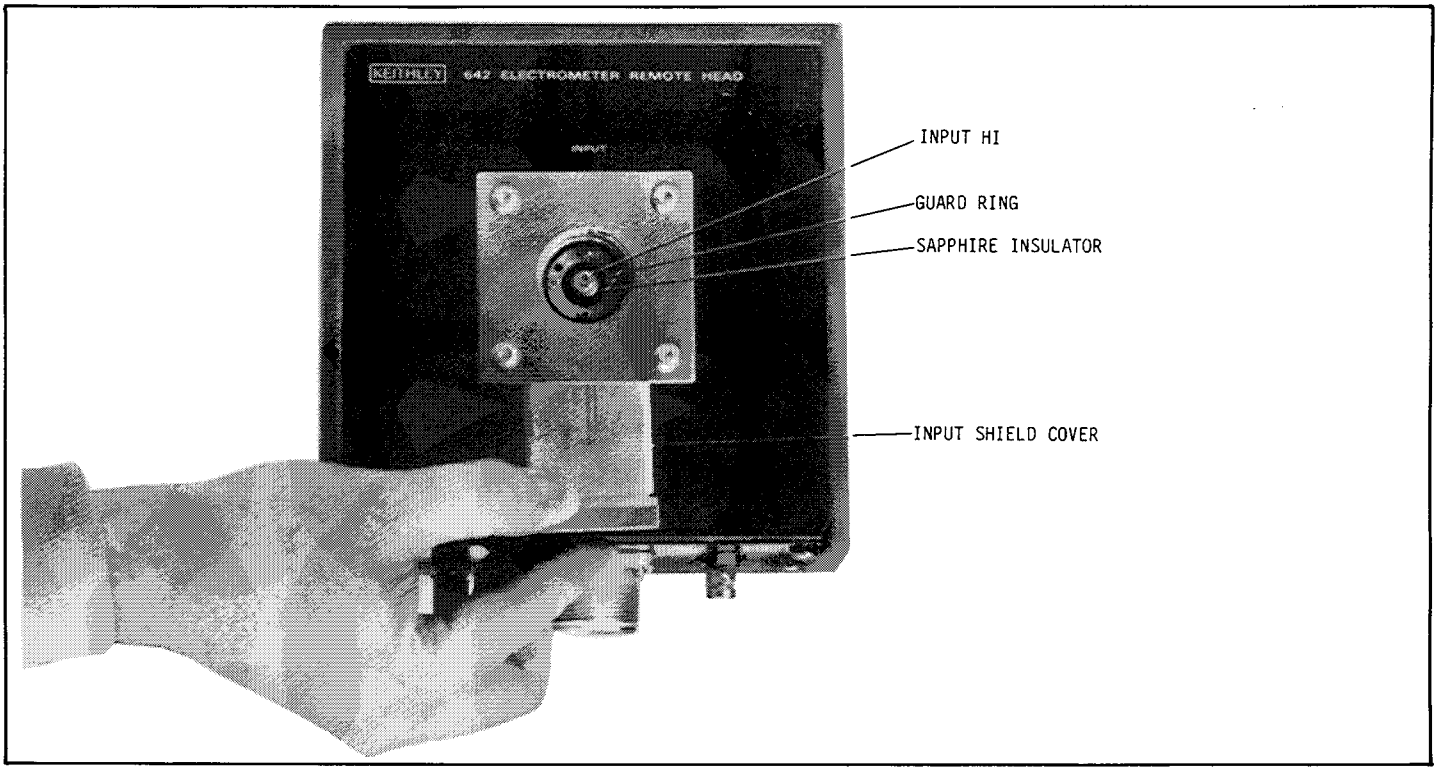


FIGURE 2-2. Remote Head Input Connector

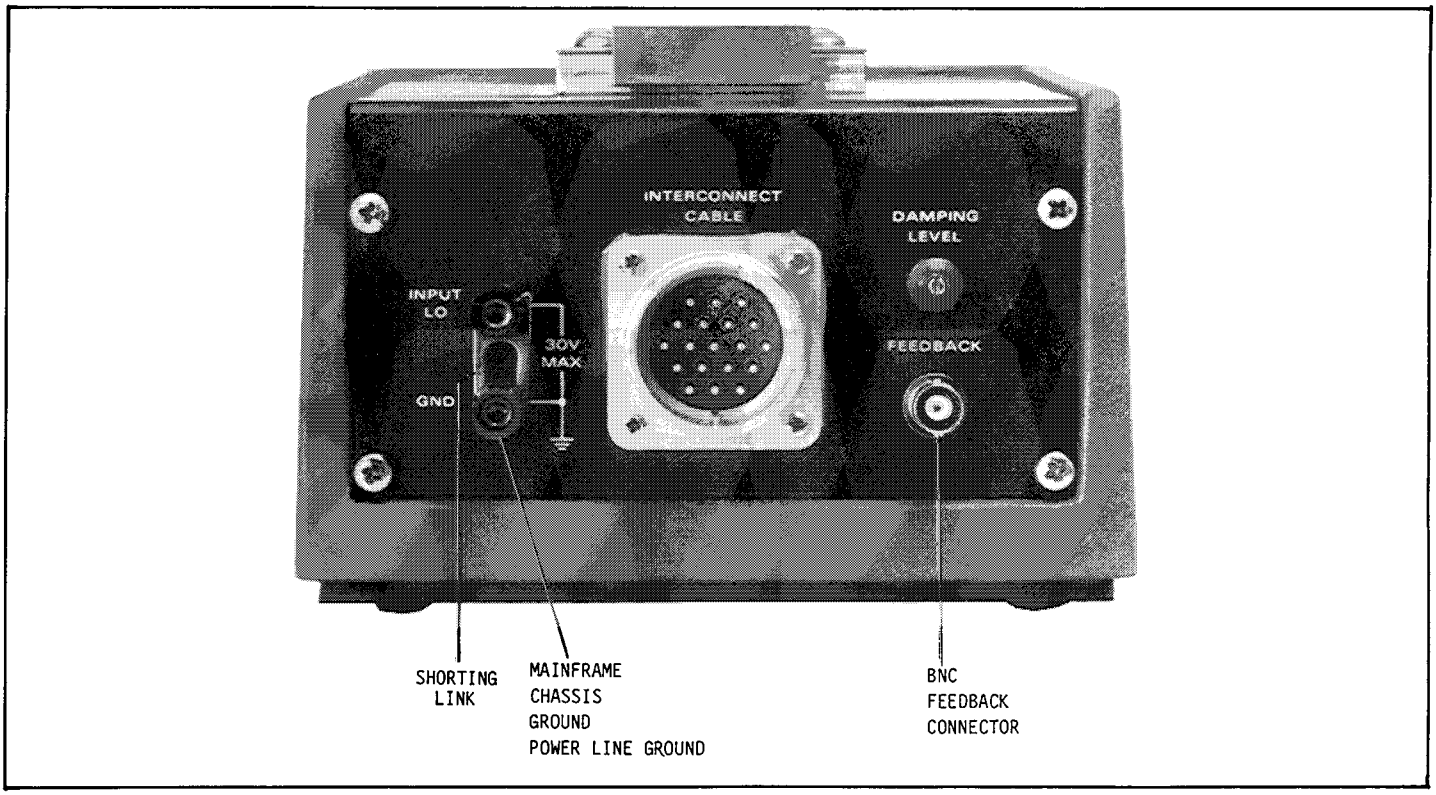


FIGURE 2-3. Remote Head Feedback and Ground Connections

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b. FEEDBACK Connector (Figure 2-3). This connector permits the use of external feedback components (i.e. a resistor for current measurements or a capacitor for charge measurements). The remote head analog output voltage is connected to the center contact of the feedback connector through a 1 kilohm resistor, a 1500pF capacitor is connected between the resistor and the FEEDBACK connector to signal common. This impedance must be considered if external feedback components are to be used. The outer shell of the FEEDBACK connector is at signal common (input low). Depressing the EXT FDBK function pushbutton on the mainframe front panel mechanically rejects the other function pushbuttons. This results in the preamplifier being in the feedback mode with all feedback components disconnected. Additional information concerning the use of the FEEDBACK connector is provided in the discussion on Analog Outputs in Paragraph 2-20.

c. Grounding. Signal common and the remote head chassis are connected to INPUT LO binding post on the remote head. Power line ground and mainframe chassis are connected to GND binding post on the remote head. The remote head is grounded when the link is connected between the two binding posts. Removal of this link will permit operation with input low connected to a ground which is within 30 volts RMS of power line ground. Note, for this condition, the remote head chassis will be at the common mode potential.

WARNING

To prevent a shock hazard, maintain INPUT LO within 30 volts rms of power line ground when the shorting link is removed.

2-23. Optional Input Adapters and Cables.

2-24. The available accessories include two coaxial cables and three input adapters which mate with the remote head sapphire insulated input connector. Each of these items are described in Section 4, under the titles listed below:

a. Model 6424 BNC Input Adapter.

b. Model 6425 GR874 Input Adapter.

c. Model 6426 Sapphire-Insulated Test Box.

d. Model 4801 BNC Low Noise Cable.

e. Model 4803 BNC Low Noise Cable Kit.

2-25. User Manufactured Input Adapters.

2-26. Figure 2-4 contains dimensional data necessary for making an input adapter that will mate with the remote head input connector of the Model 642. This information permits the user to manufacture an input adapter tailored to accomodate a particular measurement application, while assuring mating compatibility with any Model 642 remote head.

2-27. OPERATING ENVIRONMENT.

2-28. Temperature.

2-29. The Model 642 is primarily intended to be used in a stable controlled temperature environment such as can be found inside of a typical laboratory. The specified accuracy temperature ranges for the Model 642 are 20°-30°C when used as a DC voltmeter and 25°C ±1°C when used as a DC ammeter or a coulombmeter. Operating the Model 642 outside of these specified performance temperature ranges will result in measurements of reduced accuracy. Typical temperature coefficients of accuracy are given in Table 2-2. These typical values can be used to determine the approximate accuracy of a measurement taken at a temperature that is outside of the specified accuracy range of the Model 642.

TABLE 2-2
Typical Temperature Coefficients
(Independent of Zero)

FUNCTION	RANGE	TEMPERATURE COEFFICIENT
DC Voltmeter	0.1	± (0.005%)/°C
	1.0	± (0.005%)/°C
	10	± (0.005%)/°C
DC Ammeter		
10^{-8}A		± (0.25%)/°C
10^{-10}A		± (0.3%)/°C
10^{-11}A		± (0.35%)/°C
10^{-12}A		± (0.5% + 1 Digit)/°C
Coulombmeter		± (0.03%)/°C

*Input Bias Current approximately doubles with each 10°C increase.

2-30. Contamination.

2-31. With the exception of the sapphire-insulated input connector (protected by the input slide cover) all components whose performance would be affected by dust, moisture, or other contaminants are sealed inside of the remote head. Further protection against moisture is provided by an internal desiccant and a relative humidity indicator which may be read from the bottom of the remote head. It is suggested that the relative humidity indicator be checked weekly or whenever a reduction of Model 642 performance is indicated. The desiccant paper should be replaced or reactivated whenever the indicator shows a relative humidity of approximately 40%. See the Maintenance Section in this manual for instructions on how to reactivate or replace the desiccant paper. When closed, the input slide cover protects the sapphire-insulated input connector from contamination and the resulting degradation of its insulating qualities in all but excessively humid or dusty atmospheres. These conditions should be

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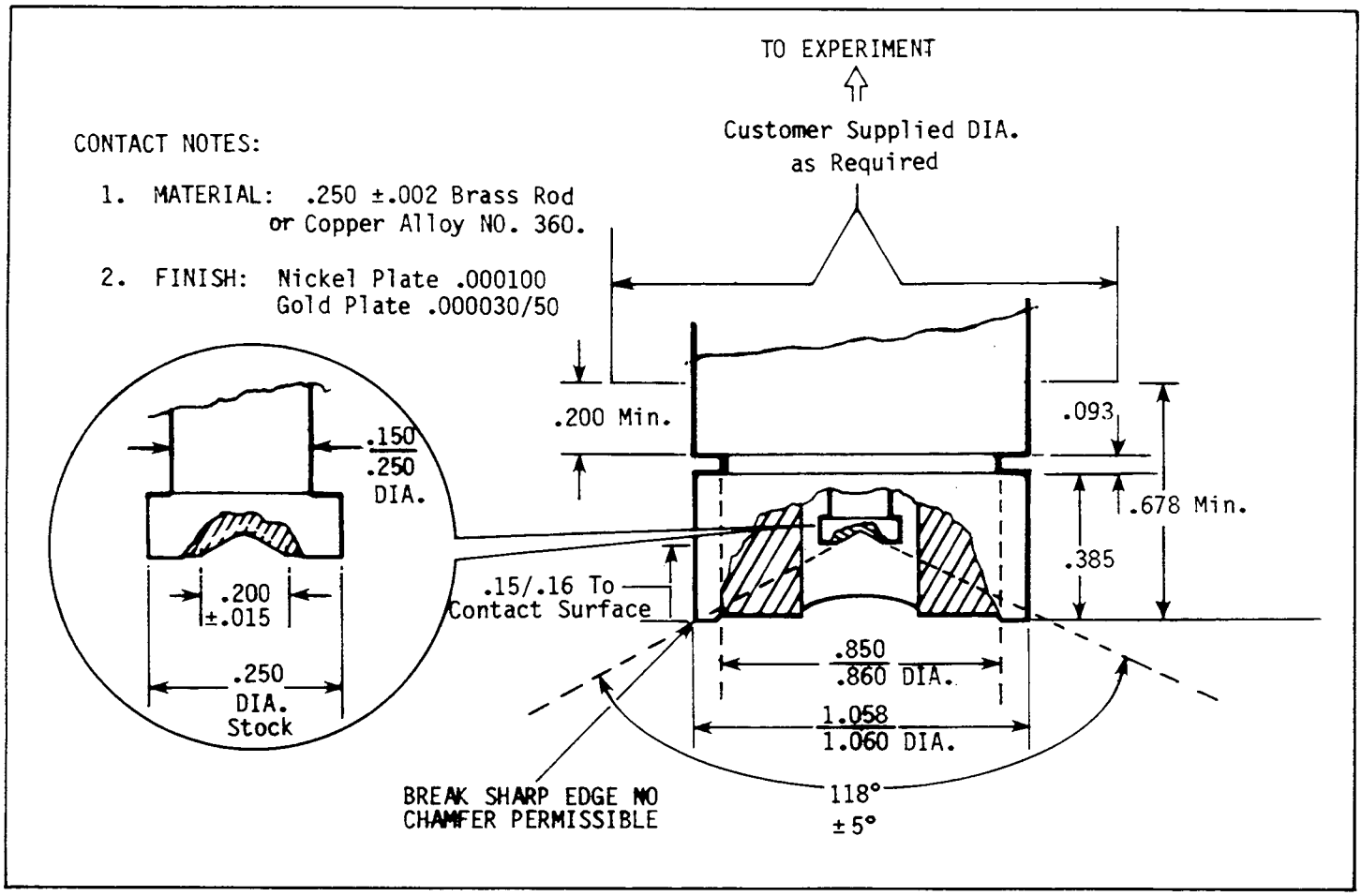


FIGURE 2-4. Required Dimensions for Model 642 Input Connector

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strictly avoided since measurements (especially high impedance) would be adversely affected. In addition, the input slide cover shields the insulated gate of the MOSFET from RF pulses and light, and reduces the effect of background radiation. Care should be taken when connecting a source to insure that the fingers do not come in contact with the sapphire-insulated input connector or that portion of the input adapter which will come in contact with it.

2-32. Radioactivity and High Energy Fields.

2-33. Operating the Model 642 in areas having a high background radiation level will increase its background noise. Shielding of external circuitry will normally be required if the Model 642 is to be operated in the presence of large electric or magnetic fields. For electric fields, the shield of the measurement circuit and leads should be connected together to ground at only one point. This provides a tree configuration, which minimizes ground loops. For magnetic fields, the magnetic shielding should enclose the measuring circuit, the lead wires, and the Model 642 itself.

2-34. GENERAL MEASUREMENT CONSIDERATIONS.

2-35. The following descriptions and instructions are common to all measurements. Standard operating practices are described. Safety precautions are included that describe how to avoid conditions which could result in personal injury or damage to the Model 642. This information should be carefully read and understood before making measurements to insure the safest, most effective use of the Model 642.

2-36. Use of Zero Check.

2-37. The ZERO CHECK pushbutton and ZERO ADJUST knob (shown in Figure 2-1) are located on the mainframe front panel. Momentary or locking action of the ZERO CHECK pushbutton can be obtained, depending on how far the button is pressed. Pressing the pushbutton to IN position shorts the preamplifier feedback elements in current or charge mode and shorts the preamplifier input in voltage mode. During zero check in the voltage function, the input impedance is reduced from $10^{16}\Omega$ to 100KΩ. With the Model 642 in zero check, an input offset will be displayed and can be compensated using the ZERO ADJUST knob. In general, the instrument should be in zero check except when actually making a measurement. It is especially important that the instrument be in zero check when turning power on or changing functions. It is normal to have to readjust zero when changing functions.

2-38. Settling Time.

2-39. Applying power to the Model 642 or subjecting it to other conditions such as an input overload can cause significant charge transfer in the input circuitry and result in higher input bias current and input offset voltage. As a result, depending upon the sensitivity of the required measurement, time may have to be allowed for the input current to decay and the input circuitry to stabilize. As a worst case example, on the order of 24 hours settling time may be required to obtain measurements near the maximum specified sensitivity after an input overload. A list of conditions requiring settling time is given below.

a. Power application or momentary loss of line power.

b. Switching from volts to current or charge function or back again.

c. An input overload.

d. Light, radiation, or RF pulses striking the input circuitry (can be minimized by keeping the input slide cover closed).

e. Making connections at the Model 642 input. (Disturbances caused by making input connections can be minimized by having the instrument in ZERO CHECK.)

2-40. Input Overload and Overrange.

2-41. As previously described, input overloads should be avoided. An input overload can be defined as the condition that exists whenever the preamplifier output in the remote head exceeds approximately ±12 volts. These points are the maximum voltage swing limits of the preamplifier in the remote head. Any further increase in the input signal when these limits are reached will result in a difference in potential between the input node of the MOSFET and the GUARD RING shown in Figure 2-2. As a result, a charge will be injected into all insulators between these two points, dependent on the severity of the input overload. It is the subsequent discharge of these insulators which accounts for long input bias current settling times after severe input overloads. Thus, it can be seen that it is important to detect input overloads in order to limit their duration or severity. One way of detecting an input overload is to monitor the FEEDBACK BNC connector on the remote head. Another way is that an input overload will cause an overrange indication. However, an overrange indication does not necessarily mean that the input is overloaded. An overrange indication will be displayed whenever the range of the A/D converter in the mainframe is exceeded, 19,999 counts for the 0.1 and 1.0 ranges and 10,999 counts for the 10 range. Table 2-3 gives a correlation between the preamplifier output voltage and the overrange indication. The output voltage values listed are the minimums at which an overrange indication would occur. As a further explanation, the following sequence of events would occur when a positive ramping voltage was applied to the Model 642 with 10 range and voltage function selected. An overrange indication will be displayed when the voltage reaches 11 volts. An input overload will exist when the voltage reaches 12 volts. In summary, you can avoid or detect input overloads by either monitoring the feedback output or considering that an input overload may exist whenever an overrange is indicated.

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TABLE 2-3
Correlation of Preamplifier Output to Overrange Indication.

MAINFRAME RANGE	MAINFRAME FUNCTION	OVERRANGE INDICATION	HEAD OUTPUT
0.1	Volts or Current	Flashing .00000	±200mV
0.1	Charge	Flashing .00000	±100mV (2.0000×10^{-12} coul)
1	Volts or Current	Flashing .0000	±2V
1	Charge	Flashing .0000	±1V (2.0000×10^{-11} coul)
10	Volts or Current	Flashing 88.888	±11V
10	Charge	Flashing 88.888	±5.5V (1.1000×10^{-10} coul)

NOTE

An Operational Checkout Procedure is provided in Section 3 of this manual. Upon receipt and set-up of the Model 642, this procedure can be used as an initial checkout procedure to verify that the instrument responds on all ranges and functions, and that all front panel controls operate properly. It can also be used as a periodic confidence test of Model 642 operation. Since Model 642 accuracy is not checked by this procedure, only a minimum amount of commercially available equipment is required.

2-42. MEASUREMENT INSTRUCTIONS.

2-43. The remainder of this section provides measurement instructions and important considerations necessary for using the Model 642 to make sensitivie measurements.

2-44. Voltage Measurements.

2-45. With voltage function selected, the Model 642 has 10^{16} ohms input resistance and will measure voltages from 10 microvolts/digit to ±10.999 volts. The specified accuracies for voltage measurement assume the proper accuation of ZERO CHECK and ZERO adjustment. Guarding must be employed to achieve minimum settling times when making measurements from very high source impedances. This means that the Model 6426 Sapphire-Insulated Test Box, or an equivalent, must be used. Overrange indications are given in Table 2-3. Use the Model 642 to measure voltage as follows:

a. Interconnect the Model 642 Mainframe and Remote Head as directed in Paragraph 2-7.

b. Configure the Model 642 for Line Power Operation (Paragraph 2-9) or Battery Power Operation (Paragraph 2-11).

c. Set up Mainframe Controls. Refer to Figure 2-1 and proceed as follows:

1. Depress ZERO CHECK pushbutton to the latch position. The instrument should be left in ZERO CHECK except during the actual measurement. A 100 kilohm resistor is connected across the electrometer input in ZERO CHECK.

2. Depress POWER pushbutton to ON position.

3. Select volts function and desired range.

NOTE

Zero in voltage function can be adjusted on any range, for that particular range, as long as the instrument is in ZERO CHECK. Also, a ZERO adjustment made on a lower range (more sensitive range) will be valid when the instrument is upranged. However, Zero will have to be readjusted when the instrument is downranged due to the increasing voltage resolution.

d. Grounding Considerations. INPUT LO is to be connected to a ground which is within 30V RMS of the 642 power line ground. This may be done by means of the link connecting INPUT LO and GND on the remote head, or at a ground point external to the 642. If the connection to power line ground is made at a point other than the 642, disconnect the link between INPUT LO and GND terminals on the front of the remote head, and connect the INPUT LO terminal to the external ground.

WARNING

A Shock Hazard is created if "INPUT LO" is connected to a potential of greater than 30V with respect to exposed ground connections of nearby equipment.

e. Installation of the Input Adapter. Open the input slide cover and install the input adapter or sapphire-insulated test box on the remote head. Take care not to touch the sapphire insulator with the fingers or anything that can cause contamination.

f. Connect Source to Electrometer Input.

g. Adjust zero for selected range.

h. Release zero check.

i. Make the measurement by applying the voltage to be measured and reading the number on the display. Since the function in this case is 1V, the measured voltage is read directly on the display. The polarity of the measured input voltage is automatically displayed by the Model 642.

2-46. Current Measurements.

2-47. With a current function selected, the Model 642 preamplifer operates as a feedback current-to-voltage converter. As shown in Figure 2-1, four

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current function pushbuttons provide selection of four current sensitivities, while the three range pushbuttons provide three different resolutions of the selected current function.

2-48. Since the Model 642 uses a feedback ammeter for current measurements, it has a low input voltage burden. Assuming proper adjustment of zero, typical fullscale input voltage burdens are 30μV on the 0.1 range, 150μV on the 1 range and 1.5mV on the 10 range. Overrange indications are given in Table 2-3.

2-49. Use the Model 642 to measure current as follows:

a. Interconnect Model 642 mainframe and remote head as described in Paragraph 2-7.

b. Configure the Model 642 for Line Power Operation (Paragraph 2-9) or Battery Power Operation (Paragraph 2-11).

c. Set-up of Mainframe Controls (refer to Figure 2-1).

1. Depress ZERO CHECK to latch position.

2. Depress POWER pushbutton to ON position.

3. Selected desired current function and range.

4. Select MIN or VAR damping. Maximum damping is obtained by pressing the DAMPING pushbutton to VAR and adjusting the DAMPING LEVEL control on the remote head fully clockwise. Conversely, minimum settling time (fastest response) is obtained by releasing the DAMPING pushbutton to the MIN position. In variable damping, the DAMPING control covers a wide range of noise/bandwidth tradeoffs. Typically, the time constants can be adjusted within a 1.5:1 span on 10^{-8}A function, within a 10:1 span on 10^{-10}A, within a 25:1 span on 10^{-11}A, and within a 100:1 span on 10^{-12}A.

d. Open the INPUT slide cover and install the input adapter or sapphire-insulated test box on the remote head.

NOTE

In general, currents from 10^{-7}A to 10^{-15}A should be measured using the Current function. Currents from 10^{-13}A to 10^{-15}A may be measured using either the Current function or the Charge function. For currents below 10^{-15}A, best performance can be obtained using the Charge function. See Ultra Low Current Measurements in this section for instructions on using the Charge function to measure current.

e. Connect the source to the input adapter.

f. Adjust zero for the selected range.

g. Release ZERO CHECK.

h. Apply the signal and make the measurement by reading the number and decimal point on the display. The current is read directly in units designated by the selected function (10^{-8}, 10^{-10}, 10^{-11} or 10^{-12} ampere). The polarity of the measured current is automatically displayed by the Model 642.

NOTE

Specified accuracies for current measurement assume proper actuation of ZERO CHECK and zero adjustment. The instrument should be in zero check when changing current sensitivities. Adjustment of zero should be accomplished after changing current sensitivity or selecting a lower range (i.e., from 10 to 1 or 1 to 0.1). Specified noise is measured at the 1V/10K count ANALOG OUTPUT with the Model 642 set to 10^{-12}A current function, 0.1 range and maximum damping.

2-50. Charge Measurements.

2-51. In charge function, the Model 642 Preamplifier operates as a charge to voltage converter, integrating the input current with an air capacitor. The 10^{-11}C Charge function pushbutton and three range pushbuttons allow the Model 642 to measure and digitally display charge from 10^{-16}c/digit to 10.999 x 10^{-11} coulombs. Use the Model 642 to measure charge as follows:

a. Connect Model 642 Mainframe and Remote Head as described in Paragraph 2-7.

b. Set up the Model 642 for Line Power Operation (Paragraph 2-9) or Battery Power Operation (Paragraph 2-11).

c. Set up Mainframe controls (refer to Figure 2-1).

1. Depress ZERO CHECK to Latch position.

2. Depress POWER pushbutton to ON position.

3. Depress 10^{-11}C pushbutton and select the desired range.

d. Open the input slide cover and install the input adapter or sapphire-insulated test box on the remote head.

e. Connect the source to the input adapter.

f. Adjust ZERO for selected range.

NOTE

If a lower range is selected later during the measurement, place the instrument in zero check and readjust zero for the lower range.

g. Release ZERO CHECK and record the reading of the digital display. This displayed reading is the small amount of charge error introduced by releasing the ZERO CHECK pushbutton.

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h. Apply the signal and make the measurement by reading the number, decimal point and polarity sign on the display. The digital display reads directly in units (i.e., 10^{-11} coulombs). For the most accurate measurement, subtract the zero check charge error that was recorded in Step g.

NOTE

Specified accuracy for charge measurements assumes proper actuation of ZERO CHECK and ZERO adjustment. The stated input bias current is obtainable after a 12 to 24 hour stabilization time (with no recent history of an input overload). Specified noise is measured at the 1V/10k count ANALOG OUTPUT in the 0.1 range.

2-52. Ultra Low Current Measurements.

2-53. The charge function can be used for measuring currents from 10^{-17}A to 10^{-13}A. The measurement is done by observing the change in charge over a known period of time and calculating the current as follows:

$$I\ (\text{Amperes}) = \frac{\Delta Q\ (\text{coulombs})}{\Delta T\ (\text{seconds})}$$

Either the display or a chart recorder can be used to observe the change in charge. Use the chart recorder to determine input bias current and correct for alpha ionization. Separate procedures are given below.

NOTE

For ultra low current measurements, the Model 6426, or an equivalent, must be used for currents less than 10^{-15}A. The Model 6425, or equivalent, can be used for currents down to 10^{-15}A.

a. Using the digital display.

1. Perform steps a through g of the Charge Measurement procedure.

2. Using a stop watch or other suitable timer, apply the signal to be measured for a known number of seconds. Record the displayed reading at the beginning and end of the time period. The difference between these readings is the change in charge (ΔQ). Calculate the current: $I = \Delta Q \div \Delta T$.

b. Using a chart recorder (refer to Figure 2-5).

1. Perform steps a through f of the Charge Measurement procedure.

2. Connect chart recorder to 1V/10k counts analog output on the mainframe rear panel. Set recorder, span and speed as appropriate for the measurement. Turn on the recorder.

3. With no signal applied, release ZERO CHECK and allow sufficient time to determine the slope of the integrated input bias current on the chart. Calculate current, $I_1 = (\Delta Q_1 - \Delta Q_4)/\Delta T_1$, subtracting the effects of alpha ionization, ΔQ_4.

NOTE

Alpha ionization (ΔQ_4, ΔQ_5) will result in a charge transition similar to that which occurs at release of Z-C.

4. Apply the signal for the desired duration of the measurement. Remove the signal and subtract the effects of alpha ionization ΔQ_5 then calculate current: $I_2 = (\Delta Q_2 - \Delta Q_5)/\Delta T_2$.

5. Let the recorder continue to run to determine the input bias current as in step c. Calculate the current: $I_3 = \Delta Q_3 \div \Delta T_3$.

6. With I_1 equal to I_3, then: $I_{EXP} = I_2 - I_3$.

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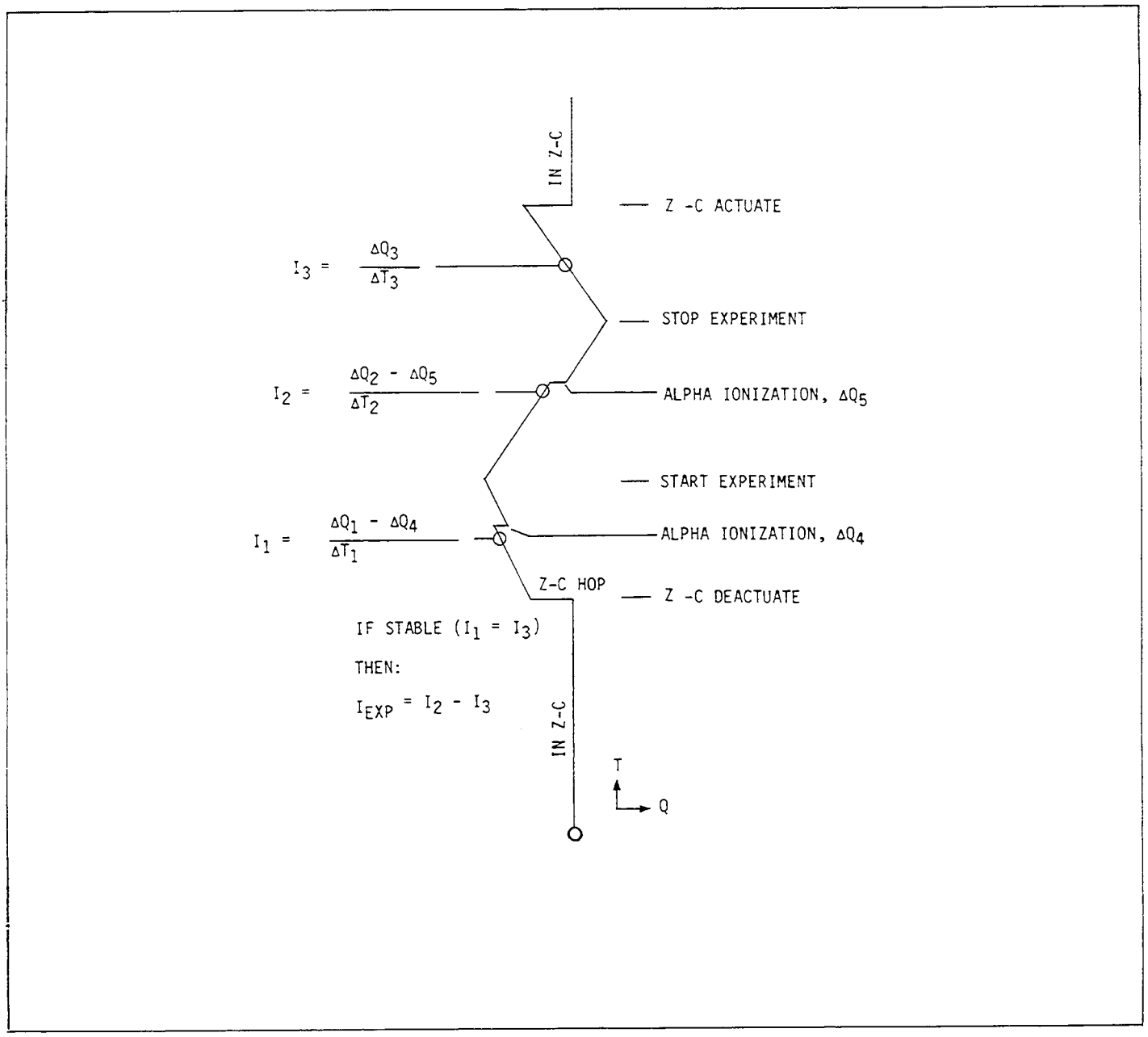


FIGURE 2-5. Current Measurements Using Charge Function and Chart Recorder

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SECTION 3. PERFORMANCE VERIFICATION.

3-1. GENERAL.

3-2. The Operational Checkout and Performance Verification procedures may be performed upon receipt of the instrument to insure that no damage or misadjustment has occurred during transit. It is suggested that the Operational Checkout be performed first since no lengthy settling time is necessary. The Performance Verification may also be performed whenever there is question of the instrument's accuracy and following calibration, if desired.

NOTE

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

3-3. OPERATIONAL CHECKOUT.

3-4. The purpose of this checkout is to verify that the instrument responds on all ranges and functions and that all front panel controls operate properly. This procedure can be performed upon receipt of the instrument before doing the more complex and time consuming Performance Verification.

3-5. Recommended Test Equipment.

3-6. The following equipment is recommended for the Operational Checkout of the Model 642; however, alternate test equipment may be used.

a. Keithley Model 261 Picoampere Source.

b. Keithley Model 6424 BNC Input Adapter.

c. Keithley Model 260 Nanovolt Source.

3-7. Environmental Conditions.

3-8. The Operational Checkout should be performed in the normal operating environment of the 642 which is 20°C to 30°C and up to 70% relative humidity.

3-9. Desiccant Indicator.

3-10. Verify that the desiccant indicator, located on the bottom of the remote head, reads less than 40% relative humidity.

3-11. ZERO CHECK and ZERO ADJUST Operational Check.

a. ZERO CHECK the 642 and set to the 1X RANGE, and VOLTS function.

b. Rotate the ZERO ADJUST knob fully clockwise and note the reading on the display. Now turn the ZERO ADJUST knob fully counterclockwise. The display should go from a positive offset through zero to a negative offset approximately 100 digits from the noted reading (approximately 10mV).

c. With ZERO CHECK still IN, zero the display with the ZERO ADJUST.

d. Push ZERO CHECK IN and OUT several times and make sure the display returns to zero.

3-12. RANGE Selectors Operational Check.

a. ZERO CHECK the 642 and set to the VOLTS function.

b. On the 0.1X RANGE there should be a decimal point followed by five digits.

c. On the 1X RANGE there should be a decimal point followed by four digits.

d. On the 10X RANGE there should be a decimal point followed by three digits.

3-13. VOLTS Operational Check.

a. ZERO CHECK the 642 and set to the 1X RANGE, and VOLTS function.

b. Zero the display using ZERO ADJUST.

c. Using a Keithley Model 260 Nanovolt Source, apply +1 volt to the input of the 642.

d. Release ZERO CHECK and verify a display reading of nominally +1.0000.

e. Repeat the check using negative voltage.

3-14. CURRENT Operational Check.

a. ZERO CHECK the 642 and set to the 1X RANGE, and 10^{-8} CURRENT function.

b. Using a Keithley Model 261 Picoammeter Source apply 10^{-8} amperes to the input of the 642.

c. Release ZERO CHECK and verify a display reading of nominally 1.0000.

d. Repeat the above procedure for the 10^{-10}, 10^{-11}, and 10^{-12} current ranges.

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3-15. CHARGE Operational Check.

3-16. The operation of the CHG function can be checked by integrating the input bias current of the input MOSFET as follows.

a. ZERO CHECK and ZERO ADJUST the 642 and set to the 0.1X RANGE, and CHG function. Make sure the slider cover on the input is closed, as no input is used.

b. Release ZERO CHECK and observe the charge error that is generated, which is typically less than 100 digits on the display.

c. By observing the display for a couple of minutes a small rate of charge change should be realized, indicating that the leakage current of the input MOSFET is being integrated.

3-17. DAMPING Operational Check.

a. ZERO CHECK the 642 and set to the 0.1X RANGE, and CHG function.

b. Using a Keithley Model 261 apply 10^{-11} amperes to the input of the 642.

c. Release ZERO CHECK and observe how quickly the display responds to the input. Also, note how noisy the least two significant digits are.

d. ZERO CHECK the 642 and set to VAR DAMPING. Turn the DAMPING LEVEL adjustment located on the remote head fully clockwise. The 642 is now set for maximum damping.

e. Release ZERO CHECK and it should be observed that the rise time is now much slower. Also, the noise level should be much quieter.

3-18. EXTERNAL FEEDBACK Operational Check.

3-19. Depressing EXTERNAL FEEDBACK should release the VOLTS, CHG, and CURRENT pushbuttons, thus allowing the use of the FEEDBACK BNC connector, located on the remote head, for external feedback circuitry.

3-20. PERFORMANCE VERIFICATION PROCEDURE.

3-21. After it is determined that the 642 is operating properly, the accuracy of the instrument can be verified with the following procedures.

3-22. Recommended Test Equipment.

3-23. Recommended test equipment for performance verification is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy of the alternate test equipment is not at least 5 times better than the instrument specifications, additional allowance must be made in the readings obtained.

TABLE 3-1
Recommended Test Equipment for Performance Verification

ITEM	DESCRIPTION	MFR.	MODEL
A	Sapphire Test Box	Keithley	6426
B	100pF Air Capacitor, 0.1%	Gen Rad	1403B
C	1000pF Air Capacitor, 0.1%	Gen Rad	1403A
D	Strip Chart Recorder	H-P	7132A
E	DC Calibrator	Fluke	341A
F	BNC to Airline Cable	Gen Rad	776-9702
G	BNC Input Adaptor	Keithley	6424
H	Airline Input Adaptor	Keithley	6425
I	100KΩ Resistor, 0.1% (Built into a shielded test fixture)	--	--
J	10MΩ Resistor, 0.1%	--	--
K	Oscilloscope with Differential Amplifier	Tektronix	7623A w/7A22
L	Ramp Generator (Build to specifications contained in Paragraph 6-16)	--	--

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3-24. Initial Conditions.

3-25. Before beginning the verification procedures, the instrument must meet the following conditions:

a. Check the desiccant indicator and make sure the relative humidity inside the remote head is <40%.

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

c. Turn on and ZERO CHECK the Model 642, and allow it to stabilize for four hours.

3-26. DC Voltage Accuracy Verification.

a. Environmental Conditions: 20-30°C, <70% (External) relative humidity.

b. ZERO CHECK the 642 and set for the 10X RANGE, and VOLTS function.

c. Connect the DC Calibrator (Item E, Table 3-1) to the 642 via the Model 6424 BNC Input Adaptor (Item G).

d. Set the DC Calibrator to -0- and ZERO ADJUST the 642 display for a .000 reading.

e. Set the DC Calibrator to +10.000V and release the ZERO CHECK. The display should read +10.000 ±6 digits.

f. ZERO CHECK the 642 and set to the 1X RANGE. Set the DC Calibrator to -0- and ZERO ADJUST the 642 display.

g. Set the DC Calibrator to +1.9000V and release the ZERO CHECK. The 642 display should read +1.9000 ±11 digits.

h. ZERO CHECK the 642 and set to the 0.1X RANGE. Set the DC Calibrator to -0- and ZERO ADJUST the 642 display.

i. Set the DC Calibrator to +0.19000V and release the ZERO CHECK. The display should read +.19000 ±13 digits.

j. Repeat the above procedures using negative voltage.

3-27. DC Current Accuracy Verification.

3-28. In order to accurately verify the accuracy of the 642 current ranges, a current source with an accuracy of 0.2% or better is necessary. Equipment with this level of accuracy is not readily available on the commercial market and may have to be built. Paragraphs 6-12 thru 6-17 in Section 6, detail suggested methods for generating the necessary current levels. If a current source that is not at least 0.2% accurate is to be used, additional allowance must be made in the readings obtained.

a. Environmental Conditions: 25°C ±1°C, <50% relative humidity.

b. ZERO CHECK the 642 and set to the 10X RANGE and the 10^{-8} CURRENT function.

c. Apply 10^{-7}A to the INPUT of the 642, and ZERO ADJUST the display.

d. Release the ZERO CHECK. The display should read 10.000 ±90 digits.

e. Referring to Table 3-2, repeat steps a thru d for the 10^{-10}A, 10^{-11}A and 10^{-12}A current ranges.

TABLE 3-2
Current Checkout Using 0.2% Current Source

642 Settings*			Applied Current	642 Display Reading
Current	Range	Damping		
10^{-8}	10X	MIN	10^{-7}A	10.000 ±90d
10^{-10}	10X	MIN	10^{-9}A	10.000 ±80d
10^{-11}	10X	VAR**	10^{-10}A	10.000 ±110d
10^{-12}	10X	VAR**	10^{-11}A	10.000 ±130d

*ZERO CHECK AND ZERO ADJUST the 642 display prior to making readings on each current range.

**See Step 4 of Paragraph 2-49c.

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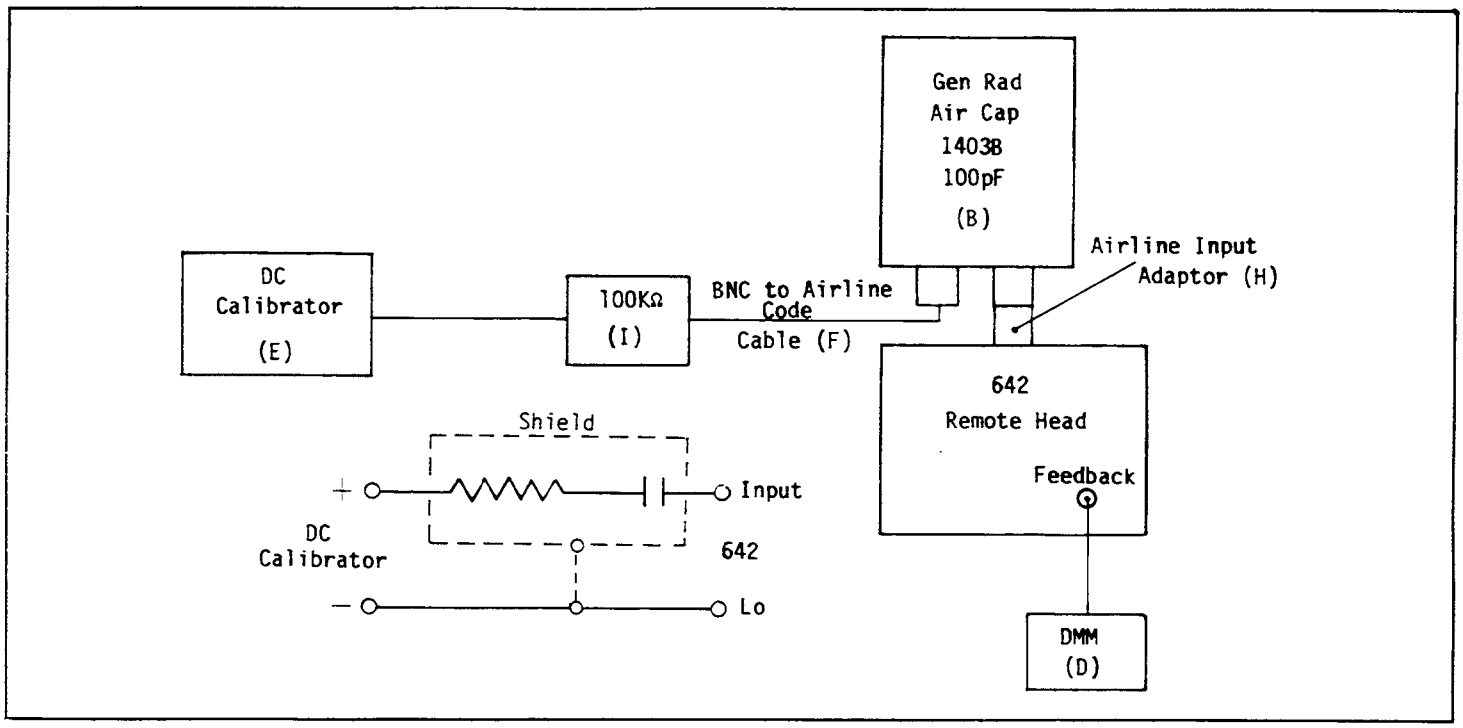


FIGURE 3-1. Circuit for Coulombs Accuracy Verification

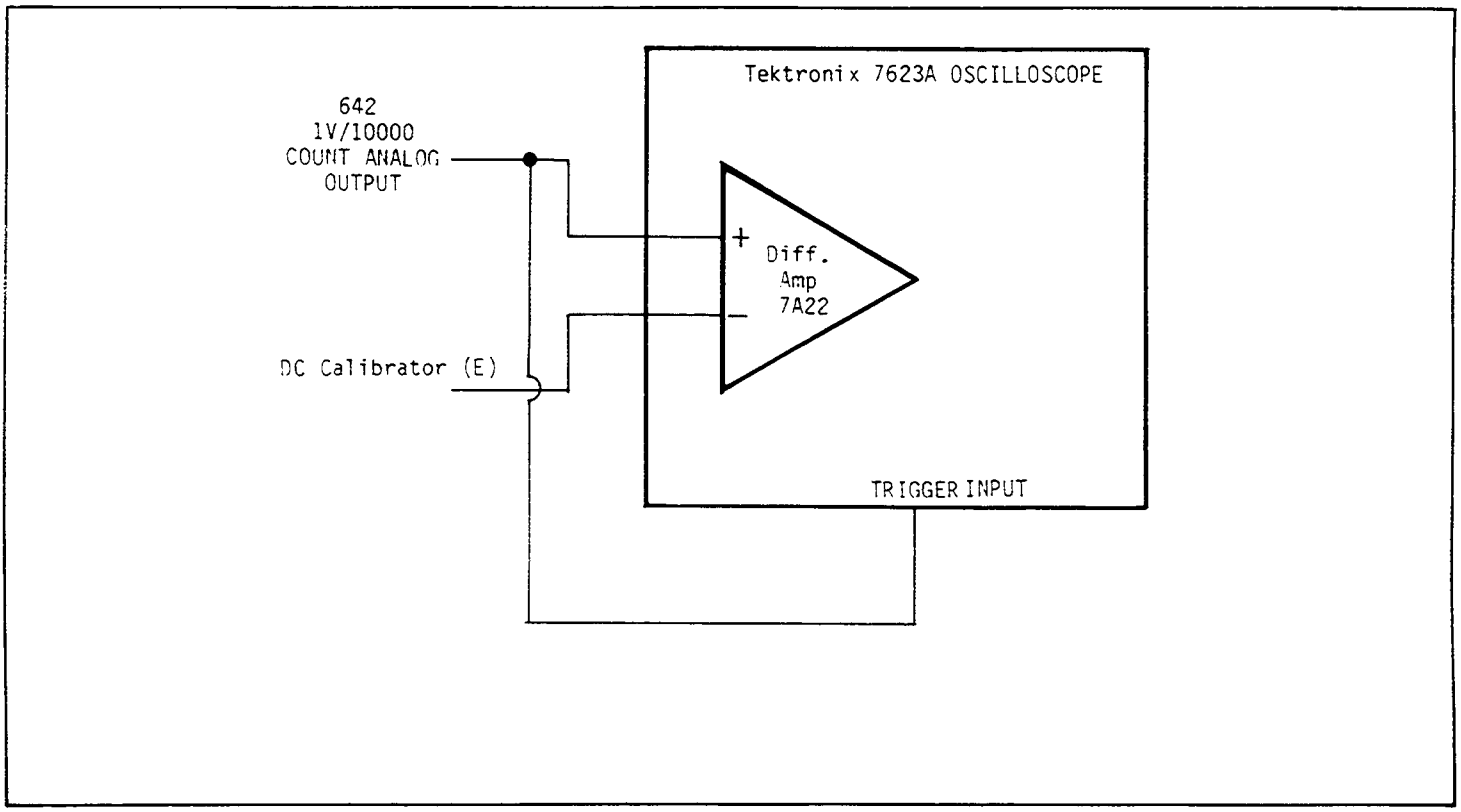


FIGURE 3-2. Using a Scope with a Differential Amplifier to Measure 1% Settling Time

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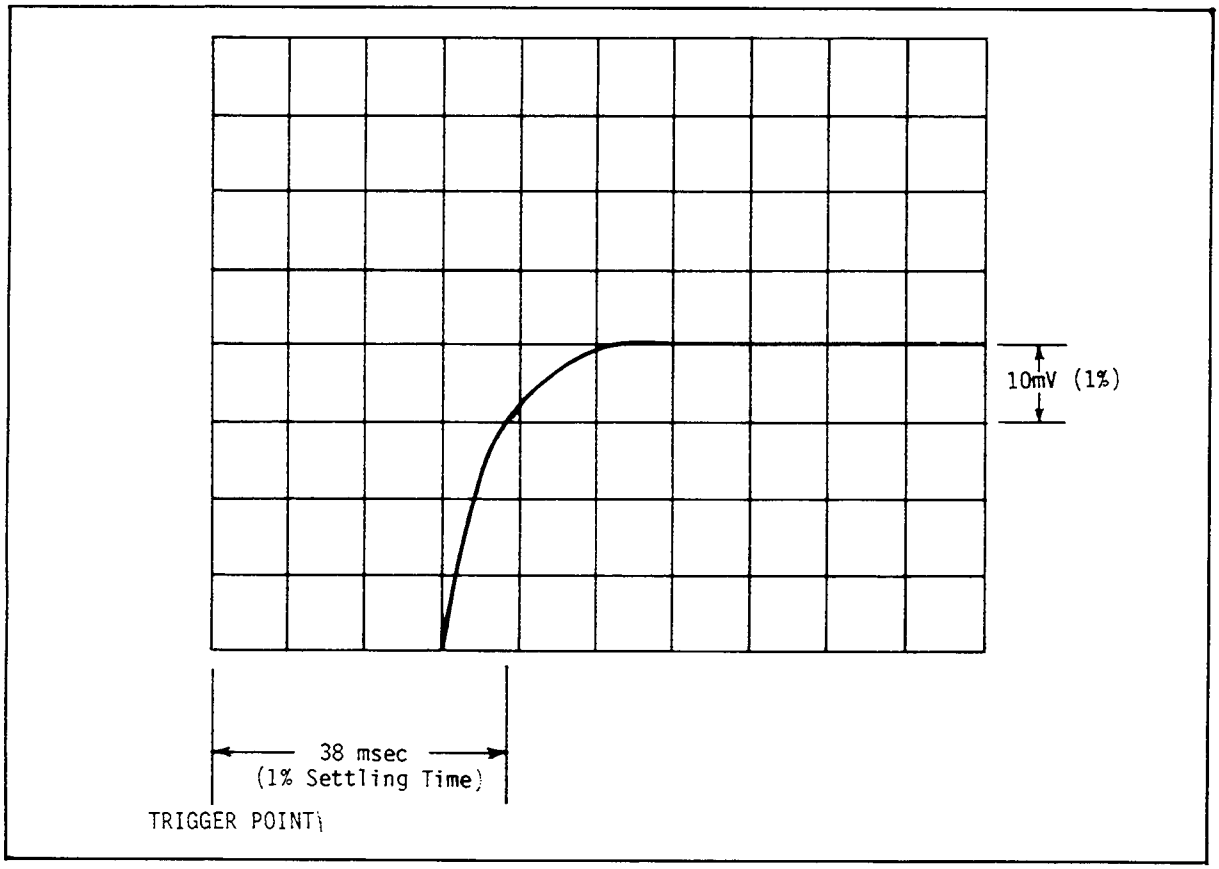


FIGURE 3-3. Typical Scope Display for 1% Settling Time on the 10^{-8}A Range

3-29. Coulombs Accuracy Verification.

a. Environmental Condition: 25°C ±1°C, <50% relative humidity.

b. ZERO CHECK the 642 and set to the 10X RANGE and CHG function.

c. Set up the circuit shown in Figure 3-1 using the equipment listed in Table 3-1.

d. With the DC Calibrator (E) set to -0- volts, ZERO ADJUST the display for a .000 reading.

e. Release the ZERO CHECK and record the 642 display reading, which is the zero check hop.

f. Step the DC Calibrator to a +1.0000V output and record the 642 display reading.

g. Compute the difference between the two readings, which should be +10.000 ±25 digits.

3-30. 1% Settling Time Accuracy Verification.

3-31. The 1% Settling Time can be checked by using an oscilloscope which has a differential amplifier. Input (such as tektronix 7A22 in a 7000 Series Mainframe).

a. ZERO CHECK the 642 and set to the 10X RANGE, 10^{-8} CURRENT function and MIN DAMPING.

b. Connect the Oscilloscope (K) to the 1V/10000 COUNT ANALOG OUTPUT of the 642 and to the DC Calibrator (E) as shown in Figure 3-2.

c. Set the Differential Amplifier of the Scope for a gain of 10mv/div, and 10ms/div, and supply 10^{-7}A to the INPUT of the 642.

d. With 10^{-7}A supplied to the input release ZERO CHECK and adjust the oscilloscope trigger level such that the trace starts at the beginning of the risetime response.

e. Adjust horizontal position control so that beginning of trace aligns with left edge of the display graticule.

f. Use the DC Calibrator to "Offset" the display to permit viewing of the settling of the response to its final value.

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TABLE 3-3
1% Settling Time

642 SETTINGS			Applied	"0" SCOPE SETTINGS		1% SETTLING
Range	Current	Damping	Current	Volts/Div	Time/Div	TIME
10X	10^{-8}	MIN	10^{-7}A	10mV	10ms	≤40ms
10X	10^{-10}	MIN	10^{-9}A	10mV	20ms	≤100ms
10X	10^{-11}	MIN	10^{-10}A	10mV	100ms	≤400ms
10X	10^{-12}	MIN	10^{-11}A	10mV	200ms	≤1sec

g. Release the ZERO CHECK and verify that the 1% Settling Time on the scope is ≤40ms (see Figure 3-3).

h. Repeat steps a thru g for 10^{-10}A, 10^{-11}A, and 10^{-12}A current ranges using Table 3-3 as a guide.

3-32. Input Bias Current Verification.

3-33. Perform the following procedures to verify the low input bias current integrity of the input MOSFET.

a. Environmental Conditions: Ambient temperature 25° ±1°C, ambient relative humidity <50% and internal remote head relative humidity <40%, as displayed by the desiccant indicator.

b. ZERO CHECK the 642 and set to the 1X RANGE, CHARGE function and MIN DAMPING.

c. Remove the connector from the 642 INPUT and close the slider cover, as no inputs are used.

d. Allow the 642 to settle for a 24-hour time period. Make sure that the 642 controls are not tampered with, or that power to the instrument is not interrupted during this settling period.

e. Connect the Strip Chart Recorder (D) to the 1V/10,000 COUNT ANALOG OUTPUT and set the recorder to provide 10min/inch and 1mV/inch sensitivity.

f. Release the ZERO CHECK and allow the 642 to self-integrate its own bias current for 30 minutes to one hour.

g. Compute the input current using data taken from the strip chart, using the following formula:

$$I = \frac{\Delta Q}{\Delta T}$$

where: I = Input bias current in amperes
ΔQ = Measured charge
10,000 counts = 1×10^{-11} coul
1mV (=1 inch)= 10^{-14} coul
ΔT = Change in time in seconds

h. The computed input bias current should be <5 x 10^{-17} amperes. A higher current would indicate input MOSFET damage or contamination within the remote head.

NOTE

The zero check hop and any α pulse ionization should not be considered in ΔQ. See Section 2-49.

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SECTION 4. ACCESSORIES

4-1. GENERAL.

4-2. This section describes the various accessories and options for use with the Model 642 Electrometer.

4-3. MODEL 6421 DESICCANT PAPER REFILL.

4-4. This is a refill desiccant paper pack. One piece at a time may be installed in the remote head as needed. Each of the three pieces is individually packaged in its own moisture resistant bag. The desiccant paper helps to hold down humidity in the remote head. See Section 6 of this manual for desiccant paper replacement instructions.

4-5. MODEL 6422 ISOLATED BCD OUTPUT.

4-6. The Model 6422 Isolated BCD Output converts the displayed reading to an electrically isolated, latched, and buffered parallel BCD format. Additional data lines include Sign, Overrange, and Busy. To install and/or operate the Model 6422, refer to the Instruction Manual, Model 1792/6422 Isolated BCD Output (Keithley Part No. 30155).

NOTE

Models 6422, 6423, and 6428 are mutually exclusive. The use of one precludes the use of the others.

4-7. MODEL 6423 ISOLATED IEEE-488 OUTPUT.

4-8. MODEL 6423 provides the logic and control functions necessary to interface the Model 642 to an IEEE Standard 488-1978 Bus. The Model 6423 is compatible with the Model 642 Electrometer, Serial Number 53400 and above.

To install and/or operate the Model 6423, refer to the Instruction Manual, Model 1793/6423 IEEE Standard 488 Output (Keithley Part No. 30535).

4-9. MODEL 6424 BNC INPUT ADAPTER (FIGURE 4-1).

4-10. The Model 6424 adapts the Model 642 input for use with a coaxial cable having a male BNC connector. When used with low noise coaxial cable such as Keithley part number SC-9, the Model 6424 can be used for measurements down to 10^{-12} amperes. The Model 6424 can also be used for unguarded voltage measurements.

To Use: Ensure that ZERO CHECK is IN if power is applied to the Model 642. Pull back the input slide cover and insert the Model 6424 into the adapter cavity on the remote head. Take care not to touch the sapphire insulator with the fingers or with anything that can cause contamination. Release the input slide cover gently until it makes contact with the Model 6424. Connect the source to be measured to the female BNC connector on the Model 6424.

Specifications: Insulation resistance is greater than 10^{12} ohms. Use of the Model 6424 is suitable for input currents down to 10^{-12} amperes.

4-11. MODEL 6425 GENRAD GR874® AIRLINE INPUT ADAPTER (FIGURE 4-1).

4-12. This accessory adapts the Model 642 input for use with General Radio 874® series coaxial accessories. The Model 6425 can be used for currents down to 10^{-15} ampere and for unguarded voltage measurements.

To Use: Install the Model 6425 in the same manner as the Model 6424. Connect the source to be measured to the Air Line connector on the Model 6425.

Specifications: Insulation resistance is greater than 10^{14} ohms. Use of the Model 6425 is suitable for currents down to 10^{-15} amperes.

4-13. MODEL 6426 SAPPHIRE-INSULATED TEST BOX.

4-14. The Model 6426, shown in Figure 4-1, provides the means for making input connections to the Model 642, and permits its use to the full sensitivity of 10^{-17} amperes. It has a sapphire-insulated INPUT terminal to maintain a 10^{16} input impedance, and has provisions for shielding the source, guarding, and connecting both feedback elements and an external source. The Model 6426 is useful for testing semiconductor leakage and high resistance measurements of small geometry parts. The following paragraphs provide the performance specifications and instructions for using the Model 6426.

4-15. Installation of the Model 6426.

4-16. Ensure that ZERO CHECK is IN if power is applied to Model 642. Open the INPUT slide cover and install the Model 6426 on the remote head. Take care not to touch either sapphire insulator with the fingers or anything which could contaminate them. Connect the black wire to the INPUT LO binding post on the remote head. It is important to note that the cover should be kept closed on the Model 6426 except when making connections to the circuit to be tested. This is necessary to prevent contamination of the sapphire insulator and to prevent light, radiation, etc. from striking the input circuitry.

4-17. Connections for Voltage Measurements.

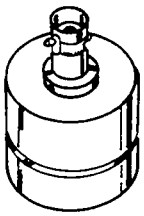
4-18. With the Model 642 in Zero Check, connect the source to the Model 6426 as follows:

a. Connect source high to the sapphire-insulated INPUT post on the Model 6426.

b. Connect source low to INPUT LO binding post on the Model 6426.

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MODEL 6424 BNC ADAPTER



MODEL 6425 GENRAD GR874
AIR LINE INPUT ADAPTER



MODEL 6426 SAPPHIRE -INSULATED TEST BOX

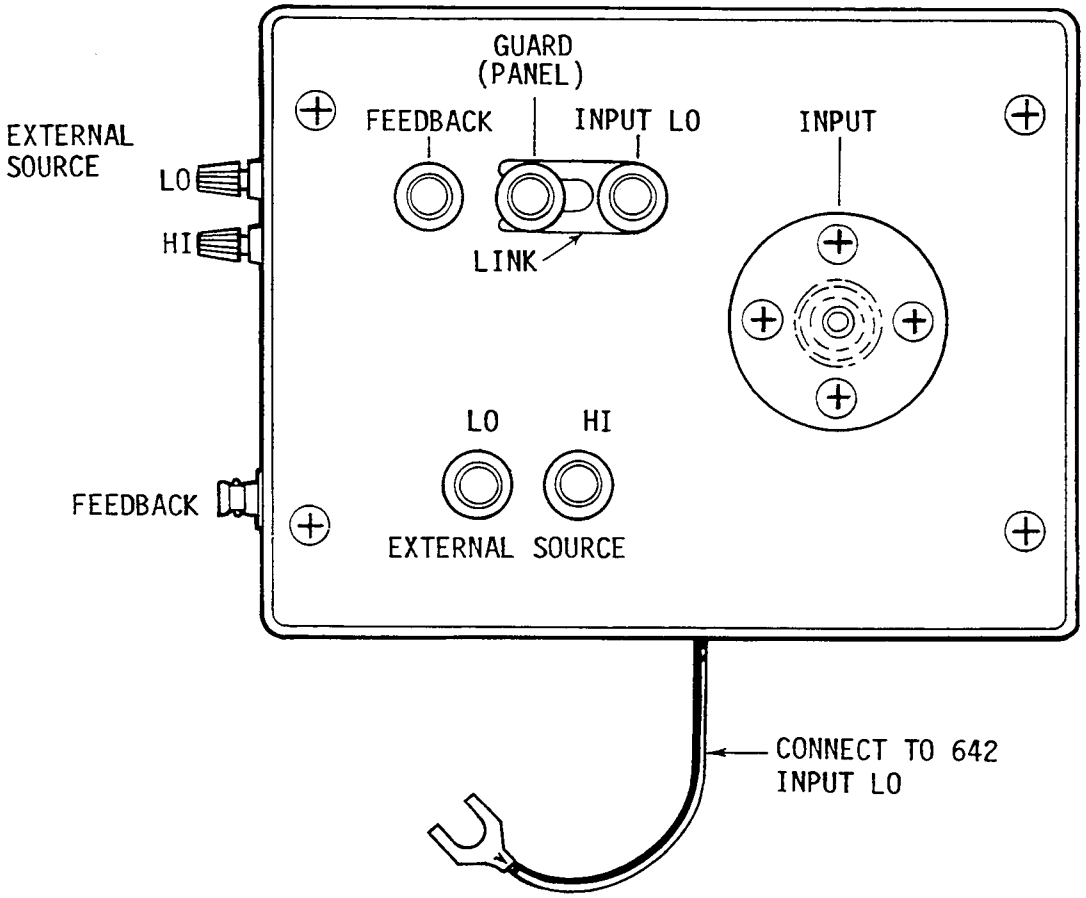


FIGURE 4-1. Optional Input Adapter

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c. Employ guarding by connecting the shorting link between the GUARD and FEEDBACK binding posts. Connect the supplied BNC-to-BNC coaxial cable between the FEEDBACK connectors on the Model 6426 and the remote head.

4-19. Connections for Current/Charge Measurements.

4-20. With the Model 642 in Zero Check, connect the source to the Model 6426 as follows:

a. Connect source high to the sapphire-insulated INPUT post on the Model 6426.

b. Connect source low to the INPUT LO binding post.

c. Connect link between GUARD and INPUT LO binding post.

4-21. Connections for using External Feedback Components.

4-22. With the Model 642 in Zero Check, connect a user supplied external feedback component and the source to the Model 6426 as follows:

a. Connect the external capacitor or feedback resistor between the FEEDBACK binding post and the sapphire-insulated INPUT post on the Model 6426.

b. Connect source high to the sapphire-insulated INPUT post.

c. Connect source low to INPUT LO binding post.

d. Connect the supplied BNC to BNC coaxial cable between the FEEDBACK connectors on the Model 6426 and the remote head.

4-23. Performance Specifications of Model 6426.

a. Insulation Resistance. The input node insulation resistance will be in excess of 10^{16} ohms.

b. Input Current Suitability. The 6426 sapphire test box will permit use of the 642 electrometer to its full sensitivity of 10^{-17} amperes.

c. External Source Capabilities. The 6426 sapphire test box external source connections can be used with voltage sources up to 42V peak and current sources of up to 1 amp. Note that voltage potentials in excess of 10V can cause air ionization which could be detected by the instrument as an input current.

4-24. MODEL 6427-10. 10-FOOT INTERCONNECT CABLE.

4-25. The Model 6427-10 is a 10-foot interconnect cable. This connects the mainframe to the remote head in applications requiring their separation up to 10 feet.

4-26. MODEL 6427-50. 50-FOOT INTERCONNECT CABLE WITH REMOTE SUPPLY.

4-27. The Model 6427-50 is a 50-foot interconnect cable with a Remote Supply. The Remote Supply delivers the necessary power to the Remote Head regardless of the voltage drop across the long cable. The Remote Supply is powered from a 115V or 230V AC line. Operating instructions for the Model 6427-50 are included in the packing list that accompanies the Model 6427-50. The Remote Supply powers the +6 volt supply to make sure it has adequate power to drive the relay circuitry.

4-28. MODEL 6427-150. 150-FOOT INTERCONNECT CABLE WITH REMOTE SUPPLY.

4-29. The Model 6427-150 is the same as the Model 6427-50 except that the 6427-150 has a 150-foot cable instead of a 50-foot cable. It has a Remote Supply and operates the same as the Model 6427-50.

4-30. MODEL 6428 BATTERY ADAPTER.

4-31. The optional Model 6428 Battery Adapter permits operation of the Model 642 from an external 12 volt lead acid battery. The battery adapter provides high and low voltage cutouts and reverse polarity protection. The following paragraphs provide installation instructions for the battery adapter and describe important considerations for operating the Model 642 on battery power.

NOTE

Models 6422, 6423 and 6428 are mutually exclusive. The use of one precludes the use of the others.

a. Battery Adapter Installation. The battery adapter components are mounted on a plate which fits on the rear panel of the mainframe. With the plate installed, the input protection fuse and the two 5-way binding posts for connecting the battery are accessible from the rear panel of the mainframe. Electrical connections to the Model 642 are made by a plug which mates with a receptacle on the mainframe mother board. Refer to Figure 4-2 and install the battery adapter as follows.

WARNING

Disconnect the line cord before removing the mainframe top cover

1. Turn off the power and disconnect the line cord.

2. Remove the four attaching screws and remove the top cover.

3. Remove the two screws and remove the plate on the rear panel of the mainframe.

4. Insert the battery adapter circuit board into the opening on the rear panel and install the spacer with the 6-32 × 2-1/4" slot-head screw furnished.

5. Attach the mounting plate to the rear panel with the two 6-32 × 1/4" Phillips Head screws provided.

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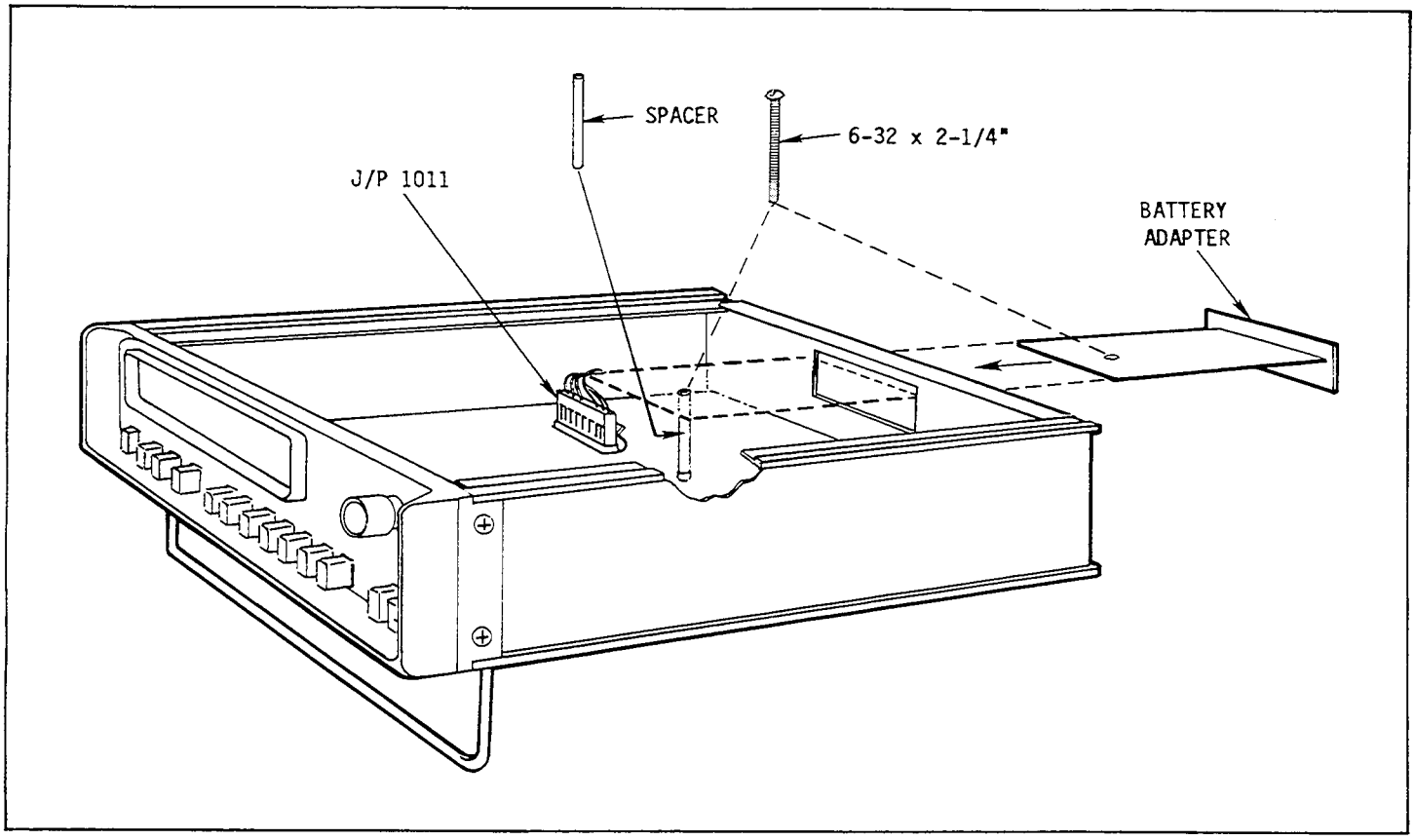


FIGURE 4-2. Model 6428 Battery Adapter Installation

6. Connect plug J1011 to P1011 on the mother board.

7. Reinstall mainframe top cover.

8. This completes the installation of the battery adapter. Select battery capacity and operate in accordance with the following instructions.

9. NOTE: The NEGATIVE battery connection is input common.

b. Selection of Battery and Wiring. The wiring used from the external battery to the battery adapter should be AWG 16 gauge or greater current capacity. AWG 16 is suitable for runs up to six feet. The maximum input current to the Model 6428 is 1-1/4 amperes and the minimum recommended battery capacity is 10 ampere hours, which will provide approximately 8 hours of operation. The actual selection of battery capacity is left to the user as it will depend on whether the Model 642 is to be operated on battery only or whether a battery charging system will be used. Battery charging is not furnished by Keithley but recommendations are included in the Set-Up to Provide Stand-by Power discussion (Paragraph d).

c. Voltage Cutouts and Reverse Polarity Protection. High and low voltage cutouts are incorporated into the Model 6428 in order to limit power dissipation of the 642 mainframe at one extreme and to prevent erratic operation on the other. Normal operation can be expected as long as the input voltage is between 10.5 volts and 15 volts. When a voltage outside of this range is applied shut-down of power to the Model 642 can be expected. The specified limits where power shutdown is assured are 9 volts minimum and 17 volts maximum. Reverse input polarity protection is provided by a high current capacity diode which is connected across the input terminals of the battery adapter such that it is normally reversed biased. If the input leads to the battery adapter are inadvertantly reversed, the diode will be forward biased and the input protection fuse will open.

d. Set-Up to Provide Stand-by Power. As described in the General Measurement Considerations (Section 2), up to 24 hours settling time may be required after power turn on to obtain measurements to the maximum sensitivity specified. This same settling time would also be required for a momentary interruption of power to the Model 642. Therefore, if the experiments to be performed require making measurements near the sensitivity limits of the Model 642 and if a 24 hour settling time would be disruptive, it is recommended that a stand-by power system be used to prevent power interruption.

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The recommended configuration to insure continuous power to the Model 642 consists of the battery adapter, an external battery and a battery charging circuit operating from line power. A constant current type charger is recommended. A constant current source should provide the maximum input current required for the 642 (1.25A) plus the maximum continuous charge current recommended by the battery manufacturer to maintain the battery at full charge. Then, if line current is interrupted, the battery can take the full load of the 642 and prevent interruption of power for the time defined by its full rated capacity. The only maintenance required for this type of installation would be a periodic check of the fluid level in the battery per the manufacturer's instructions.

In summary, the foregoing configuration with the Model 642 line cord disconnected is the only one recommended for insuring that power to the Model 642 is not interrupted. A combination using Model 642 line power, the battery adapter, and an external battery simultaneously is not recommended because it is not possible to assure that Model 642 power would be supplied by the line, rather than the battery.

4-32. MODEL 4801 INPUT CABLE.

4-33. The Model 4801 is a 4 foot BNC to BNC low noise input cable.

NOTE

Both the 4801 and 4803 are suitable for measurements down to approximately 10^{-12}A as well as unguarded voltage measurements.

4-34. MODEL 4803 LOW NOISE CABLE KIT.

4-35. The Model 4803 Low Noise Cable Kit includes 50 feet of low noise coaxial cable, 10 BNC male connectors and 5 BNC female chassis mount connectors.

NOTE

Both the 4801 and 4803 are suitable for measurements down to approximately 10^{-12}A as well as unguarded voltage measurements.

4-36. RACK MOUNTING.

4-37. Two rack mounting kits are available to mount the Model 642 mainframe into a NEMA standard 19-inch rack or cabinet. Since the mainframe is half-rack size, the Model 1007 Dual Rack Mounting Kit permits mounting it side-by-side with another 3-1/2 inch half-rack instrument. The Model 2000 Single Rack Mounting Kit adapts the mainframe for installation in half the rack and a blank panel is furnished for the other half. If rack or cabinet mounting is desired, order the applicable rack mounting kit and install the mainframe in accordance with the instructions shipped with the kit.

4-38. MODEL 6900 6-1/2 Digit DMM.

4-39. The Model 6900 extends the measurement capabilities of the Model 642 by allowing 6-1/2 digit resolution when monitoring the most accurate output, the FEEDBACK output of the remote head. The Model 6900 is also systems compatible and can interface with other instrumentation utilizing the IEEE Standard Interface Bus. To interface with the IEEE Standard Interface Bus the Model 6900 needs two options. Option 50 Remote Programming and Option 55 GPIB which is the General Purpose Interface Bus.

To Operate: Connect the FEEDBACK output of the Remote Head to the input of the Model 6900. Use a BNC to BANANA plug cable (not supplied).

For complete operating instructions refer to the Model 6900 Instruction Manual (Keithley Part No. 28603).

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SECTION 5. THEORY OF OPERATION

5-1. GENERAL.

5-2. This section contains block diagram and circuit descriptions for the Model 642 Electrometer and the Model 6428 Battery Adapter. An overall block diagram is provided in Figure 5-1 in this section. Circuit descriptions are keyed to the Schematic diagrams contained in Section 7.

5-3. BLOCK DIAGRAM ANALYSIS.

5-4. The Model 642 Electrometer is partitioned into a remote head, mainframe and interconnect cable as shown in Figure 5-1.

5-5. Contained in the remote head are the special low input current MOSFET, its buffer amplifier and the required feedback circuitry necessary to generate all the instrument measurement functions. In addition, the remote head contains the high impedance switching actuators and input offset voltage compensation circuitry. Operator controls at the remote head are limited to a damping level control and two binding posts which permit, with a shorting link removed, operation with a common mode input voltage. (Recall that INPUT LO must be maintained within 30 volts RMS of power line ground for safety). A feedback output, which is the remote head output signal, is also provided at a BNC connector. All other controls as well as electrical power are provided from the mainframe via an interconnect cable. Signal input is via a special slide covered connector located on top of the remote head. The remote head is electrically alterable to perform two basic functions. First, in one configuration it is an ultra-high input impedance voltage buffer. In the second arrangement it becomes a current-to-voltage or charge-to-voltage converter. This output voltage is then further processed by the mainframe.

5-6. Contained in the mainframe are the power supply for both the head and mainframe, a scaling amplifier to provide the 0.1, 1, and 10 ranges and an analog-to-digital converter along with its digital LED display. Additionally, front panel operator controls establish instrument function for both mainframe and remote head. Analog outputs are also provided and a power adapter option is available which will permit operation from an external 12 volt battery in addition to the AC power line. The mainframe processes the head output signal, providing three voltage ranges to a 4-1/2 digit, two volt A/D converter and to an analog output. This scaled signal is also fed to the second analog output after being buffered by an amplifier with a gain of 100.

5-7. Linking both mainframe and remote head is a four foot interconnect cable. Connection is made from the mainframe rear panel to the remote head front panel. In addition to the standard four foot cable supplied with each Model 642, optional 10 foot, 50 foot and 150 foot interconnect cables are available. See Models 6427-10, 6427-50 and 6427-150 described in Section 4.

5-8. DETAILED THEORY OF OPERATION

5-9. Detailed circuit descriptions for the Model 642 Electrometer and 6428 Battery Adapter are given in the following paragraphs. These descriptions are referenced to the Schematic Diagrams contained in Section 7. The schematics which apply to the 642 Electrometer are 29653E (mainframe) and 29654E (remote head). Schematic 29968D describes the Model 6428. These drawings should be referred to during the following discussions of circuit operation. The remote head circuits are treated first, followed by the mainframe and battery adapter circuits.

5-10. REMOTE HEAD CIRCUIT DESCRIPTION.

5-11. General.

5-12. As previously mentioned, the remote head portion of the instrument can be configured as a high impedance voltage follower or a feedback amps/coulombs converter.

5-13. The remote head is mechanically partitioned with most of the electronic components located on a large PC board at the bottom of the structure. The input MOSFET (Q201) and temperature compensating diode (CR201) are located on a separate board which mounts to the side of the input guard tube. All of the feedback elements, C101 thru C104 and R122 thru R124, along with zero-check, are mounted radially around the input guard tube on two levels above the main printed circuit board. Along with these elements are the relay actuators, K102 thru K107, with wiring running down the outside of the structure to the main PC board. Contact to the input node is made through holes in the input guard tube by contact leads which are manipulated by the relay actuators.

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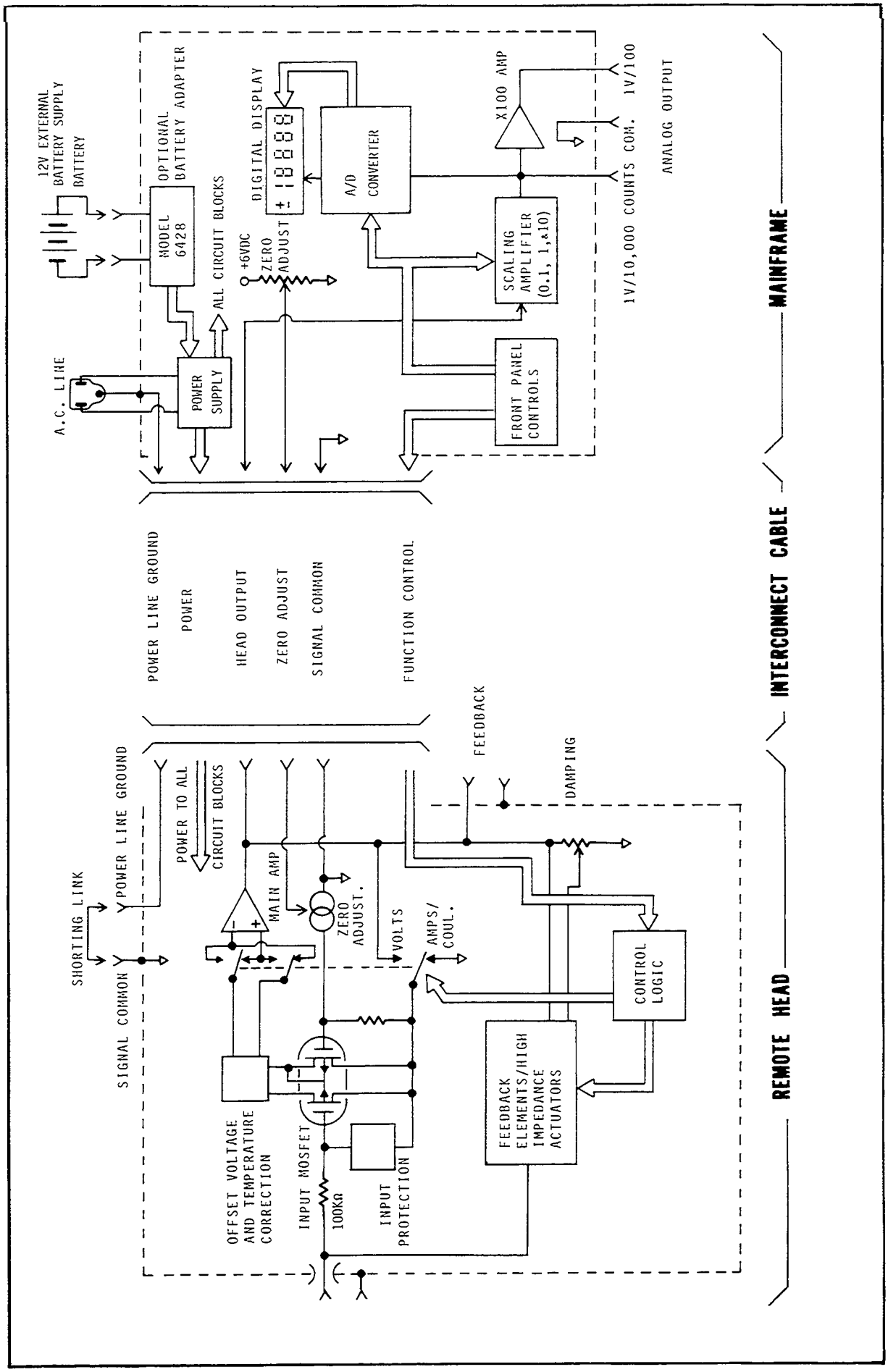


FIGURE 5-1. Model 642 Electrometer Block Diagram

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5-14. Input MOSFET and Current Sources.

5-15. Q201 is the special low leakage MOSFET pair which serves as the active input device. The sources of this MOSFET pair are supplied by constant current sources comprised of Q101, R106 thru R110, CR101, CR105, and VR104. VR104 provides a voltage reference which is scaled by R108 and R109 to drive the bases of Q101. The level of the constant current (approximately 500μA) is established by this voltage across R106 and R107. CR101 and CR105 compensate the reference voltage to offset the change, due to temperature, in Q101 base to emitter voltage drop.

5-16. Input MOSFET Temperature and Offset Voltage Compensation.

5-17. The input MOSFET is driven by the above current sources through two circuit blocks which serve to 1) compensate for offset voltage temperature variations, and 2) cancel out initial offset voltage. These circuit functions are situated between Q201 and operational amplifier U101.

5-18. The first consists of CR201, R111 thru R116, positions 6 thru 10 of S101 and S102. Diode CR201 is positioned along with Q201 on the separate FET PC board and effectively monitors its environmental temperature. It is forward biased by one of the constant current sources and its forward voltage temperature coefficient used to cancel the voltage offset temperature variation of Q201. The diode T.C. (temperature coefficient) is scaled down by R111 thru R116. Switch contacts 6 thru 10 of S101 set the level of this scaling to meet the compensation requirements of individual MOSFETs. Since the diode T.C. is always one polarity, S102 is required to transpose this circuit block between the two sources of Q201 in order to compensate for either polarity of compensation required by Q201.

5-19. The second circuit function consisting of R117 thru R121, R136 and positions 1 thru 5 of S101 serves to cancel out not only the initial offset voltage of Q201, but also the scaled down forward voltage of CR201. Voltage levels are introduced by opening a contact (1 thru 5) of S101. The constant current supplying the sources of Q201 thus generate a constant voltage across the unshorted resistors.

5-20. The configuration for both of these compensation circuit blocks will be unique for each MOSFET (Q201) and will be predetermined by testing the MOSFET in accordance with the established factory procedure. The MOSFET and compensation diode (CR201) are located on a separate PC board from the balance of the circuitry. Thus, when a particular MOSFET is installed, S101 and S102 are manually programmed for it in compliance with the results from this test procedure.

5-21. Zero Adjust.

5-22. Also included on the MOSFET PC board is resistor R201 which is driven by a voltage controlled current source comprised of U102, R140 thru R144, and C108. A "zero adjust" voltage (0 to approximately 6Vdc) is generated in the mainframe and supplied to this circuit via the interconnect cable. The circuitry converts this voltage source to a current source to drive R201 which in turn converts it back to a voltage which appears as an offset voltage at Q201. In this manner the mainframe front panel "zero adjust" control varies the input offset voltage at Q201 over a small range. This control is used to adjust out any residual offset voltage missed by the compensation networks previously mentioned and to permit compensation for time drift in this parameter. A current source configuration is required since Q201 is "boot-strapped" in the voltage measurement instrument operation. C108 provides noise rejection for the voltage controlled current source. R202 prevents the gate of Q201 from being "uncommitted" prior to installation in the remote head. After installation it is effectively shorted by K109.

5-23. Main Amplifier.

5-24. Operational amplifier U101 forms the gain block of the remote head. Buffered by the MOSFET pair Q201 and configured with various feedback circuits, it performs the essential function of the remote head. The positive power supply to both U101 and U102 is derived from R145, VR101, and C105 from the +24V power supply. +24V is required by the remote head to provide "head-room" for the current sources which in turn drive the input MOSFET pair. R137 thru R139 form an offset voltage nulling circuit for U101. A shorting socket (pin 1 to pin 2 and pin 3 to pin 4) placed in P1027 will permit this adjustment independently of the MOSFET and its compensation networks. C114 and C115 provide frequency compensation around U101. VR102 and VR103 provide a ±16V output voltage clamp on the output of U101.

5-25. Mode Selection.

5-26. As previously mentioned the remote head operates in two basic modes, a "bootstrapped" voltage buffer and a "feedback" amps/coulombs converter. The circuit is configured into either of these modes by relay K109. Energized by circuitry consisting of CR102, Q102, and R149 and a voltage command from the mainframe, the contacts of K109 orient the circuitry for voltage or current/charge measurement modes. The apparent duplication of contacts K109C and K109B are required to insure that the drains of MOSFET Q201 are connected to analog power ground while R201 and the MOSFET gate are connected to signal common. The connection between these is made at the mainframe. Also since K109B contacts carry only the "zero adjust" current (50μA max.) no extra offset voltage will be generated by the total drain current (approximately 1mA) acting on the contact resistance.

5-27. Feedback Network.

5-28. Feedback elements used in the current/charge mode consist of air capacitor C101 and high meg resistors R122 thru R125. The resistances convert an input current to a voltage level while the air capacitor time integrates the input current providing an output voltage proportional to charge. C102 thru C104 serve to slow the response time and to stabilize the circuit on the top three current ranges (R122 thru R124). C103 and C104 are scaled down in effective capacitance by divider network consisting of R132 thru R134. The feedback elements are calibrated by potentiometers R126 thru R130. The range of adjustment is limited by R131 to

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approximately 22%. Potentiometer R135 provides a response adjustment for R125. The wiper of R135 is connected to the mounting clip for R125. The capacitance from the clip to R125 permits R135 to adjust for a critically damped response. C101, in addition to being used to measure charge, can also be used to add extra damping on the current ranges. This is accomplished by a "damping" command from the mainframe through K108. The level of this additional damping can be adjusted from the remote head front panel via potentiometer R148.

5-29. Feedback and Zero-Check Selection.

5-30. Relay actuators K102 and K107 are energized under command from the mainframe by U104. These actuators in turn switch in the various feedback elements and actuate "zero check". Zero check shorts the feedback elements in current/charge mode and shorts the input in voltage mode. It is important to note that a custom feedback element can be connected from the FEEDBACK BNC to the Model 642 INPUT and selected by depressing EXT FDBK on the mainframe front panel. Depressing EXT FDBK, places K109 in the charge/current mode and disconnects the internal feedback elements by de-energizing relays K102 thru K106.

5-31. Zero-Check Hop Compensation.

5-32. One result of deactuating zero-check is the injection of a small amount of charge (approximately 10^{-14} coulombs). In volts and current this would create only a transient response. However in charge, this will result in a step output ("zero-check hop") as the charge is collected on C101. This charge injection is compensated by a circuit which consists of R101 thru R105, R150, R151, K101, CR103, CR104, C110, and U105. Function of the "zero-check hop" compensator proceeds as follows: During actuation of zero check, K101 is energized, placing a small voltage across R105. This voltage is also impressed across C113 which consists of a small insulated conductor placed near the input node. The level of this voltage is adjusted by potentiometer R151. The range of adjustment is limited by R101 thru R104. Upon deactuation of zero-check, a delay in de-energizing K101 is developed by U105, R150, C110, and CR104. After K101 de-energizes the charge on C113 is dissipated by R105. This charge level on C113 is made equal and opposite (by adjusting the voltage through the use of R151) to the charge injection by the zero-check contact opening, thus nulling its effect. It is important that the action of the zero-check contact occur prior to the compensation charge injection.

5-33. Input Protection.

5-34. Input overload protection is provided by R152 and CR105. CR105 consists of gallium phosphide diodes. These devices provide a low leakage path at small input voltage burdens while clamping the maximum voltage during input overloads. R152 serves as a current limiting device during overload.

5-35. Filtering and Decoupling of Remote Head/Mainframe Interconnect Lines.

5-36. C106 and C107 are used as filters on the +24V, -15V power supply lines, insuring a low dynamic impedance for op-amps U101 and U102. R146 and R147 serve as decoupling impedances between the active circuitry of the head and mainframe and feedback (J1014) outputs. Capacitors C111, C112, and C116 thru C127 provide decoupling on all signal lines leaving or entering the remote head via interconnect cable plug P1015. J1027 and J1028 are located on the remote head front panel and permit the ungrounding of the instrument for operation with common mode input signals or to prevent ground loop situations.

5-37. MAINFRAME CIRCUIT DESCRIPTIONS.

5-38. The 642 mainframe serves four basic purposes: (1) function control, (2) scaling amplifier, (3) analog-to-digital converter, and (4) power supply. These four major circuit blocks and their associated subcircuits are described below.

5-39. Function Control.

5-40. As previously mentioned, voltage commands from the mainframe are applied to Q102 and U104 in the remote head to select the mode of operation, feedback elements, damping and zero check. Mainframe front panel switches S303, S304 and S305 supply these commands. With the exception of the voltage mode command (which is connected to digital common when voltage mode is selected) +6V is used as the command to select each function. It should be noted that depressing one of the S303 switch pushbuttons selects the desired function and mechanically rejects the previously selected S303 pushbutton. This rejection feature is how the EXT FDBK pushbutton works. With all other S303 pushbuttons out, the head is placed in the current/charge mode without a feedback element being selected. This allows a user supplied element to be used as previously described. There are also provisions provided for remote sensing of the selected function and range. Each of the switches S302 thru S305 connect digital common to a pin on J1015 when selected. J1015 is a pad pattern where the user can install a 14-Pin DIP connector and custom wiring to remotely sense the selected function and range of the 642. The connector and wiring provisions are left to the user.

5-41. Additional control circuitry in the mainframe can be described as follows: U301 along with R301, R302, C301, and front panel potentiometer R404 provide the zero adjust voltage which in turn regulates the voltage controlled current source in the remote head. The voltage reference circuit which includes U304, R325 thru R330, R335, and reference diode VR305. R325 calibrates TP-6 to 1.00000V DC which is the reference for the analog-to-digital converter.

5-42. Scaling Amplifier.

5-43. The scaling amplifier is a circuit block comprising R303, R305 thru R118, U302, Q301, Q302, VR301, VR302, VR310, VR311, C302, and C303. The three feedback networks around U302 provide gains of 0.1, 1, 10 which are used in the 10, 1 and 0.1 ranges respectively. Potentiometers R309, R312, and R314 calibrate these three ranges. S303B switches in R305 and R307 during the "coulombs" function thus doubling each of the gains. This compensates for the fact that the remote head feedback capacitor is 20pF and enables the circuit to read coulombs

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directly. Potentiometer R305 calibrates this gain doubling. R316 thru R318 comprise a network which permits the cancellation of the input offset voltage of U302. C302 provides a level of input noise rejection. Feedback capacitor C303 sets the response time for the three range selections. VR310 and VR311 limit the input voltage during the "coulombs" function. This is required by the special overrange circuit during operation in the "10" range. This point will be discussed with the special overrange circuitry later in this section. Q301 and Q302 provide input overload protection for U302. VR301 and VR302 protect the output of U302 from excess voltage applied at the 1 volt/10,000 count analog output. R319 serves as a current limiting device. These two diodes also protect the A/D converter from input overloads. C320 filters noise eminating from the A/D converter input.

5-44. An additional analog output, 1V/100 counts, is provided by U303, R320 thru R324, R346, C319, VR303, and VR304. R320 is used to null the input offset voltage of U303. C319 serves the same function as C320. VR303 and VR304 protect U303 from excessive voltage at the analog output with R324 providing current limiting. R333 serves as a fuse in the event that a voltage is applied to the analog output common with respect to circuit common.

5-45. Analog-To-Digital Converter.

5-46. The next major circuit block is the analog-to-digital converter. This circuitry consists of U305, U306, CR305 thru CR308, C314 thru C316, and R336 thru R338. This is a dual slope technique providing a 4-1/2 digit multiplexed BCD output and a ±1.9999 volt input voltage span. The A/D timing sequences are controlled by a 100kHz clock circuit consisting of U307B, R331, R332, Y301, and C304. The clock also provides a timing signal for the battery adapter.

5-47. The multiplexed A/D output is used to drive the display circuitry consisting of U313, U401, U402, R401 thru R403, Q401, and DS401 thru DS406. U402 decodes the BCD to seven segment and drives the LED display segments through R402. The digit signals are buffered by U313 and applied to the digit driver U401. This combination of circuitry effectively decodes and displays the A/D output.

5-48. Q401 and R403 provide drive to the "+" display while U401 and R401 to the "-" display. Q303, R342, and R343 comprise an inverter which is placed in the polarity signal line from the A/D converter. This is switched in on the "volts" function to compensate for the scaling amplifier polarity inversion. It is not needed for current or coulombs since the remote head also provides a cancelling inversion on these functions. The appropriate decimal point indication is provided through R344 via range switches S302A thru C.

5-49. Between the A/D converter and the display is a block of circuitry consisting of U307, U309 thru U312, R339, R341, CR309, and C317. This circuitry provides leading zero suppression on the display and generates a special overrange display on the 10X range. Normal overrange occurs at 19,999 counts on the A/D and results in a flashing "0000" display. The special overrange on "10X" occurs at 10.999 counts and results in a flashing "88.888" display. During the use of the special overrange the normal overrange must not be activated. This is the reason that VR310 and VR311 are used to limit the "coulombs" input signal.

5-50. Power Supply.

5-51. Both the remote head and mainframe receive power from a power supply located in the mainframe. This circuitry consists of F301, S306, S307, T301, CR301 thru CR303, C305, C307 thru C313, C318, and VR306 thru VR309. The supply can be configured, via S306 and S307, to function from four ac line voltage ranges to provide four regulated dc output voltages, +6Vdc, +24Vdc, and ±15Vdc. In addition, the supply will interface via P1011 to the 6428 battery adapter which will power the instrument from a 12Vdc external battery. The power switch, S301, is located on the low voltage side of T301 to eliminate both the necessity of a 250Vac rating for S301, and the running of 250Vac printed circuit wiring from the back to the front of the instrument. F301 provides protection for instrument malfunctions resulting in excessive power supply currents.

5-52. MODEL 6428 BATTERY ADAPTER

5-53. The Model 6428 is an optional accessory that provides for operation of the Model 642 Electrometer from a 12Vdc automotive battery. The Model 6428 consists of a single printed circuit board that contains two major circuit blocks, a +6V input supply and a dc-to-dc converter. These circuits are described below and are shown in Schematic 299680 contained in Section 7.

5-54. +6V Regulator Input Supply.

5-55. Power for the 6-volt regulator in the 642 is supplied to Pin 8 of J1011 direct from the battery (J101) through Q101 and CR101. Thus, as long as the applied battery voltage is between 10.5V and 15V (guaranteed operating range of 6428) the voltage supplied to Pin 8 will follow the voltage applied to J101 less the forward voltage drop of CR101 and the saturation voltage of Q101. Using the specified worst case for these devices, the voltage supplied to pin 8 would be -2.5V below battery voltage.

5-56. In order to limit power dissipation in the 642 mainframe at one extreme and to prevent erratic operation on the other, it is necessary that this +6 volt regulator supply cut out below a preset "low cutout" value and above a preset "high cutout" value. These specified values for the 6428 are 9V as the "low cutout" minimum and 17V as the "high cutout" maximum. The cutout circuit consists of two micro-power voltage comparators (U101 and U102), transistor Q102 and associated resistors (R120, R122 and R102 thru R109). The circuit is arranged so that Q101 cuts off when Q102 conducts. Q102, in turn, is turned on by U101 (high cutout) and U102 (low cutout). Since the 6428 is guaranteed to operate between 10.5 and 15V, a 0.4 volt hysteresis margin has been incorporated into the design to assure that erratic operation does not occur near cutout. Thus, the low cutout can vary from 9 to 10.1V and the high cutout from 15.4 to 17V. Reverse polarity protection is provided through CR103 and F101. F101 will open if power is improperly applied, or if current is excessive due to a circuit malfunction.

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5-57. DC-to-DC Inverter.

5-58. A dc-dc power converter supplies ±19V and +30V. Input voltage to the inverter is regulated by Q103 and Q104. (Reference for the regulator is the current from the regulated +6Vdc through R112). Feedback is accomplished through CR115, R123, VR101, and C110. Capacitor C103 and resistor R110 guarantee dynamic stability. The -19V supply serves as the sense voltage for the regulator. The power converter is a driven-type oscillator operating from the 642 A/D clock, supplied at pin 1. This signal, a 100kHz square wave of approximately 6V p-p amplitude (CMOS source), is divided by 4 to obtain a 25kHz square wave by U103. The Q and $\overline{Q}$ outputs each drive a complementary pair of predriver transistors, Q105 and 106, and Q107 and 108. These predrivers provide current gain and supply base drive for the oscillators Q109 and Q110. Capacitive coupling assures a reverse bias for Q109 and Q110 to facilitate switching. CR104 and CR105 clamp this reverse bias to -.7V. Q109 and Q110 drive T101 which supplies all necessary output voltages, rectified by CR106-113. The converter circuit will only operate when +6 volts is applied to pin 3. This 6 volts supplies bias to regulator transistor Q104 as well as power to U103 and the predriver transistors.

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SECTION 6. MAINTENANCE

6-1. GENERAL.

6-2. Because of special handling, expertise, and equipment that is not readily available on the commercial market, it is strongly recommended that the 642 be sent back to the factory for service and/or calibration. The calibration cycle of the 642 is 6 months.

6-3. This section contains information that is needed to calibrate, troubleshoot and replace parts that are considered replaceable outside of the factory.

6-4. CALIBRATION PROCEDURE.

6-5. Because of the interaction between the various circuit blocks in the 642, the calibration procedure can be divided into four sections.

a. Zero Calibration.

b. Voltage Calibration.

c. Current Calibration

d. Charge Calibration.

Perform the following procedures and make the adjustments indicated to calibrate the Model 642 Electrometer. The "300" series cal pots are located in the mainframe and the "100" series cal pots are located in the remote head.

6-6. Calibration Covers.

6-7. In order to calibrate the 642, calibration covers are needed for both the mainframe and the remote head. The covers are necessary in order to maintain proper internal temperatures while making the calibration adjustments. The calibration covers are not available as an option from Keithley and must be built. Figures 6-4 and 6-5 provide the information necessary to build the Cal Covers.

6-8. Environmental Conditions.

6-9. Calibration should be performed under laboratory conditions, in a clean room environment, having an ambient temperature of 25°C ±1°C and a relative humidity <40%.

6-10. Initial Conditions.

6-11. With the calibration covers installed, turn on the 642 and allow it to thermally stabilize for four hours in the clean room environment. Make certain that the remote head is placed bottom side down on a clean surface during warm-up.

6-12. 10^{-7}A Current Source.

6-13. The following is a suggested method for generating an accurate 10^{-7}A current source required to calibrate the 10^{-8}A current range of the 642.

a. Mount the Model 6426 Sapphire Test Box (Item A Table 6-1) on to the 642 remote head. Connect the 10MΩ, 0.1% resistor (Item J) from the EXTERNAL SOURCE HI binding post to the INPUT binding post, and connect a wire from the EXTERNAL SOURCE LO binding post to the INPUT LO binding post. Connect the black wire that is attached to the test box, to the INPUT LO binding post on the remote head. (See Figure 6-1.) Close the lid of the test box.

b. Apply +1.0000V to the EXTERNAL SOURCE input of the Sapphire Test Box using the DC Calibrator (E).

c. This setup will supply the 642 with an accurate 10^{-7}A input.

6-14. 10^{-9}A, 10^{-10}A, and 10^{-11}A Current Sources.

6-15. The following is a suggested method for generating accurate 10^{-9}, 10^{-10}, and 10^{-11}A current sources required to calibrate the 10^{-10}A, 10^{-11}A and 10^{-12}A current ranges. A ramp generator, when used with precision 100pF and 1000pF capacitors (Items B and C), will supply the necessary precise current levels.

6-16. Ramp Generator Characteristics.

a. The ramp generator must provide two ramps, ±0.1V/sec and ±1V/sec.

b. The ramp should change polarity at approximately plus and minus 11V.

c. The ramp duration on the 0.1V/sec range is approximately 3.6 minutes, and the ramp duration on the 1V/sec range is approximately 20 seconds.

d. The ramp generator must have a total accuracy of 0.1% or better.

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TABLE 6-1
Recommended Test Equipment for Calibration

ITEM	DESCRIPTION	MFR.	MODEL
A	Sapphire Test Box	Keithley	6426
B	100pF Air Capacitor, 0.01%*	Gen Rad	1403B
C	1000pF Air Capacitor, 0.01%*	Gen Rad	1403A
D	DMM, 5-1/2 Digit, 0.01%	Keithley	191
E	DC Calibrator	Fluke	341A
F	BNC to Airline Cable	Gen Rad	776-9702
G	BNC Input Adaptor	Keithley	6424
H	Airline Input Adaptor	Keithley	6425
I	100KΩ Resistor, 0.1% (Built into a shielded test fixture)	--	--
J	10MΩ Resistor, 0.1%	--	--
K	Oscilloscope (General purpose type with 0.2V/div and 100ms/div ranges)	--	--
L	Ramp Generator (Build to specifications contained in Paragraph 6-16)		

*The basic accuracy of the Gen Rad caps is 0.1%. These capacitors will have to be trimmed to .01% for calibrating the current ranges.

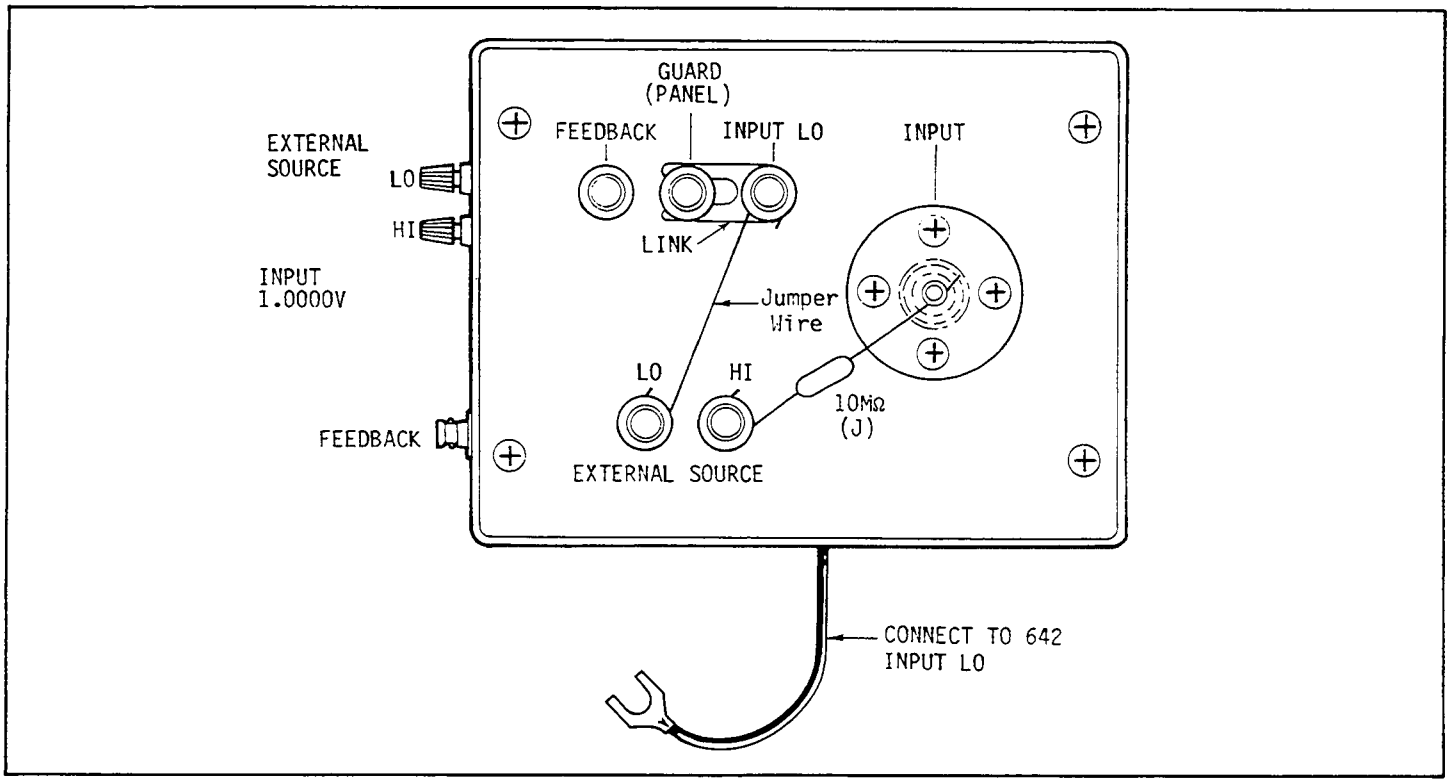


FIGURE 6-1. 10^{-7}A Current Source Using Model 6426 Sapphire Test Box

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6-17. Current Source Circuitry.

a. The two precision capacitors, when combined with the ramp generator, will provide the currents listed in Table 6-2.

b. Figure 6-2 shows how the ramp generator and capacitors should be connected to the 642.

c. The current generated can be calculated by applying the formula:

$I = C\ dv/dt$ where

I = Current
C = Capacitance
dv/dt = change in voltage/second

For example:

C = 100pf, dv/dt = .1V/sec
$I = 100 \times 10^{-12}F \times .1V/s = 10 \times 10^{-12}VF/s$

Since charge (Q) is equal to CV and I = dQ/dt

Than $I = 10 \times 10^{-12}VF/s = 10^{-11}A$

TABLE 6-2
$10^{-9}A$, $10^{-10}A$ and $10^{-11}A$ Current Sources

C	Ramp Generator Output	I	Time
100pF	0.1V/Sec	$10^{-11}A$	3.6 min
1000pF	0.1V/Sec	$10^{-10}A$	3.6 min
1000pF	1V/Sec	$10^{-9}A$	3.6 min

6-18. Recommended Test Equipment.

6-19. Recommended test equipment for calibration is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 5 times better than the Model 642 specifications.

6-20. Zero Calibration.

a. Connect the DMM (Item D) to the FEEDBACK connector on the remote head and set the DMM for 2Vdc.

b. Remove the remote head cal-cover, and short the U101 test connector (P1027) pins 1 to 2 and 3 to 4.

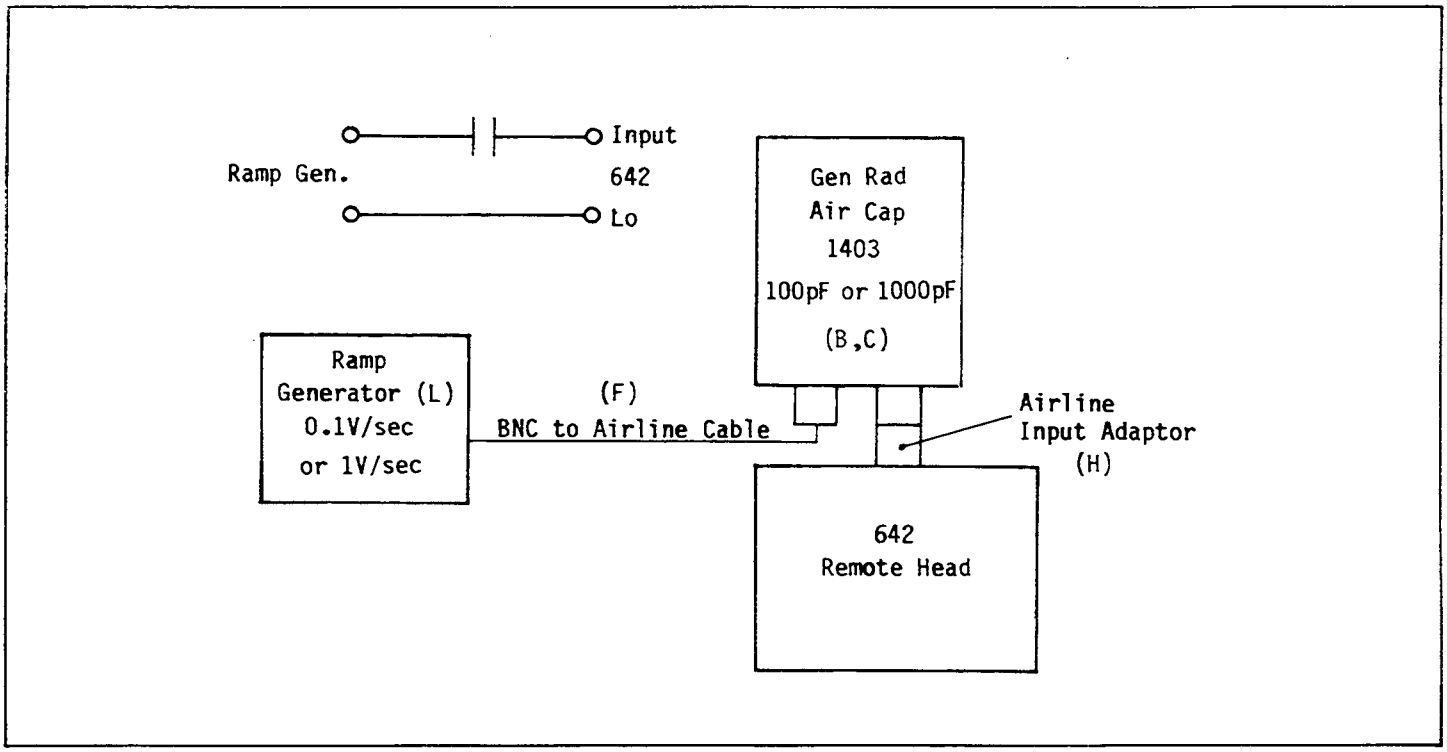


FIGURE 6-2. 10^{-9}, 10^{-10}, and $10^{-11}A$ Current Sources Circuitry

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c. Adjust R138 for a DMM reading of .00000V ±10µV.

d. Leaving the jumper wires connected, reinstall the cal-cover on the remote head.

e. ZERO CHECK the 642 and set the 0.1X RANGE, and VOLTS function.

f. Adjust R317 for a .00000 ±1 digit reading on the 642 display.

g. Connect the DMM to the 1V/100 COUNTS ANALOG OUTPUT. Adjust R320 for a DMM reading of 0.000V ±2mV.

h. Remove the jumper wires from inside the remote head and reinstall the calibration cover.

6-21. Voltage Calibration.

a. ZERO CHECK the 642 and set to the 0.1X RANGE and VOLTS function.

b. With the calibration cover installed on the mainframe, monitor TP-6 with respect to INPUT LO, using the DMM (D).

c. Adjust R325 to achieve a +1.0000V ±100µV reading on the DMM.

d. Remove the DMM from the circuit.

e. Use the front panel ZERO ADJUST knob to zero the 642 display and apply +.19000V to the INPUT of the 642 using the DC Calibrator (E).

f. Release ZERO CHECK and adjust R314 to achieve a 642 display reading of +.19000±1 digit.

g. ZERO CHECK the 642 and set to the 1X RANGE.

h. Apply +1.9000V to the INPUT of the 642 using the DC Calibrator. ZERO ADJUST the 642 display.

i. Release ZERO CHECK and adjust R312 to achieve a 642 display reading of +1.9000V ±1 digit.

j. ZERO CHECK the 642 and set to the 10X RANGE.

k. Apply +10.000V to the INPUT of the 642 using the DC Calibrator. ZERO ADJUST the 642 display.

l. Release ZERO CHECK and adjust R309 to achieve a 642 display reading of +10.000 ±1 digit.

6-22. Current Calibration.

6-23. To calibrate the Model 642 current sources of 10^{-7}A, 10^{-9}A, 10^{-10}A and 10^{-11}A, that are at least .2% accurate, are necessary. Because current sources with this high level of accuracy are not readily available on the commercial market, special equipment and circuits may have to be built. Paragraphs 6-12 thru 6-17 detail suggested equipment and circuitry that can be used to generate the necessary precise current levels.

a. ZERO CHECK the 642 and set to the 10X RANGE and 10^{-8}A CURRENT function.

b. Apply 10^{-7}A to the INPUT of the 642 and ZERO ADJUST the display.

c. Release the ZERO CHECK and adjust R127 to achieve a 642 display reading of 10.000 ±10 digits.

d. ZERO CHECK the 642 and set to the 10^{-10}A CURRENT function.

e. Apply 10^{-9}A to the INPUT of the 642 and ZERO ADJUST the display.

f. Release the ZERO CHECK and adjust R128 to achieve a 642 display reading of 10.000 ±10 digits.

g. Repeat the above steps for the 10^{-11}A, and 10^{-12}A CURRENT functions referring to Table 6-3.

TABLE 6-3
Current Calibration

642 Settings			Applied Current	Adjustment Point	642 Display Reading
Range	Current	Damping			
10X	10^{-8}A	MIN	10^{-7}A	R127	10.000±10d
10X	10^{-10}A	MIN	10^{-9}A	R128	10.000±10d
10X	10^{-11}A	VAR	10^{-10}A	R129	10.000±10d
10X	10^{-12}A	VAR	10^{-11}A	R130	10.000±10d

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6-24. Charge Calibration.

a. ZERO CHECK and ZERO ADJUST the 642, and set to the 10X RANGE and CHG function.

b. Set up the circuit shown in Figure 6-3, and set the DC Calibrator (E) to 0V.

c. While monitoring the FEEDBACK output with the DMM (D), release the ZERO CHECK and step the DC Calibrator to +1.0000V.

d. Adjust R305 for a 642 display reading of -2 times the DMM display reading within ±1 digit.

e. ZERO CHECK and ZERO ADJUST the 642, and set the DC Calibrator to 0V.

f. Release the ZERO CHECK and record the 642 display reading (zero check hop).

g. Step the DC Calibrator to +1.0000V and adjust R126 for the following computed 642 display reading:

(+10.000) + (recorded zero check hop) equals the desired 642 display reading ±10 digits.

Example: Zero check hop of -.003
(+10.000) + (-.003) = +9.997 ±10d

Adjust R126 for a 642 display reading of +9.997 ±10d

h. Repeat steps e thru g to confirm calibration. Readjust R126 if necessary.

6-25. 1% Settling Time Adjust.

6-26. The 1% Settling Time can be adjusted using an oscilloscope that has a differential amplifier.

a. ZERO CHECK the 642 and set to the 10X RANGE, 10^{-12}A CURRENT function, and MIN DAMPING.

b. Connect the Oscilloscope (Item K) to the 1V/10000 COUNTS ANALOG OUTPUT of the 642 and to the DC Calibrator (E) as shown in Figure 3-2 (Performance Verification).

c. Set the Differential Amplifier of the scope for a gain of 10mv/div and 20ms/div.

d. Apply 10^{-11}A to the INPUT of the 642.

e. Release the ZERO CHECK and adjust R135 for a 1% settling time of 0.75 seconds.

6-27. Zero Check Hop Adjust.

a. ZERO CHECK and ZERO ADJUST the 642, and set to the 1X RANGE, CHG function and INPUT open (slider cover closed).

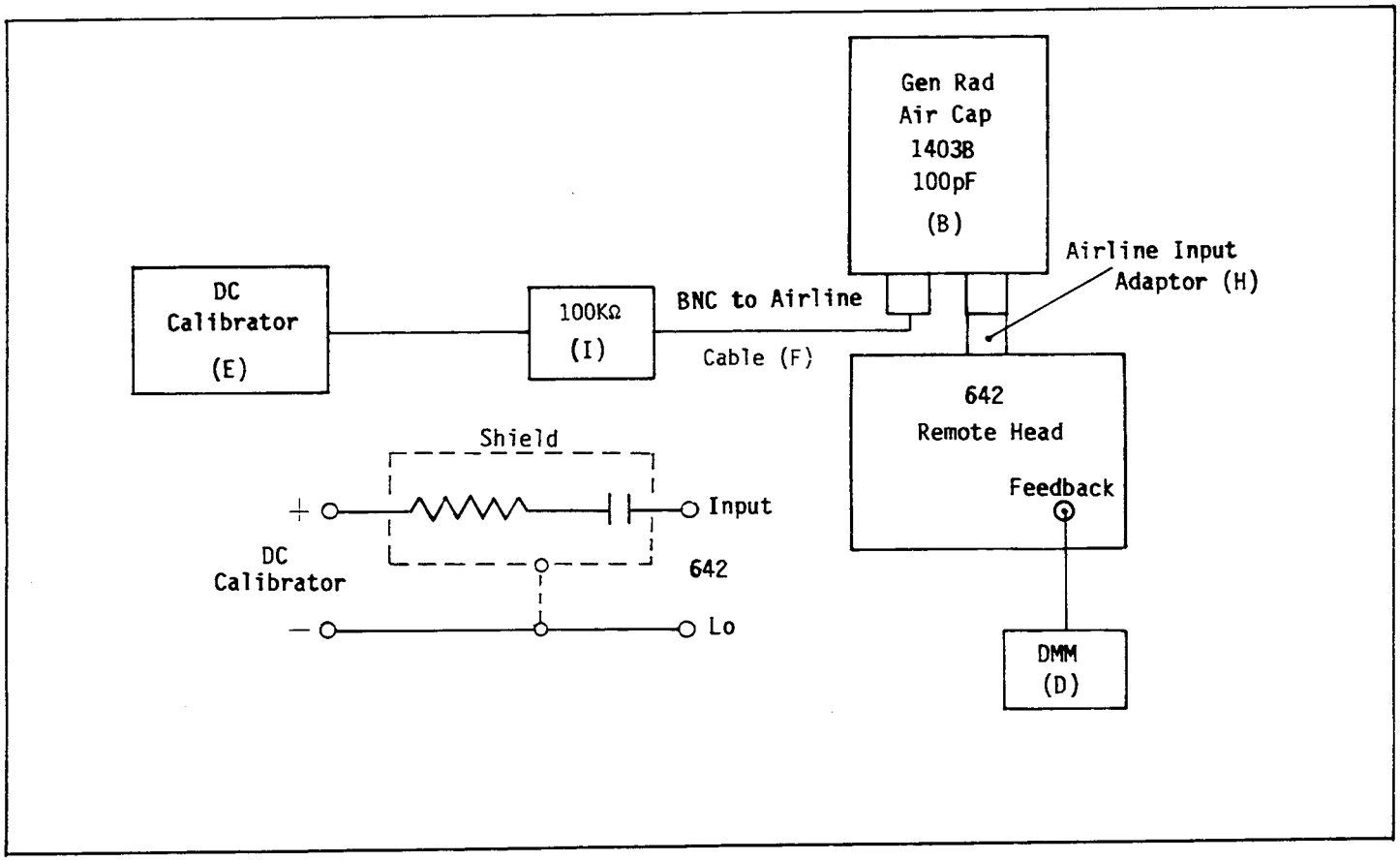


FIGURE 6-3. Charge Calibration Circuit

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Table 6-4
Mainframe Test Point Data

ITEM	REQUIRED CONDITION	REMARKS
TP-1	-23V ±10%	Input voltage to the -15V regulator
TP-2	Read Display	Output of the X100 Analog output
TP-3	+23V ±10%	Input voltage to the +15V regulator
TP-4	+13V ±10%	Input voltage to the +6V regulator
TP-5	10.0V DC ±5%	Output of U304 in the voltage reference circuit
TP-6	1.0000V	1 volt reference voltage
TP-7	6.26V MIN 6.44V MAX	The zener voltage in the voltage reference circuit
TP-8	0V to 6.4V (Zener Voltage)	Zero Control output Spans from Zero volts to the zener voltage
TP-9	1volt/10,000 counts	Remote Head Analog Output
TP-10		Comparator Input Integrator Output
TP-11	Stored Auto Zero Voltage	Stored Auto Zero Voltage
TP-12	+35V ±10%	Input voltage to the +24V regulator
TP-13	100KHz	Clock Output
TP-14		Buffer Input to U305
TP-15	Pulse "ON" and "OFF" for display to pulse 88.888	Lamp Test for U401 which is the BCD to seven segment latch decoder driver. This provides overrange in the X10 range.
TP-16		Blanking Input for U401. This input is used for leading zero suppression and during X10 range overrange.

b. Release ZERO CHECK and note the zero check hop (a sudden change in reading followed by a slow drift in either polarity).

c. Adjust R151 so that zero check hop is repeatedly less than 5 digits on the 642 display.

6-28. TROUBLESHOOTING.

6-29. The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital electronic principles and components used in precision electronic test instruments. Instructions have

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been written to assist in isolating the defective circuit. Isolation of the defective component has been left to the troubleshooter. Paragraph 6-47 defines which components are replaceable in the field. Instruments with defective non-replaceable parts should be sent back to the factory for servicing.

6-30. Power Supplies.

6-31. In general, start troubleshooting by checking that the proper voltage levels are being supplied to the electronic components. Voltage test pad locations are indicated on the mainframe and remote head PC-Boards. The +6 volt, +15 volt, -15 volt and +24 volt supplies should be accurate to ±5%. Reference voltage measurements to Input Lo.

6-32. Line Power. If line power is being used, and a problem exists with the supplies, check the following:

a. Check line fuse (F301) for continuity.

b. Make sure the line switches (S306 and S307) are set to the correct incoming line voltage.

c. Check TP1, TP3, TP4, and TP12 per Table 6-4 for correct voltage levels. These are the input voltages to the power supply regulators.

6-33. Battery Adapter. If problems exist with the battery adaptor circuitry, troubleshoot utilizing the technical information provided in Section 5, Theory of Operation, Paragraphs 5-52 thru 5-58.

6-34. Isolating Defective Circuitry.

6-35. Defective circuitry can be isolated by checking signal levels at strategic locations in the 642. An incorrect signal level present at the FEEDBACK connector would indicate that the problem lies in the remote head. An incorrect signal level present at the 1V/10,000 COUNTS ANALOG OUTPUT suggests that the problem lies within the Scaling Amplifier circuitry (U302). If the signal levels present at these two locations check out good, the problem lies in the A/D Converter or Display circuitry. Utilize the Test Point Data in Table 6-4 and 6-5 to further identify faulty components/circuitry.

6-36. Zero Check Does Not Function.

a. Mainframe. Check pin 8 of J/P1003 for 6V while the instrument is in ZERO CHECK and 0V when not in Zero Check.

b. Remote Head. Check pin 6 of U104 for the same conditions as Step a.

c. Remote Head. Check pin 2 referenced to pin 3 of J/P1021 for 6V while the 642 is in ZERO CHECK and 0V when not in ZERO CHECK.

d. Proper responses for a thru c would indicate a faulty ZERO CHECK actuator assembly.

6-37. Lack of Zero Control Adjust.

a. Mainframe. In the "Zero Control" circuit, check TP-8 for a swing of 0 to 6.4 volts with the ZERO ADJUST control.

Table 6-5
Remote Head Test Point Data

ITEM	REQUIRED CONDITION	REMARKS
TP-1 REFERENCED To TP-3	0.55V to 0.65V	TC MOSFET compensation diode
24V REFERENCED To TP-2	3.1V ±0.2V	Emitter bias voltage for constant current sources Q101, R106, and R107
TP-4	A delayed zero check signal	Output of Zero Check Hop Compensator
TP-5		It is the reset of U105. It is also Zero Check.
TP-7 REFERENCED To TP-6	75mV MAX (If remote head is not in overrange)	MOSFET ΔV_{GS} (Vos)(differential gate to source voltage). Q201 (TG-134).

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b. Remote Head. Check the ZERO test point for 0 to 6.4 volts.

c. Remote Head. In the "Zero Adjust Voltage To Current Converter" circuit, check pins 3 to 4 of J/P1026 for a swing of approximately 0 to 10mV with the ZERO ADJUST control.

d. Proper responses for Steps a thru c would indicate that the problem is in the balance of the instrument circuitry.

6-38. Excessive Zero Check Hop.

6-39. If zero check hop cannot be properly adjusted with R151, check the operation of U501 and the associated "Zero Check Hop Compensator" circuitry. Continued improper operation would indicate faulty operation of the Zero Check Actuator.

6-40. Specific Range Does Not Function.

6-41. If zero check is OK, but the instrument overranges for inputs on the CHARGE and CURRENT functions, troubleshoot by following the command signals from the mainframe to the appropriate relay actuator in the remote head.

6-42. Instrument Overranges Regardless of Control Settings.

6-43. Verify that the problem is in the remote head, by checking that the voltage level at FEEDBACK is greater than 11 volts, and check the following components and related circuitry.

a. U101 - Main Amplifier.

b. K109 - Volts function relay.

c. S102 - Temperature Compensation polarity switch (set at factory or when replacing FET card).

d. Q201 - Input MOSFET.

e. CR105 - Protection Diodes for Q201.

f. Q101 - Current Source circuitry.

g. Feedback element relay actuators

6-44. Current Source (Q101) Checkout.

a. The voltage drop across R106 should be equal to the voltage drop across R107 and should be approximately 3.17V.

b. Measure TP-1 referenced to TP-3 for approximately 0.55 to 0.65V.

c. Measure TP-6 referenced to TP-7 for <75mV.

d. If step c is > 75mV the MOSFET assembly will have to be replaced.

NOTE

Tests in Steps c and d are valid only if the remote head output is not overranged. Should this not be the case, place instrument in "External Feedback" and ground input and make this measurement. Should the constant current source, temperature and offset networks and K109 be operating properly, then the MOSFET assembly requires replacement.

6-45. Protection Diode (CR105) Checkout.

a. Remove CR105 from the remote head as explained in Paragraph 6-50.

b. Using a Current Source, apply 1mA accross the diode, with the compliance voltage set for 20V.

c. Using an electrometer voltmeter ($Zin > 10^{10}\Omega$) and verify that the voltage drop across the diode is between 5 to 13V.

d. Reverse the polarity of the 261 and repeat steps b and c.

6-46. NON-REPLACEABLE PARTS.

6-47. The following parts are not replaceable outside of the factory because of special handling requirements, special expertise in replacing and adjusting critical assemblies, and special parameter matching that can only be done at Keithley.

a. Individual components of the MOSFET card and cable assembly.

b. Feedback elements, their relay actuators, and metal work in the head.

6-48. REPLACEABLE PARTS.

6-49. The following are replaceable parts:

a. Fully tested MOSFET card and Protection Diode.

b. All "normal" electronic components on PC boards or chassis panels in the head and mainframe.

c. The 4-foot interconnect cable and its component parts.

d. Desiccant Paper.

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6-50. MOSFET Card and Protection Diode Replacement.

NOTE

The remote head must be opened in a clean room environment with <40% relative humidity to prevent contamination. Special care must be taken not to touch the components on the MOSFET card, the sapphire insulator, the Protection Diode insulator, and parts in and around the input tube assembly.

a. Disconnect all cabling and input adapters from the 642 remote head.

b. Place the remote head upside down and remove the four screws from the bottom. Remove the plastic base and bottom cover from the remote head.

c. Disconnect all the cable connections on the remote head PC-board (note where each connector belongs for reinstallation).

d. Loosen the four screws securing the PC-board to the head assembly. These screws are held to the PC-board by rubber "O" rings. There is a green lugged ground wire positioned under one of the screws which will have to be moved out of the way.

e. Remove the PC-board from the remote head.

f. Turn the remote head right side up and remove the four screws securing the side panel to the remote head.

g. Remove the four allen screws holding the Input Slider Cover Assembly and remove it from the remote head.

⚠ CAUTION

The sapphire insulator is now exposed. DO NOT TOUCH.

h. Remove the panel assembly from the remote head.

i. Turn the remote head upside down and remove the Input Tube Cover that is secured by three screws.

NOTE

Provide support so that input connector spring is not disturbed.

j. Remove the two screws securing the MOSFET card to the side of the Input Tube. Gently pull the card outward to disengage the MOSFET lead from the Input Node.

k. The Protection Diode (CR105) is secured to the Input Tube by the Diode Retainer plate. Remove the two screws holding the retainer plate to the Input tube and remove it from the head. Gently pull the diode outward to disengage the diode lead from the Input Node.

l. The new MOSFET card assembly comes with instructions for setting the voltage and temperature compensation switches, located on the remote head PC-board (S101 and S102). Set these switches before reinstalling the bottom cover.

m. Reverse the above procedures to put the remote head back together.

NOTE

Proper alignment is essential when reinstalling the Input Slider Cover Assembly. Attach the assembly loosely onto the head using the four allen screws. Pull back the slider and install an Input Adapter Connector. Press down firmly on the adapter until it seats properly into the head casting. Release the slider making sure it engages into the Adapter body. Tighten down the four retaining screws.

6-51. Interconnect Cable.

6-52. The individual components of the 4-foot interconnect cable can be found in the cable assembly drawing (29815C) located in Section 7, Replaceable Parts.

6-53. Remote Head PC-Board Removal.

6-54. The PC board in the remote head can be removed for servicing by following the instructions in Paragraph 6-50, Steps a thru e.

6-55. Desiccant Paper Replacement/Reactivation.

6-56. When the desiccant indicator approaches 40%, the desiccant paper should be replaced or reactivated if the instrument is required to operate at its rated input bias current. The remote head should only be opened in an environment with <40% relative humidity.

a. Disconnect all cabling and input adapters from the 642 remote head.

b. Place the remote head upside down and remove the four screws from the bottom. Remove the plastic base and bottom cover from the remote head.

c. The desiccant paper is secured to the bottom panel by the indicator assembly. Remove the large hex nut and washer to remove the desiccant paper.

d. If replacing the paper, install one new sheet onto the bottom cover. To reactivate the old paper, place in an oven at 121°C (250°F) for 15 minutes, and reinstall onto the bottom cover.

NOTE

When placing in oven, be sure that desiccant is supported in such a manner as to provide air circulation around both sides.

e. Reinstall the bottom cover and base plate onto the remote head.

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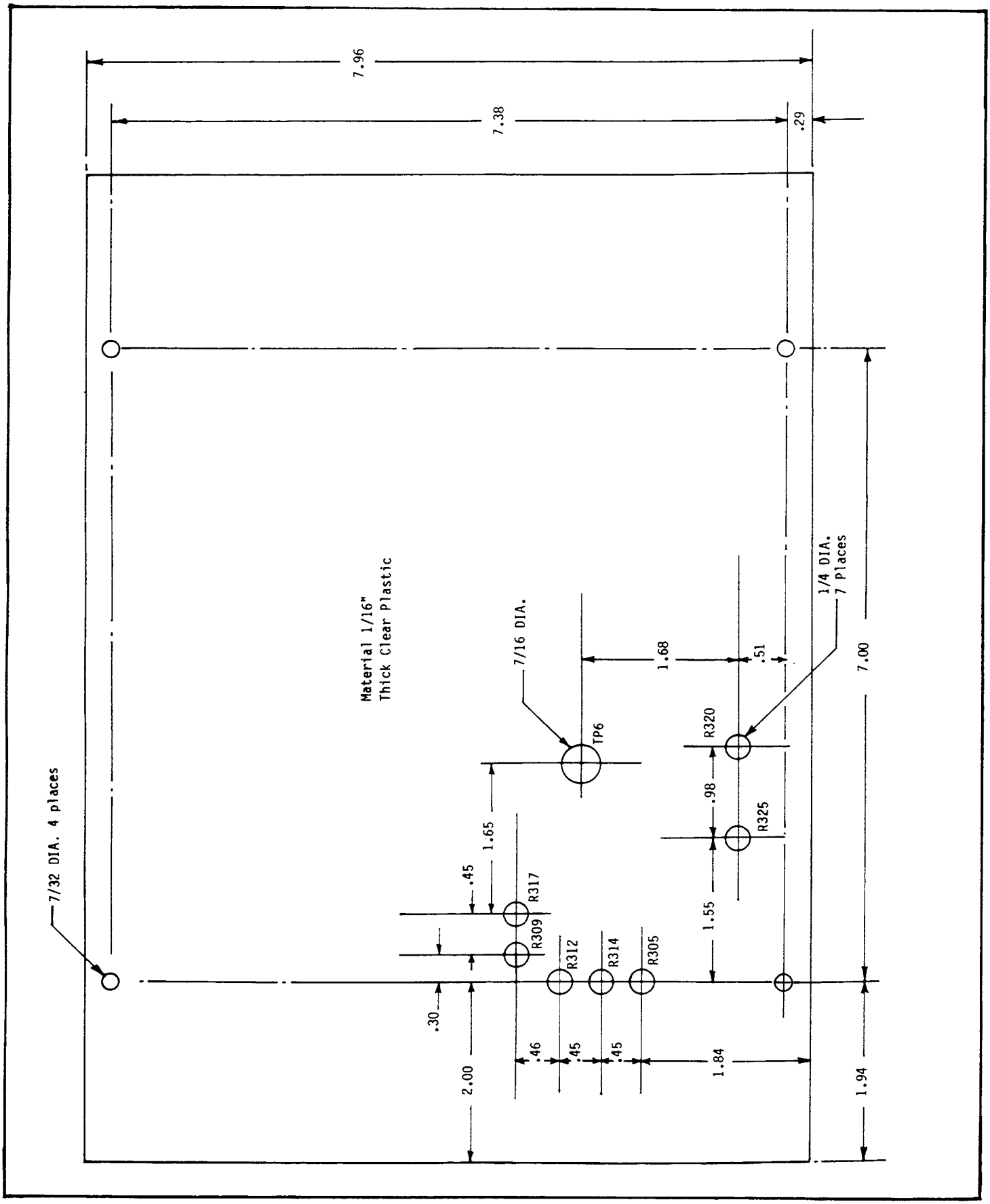


FIGURE 6-4. Mainframe Cal Cover

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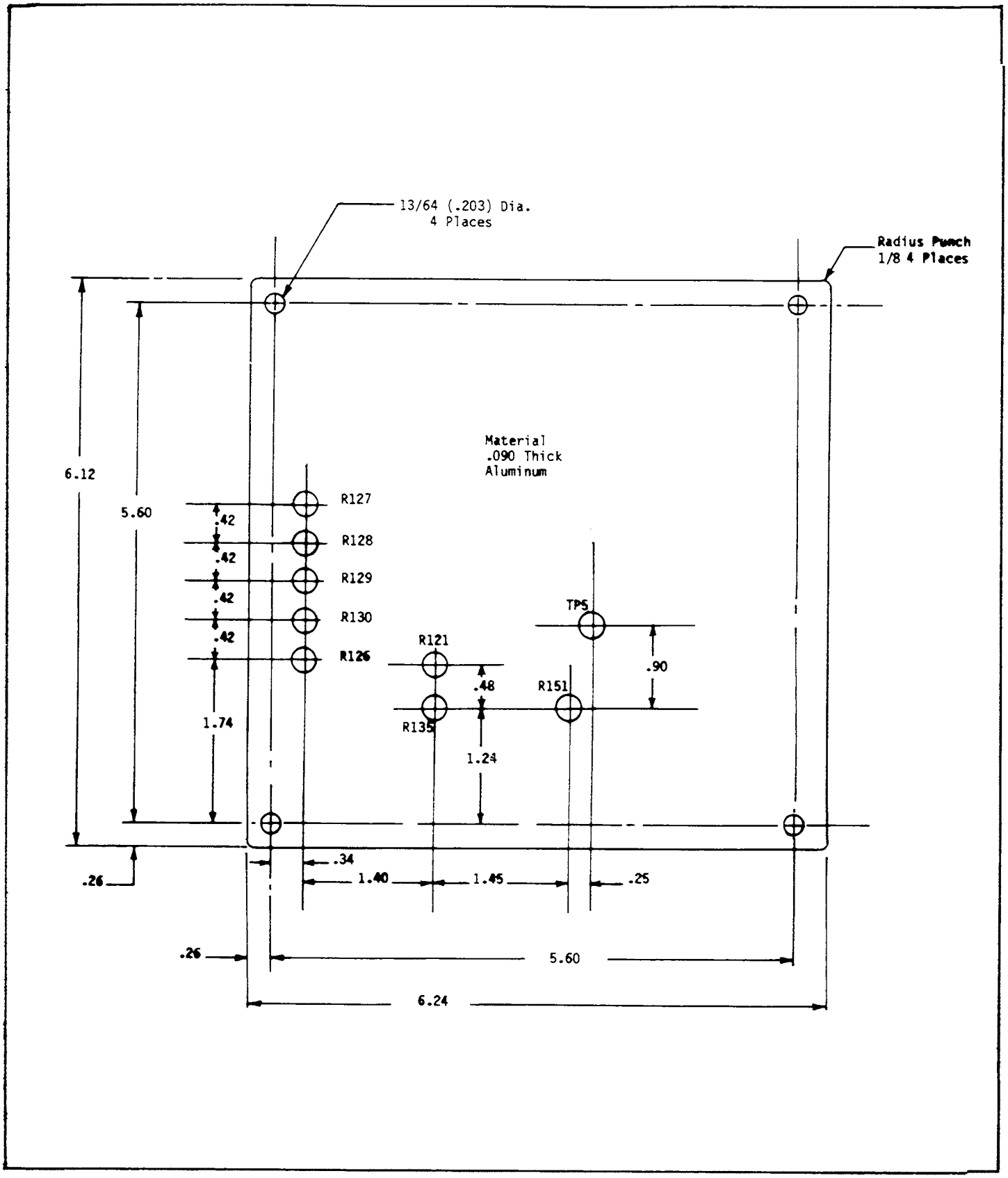


FIGURE 6-5. Remote Head Cal Cover

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SECTION 7. REPLACEABLE PARTS

7-1. GENERAL.

7-2. This section contains information for ordering replacement parts. The Replaceable Parts Lists are arranged in alphabetical order of the circuit designations of their components. Table 7-1 lists the components of the 642 mainframe. The remote head components are listed in Table 7-2 and Table 7-3 lists the components of the Model 6428 Battery Adapter. A cross- reference list of manufacturers, including their addresses, is given in Table 7-4.

7-3. ORDERING INFORMATION.

7-4. To place an order or to obtain information concerning replacement parts contact your Keithley Representative or the factory. See the inside front cover for addresses. When ordering, include the following information:

a. Instrument Model Number

b. Instrument Serial Number

c. Part Description

d. Circuit Designation (if applicable)

e. Keithley Part Number

7-5. FACTORY SERVICE.

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

7-7. SCHEMATICS.

a. The Model 642 mainframe circuits are shown in Schematic 29653E, Page 7-15.

b. The Model 642 remote head circuits are shown in Schematic 29654E, Page 7-17.

c. The Model 6428 battery adapter circuits are shown in Schematic 29968D, Page 7-19.

d. The Model 6426 Sapphire Insulated Test Box circuits are shown in Schematic 30105C, Page 7-23.

7-8. COMPONENT LAYOUTS.

a. Model 642 Mainframe, PC-481, Component Layout Number 29718D, Page 7-16.

b. Model 642 Remote Input Head, PC-480, Component Layout Number 29793D, Page 7-18.

c. Model 6428 Battery Adapter, PC-494, Component Layout Number 29971D, Page 7-20.

d. Model 642 Display Board, PC-482, Component Layout Number 29708C, Page 7-21.

e. Model 642 FET Board, PC-479, Component Layout Number 29797A, Page 7-22.

f. Model 642 Interconnect Cable, Number 29815C, Page 7-24.

TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C301	.01µF, 16V, CerD	C1	2/D1	CLB	UK16-103	C-238-.01
C302	.01µF, 16V, CerD	C2	3/D2	CLB	UK16-103	C-238-.01
C303	5µF, 100V, Poly F	D1	4/D1	P B	4309B505K	C-294-5
C304	100pF, 1000V, CerD	G3	5/C2	CLB	DD-101	C-64-100p
C305	2200µF, 16V, ETT	F4	6/B3	CAL	CSD220016-1	C-290-2200
C306	Not Used					
C307	22µF, 10V, Tant	G4	8/B2	SIE	D22C2B10M	C-180-22
C308	470µF, 35V, ETT	F5	9/B3	NIC	35ELA470	C-289-470
C309	10µF, 20V, ETT	G5	10/C3	ITT	TAPA10µFK20	C-179-10

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TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C310	470µF, 35V, ETT	F6	11/B3	NIC	35ELA470	C-289-470
C311	10µF, 20V, ETT	G6	12/C3	ITT	TAPA10µFK20	C-179-10
C312	470µF, 50V, ETT	G7	13/C4	NIC	50ELA470	C-292-470
C313	10µF, 35V, Tant	G7	14/C3	SIE	D10GS2C35M	C-170-10
C314	4µF, 100V, Poly F	K1	15/C3	P B	4309B504K	C-294-4
C315	.22µF, 50V, Poly P	L1	16/C3	WES	32MPL	C-269-.22
C316	1µF, 100V, Poly F	K2	17/C3	P B	4309C105	C-294-1
C317	.01µF, 16V, CerD	M4	18/D5	CLB	UK16-103	C-238-.01
C318	4.7µF, 35V, EAL	F4	19/B3	ITT	TAPA4.7µFK20	C-179-4.7
C319	.01µF, 16V, CerD	F2	20/B2	CLB	UK16-103	C-238-.01
C320	.01µF, 16V, CerD	G1	21/B1	CLB	UK16-103	C-238-.01
CR301	Bridge Rectifier, 100V, 2A	F4	23/B4	EDI	PD10	RF-36
CR302	Bridge Rectifier, 400V, 1A	F5	24/B4	EDI	PF40	RF-46
CR303	Bridge Rectifier, 400V, 1A	F6	25/B4	EDI	PF40	RF-46
CR304	Not Used					
CR305	Rectifier, 75mA, 75V	L1	27/D3	T-I	1N4148	RF-28
CR306	Rectifier, 75mA, 75V	L1	29/D3	T-I	1N4148	RF-28
CR307	Rectifier, 75mA, 75V	L2	30/D3	T-I	1N4148	RF-28
CR308	Rectifier, 75mA, 75V	L2	31/D3	T-I	1N4148	RF-28
CR309	Rectifier, 75mA, 75V	M5	32/D5	T-I	1N4148	RF-28
DS401	Digital Display ±1	K8	5/B2	G-I	MAN6690	DD-21
DS402	7 Segment Digital Display	K8	6/B2	G-I	MAN6690	DD-20
DS403	7 Segment Digital Display	K8	7/B2	G-I	MAN6690	DD-20
DS404	7 Segment Digital Display	K8	8/C2	G-I	MAN6690	DD-20
DS405	7 Segment Digital Display	L8	9/C2	G-I	MAN6690	DD-20
DS406	7 Segment Digital Display	L8	10/D2	G-I	MAN6690	DD-20
F301	Fuse, SLO-BLO, 1/4A/250V/3AG	D8	--	L-F	313.250	FU-17
F301	Fuse, SLO-BLO, 1/8A/250V/3AG	D8	--	L-F	313.125	FU-20
J1001	Not Used					
J1002	4 pin housing	B1	--	BRG	65039	CS-371-4
J1003	8 pin housing	B3	--	BRG	65039	CS-310
J1004	5 pin housing	B5	--	MOL	2139-5	CS-287-5
J1005	3 pin housing	C1	--	BRG	65039-034	CS-270
J1006	3 pin housing	D7	--	MOL	2139-3	CS-287-3
J1007	3 pin housing	G1	--	BRG	65039-034	CS-270

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TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
J1008	Binding Post, Red	G1	--	HHS	1517	BP-11-2
J1009	Binding Post, Black	G1	--	HHS	1517	BP-11-0
J1010	Binding Post, Red	G2	--	HHS	1517	BP-11-2
J1011	Not Used					
J1012	20 pin Connector	J7, J8	22/E4	MMM	34213000	CS-297-20
J1013	14 Pin DIP Connector	P2	49/D4	-	--	SO-70
J1015	Not Provided	P7	-/D4	-	--	
P1001	19 pin, Non-Hermetic	B1	--	CAN	MS-3102E22-14P-A105	CS-370-1
P1002	4 pin, Connector	B1	36/D2	BRG	65507-136	CS-339-4
P1003	8 pin, Connector	B3	37/D1	BRG	65507-136	CS-339-8
P1004	5 pin, Molex Connector	B5	38/B3	MOL	A-2391-5A	CS-288-5
P1005	3 pin, Connector	C1	39/D1	BRG	65507-136	CS-339-3
P1006	3 pin, Molex Connector	D7	40/A4	MOL	A-2391-3A	CS-288-3
P1007	3 pin, Connector	G1	41/B1	BRG	65507-136	CS-339-3
P1008	Not Used					
P1009	Not Used					
P1010	Not Used					
P1011	7 pin, Modified CS-288-8	H3	45/C4	K-I	--	30109
P1012	20 pin	J7, J8	46/E4	MMM	3492-2002	CS-368-20
P1013	Not Used					
P1014	AC Receptacle	D8	--	TOW	CS-254	CS-254
Q301	N-Chan, JFET	C2	51/D2	INT	ITE4392	TG-77
Q302	N-Chan, JFET	C2	52/D2	INT	ITE4392	TG-77
Q303	NPN Switch	J5	53/D3	MOT	2N3904	TG-47
R301	12KΩ, 5%, 1/4W, Carb F	B1	57/D2	MEP	CR25*	R-76-12K
R302	100Ω, 5%, 1/4W, Carb F	B1	58/D2	MEP	CR25*	R-76-100
R303	866Ω, 1%, 1/8W, MtF	B2	59/D2	PRP	**	R-88-866
R304	Not Used					
R305	50Ω, 10%, Cermet Trimmer	C2	61/E2	BRN	3386F-1-500	RP-97-50
R306	9.09KΩ, .1%, 1/10W, MtF	C2	62/D2	TRW	MAR-5*	R-263-9.09K

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TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R307	7.39KΩ, .1%, 1/10W, MtF	C2	63/D2	TRW	MAR-5*	R-263-7.39K
R308	270KΩ, 5%, 1/4W, Carb F	D1	64/D2	MEP	CR25*	R-76-270K
R309	50KΩ, 10%, 1/10W, MtF	D1	65/D3	BRN	3386F-1-503	RP-97-50K
R310	1.002KΩ, .1%, 1/10W, MtF	D2	66/D2	TRW	MAR-5*	R-263-1.002K
R311	9.98KΩ, .1%, 1/10W, MtF	D2	67/D2	TRW	MAR-5*	R-263-9.98K
R312	50Ω, 10%, Cermet Trimmer	D2	68/E2	BRN	3386F-1-500	RP-97-50
R313	99.8KΩ, .1%, 1/10W, MtF	D2	69/D2	TRW	MAR-5*	R-263-99.8K
R314	500Ω, 10%, Cermet Trimmer	D2	70/E2	BRN	3386F-1-501	RP-97-500
R315	1.2KΩ, 5%, 1/4W, Carb F	D3	71/D3	MEP	CR25*	R-76-1.2K
R316	1MΩ, 1%, 1/8W, MtF	D3	72/D3	PRP	**	R-88-1M
R317	100KΩ, 10%, Cermet Trimmer	D3	73/D3	BRN	3386F-1-104	RP-97-100K
R318	20Ω, 1%, 1/8W, MtF	D3	74/D3	PRP	**	R-88-20
R319	1KΩ, 1%, 1/2W, MtF	G1	75/C2	DLE	MFF*	R-94-1K
R320	100KΩ, 10%, Cermet Trimmer	E2	77/C1	BRN	3386F-1-104	RP-97-100K
R321	1.2KΩ, 5%, 1/4W, Carb F	F2	78/C2	MEP	CR25*	R-76-1.2K
R322	9.9KΩ, .1%, 1/8W, MtF	F2	79/C2	DLE	MFF*	R-168-9.9K
R323	100Ω, .1%, 1/8W, MtF	F2	80/C2	DLE	MFF*	R-168-100
R324	1KΩ, 1%, 1/2W, MtF	G2	81/C2	DLE	MFF*	R-94-1K
R325	50Ω, 10%, Cermet Trimmer	H1	82/D1	BRN	3386F-1-500	RP-97-50
R326	Selected Resistor	H1	83/C2	K-I	--	27699
R327	402Ω, .1%, 1/10W, MtF	H1	84/D2	TRW	MAR-5*	R-263-402
R328	806Ω, 1%, 1/8W, MtF	H1	85/C2	PRP	**	R-88-806
R329	3.65KΩ, 1%, 1/8W, MtF	J1	86/C2	PRP	**	R-88-3.65K
R330	6.49KΩ, 1%, 1/8W, MtF	J1	87/C2	PRP	**	R-88-6.49K
R331	22MΩ, 10%, 1/4W, Carb F	G3	88/C3	MEP	CR25*	R-76-22M
R332	47KΩ, 5%, 1/4W, Carb F	G3	89/C3	MEP	CR25*	R-76-47K
R333	100Ω, 5%, 1/4W, Carb F	G1	90/B1	MEP	CR25*	R-76-100
R334	Not Used					
R335	2.15KΩ, .1%, 1/10W, MtF	H1	92/D2	TRW	MAR-5*	R-263-2.15K
R336	100KΩ, 5%, 1/4W, Carb F	L1	93/D3	MEP	CR25*	R-76-100K
R337	33KΩ, 5%, 1/4W, Carb F	L2	94/D3	MEP	CR25*	R-76-33K

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TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R338	270KΩ, 5%, 1/4W, Carb F	L2	95/D3	MEP	CR25*	R-76-270K
R339	68KΩ, 5%, 1/4W, Carb F	M4	96/D5	MEP	CR25*	R-76-68K
R340	100KΩ, 5%, 1/4W, Carb F	M5	97/D5	MEP	CR25*	R-76-100K
R341	100KΩ, 5%, 1/4W, Carb F	L7	98/C5	MEP	CR25*	R-76-100K
R342	1KΩ, 5%, 1/4W, Carb F	J4	99/D3	MEP	CR25*	R-76-1K
R343	10KΩ, 5%, 1/4W, Carb F	J5	100/D3	MEP	CR25*	R-76-10K
R344	120Ω, 5%, 1/4W, Carb F	J8	101/D3	MEP	CR25*	R-76-120
R345	Not Used					
R346	649KΩ, 1%, 1/8W, MtF	E2	103/C1	PRP	**	R-88-649K
U301	Op-Amp, 8-pin DIP	C1	117/D2	F-I	U9T7741393	IC-42
U302	Ultra-Low Offset Voltage Op-Amp	D3	118/D3	PMI	OP-07EP	IC-207
U303	Frequency Compensated Op-Amp	F2	119/C1	INT	ITS6423	IC-97
U304	Op-Amp, 8-pin DIP	J1	120/D1	F-I	U9T7741393	IC-42
U305	4-1/2 Digit Analog Processor	L1	121/D3	INT	8052A	LSI-12
U306	4-1/2 Digit Logic Processor	L3	122/C4	INT	T103	LSI-11-1 or LSI-11-3
U307	Dual D-Type Flip-Flop 14-pin DIP	M5, M6	123/D4	RCA	CD4013A3	IC-103
U308	Not Used					
U309	Dual 4-Input NOR	Several	125/D4	T-I	TP4002	IC-105
U310	4011 CMOS UnBuffered	Several	126/D4	MOT	MC14011CP	IC-102
U311	Triple 3 Input NOR	Several	127/D4	MOT	MC140258P	IC-208
U312	Quad 2-Input AND, 14-pin DIP	Several	128/D4	RCA	CD4081BE	IC-138
U313	Hex Buffer	J7	129/D4	MOT	MC14050CP	IC-107
U314	Quad 2-Input NOR, 14-pin DIP	N3	130/D3	RCA	CD4001AE	IC-108
U401	Segment Drive	M8	18/E2	MOT	4511	IC-168
U402	Digit Driver	J7	19/E2	T-I	75492	IC-169

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TABLE 7-1
Replaceable Parts List
PC-481 - Schematic 29653E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
VR301	Diode, Zener	E3	132/D3	MOT	1N751	DZ-59
VR302	Diode, Zener	E3	133/D3	MOT	1N751	DZ-59
VR303	Diode, Zener	G2	134/C2	MOT	1N751	DZ-59
VR304	Diode, Zener	G2	135/C2	MOT	1N751	DZ-59
VR305	Diode, Zener	H1	136/C2	MOT	1N4577	DZ-58
VR306	3-Term Positive Voltage Regulator	G4	137/B2	F-I	µA7806KC	IC-211
VR307	3-Term Positive Voltage Regulator	G5	138/C3	MOT	MC-7815CP	IC-96
VR308	+15V, 3-Term, LO-Power	G6	139/C3	MOT	MC7915CT	IC-174
VR309	+24V, Positive Voltage Regulator	G7	140/C3	F-I	µA78M24C	IC-210
VR310	Diode, Zener	C2	141/E3	DIC	1N754A	DZ-50
VR311	Diode, Zener	C2	142/E3	DIC	1N754A	DZ-50

Replaceable Parts List
PC-482 - Schematic 29653E

Q401	NPN Switch	J7	12/A2	MOT	2N3904	TG-47
R401	120Ω, 5%, 1/4W, Carb F	J7	14/B3	MEP	CR25*	R-76-120
R402	Thick Film	M8	15/D2	K-I	--	TF-89
R403	120Ω, 5%, 1/4W, Carb F	J7	16/A2	MEP	CR25*	R-76-120
R404	50KΩ, 5%, 2W, Pot	C1	17/F2	BRN	*	RP-115-50K

*Manufacturers Designation Includes Part Description (e.g. CR25, 12K, 5%, 1/4W, Comp. for R301)

**Manufacturers Designation is GP 1/4, 1%, +100, Resistance Value

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TABLE 7-2
Replaceable Parts List
PC-480 - Schematic 29654E

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C101	Air Capacitor, 20pF	A6	*	-	--	29765
C102	33pF, 500V, Polystyrene	B6	**	CLB	CPR-33p	C-138-33p
C103	5pF, 200V, Polystyrene	C6	**	MAL	SX-550	C-31-5p
C104	5pF, 200V, Polystyrene	C6	**	MAL	SX-550	C-31-5p
C105	10µF, 20V, ETT	J3	7/C5	ITT	TAPA10µFK20	C-179-10
C106	10µF, 35V, Tant	J2	8/C4	SIE	010652C35M	C-170-10
C107	10µF, 20V, ETT	K4	9/B4	ITT	TAPA10µFK20	C-179-10
C108	1µF, 50V, Cer	J4	10/B3	ERI	8131M050	C-237-1
C109	33µF, 15V, Tant	M5	11/B5	NCI	DNS336B015KR	C-228-33
C110	.05µF, 50V, Polycarb	L8	12/B3	ECI	62581A503J	C-201-.05
C111	1500pF, 250V, Mono, Cer, Network	Several	13/B4	ACI	02320	C-302-1500p
C112	1500pF, 250V, Mono, Cer, Network	Several	14/B4	ACI	02320	C-302-1500p
C113	Not Used					
C114	.01µF, 16V, CerD	H2	16/B4	CLB	UK16-103	C-238-.01
C115	.01µF, 16V, CerD	H3	17/B4	CLB	UK16-103	C-238-.01

*C101 is fastened to the capacitor bracket which is fastened to the top plate of the remote input head.
**C102, C103, C104 are shunting the Hi Meg Resistors 10^8, 10^{10}, 10^{11} Ω respectively.

CR101	Rectifier, 75mA, 75V	F1	19/C4	T-I	1N4148	RF-28
CR102	Rectifier, 75mA, 75V	K5	20/B5	T-I	1N4148	RF-28
CR103	Rectifier, 75mA, 75V	K8	21/B3	T-I	1N4148	RF-28
CR104	Rectifier, 75mA, 75V	M8	22/B3	T-I	1N4148	RF-28
CR106	Rectifier, 75mA, 75V	F1	23/C4	T-I	1N4148	RF-28
J1014	BNC	P3	--	AMP	31-221	CS-15
J1016	22 pin housing	N1	-/B4	BRG	CS-335-22	CS-335-22
J1017	Mini PV	C4	-/C3	BRG	75691-5	CS-236
J1018	1 pin Socket	E5	--	BRG	75315-001	SO-85
J1019	1 pin Socket	E6	--	BRG	75315-001	SO-85
J1020	3 pin housing	Several	--	BRG	65039-034	CS-270
J1021	3 pin housing	Several	--	BRG	65039-034	CS-270
J1022	4 pin housing	Several	--	BRG	65039-089	CS-371-4
J1023	4 pin housing	Several	--	BRG	65039-089	CS-371-4
J1024	4 pin housing	Several	--	BRG	65039-089	CS-371-4

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TABLE 7-2
Replaceable Parts List
PC-480 - Schematic 29654E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
J1025	4 pin housing	Several	--	BRG	65039-089	CS-371-4
J1026	8 pin housing	G5	--	BRG	65039C	CS-310
J1027	Binding Post, Black	M2	--	HHS	1517BL	BP-11-0
J1028	Binding Post, Green	M2	--	HHS	1517GR	BP-11-5
P1015	19 pin, Hermetic, Not Provided	Several	--	CAN	MS-3102E -22-14P-AIV5	CS-370-2
P1016	11 pin, Right Angle	N1	26, 27/B4	BRG	65532-136	CS-362-11
P1017	1 pin, Right Angle	C4	28/C3	BRG	65532-136	CS-362-1
P1018	Not Used					
P1019	Not Used					
P1020	6 pin, Right Angle	Several	31/B3	BRG	65532-136	CS-362-6
P1021	6 pin, Right Angle	Several	32/B3	BRG	65532-136	CS-362-6
P1022	8 pin, Right Angle	Several	33/D3	BRG	65532-136	CS-362-8
P1023	8 pin, Right Angle	Several	35/D5	BRG	65532-136	CS-362-8
P1024	8 pin, Right Angle	Several	36/C5	BRG	65532-136	CS-362-8
P1025	8 pin, Right Angle	Several	34/D3	BRG	65532-136	CS-362-8
P1026	8 pin, Right Angle	Several	37/C5	BRG	65532-136	CS-362-8
P1027	4 pin, Connector	H2	38/B4	BRG	65507-136	CS-379-4
Q101	Monolithic PNP, Dual	E1	49/C4	A-D	AD820	TG-121
Q102	PNP, Silicon	K5	50/A5	G-E	2N3906	TG-84
R101	39.2KΩ, 1%, 1/8W, MtF	B3	53/C3	PRP	**	R-88-39.2K
R102	7.15KΩ, 1%, 1/8W, MtF	B3	54/C3	PRP	**	R-88-7.15K
R103	100KΩ, 1%, 1/8W, MtF	C3	55/C3	PRP	**	R-88-100K
R104	4.75KΩ, 1%, 1/8W, MtF	C3	56/C3	PRP	**	R-88-4.75K
R105	1MΩ, 1%, 1/8W, MtF	B4	57/B3	PRP	**	R-88-1M
R106	6.336KΩ, .1%, 1/8W, MtF	E1	58/D4	DLE	MFF*	R-168-6.336K
R107	6.336KΩ, .1%, 1/8W, MtF	E1	59/D4	DLE	MFF*	R-168-6.336K
R108	4.99KΩ, .1%, 1/8W, MtF	F1	60/D4	DLE	MFF*	R-176-4.99K
R109	4.99KΩ, .1%, 1/8W, MtF	F1	61/D4	DLE	MFF*	R-176-4.99K
R110	7.15KΩ, 1%, 1/8W, MtF	F2	62/D5	PRP	**	R-88-7.15K
R111	32.4KΩ, .1%, 1/8W, MtF	D2	63/D4	DLE	MFF*	R-168-32.4K

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TABLE 7-2
Replaceable Parts List
PC-480 - Schematic 29654E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R112	1.62KΩ, 1%, 1/8W, MtF	D2	64/D4	DLE	MFF*	R-177-1.62K
R113	806Ω, 1%, 1/8W, MtF	D2	65/D4	DLE	MFF*	R-177-806
R114	402Ω, 1%, 1/8W, MtF	D2	66/D4	DLE	MFF*	R-177-402
R115	200Ω, 1%, 1/8W, MtF	D3	67/D4	DLE	MFF*	R-177-200
R116	100Ω, 1%, 1/8W, MtF	D3	68/D3	PRP	**	R-88-100
R117	162Ω, 1%, 1/8W, MtF	D4	69/D3	DLE	MFF*	R-177-162
R118	80.6Ω, 1%, 1/8W, MtF	D4	70/D3	DLE	MFF*	R-177-80.6
R119	40.2Ω, 1%, 1/8W, MtF	D4	71/D3	DLE	MFF*	R-177-40.2
R120	20Ω, 1%, 1/8W, MtF	D5	72/D3	PRP	**	R-88-20
R121	20Ω, 10%, Cermet Trimmer	D5	73/C3	BRN	3386F-1-200	RP-97-20
R122	10^8Ω, +0, -20%, 1/2W, Film	B6	--	DLE	M51*	R-270-10^8
R123	10^{10}Ω, +0, -20%, 1/2W, Film	C6	--	DLE	M51*	R-270-10^{10}
R124	10^{11}Ω, +0, -20%, 1/2W, Film	D6	--	DLE	M51*	R-270-10^{11}
R125	10^{12}Ω, +0, -20%, 1/2W, Film	D6	--	DLE	M51*	R-270-10^{12}
R126	200KΩ, 10%, Cermet Trimmer	B7	77/D3	BRN	3386F-1-204	RP-97-200K
R127	200KΩ, 10%, Cermet Trimmer	B7	78/D4	BRN	3386F-1-204	RP-97-200K
R128	200KΩ, 10%, Cermet Trimmer	C7	79/D4	BRN	3386F-1-204	RP-97-200K
R129	200KΩ, 10%, Cermet Trimmer	D7	80/D4	BRN	3386F-1-204	RP-97-200K
R130	200KΩ, 10%, Cermet Trimmer	D7	81/D3	BRN	3386F-1-204	RP-97-200K
R131	140KΩ, 1%, 1/8W, MtF	B8	82/C3	PRP	**	R-88-140K
R132	28.7KΩ, 1%, 1/8W, MtF	E7	83/C4	PRP	**	R-88-28.7K
R133	9.09KΩ, 1%, 1/8W, MtF	E8	84/C4	PRP	**	R-88-9.09K
R134	6.04KΩ, 1%, 1/8W, MtF	E8	85/C4	PRP	**	R-88-6.04K
R135	200KΩ, 10%, Cermet Trimmer	D7	86/C3	BRN	3386F-1-204	RP-97-200K
R136	301Ω, 1%, 1/8W, MtF	E4	87/D3	DLE	MFF*	R-177-301
R137	9.09KΩ, 1%, 1/8W, MtF	J2	88/C4	PRP	**	R-88-9.09K
R138	5KΩ, 10%, Cermet Trimmer	J3	89/C5	BEC	89P*	RP-89-5K
R139	9.09KΩ, 1%, 1/8W, MtF	J3	90/C4	PRP	**	R-88-9.09K
R140	7.32KΩ, .1%, 1/8W, MtF	H4	91/B4	DLE	MFF*	R-168-7.32K
R141	127KΩ, .1%, 1/8W, MtF	H4	92/B4	DLE	MFF*	R-168-127K
R142	7.32KΩ, .1%, 1/8W, MtF	H5	93/B3	DLE	MFF*	R-168-7.32K

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TABLE 7-2
Replaceable Parts List
PC-480 - Schematic 29654E
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R143	118KΩ, .1%, 1/8W, MtF	H5	94/B3	DLE	MFF*	R-168-118K
R144	9.09KΩ, 1%, 1/8W, MtF	J5	95/B3	PRP	**	R-88-9.09K
R145	330Ω, 10%, 1/2W, Comp	K2	96/C5	A-B	EB*	R-1-330
R146	49.9Ω, 1%, 1/8W, MtF	L3	97/C4	PRP	**	R-88-49.9
R147	1KΩ, 1%, 1/8W, MtF	L3	98/C4	PRP	**	R-88-1K
R148	100KΩ, 20%, 3/4W, Variable Carb Cer	P4		CTS	CU5LAYSB104A-100K	RP-118-100K
R149	470Ω, 5%, 1/4W, CarbF	L5	100/B5	MEP	CR25*	R-76-470
R150	2.2MΩ, 10%, 1/4W, CarbF	L8	101/B3	MEP	CR25*	R-76-2.2M
R151	200KΩ, 10%, Cermet Trimmer	B3	102/C3	BRN	3386F-1-204	RP-97-200K
R152	100KΩ, 1%, 1/2W, MtF	C5		DLE	MFF*	R-94-100K

*Manufacturers Designation Includes Part Description (e.g. MFF, 6.336K 1/8W MF, for R107).
**Manufacturers Designation is GP1/4, 1%, T100, Resistance Value.

U101	Op-Amp, Monolithic JFET	H3	124/B5	NAT	LF-356A	IC-209
U102	Integrated Circuit Op-Amp	H4	125/B4	F-I	LM307N	IC-61
U103	Not Used					
U104	High Voltage, High Current Transistor Array	Several	127/B4	SIG	ULN2003A	IC-206
U105	Timing Logic, 8-pin DIP	K8	128/B3	SIG	NE555U	IC-71
VR101	Silicon Voltage Regulator Diode	J3	129/C5	DIC	1N967A	DZ-35
VR102	Diode, Zener	J3	130/B4	TEL	1N718	DZ-18
VR103	Diode, Zener	J3	131/B4	TEL	1N718	DZ-18
VR104	Diode, Zener	F1	132/D4	MOT	1N4577	DZ-58

Replaceable Parts List
PC-479 - Schematic 29654E

CR201	Rectifier, 75mA, 75V	F5	7/-	T-I	1N4148	RF-28
PC-479	Input FET Card	--	--	K-I	PC-479	30845

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TABLE 7-3
Replaceable Parts List
PC-494 - Schematic 29968D

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C101	1µF, 50V, Cer	D2	4/D5	ERI	8131M50	C-237-1.0
C102	22µF, 35V, EAL	E1	5/D5	ITT	TAPA/22µFK20	C-179-22
C103	1.2µF, 35V, EAL	E2	6/C5	ITT	TAPA/1.2µFK20	C-179-1.2
C104	4.7µF, 35V, EAL	D4	7/D4	ITT	TAPA/4.7µFK20	C-179-4.7
C105	4.7µF, 35V, EAL	D5	8/DA	ITT	TAPA/4.7µFK20	C-179-4.7
C106	10µF, 35V, TANT	E4	9/E4	SIE	D10GS/2C35M	C-170-10
C107	10µF, 35V, TANT	E5	10/E4	SIE	D10GS/2C35M	C-170-10
C108	10µF, 35V, TANT	E5	11/E4	SIE	D10GS/2C35M	C-170-10
C109	22µF, 35V, EAL	D4	12/D4	ITT	TAPA/22µFK20	C-179-22
C110	4.7µF, 35V, EAL	E3	13/E4	ITT	TAPA/4.7µFK20	C-179-4.7
C111	1µF, 50V, Cer	B2	14/E5	ERI	8131M50	C-237-1.0
CR101	Rectifier, 1A, 800V	A1	17/E5	MOT	1N4006	RF-38
CR102	Rectifier, 1A, 800V	E2	18/D5	MOT	1N4006	RF-38
CR103	Rectifier, 3A, 50V	F2	19/C4	MOT	MR-501	RF-34
CR104	Rectifier, 75mA, 75V	D4	20/D4	T-I	1N4148	RF-28
CR105	Rectifier, 75mA, 75V	D4	21/D4	T-I	1N4148	RF-28
CR106	Rectifier, 75mA, 75V	E4	22/D4	T-I	1N4148	RF-28
CR107	Rectifier, 75mA, 75V	E4	23/E4	T-I	1N4148	RF-28
CR108	Rectifier, 75nmA, 75V	E4	24/E4	T-I	1N4148	RF-28
CR109	Rectifier, 75mA, 75V	E4	25/E4	T-I	1N4148	RF-28
CR110	Rectifier, 75mA, 75V	E4	26/E4	T-I	1N4148	RF-28
CR111	Rectifier, 75mA, 75V	E4	27/E4	T-I	1N4148	RF-28
CR112	Rectifier, 75mA, 75V	E5	28/E4	T-I	1N4148	Rf-28
CR113	Rectifier, 75mA, 75V	E5	29E4	T-I	1N4148	RF-28
CR114	Rectifier, 75mA, 75V	D3	30/D5	T-I	1N4148	RF-28
F101	Fuse, 1.5A, 250V, 3AG	F1	35/B4	L-F	31201.5	FU-8
J101	Binding Post, Red	F1	37/C5	HHS	1517 (Color)	BP-11-2
J102	Binding Post, Black	F2	38/C4	HHS	1517 (Color)	BP-11-0
J1011	8 Pin Housing	A1	41/G3	MOL	2139-8	CS-287-8
Q101	PNP, Darlington	A1	44/E5	MOT	MPS-U95	TG-133
Q102	PNP, Switch	B2	45/E5	MOT	2N3906	TG-84

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TABLE 7-3
Replaceable Parts List
PC-494 - Schematic 29968D
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q103	PNP, Darlington	E2	46/C5	GE	D45E1	TG-127
Q104	NPN, Amplifier	D3	47/D5	T-I	2N3904	TG-47
Q105	NPN, Switch	C4	48/D4	T-I	2N3904	TG-47
Q106	PNP, Switch	C4	49/D4	MOT	2N3906	TG-84
Q107	PNP, Switch	C4	50/D4	MOT	2N3906	TG-84
Q108	NPN, Switch	C5	51/D4	T-I	2N3904	TG-47
Q109	NPN, Switch	D4	52/C4	MOT	MJE521	TG-124
Q110	NPN, Swtich	D5	53/C4	MOT	MJE521	TG-124
R101	10KΩ, 5%, 1/4W, Carb F	B2	57/E5	MEP	CR25*	R-76-10K
R102	10KΩ, 5%, 1/4W, Carb F	B2	58/E5	MEP	CR25*	R-76-10K
R103	10KΩ, 5%, 1/4W, Carb F	B2	59/E5	MEP	CR25*	R-76-10K
R104	10KΩ, 5%, 1/4W, Carb F	C2	60/E5	MEP	CR25*	R-76-10K
R105	44.2KΩ, 1%, 1/8W, MtF	D2	61/D5	PRP	**	R-88-44.2K
R106	3.16KΩ, 1%, 1/8W, MtF	C2	62/D5	PRP	**	R-88-3.16K
R107	4.53KΩ, 1%, 1/8W, MtF	D3	63/D5	PRP	**	R-88-4.53K
R108	820KΩ, 5%, 1/4W, Carb F	C2	64/D5	MEP	CR25*	R-76-820K
R109	1.8MΩ, 5%, 1/4W, Carb F	C3	65/D5	MEP	CR25*	R-76-1.8M
R110	10KΩ, 5%, 1/4W, Carb F	D2	66/C5	MEP	CR25*	R-76-10K
R111	10KΩ, 5%, 1/4W, Carb F	D2	67/D5	MEP	CR25*	R-76-10K
R112	10KΩ, 5%, 1/4W, Carb F	C3	68/D5	MEP	CR25*	R-76-10K
R113	10KΩ, 5%, 1/4W, Carb F	D3	69/D5	MEP	CR25*	R-76-10K
R114	NOT USED					
R115	33Ω, 5%, 1/4W, Carb F	D4	71/D4	MEP	CR25*	R-76-33
R116	33Ω, 5%, 1/4W, Carb F	D5	72/D4	MEP	CR25*	R-76-33
R117	10Ω, 5%, 1/4W Carb F	F4	73/E4	MEP	CR25*	R-76-10
R118	10Ω, 5%, 1/4W, Carb F	F5	74/E4	MEP	CR25*	R-76-10
R119	10Ω, 5%, 1/4W, Carb F	F5	75/E4	MEP	CR25*	R-76-10
R120	15KΩ, 1%, 1/8W, MtF	D2	76/D5	PRP	**	R-88-15K
R121	1KΩ, 5%, 1/4W, Carb F	D3	77/D5	MEP	CR25*	R-76-1K
R122	1KΩ, 5%, 1/4W, Carb F	C1	78/E5	MEP	CR25*	R-76-1K
R123	1.5KΩ, 5%, 1/4W, Carb F	E3	79/E5	MEP	CR25*	R-76-1.5K

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TABLE 7-3
Replaceable Parts List
PC-494 - Schematic 29968D
(Continued)

Circuit Desig.	Description	Schematic Location	PC-Board Item No./Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
T101	Transformer, Inverter	E5	80/D4	K-I	--	TR-172
U101	1.1V Micro-Power Detector Selected ICL8211CPA	C2	82/D5	K-I	--	IC-177
U102	1.1V Micro-Power Detector Selected ICL8211CPA	C3	83/E4	K-I	--	IC-177
U103	Dual D-type Flip-Flop, 14 Pin DIP	B5	84/D4	RCA	CD4013A3	IC-103
VR101	Diode, Zener 20V, 5%	E3	87/E5	SIE	1N4747A	DZ-25

*Manufacturers Designation Includes Part Description (e.g. CR25, 10K, 5%, 1/4W, Comp. for R101.)

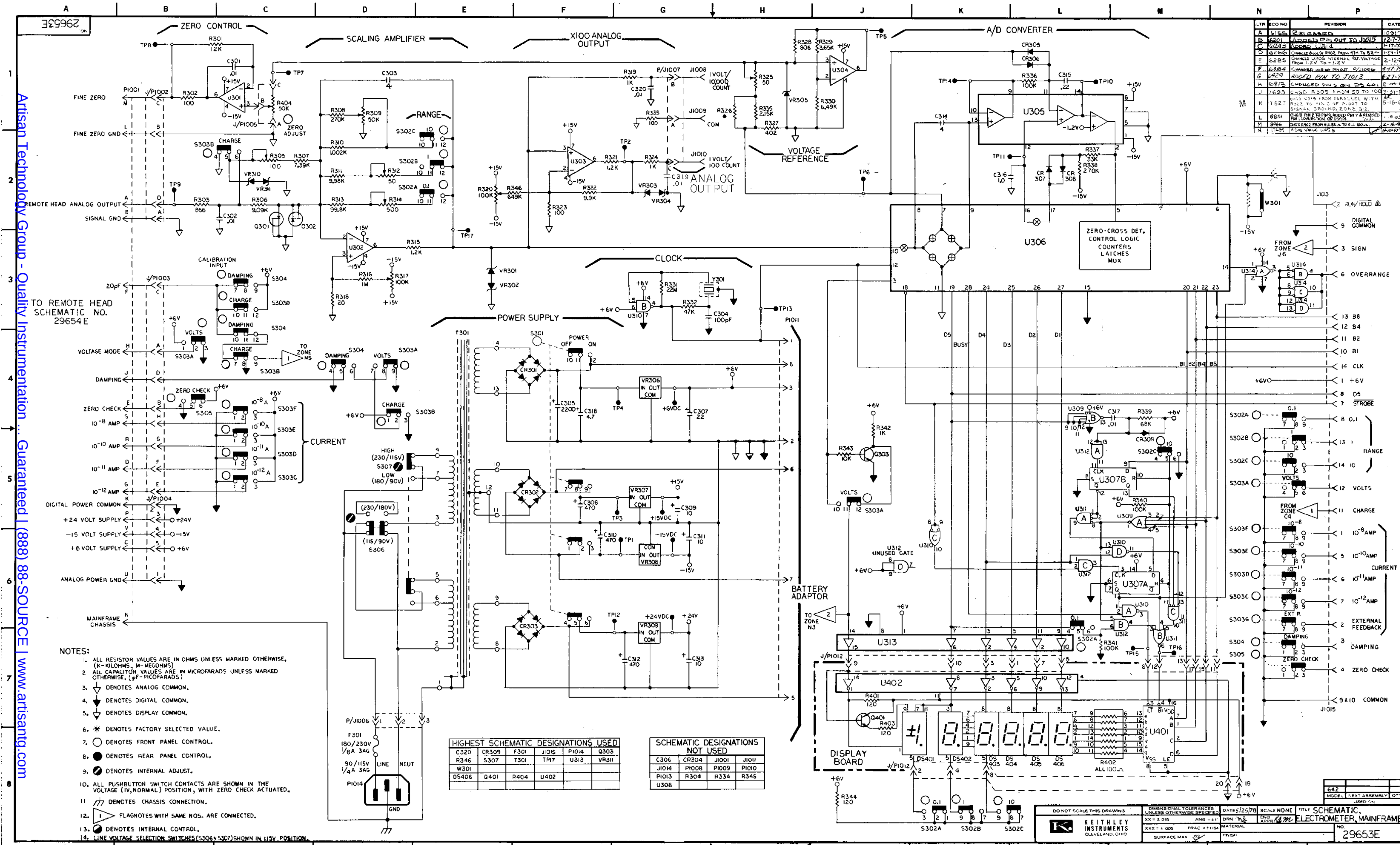
**Manufacturers Designation is GP 1/4, 1%, +100, Resistance Value.

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TABLE 7-4
Cross Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE	MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE
A-B	Allen-Bradley Corp. Milwaukee, WI 53204	01121	ITT	ITT Semiconductor Lawrance, MA 01841	15238
A-D	Analog Devices, Inc. Norwood, MA 02026	24355	K-I	Keithley Instruments, Inc. Cleveland, OH 44139	80164
ACI	American Components, Inc. Conshohocken, PA 19423	14298	L-F	Little Fuse, Inc. Des Plaines, IL 60016	75915
AMP	Amphenol Broadview, IL 60153	02660	MAL	Mallory Indianapolis, IN 46206	90201
BEC	Beckman Instruments, Inc. Fullerton, CA 92634	73188	MEP	Mepco, Inc. Morristown, NJ 07960	80031
BRG	Berg Electronic, Inc. New Cumberland, PA 17070	22526	MMM	3M Company St. Paul, MN 55101	
BRN	Bourns, Inc. Riverside,CA 92507	80294	MOL	Molex Downers Grove, IL 60515	27264
CAL	Callins Ind. Greenfield, TN 38230	05844	MOT	Motorola Semi Products, Inc. Phoenix, AZ 85008	04713
CAN	Cannon Woodbury, TN	31746	NAT	National Semi. Corp. Santa Clara, CA 94086	18324
CLB	Centralab Division Milwaukee, WI 53201	71590	NCI	National Components Inc. West Palm Beach, FL	
CTI	Circuit Technology Inc. Farmingdale, NY 11735	32116	NIC	Nichicon Corp Chicago, IL 60645	
CTS	CTS Corporation Elkhart, IN 46514	71450	P B	Potter and Brumfield Princeton, IN 47670	77342
DIC	Dickson Scotsdale, AZ 85008	04713	PMI	PMI Corp. Sacramento, CA 95813	31148
DLE	Dale Electronics Columbus, NE 68601	91637	PRP	Precision Resistive Products Mediapolis, IA 53237	
ECI	Electro-Cube, Inc. San Gabriel, CA 91776	14752	RCA	RCA Corporation Moorestown, NJ 08050	02734
EDI	Electronic Devices Inc. Yonkers, NY 10710	83701	SIE	Siemens Corp. Iselin, NJ 08830	25088
ERI	Erie Technological Prod. Erie, PA 16512	72982	SIG	Signetics Corp. Sunnyvale, CA 94086	18324
G-E	General Electric Co. Syracuse, NY 13201	03508	T-I	Texas Instruments, Inc. Dallas, TX 75231	01295
G-I	General Instrument Corp. Newark, NJ 07104	72699	TEL	Teledyne Mountain View, CA 94040	15818
HHS	H.H. Smith Brooklyn, NY 11207	83330	TOW	Tower Mfg. Corp. Providence, RI 02903	87930
INT	Intersil, Inc. Cupertino, CA 95014	32293	TRW	TRW Elect. Components IRC Boone, NC 28607	11502
			WES	Wesco Electric Greenfield, MA 01301	12673

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NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. DENOTES ANALOG COMMON.
4. DENOTES DIGITAL COMMON.
5. DENOTES DISPLAY COMMON.
6. ✳ DENOTES FACTORY SELECTED VALUE.
7. ○ DENOTES FRONT PANEL CONTROL.
8. ● DENOTES REAR PANEL CONTROL.
9. DENOTES INTERNAL ADJUST.
10. ALL PUSHBUTTON SWITCH CONTACTS ARE SHOWN IN THE VOLTAGE (1V, NORMAL) POSITION, WITH ZERO CHECK ACTUATED.
11. DENOTES CHASSIS CONNECTION.
12. FLAGNOTES WITH SAME NOS. ARE CONNECTED.
13. DENOTES INTERNAL CONTROL.
14. LINE VOLTAGE SELECTION SWITCHES (S306+S307) SHOWN IN 115V POSITION.

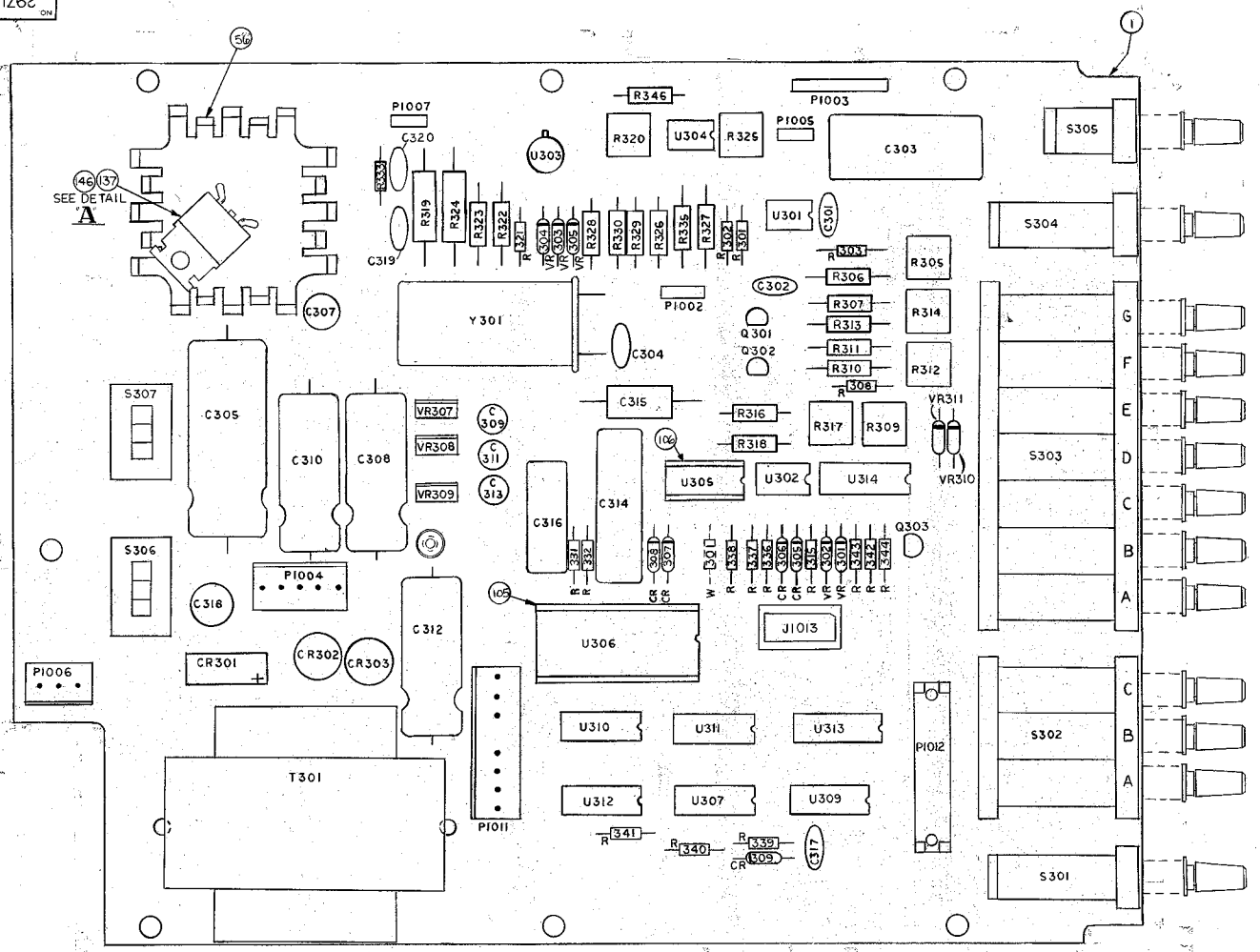
HIGHEST SCHEMATIC DESIGNATIONS USED					
C320	CR309	F301	J1015	P1014	Q303
R346	S307	T301	TP17	U313	VR311
W301					
DS406	Q401	R404	U402		

SCHEMATIC DESIGNATIONS NOT USED			
C306	CR304	J1001	J1011
J1014	P1008	P1009	P1010
P1013	R304	R334	R345
U308			

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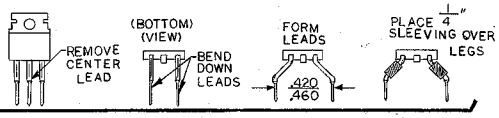
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29718D



ZONE	LTR	ECO NO	REVISION	DATE
	A	6017	RELEASED	8-9-78
	B	6064	ADDED JUMPER	9/6/78
	C	6089	REVISED	8-22-78
	D	6112	ITEM #45 WAS CS-288-8	9/14/78
	E	6201	REVISED	12-1-78
	F	6243	ADDED ITEM #43 & #130	1/15/79
	G	6285	CHANGED PC ARTWORK PICTURED FROM REV. F TO REV. G	2-12-79
	H	6429	CHANGED PC ARTWORK PICTURE FROM REVS. TO REV H	5-3-79
	J	7693	CHGD ITEM 61 FROM 50 TO 100Ω	3-1-81
	K	7820	CHG'D. ARTWORK WAS REV. H & LOCATION OF MOUNTING HOLES	7-2-81
M	L	8932	ITEM 122 WAS LS1-11-1 OR -3	11-24-81
	M	9967	ADDED DET. A'S 137 WAS IC-211	6-6-84
	N	17639	Item 4 was C-294-5	10-4-91

DETAIL A: ASSEMBLE IC-64 TO HS-11 AS FOLLOWS:



ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29830 B STAKING		F1
2	C238-.01	C301	D1
3	" "	C302	D2
4	C294-4	C303	D1
5	C64-100P	C304	C2
6	C290-2200	C305	B3
7			
8	C180-22	C307	B2
9	C289-470	C308	B3
10	C179-10	C309	C3
11	C289-470	C310	B3
12	C179-10	C311	C3
13	C292-470	C312	C4
14	C170-10	C313	C3

ITEM	PART NO.	SCHEM. DESIG.	ZONE
15	C294-4	C314	C3
16	C249-.22	C315	C3
17	C294-1	C316	C3
18	C238-.01	C317	D5
19	C179-4.7	C318	B3
20	C-238-0.01	C319	B2
21	"	C320	B1
22			
23	RF-36	CR301	B4
24	RF-46	CR302	B4
25	"	CR303	B4
26			
27	RF-28	CR305	D3
28			

ITEM	PART NO.	SCHEM. DESIG.	ZONE
29	RF-28	CR306	D3
30	"	CR307	D3
31	"	CR308	D3
32	"	CR309	D5
33			
34			
35			
36	CS-339-4	P1002	D2
37	CS-339-8	P1003	D1
38	CS-288-5	P1004	B3
39	CS-339-3	P1005	D1
40	CS-288-3	P1006	A4
41	CS-339-3	P1007	B1
42			

ITEM	PART NO.	SCHEM. DESIG.	ZONE
43			
44			
45	30109A	P1011	C4
46	CS-348-20	P1012	E4
47			
48			
49	SO-70	J1013	D4
50			
51	TG-77	Q301	D2
52	"	Q302	D2
53	TG-47	Q303	D3
54			
55			
56	HS-11	~	B2

ITEM	PART NO.	SCHEM. DESIG.	ZONE
57	R76-12K	R301	D2
58	R76-100	R302	D2
59	R88-866	R303	D2
60			
61	RP-97-100	R305	E2
62	R263-9.09K	R306	D2
63	R263-7.39K	R307	D2
64	R76-270K	R308	D2
65	RP-97-50K	R309	D3
66	R263-1.00K	R310	D2
67	R263-9.98K	R311	D2
68	RP-97-50	R312	E2
69	R263-99.8K	R313	D2
70	RP-97-500	R314	E2
71	R76-1.2K	R315	D3
72	R88-1M	R316	D3
73	RP-97-100K	R317	D3
74	R88-20	R318	D3
75	R94-1K	R319	C2
76			
77	RP-97-100K	R320	C1
78	R76-1.2K	R321	C2
79	R168-9.9K	R322	C2
80	R168-100	R323	C2
81	R94-1K	R324	C2
82	RP-97-50	R325	D1
83	27699A	R326	C2
84	R263-402	R327	D2
85	R88-806	R328	C2
86	R88-3.65K	R329	C2
87	R88-6.49K	R330	C2
88	R76-22M	R331	C3
89	R76-47K	R332	C3
90	R-76-100	R333	B1
91			
92	R263-2.15K	R335	D2
93	R76-100K	R336	D3
94	R76-33K	R337	D3
95	R76-270K	R338	D3
96	R76-68K	R339	D5
97	R76-100K	R340	D5
98	" "	R341	C5
99	R76-1K	R342	D3
100	R76-10K	R343	D3
101	R76-120	R344	D3
102			
103	R88-649K	R346	C1
104			
105	SO-69	~	C4
106	SO-70	~	D3

ITEM	PART NO.	SCHEM. DESIG.	ZONE
107	SW-406	S301	E5
108	SW-411	S302	E4
109	SW-412	S303	E3
110	SW-406	S304	E2
111	SW-410	S305	E1
112	SW-397	S306	A3
113	"	S307	A3
114			
115	TR-171	T301	B5
116			
117	IC-42	U301	D2
118	IC-207	U302	D3
119	IC-97	U303	C1
120	IC-42	U304	D1
121	LS1-12	U305	D3
122	LS1-11	U306	C4
123	IC-103	U307	D4
124			
125	IC-105	U309	D4
126	IC-102	U310	D4
127	IC-208	U311	D4
128	IC-138	U312	D4
129	IC-107	U313	D4
130	IC-108	U314	D3
131			
132	DZ-59	VR301	D3
133	"	VR302	D3
134	"	VR303	C2
135	"	VR304	C2
136	DZ-58	VR305	C2
137	IC-64	VR306	B2
138	IC-96	VR307	C3
139	IC-174	VR308	C3
140	IC-210	VR309	C3
141	DZ-50	VR-310	E3
142	"	VR-311	E3
143	J-3	W301	D3
144	CR-8	Y301	C2
145			
146	MK-18	—	B2

OBSOLETE PER ECA 260016

642		
MODEL	NEXT ASSEMBLY	QTY
	USED ON	

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

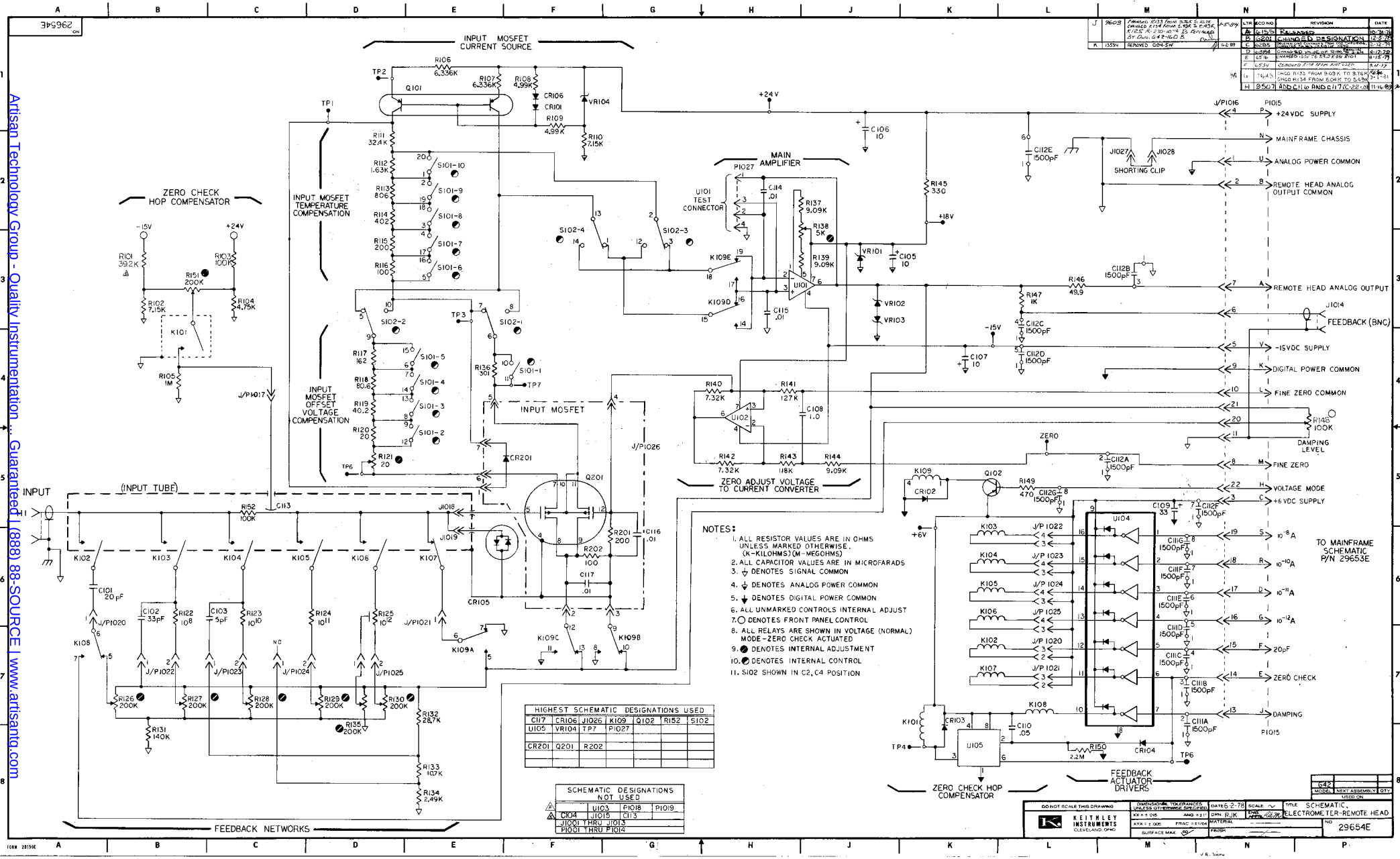
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .015, ANG. = ±1°, XXX = ± .005, FRAC. = ±1/64, SURFACE MAX 63

DATE 7-27-78 | SCALE 2:1 | DRN. R.J.K. | ENG. APPR. RGM | MATERIAL ~ | FINISH ~

TITLE COMPONENT LAYOUT PC-481

NO. 29718D

FORM 28511D

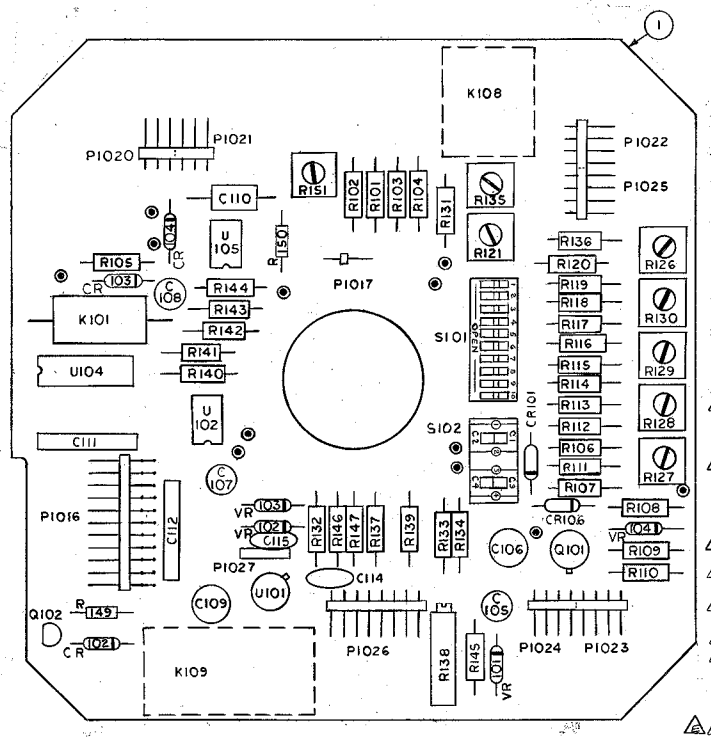


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29793D

ZONE	LTR	ECO NO	REVISION	DATE
	A	6077	RELEASED	8-9-78
	B	6078	REVISED	8-14-78
	C	6089	WAS C-64-100pf WAS 29726C	8-22-78
	D	6155	REVISED	10-25-78
	E	6201	REVISED	12-7-78
	F	6284	CHANGED R150 FROM 2.49M TO 2.49K	4-1-79
	G	6516	WAS R-88-100K (R101)	8-15-79
M	H	7643	CHGD ITEM 84 FROM 9.09K TO 9.76K CHGD ITEM 85 FROM 6.04K TO 5.49K	3-1-81
	J	9603	CHG'D R133 FROM 9.76K TO 10.7K CHG'D R134 FROM 5.49K TO 2.49K	4-5-84
	K	13534	CHG'D ITEM 46 FROM R151 TO R152	11-2-89



ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29795C	PC-480	D2
2			
3			
4			
5			
6			
7	C-179-10	C105	C5
8	C-170-10	C106	C4
9	C-179-10	C107	B4
10	C-237-1	C108	B3
11	C-228-33	C109	B5
12	C-201-.05	C110	B3
13	C-302-1500pF	C111	B4
14	"	C112	B4
15			
16	C-238-.01	C114	B4
17	"	C115	B4
18			
19	RF-28	CR101	C4
20	"	CR102	B5
21	"	CR103	B3
22	"	CR104	B3
23	"	CR106	C4
24			
25			
26	CS-362-11	P1016	B4
27	CS-363-11	P1016	B4
28	CS-362-1	P1017	C3
29			
30			
31	CS-362-6	P1020	B3
32	—	P1021	B3
33	CS-362-8	P1022	D3
34	—	P1025	D3
35	CS-362-8	P1023	D5

ITEM	PART NO.	SCHEM. DESIG.	ZONE
36	—	P1024	C5
37	CS-362-8	P1026	C5
38	CS-339-4	P1027	B4
39	RL-57	K101	B3
40			
41			
42			
43			
44			
45			
46	RL-72	K108	C2
47	RL-62	K109	B5
48			
49	TG-121	Q101	C4
50	TG-84	Q102	A5
51			
52			
53	R88-39.2K	R101	C3
54	R88-7.15K	R102	C3
55	R88-100K	R103	C3
56	R88-4.75K	R104	C3
57	R88-1M	R105	B3
58	R168-6836K	R106	D4
59	" "	R107	D4
60	R176-4.99K	R108	D4
61	"	R109	D4
62	R88-7.15K	R110	D5
63	R168-32.4K	R111	D4
64	R177-1.62K	R112	D4
65	R177-806	R113	D4
66	R177-402	R114	D4
67	R177-200	R115	D4
68	R88-100	R116	D3
69	R177-162	R117	D3
70	R177-80.6	R118	D3

ITEM	PART NO.	SCHEM. DESIG.	ZONE
71	R177-40.2	R119	D3
72	R88-20	R120	D3
73	RP-97-20	R121	C3
74			
75			
76			
77	RP97-200K	R126	D3
78	" "	R127	D4
79	" "	R128	D4
80	" "	R129	D4
81	" "	R130	D3
82	R88-140K	R131	C3
83	R-88-2.8K	R132	C4
84	R-88-10.7K	R133	C4
85	R-88-2.49K	R134	C4
86	RP-97-200K	R135	C3
87	R-177-301	R136	D3
88	R88-9.09K	R137	C4
89	RP89-5K	R138	C5
90	R88-9.09K	R139	C4
91	R168-7.32K	R140	B4
92	R168-127K	R141	B4
93	R168-7.32K	R142	B3
94	R168-118K	R143	B3
95	R88-9.09K	R144	B3
96	R-1-330	R145	C5
97	R88-49.9	R146	C4
98	R88-1K	R147	C4
99			
100	R76-470	R149	B5
101	R76-2.2M	R150	B3
102	RP97-200K	R151	C3
103			
104			
105			

ITEM	PART NO.	SCHEM. DESIG.	ZONE
106			
107			
108	SW-413	S101	C3
109	SW-414	S102	C4
110			
111	24249A	TP1	C4
112	"	TP2	C4
113	"	TP3	C4
114	"	TP4	B3
115	"	TP5	B3
116	"	TP6	C3
117	"	TP7	C3
118	"	+5V	B3
119	"	+18V	B4
120	"	-15V	B4
121	"	+24V	D4
122	"	ZERO	B3
123			
124	IC-209	U101	B5
125	IC-61	U102	B4
126			
127	IC-206	U104	B4
128	IC-71	U105	B3
129	D2-35	VR101	C5
130	D2-18	VR102	B4
131	"	VR103	B4
132	D2-58	VR104	D4

OBSOLETE PER ECA 26016

642		
MODEL	NEXT ASSEMBLY	QTY
USED ON		

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .015, ANG. ± 1°, XXX ± .005, FRAC. ± 1/64, SURFACE MAX. 63

DATE 6-3-79 | SCALE 2:1 | DRN RJK | ENG APPR | MATERIAL | FINISH

TITLE COMPONENT LAYOUT PC-480

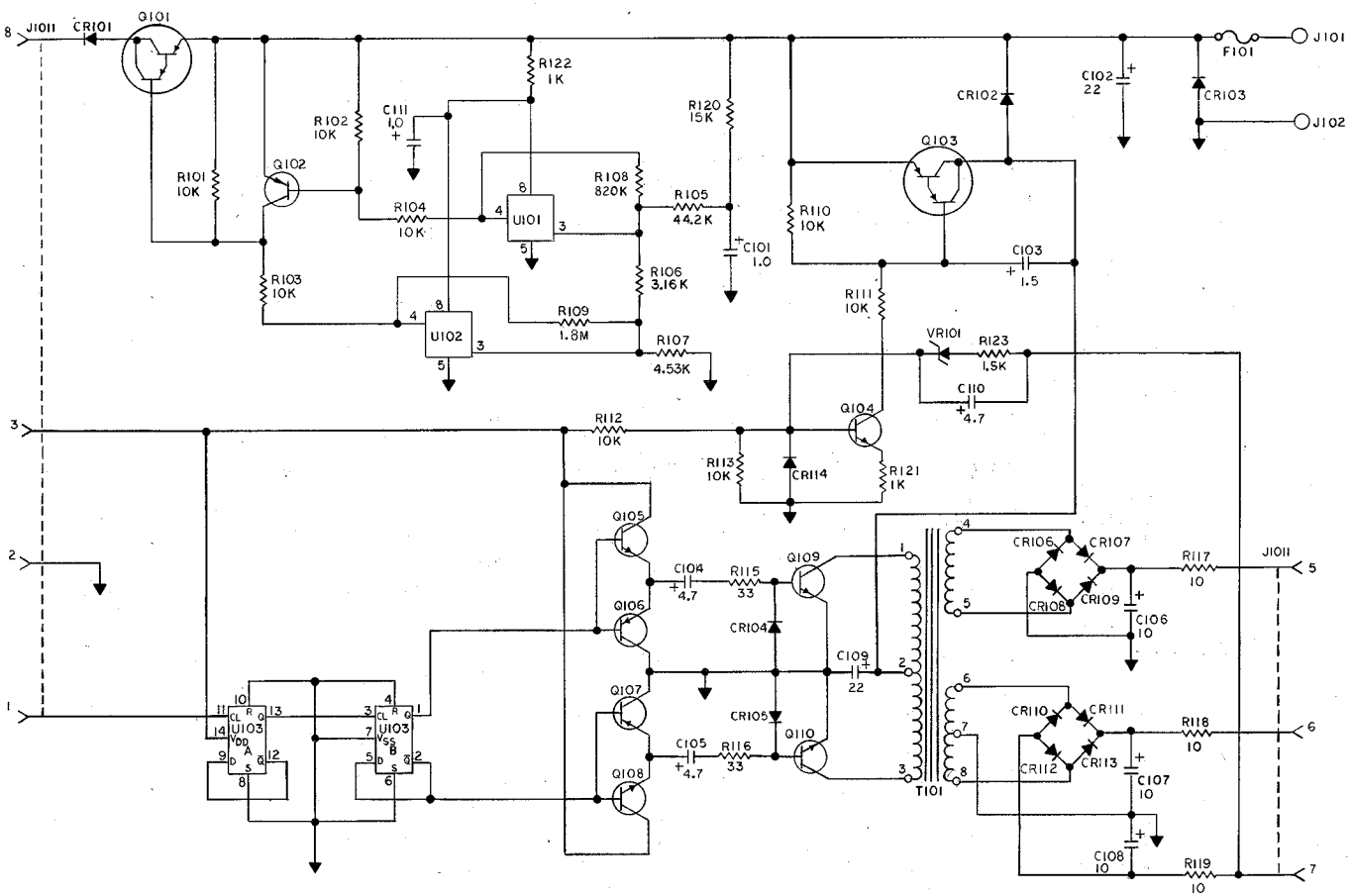
NO. 29793D

FORM 28511D

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29968D ON

ZONE	LTR	ECO NO	REVISION	DATE
	A	6103	RELEASED	8-7-78
	B	6161	REVISED	12-8-78
	C	6952	R108 WAS 1M; R102 WAS 15M; R120 WAS 22K	2-2-79 M
M	D	8192	C103 WAS 1.2	1-10-82



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ↓ DENOTES POWER SUPPLY COMMON.

HIGHEST SCHEMATIC DESIGNATIONS USED

R123	Q110	CR114	VR101
C111	U103	T101	F101
J102	J1011		

SCHEMATIC DESIGNATIONS NOT USED

J1001 THRU J1010		CR115	

OBSOLETE PER ECA 26016

6428		
MODEL	NEXT ASSEMBLY	QTY USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .015, ANG. = ±1°, XXX = ± .005, FRAC. = ±1/64, SURFACE MAX 63

DATE 8-11-78 | SCALE ⟷ | DRN KURET | ENGR APPR. KAR | MATERIAL | FINISH

TITLE SCHEMATIC, MODEL 6428 BATTERY ADAPTER

NO. 29968D

FORM 28511D

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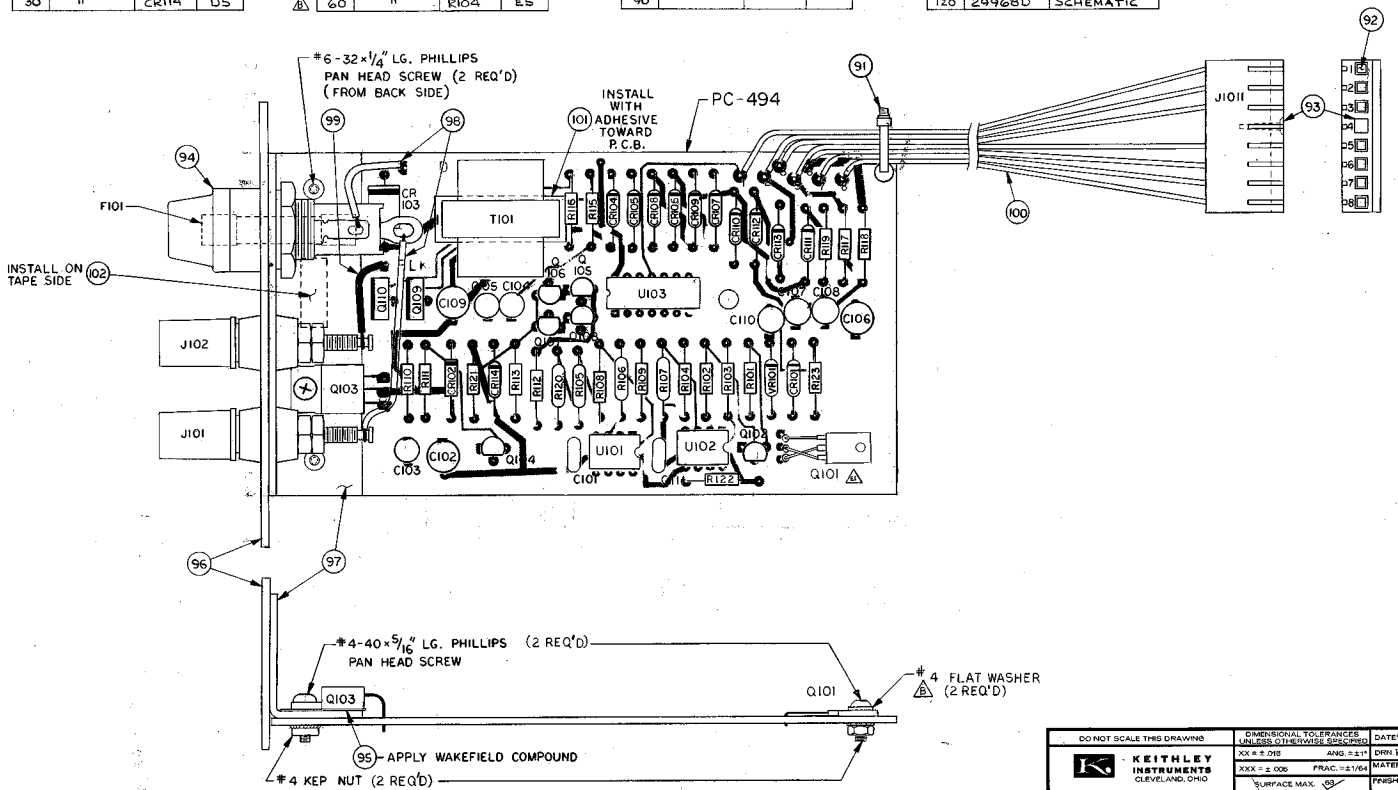
ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29972C	PC-494	E3
2			
3			
4	C-237-1.0	C101	D5
5	C-179-22.	C102	D5
6	C-179-1.5	C103	C5
7	C-179-4.7	C104	D4
8	"	C105	D4
9	C-170-10	C106	E4
10	"	C107	E4
11	"	C108	E4
12	C-179-22.	C109	D4
13	C-179-4.7	C110	E4
14	C-237-1.0	C111	E5
15			
16			
17	RF-38	CR101	E5
18	"	CR102	D5
19	RF-38	CR103	C4
20	RF-28	CR104	D4
21	"	CR105	D4
22	"	CR106	D4
23	"	CR107	E4
24	"	CR108	E4
25	"	CR109	E4
26	"	CR110	E4
27	"	CR111	E4
28	"	CR112	E4
29	"	CR113	E4
30	"	CR114	D5

ITEM	PART NO.	SCHEM. DESIG.	ZONE
31			
32			
33			
34			
35	FU-8	F101	B4
36			
37	BP-11-Z	J101	C5
38	BP-11-0	J102	C4
39			
40			
41	CS-287-8	J1011	G3
42			
43			
44	TG-342	Q101	E5
45	TG-84	Q102	E5
46	TG-127	Q103	C5&C6
47	TG-47	Q104	D5
48	"	Q105	D4
49	TG-84	Q106	D4
50	"	Q107	D4
51	TG-47	Q108	D4
52	TG-129	Q109	C4
53	"	Q110	C4
54			
55			
56			
57	R-76-10K	R101	E5
58	"	R102	E5
59	"	R103	E5
60	"	R104	E5

ITEM	PART NO.	SCHEM. DESIG.	ZONE
61	R-88-44.2K	R105	D5
62	R-88-3.16K	R106	D5
63	R-88-4.53K	R107	D5
64	R-76-820K	R108	D5
65	R-76-1.8M	R109	D5
66	R-76-10K	R110	C5
67	"	R111	D5
68	"	R112	D5
69	"	R113	D5
70			
71	R-76-33	R115	D4
72	"	R116	D4
73	R-76-10	R117	E4
74	"	R118	E4
75	"	R119	E4
76	R-88-15K	R120	D5
77	R-76-1K	R121	D5
78	"	R122	E5
79	R-76-1.5K	R123	E5
80	TR-172	T101	D4
81			
82	IC-177	U101	D5
83	"	U102	E5
84	IC-103	U103	D4
85			
86			
87	DZ-25	VR101	E5
88			
89			
90			

ITEM	PART NO.	SCHEM. DESIG.	ZONE
91	CC-38-2	1/U	E3
92	CS-276	7/U	G3
93	CS-345	1/U	G3
94	FH-3	1/U	C4
95	WA-79	1/U	C6
96	29998B	1/U	C5
97	30100B	1/U	C5
98	#18 GA. WIRE, TEFLON	LENGTH TO SUIT	D3
99	#18 GA. WIRE, BLACK	"	C3
100	#22 GA. WIRE	LENGTH & COLOR TO SUIT	F4
101	27493A-11	1/U	D3
102	MC-149	1/U	B4
103			
104			
105			
106			
107			
108			
109			
110			
111			
112			
113			
114			
115			
116			
117			
118			
119			
120	29968D	SCHEMATIC	

ZONE	LTR	ECO NO.	REVISION	DATE
	A	6103	RELEASED	9-14-78
	B	6161	REVISED	12-8-78
	C	6266	ADDED ITEM 101 & 102	1-29-79
	D	6350	ITEM 64 WAS R-76-1.2M ITEM 69 WAS R-76-1.2M	3-5-79
M	E	8192	ITEM 4 WAS C-179-1.2	1-10-82
M	E1	19238	Q101 WAS TG-135.	11-20-98



6428			
MODEL	NEXT ASSEMBLY	QTY.	
USED ON			

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KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± ±.015, ANG. = ±1°, XXX = ± .005, FRAC. = ±1/64, SURFACE MAX. 63

DATE 9-12-78 | SCALE 2 - 1 | DRN R. SMITH | ENG APPR | MATERIAL | FINISH

TITLE: COMPONENT LAYOUT, PC-494

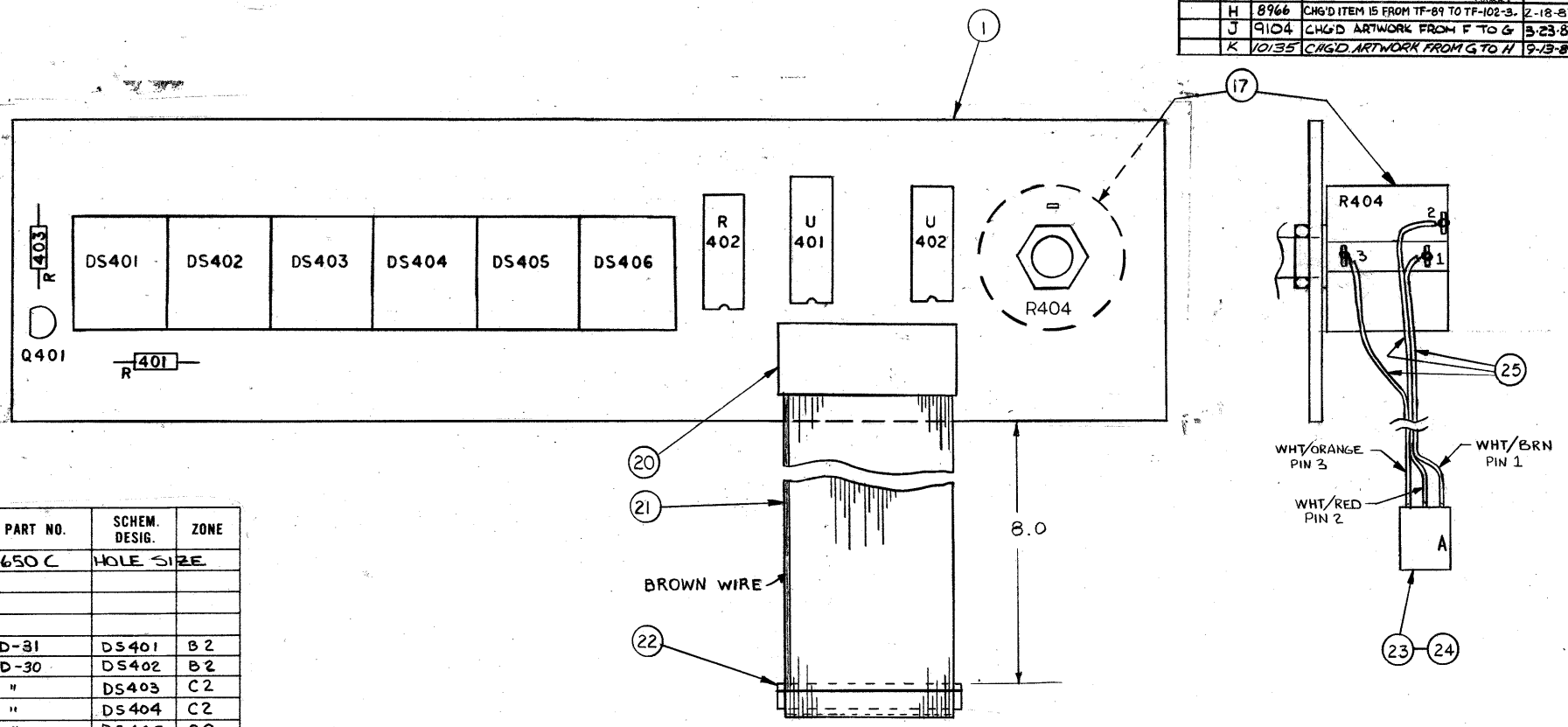
NO. D29971

FORM 28511D

29708C ON

L | 12755 | ITEM 17 WAS RP-115-50K | 5-17-88

ZONE	LTR.	ECO NO.	REVISION	DATE
	A	6072	RELEASED	8-9-78
	B	6084	REVISED	8/16/78
	C	6089	REVISED	8-22-78
	E	6813	CHG'D ARTWORK FROM REV. D TO E	2-4-80
	F	8198	CHG'D ITEM 5 FROM DD-21 TO DD-32	1-22-82
	G	8851	CHG'D DD-21 TO DD-31, DD-20 TO DD-30. CHG'D ARTWORK FROM REV. E TO REV. F.	1-18-83
	H	8966	CHG'D ITEM 15 FROM TF-89 TO TF-102-3.	2-18-83
	J	9104	CHG'D ARTWORK FROM F TO G	3-23-83
	K	10135	CHG'D ARTWORK FROM G TO H	9-13-84



ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29650C	HOLE SIZE	
2			
3			
4			
5	DD-31	DS401	B2
6	DD-30	DS402	B2
7	"	DS403	C2
8	"	DS404	C2
9	"	DS405	C2
10	"	DS406	D2
11			
12	TG-47	Q401	A2
13			
14	R76-120	R401	B3
15	TF-102-3	R402	D2
16	R76-120	R403	A2
17	RP-125-50K	R404	G2
18	IC-168	U401	E2
19	IC-169	U402	E2
20	CS-369-20	—	E3
21	SC-67-20	—	E3,4
22	CS-297-20	J1012	E4
23	CS-270	J1005	G3
24	CS-236	3 REQ'D	G3
25	22 GA. WIRE	AS REQ'D	G3
26			
27			
28			
29			
30			

642		
MODEL	NEXT ASSEMBLY	QTY.
USED ON		

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KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ±.015 ANG. = ±1°
XXX = ±.005 FRAC. = ±1/64
SURFACE MAX. 63

DATE 6-30-78 | SCALE 2:1 | DRN. RJK | ENG. APPR. RAM | MATERIAL | FINISH

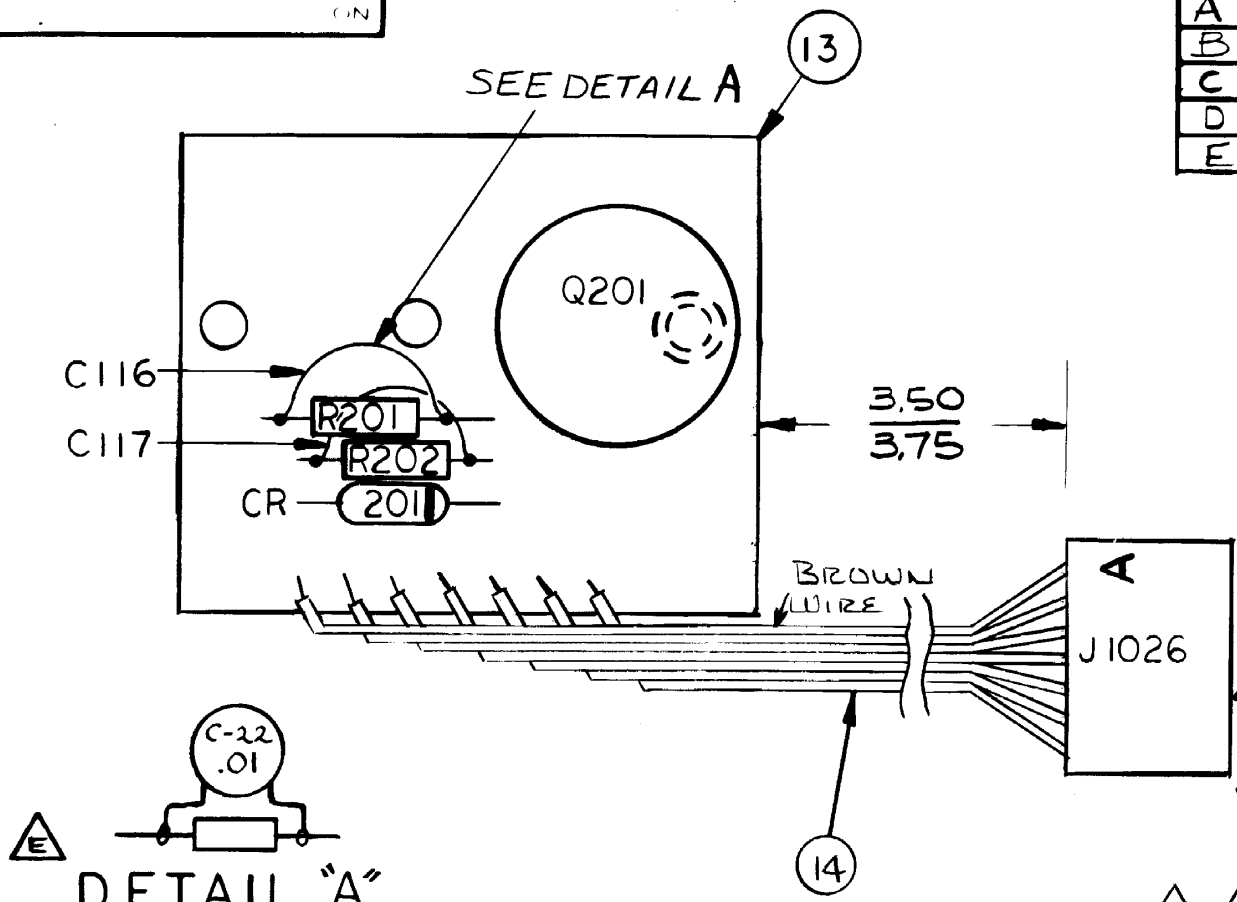
TITLE COMPONENT LAYOUT PC-482

NO. 29708C

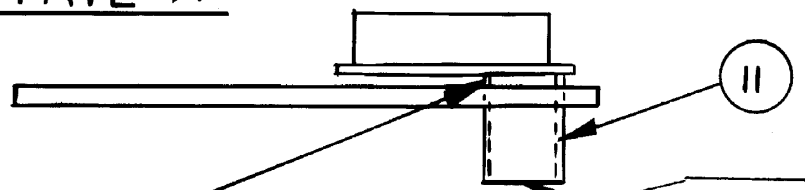
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A 29797

LTR	ECO NO.	REVISION	DATE
A	6012	RELEASED	8.9.78
B	6084	WAS 29799; NOW 29797	8/16/78
C	6089	#13 WAS 29797B; ADDED #14	8-22-78
D	6266	CHANGED ARTWORK REV. FROM A TO B	1-29-79
E	9507	ADDED ITEMS 8+10 mike	11.16.83



DETAIL "A"



SPACE TG-134 OFF P.C.B. .030 ALONG WITH 29755A AND SOLDER 29755A TO P.C.B. ON SIDE 2.

AFTER ASSEMBLY SHORT MOSFET (Q201) INPUT LEAD TO ITEM 11 BY STUFFING CONDUCTIVE FOAM OR ALUMINUM FOIL INTO TUBE

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	CS-236	J1026	
2	CS-310	J1026	
3			
4	R-76-100	R202	
5	R-88-200	R201	
6			
7	RF-28	CR201	
8 (E)	C-22-.01	C116	
9	TG-134	Q201	
10 (E)	C-22-.01	C117	
11	29755A	—	
12			
13 (C B)	29799B	PC-479	
14 (C)	SC-67-7	—	

MODEL	NEXT ASSEMBLY	QTY
642		1

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MATERIAL	~	DATE 8.8.78	SCALE 2:1
FINISH	~	DRAWN D.J.K.	CHECKED RAM

TITLE: COMPONENT LAYOUT, PC-479

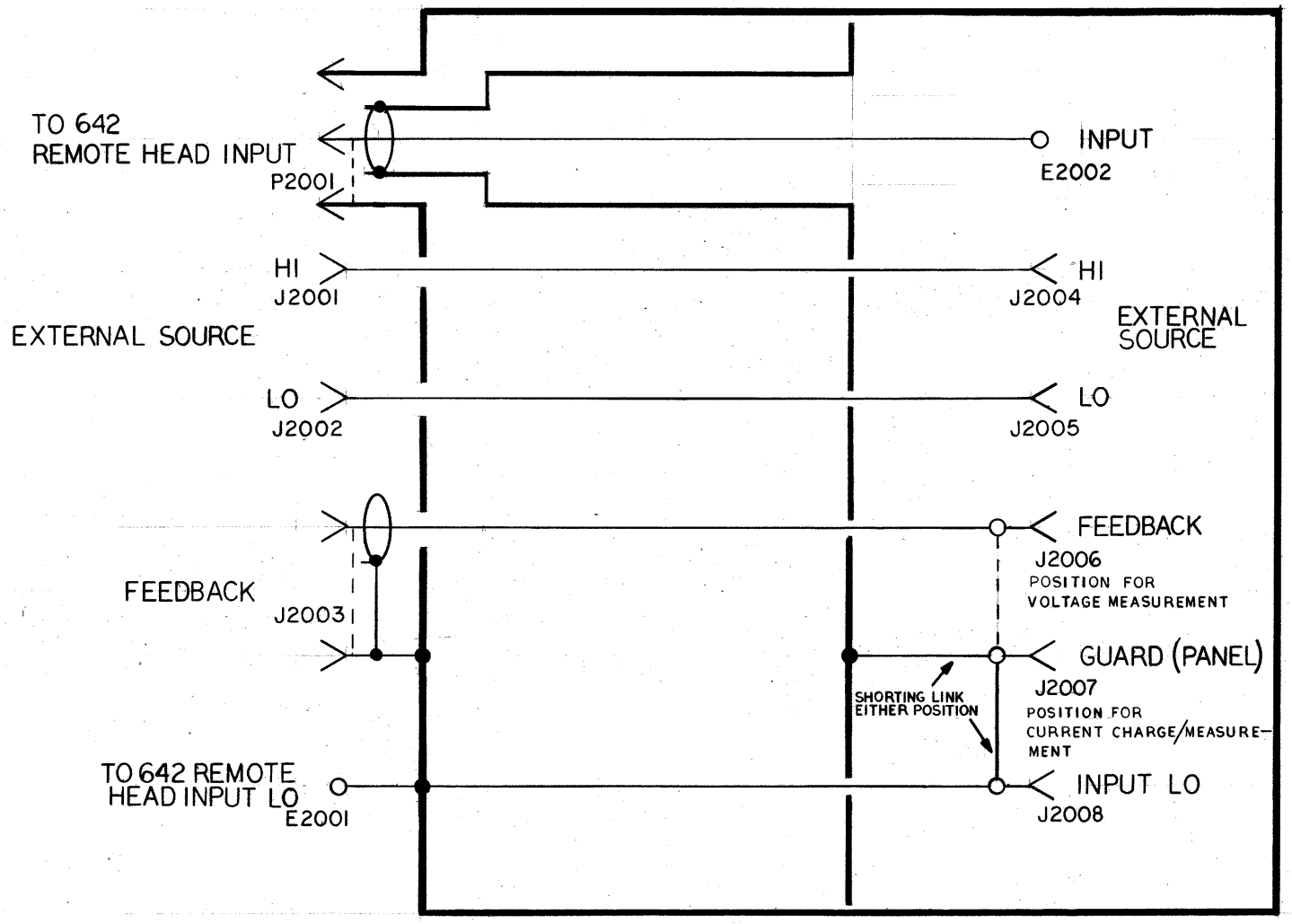
NO. 29797 A

FORM 28 44

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30105C ON

ZONE	LTR.	ECO NO.	REVISION	DATE
	A	6110	RELEASED	9-14-78
	B	6207	ADDED NOTES FOR ↕ CURRENT ↕ VOLTAGE MEASUREMENT	12-4-78



HIGHEST SCHEMATIC DESIGNATIONS USED		
E2002	J2008	P2001

MODEL	NEXT ASSEMBLY	QTY.
6426		

USED ON

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KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG. = ±1°
XXX = ± .005 FRAC. = ±1/64
SURFACE MAX. 63

DATE 9/13/78 SCALE NONE
DRN. MS ENG. APPR. RAM
MATERIAL
FINISH

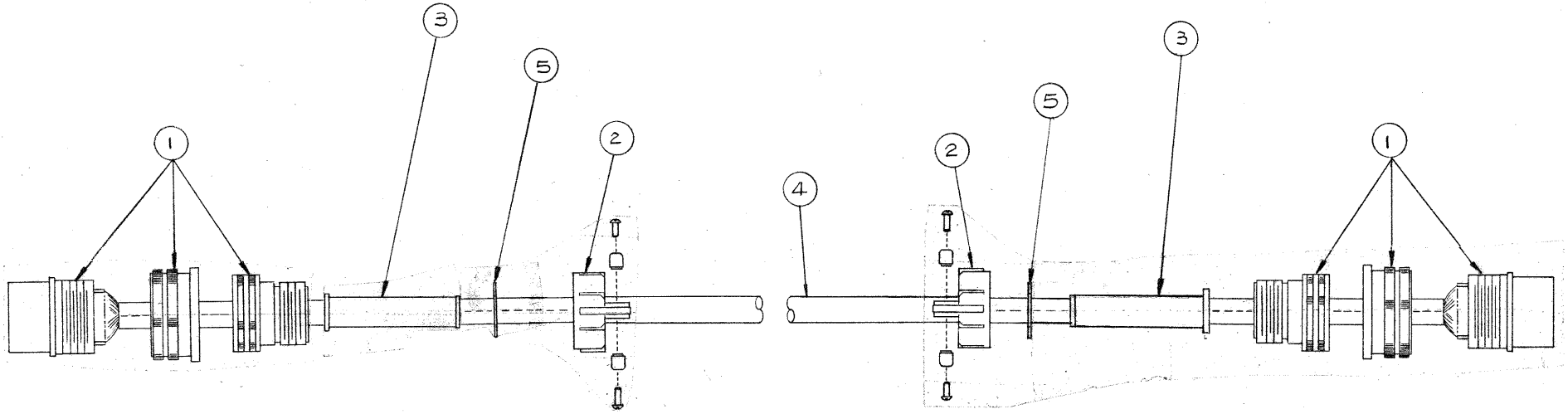
SCHEMATIC, SAPPHIRE INSULATED TEST BOX

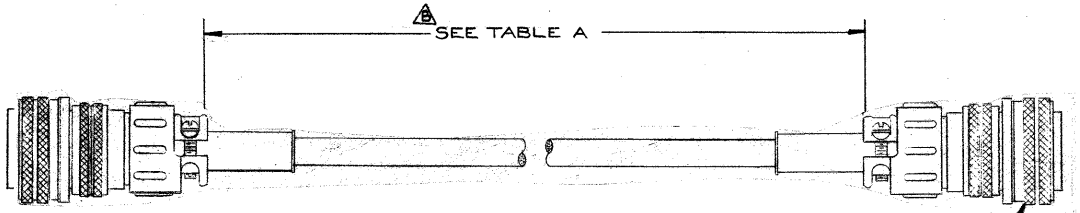
NO. 30105C

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29815C ON

ZONE	LTR.	ECO NO.	REVISION	DATE
	A	6035	RELEASED	6-29-78
	B	6881	ADDED CABLE LENGTHS	3-31-80





PARTS LEGEND			
NO.	PART NO.	DESCRIPTION	QTY
1	CS-372	CONNECTOR SOCKET	2
2	CC-43-1	CABLE CLAMP	2
3	BU-25	BUSHING	2
4	SC-79-19	CABLE, SHIELDED	1
5	WA-87-2	WASHER	2

B	TABLE A	
	- *	CABLE LENGTH
	- 4	4 FEET
	- 10	10 FEET
	-50	50 FEET
	-150	150 FEET

NOTE: INDIVIDUAL CONDUCTORS OF SC-79-19 CABLE TO BE WIRED: "A" TO "A", "B" TO "B", "C" TO "C", ETC., ON THE TWO CS-372 CONNECTORS; EXCEPT THE CABLE SHIELD WHICH IS TO BE COMBED AND WIRED TO PIN "N" ON BOTH CS-372 CONNECTORS.

MODEL	NEXT ASSEMBLY	QTY.
CA2		1
USED ON		

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KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG. = ±1°
XXX = ± .005 FRAC. = ±1/64
SURFACE MAX. 63

DATE 8/14/78 SCALE NTS
DRN kmet ENG APPR DW
MATERIAL
FINISH

TITLE ASSEMBLY, CABLE
NO. 29815C-*

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