ARTISAN®
TECHNOLOGY GROUP

Your **definitive** source for quality pre-owned equipment.

Artisan Technology Group
(217) 352-9330 | sales@artisantg.com | artisantg.com

Full-service, independent repair center
with experienced engineers and technicians on staff.

We buy your excess, underutilized, and idle equipment
along with credit for buybacks and trade-ins.

Custom engineering
so your equipment works exactly as you specify.

- Critical and expedited services
- In stock / Ready-to-ship
- Leasing / Rentals / Demos
- ITAR-certified secure asset solutions

Expert team | Trust guarantee | 100% satisfaction

All trademarks, brand names, and brands appearing herein are the property of their respective owners.

Find the *Keithley 480* at our website: *Click HERE*

Model 480
Digital Picoammeter
Instruction Manual

Contains Operating and Servicing Information

KEITHLEY

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE. THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES.

NEITHER KEITHLEY INSTRUMENTS, INC. NOR ANY OF ITS EMPLOYEES SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OF ITS INSTRUMENTS AND SOFTWARE EVEN IF KEITHLEY INSTRUMENTS, INC., HAS BEEN ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES. SUCH EXCLUDED DAMAGES SHALL INCLUDE, BUT ARE NOT LIMITED TO: COSTS OF REMOVAL AND INSTALLATION, LOSSES SUSTAINED AS THE RESULT OF INJURY TO ANY PERSON, OR DAMAGE TO PROPERTY.

KEITHLEY

Keithley Instruments, Inc. • 28775 Aurora Road • Cleveland, OH 44139 • 216-248-0400 • Fax: 216-248-6168 • http://www.keithley.com

CHINA:	**Keithley Instruments China** • Yuan Chen Xin Building, Room 705 • 12 Yumin Road, Dewai, Madian • Beijing 100029 • 8610-62022886 • Fax: 8610-62022892
FRANCE:	**Keithley Instruments SARL** • BP 60 • 3 Allée des Garays • 91122 Palaiseau Cédex • 33-1-60-11-51-55 • Fax: 33-1-60-11-77-26
GERMANY:	**Keithley Instruments GmbH** • Landsberger Strasse 65 • D-82110 Germering, Munich • 49-89-8493070 • Fax: 49-89-84930759
GREAT BRITAIN:	**Keithley Instruments, Ltd.** • The Minster • 58 Portman Road • Reading, Berkshire RG30 1EA • 44-118-9575666 • Fax: 44-118-9596469
ITALY:	**Keithley Instruments SRL** • Viale S. Gimignano 38 • 20146 Milano • 39-2-48303008 • Fax: 39-2-48302274
NETHERLANDS:	**Keithley Instruments BV** • Avelingen West 49 • 4202 MS Gorinchem • 31-(0)183-635333 • Fax: 31-(0)183-630821
SWITZERLAND:	**Keithley Instruments SA** • Kriesbachstrasse 4 • 8600 Dübendorf • 41-1-8219444 • Fax: 41-1-8203081
TAIWAN:	**Keithley Instruments Taiwan** • 1FL., 1, Min Yu First Street • Hsinchu, Taiwan, R.O.C. • 886-35-778462 • Fax: 886-35-778455

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Model 480 Digital Picoammeter
Instruction Manual

© 1978, Keithley Instruments, Inc.
Test Instrumentation Group
All rights reserved.
Cleveland, Ohio, U.S.A.
January 1990, Third Printing
Document Number: 29431 Rev. C

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SPECIFICATIONS

RANGE	MAXIMUM READING	ACCURACY (12 MONTHS) 18°—28°C, UP TO 70% RH ±(% RDG + DIGITS)	ANALOG RISE TIME (10%—90%)	NORMAL MODE REJECTION RATIO 50 OR 60 Hz)	MAXIMUM ALLOWABLE INPUT
1nA	1.999	0.8% + 4d	70ms	70dB	600V
10nA	19.99	0.8% + 3d	70ms	70dB	600V
100nA	199.9	0.5% + 3d	7ms	60dB	600V
1μA	1.999	0.5% + 3d	7ms	60dB	600V
10μA	19.99	0.5% + 3d	4ms	50dB	75V
100μA	199.9	0.5% + 3d	1ms	50dB	75V
1mA	1.999	0.5% + 3d	1ms	50dB	20V

MAXIMUM TRANSIENT OVERLOAD VOLTAGE: 1000V for 3 seconds from a Keithley supply limited to 10mA.

INPUT VOLTAGE BURDEN: Less than 200μV.

SETTLING TIME AT DISPLAY: Less than 1 second.

DISPLAY: Four 0.5" LED digits with appropriate decimal point and polarity indications.

CONVERSION PERIOD: 400 milliseconds.

OVERRANGE INDICATION: Display blinks all zeros above 1999 counts.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, DC to 60Hz sine wave.

ANALOG OUTPUT:
Output Voltage: 1 volt = 1000 counts.
Output Resistance: 1000 ohms.

CONNECTORS: Input: BNC, Output: Banana Jacks.

POWER: 105-125 or 210-250 volts (switched selected), 50-60HZ, 6 watts nominal, 20VA maximum.

DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep. (3½ in. × 9¼ in. × 10¾ in.) Net weight: 1.7kg (4 lbs.)

ACCESSORIES AVAILABLE:

Model 1788 Rechargable Battery Pack: 6 hour minimum operation from full charge, recharges within 14 hours. Field installable. Adds 0.9 kg. (2 lbs.), 7 watts.

Model 4801 Input Cable: 4-ft. BNC to BNC low noise input cable.

Model 4803 Low Noise Cable Kit: Includes 50 ft. of low-noise coaxial cable, 10 BNC male connectors and 5 BNC female chassis-mount connectors.

Model 1017 Dual Rack Mount Kit

Model 1010 Rack Mount Kit

Model 1684 Carrying Case

Model 1792 BCD Output

Model 1793 IEEE-488 Output

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

TABLE OF CONTENTS

Paragraph	Title	Page
	SECTION 1—GENERAL INFORMATION	
1.1	Introduction	1-1
1.2	Warranty Information	1-1
1.3	Manual Addenda	1-1
1.4	Safety Symbols and Terms	1-1
1.5	Specifications	1-1
1.6	Unpacking and Inspection	1-2
1.7	Preparation for Use	1-1
1.8	Accessories	1-1
1.8.1	Model 1010 Rack Mounting Kit	1-1
1.8.2	Model 1017 Rack Mounting Kit	1-1
1.8.3	Model 1684 Carrying Case	1-1
1.8.4	Model 1788 Battery Pack	1-1
1.8.5	Model 1792 BCD Output	1-1
1.8.6	Model 1793 Isolated IEEE-488 Interface	1-1
1.8.7	Model 4801 Input Cable	1-2
1.8.8	Model 4803 Low Noise Cable Kit	1-2
	SECTION 2—OPERATION	
2.1	Introduction	2-1
2.2	Line Voltage Selection	2-1
2.3	Operating on Line Power	2-1
2.4	Operation on Battery Pack Power	2-1
2.5	Battery Charging	2-1
2.6	Tilt Bail	2-1
2.7	Operating Instructions	2-1
2.8	Measurement Considerations	2-3
2.8.1	Source Resistance	2-4
2.8.2	Source Capacitance	2-4
2.8.3	Leakage Resistance	2-4
2.8.4	Operation Outside of Specified Temperature Humidity Range	2-5
2.8.5	Zero Time Stability	2-5
2.8.6	Grounding Considerations	2-5
2.8.7	Storage Temperature Limits	2-5
	SECTION 3—PERFORMANCE VERIFICATION	
3.1	Introduction	3-1
3.2	Recommended Test Equipment	3-1
3.3	Environmental Conditions	3-1
3.4	Performance Verification Procedure	3-1
3.4.1	Initial Conditions	3-1
3.4.2	Battery Pack Removal	3-1
3.4.3	Normal Mode Rejection Ratio (NMRR) Test	3-2
3.4.4	Range Accuracy Check	3-2
3.4.5	Rise Time Check	3-2
3.4.6	Post Test Set Up	3-2
	SECTION 4—APPLICATIONS	
4.1	Introduction	4-1
4.2	Leakage Current Tests	4-1
4.3	Resistivity Tests	4-1
	SECTION 5—THEORY OF OPERATION	
5.1	Introduction	5-1
5.2	Overall Block Diagram	5-1
5.2.1	Current-to-Voltage Converter	5-1
5.2.2	A/D Converter	5-1
5.2.3	Power Supply	5-1
5.3	Current-to-Voltage Converter	5-1
5.3.1	Input Overload Protection	5-1
5.3.2	Zero Check and Adjustment	5-2

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

TABLE OF CONTENTS (CONT.)

Paragraph	Title	Page
5.4	A/D Converter	5-2
5.4.1	Auto-Zero	5-2
5.4.2	Signal-Integrate	5-2
5.4.3	Reference-Integrate	5-2
5.5	Display	5-3
5.6	AC Power Supply	5-3
5.7	Model 1788 Battery Pack	5-3
5.7.1	Battery Charging Circuit	5-3
5.7.2	Battery Operation and Shutdown Circuit	5-3
	SECTION 6—MAINTENANCE	
6.1	Introduction	6-1
6.2	Recommended Test Equipment	6-1
6.3	Environmental Conditions	6-1
6.2	Calibration Procedure	6-1
6.5	Troubleshooting Overview	6-2
6.6	Troubleshooting Procedure	6-2
6.7	Battery Pack Installation	6-7
6.8	Fuse Replacement	6-7
	SECTION 7—REPLACEABLE PARTS	
7.1	Introduction	7-1
7.2	Ordering Information	7-1
7.3	Factory Service	7-1
7.4	Component Layouts	7-1
7.5	Schematic Diagrams	7-1

LIST OF ILLUSTRATIONS

Figure	Title	Page
2-1	Model 480 Rear Panel	2-2
2-2	Model 480 Operating Controls	2-2
2-3	Model 480 Feedback Picoammeter	2-3
2-4	Measurement Considerations	2-4
2-5	Test Fixture Guarding	2-5
3-1	Shielded Test Fixture-Range Accuracy Set Up	3-2
3-2	Rise Time Set Checks	3-3
3-3	Model 480 Rise Time on 10nA Range	3-3
4-1	Leakage Test Set Up	4-1
4-2	Resistivity Test Hook Up	4-2
5-1	Model 480 Overall Block Diagram	5-1
5-2	Simplified Schematic of Current-to-Voltage Converter	5-1
5-3	A/D Converter Function	5-2
6-1	Test Point and Adjustment Locations	6-3
6-2	Integrator and Comparator Waveforms	6-7
6-3	Battery Pack Installation	6-8
7-1	Model 480 Mechanical Parts View	7-2
7-2	Display Board, Component Location Drawing, Dwg. No. 29315C	7-5
7-3	Battery Pack Board, Component Location Drawing, Dwg. No. 29007C	7-6
7-4	Mother Board, Component Location Drawing, Dwg. No. 29314D	7-7
7-5	Model 480 and Model 1788, Schematic Diagram, Dwg. No. 29312E	7-9

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

LIST OF TABLES

Table	Title	Page
2-1	Summary of Range, Accuracy and Input Overload Information	2-3
3-1	Recommended Test Equipment for Performance Verification	3-1
3-2	Range Accuracy Check	3-3
3-3	Rise Time Test	3-3
6-1	Recommended Test Equipment for Calibration and Troubleshooting	6-1
6-2	Power Supply Checks	6-2
6-3	Battery Power Checks	6-4
6-4	Display Checks	6-5
6-5	A/D Converter Checks	6-5
6-6	Current-to-Voltage Converter Checks	6-6
6-7	Adjustment of Battery Charge Voltage	6-6
6-8	Fuse Types	6-7
7-1	Mother Board, PC-472, Parts List	7-2
7-2	Display Board, PC-473, Parts List	7-3
7-3	Model 1788 Battery Pack, PC-451, Parts List	7-4

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Model 480 is a 3½ digit Picoammeter that provides seven decade current ranges from 10^{-9} to 10^{-3} ampere, with 100% overranging on all ranges. The instrument features include an input voltage burden of $\leq$200V, front panel zero check and adjustment, an analog output and automatic polarity indication of the input current.

1.2 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. If there is a need to use the warranty, contact the Keithley representative in your area to determine the proper action to be taken. Keithley Instruments maintains service facilities in Great Britain, West Germany, France, the Netherlands, Switzerland, and Austria, as well as in the United States. Check the inside front cover of this manual for addresses.

1.3 MANUAL ADDENDA

Improvements or changes to the instrument which occur after printing of this manual will be explained on an addendum sheet supplied with the unit.

1.4 SAFETY SYMBOLS AND TERMS

The following safety terms and symbols are used in this manual or found on the Model 480:
The symbol ⚠ on the instrument indicates that the user should refer to the operating instructions.
The **WARNING** heading used in this manual explains dangers that could cause personal injury or death.
The **CAUTION** heading used in this manual explains hazards that could damage the instrument.

1.5 SPECIFICATIONS

Detailed Model 480 specifications are located at the front of this manual.

1.6 UNPACKING AND INSPECTION

The Model 480 was carefully inspected, both mechanically and electrically before shipment. Upon receiving the Model 480, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage. Report any damage to the shipping agent at once. Retain the original packing materials in case reshipment becomes necessary.

The following items are included with every Model 480 order:
1. Model 480 Digital Picoammeter
2. Model 480 Instruction Manual
3. Additional accessories as ordered.

1.7 PREPARATION FOR USE

The Model 480 is shipped ready to use on line power. The unit may be operated on 105-125V or 210-250V power sources. A rear panel switch selects the appropriate operating voltage, as described in Section 2.

The Model 480 may also be operated from the optional Model 1788 battery pack. Installation instructions may be found in Section 6.

1.8 ACCESSORIES

A brief description of optional Model 480 accessories is given below. Contact your Keithley representative or the factory for information on ordering accessories.

1.8.1 Model 1010 Rack Mounting Kit

The Model 1010 Rack Mounting Kit allows the mounting of a single Model 480 in a standard 19 inch rack.

1.8.2 Model 1017 Rack Mounting Kit

The Model 1017 Rack Mounting Kit mounts two Model 480s side by side in a standard 19 inch rack.

1.8.3 Model 1684 Carrying Case

The Model 1684 Carrying Case is a hard vinyl case with a fitted foam insert; the Model 1684 has sufficient room to accommodate the Model 480, an instruction manual, and other small accessories.

1.8.4 Model 1788 Battery Pack

The Model 1788 is a rechargeable battery pack that allows a minimum of six hours of operation on a full charge. The Model 1788 is field installable and recharges in 14 hours.

1.8.5 Model 1792 BCD Output

The Model 1792 BCD output option provides parallel BCD output of data from the Model 480 including sign, overrange, and busy. The Model 1792 is field installable in Model 480s with serial numbers 12000 and above; note that installation of the Model 1792 precludes the use of the Model 1788 or Model 1793.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

1.8.6 Model 1793 Isolated IEEE-488 Interface

The Model 1793 provides a convenient way of connecting the Model 480 to the IEEE-488 bus. The Model 1793 provides isolated data output and has switch selectable talk-only and addressable modes. The Model 1793 is field installable in Model 480s with serial numbers 12000 and above. The Model 1788 and Model 1792 cannot be used when the Model 1793 is installed.

1.8.7 Model 4801 Input Cable

The Model 4801 is a low noise coaxial cable four feet (1.2m) in length with a male BNC connector on each end.

1.8.8 Model 4803 Low Noise Cable Kit

The Model 4803 Kit consists of 50 feet (15.2m) of low noise coaxial cable, 10 male BNC connectors, and five female chassis mount BNC connectors.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 2
OPERATION

2.1 INTRODUCTION

This section contains basic operating information for the Model 480. Also included are measurement considerations which should be taken into account under certain operating conditions.

2.2 LINE VOLTAGE SELECTION

The Model 480 may be line operated from either 105-125V or 210-250V power sources. Before connecting the instrument to the power line, make sure the LINE VOLTAGE selection switch (Figure 2-1) is in the correct position.

CAUTION

Operating the Model 480 on an incorrect power source may damage the instrument, possibly voiding the warranty.

2.3 OPERATION ON LINE POWER

The Model 480 is equipped with a 3-wire power cord designed to mate with earth grounded power line receptacles. To use the instrument on line power, connect the line cord plug to a properly grounded AC power receptacle.

WARNING

Use only properly grounded outlets to ensure proper grounding of the instrument. Failure to properly ground the instrument in this manner could result in severe injury or death due to shock in the event of a short circuit or malfunction.

2.4 OPERATION ON BATTERY PACK POWER

The Model 480 may also be operated from rechargeable sealed lead-acid batteries contained in the optional Model 1788 battery pack. The battery pack will operate the Model 480 for at least six hours from full charge. Circuits within the battery pack will automatically shut down the instrument when the battery charge is insufficient to maintain accurate readings. See Section 6 for battery pack installation instructions.

2.5 BATTERY CHARGING

The Model 1788 Battery Pack contains an integral battery charger. To charge the battery pack, proceed as follows:

1. Connect the instrument to line power as described in paragraph 2.3.
2. With the power switch off, the battery charge circuitry is automatically energized to charge the battery at the maximum rate. When the battery pack is first installed, or if it has completely discharged, allow it to charge for at least 14 hours in this condition.

NOTE

For maximum battery life, do not allow the battery pack to remain completely discharged. Constant charging will not harm either the battery pack or the instrument.

3. When the Model 480 is in use on line power, the battery charger maintains a trickle charge in the battery pack.

2.6 TILT BAIL

The Model 480 is equipped with a tilt bail which makes it possible to elevate the instrument to a convenient viewing position. To change the bail position, pull out the bail handle from each side of the case until it rotates freely; rotate the bail to the desired position and release the bail to allow it to lock into place.

2.7 OPERATING INSTRUCTIONS

Refer to Figure 2-2 and operate the Model 480 as follows:

1. Turn on the power by depressing the on/off pushbutton.
2. Select the current range by depressing the appropriate pushbutton.
3. To check or adjust zero, proceed as follow:
   A. Have INPUT connected to a source of less than 200μA or to an open circuit. Do not short INPUT as this condition would cause the instrument to overrange.
   B. Depress the ZERO CHECK pushbutton. Momentary or locking action can be achieved depending on how far the button is depressed. To adjust zero, push button in to the lock position.
   C. Adjust zero level trimpot via access hole on front panel for a zero indication on the digital display, if desired.

NOTE

When zero is properly adjusted, the input voltage burden for an on-range reading will be less than or equal to 200μV.

CAUTION

During power up and power down, using AC line or battery pack, a current surge ($\approx$25mA, 5V maximum) can appear at the INPUT of the Model 480. Protect any circuitry that would be damaged by these levels by making circuit connections only after turning on the Model 480. Disconnect these ciruits before turning off the Model 480.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

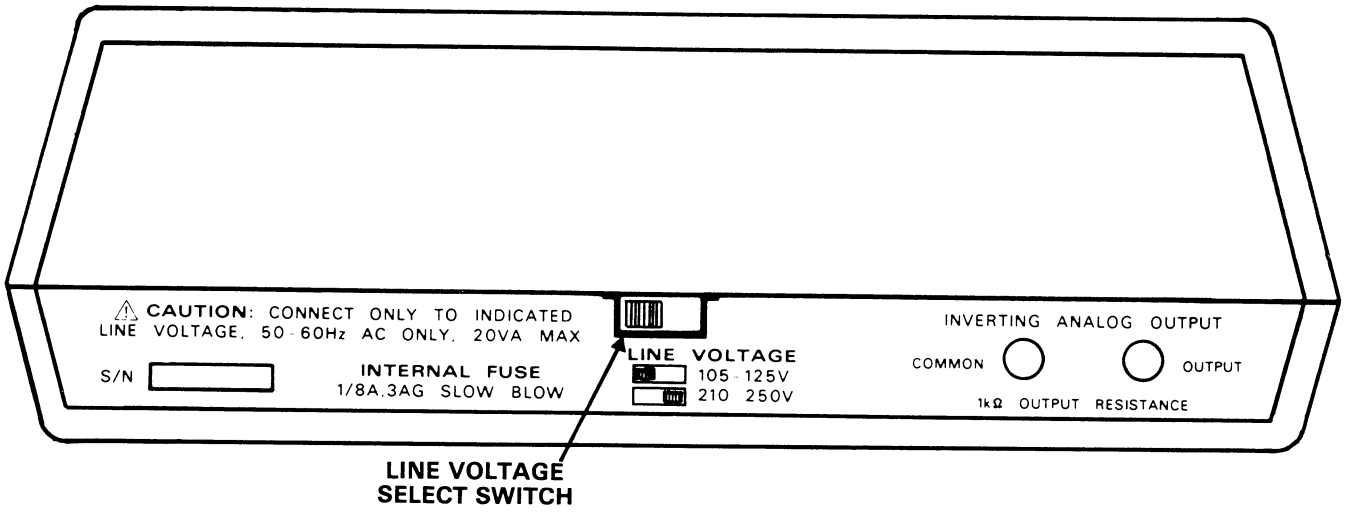


Figure 2-1. Model 480 Rear Panel

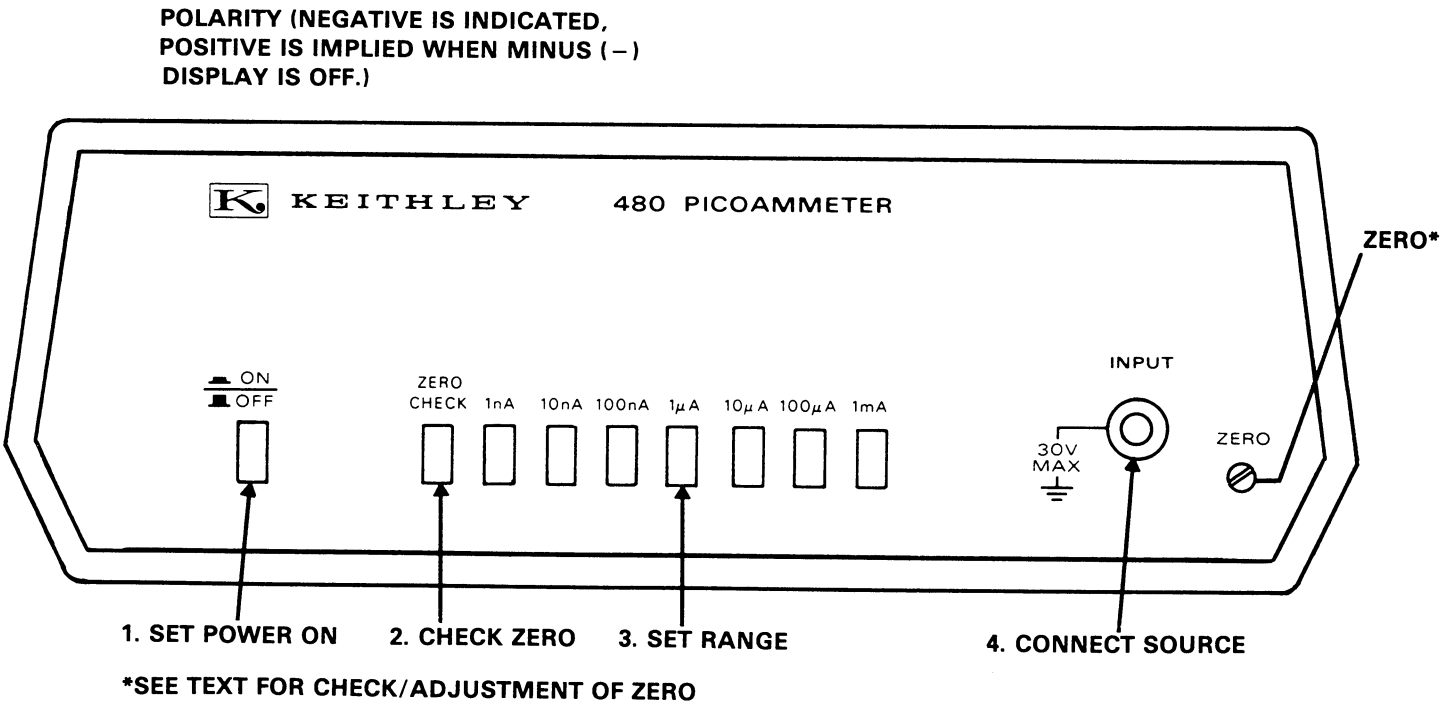


Figure 2-2. Model 480 Operating Controls

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

4. Connect the source to the INPUT connector on the front panel. Low-noise cable and connector accessories described in Section 1 should be used as required. Measurement considerations are discussed in paragraph 2.8. A summary of range, accuracy and input overload information is given in Table 2-1.

WARNING

Do not exceed 30V RMS between input low and power line ground or a shock hazard will result.

CAUTION

Do not exceed the maximum input overload ratings or instrument damage may occur.

5. Read the input current on the digital display, overrange is indicated by a flashing 000 display.

NOTE

On the 1mA current range an input overload exceeding approximately 10V could result in an on scale reading, rather than the flashing 000 indication. This will not damage the instrument, providing that the specified 20V is not exceeded, but will result in an erroneous display.

6. Inverting Analog Output. Two banana jacks (shown in Figure 2-1) are rear panel accessible, and permit monitoring or recording of the output from the current-to-voltage converter within the Model 480. Since the 480 is a feedback picoammeter, as shown in Figure 2-3, the input current is forced through the feedback resistor and an inverted analog output voltage is developed by the operational amplifier. The feedback (Range) resistors are selected such that voltage for an on-scale reading on any range will be between zero and ±2V. The relationship between the analog output signal and the digital display is 1000 digits = 1V, or 1mV/digit except during zero check when it is 100μV/digit. The analog output is input protected up to 20V rms and during an input current overload is clamped to a maximum voltage swing of approximately ±5V. Although protected up to 20V to prevent instrument damage, a voltage applied to the Analog Output greater than 10V could cause an erroneous display, rather than the flashing 000.

Since the output of the current-to-voltage converter is bipolar, the Analog Inverting Output can also be used to measure low frequency AC currents which fall within the specified analog rise times. The Inverting Analog Output resistance is 1kΩ.

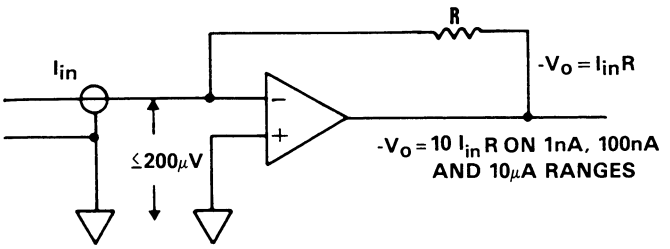


Figure 2-3. Model 480 Feedback Picoammeter

2.8 MEASUREMENT CONSIDERATIONS

This section describes the effects of source resistance, capacitance, noise and leakage resistance on the measurement. Minimum and maximum values of these source parameters are defined, at which point a significant degradation of the measurement can begin to occur, and compensation methods are described to minimize these effects. Refer to Figure 2-4 for the following discussion.

Table 2-1. Summary of Range, Accuracy and Input Overload Information

Range	Maximum Reading (Note 1)	Accuracy ±(Reading + Digits) 18°C - 28°C	Minimum Recommended Source Resistance (Note 2)	Continuous Overload	
1nA	1.999nA	0.8% + 4d	100MΩ	600V	Transient Overload
10nA	19.99nA	0.8% + 3d	10MΩ	600V	Transient Overload
100nA	199.9nA	0.5% + 3d	1MΩ	600V	1000VDC for up to 3 seconds using a Keithley supply limited to 10mA output current.
1μA	1.999μA	0.5% + 3d	100kΩ	600V	
10μA	19.99μA	0.5% + 3d	10kΩ	75V	
100μA	199.9μA	0.5% + 3d	1kΩ	75V	
1mA	1.999mA	0.5% + 3d	100Ω	20V	
		ZERO CHECK		50mA	5 volt internal voltage clamp

NOTE: 1. Current above maximum reading will result in a flashing 000 display.
2. Since source resistance is not always known, this recommendation can be restated in terms of minimum source voltage; i.e., current range × minimum source resistance = minimum source voltage. Thus, it can be seen that the recommended minimum souce voltage for all current ranges is 100 millivolts.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

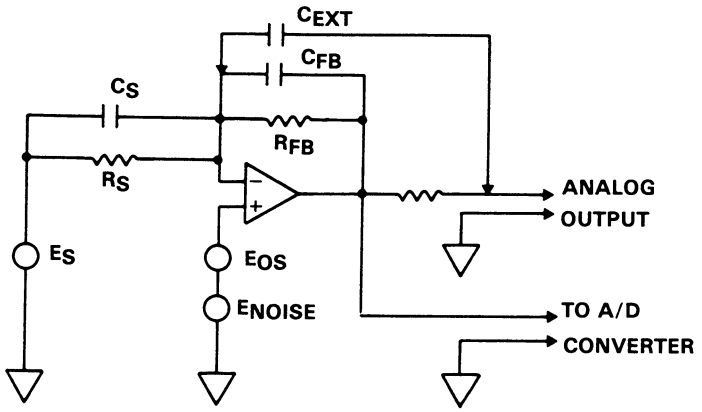


Figure 2-4. Measurement Considerations

2.8.1 Source Resistance

As listed in Table 2-1, a minimum value of source resistance is recommended for each current range because E_{OS} is multiplied by $(R_{FB}+R_S)/R_S$ and because the input burden (200μV) becomes important as E_S gets smaller.

For example: On 1nA Range where:

$$E_S = 100mV$$
$$R_S = 10M\Omega$$
$$R_{FB} = 100M\Omega \qquad \frac{R_{FB}+R_S}{R_S} = 11$$

The zero error would now be 11 digits, assuming zero check to one digit. If E_S can be shorted, this error can be compensated for by readjusting zero without actuating the ZERO CHECK pushbutton. An alternate method would be to disconnect the source and connect a resistor equivalent to R_S across the input of the Model 480. Zero could then be readjusted without depressing the ZERO CHECK pushbutton, as described above. There would still be an error due to the effect of the burden on E_S. This error is determined by:

$$\text{SPAN ERROR} = \frac{200\mu V}{10mV} = 2\%$$

This error would shift the operating characteristics of the circuit being measured by approximately 2%. Replacing the values above with the minimum recommended values for the 1nA range (100MΩ and 100mV), it can be seen that the SPAN ERROR would be reduced to 0.2%, which would result in the displayed current being within the specified accuracy for the 1nA range. In addition, E_{NOISE} is also multiplied by $(Z_F+Z_S)R_S$.

However, $E_{NOISE} << E_{OS}$ and is not significant until C_S becomes large.

2.8.2 Source Capacitance

The instrument is designed to accommodate up to 10,000pF input capacitance. Increasing input capacitance beyond this level will increase noise and induce instrument instability.

$$\text{NOISE OUT} = E_{NOISE}\frac{(Z_F+Z_S)}{Z_S}$$

$$\text{WHERE: } Z_S = R_S||C_S \text{ and } Z_F = R_F||C_F$$

With a large value of C_S, Z_S could become less than Z_F at low frequencies. Combined with the 1/f (f = Frequency) distribution of JFET input noise, this could result in excessive noise on the Inverting Analog Output and on the display. Beyond this point, increased input capacitance could cause instrument instability. However, the instrument can be used with large input capacitances by adding additional capacitances (C_{EXT}) across C_F. This can be accomplished by connecting a capacitor from the Inverting Analog Output to the input. In order for the 1kΩ output resistor to have little effect on this compensation, it should only be performed on the bottom four current ranges (1nA-1A). In addition, the capacitors used should have an extremely low dielectric leakage characteristic (i.e., Polystyrene or Polyethylene). The addition of external feedback capacitance will have the direct effect of slowing instrument response time.

Example: 1nA range

WHERE: $C_{EXT} = 1000pF$
$R_{FB} = 100M\Omega$
$C_{FB} = 220pF$

$$T = [R_{FB}(C_{FB} + 10\ C_{EXT})]^{-1}$$

(10 C_EXT: due to X 10 feedback divider.)

$$T = (1E8 \times 10{,}220\ E\text{-}12)\text{-}1$$
$$\approx 1 \text{ second}$$

This will result in a 10-90% response time of approximately 2.2 seconds. When adding external feedback capacitance, the noise performance will be improved by a level that is dependent on the characteristics of input impedance. Reduction of noise level can best be accomplished by experimenting with increasing values of C_{EXT} until an adequate noise versus response time compromise is obtained.

2.8.3 Leakage Resistance

The effect of leakage currents should be considered when making small current measurements with high impedance sources. Leakage current and its effects can be minimized by using high resistance insulation in the test circuits and guarding. Since the Model 480 is a feedback picoammeter, it is effectively guarded at the input ($\leq$200μV). The effect of leakage paths on the measurement can be further minimized by using a guarded test fixture as shown in Figure 2-5. In the configuration shown, the current through the component under test will not be shunted significantly by either leakage resistance path. If a high voltage supply without internal current limiting is used to make high resistance leakage measurements, it is suggested that a series current limiting resistor be used to prevent exceeding the maximum overload input limit of the Model 480 in the event the item under test is shorted.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

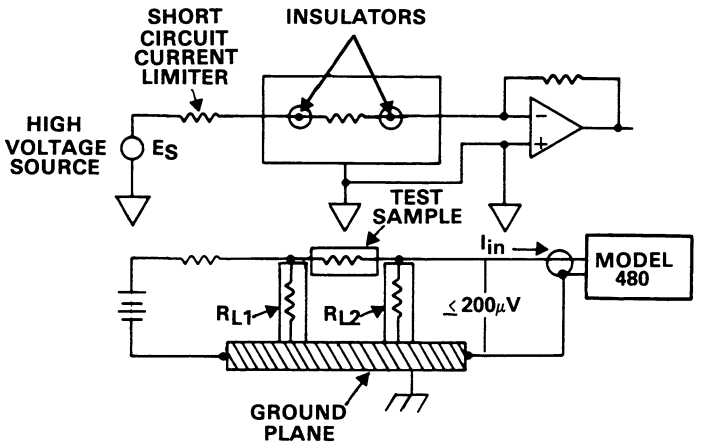


Figure 2-5. Test Fixture Guarding

2.8.4 Operation Outside of Specified Temperature Humidity Range

Typical Model 480 performance outside the operating range of 18°C to 28°C (but within, 0°C to 50°C and up to 70% relative humidity) will be ±(0.02% ±0.5d)/°C for the 1nA, 100nA and 10μA ranges and ±(0.02% ±0.05d)/°C on all other ranges. Above 70% relative humidity the instrument's accuracy can be expected to decrease significantly. However, no permanent accuracy impairment will occur unless a condensing condition is encountered.

2.8.5 Zero Time Stability

The typical zero time stability of the Model 480 is less than one digit per week, exclusive of temperature effects.

2.8.6 Grounding Considerations

Input LO (outer ring of input connector) is to be connected to a ground at the source which within 30V RMS of power line ground of the Model 480 or the equipment near it. Connection to power line ground is not made internally in order to avoid possible ground loops.

2.8.7 Storage Temperature Limits

Do not store the Model 480 outside the temperature range of -25°C to +55°C.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 3
PERFORMANCE VERIFICATION

3.1 INTRODUCTION

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

NOTE

If the instrument is still under warranty (less than 12 months since date of shipment), and it does not meet specifications, contact your Keithley representative or the factory to determine the action to be taken.

3.2 RECOMMENDED TEST EQUIPMENT

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 10 times better than the instrument specifications or equal to the specifications in Table 3-1, additional allowance must be made in the reading obtained.

3.3 ENVIRONMENTAL CONDITIONS

All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F), and a relative humidity of less than 70%.

3.4 PERFORMANCE VERIFICATION PROCEDURE

Use the following procedures to verify the basic accuracy of the Model 480 for current measurements. If the instrument is out of specifications at any point, perform a complete calibration as described in Section 6, unless the instrument is still under warranty.

NOTE

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

3.4.1 Initial Conditions

If the instrument has been subjected to extremes of temperature, allow the internal temperatures to stabilize for one hour minimum at the environmental conditions specified in paragraph 3.3 before beginning the verification procedure.

WARNING

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

3.4.2 Battery Pack Removal

If the Model 1788 is installed in the instrument it must be removed to gain access to internal adjustments and test points.

WARNING

Disconnect the line cord before removing the case cover.

1. Turn off the power and disconnect the line cord. Remove the four screws from the bottom of the case, and separate the top cover from the bottom cover.
2. Push back the ground clip from the upper side of the battery pack, and remove the battery pack from the spacers. Disconnect the battery pack connector.

Table 3-1. Recommended Test Equipment for Performance Verification

Description	Specification	Mfr.	Model
DC Calibrator	0.190000V, 1.900000V, 19.000000V, 190.0000V, to within 20ppm or 20μV	Fluke	343A
Oscilloscope		TEK	2213
Step Function Generator	2V, 20V Square Wave 0-50Hz	Wavetek	110
Frequency Counter	100kHz, within 0.01%	Fluke	1900A
Precision Shielded Resistors	10kΩ ± 175ppm, 10MΩ ± 300ppm, 100MΩ ± 2000ppm, @25°C ± 3°C		

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

NOTE

For test point locations see Figure 6-1. The measurements should be made between the test points and power supply common. For convenience, the INVERTING ANALOG OUTPUT-COMMON may be used.

3.4.3 Normal Mode Rejection Ratio (NMRR) Test

Since NMRR is dependent on the clock frequency, the clock frequency may be checked as follows:

1. Set up the frequency counter for an input signal of 0-5V at 100kHz.
2. Connect the frequency counter to TP3 and verify that the clock frequency is 100kHz ±90Hz.

3.4.4 Range Accuracy Check

To properly check the accuracy of the Model 480 current ranges, precision current sources are necessary. These precise currents are obtained by using the DC calibrator and shielded test fixture, as shown in Figure 3-1. This arrangement will facilitate checkout without having to change connections. This fixture can also be used during the rise time check.

1. With power off, connect the Model 343A DC calibrator and the Model 480 to the test fixture.
2. Turn the Model 480 on, and perform the checks in Table 3-2 by setting the Model 480, Model 343A and test fixture to the specified settings. Note that, the Model 343A output must be floating.
3. Turn the Model 343A off and disconnect it from the fixture.

3.4.5 Rise Time Check

See Figure 3-2 for test set up.

1. Connect Model 110 Function Generator SYNC OUTPUT to EXTERNAL TRIGGER INPUT of oscilloscope.
2. Connect Model 480 INVERTING ANALOG OUTPUT to VERTICAL INPUT of oscilloscope.
3. Connect Model 110 OUTPUT to test fixture INPUT.
4. Connect oscilloscope ground to test fixture case. Set test fixture to POS. position.
5. Set Model 110 to SQUARE WAVE OUTPUT, 50Hz.
6. Set oscilloscope to .5V/div., DC Coupled, EXTERNAL TRIGGER, -SLOPE, TRIGGER LEVEL as required.
7. Perform the checks in Table 3-3 by setting Model 480, oscilloscope, Model 110 and test fixture to the condition specified. Adjust Model 110 amplitude for 2V peak-to-peak analog output from Model 480. Check 10% to 90% rise time and verify response is free of ringing. A typical response on the 10nA range is shown in Figure 3-3. Figure 3-3 also shows the 10nA range with the oscilloscope time compressed to 20mS/div. to verify the absence of ringing and overshooting.

3.4.6 Post Test Setup

After satisfactory completion of the rise time tests in Table 3-3, return the Model 480 to normal operating condition as follows:

1. Disconnect power from the Model 480 and test instrument.
2. Disconnect the Model 480 from the test equipment.
3. If applicable, install Model 1788 battery pack in accordance with the instructions in Section 6.
4. Reinstall the top cover.

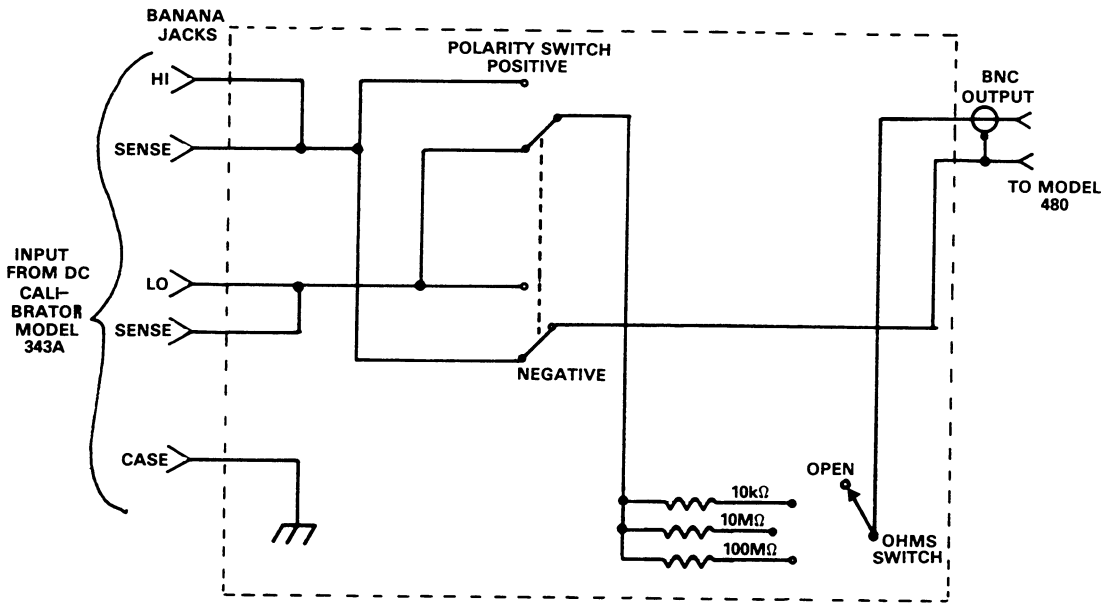


Figure 3-1. Shielded Test Fixture — Range Accuracy Set Up

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

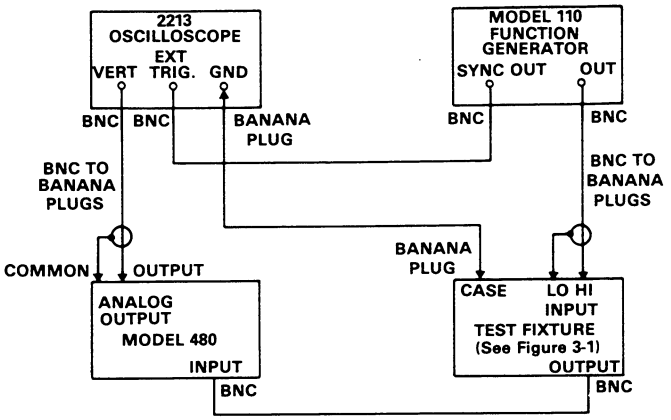


Figure 3-2. Rise Time Set Checks

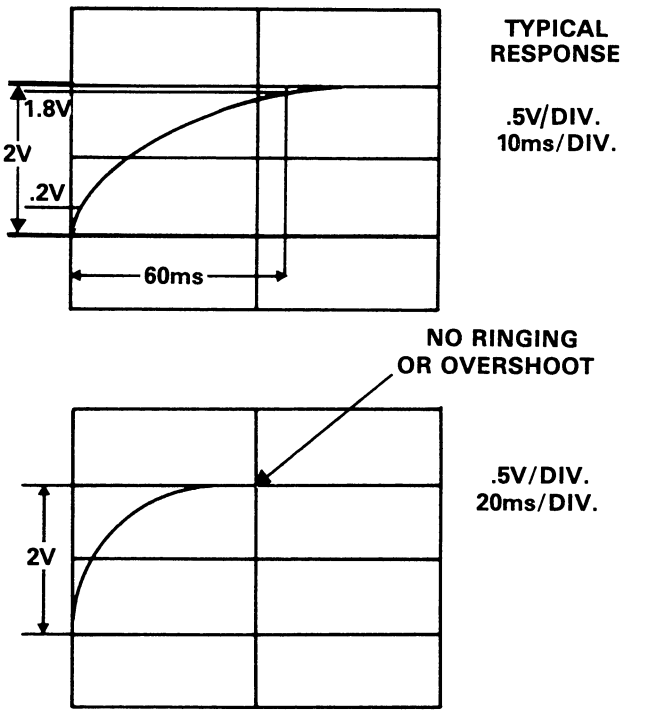


Figure 3-3. Model 480 Rise Time On 10nA Range

Table 3-2. Range Accuracy Check

343A Setting	Test Fixture Setting	480 Setting	480 Display
1.90000V	Open	1mA zero check (adjust if required)	.000
		1nA	.000 ± 1 digit
		10nA	0.00
		100nA	00.0
		1μA	.000
		10μA	0.00
		100μA	00.0
		1mA	.000
19.000000V	10kΩ Pos	1mA	1.900 ± 12d
19.000000V	10kΩ Neg		−1.900 ± 12d
1.900000V	10kΩ Neg	100μA	−190.0 ± 12d
190.0000V	10MΩ Neg	10μA	−19.00 ± 12d
19.00000V	10MΩ Pos	1μA	1.900 ± 12d
1.900000V	10MΩ Pos	100nA	190.0 ± 12d
.190000V	100MΩ Pos	1nA	1.900 ± 15d*
.190000V	100MΩ Neg		−1.900 ± 15d*

*The possible 0.2% error of the 100MΩ resistor has been subtracted.

Table 3-3. Rise Time Tests

480 Range	Test Fixture Seting	Model 110 Frequency	Scope Time	Rise Time 10% to 90%
1mA	10kΩ	50Hz	.2ms/div.	.5ms to 1.0ms
100μA	10kΩ	50Hz	.2ms/div.	.5ms to 1.0ms
10μA	10kΩ	5Hz	1ms/div.	2ms to 4.0ms
100nA	10MΩ	5Hz	1ms/div.	3.5ms to 7.0ms
10nA	100MΩ	2Hz	10ms/div.	35ms to 70ms

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 4
APPLICATIONS

4.1 INTRODUCTION

This section contains suggested applications for the Model 480.

4.2 LEAKAGE CURRENT TESTS

The Model 480 may be used in conjunction with the Model 6104 to perform leakage tests. The Model 6104 is a guarded and shielded test box for 2-terminal or 3-terminal connections. Voltages up to 1200V may be used. The Model 6104 provides excellent electrostatic shielding and high isolation resistance for the component under test. Clips plug into banana jacks allowing the user to fashion modified connections to suit the component to be tested.

The Model 6104 is useable with the Model 480 picoammeter and Keithley voltage supplies, such as the optional Model 247. When connected together as a system, using the cable and connector options, they form a complete test facility for measuring leakage current and other low current parameters for various test applications. A possible test set up is shown in Figure 4-1. The measurement sample would be connected between J1 and J7 or J8.

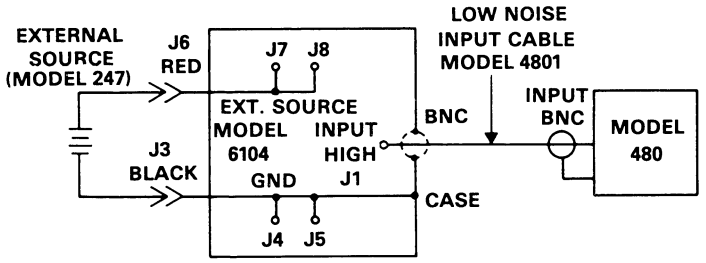


Figure 4-1. Leakage Test Set Up

4.3 RESISTIVITY TESTS

The Model 480 may be used along with the Model 6105 to perform resistivity tests. The Model 6105 is a guarded test fixture for measurement of surface and volume resistivities. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulating Materials, D257-66. The Model 6105 can be used in conjunction with the Model 480 and a high voltage power supply, such as the Model 247.

Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The Model 6105 can accomodate non-rigid sheet samples 2½ inches (63mm) to four inches (102mm) in diameter and ¼ inch (6mm) thick with excitation voltages up to 1000V. The Model 6105 has a UHF connector for the bias supply and a BNC output to the Model 480. A test hook up using the Model 247 power supply is shown in Figure 4-2.

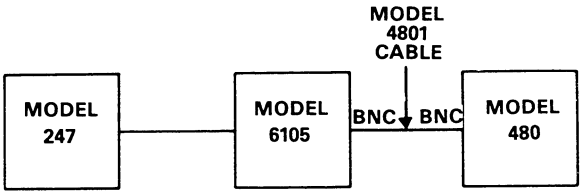


Figure 4-2. Resistivity Test Hook Up

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 5
THEORY OF OPERATION

5.1 INTRODUCTION

This section contains circuit description for the Model 480 picoammeter and for the Model 1788 battery pack. An overall block diagram of signal flow is provided in Figure 5-1. The overall schematic diagram is contained in Section 7.

5.2 OVERALL BLOCK DIAGRAM

As shown in Figure 5-1, the Model 480 circuitry consists of a current-to-voltage converter, a 3½ digit analog-to-digital converter and display and a power supply.

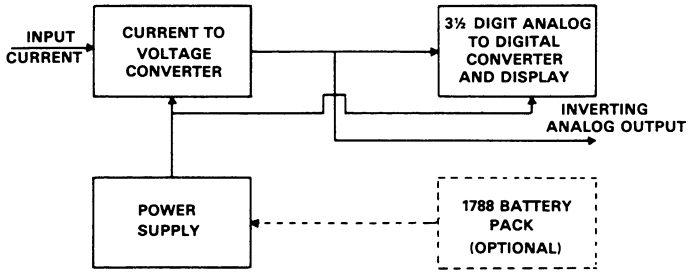


Figure 5-1. Model 480 Overall Block Diagram

5.2.1 Current-to-Voltage Converter

The current-to-voltage converter consists of a feedback ammeter circuit with selectable precision feedback impedances to generate the seven current ranges. Ranges are selected using front panel pushbuttons. The voltage output from the converter is used to drive the analog-to-digital converter and is also presented as an analog output on the rear of the instrument.

5.2.2 A/D Converter

The Model 480 uses a 2V fullscale analog-to-digital (A/D) converter with a 3½ digit multiplexed display. The A/D converter is a large scale integration (LSI) ratiometric device. Converter output is a multiplexed 4 digit binary coded decimal (BCD) number which is equal to the ratio of input voltage to an internal reference voltage. A separate clock circuit, not shown, supplies a 100kHz signal for converter timing and multiplexing the BCD output to the display.

5.2.3 Power Supply

The power supply circuits develop the internal operating voltages for the Model 480. These circuits may be powered either from line power or the optional Model 1788 battery pack.

5.3 CURRENT-TO-VOLTAGE CONVERTER

The voltage-to-current converter is shown in simplified form on Figure 5-2. Operational amplifier U104 is connected as a feedback amplifier with switch selectable feedback resistors. In this configuration, virtually all of the input current is forced through the feedback resistor and the linear transfer function of U104 is $-(I_{in})\ R = V_O$. On the 1nA, 100nA and 10μA ranges, a divider is switched to change the function to $-10\ (I_{in})\ R = V_O$. This permits using only four separate feedback networks instead of seven and simplifies instrument calibration. On all ranges, the feedback resistance is selected such that a fullscale current input will result in a 1V output from the converter (e.g. $-(1mA)4 \times 1K\Omega = -1V$). Since the maximum display on all ranges equals fullscale plus 100% overrange minus one digit, the maximum output voltage from the converter for an on-scale reading is $\pm 1.999V$. The converter output voltage is used to drive the A/D converter and is also furnished through a 1kΩ resistor as Inverting Analog Output for external use.

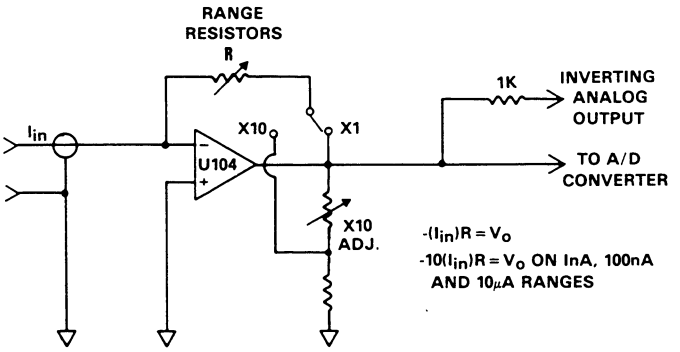


Figure 5-2. Simplified Schematic of Current-to-Voltage Converter

5.3.1 Input Overload Protection

Converter input protection to U104 is provided by a 1MΩ resistor (R110), Q102 and Q103 (See Schematic 29312E). Q102 and Q103 limit the input voltage to one diode drop. R115, R116 and the two halves of JFET Q104 form a matched pair of source followers which buffer the signal and limit the input current to $\leq 0.5pA$.

NOTE

Q104, R115 and R116 must be ordered and replaced as a matched set.

During input overloads, zener diodes VR101 and VR102 limit the output voltage swing of U104 to approximately $\pm 5V$. These diodes, along with R118, protect U104 and the A/D converter with up to 20V continuously applied to the Inverting Analog Output. Capacitors C119 and C120 absorb the

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

transient current surge during application of a 1000V, 10mA limited input overload.

5.3.2 Zero Check and Adjustment

Actuating the ZERO CHECK pushbutton closes S107 and opens S103H. S107 shorts the feedback resistance of U104 which results in the offset of U104 being presented at its output. S103H inserts R104 into the A/D converter reference voltage divider which shifts the reference from 1V to approximately 100mV. This serves to change the A/D converter from 2V fullscale to 200mV fullscale. This is necessary because whenever the output divider is used in the current converter, the input offset voltages are multiplied by 10. Since actuation to the ZERO CHECK switch disables the divider, it is necessary to add a gain of 10 to the A/D converter to permit accurate zero adjustment during zero check.

5.4 A/D CONVERTER

The A/D converter operates on the dual slope principle and is comprised of two large scale integration circuits U101 and U103, plus their associated discrete components. It is important to note that internally the converter operates as a 4½ digit converter with 20,000 counts full scale. However, in the Model 480, the least significant digit is blanked, resulting in a 3½ digit fullscale display of 2000 counts minus 1. The timing of the A/D is divided into three periods as described below.

5.4.1 Auto-Zero

The auto-zero period (A, Figure 5-3) is 100msec in length, which corresponds to 10,000 clock pulses. During this period, the reference voltage (V_{REF}) is stored on capacitor C102. Capacitor C105 stores $V_{REF} + V_{OS1} - V_{OS2}$.

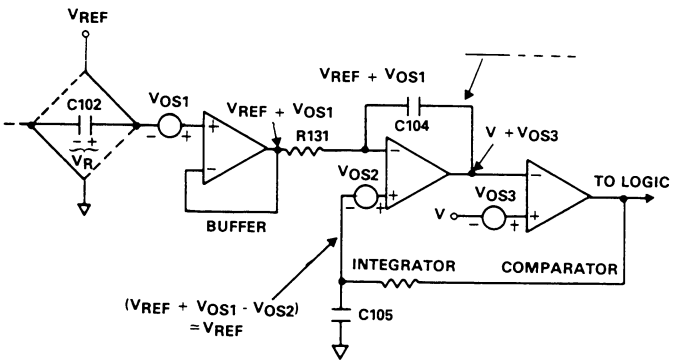
5.4.2 Signal-Integrate

The signal-integrate period (B, Figure 5-3) is also 100msec in length. The A/D input is buffered and integrated by U103. Positive signals generate a negative-going ramp at the integrator output (Pin 14), while negative signals produce a positive-going ramp. The level of the integrated signal at the end of the signal-integrated period is proportional to the average of the applied signal during this period. Since signal integration continues for 100msec, the A/D converter exhibits high normal mode rejection for AC signals in multiples of 10Hz, particularly 50 and 60Hz line frequencies.

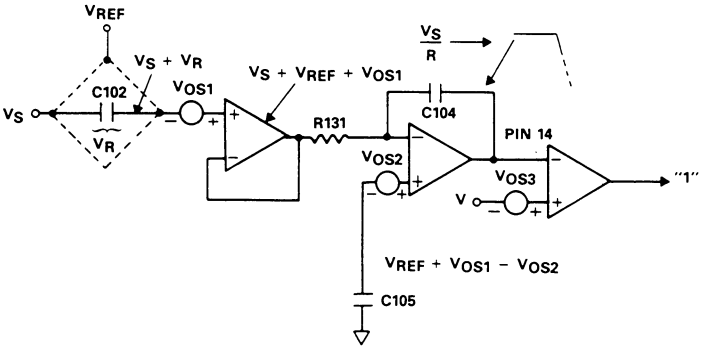
5.4.3 Reference-Integrate

The reference-integrate period (C or D, Figure 5-3) is a maximum of 200msec or 20,000 counts of length. During this period the integrator is returned to baseline level by applying a reference voltage of a polarity opposite to that of the signal. A positive-going ramp is obtained by grounding the buffer input, while a negative-going ramp is produced by the integration of $2 \times V_{REF}$ (that is, V_{REF} + the voltage stored on C102). The time, or number of clock pulses, required for discharge is the number of clock pulses required for the integrator to return to baseline level. The maximum count during this period is 20,000 which corresponds to a discharge period of 200msec for fullscale input. For an input of less than fullscale, the A/D automatically reverts to auto-zero for that period of the 200msec remaining after return to the baseline level. V_{REF} is provided by a divider connected to the internal reference supply of U103. The reference voltage is 1V for current measurements and 100mV during zero check. Calibration of the A/D converter is accomplished by adjusting R102 for a reference voltage of 1.0000 ±0.0008V.

A. AUTO-ZERO (10k COUNT)



B. SIGNAL INTEGRATE (10k COUNTS)



C. NEGATIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE) (POSITIVE INPUTS TO A/D)

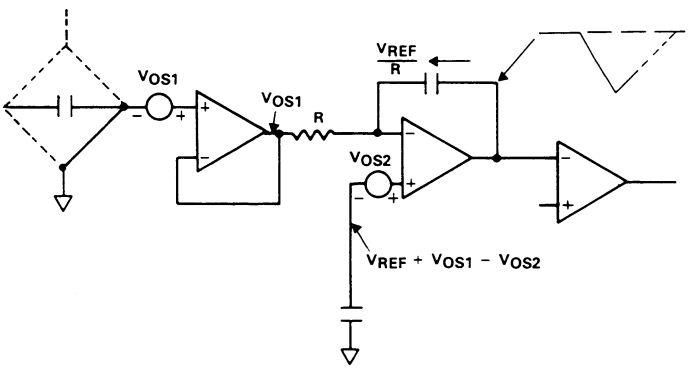


Figure 5-3. A/D Converter Function

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

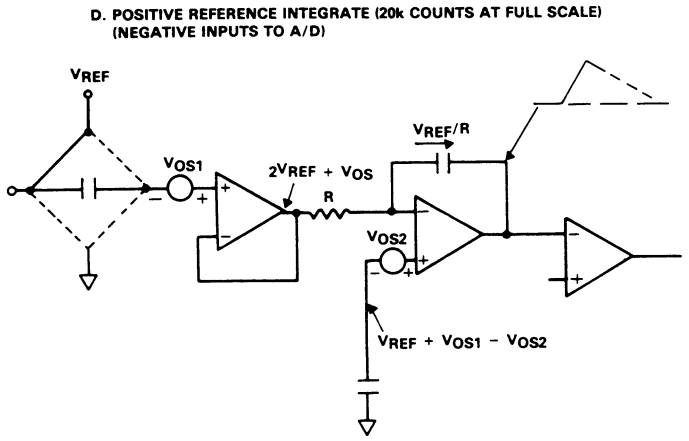


Figure 5-3. A/D Converter Function

5.5 DISPLAY

Four LED displays are driven by U202, which is a CMOS BCD-to-seven segment decoder/driver with bipolar current-sourcing outputs. Segment currents are limited to approximately 20mA peak by resistor network R202. The LED readout is a multiplexed, common-cathode configuration with Darlington array U201 sequentially sinking current from each digit. Blanking of the overrange digit is accomplished by gates U102A and U102B. Emitter-follower Q101 ensures that CMOS-compatible levels are maintained on U104A, pin 1, regardless of the loading of U201.

5.6 AC POWER SUPPLY

When the Model 480 is operated from AC line power, the power supply furnishes +5, +15, and -15 volts from regulators VR103, VR104 and VR105, respectively. Full-wave rectified AC from bridge rectifier CR103 and rectifiers CR101 and CR102 is filtered by capacitors C112, C115, C117 and C118 and is applied to the linear voltage regulators.

5.7 MODEL 1788 BATTERY PACK

When the Model 1788 battery pack is installed in the Model 480, S101 must be set to the BAT position to provide additional secondary voltage for battery charging. S101 also switches the input to VR103 from bridge rectifier CR103 to battery BT301. Four 2V, 2.5 ampere-hour lead-acid cells supply approximately 9.8V at full charge. After six hours of use on battery power, the battery pack should be recharged to ensure long battery life.

5.7.1 Battery Charging Circuit

While the Model 480 is plugged into line power and the battery pack is installed, battery charging proceeds as follows:

1. Full-wave rectified voltage from CR103 is applied to the anode Q301, which is an SCR which regulates charging voltage. When Q301 is triggered on by a sufficient gate-cathode voltage differential, the batteries receive charge. Charging continues as long as the bridge output voltage exceeds battery voltage by 1 volt or more. Resistor R304 limits charging current when recharging a set of completely discharged cells. A filtered positive output from CR102 (or T301) provides the necessary gate turn-in bias through R306 and diode CR301. Resistor R303 ensures proper high-temperature operation of Q301.

2. When the battery voltage reaches the present float voltage of 9.8V, zener VR301 conducts sufficient current to turn on Q302 and thus remove the gate trigger voltage from Q301. Float voltage is adjusted with R301. This is a factory adjustment which will normally not need field readjustment.

5.7.2 Battery Operation and Shutdown Circuit

The Model 480 operates as follows on battery power:

1. When the power is turned on, the batteries are connected to the input of VR103 to supply +5V for the logic, display and the clock circuit. The clock output is applied to the A/D converter as described in paragraph 5.4, and to U301 which is a divide-by-four binary counter. The outputs of U301 drive a DC-to-DC inverter which is synchronized to the A/D converter to filter out inverter noise. The 25kHz operating frequency is optimal for small transfomer size and results in low switching losses. Blocking capacitors C301 and C302 protect Q307 and Q308 from damage if the drive is lost. Two half-wave rectifiers (CR304 and CR305) on the secondary of T301 provide rectified AC to filter capacitors C304 and C305, which provide power +15 and -15V regulator VR104 and VR105.
2. To prevent permanent loss of battery capacity cause by deep discharge, a shutdown circuit stops operation on battery power when the battery voltage drops below approximately 7.2V. Shutdown is performed by micropower voltage detector U302. The open-collector output (U302, pin 4) saturates low and turns off pass transistor Q309 when the input voltage (at U302, pin 3) drops below 1.15V (typical). Resistor R314 provides sufficient hysteresis to prevent discharge from resuming when the battery voltage rises following disconnection of the load.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 6
MAINTENANCE

6.1 INTRODUCTION

This section provides calibration and troubleshooting information for the Model 480 and Model 1788 battery pack. Calibration should be performed yearly (every 12 months) or whenever performance verification (see Section 3) indicates that the Model 480 is out of specifications. If any step in the calibration procedure cannot be performed properly, refer to troubleshooting information in this section, or contact your Keithley representative or the factory as described in Section 3.

NOTE

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

6.2 RECOMMENDED TEST EQUIPMENT

Recommended test equipment for calibration and troubleshooting is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 10 times better than the instrument specification, or equal to Table 6-1 specifications.

6.3 ENVIRONMENTAL CONDITIONS

Calibration should be performed under laboratory conditions having an ambient temperature of 20°C to 26°C (68° to 78°F), and a relative humidity of less than 70%.

6.4 CALIBRATION PROCEDURE

Perform the following adjustments to calibrate the Model 480 and restore its operation to specified limits.

1. **Battery Pack Removal**—If the Model 1788 battery pack is installed in the instrument it must be removed to gain access to internal adjustments and test points.

   WARNING

   Disconnect the line cord before removing the case cover.

   A. Turn off the power and disconnect the line cord. Remove the four screws from the bottom of the case and separate the top cover from the bottom cover.
   B. Push back the ground clip (shown in Figure 6-3) from the upper side of the battery pack and remove the battery pack from the spacers.
   C. Calibration may be performed on battery power as long as the battery pack is sufficiently charged. Leave the battery pack plugged into the instrument, but set the battery pack behind the DMM on the bench or table. If the battery pack is not sufficiently charged, operate from line power.
2. **Warm Up**—Turn the Model 480 on and allow a one-half hour warm up time.

   NOTE

   If the instrument has been subjected to extremes of temperature, allow the internal temperatures to stabilize for a minimum of one hour at the environmental conditions specified in paragraph 6.3.

3. **Reference Adjustment**—Calibrate the A/D converter as follows:
   A. Connect LO lead of the DMM to INVERTING ANALOG OUTPUT-COMMON.
   B. With the HI DMM lead on TP4, adjust R102 for

Table 6-1. Recommended Test Equipment for Calibration and Troubleshooting

Description	Specification	Mfr.	Model
DC Calibrator	1.900000V, 190.0000V, to within 0.002% or 20μV.	Fluke	343A
Multimeter, Digital	1.9V ± .5mV, 0.00mV ± 0.05mV, 1.0000V ± 800μV, to within 0.013% of reading. 0-500mA.	Keithley	195
Precision Shielded Resistors (see Figure 3-1)	10kΩ ± 175ppm. 10MΩ ±300ppm, 100MΩ ± 2000ppm, @25°C ± 3°C.		
Picoampere Source* (used for troubleshooting only).	10.00×10^{-5} through 10^{-7} ± 0.25%, 10.00×10^{-8} ± 0.5% 10.00×10^{-9} ± 0.8%.	Keithley	261

*Not to be used for calibration.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

1.0000V ±0.0008 reading on DMM. See Figure 6-1 for test point and adjustment locations.

4. **Zero Adjustment**
   A. Connect DMM to INVERTING ANALOG OUTPUT.
   B. Set Model 480 to 10μA range, depress ZERO CHECK to latch position.
   C. Adjust R101 (front panel ZERO) for a DMM reading of 0.00mV ±0.05mV.
   D. Unlatch ZERO CHECK.
5. **Gain Adjustment, 10μA, and 100μA Ranges**
   A. Connect test fixture output to Model 480 and connect Model 343A DC calibrator output to the test fixture input. (See Figure 3-1 for set up).
   B. Set Model 480 to 100μA range.
   C. Set test fixture to 10kΩ and POS polarity positions.
   D. Set Model 343A to 1.900000V and output to ON position.
   E. Record INVERTING ANALOG OUTPUT voltage displayed on DMM. Verify Model 480 display indicates 190.0 ±5 digits.
   F. Set test fixture to 10MΩ position, POS polarity.
   G. Set Model 480 to 10μA range.
   H. Set Model 343A to 190.0000, output ON.
   I. Adjust R121 for same reading on DMM as noted in step E ±.0005V. Verify Model 480 display indicates 19.00 ±5 digits.
6. **10nA Range Adjustment**
   A. Set Model 343A to 1.900000V, output ON.
   B. Set test fixture to 100MΩ position, POS polarity.
   C. Set Model 480 to 10nA range.
   D. Adjust R124 for a Model 480 display indication of 19.00nA ±0 digits.
7. **Verification**—After completing the calibration procedures, the performance verification tests in Section 3 may be performed to ensure that the Model 480 operation is within specifications.

6.5 TROUBLESHOOTING OVERVIEW

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

6.6 TROUBLESHOOTING PROCEDURE

This section contains listed step-by-step checks of the major Model 480 circuits described in Section 5, Theory of Operation. Proceed as follows:

1. In general, start troubleshooting with Table 6-2, to verify that the power supplies are providing the specified voltage to the electronic components.
2. If troubleshooting occurs on battery power only, or if battery operating time is substantially less than six hours after overnight charging, test the batteries and charging circuit per Table 6-3.
3. Proper operation of the A/D converter and display should be verified before troubleshooting the current-to-voltage converter. Check these circuits per Tables 6-5 and 6-4, respectively.
4. Check the current-to-voltage converter circuitry per Table 6-6.
5. Table 6-7 provides instructions to adjust the Model 1788 battery pack float voltage. This voltage is preset at the factory and readjustment in the field will normally not be required.
6. Unless otherwise specified, all measurements are referenced to COMMON of the INVERTING ANALOG OUTPUT and/or battery pack ground clip.

Table 6-2. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S105 line switch	Must be set to 105-125V or 210-250V as appropriate.	
2	S101 LINE/BAT switch	Must be set to BAT for use with battery pack.	
3	F101 line fuse	Continuity.	
4	P1008 line cord	Plugged into live receptacle.	
5	S108 OFF/ON power switch.	Turn on power.	
6	+5V pad*	+5 volts ± 10%	Output of VR103.
7	TP2*	+7 volts minimum.	Output of CR103, input to VR103.
8	+15V pad*	+15 volts ± 10%.	Output of VR104.
9	TP10*	+17.5 volts minimum.	Output of CR102, input to VR104.
10	−15V pad*	−15 volts ± 10%.	Output of VR105.
11	TP1*	−17.5 volts minimum.	Output of CR101, input to VR105.
			NOTE: Hot regulator may indicate shorted load.

*On main printed circuit board (see Figure 6-1 for location).

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

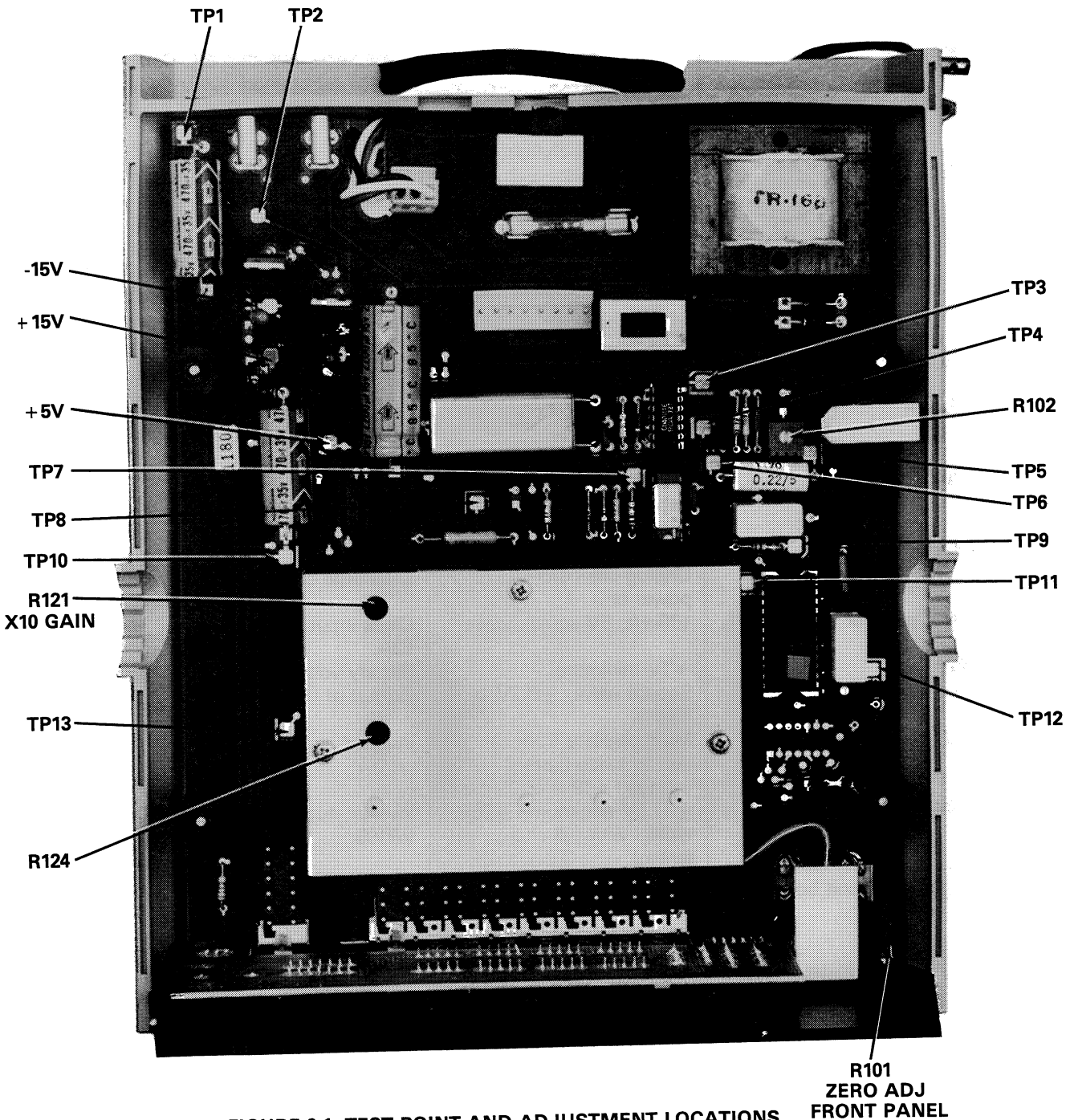


FIGURE 6-1. TEST POINT AND ADJUSTMENT LOCATIONS

Figure 6-1. Test Point and Adjustment Locations

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 6-3. Battery Power Checks

Step	Item/Component	Required Condition	Remarks
1		Check AC line power per Table 6-2.	
2		Turn off power.	
3	S101 line/bat switch.	Move to BAT.	
4	P1008 line cord.	Plugged into live receptacle.	Charge circuit checks.
5	F301	Remove fuse and connect DMM to fuse clip. 0 to 500mA charging rate varies with line voltage and battery state of charge.	No charge, see step 5A. Correct charging but short battery operating time, see step 6.
5A	BT301 batteries	Full charge is ≈9.8 volts over 4 cells. R301 adjusts charging rate (float voltage).	If voltage is low & adjustment of R301 does not start charging, see steps 7 & following. If voltage is low & adjustment of R301 does start charging, see Table 6-7 for adjustment of battery charge voltage.
6	Each battery cell voltage during charging.	Less than 3V for any cell.	High voltage or zero indicates damaged cell.
7	Q301 anode.	Full wave rectified voltage, 15VDC nominal.	Output of CR105.
8	C304 +	+17.5V minimum.	Output of CR102. Triggers Q301 gate through R306 and CR301 unless Q302 is on.
9	Q302	Should saturate only when battery approaches full charge.	
10	VR301	8.2V zener.	
11		Unplug line cord and turn power on.	Discharge checks.
12	P1004 pin 8 or U301 pin 11.	100kHz; 5V square wave.	Clock input. If no input, see step 12A.
12A	TP2*	+7V minimum.	Battery voltage input to VR103.
13	Q307 and Q308 base.	Square wave, ±0.7V at 25kHz.	Output of U301, ÷4.
14	Q307, Q308 collector.	Must oscillate from saturation to twice battery voltage (≈19V) at 25kHz.	Inverter
15	C304, C305	±17.5V minimum (±25V typical with full charge batteries.)	Inverter output; input to VR104 and VR105.

*On main printed circuit board (see Figure 6-1).

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 6-4. Display Checks

Step	Item/Component	Required Condition	Remarks
1		Turn on power and select any range.	
2	+5V*	+5 volts ± 10%	If low, check per Table 6-2.
3	U201, pins 1, 2, 6 and 7.	Digit drive. Low = enabled.	LED cathode.
4	U202, pins 1, 2, 6 and 7.	HI = enabled	BCD input to U202 segment decoder/drive.
5	U202, pin 4.	Positive-going signal lasting for 200 clock pulses.	Leading digit suppression. Output of U102A.
6	J1003, pin 8	Polarity line (sign). HI = off LO = −	
7	J1007, pins 3, 4 and 5.	Appropriate DP line high (on).	Depress applicable range pushbuttons to verify all DP lines.

*On main printed circuit board (see Figure 6-1).

Table 6-5. A/D Converter Checks

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 1mA range. Open circuit to INPUT of 480.	
2	Display	.000	
3	TP9*	0.000 ± 100μV	Input to U101. If different, check I/V converter Table 6-6.
4	TP4*	+1.0000 ± 0.0008V	Reference output. Calibration point.
5	TP3*	0 to +5 volt square wave at 100kHz.	Clock input to A/D converter.
6	TP11*	+1.0 ± 0.1V	Stored autozero voltage.
7	U103, pin 11	+1.0 ±0.1V	Σ-node voltage to integrator in U103.
8	TP5*	−1.2 ± 0.2V	U103 integrator output voltage.
9	U103, pin 13	+1V	U103 buffer input.
10	TP7*	+1V	U103 buffer output.
11		Connect TP4* to TP9*.	
12	Display.	1.000 ± 1 digit.	If different, check U101 input.
13	TP9*	1.0000V, reference.	Input to U101.
14	TP5*	Waveform per Figure 6-2.	Integrator output.
15	U103-2	Waveform per Figure 6-2 during ramping of integrator output.	Comparator output.

*On main printed circuit board (see Figure 6-1).

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 6-6. Current-to-Voltage Converter Checks

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 10μA range. Depress ZERO CHECK & adjust front panel ZERO R101.	
2	TP8*	00.00mV ± 0.05mV	U104 offset, S107, R101, input buffer circuit.
3		Release ZERO CHECK. Select 100μA range.	
4	External current source.	Apply 10.00×10^{-5}A.	
5	TP8*	−1.000V ± 7.5mV, typical	U104 and feedback components: R113, R120, C109, C120, S103C, S104.
6	External current source.	Apply 10.00×10^{-5}A. Select 1mA range.	
7	TP8*	−100mV ± 0.75mV, typical	U104, R107, C107, S102
8	External current source.	Apply 10.00×10^{-6}A. Select 10μA range.	
9	TP8*	−1.000V ± 7.5V, typical	U104, R113, R121, R122, R123, C109, C119, S103C and S104.
10	External current source.	Apply 10.00×10^{-7}A. Select 1μA range.	
11	TP8*	−1.000V ± 7.5mV, typical.	U104, R117, C110, S106 and S103E.
12	External current source.	Apply 10.00×10^{-8}A. Select 100nA range.	
13	TP8*	−1.00V ± 10mV, typical	U104, R117, C110, S106 and S103E.
14	External current source.	Apply 10.00×10^{-9}A. Select 10nA range.	
15	TP8*	−1.000V ± 16mV, typical	U104, R119, R124, S103F, and S103G.
16	External current source.	Apply 10.00×10^{-9}A. Select 1nA range.	
17	TP8*	Approximately −5 volts.	Input current overload due to action of X10 divider. Zener VR101 clamps U104 output to ≈ −5V.

*For convenience, Inverting Analog Output may be used.

Table 6-7. Adjustment of Battery Charge Voltage

Step	Item/Component	Required Condition	Remarks
1		Instrument off.	
2	R201	Turn full CCW. (maximum charge rate).	
3	BT301	Monitor battery voltage for >9.8V.	Fully charged cells require several minutes to reach this level. Discharged cells require several hours. CAUTION: charging to >10V for longer than 30 minutes will reduce battery life.
4	R301	When cells reach 9.8V, turn unit on and adjust to maintain 9.8V across BT301.	

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

NOTE

The current source (Model 261) used in Table 6-6 cannot be used to either verify Model 480 accuracy specifications or calibrate the instrument.

6.7 BATTERY PACK INSTALLATION

WARNING

Disconnect the line cord before removing the case cover.

1. Turn the instrument over so that the bottom cover faces up. Loosen four slotted screws on the bottom cover. Turn over the instrument with the top cover facing up, taking care to hold the top and bottom covers together. Carefully remove the top cover to gain access to the printed circuit board.
2. Set the BAT/LINE switch to the BAT position shown in Figure 6-3. Note that the battery pack will not operate properly if this switch is not in the BAT position.
3. Remove fuse F301 on the battery pack.
4. Install the battery pack in the instrument so that it rests on the plastic spacers. The ground clip must make contact with the upper side of the battery pack plate.
5. Carefully align the battery pack plug with connector P1004 on the circuit board. Push the plug firmly onto the connector until the lip on the plug engages the lip on the connector to lock the plug in place.

CAUTION

Make sure the connector is aligned so that all the pins mate properly, otherwise, damage to the unit will result.

6. Install the fuse F301. Reinstall top cover and secure with four screws.
7. Charge the battery pack as described in paragraph 2.5.

6.8 FUSE REPLACEMENT

A line fuse (F101) protects the Model 480 from excessive line current. Similarly, the Model 1788 has an integral fuse. To replace either of these fuses, use the procedure below.

1. Remove the top cover as described in paragraph 6.7.

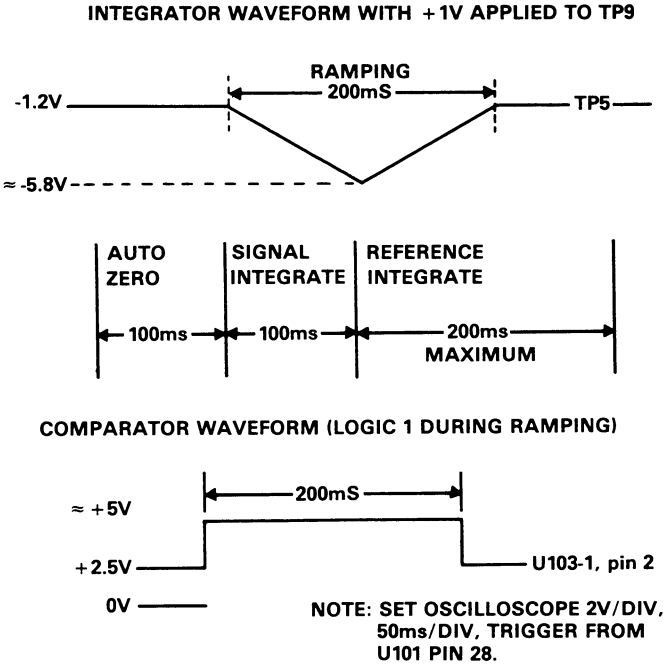


Figure 6-2. Integrator and Comparator Waveforms

WARNING

Disconnect the line cord before removing the top cover.

2. Refer to Figure 6-3, which shows the location of the line fuse (F101) and the battery fuse (F301). To replace the fuse, simply pry the old fuse out of the holder with a screwdriver.
3. Replace the fuse with the type recommended in Table 6-8.

CAUTION

Do not install a fuse with a larger rating than specified, or instrument damage may occur.

4. Replace and secure the top cover.

Table 6-8. Fuse Types

Fuse	Specifications	Keithley Part No.
Line Fuse (F101)	3AG, 1/8A, 250V, slow blow	FU-20
Battery Fuse (F301)	3AG, 2A, 250V, normal blow	FU-13

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

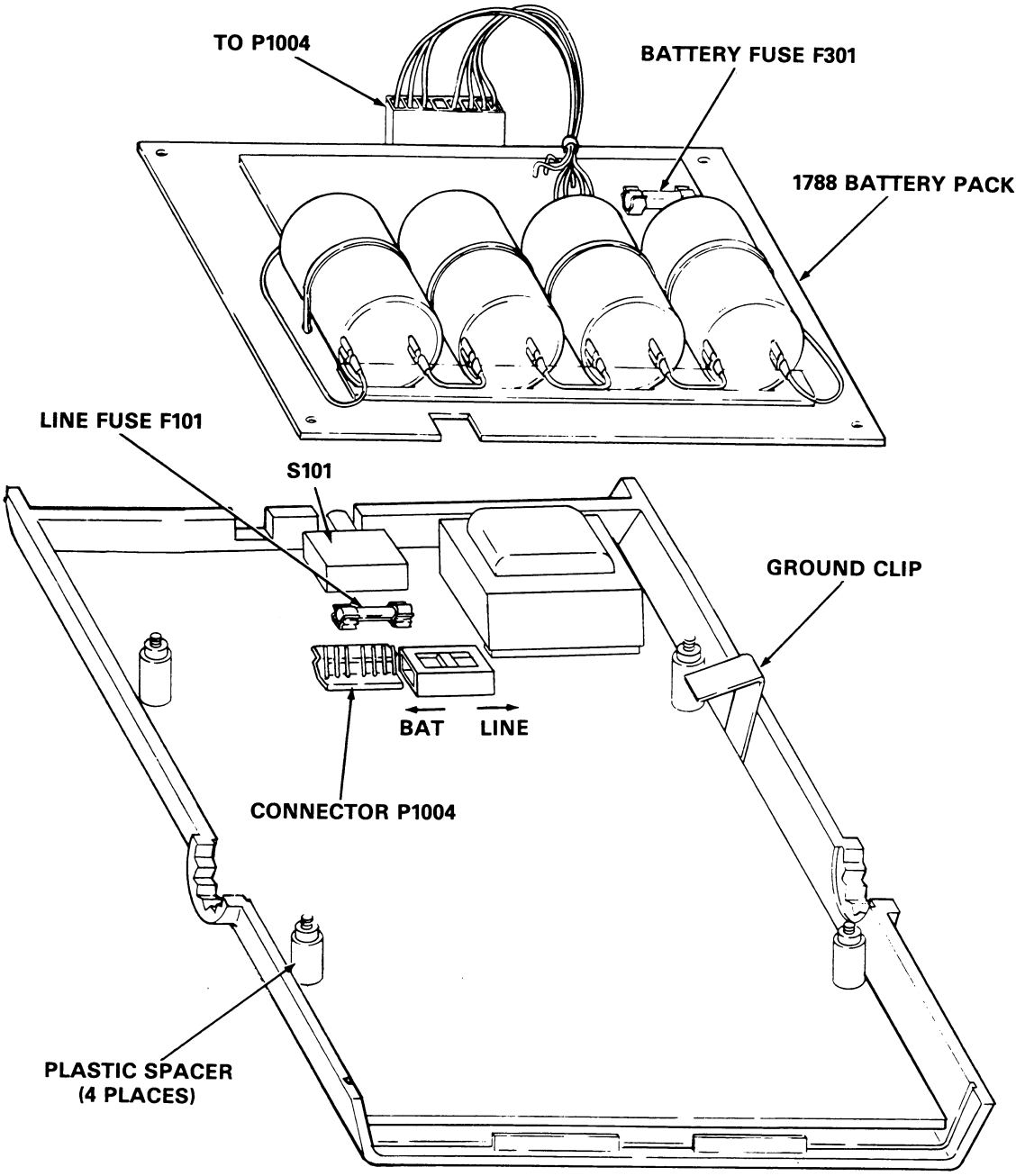


Figure 6-3. Battery Pack Installation

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

SECTION 7
REPLACEABLE PARTS

7.1 INTRODUCTION

This section contains information necessary to identify and order replacement parts for the Model 480. Figure 7-1 shows Model 480 mechanical parts. Table 7-1 lists mother board parts, Table 7-2 lists display board parts, and parts for the optional Model 1788 battery pack are listed in Table 7-3. Each of these parts lists is arranged in alphabetical order of component circuit designations.

7.2 ORDERING INFORMATION

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

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Circuit Designation (if applicable)
5. Keithley Part Number

7.3 FACTORY SERVICE

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

7.4 COMPONENT LAYOUTS

The following component layouts are included in this section.

1. Figure 7-2, drawing number 29314D, contains the component layout of the Model 480 main circuit board (PC-472).
2. Figure 7-3 shows the component layout of the display circuit board (PC-473).
3. The layout of the battery pack circuit board (PC-451) is shown on Figure 7-4.

7.5 SCHEMATIC DIAGRAM

Figure 7-5, drawing number 29312E, is the schematic diagram for the Model 480 and the Model 1788 battery pack.

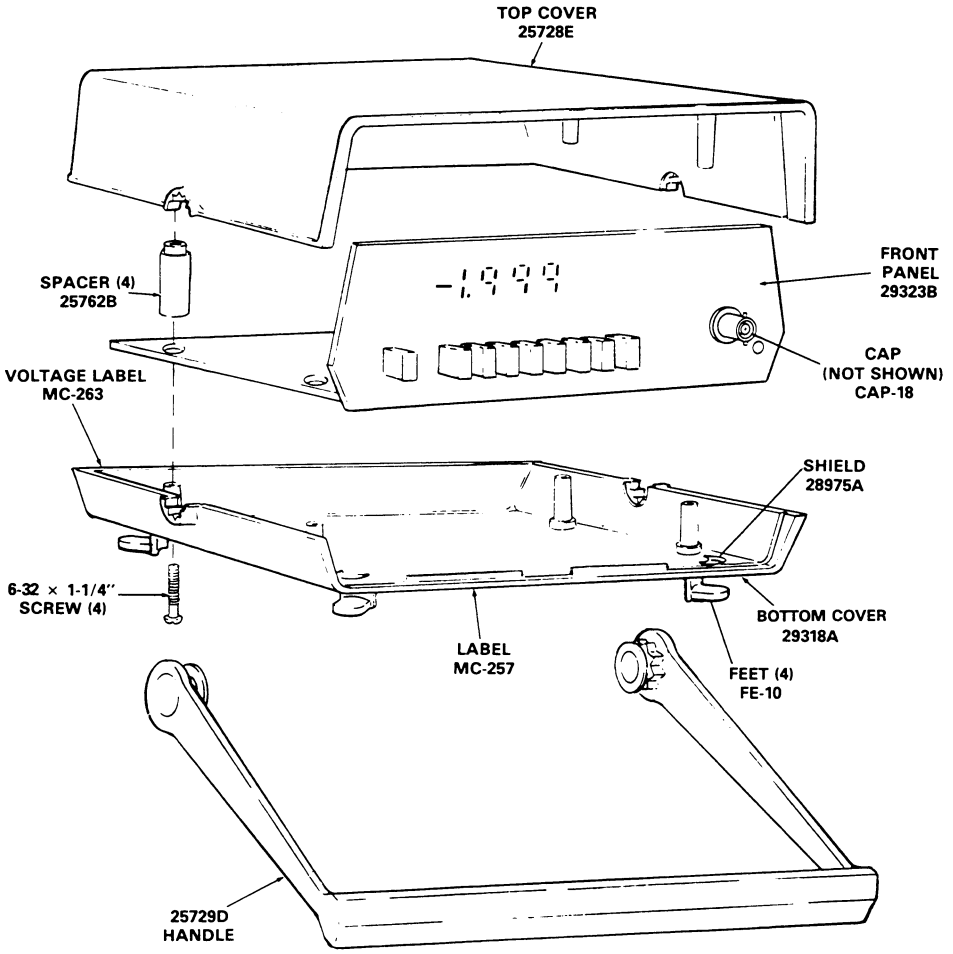


Figure 7-1. Covers and Panels

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 7-1. Mother Board, PC-472, Parts List

Circuit Desig.	Description	SCH Location	PCB Location	Keithley Part No.
C101	Capacitor, .1μF, ±20%, 250VDC, Metalized Polyester	J-4	D-1	C-178-.1
C102	Capacitor, 1μF, ±10%, 100VDC, Metalized Polyester	K-3	D-1	C-294-1
C103	Not Used			
C104	Capacitor, .22μF, 10%, 50VDC, Polypropylene	M-1	C-2	C-269-.22
C105	Capacitor, 1μF, ±10%, 100VDC, Polyester	L-3	D-2	C-294-1
C106	Capacitor, .01μF, 16V, Ceramic Disc	K-2	D-2	C-238-.01
C107	Capacitor, .25μF, ±20%, 400VDC, Mylar	F-3	E-2	C-73-.25
C108	Capacitor, 100pF, 100VDC, Ceramic Disc	E-4	C-3	C-64-100pF
C109	Capacitor, .022pF, ±20%, 600VDC, Polyester Film	F-3	E-3	C-220-.022
C110	Capacitor, 2200pF, ±5%, 500VDC, Polystyrene	F-2	E-3	C-138-2200pF
C111	Capacitor, 2200pF, 1000V, Ceramic Disc	F-4	D-3	C-64-2200pF
C112	Capacitor, 2200μF, 15V, Aluminum Electrolytic	C-7	C-4	C-290-2200
C113	Not Used			
C114	220pF, ±5%, 500VDC, Polystyrene	F-2	E-4	C-138-220pF
C115	4.7μF, 20V, Tantalum	D-7	C-4	C-179-4.7
C116	22μF, ±20%, 20V, Tantalum	D-7	C-4	C-180-22
C117	470μF, 35V, Aluminum Electrolytic	C-8	B-5	C-289-470
C118	470μF, 35V, Aluminum Electrolytic	C-7	C-5	C-289-470
C119	1μF, 100V, Mylar	H-1	D-4	C-245-1
C120	1μF, 100V, Mylar	G-3	E-4	C-245-1
C121	10μF, 20V, Tantalum	D-8	C-5	C-179-10
CR101	Rectifier, 1A, 800V, 1N4006	B-7	C-1	RF-38
CR102	Rectifier, 1A, 800V, 1N4006	B-7	C-1	RF-38
CR103	Bridge Rectifier, 100V, 2A	B-6	C-2	RF-36
CR104	Rectifier, 75mA, 1N914	L-1	D-3	RF-28
CR105	Rectifier, 75mA, 1N914	L-1	D-4	RF-28
F101	Fuse, Slo-Blo, 1/8A, 250V	A-7	B-3	FU-20
J1001	Receptacle, BNC	E-3	F-1	CS-249
J1002	Not Used			
J1003	Display Connector Socket	K-6	F-2	CS-356-6
J1004	Connector Housing	E-5	F-2	CS-287-8
J1005	Connector Housing	A-8		CS-287-3
J1006	Contact	H-3	A-5	29316A
J1007	Display Connector Housing	K-7	F-5	CS-356-3
P1001	Not Used			
P1002	Not Used			
P1003	12-pin Male	K-6	F-3*	CS-355-6
P1004	Receptacle 8-pin	E-5	C-3	CS-288-8
P1005	Receptacle 3-pin	A-8	B-5	CS-288-3
P1006	Not Used			
P1007	6-pin Male	K-7	B-3*	CS-355-3
P1008	Line Cord	A-8	CO-9	
Q101	Transistor, NPN, Silicon, 2N3904	K-6	E-2	TG-47
Q102	Transistor, N-Chan, JFET, Case R-110	F-3	D-2	TG-77
Q103	Transistor, N-Chan, JFET, Case R-110	E-3	D-3	TG-77
Q104	Transistor, Matched Set with R115 & R116	F-4	D-3	29427A
R101	Resistor, 25kΩ, 75W, Cermet Variable	F-3	F-1	RP-89-25k
R102	Resistor, 200Ω, Cermet Trimmer	J-2	C-2	RP-97-200
R103	Resistor, 100kΩ, 10%, ¼W, Composition	J-3	D-2	R-76-100k
R104	Resistor, 17.4kΩ, 1%, 1/8W, Metal Film	K-2	C-2	R-88-17.4k
R105	Resistor, 768Ω, 1%, 1/8W, Metal Film	J-2	C-2	R-88-768
R106	Resistor, 1.1kΩ, 1%, 1/8W, Metal Film	J-2	C-2	R-88-1.1k

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 7-1. Mother Board, PC-472, Parts List (Cont.)

Circuit Desig.	Description	SCH Location	PCB Location	Keithley Part No.
R107	Resistor, 1k, .1%, ½W, Metal Film	F-3	E-2	R-169-1k
R108	Resistor, 22M, 10%, ¼W, Composition	D-4	C-3	R-76-22M
R109	Resistor, 100kΩ, 10%, ¼W, Composition	L-1	D-3	R-76-100k
R110	Resistor, 1MΩ, 1%, ½W, Metal Film	E-3	D-3	R-94-1M
R111	Resistor, 47kΩ, 10%, ¼W, Composition	D-4	C-3	R-76-47k
R112	Resistor, 33kΩ, 10%, ¼W, Composition	M-2	D-3	R-76-33k
R113	Resistor, 9.91kΩ, .1%, ½W, Metal Film	F-2	E-3	R-169-9.91k
R114	Resistor, 270kΩ, 10%, ¼W, Composition	M-3	D-3	R-76-270k
R115	Resistor, Matched Set with Q104	F-4	D-3	R-88-(SEL)
R116	Resistor, Matched Set with Q104	F-4	D-3	R-88-(SEL)
R117	Resistor, 1.01M, .1%, ½W, Metal Film	F-2	E-3	R-169-1.01M
R118	Resistor, 1kΩ, !1%, ½W, Metal Film	G-3	D-4	R-94-1k
R119	Resistor, 99M, .1%, ½W, Metal Film	F-1	E-4	R-269-99M
R120	Resistor, 90.9Ω, 1%, 1/8W, Metal Film	G-2	E-4	R-88-90.9
R121	Resistor 10Ω, 0.5W, Potentiometer	H-1	D-4	RP-97-10
R122	Resistor, 899Ω, .1%, ½W, Metal Film	H-1	D-4	R-169-899
R123	Resistor, 95.4Ω, .1%, ½W, Metal Film	H-2	D-4	R-169-95.4
R124	Resistor, 2MΩ, 0.5W, Potentiometer	F-1	E-4	RP-97-2M
R125	Resistor, 120Ω, 10%, ¼W, Composition	J-6	F-5	R-76-120
S101	Switch, Line Battery	B-6	C-2	SW-397
S102	Switch, Pin, Contact	F-3	E-2	CS-357
S103	Switch, Pushbutton	Sev	F-2	SW-405
S104	Switch, Pin, Contact	F-2	E-3	CS-357
S105	Switch, Slide, DPDT	A-6	B-3	SW-318
S106	Switch, Pin, Contact	F-2	E-3	CS-357
S107	Switch, Pin Contact	F-1	E-4	CS-357
S108	Switch, Power	C-8	E-5	SW-406
T101	Transformer, Power	A-6	B-2	TR-168
U101	IC, 4½ Digit Logic Processor, 7103A	L-4	D-2	LSI-11-1
U102	IC, CMOS, 4011	K-5	C-2	IC-102
U103	IC, 4½ Digit Analog-Processor, 8052A	M-2	D-2	LSI-12
U104	IC, Operational-Amp, LF356-4	F-3	D-3	IC-152
VR101	Regulator, Diode, Zener, 1N751	G-4	D-4	DZ-59
VR102	Regulator, Diode, Zener, 1N751	G-4	D-4	DZ-59
VR103	Regulator, +5V, 3-Term, TO-220, 7805	D-6	B-4	IC-93
VR104	Regulator, +15V, 3-Term, LO-Power, 78L15	C-7	C-5	IC-170
VR105	Regulator, -15V, 3-Term, 7915	D-8	B-5	IC-174
Y101	Quartz, Crystal, ±0.01%, 100kHz	E-4	C-3	CR-8

Table 7-2. Display Board, PC-473, Parts List

Circuit Desig.	Description	SCH Location	PCB Location	Keithley Part No.
DS201	±1 LED Digit	K-7	D-3	DD-31
DS202	7-Segment LED Digit	L-7	D-3	DD-30
DS203	7-Segment LED Digit	L-7	D-3	DD-30
DS204	7-Segment LED Digit	L-7	D-3	DD-30
R201	Resistor, 120Ω, 10%, 1/4W, Composition	K-7	B-3	R-76-120
R202	Resistor, Thick Film	M-7	E-3	TF-102-3
U201	IC, Digit Driver, 75492	K-6	C-3	IC-169
U202	IC, Segment Driver, 4511	M-7	F-3	IC-168

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Table 7-3. Model 1788 Battery Pack, PC-451, Parts List

Circuit Desig.	Description	SCH Location	PCB Location	Keithley Part No.
C301	Capacitor, 4.7μF, 20V, Tantalum	G-7	E-3	C-179-4.7
C302	Capacitor, 4.7μF, 20V, Tantalum	G-7	E-3	C-179-4.7
C303	Capacitor, 1.0μF, 250V, Metalized Polyester	H-7	E-3	C-256-1
C304	Capacitor, 100μF, 35V, Aluminum Electrolytic	E-7	F-4	C-295-100
C305	Capacitor, 100μF, 35V, Aluminum Electrolytic	E-8	F-3	C-295-100
CR301	Rectifier, 75mA, 75V, 1N914	E-6	D-4	RF-28
CR302	Rectifier, 75mA, 75V, 1N914	G-7	E-3	RF-28
CR303	Rectifier, 75mA, 75V, 1N914	G-7	E-3	RF-28
CR304	Rectifier, 75mA, 75V, 1N914	F-7	F-4	RF-28
CR305	Rectifier, 75mA, 75V, 1N914	F-8	F-4	RF-28
F301	Fuse, 2A, 250V, 3AG, Fast Blow	H-5	C-3	FU-13
Q301	Thyristor, SCR, 106F1	E-6	C-4	TG-132
Q302	Transistor, NPN, Silicon, 2N3904	E-6	C-3	TG-47
Q303	Transistor, NPN	G-6	D-4	TG-53
Q304	Transistor, NPN, Silicon, 2N3904	G-6	E-4	TG-47
Q305	Transistor, NPN, Silicon, 2N3904	G-7	E-4	TG-47
Q306	Transistor, PNP, Silicon, TO-92 Case	G-7	E-4	TG-53
Q307	Transistor, NPN, Silicon, 2N3725	G-6	E-3	TG-131
Q308	Transistor, NPN, Silicon, 2N3725	G-7	E-3	TG-131
Q309	Transistor, PNP, Silicon, MPS-WA5	F-5	D-3	TG-133
Q310	Transistor, PNP, Silicon, TO-92 Case	G-5	D-3	TG-53
R301	Resistor, 20kΩ, 0.5W, Potentiometer	F-6	C-3	RP-97-20k
R302	Resistor, 330Ω, 10%, ¼W, Composition	F-6	C-3	R-76-330
R303	Resistor, 1kΩ, 10%, ¼W, Composition	F-6	D-4	R-76-1k
R304	Resistor, 3.9Ω, 20%, 3W, Wire Wound	E-6	D-4	R-268-3.9
R305	Resistor, 4.7kΩ, 10%, ¼W, Composition	F-7	D-3	R-76-4.7k
R306	Resistor, 3.3kΩ, 10%, ¼W, Composition	E-7	C-3	R-76-3.3k
R307	Resistor, 82Ω, 10%, ¼W, Composition	G-7	E-3	R-76-82
R308	Resistor, 82Ω, 10%, ¼W, Composition	G-7	E-3	R-76-82
R309	Resistor, 10Ω, 10%, ¼W, Composition	E-8	F-4	R-76-10
R310	Resistor, 10Ω, 10%, ¼W, Composition	E-7	F-4	R-76-10
R311	Resistor, 100kΩ, 10%, ¼W, Composition	G-6	E-3	R-76-100k
R312	Resistor, 100kΩ, 5%, ¼W, Composition	G-6	E-3	R-76-100k
R313	Resistor, 6.8MΩ, 5%, ¼W, Composition	G-5	E-3	R-76-6.8M
R314	Resistor, 6.8MΩ, 5%, ¼W, Composition	G-5	E-3	R-76-6.8M
R315	Resistor, 576kΩ, 1%, 1/8W, Composition	G-5	E-3	R-88-576k
R316	Resistor, 100kΩ, 1%, 1/8W, Composition	G-6	E-3	R-88-100k
T301	Transformer, Power	H-6	F-3	TR-170
U301	IC, Dual D-Type Flip-Flop, 4013	F-7	D-3	IC-103
U302	IC, 1.1V Micro-Power Detector, ICL8211 CPA	G-6	E-3	IC-177
VR301	Regulator, 8.2V, Zener, 1N756A	F-6	C-3	DZ-61

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

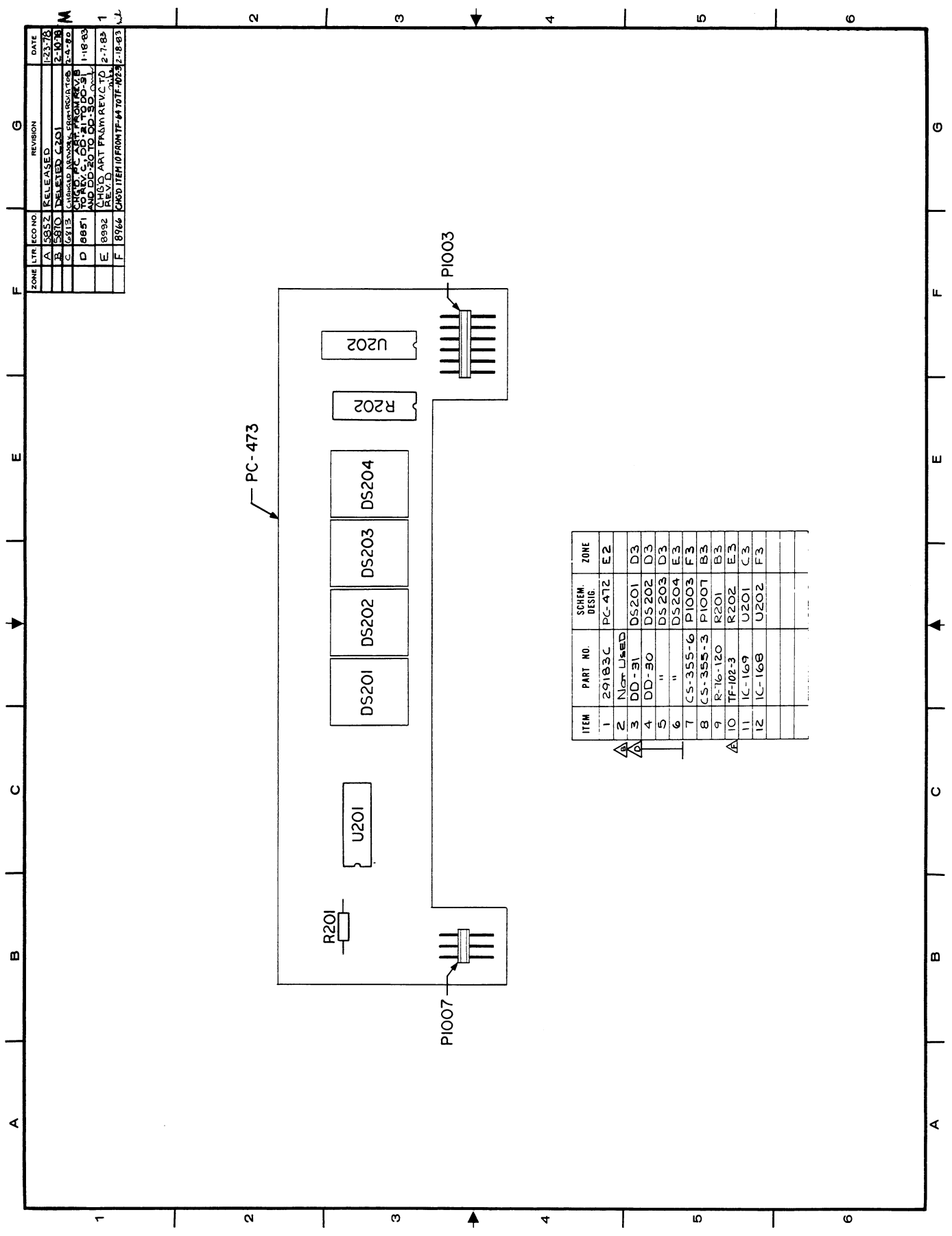


Figure 7-2. Display Board, Component Location Drawing, Dwg. No. 29315C

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

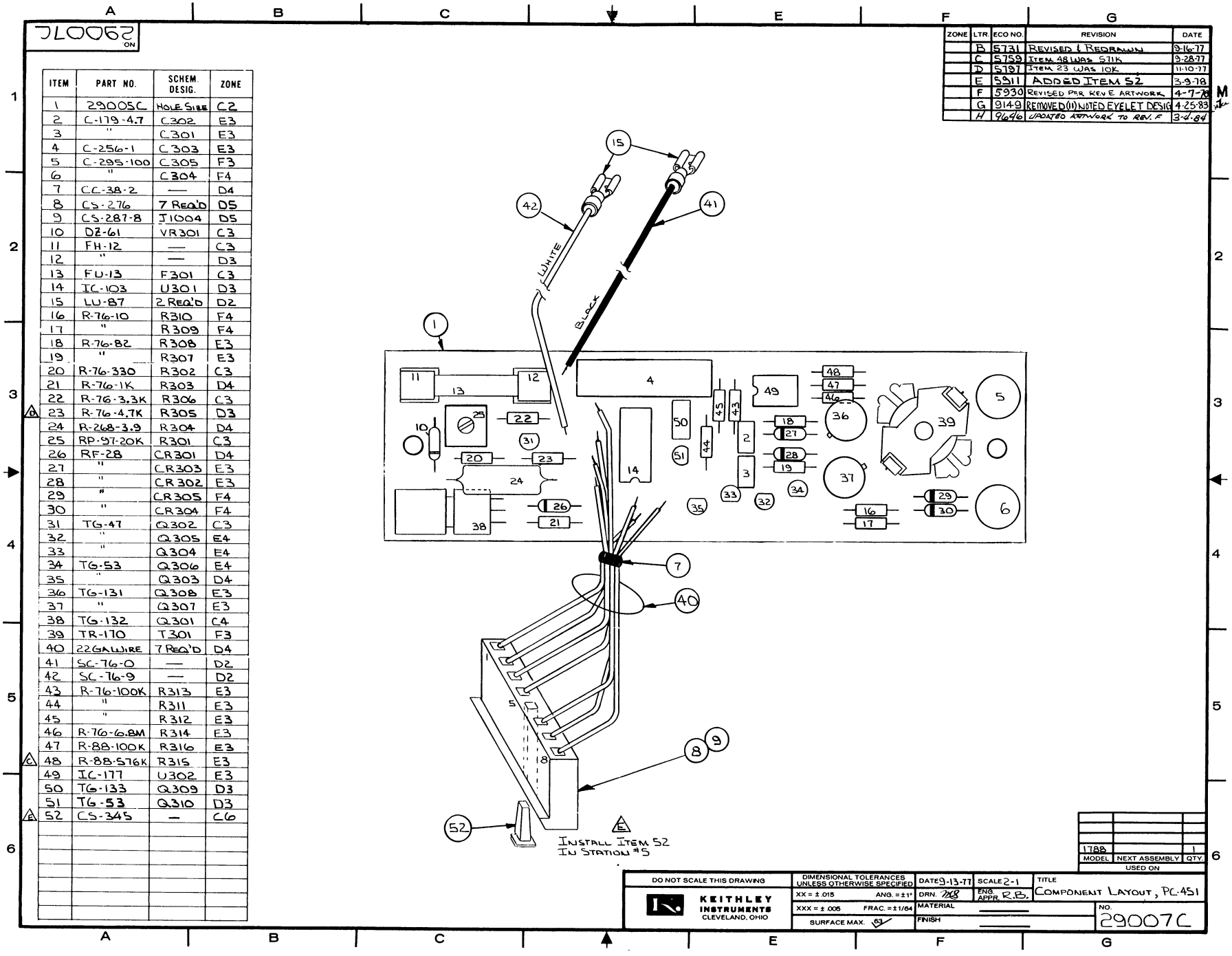


Figure 7-3. Battery Pack Board, Component Location Drawing, Dwg. No. 29007C

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

KEITHLEY

Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

- ❑ Intermittent
- ❑ Analog output follows display
- ❑ Particular range or function bad; specify _____
- ❑ IEEE failure
- ❑ Obvious problem on power-up
- ❑ Batteries and fuses are OK
- ❑ Front panel operational
- ❑ All ranges or functions are bad
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unable to zero
- ❑ Unstable
- ❑ Will not read applied input
- ❑ Overload

- ❑ Calibration only
- ❑ Certificate of calibration required
- ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient temperature? _____°F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group - Quality Instrumentation ... Guaranteed | (888) 88-SOURCE | www.artisantg.com

Artisan Technology Group is an independent supplier of quality pre-owned equipment

Gold-standard solutions

Extend the life of your critical industrial, commercial, and military systems with our superior service and support.

We buy equipment

Planning to upgrade your current equipment? Have surplus equipment taking up shelf space? We'll give it a new home.

Learn more!

Visit us at **artisantg.com** for more info on price quotes, drivers, technical specifications, manuals, and documentation.

Artisan Scientific Corporation dba Artisan Technology Group is not an affiliate, representative, or authorized distributor for any manufacturer listed herein.

We're here to make your life easier. How can we help you today?

(217) 352-9330 | sales@artisantg.com | artisantg.com

ARTISAN® TECHNOLOGY GROUP