FLUKE®
Calibration

5502A

Multi-Product Calibrator

Operators Manual

September 2012

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OPERATOR SAFETY SUMMARY

WARNING

HIGH VOLTAGE

is used in the operation of this equipment

LETHAL VOLTAGE

may be present on the terminals, observe all safety precautions!

To prevent electrical shock hazard, the operator should not electrically contact the output HI or sense HI terminals or circuits connected to these terminals. During operation, lethal voltages of up to 1020 V ac or dc may be present on these terminals.

When the nature of the operation permits, keep one hand away from equipment to reduce the hazard of current flowing through vital organs of the body.

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Introduction

⚠⚠Warning

To prevent possible electrical shock, fire, or personal injury, read all safety Information before you use the Product.

The 5502A Calibrator ("the Product" or "the Calibrator") in Figure 1-1 can be configured to source:

- DC voltage from 0 V to ±1020 V.
- AC voltage from 1 mV to 1020 V, with output from 10 Hz to 500 kHz.
- AC current from 29 µA to 20.5 A, with variable frequency limits.
- DC current from 0 to ±20.5 A.
- Resistance values from a short circuit to 1100 MΩ.
- Capacitance values from 220 pF to 110 mF.
- Simulated output for eight types of Resistance Temperature Detectors (RTDs).
- Simulated output for 11 types of thermocouples.

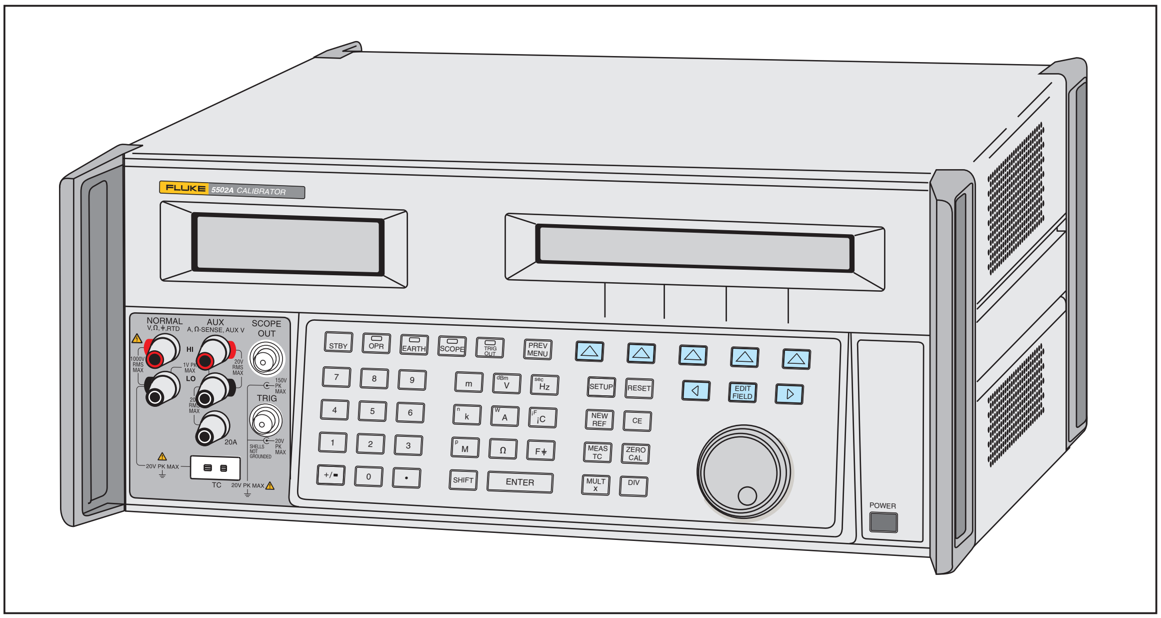

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Figure 1-1. 5502A Multi-Product Calibrator

Calibrator features include:

- Automatic meter error calculation, with reference values that you can select.
- MULT X and DIV ÷ keys that change the output value to predetermined values for various functions.
- Programmable entry limits. These limits do not let you go above preset output limits.
- Voltage and current that can be output at the same time, to an equivalent of 20.9 kW.
- 10 MHz reference input and output. Use this to input a high-accuracy 10 MHz reference to move the frequency accuracy to the 5502A, or to put one or more Calibrators in the control of a master 5502A.
- The power to output two voltages at the same time.
- Extended bandwidth mode outputs multiple waveforms down to 0.01 Hz, and sine

waves to 2 MHz.

- A Standard IEEE-488 (GPIB) interface that complies with ANSI/IEEE Standards 488.1-1987 and 488.2-1987.
- A EIA Standard RS-232 serial data interface to print, show, or move internally stored calibration constants, and for remote control of the 5502A.
- A pass-through RS-232 serial data interface to send data to the Unit Under Test (UUT).

Safety Information

In this manual, A **Warning** identifies conditions and procedures that are dangerous to the user. A **Caution** identifies conditions and procedures that can cause damage to the Product or the equipment under test.

⚠⚠Warning

To prevent possible electrical shock, fire, or personal injury:

- **Use the Product only as specified, or the protection supplied by the Product can be compromised.**
- **Carefully read all instructions.**
- **Do not use the Product around explosive gas, vapor, or in damp or wet environments.**
- **Use this Product indoors only.**
- **Do not touch voltages > 30 V ac rms, 42 V ac peak, or 60 V dc.**
- **Do not use the Product if it operates incorrectly.**
- **Do not use and disable the Product if it is damaged.**
- **Do not use test leads if they are damaged. Examine the test leads for damaged insulation, exposed metal, or if the wear indicator shows. Check test lead continuity.**
- **Use only cables with correct voltage ratings.**
- **Connect the common test lead before the live test lead and remove the live test lead before the common test lead.**
- **Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.**
- **Make sure the ground conductor in the mains power cord is connected to a protective earth ground. Disruption of the protective earth could put voltage on the chassis that could cause death.**

- **Replace the mains power cord if the insulation is damaged or if the insulation shows signs of wear.**
- **Do not connect directly to mains.**
- **Do not use an extension cord or adapter plug.**
- **For safe operation and maintenance of the Product, make sure that the space around the Product meets minimum requirements.**

This Calibrator complies with:

- ANSI/ISA-61010-1 (82.02.01)
- CAN/CSA C22.2 No. 61010-1-04
- ANSI/UL 61010-1:2004
- EN 61010-1:2001
- ANSI/IEEE Standards 488.1-1987 and 488.2-1987.

Symbols used in this manual and on the Product are in Table 1-1.

Table 1-1. Symbols

Symbol	Description	Symbol	Description
CAT I	IEC Measurement Category I – CAT I is for measurements not directly connected to mains. Maximum transient Overvoltage is as specified by terminal markings.	CSA c us	Conforms to relevant North American Safety Standards.
CE	Conforms to European Union directives.	☒	Do not dispose of this product as unsorted municipal waste. Go to the Fluke Calibration website for recycling information.
⚠	Risk of Danger. Important information. See manual.	⚡	Hazardous voltage
⏚	Earth ground	N10140	Conforms to relevant Australian EMC requirements.

Overload Protection

The Calibrator supplies reverse-power protection, fast output disconnection, and/or fuse protection on the output terminals for all functions.

Reverse-power protection prevents damage to the calibrator from occasional, accidental, normal-mode, and common-mode overloads to a maximum of ±300 V peak. It is not intended as protection against frequent (systematic and repeated) abuse. Such abuse will cause the Calibrator to fail.

For volts, ohms, capacitance, and thermocouple functions, there is fast output disconnection protection. This protection senses applied voltages higher than 20 volts on the output terminals. It quickly disconnects the internal circuits from the output terminals and resets the calibrator when such overloads occur.

For current and aux voltage functions, user replaceable fuses supply protection from overloads applied to the Current/Aux Voltage output terminals. The fuses are accessed by an access door on the bottom of the calibrator. You must use replacement fuses of the same rating and type specified in this manual, or the protection supplied by the Calibrator will be compromised.

Operation Overview

The Calibrator can be operated at the front panel or remotely with the RS-232 or IEEE-488 ports. For remote operations, software is available to integrate 5502A operation into a wide variety of calibration requirements.

Local Operation

Typical local operations include front-panel connections to the UUT, and then manual keystroke entries at the front panel to put the Calibrator in the necessary output mode. [MULT X] and [DIV ÷] make it easy to step up or down at the push of a key. You can also examine Calibrator specifications at the push of two buttons. The backlit LCD is easy to read from many different angles and can be read in dim or bright light. The large, easy-to-read keys are color-coded and give tactile feedback.

Remote Operation (RS-232)

There are two rear-panel serial data RS-232 ports: SERIAL 1 FROM HOST, and SERIAL 2 TO UUT (see Figure 1-2). Each port is dedicated to serial-data communications to operate and control the Product during calibration procedures. For complete information on remote operation, see Chapter 5.

The SERIAL 1 FROM HOST serial data port connects a host terminal or personal computer (PC) to the Calibrator. To send commands to the Calibrator: enter commands from a terminal (or a PC running a terminal program), write your own procedures with BASIC, or use optional Windows-based software such as MET/CAL Plus.

The SERIAL 2 TO UUT serial data port connects a UUT to a PC or terminal with the 5502A (see Figure 1-2). This "pass-through" configuration removes the requirement for two COM ports at the PC or terminal. A set of four commands control the operation of the SERIAL 2 TO UUT serial port. See Chapter 6 for a discussion of the UUT_ commands.

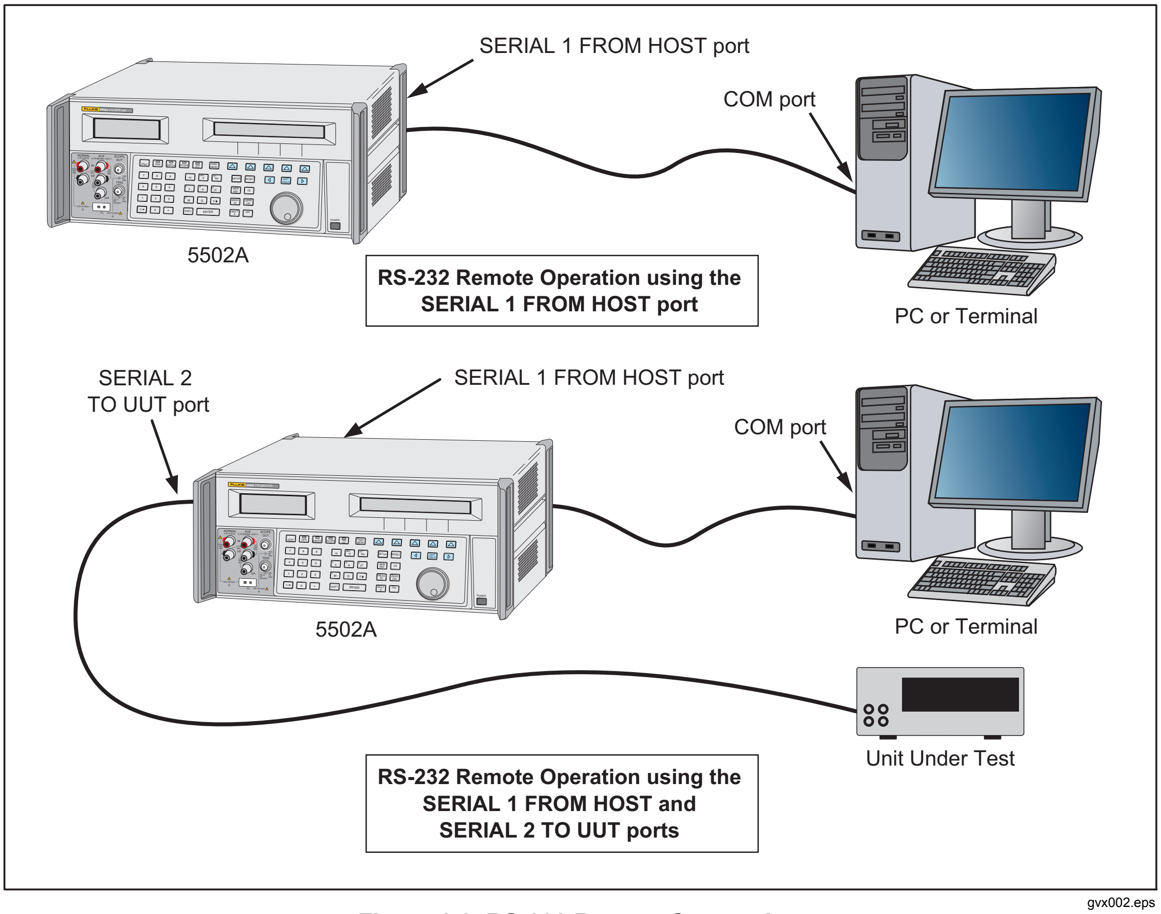

Figure 1-2. RS-232 Remote Connection

Remote Operation (IEEE-488)

The rear-panel IEEE-488 port is a fully programmable parallel interface bus that complies with standard IEEE-488.1 and supplemental standard IEEE-488.2. When the Calibrator is used by remote control of an instrument controller, the Calibrator operates exclusively as a "talker/listener." You can write your own programs with the IEEE-488 command set or run the optional Windows-based MET/CAL Plus software. See Chapter 6 for a discussion of the commands available for IEEE-488 operation.

Instruction Manuals

The 5502A Manual Set includes:

- *5502A Operators Manual* on included CD-ROM (PN 4155227)
- *5502A Getting Started* (PN 4155209)

One of each manual above comes with the instrument. Refer to the Fluke Calibration Catalog or speak to a Fluke Calibration sales representative (see “Contact Fluke Calibration” in this chapter) if more printed copies are necessary. The manuals are also available on the Fluke Calibration website.

5502A Getting Started Manual

The *5502A Getting Started Manual* contains a brief introduction to the 5502A Manual Set, instructions on how to get your calibrator prepared for operation and a complete set of specifications.

5502A Operators Manual

This *5502A Operators Manual* supplies complete information to install the Calibrator and operate it from the front-panel keys and in remote configurations. The manual also has a glossary of calibration, specifications, and error-code information. The Operators Manual includes:

- Installation
- Controls and features, front-panel operation
- Remote operation (IEEE-488 bus or serial port remote control)
- Serial port operation (print, show, or transfer data, and setup for serial port remote control)
- Operator maintenance, with verification and calibration procedures
- Accessories
- SC600 and SC300 oscilloscope calibration options

Contact Fluke Calibration

To contact Fluke Calibration, call one of the following telephone numbers:

- Technical Support USA: 1-877-355-3225
- Calibration/Repair USA: 1-877-355-3225
- Canada: 1-800-36-FLUKE (1-800-363-5853)
- Europe: +31-40-2675-200
- Japan: +81-3-6714-3114
- Singapore: +65-6799-5566
- China: +86-400-810-3435
- Brazil: +55-11-3759-7600
- Anywhere in the world: +1-425-446-6110

To see product information and download the latest manual supplements, visit Fluke Calibration’s website at www.flukecal.com.

To register your product, visit http://flukecal.com/register-product .

Specifications

General Specifications

The following tables list the 5502A specifications. All specifications are valid after allowing a warm-up period of 30 minutes, or twice the time the 5502A has been turned off. (For example, if the 5502A has been turned off for 5 minutes, the warm-up period is 10 minutes.)

All specifications apply for the temperature and time period indicated. For temperatures outside of tcal ±5 °C (tcal is the ambient temperature when the 5502A was calibrated), the temperature coefficient as stated in the General Specifications must be applied.

The specifications also assume the Calibrator is zeroed every seven days or whenever the ambient temperature changes more than 5 °C. The tightest ohms specifications are maintained with a zero cal every 12 hours within ±1 °C of use.

Also see additional specifications later in this chapter for information on extended specifications for ac voltage and current.

Warmup Time .... Twice the time since last warmed up, to a maximum of 30 minutes.

Settling Time .... Less than 5 seconds for all functions and ranges except as noted.

Standard Interfaces .... IEEE-488 (GPIB), RS-232

Temperature

Operating .... 0 °C to 50 °C

Calibration (tcal) .... 15 °C to 35 °C

Storage .... -20 °C to +70 °C; The DC current ranges 0 to 1.09999 A and 1.1 A to 2.99999 A are sensitive to storage temperatures above 50 °C. If the 5502A is stored above 50 °C for greater than 30 minutes, these ranges must be re-calibrated. Otherwise, the 90 day and 1 year uncertainties of these ranges double.

Temperature Coefficient .... Temperature coefficient for temperatures outside of tcal ±5 °C is 10 % of the stated specification per °C.

Relative Humidity

Operating .... <80 % to 30 °C, <70 % to 40 °C, <40 % to 50 °C

Storage .... <95 %, non-condensing. After long periods of storage at high humidity, a drying-out period (with power on) of at least one week may be required.

Altitude

Operating .... 3,050 m (10,000 ft) maximum

Non-operating .... 12,200 m (40,000 ft) maximum

Safety .... Complies with EN/IEC 61010-1:2001, CAN/CSA-C22.2 No. 61010-1-04, ANSI/UL 61010-1:2004;

Output Terminal Electrical Overload Protection Provides reverse-power protection, immediate output disconnection, and/or fuse protection on the output terminals for all functions. This protection is for applied external voltages up to ±300 V peak.

Analog Low Isolation .... 20 V normal operation, 400 V peak transient

EMC .... Complies with EN/IEC 61326-1:2006, EN/IEC 61326-2-1:2006 for controlled EM environments under the following conditions. If used in areas with Electromagnetic fields of 1 to 3 V/m from 0.08-1GHz, resistance outputs have a floor adder of 0.508 Ω Performance not specified above 3 V/m. This instrument may be susceptible to electro-static discharge (ESD) to the binding posts. Good static awareness practices should be followed when handling this and other pieces of electronic equipment. Additionally this instrument may be susceptible to electrical fast transients on the mains terminals. If any disturbances in operation are observed, it is recommended that the rear panel chassis ground terminal be connected to a known good earth ground with a low inductance ground strap. Note that a mains power outlet while providing a suitable ground for protection against electric shock hazard may not provide an adequate ground to properly drain away conducted rf disturbances and may in fact be the source of the disturbance. This instrument was certified for EMC performance with data I/O cables not in excess of 3m.

Line Power .... Line Voltage (selectable): 100 V, 120 V, 220 V, 240 V

Line Frequency: 47 Hz to 63 Hz

Line Voltage Variation: ±10 % about line voltage setting. For optimal performance at full dual outputs (e.g. 1000 V, 20 A) choose a ling voltage setting that is ±7.5 % from nominal.

Power Consumption .... 600 VA

Dimensions (HxWxL) .... 17.8 cm x 43.2 cm x 47.3 cm (7 in x 17 in x 18.6 in) Standard rack width and rack increment, plus 1.5 cm (0.6 in) for feet on bottom of unit.

Weight (without options) .... 22 kg (49 lb)

Absolute Uncertainty Definition .... The 5502A specifications include stability, temperature coefficient, linearity, line and load regulation, and the traceability of the external standards used for calibration. You do not need to add anything to determine the total specification of the 5502A for the temperature range indicated.

Specification Confidence Level .... 99 %

Detailed Specifications

DC Voltage

Range	Absolute Uncertainty, tcal ± 5 °C ±(% of output + µV)		Stability	Resolution (µV)	Max Burden [1]
	90 Day	1 Year	24 hours, ± 1 °C ±(ppm of output + µV)		
0 to 329.9999 mV	0.005 + 3	0.006 + 3	5 + 1	0.1	65 Ω
0 to 3.299999 V	0.004 + 5	0.005 + 5	4 + 3	1	10 mA
0 to 32.99999 V	0.004 + 50	0.005 + 50	4 + 30	10	10 mA
30 to 329.9999 V	0.0045 + 500	0.0055 + 500	4.5 + 300	100	5 mA
100 to 1020.000 V	0.0045 + 1500	0.0055 + 1500	4.5 + 900	1000	5 mA
Auxiliary Output (dual output mode only) [2]					
0 to 329.999 mV	0.03 + 350	0.04 + 350	30 + 100	1	5 mA
0.33 to 3.29999 V	0.03 + 350	0.04 + 350	30 + 100	10	5 mA
3.3 to 7 V	0.03 + 350	0.04 + 350	30 + 100	100	5 mA
TC Simulate and Measure in Linear 10 µV/°C and 1 mV/°C modes [3]					
0 to 329.999 mV	0.005 + 3	0.006 + 3	5 + 1	0.1	10 Ω

[1] Remote sensing is not provided. Output resistance is < 5 mΩ for outputs ≥ 0.33 V. The AUX output has an output resistance of <1 Ω. TC simulation has an output impedance of 10 Ω ± 1 Ω.

[2] Two channels of dc voltage output are provided.

[3] TC simulating and measuring are not specified for operation in electromagnetic fields above 0.4 V/m.

Range	Noise	
	Bandwidth 0.1 Hz to 10 Hz p-p ±(ppm of output + floor in µV)	Bandwidth 10 Hz to 10 kHz rms
0 to 329.9999 mV	0 + 1	6 µV
0 to 3. 3.299999 V	0 + 10	60 µV
0 to 32.99999 V	0 + 100	600 µV
30 to 329.9999 V	10 + 1000	20 mV
100 to 1020.000 V	10 + 5000	20 mV
Auxiliary Output (dual output mode only) [1]		
0 to 329.999 mV	0 + 5 µV	20 µV
0.33 to 3.29999 V	0 + 20 µV	300 µV
3.3 to 7 V	0 + 100 µV	1000 µV

[1] Two channels of dc voltage output are provided.

DC Current

Range	Absolute Uncertainty, tcal ±5 °C ±(% of output +µA)		Resolution	Max Compliance Voltage V	Max Inductive Load mH
	90 Day	1 Year			
0 to 329.999 µA	0.012 + 0.02	0.015 + 0.02	1 nA	10	400
0 to 3.29999 mA	0.010 + 0.05	0.010 + 0.05	0.01 µA	10	
0 to 32.9999 mA	0.008 + 0.25	0.010 + 0.25	0.1 µA	7	
0 to 329.999 mA	0.008 + 3.3	0.010 + 2.5	1 µA	7	
0 to 1.09999 A	0.023 + 44	0.038 + 44	10 µA	6	
1.1 to 2.99999 A	0.030 + 44	0.038 + 44	10 µA	6	
0 to 10.9999 A (20 A Range)	0.038 + 500	0.060 + 500	100 µA	4	
11 to 20.5 A [1]	0.080 + 750 [2]	0.10 + 750 [2]	100 µA	4	

[1] Duty Cycle: Currents <11 A may be provided continuously. For currents >11 A, see Figure 1-3. The current may be provided Formula 60-T-I minutes any 60 minute period where T is the temperature in °C (room temperature is about 23 °C) and I is the output current in amperes. For example, 17 A, at 23 °C could be provided for 60-23-17 = 20 minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents <5 A for the "off" period first.

[2] Floor specification is 1500 µA within 30 seconds of selecting operate. For operating times >30 seconds, the floor specification is 750 µA.

Range	Noise	
	Bandwidth 0.1 Hz to 10 Hz p-p	Bandwidth 10 Hz to 10 kHz rms
0 to 329.999 µA	2 nA	20 nA
0 to 3.29999 mA	20 nA	200 nA
0 to 32.9999 mA	200 nA	2.0 µA
0 to 329.999 mA	2000 nA	20 µA
0 to 2.99999 A	20 µA	1 mA
0 to 20.5 A	200 µA	10 mA

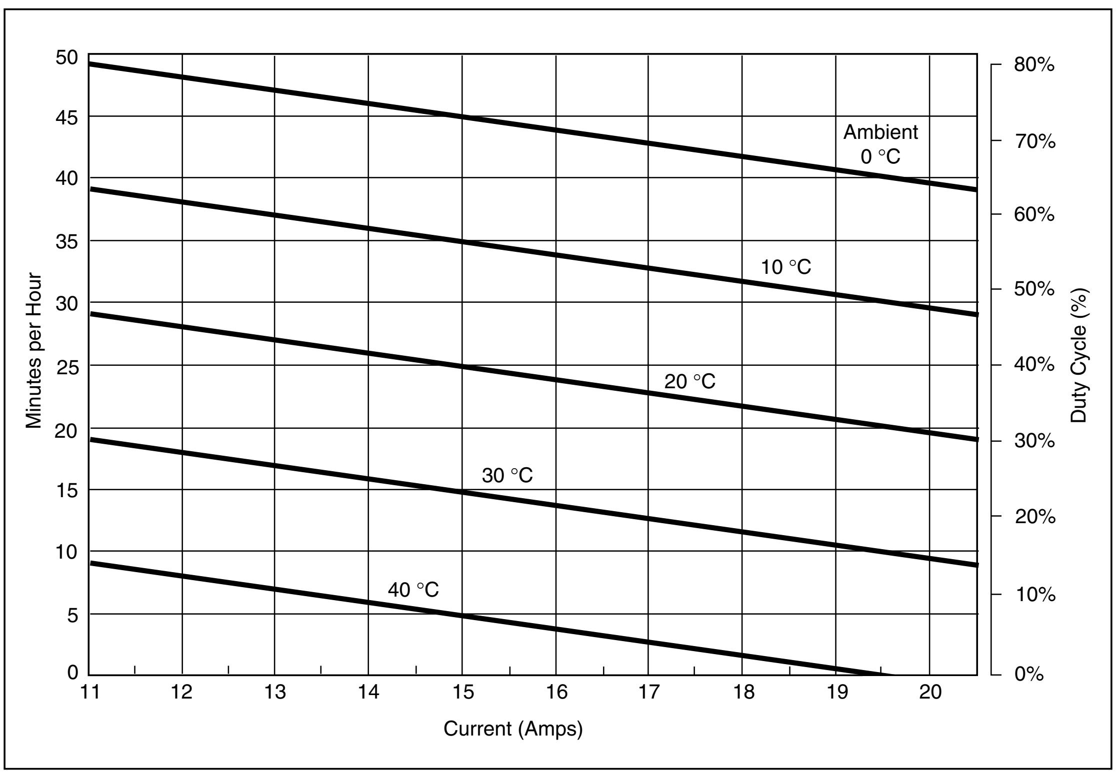

Figure 1-3. Allowable Duration of Current >11 A

Resistance

Range [1]	Absolute Uncertainty, tcal ±5 °C ±(% of output + floor) [2]				Resolution (Ω)	Allowable Current [3] (A)
	% of output		Floor (Ω) Time and temp since ohms zero cal			
	90 Day	1 Year	12 hrs ±1 °C	7 days ±5 °C		
0 to 10.999 Ω	0.009	0.012	0.001	0. 01	0.001	1 mA to 125 mA
11 to 32.999 Ω	0.009	0.012	0.0015	0.015	0.001	1 mA to 125 mA
33 to 109.999 Ω	0.007	0.009	0.0014	0.015	0.001	1 mA to 70 mA
110 to 329.999 Ω	0.007	0.009	0.002	0.02	0.001	1 mA to 40 mA
330 to 1.09999 kΩ	0.007	0.009	0.002	0.02	0.01	1 mA to 18 mA
1.1 to 3.29999 kΩ	0.007	0.009	0.02	0.2	0.01	100 µA to 5 mA
3.3 to 10.9999 kΩ	0.007	0.009	0.02	0.1	0.1	100 µA to 1.8 mA
11 to 32.9999 kΩ	0.007	0.009	0.2	1	0.1	10 µA to .5 mA
33 to 109.999 kΩ	0.008	0.011	0.2	1	1	10 µA to 0.18 mA
110 to 329.999 kΩ	0.009	0.012	2	10	1	1 µA to 50 µA
330 kΩ to 1.09999 MΩ	0.011	0.015	2	10	10	1 µA to 18 µA
1.1 to 3.29999 MΩ	0.011	0.015	30	150	10	250 nA to 5 µA
3.3 to 10.9999 MΩ	0.045	0.06	50	250	100	250 nA to 1.8 µA
11 to 32.9999 MΩ	0.075	0.1	2500	2500	100	25 nA to 500 nA
33 to 109.999 MΩ	0.4	0.5	3000	3000	1000	25 nA to 180 nA
110 to 329.999 MΩ	0.4	0.5	100000	100000	1000	2.5 nA to 50 nA
330 to 1100.00 MΩ	1.2	1.5	500000	500000	10000	1 nA to 13 nA

[1] Continuously variable from 0 Ω to 1.1 GΩ.

[2] Applies for 4-WIRE compensation only. For 2-WIRE and 2-WIRE COMP, add 5 µV per amp of stimulus current to the floor specification. For example, in 2-WIRE mode, at 1 kΩ the floor specification within 12 hours of an ohms zero cal for a measurement current of 1 mA is: 0.002 Ω + 5 µV / 1 mA = (0.002 + 0.005) Ω = 0.007 Ω.

[3] Do not exceed the largest current for each range. For currents lower than shown, the floor adder increases by $Floor_{(new)} = Floor_{(old)} \times I_{min}/I_{actual}$. For example, a 50 µA stimulus measuring 100 Ω has a floor specification of: 0.0014 Ω x 1 mA/50 µA = 0.028 Ω, assuming an ohms zero calibration within 12 hours.

AC Voltage (Sine Wave)

Range	Frequency	Absolute Uncertainty, tcal ±5 °C ±(% of output + μV)		Resolution	Max Burden	Max Distortion and Noise 10 Hz to 5 MHz Bandwidth ±(% of output + floor)
		90 Day	1 Year			
1.0 to 32.999 mV	10 Hz to 45 Hz	0.120 + 20	0.150 + 20	1 μV	65 Ω	0.15 + 90 μV
	45 Hz to 10 kHz	0.080 + 20	0.100 + 20			0.035 + 90 μV
	10 kHz to 20 kHz	0.120 + 20	0.150 + 20			0.06 + 90 μV
	20 kHz to 50 kHz	0.160 + 20	0.200 + 20			0.15 + 90 μV
	50 kHz to 100 kHz	0.300 + 33	0.350 + 33			0.25 + 90 μV
	100 kHz to 500 kHz	0.750 + 60	1.000 + 60			0.3 + 90 μV [1]
33 mV to 329.999 mV	10 Hz to 45 Hz	0.042 + 20	0.050 + 20	1 μV	65 Ω	0.15 + 90 μV
	45 Hz to 10 kHz	0.029 + 20	0.030 + 20			0.035 + 90 μV
	10 kHz to 20 kHz	0.066 + 20	0.070 + 20			0.06 + 90 μV
	20 kHz to 50 kHz	0.086 + 40	0.100 + 40			0.15 + 90 μV
	50 kHz to 100 kHz	0.173 + 170	0.230 + 170			0.2 + 90 μV
	100 kHz to 500 kHz	0.400 + 330	0.500 + 330			0.2 + 90 μV [1]
0.33 V to 3.29999 V	10 Hz to 45 Hz	0.042 + 60	0.050 + 60	10 μV	10 mA	0.15 + 200 μV
	45 Hz to 10 kHz	0.028 + 60	0.030 + 60			0.035 + 200 μV
	10 kHz to 20 kHz	0.059 + 60	0.070 + 60			0.06 + 200 μV
	20 kHz to 50 kHz	0.083 + 60	0.100 + 60			0.15 + 200 μV
	50 kHz to 100 kHz	0.181 + 200	0.230 + 200			0.2 + 200 μV
	100 kHz to 500 kHz	0.417 + 900	0.500 + 900			0.2 + 200 μV [1]
3.3 V to 32.9999 V	10 Hz to 45 Hz	0.042 + 800	0.050 + 800	100 μV	10 mA	0.15 + 2 mV
	45 Hz to 10 kHz	0.025 + 600	0.030 + 600			0.035 + 2 mV
	10 kHz to 20 kHz	0.064 + 600	0.070 + 600			0.08 + 2 mV
	20 kHz to 50 kHz	0.086 + 600	0.100 + 600			0.2 + 2 mV
	50 kHz to 100 kHz	0.192 + 2000	0.230 + 2000			0.5 + 2 mV
33 V to 329.999 V	45 Hz to 1 kHz	0.039 + 3000	0.050 + 3000	1 mV	5 mA, except 20 mA for 45 Hz to 65 Hz	0.15 + 10 mV
	1 kHz to 10 kHz	0.064 + 9000	0.080 + 9000			0.05 +10 mV
	10 kHz to 20 kHz	0.079 + 9000	0.090 + 9000			0.6 + 10 mV
	20 kHz to 50 kHz	0.096 + 9000	0.120 + 9000			0.8 + 10 mV
	50 kHz to 100 kHz	0.192 + 80000	0.240 + 80000			1 + 10 mV
330 V to 1020 V	45 Hz to 1 kHz	0.042 + 20000	0.050 + 20000	10 mV	2 mA, except 20 mA for 45 to 65 Hz	0.15 + 30 mV
	1 kHz to 5 kHz	0.064 + 20000	0.080 + 20000			0.07 + 30 mV
	5 kHz to 10 kHz	0.075 + 20000	0.090 + 20000			0.07 + 30 mV

[1] Max Distortion for 100 kHz to 200 kHz. For 200 kHz to 500 kHz, the maximum distortion is 0.9 % of output + floor as shown.

Note

Remote sensing is not provided. Output resistance is <5 mΩ for outputs ≥0.33 V. The AUX output resistance is <1 Ω. The maximum load capacitance is 500 pF, subject to the maximum burden current limits.

AC Voltage (Sine Wave) (cont.)

AUX (Auxiliary Output) [dual output mode only]						
Range	Frequency [1]	Absolute Uncertainty, tcal ±5 °C ±(% of output + µV)		Resolution	Max Burden	Max Distortion and Noise 10 Hz to 5 MHz Bandwidth ±(% of output + floor)
		90 Day	1 Year			
1.0 to 329.999 mV	10 to 20 Hz	0.15 + 370	0.20 + 370	1 µV	5 mA	0.20 + 200 µV
	20 to 45 Hz	0.08 + 370	0.10 + 370			0.06 + 200 µV
	45 to 1 kHz	0.08 + 370	0.10 + 370			0.08 + 200 µV
	1 to 5 kHz	0.15 + 450	0.20 + 450			0.30 + 200 µV
	5 to 10 kHz	0.30 + 450	0.40 + 450			0.60 + 200 µV
	10 to 30 kHz	4.00 + 900	5.00 + 900			1.00 + 200 µV
0.33 to 3.29999 V	10 to 20 Hz	0.15 + 450	0.20 + 450	10 µV	5 mA	0.20 + 200 µV
	20 to 45 Hz	0.08 + 450	0.10 + 450			0.06 + 200 µV
	45 to 1 kHz	0.07 + 450	0.09 + 450			0.08 + 200 µV
	1 to 5 kHz	0.15 + 1400	0.20 + 1400			0.30 + 200 µV
	5 to 10 kHz	0.30 + 1400	0.40 + 1400			0.60 + 200 µV
	10 to 30 kHz	4.00 + 2800	5.00 + 2800			1.00 + 200 µV
3.3 to 5 V	10 to 20 Hz	0.15 + 450	0.20 + 450	100 µV	5 mA	0.20 + 200 µV
	20 to 45 Hz	0.08 + 450	0.10 + 450			0.06 + 200 µV
	45 to 1 kHz	0.07 + 450	0.09 + 450			0.08 + 200 µV
	1 to 5 kHz	0.15 + 1400	0.20 + 1400			0.30 + 200 µV
	5 to 10 kHz	0.30 + 1400	0.40 + 1400			0.60 + 200 µV

[1] There are two channels of voltage output. The maximum frequency of the dual output is 30 kHz.

Note

Remote sensing is not provided. Output resistance is <5 mΩ for outputs ≥0.33 V. The AUX output resistance is <1 Ω. The maximum load capacitance is 500 pF, subject to the maximum burden current limits.

AC Current (Sine Wave)

Range	Frequency	Absolute Uncertainty, tcal ±5 °C ±(% of output + µA)		Compliance adder ±(µA/V)	Max Distortion and Noise 10 Hz to 100 kHz BW ±(% of output + floor)	Max Inductive Load µH
		90 Day	1 Year			
LCOMP Off						
29 to 329.99 µA	10 to 20 Hz	0.16 + 0.1	0.2 + 0.1	0.05	0.15 + 0.5 µA	200
	20 to 45 Hz	0.12 + 0.1	0.15 + 0.1	0.05	0.10 + 0.5 µA	
	45 Hz to 1 kHz	0.1 + 0.1	0.125 + 0.1	0.05	0.05 + 0.5 µA	
	1 to 5 kHz	0.25 + 0.15	0.3 + 0.15	1.5	0.50 + 0.5 µA	
	5 to 10 kHz	0.6 + 0.2	0.8 + 0.2	1.5	1.00 + 0.5 µA	
	10 to 30 kHz	1.2 + 0.4	1.6 + 0.4	10	1.20 + 0.5 µA	
0.33 to 3.29999 mA	10 to 20 Hz	0.16 + 0.15	0.2 + 0.15	0.05	0.15 + 1.5 µA	200
	20 to 45 Hz	0.1 + 0.15	0.125 + 0.15	0.05	0.06 + 1.5 µA	
	45 Hz to 1 kHz	0.08 + 0.15	0.1 + 0.15	0.05	0.02 + 1.5 µA	
	1 to 5 kHz	0.16 + 0.2	0.2 + 0.2	1.5	0.50 + 1.5 µA	
	5 to 10 kHz	0.4 + 0.3	0.5 + 0.3	1.5	1.00 + 1.5 µA	
	10 to 30 kHz	0.8 + 0.6	1.0 + 0.6	10	1.20 + 0.5 µA	
3.3 to 32.9999 mA	10 to 20 Hz	0.15 + 2	0.18 + 2	0.05	0.15 + 5 µA	50
	20 to 45 Hz	0.075 + 2	0.09 + 2	0.05	0.05 + 5 µA	
	45 Hz to 1 kHz	0.035 + 2	0.04 + 2	0.05	0.07 + 5 µA	
	1 to 5 kHz	0.065 + 2	0.08 + 2	1.5	0.30 + 5 µA	
	5 to 10 kHz	0.16 + 3	0.2 + 3	1.5	0.70 + 5 µA	
	10 to 30 kHz	0.32 + 4	0.4 + 4	10	1.00 + 0.5 µA	
33 to 329.999 mA	10 to 20 Hz	0.15 + 20	0.18 + 20	0.05	0.15 + 50 µA	50
	20 to 45 Hz	0.075 + 20	0.09 + 20	0.05	0.05 + 50 µA	
	45 Hz to 1 kHz	0.035 + 20	0.04 + 20	0.05	0.02 + 50 µA	
	1 to 5 kHz	0.08 + 50	0.10 + 50	1.5	0.03 + 50 µA	
	5 to 10 kHz	0.16 + 100	0.2 + 100	1.5	0.10 + 50 µA	
	10 to 30 kHz	0.32 + 200	0.4 + 200	10	0.60 + 50 µA	
0.33 to 1.09999 A	10 to 45 Hz	0.15 + 100	0.18 + 100		0.20 + 500 µA	2.5
	45 Hz to 1 kHz	0.036 + 100	0.05 + 100		0.07 + 500 µA	
	1 to 5 kHz	0.5 + 1000	0.6 + 1000	[2]	1.00 + 500 µA	
	5 to 10 kHz	2.0 + 5000	2.5 + 5000	[3]	2.00 + 500 µA	
1.1 to 2.99999 A	10 to 45 Hz	0.15 + 100	0.18 + 100		0.20 + 500 µA	2.5
	45 Hz to 1 kHz	0.05 + 100	0.06 + 100		0.07 + 500 µA	
	1 to 5 kHz	0.5 + 1000	0.6 + 1000	[2]	1.00 + 500 µA	
	5 to 10 kHz	2.0 + 5000	2.5 + 5000	[3]	2.00 + 500 µA	
3 to 10.9999 A	45 to 100 Hz	0.05 + 2000	0.06 + 2000		0.2 + 3 mA	1
	100 Hz to 1 kHz	0.08 + 2000	0.10 + 2000		0.1 + 3 mA	
	1 kHz to 5 kHz	2.5 + 2000	3.0 + 2000		0.8 + 3 mA	
11 to 20.5 A [1]	45 to 100 Hz	0.1 + 5000	0.12 + 5000		0.2 + 3 mA	1
	100 Hz to 1 kHz	0.13 + 5000	0.15 + 5000		0.1 + 3 mA	
	1 to 5 kHz	2.5 + 5000	3.0 + 5000		0.8 + 3 mA	

[1] Duty Cycle: Currents <11 A may be provided continuously. For currents >11 A, see Figure 1-3. The current may be provided 60-T-I minutes any 60 minute period where T is the temperature in °C (room temperature is about 23 °C) and I is the output current in amps. For example, 17 A, at 23 °C could be provided for 60-17-23 = 20 minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents <5 A for the "off" period first.

[2] For compliance voltages greater than 1 V, add 1 mA/V to the floor specification from 1 to 5 kHz.

[3] For compliance voltages greater than 1 V, add 5 mA/V to the floor specification from 5 to 10 kHz.

AC Current (Sine Wave) (cont.)

Range	Frequency	Absolute Uncertainty, tcal ±5 °C ±(% of output + µA)		Max Distortion and Noise 10 Hz to 100 kHz BW ±(% of output + floor)	Max Inductive Load
		90 Day	1 Year		
LCOMP On					
29 to 329.99 µA	10 to 100 Hz	0.20 + 0.2	0.25 + 0.2	0.1 + 1.0 µA	400 µH
	100 Hz to 1 kHz	0.50 + 0.5	0.60 + 0.5	0.05 + 1.0 µA	
330 µA to 3.29999 mA	10 to 100 Hz	0.20 + 0.3	0.25 + 0.3	0.15 + 1.5 µA	
	100 Hz to 1 kHz	0.50 + 0.8	0.60 + 0.8	0.06 + 1.5 µA	
3.3 to 32.9999 mA	10 to 100 Hz	0.07 + 4	0.08 + 4	0.15 + 5 µA	
	100 Hz to 1 kHz	0.18 + 10	0.20 + 10	0.05 + 5 µA	
33 to 329.999 mA	10 to 100 Hz	0.07 + 40	0.08 + 40	0.15 + 50 µA	
	100 Hz to 1 kHz	0.18 + 100	0.20 + 100	0.05 + 50 µA	
330 mA to 2.99999 A	10 to 100 Hz	0.10 + 200	0.12 + 200	0.2 + 500 µA	
	100 to 440 Hz	0.25 + 1000	0.30 + 1000	0.25 + 500 µA	
3.3 A to 20.5 A [1]	45 to 100 Hz	0.10 + 2000 [2]	0.12 + 2000 [2]	0.1 + 0 µA	400 µH [4]
	100 to 440 Hz	0.80 + 5000 [3]	1.00 + 5000 [3]	0.5 + 0 µA	

[1] Duty Cycle: Currents <11 A may be provided continuously. For currents >11 A, see Figure 1-3. The current may be provided 60-T-I minutes any 60 minute period where T is the temperature in °C (room temperature is about 23 °C) and I is the output current in amps. For example, 17 A, at 23 °C could be provided for 60-17-23 = 20 minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents <5 A for the "off" period first.

[2] For currents >11 A, Floor specification is 4000 µA within 30 seconds of selecting operate. For operating times >30 seconds, the floor specification is 2000 µA.

[3] For currents >11 A, Floor specification is 1000 µA within 30 seconds of selecting operate. For operating times >30 seconds, the floor specification is 5000 µA.

[4] Subject to compliance voltages limits.

Range	Resolution µA	Max Compliance Voltage V rms [1]
29 to 329.99 µA	0.01	7
0.33 to 3.29999 mA	0.01	7
3.3 to 32.9999 mA	0.1	5
33 to 329.999 mA	1	5
0.33 to 2.99999 A	10	4
3 to 20.5 A	100	3

[1] Subject to specification adder for compliance voltages greater than 1 V rms.

Capacitance

Range	Absolute Uncertainty, tcal ±5 °C ±(% of output + floor) [1] [2] [3]		Resolution	Allowed Frequency or Charge-Discharge Rate		
	90 Day	1 Year		Min and Max to Meet Specification	Typical Max for <0.5 % Error	Typical Max for <1 % Error
220.0 to 399.9 pF	0.38 + 0.01 nF	0.5 + 0.01 nF	0.1 pF	10 Hz to 10 kHz	20 kHz	40 kHz
0.4 to 1.0999 nF	0.38 + 0.01 nF	0.5 + 0.01 nF	0.1 pF	10 Hz to 10 kHz	30 kHz	50 kHz
1.1 to 3.2999 nF	0.38 + 0.01 nF	0.5 + 0.01 nF	0.1 pF	10 Hz to 3 kHz	30 kHz	50 kHz
3.3 to 10.999 nF	0.19 + 0.01 nF	0.25 + 0.01 nF	1 pF	10 Hz to 1 kHz	20 kHz	25 kHz
11 to 32.999 nF	0.19 + 0.1 nF	0.25 + 0.1 nF	1 pF	10 Hz to 1 kHz	8 kHz	10 kHz
33 to 109.99 nF	0.19 + 0.1 nF	0.25 + 0.1 nF	10 pF	10 Hz to 1 kHz	4 kHz	6 kHz
110 to 329.99 nF	0.19 + 0.3 nF	0.25 + 0.3 nF	10 pF	10 Hz to 1 kHz	2.5 kHz	3.5 kHz
0.33 to 1.0999 µF	0.19 + 1 nF	0.25 + 1 nF	100 pF	10 to 600 Hz	1.5 kHz	2 kHz
1.1 to 3.2999 µF	0.19 + 3 nF	0.25 + 3 nF	100 pF	10 to 300 Hz	800 Hz	1 kHz
3.3 to 10.999 µF	0.19 + 10 nF	0.25 + 10 nF	1 nF	10 to 150 Hz	450 Hz	650 Hz
11 to 32.999 µF	0.30 + 30 nF	0.40 + 30 nF	1 nF	10 to 120 Hz	250 Hz	350 Hz
33 to 109.99 µF	0.34 + 100 nF	0.45 + 100 nF	10 nF	10 to 80 Hz	150 Hz	200 Hz
110 to 329.99 µF	0.34 + 300 nF	0.45 + 300 nF	10 nF	0 to 50 Hz	80 Hz	120 Hz
0.33 to 1.0999 mF	0.34 + 1 µF	0.45 + 1 µF	100 nF	0 to 20 Hz	45 Hz	65 Hz
1.1 to 3.2999 mF	0.34 + 3 µF	0.45 + 3 µF	100 nF	0 to 6 Hz	30 Hz	40 Hz
3.3 to 10.999 mF	0.34 + 10 µF	0.45 + 10 µF	1 µF	0 to 2 Hz	15 Hz	20 Hz
11 to 32.999 mF	0.7 + 30 µF	0.75 + 30 µF	1 µF	0 to 0.6 Hz	7.5 Hz	10 Hz
33 to 110.00 mF	1.0 + 100 µF	1.1 + 100 µF	10 µF	0 to 0.2 Hz	3 Hz	5 Hz

[1] The output is continuously variable from 220 pF to 110 mF.

[2] Specifications apply to both dc charge/discharge capacitance meters and ac RCL meters. The maximum allowable peak voltage is 3 V. The maximum allowable peak current is 150 mA, with an rms limitation of 30 mA below 1.1 µF and 100 mA for 1.1 µF and above.

[3] The maximum lead resistance for no additional error in 2-wire COMP mode is 10 Ω.

Temperature Calibration (Thermocouple)

TC Type [1]	Range °C [2]	Absolute Uncertainty Source/Measure tcal ±5 °C ± °C [3]		TC Type [1]	Range °C [2]	Absolute Uncertainty Source/Measure tcal ±5 °C ± °C [3]	
		90 Day	1 Year			90 Day	1 Year
B	600 to 800	0.42	0.44	L	-200 to -100	0.37	0.37
	800 to 1000	0.34	0.34		-100 to 800	0.26	0.26
	1000 to 1550	0.30	0.30		800 to 900	0.17	0.17
	1550 to 1820	0.26	0.33	N	-200 to -100	0.30	0.40
C	0 to 150	0.23	0.30		-100 to -25	0.17	0.22
	150 to 650	0.19	0.26		-25 to 120	0.15	0.19
	650 to 1000	0.23	0.31		120 to 410	0.14	0.18
	1000 to 1800	0.38	0.50		410 to 1300	0.21	0.27
	1800 to 2316	0.63	0.84	R	0 to 250	0.48	0.57
E	-250 to -100	0.38	0.50		250 to 400	0.28	0.35
	-100 to -25	0.12	0.16		400 to 1000	0.26	0.33
	-25 to 350	0.10	0.14		1000 to 1767	0.30	0.40
	350 to 650	0.12	0.16	S	0 to 250	0.47	0.47
	650 to 1000	0.16	0.21		250 to 1000	0.30	0.36
J	-210 to -100	0.20	0.27		1000 to 1400	0.28	0.37
	-100 to -30	0.12	0.16		1400 to 1767	0.34	0.46
	-30 to 150	0.10	0.14	T	-250 to -150	0.48	0.63
	150 to 760	0.13	0.17		-150 to 0	0.18	0.24
	760 to 1200	0.18	0.23		0 to 120	0.12	0.16
K	-200 to -100	0.25	0.33		120 to 400	0.10	0.14
	-100 to -25	0.14	0.18	U	-200 to 0	0.56	0.56
	-25 to 120	0.12	0.16		0 to 600	0.27	0.27
	120 to 1000	0.19	0.26				
	1000 to 1372	0.30	0.40				

[1] Temperature standard ITS-90 or IPTS-68 is selectable.
TC simulating and measuring are not specified for operation in electromagnetic fields above 0.4 V/m.

[2] Resolution is 0.01 °C

[3] Does not include thermocouple error

Temperature Calibration (RTD)

RTD Type	Range °C [1]	Absolute Uncertainty tcal ±5 °C ± °C [2]	
		90 Day	1 Year
Pt 385, 100 Ω	-200 to -80	0.04	0.05
	-80 to 0	0.05	0.05
	0 to 100	0.07	0.07
	100 to 300	0.08	0.09
	300 to 400	0.09	0.10
	400 to 630	0.10	0.12
	630 to 800	0.21	0.23
Pt 3926, 100 Ω	-200 to -80	0.04	0.05
	-80 to 0	0.05	0.05
	0 to 100	0.07	0.07
	100 to 300	0.08	0.09
	300 to 400	0.09	0.10
	400 to 630	0.10	0.12
Pt 3916, 100 Ω	-200 to -190	0.25	0.25
	-190 to -80	0.04	0.04
	-80 to 0	0.05	0.05
	0 to 100	0.06	0.06
	100 to 260	0.06	0.07
	260 to 300	0.07	0.08
	300 to 400	0.08	0.09
	400 to 600	0.08	0.10
	600 to 630	0.21	0.23
Pt 385, 200 Ω	-200 to -80	0.03	0.04
	-80 to 0	0.03	0.04
	0 to 100	0.04	0.04
	100 to 260	0.04	0.05
	260 to 300	0.11	0.12
	300 to 400	0.12	0.13
	400 to 600	0.12	0.14
	600 to 630	0.14	0.16

RTD Type	Range °C [1]	Absolute Uncertainty tcal ±5 °C ± °C [2]	
		90 Day	1 Year
Pt 385, 500 Ω	-200 to -80	0.03	0.04
	-80 to 0	0.04	0.05
	0 to 100	0.05	0.05
	100 to 260	0.06	0.06
	260 to 300	0.07	0.08
	300 to 400	0.07	0.08
	400 to 600	0.08	0.09
	600 to 630	0.09	0.11
Pt 385, 1000 Ω	-200 to -80	0.03	0.03
	-80 to 0	0.03	0.03
	0 to 100	0.03	0.04
	100 to 260	0.04	0.05
	260 to 300	0.05	0.06
	300 to 400	0.05	0.07
	400 to 600	0.06	0.07
	600 to 630	0.22	0.23
PtNi 385, 120 Ω (Ni120)	-80 to 0	0.06	0.08
	0 to 100	0.07	0.08
	100 to 260	0.13	0.14
Cu 427 10 Ω [3]	-100 to 260	0.3	0.3

[1] Resolution is 0.003 °C
[2] Applies for COMP OFF (to the 5502A Calibrator front panel NORMAL terminals) and 2-wire and 4-wire compensation.
[3] Based on MINCO Application Aid No. 18

Phase

1-Year Absolute Uncertainty, tcal ±5 °C, (Δ Φ °)					
Frequency (Hz)					
10 to 65 Hz	65 to 500 Hz	500 Hz to 1 kHz	1 to 5 kHz	5 to 10 kHz	10 to 30 kHz
0.15 °	0.9 °	2 °	6 °	10 °	15 °

Note
See Power and Dual Output Limit Specifications for applicable outputs.

Phase (Φ) Watts	Phase (Φ) VARs	PF	Power Uncertainty Adder due to Phase Error				
			10 to 65 Hz	65 to 500 Hz	500 Hz to 1 kHz	1 to 5 kHz	5 to 10 kHz
			0.00 %	0.01 %	0.06 %	0.55 %	1.52 %
5 °	85 °	0.996	0.02 %	0.15 %	0.37 %	1.46 %	3.04 %
10 °	80 °	0.985	0.05 %	0.29 %	0.68 %	2.39 %	4.58 %
15 °	75 °	0.966	0.07 %	0.43 %	1.00 %	3.35 %	6.17 %
20 °	70 °	0.940	0.10 %	0.58 %	1.33 %	4.35 %	7.84 %
25 °	65 °	0.906	0.12 %	0.74 %	1.69 %	5.42 %	9.62 %
30 °	60 °	0.866	0.15 %	0.92 %	2.08 %	6.58 %	11.54 %
35 °	55 °	0.819	0.18 %	1.11 %	2.50 %	7.87 %	13.68 %
40 °	50 °	0.766	0.22 %	1.33 %	2.99 %	9.32 %	16.09 %
45 °	45 °	0.707	0.26 %	1.58 %	3.55 %	11.00 %	18.88 %
50 °	40 °	0.643	0.31 %	1.88 %	4.22 %	13.01 %	22.21 %
55 °	35 °	0.574	0.37 %	2.26 %	5.05 %	15.48 %	26.32 %
60 °	30 °	0.500	0.45 %	2.73 %	6.11 %	18.65 %	31.60 %
65 °	25 °	0.423	0.56 %	3.38 %	7.55 %	22.96 %	38.76 %
70 °	20 °	0.342	0.72 %	4.33 %	9.65 %	29.27 %	49.23 %
75 °	15 °	0.259	0.98 %	5.87 %	13.09 %	39.56 %	66.33 %
80 °	10 °	0.174	1.49 %	8.92 %	19.85 %	59.83 %	100.00 %
85 °	5 °	0.087	2.99 %	17.97 %	39.95 %		
90 °	0 °	0.000	—	—			

To calculate exact ac watts power adders due to phase uncertainty for values not shown, use the subsequent formula:

$$Adder(\%) = 100(1 - \frac{Cos(\Phi + \Delta\Phi)}{Cos(\Phi)})$$

For example: For a PF of .9205 (Φ = 23) and a phase uncertainty of $\Delta\Phi$ = 0.15, the ac watts power adder is:

$$Adder(\%) = 100(1 - \frac{Cos(23 + .15)}{Cos(23)}) = 0.11\%$$

AC and DC Power Specifications

Power is simulated through the controlled simultaneous outputs of voltage and current from the Calibrator. While the amplitude and frequency ranges of the outputs are broad, there are certain combinations of voltage and current where the specifications are valid. In general these are for all dc voltages and currents, and AC voltages of 30 mV to 1020 V, ac currents from 33 mA to 20.5 A, for frequencies from 10 Hz to 30 kHz. Operation outside of these areas, within the overall calibrator capabilities, is possible, but it is not specified. The table and figure below illustrate the specified areas where power and dual output are possible.

Specification Limits for Power and Dual Output Operation

Frequency	Voltages (NORMAL)	Currents	Voltages (AUX)	Power Factor (PF)
dc	0 to ±1020 V	0 to ±20.5 A	0 to ±7 V	—
10 to 45 Hz	33 mV to 32.9999 V	3.3 mA to 2.99999 A	10 mV to 5 V	0 to 1
45 to 65 Hz	33 mV to 1020 V	3.3 mA to 20.5 A	10 mV to 5 V	0 to 1
65 to 500 Hz	330 mV to 1020 V	33 mA to 2.99999 A	100 mV to 5 V	0 to 1
65 to 500 Hz	3.3 to 1020 V	33 mA to 20.5 A	100 mV to 5 V	0 to 1
500 Hz to 1 kHz	330 mV to 1020 V	33 mA to 20.5 A	100 mV to 5 V	0 to 1
1 to 5 kHz	3.3 to 500 V	33 mA to 2.99999 A	100 mV to 5 V	0 to 1
5 to 10 kHz	3.3 to 250 V	33 to 329.99 mA	1 to 5 V	0 to 1
10 to 30 kHz	3.3 V to 250 V	33 mA to 329.99 mA	1 V to 3.29999 V	0 to 1

Notes

The range of voltages and currents shown in “DC Voltage Specifications,” “DC Current Specifications,” “AC Voltage (Sine Wave) Specifications,” and “AC Current (Sine Wave) Specifications” are available in the power and dual output modes (except minimum current for ac power is 0.33 mA). Only those limits shown in this table and illustrated in the following figure are specified.

See “Calculate Power Uncertainty” to determine the uncertainty at these points.

The phase adjustment range for dual ac outputs is 0 ° to ±179.99 °. The phase resolution for dual ac outputs is 0.01 °.

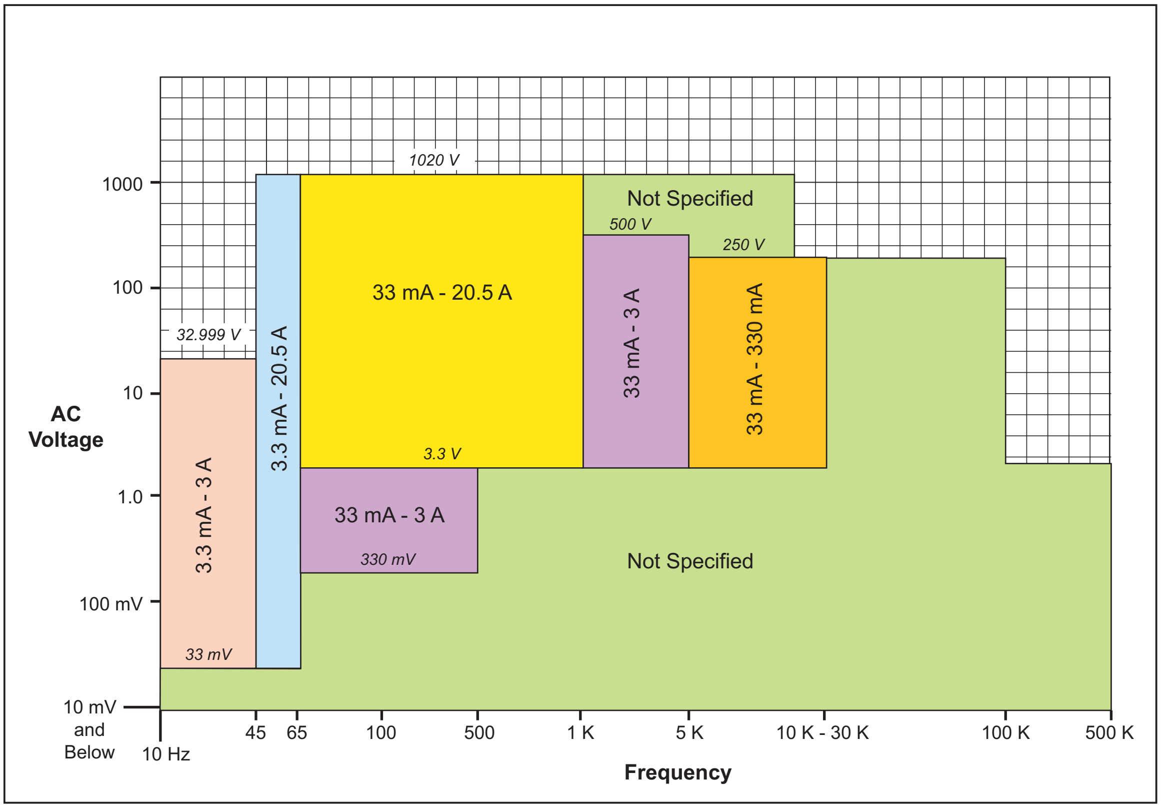

Figure 1-4. Permissible Combinations of AC Voltage and AC Current for Power and Dual Output

Calculate the Uncertainty Specifications of Power and Dual Output Settings

Overall uncertainty for power output in watts (or VARs) is based on the root sum square (rss) of the individual uncertainties in percent for the selected voltage, current, and, if AC power, the phase parameters:

Watts uncertainty $U_{power} = \sqrt{U^2_{Voltage} + U^2_{Current} + U^2_{Phase}}$

VARs uncertainty $U_{VARs} = \sqrt{U^2_{Voltage} + U^2_{Current} + U^2_{Phase}}$

Dual Output uncertainty $U_{Dual} = \sqrt{U^2_{Voltage} + U^2_{AuxVoltage} + U^2_{Phase}}$

Because there are an infinite number of combinations, you must calculate the actual ac power uncertainty for your selected parameters. The results of this method of calculation are shown in the subsequent example. These examples are at various selected calibrator settings (with 1-year specifications):

Examples of Specified Power Uncertainties at Various Output Settings:

Selected Output Settings						Absolute Uncertainty as specified for tcal ±5 °C, ±(% of output setting)			Power Absolute Uncerainty ±(% of Watts)[1]
Voltage Setting (Volts)	Current Setting (Amps)	Frequency Hz	Phase Setting (units of PF)	Phase Setting (Degrees)	Selected Power (Watts)	$U_{Voltage}$	$U_{Current}$	U_{Phase}	U_{Power}
+10.000	+0.500.000	DC	[redacted]	[redacted]	5	0.00550 %	0.04680 %	[redacted]	0.047 %
15.000	+2.0000	DC	[redacted]	[redacted]	30	0.00533 %	0.03220 %	[redacted]	0.033 %
100.000	+20.000	DC	[redacted]	[redacted]	2000	0.00600 %	0.10375 %	[redacted]	0.104 %
1000.00	20.000	DC	[redacted]	[redacted]	20000	0.00565 %	0.10375 %	[redacted]	0.104 %
120.000	1.00000	60	1	0.0	120	0.05250 %	0.06000 %	0.000 %	0.080 %
120.000	1.00000	60	0.766	40.0	91.92	0.05250 %	0.06000 %	0.220 %	0.234 %
240.000	1.00000	50	1	0.0	240	0.05125 %	0.06000 %	0.000 %	0.079 %
240.000	1.00000	50	0.766	40.0	183.84	0.05125 %	0.06000 %	0.220 %	0.234 %
1000.00	20	55	1	0.0	20000	0.05200 %	0.14500 %	0.000 %	0.154 %
1000.00	20	55	0.766	40.0	15320	0.05200 %	0.14500 %	0.220 %	0.269 %
1000.00	20	55	-0.906	-25.0	18120	0.05200 %	0.14500 %	0.122 %	0.196 %
100	0.30	30000	1	0.0	30.0	0.12900 %	0.4667 %	3.407 %	3.442 %
100	0.30	30000	0.766	40.0	22.98	0.12900 %	0.4667 %	25.128 %	25.133 %

[1] Add 0.02 % unless a settling time of 30 seconds is allowed for output currents >10 A or for currents on the highest two current ranges within 30 seconds of an output current >10 A.

Calculate Power Uncertainty

Overall uncertainty for power output in watts (or VARs) is based on the root sum square (RSS) of the individual uncertainties in percent for the selected voltage, current, and phase parameters:

Watts uncertainty $U_{Power} = \sqrt{U^2_{Voltage} + U^2_{Current} + U^2_{Phase}}$

VARs uncertainty $U_{VARs} = \sqrt{U^2_{Voltage} + U^2_{Current} + U^2_{Phase}}$

Because there are an infinite number of combinations, you must calculate the actual ac power uncertainty for your selected parameters. The method of calculation is best shown in the subsequent examples (with 1-year specifications):

<u>**Example 1**</u> Output: 100 V, 1 A, 60 Hz, Power Factor = 1.0 (Φ=0).

Voltage Uncertainty Uncertainty for 100 V at 60 Hz is 0.050 % + 3 mV, totaling: 100 V x .0.0005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = <u>0.053 %</u> (see “AC Voltage (Sine Wave) Specifications”).

Current Uncertainty Uncertainty for 1 A at 60 Hz is 0.05 % +100 µA, totaling: 1 A x 0.0005 = 500 µA added to 100 µA = 0.6 mA. Expressed in percent: 0. 6 mA/1 A x 100 = <u>0.06 %</u> (see “AC Current (Sine Waves) Specifications”).

Phase Uncertainty (Watts) Adder for PF = 1 (Φ=0) at 60 Hz is <u>0 %</u> (see “Phase Specifications”).

Total Power Uncertainty = $U_{power} = \sqrt{0.053^2 + 0.06^2 + 0^2} = 0.080\%$

<u>**Example 2**</u> Output: 100 V, 1 A, 400 Hz, Power Factor = 0.5 (Φ=60)

Voltage Uncertainty Uncertainty for 100 V at 400 Hz is 0.050% + 3 mV, totaling: 100 V x .0.0005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = <u>0.053 %</u> (see “AC Voltage (Sine Wave) Specifications”).

Current Uncertainty Uncertainty for 1 A at 400 Hz is 0.05 % +100 µA, totaling: 1 A x 0.0005 = 500 µA added to 100 µA = 0.6 mA. Expressed in percent: 0. 6 mA/1 A x 100 = <u>0.06 %</u> (see “AC Current (Sine Waves) Specifications”).

Phase Uncertainty (Watts) Adder for PF = 0.5 (Φ=60) at 400 Hz is <u>2.73 %</u> (see “Phase Specifications”).

Total Power Uncertainty = $U_{power} = \sqrt{0.021^2 + 0.06^2 + 2.73^2} = 2.73\%$

VARs When the Power Factor approaches 0.0, the Watts output uncertainty becomes unrealistic because the dominant characteristic is the VARs (volts-amps-reactive) output. In these cases, calculate the Total VARs Output Uncertainty, as shown in example 3:

<u>**Example 3**</u> Output: 100 V, 1 A, 60 Hz, Power Factor = 0.174 (Φ=80)

Voltage Uncertainty Uncertainty for 100 V at 60 Hz is 0.050% + 3 mV, totaling: 100 V x .0.0005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = <u>0.053 %</u> (see “AC Voltage (Sine Wave) Specifications”).

Current Uncertainty Uncertainty for 1 A at 60 Hz is 0.05 % +100 µA, totaling: 1 A x 0.0005 = 500 µA added to 100 µA = 0.6 mA. Expressed in percent: 0. 6 mA/1 A x 100 = <u>0.06 %</u> (see “AC Current (Sine Waves) Specifications”).

Phase Uncertainty (VARs) Adder for Φ=80 at 60 Hz is 0.05 % (see “Phase Specifications”).

Total VARS Uncertainty = $U_{VARs} = \sqrt{0.053^2 + 0.06^2 + 0.05^2} = 0.094\,\%$

Additional Specifications

The subsequent paragraphs provide additional specifications for the 5502A Calibrator ac voltage and ac current functions. These specifications are valid after allowing a warm-up period of 30 minutes, or twice the time the 5502A has been turned off. All extended range specifications are based on performing the internal zero-cal function at weekly intervals, or when the ambient temperature changes by more than 5 °C.

Frequency

Frequency Range	Resolution	1-Year Absolute Uncertainty, tcal ±5 °C ±(ppm + mHz)	Jitter
0.01 to 119.99 Hz	0.01 Hz	25 + 1	2 µs
120.0 to 1199.9 Hz	0.1 Hz	25 + 1	2 µs
1.2 to 11.999 kHz	1 Hz	25 + 1	2 µs
12 to 119.99 kHz	10 Hz	25 + 15	140 ns
120.0 to 1199.9 kHz	100 Hz	25 + 15	140 ns
1.2 to 2.000 MHz	1 kHz	25 + 15	140 ns

Harmonics (2nd to 50th)

Fundamental Frequency [1]	Voltages NORMAL Terminals	Currents	Voltages AUX Terminals	Amplitude Uncertainty
10 to 45 Hz	33 mV to 32.9999 V	3.3 mA to 2.99999 A	10 mV to 5 V	Same % of output as the equivalent single output, but twice the floor adder.
45 to 65 Hz	33 mV to 1020 V	3.3 mA to 20.5 A	10 mV to 5 V	
65 to 500 Hz	33 mV to 1020 V	33 mA to 20.5 A	100 mV to 5 V	
500 Hz to 5 kHz	330 mV to 1020 V	33 mA to 20.5 A	100 mV to 5 V	
5 to 10 kHz	3.3 to 1020 V	33 to 329.9999 mA	100 mV to 5 V	
10 to 30 kHz	3.3 to 1020 V	33 to 329.9999 mA	100 mV to 3.29999 V	

[1] The maximum frequency of the harmonic output is 30 kHz (10 kHz for 3.3 to 5 V on the Aux terminals). For example, if the fundamental output is 5 kHz, the maximum selection is the 6th harmonic (30 kHz). All harmonic frequencies (2nd to 50th) are available for fundamental outputs between 10 Hz and 600 Hz (200 Hz for 3.3 to 5 V on the Aux terminals).

Phase Uncertainty.. Phase uncertainty for harmonic outputs is 1 degree or the phase uncertainty shown in “Phase Specifications” for the particular output, whichever is greater. For example, the phase uncertainty of a 400 Hz fundamental output and 10 kHz harmonic output is 10 ° (from “Phase Specifications”). Another example, the phase uncertainty of a 50 Hz fundamental output and a 400 Hz harmonic output is 1 degree.

Example of determining Amplitude Uncertainty in a Dual Output Harmonic Mode

What are the amplitude uncertainties for the following dual outputs?

NORMAL (Fundamental) Output:

100 V, 100 Hz .... From “AC Voltage (Sine Wave) 90 Day Specifications” the single output specification for 100 V, 100 Hz, is 0.039 % + 3 mV. For the dual output in this example, the specification is 0.039 % + 6 mV as the 0.039 % is the same, and the floor is twice the value (2 x 3 mV).

AUX (50th Harmonic) Output:

100 mV, 5 kHz .... From “AC Voltage (Sine Wave) 90 Day Specifications” the auxiliary output specification for 100 mV, 5 kHz, is 0.15 % + 450 µV. For the dual output in this example, the specification is 0.15 % + 900 µV as the 0.15 % is the same, and the floor is twice the value (2 x 450 µV).

AC Voltage (Sine Wave) Extended Bandwidth

Range	Frequency	1-Year Absolute Uncertainty tcal ±5 °C	Max Voltage Resolution
Normal Channel (Single Output Mode)			
1.0 to 33 mV	0.01 to 9.99 Hz	±(5.0 % of output +0.5 % of range)	Two digits, e.g., 25 mV
34 to 330 mV			Three digits
0.4 to 33 V			Two digits
0.3 to 3.3 V	500.1 kHz to 1 MHz	-10 dB at 1 MHz, typical	Two digits
	1.001 to 2 MHz	-31 dB at 2 MHz, typical	
Auxiliary Output (Dual Output Mode)			
10 to 330 mV	0.01 to 9.99 Hz	±(5.0 % of output +0.5 % of range)	Three digits
0.4 to 5 V			Two digits

AC Voltage (Non-Sine Wave)

Triangle Wave & Truncated Sine Range, p-p [1]	Frequency	1-Year Absolute Uncertainty, tcal ±5 °C, ±(% of output + % of range) [2]	Max Voltage Resolution
Normal Channel (Single Output Mode)			
2.9 to 92.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz [3]	5.0 + 0.5	
93 to 929.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz [3]	5.0 + 0.5	
0.93 to 9.29999 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz [3]	5.0 + 0.5	
9.3 to 93 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz [3]	5.0 + 0.5	
Auxiliary Output (Dual Output Mode)			
29 to 929.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	5.0 + 0.5	
0.93 to 9.29999 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	5.0 + 0.5	
9.3 to 14.0000 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	5.0 + 0.5	

[1] To convert p-p to rms for triangle wave, multiply the p-p value by 0.2886751. To convert p-p to rms for truncated sine wave, multiply the p-p value by 0.2165063.

[2] Uncertainty is stated in p-p. Amplitude is verified using an rms-responding DMM.

[3] Uncertainty for Truncated Sine outputs is typical over this frequency band.

AC Voltage (Non-Sine Wave) (cont.)

Square Wave Range (p-p) [1]	Frequency	1-Year Absolute Uncertainty, tcal ±5 °C, ±(% of output + % of range) [2]	Max Voltage Resolution
Normal Channel (Single Output Mode)			
2.9 to 65.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz	5.0 + 0.5	
66 to 659.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz	5.0 + 0.5	
0.66 to 6.59999 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz	5.0 + 0.5	
6.6 to 66.0000 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 20 kHz	0.5 + 0.25	
	20 to 100 kHz	5.0 + 0.5	
Auxiliary Output (Dual Output Mode)			
29 to 659.999 mV	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz [3]	5.0 + 0.5	
0.66 to 6.59999 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz [3]	5.0 + 0.5	
6.6 to 14.0000 V	0.01 to 10 Hz	5.0 + 0.5	Two digits on each range
	10 to 45 Hz	0.25 + 0.5	Six digits on each range
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz [3]	5.0 + 0.5	

[1] To convert p-p to rms for square wave, multiply the p-p value by 0.5.
[2] Uncertainty is stated in p-p. Amplitude is verified using an rms-responding DMM.
[3] Limited to 1 kHz for Auxiliary outputs ≥6.6 V p-p.

AC Voltage, DC Offset

Range [1] (Normal Channel)	Offset Range [2]	Max Peak Signal	1-Year Absolute Uncertainty, tcal ±5 °C [3] ±(% of dc output + floor)
Sine Waves (rms)			
3.3 to 32.999 mV	0 to 50 mV	80 mV	0.1 + 33 µV
33 to 329.999 mV	0 to 500 mV	800 mV	0.1 + 330 µV
0.33 to 3.29999 V	0 to 5 V	8 V	0.1 + 3300 µV
3.3 to 32.9999 V	0 to 50 V	55 V	0.1 + 33 mV
Triangle Waves and Truncated Sine Waves (p-p)			
9.3 to 92.999 mV	0 to 50 mV	80 mV	0.1 + 93 µV
93 to 929.999 mV	0 to 500 mV	800 mV	0.1 + 930 µV
0.93 to 9.29999 V	0 to 5 V	8 V	0.1 + 9300 µV
9.3 to 93.0000 V	0 to 50 V	55 V	0.1 + 93 mV
Square Waves (p-p)			
6.6 to 65.999 mV	0 to 50 mV	80 mV	0.1 + 66 µV
66 to 659.999 mV	0 to 500 mV	800 mV	0.1 + 660 µV
0.66 to 6.59999 V	0 to 5 V	8 V	0.1 + 6600 µV
6.6 to 66.0000 V	0 to 50 V	55 V	0.1 + 66 mV

[1] Offsets are not allowed on ranges above the highest range shown above.

[2] The maximum offset value is determined by the difference between the peak value of the selected voltage output and the allowable maximum peak signal. For example, a 10 V p-p square wave output has a peak value of 5 V, allowing a maximum offset up to ± 50 V to not exceed the 55 V maximum peak signal. The maximum offset values shown above are for the minimum outputs in each range.

[3] For frequencies 0.01 to 10 Hz, and 500 kHz to 2 MHz, the offset uncertainty is 5 % of output, ±1 % of the offset range.

AC Voltage, Square Wave Characteristics

Risetime @ 1 kHz Typical	Settling Time @ 1 kHz Typical	Overshoot @ 1 kHz Typical	Duty Cycle Range	Duty Cycle Uncertainty
<1 µs	<10 µs to 1 % of final value	<2 %	1 % to 99 % <3.3 V p-p. 0,01 Hz to 100 kHz	±(0.02 % of period + 100 ns), 50 % duty cycle ±(0.05 % of period + 100 ns), other duty cycles from 10 % to 90 %

AC Voltage, Triangle Wave Characteristics (typical)

Linearity to 1 kHz	Aberrations
0.3 % of p-p value, from 10 % to 90 % point	<1 % of p-p value, with amplitude >50 % of range

AC Current (Non-Sine Wave)

Triangle Wave & Truncated Sine Wave Range p-p	Frequency	1-Year Absolute Uncertainty tcal ±5 °C ±(% of output + % of range)	Max Current Resolution
0.047 to 0.92999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
0.93 to 9.29999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
9.3 to 92.9999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
93 to 929.999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.5	
	1 to 10 kHz	10 + 2	
0.93 to 8.49999 A [2]	10 to 45 Hz	0.5 + 1.0	Six digits
	45 Hz to 1 kHz	0.5 + 0.5	
	1 to 10 kHz	10 + 2	
8.5 to 57 A [2]	45 to 500 Hz	0.5 + 0.5	
	500 Hz to 1 kHz	1.0 + 1.0	

[1] Frequency limited to 1 kHz with LCOMP on.
[2] Frequency limited to 440 Hz with LCOMP on.

AC Current (Non-Sine Wave) (cont.)

Square Wave Range p-p	Frequency	1-Year Absolute Uncertainty tcal ±5 °C ±(% of output + % of range)	Max Current Resolution
0.047 to 0.65999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
0.66 to 6.59999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
6.6 to 65.9999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.25	
	1 to 10 kHz	10 + 2	
66 to 659.999 mA [1]	10 to 45 Hz	0.25 + 0.5	Six digits
	45 Hz to 1 kHz	0.25 + 0.5	
	1 to 10 kHz	10 + 2	
0.66 to 5.99999 A [2]	10 to 45 Hz	0.5 + 1.0	
	45 Hz to 1 kHz	0.5 + 0.5	
	1 to 10 kHz	10 + 2	
6 to 41 A [2]	45 to 500 Hz	0.5 + 0.5	
	500 Hz to 1 kHz	1.0 + 1.0	

[1] Frequency limited to 1 kHz with LCOMP on.
[2] Frequency limited to 440 Hz with LCOMP on.

AC Current, Square Wave Characteristics (typical)

Range	LCOMP	Risetime	Settling Time	Overshoot
I <6 A @ 400 Hz	off	25 µs	40 µs to 1 % of final value	<10 % for <1 V Compliance
3 A & 20 A Ranges	on	100 µs	200 µs to 1 % of final value	<10 % for <1 V Compliance

AC Current, Triangle Wave Characteristics (typical)

Linearity to 400 Hz	Aberrations
0.3 % of p-p value, from 10 % to 90 % point	<1 % of p-p value, with amplitude >50 % of range

Chapter 2
Prepare for Operation

Title	Page

Introduction

This chapter has instructions to unpack and install the Calibrator, select the line voltage, replace the fuse, and connect to line power. Instructions for cable connections other than line power are in these chapters:

- UUT (Unit Under Test) connections: Chapter 4, “Front Panel Operation”
- IEEE-488 parallel interface connection: Chapter 5, “Remote Operation”
- RS-232 serial interface connection: Chapter 5, “Remote Operation”

⚠⚠Warning

To prevent possible electrical shock, fire, or personal injury:

- **Properly terminate the sense leads to prevent exposure to hazardous voltages on the sense terminals. The voltage sense terminals are at output voltage when the two-wire function is set.**
- **Do not touch exposed metal on banana plugs, they can have voltages that could cause death.**
- **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.**
- **Make sure that the Product is grounded before use.**

Unpack and Inspection

The calibrator is shipped in a container to prevent damage. Examine the calibrator carefully for damage and immediately report damage to the shipper. Instructions for inspection and claims are included in the shipping container.

When you unpack the calibrator, make sure that you have all the standard equipment in Table 2-1. Examine the shipping list to make sure other items that you purchased are included. Refer to the “Accessories” section in Chapter 8 for more information. Report missing items to the point of purchase or to the nearest Fluke Calibration Service Center (see “Contact Fluke Calibration” in Chapter 1). A performance test is in the “Maintenance” section of Chapter 7.

If you ship the calibrator to Fluke Calibration, use the initial container. If it is not available, you can get a new container from Fluke Calibration with the Calibrator model and serial number.

Table 2-1. Standard Equipment

Item	Model or Part Number
Calibrator	5502A
Mains Power Cord	See Table 2-2 and Figure 2-2
5502A Getting Started Manual	4155209
5502A Operators Manual on CD-ROM	4155227

Select Line Voltage

The calibrator comes from the factory configured for the line voltage typically applicable for the country of purchase, or as specified at the time of your purchase order. You can operate the Calibrator from one of four line-voltage settings: 100 V, 120 V, 200 V, and 240 V (47 Hz to 63 Hz). To verify the line-voltage setting, note the voltage setting that you can see through the window in the power-line fuse compartment cover (Figure 2-1). The permitted line-voltage variation is 10 % above or below the line-voltage setting.

To change the line-voltage setting, complete the following procedure:

1. **Disconnect line power**.
2. To open the fuse compartment, put a screwdriver blade in the tab on the left side of the compartment and pry until it can be removed.
3. To remove the line-voltage selector assembly, hold the line-voltage indicator tab with pliers and pull it straight out of its connector.
4. Turn the line-voltage selector assembly to the necessary voltage and reinsert.
5. Make sure to use the correct fuse for the selected line voltage (100 V/120 V, use 5 A/250 V slow blow, 220 V/240 V, use 2.5 A/250 V slow blow). To install the fuse compartment, push it into position until the tab locks.

Connect to Line Power

⚠⚠Warning

To prevent possible electrical shock, fire, or personal injury:

- **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.**
- **Do not use an extension cord or adapter plug.**

Make sure that the Product is grounded before use. The calibrator is shipped with the correct line-power plug for the country of purchase. If it is necessary to use a different type, refer to Table 2-2 and Figure 2-2 for a list and illustration of the line-power plug types available from Fluke Calibration.

After you make sure that the line voltage selection is set correctly and that the correct fuse for that line voltage is installed, connect the calibrator to a correctly-grounded three-prong outlet.

Select Line Frequency

The calibrator is shipped from the factory for nominal operation at 60 Hz line frequency. If you use 50 Hz line voltage, re-configure the Calibrator for optimal performance at 50 Hz. To do this:

1. From the front panel, go into SETUP, INSTMT SETUP, OTHER SETUP.
2. Push the softkey below MAINS to change the selection to 50 Hz.
3. Store the change.

After a correct instrument warmup (on for 30 minutes or longer), you must zero the complete instrument again. See the section on “Zero the Calibrator” in Chapter 4.

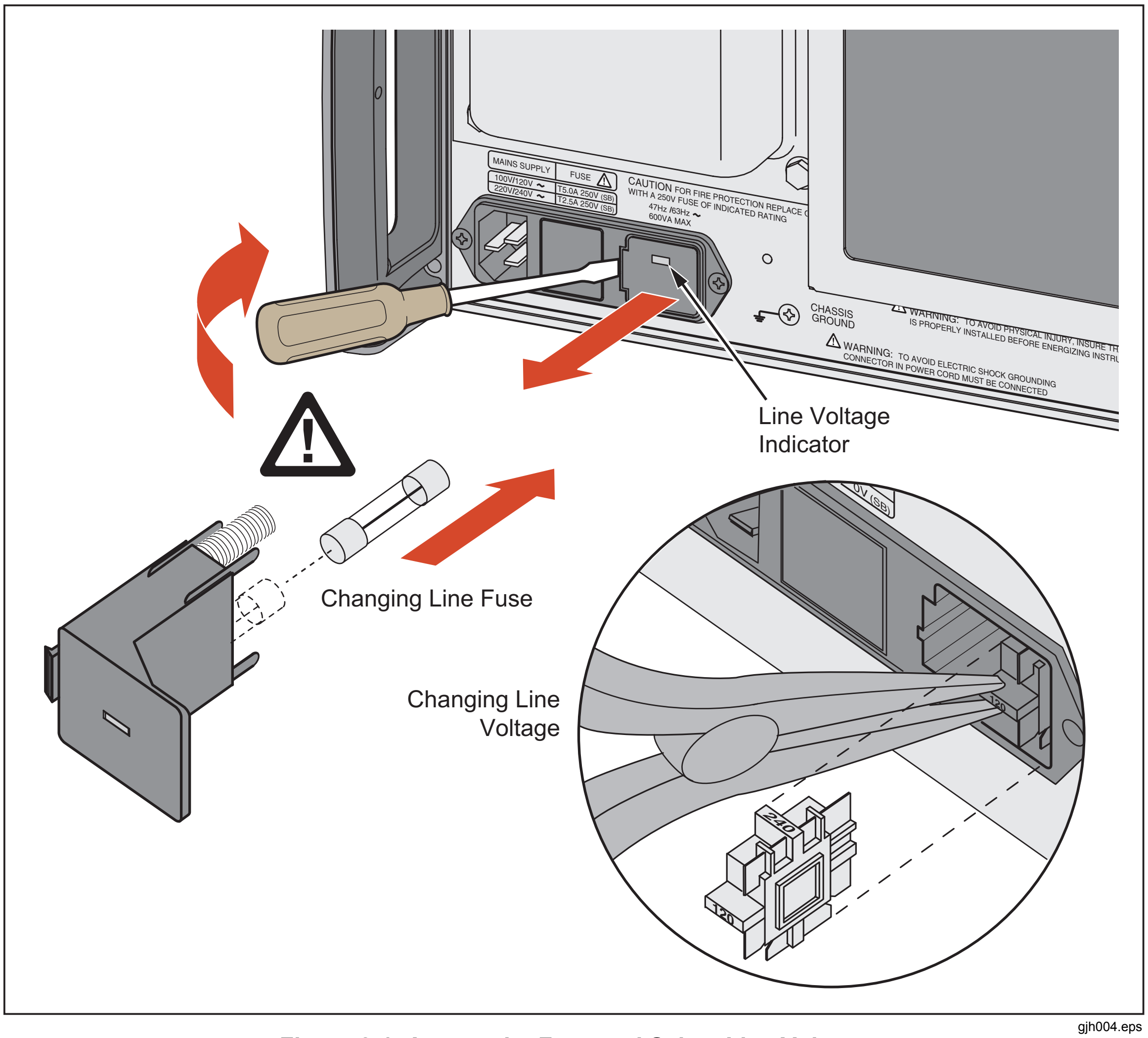

Figure 2-1. Access the Fuse and Select Line Voltage

Table 2-2. Mains-Power Cord Types Available from Fluke Calibration

Type	Voltage/Current	Fluke Calibration Option Number
North America	120 V/15 A	LC-1
North America	240 V/15 A	LC-2
Universal Euro	220 V/15 A	LC-3
United Kingdom	240 V/13 A	LC-4
Switzerland	220 V/10 A	LC-5
Australia	240 V/10 A	LC-6
South Africa	240 V/5 A	LC-7

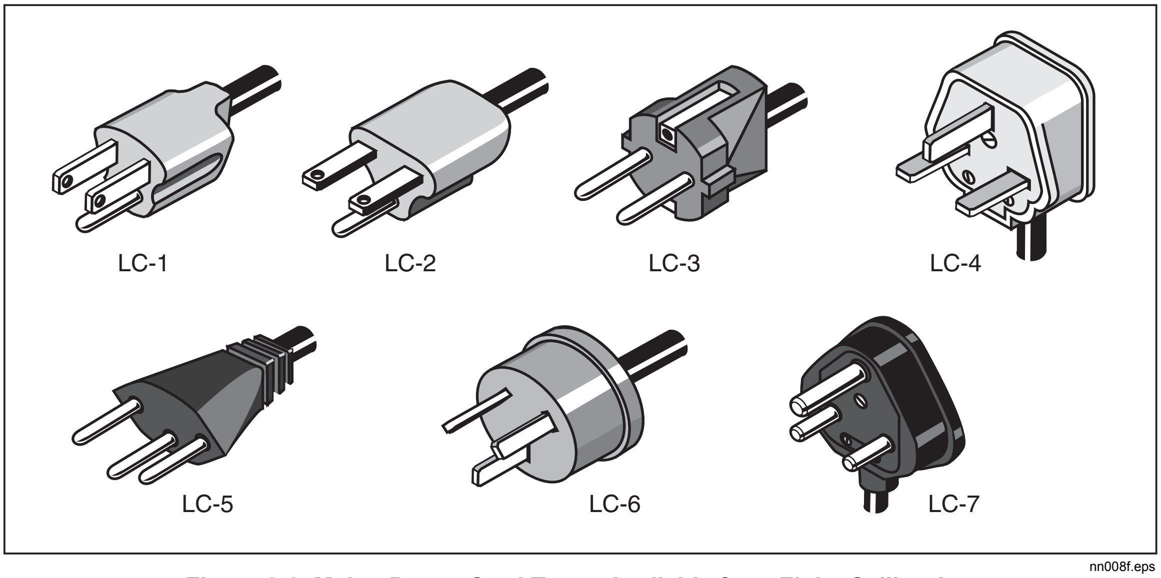

Figure 2-2. Mains-Power Cord Types Available from Fluke Calibration

Placement

You can put the Product on a bench top or install it in a standard-width 24 inch (61 cm) depth equipment rack. For bench-top use, the Calibrator has a non-slip feet. To install the Calibrator in an equipment rack, use the 5502A Rack-Mount Kit, Model Y5537. Instructions to install the Calibrator into a rack come with the kit.

Airflow Considerations

⚠⚠ Warning

For safe operation and maintenance of the Product, make sure that the space around the Product meets minimum requirements.

Baffles put cool air from the fan into the chassis to internally dissipate heat when the Calibrator is in operation. The accuracy and dependability of all internal parts of the calibrator are enhanced by a cool internal temperature. You can increase the life of the Calibrator and enhance its performance by these rules:

- The area around the air filter must be a minimum 3 inches from close walls or rack enclosures.
- The exhaust perforations on the sides of the Calibrator must be clear of blockage.
- The air that gets to the Calibrator must be at room temperature. Make sure the exhaust air from other instruments does not enter into the fan inlet.
- Clean the air filter after 30 days or more frequently if the calibrator is operated in a dusty environment. (See the “Maintenance” chapter for instructions to clean the air filter.)

Chapter 3
Features

Title	Page

Introduction

Refer to this chapter for the functions and locations of the 5502A Calibrator front and rear-panel features. Please read this information before you use the Calibrator. See the “Front-Panel Operation” section of Chapter 4 for front-panel operation instructions. For remote-operation instructions, see the “Remote Operation” section of Chapter 5.

Front-Panel Features

Front-panel features (including all controls, displays, indicators, and terminals) are shown in Figure 3-1. Each front-panel feature is given in Table 3-1.

Rear-Panel Features

Rear-panel features (including all terminals, sockets, and connectors) are shown in Figure 3-2. Each rear-panel feature is given in Table 3-2.

Softkey Menu Trees

The Setup softkeys are identified in Figures 3-3 and 3-4. The Setup softkeys go with the Calibrator front-panel SETUP key. The functions of the five softkeys are identified by name information shown directly above each key. The softkey names change during operation so you can quickly access many different functions.

A group of softkey names is a menu. A group of connected menus is a menu tree. Figure 3-3 shows the SETUP menu tree structure. Figure 3-4 tells you about each SETUP menu tree display. Table 3-3 shows the factory-default parameters for the SETUP menu tree. To change the SETUP menus to their default values, use the softkey SETUP in the Format NV Memory menu (see Figure 3-4, menu F).

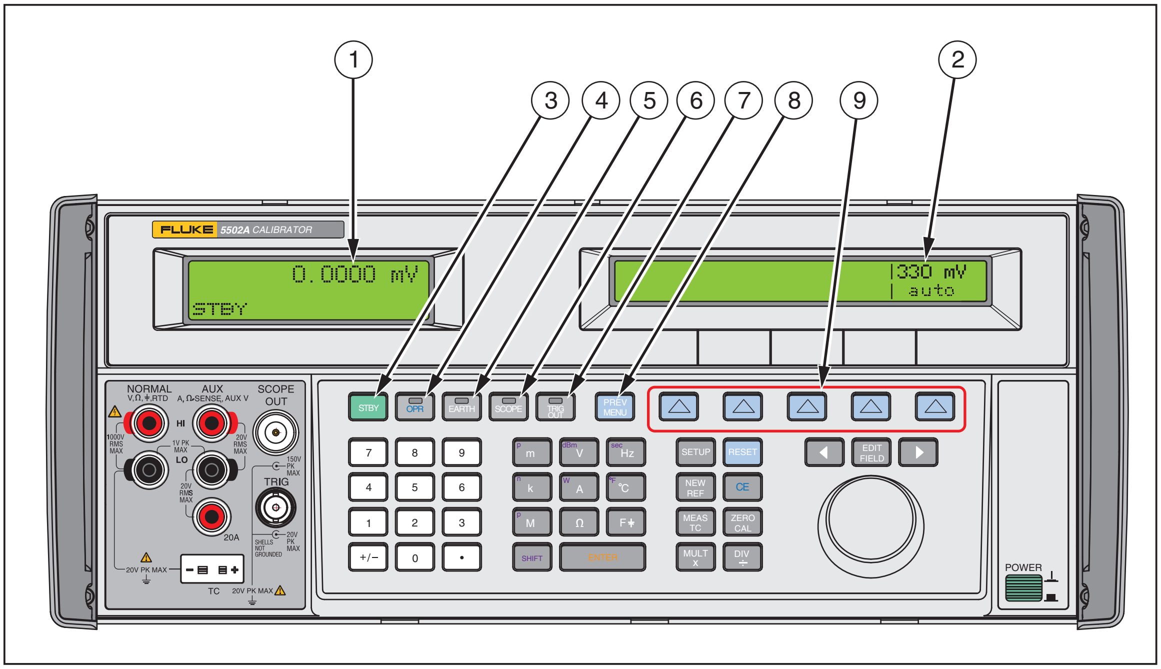

Figure 3-1. Front-Panel Features

Table 3-1. Front-Panel Features

(1) **Output Display**

The **Output Display** is a two-line backlit LCD that shows output amplitudes, frequency, and calibrator status. Output values (or potential output values if in standby) are shown with a maximum of seven digits plus a polarity sign. Output frequencies (or potential output frequencies if the Calibrator is in standby) are shown with four digits. Calibrator status is shown by these abbreviations:

OPR	Shown when an output is active at the front panel terminals.
STBY	Shown when the Calibrator is in standby.
u	When you change the output, “u” (unsettled) is shown until the output moves in to the specified accuracy.
m	Shown while the Calibrator measures. (Thermocouple and impedance measurement only.)
?	Shown when the amplitude is specified as typical only, and/or decreased resolution. This occurs when you operate the Calibrator in extended-bandwidth mode.
C	Shown when the amplitude is specified as typical only, and/or decreased resolution. This occurs when you operate the Calibrator in extended-bandwidth mode.

(2) **Control Display**

The **Control Display** is a multipurpose backlit LCD used to show data entries, UUT error adjustments, softkey names, phase angles, watts, power factors, and other prompts and messages. When there is not room on the Output Display, output frequency is shown on the Control Display. Softkey names tell you the function of the softkey directly below them. Groups of softkey names together make a menu. The menus give access to many different functions with the five softkeys plus the PREV MENU key. (See Figure3-3, Softkey Menu Tree.)

③ STBY

The **STBY** (Standby) key puts the Calibrator in standby mode. Standby mode is shown by "STBY" in the lower left corner of the Output Display. In standby mode, the **NORMAL**, **AUX** and **20A** output terminals are internally disconnected from the Calibrator. The Calibrator starts in standby mode. The Calibrator automatically changes to standby if:

- RESET is pushed.
- A voltage ≥33 V is selected when the previous output voltage was <33 V.
- The output function changes. When you change from ac or dc voltage <33 V, the Calibrator does not change to STBY.
- A current output more than 3 A is selected. This is when the output location changes to the **20A** terminal.
- An overload condition is sensed.

④ OPR

The **OPR** (Operate) key puts the Calibrator in operate mode. Operate mode is shown by "OPR" in the lower left corner of the Output Display and the illuminated indicator on OPR.

⑤ EARTH

The **EARTH** (Earth Ground) key opens and closes an internal connection from the NORMAL LO terminal to earth ground. An indicator on the key shows when this connection is made. The power-up default condition is earth disabled (indicator off).

⑥ SCOPE

The **SCOPE** (Oscilloscope) key starts or stops an oscilloscope calibration option (if it is installed). An indicator on the key shows when the option is active. If an oscilloscope calibration option is not installed in the Calibrator and the **SCOPE** key is pushed, the calibrator shows an error message.

⑦ TRIG OUT

The **TRIG OUT** (Trigger Out) key sets the external trigger when in the scope mode. An indicator on the key shows when external trigger output is active. If the Calibrator is not in scope mode when TRIG OUT is pushed, the beeper will sound.

⑧ PREV MENU

The **PREV MENU** (Previous Menu) key recalls the previous set of menu selections. Each push of this key retreats up one level of the menu tree until the display shows the top-level menu selection of the function selected.

⑨ **Softkeys**

The functions of the five unlabeled blue softkeys are shown by names on the Control Display above each key. The functions change when in operation so that many different functions can be accessed with these keys. A group of softkey names is a menu. A group of connected menus is called a menu tree.

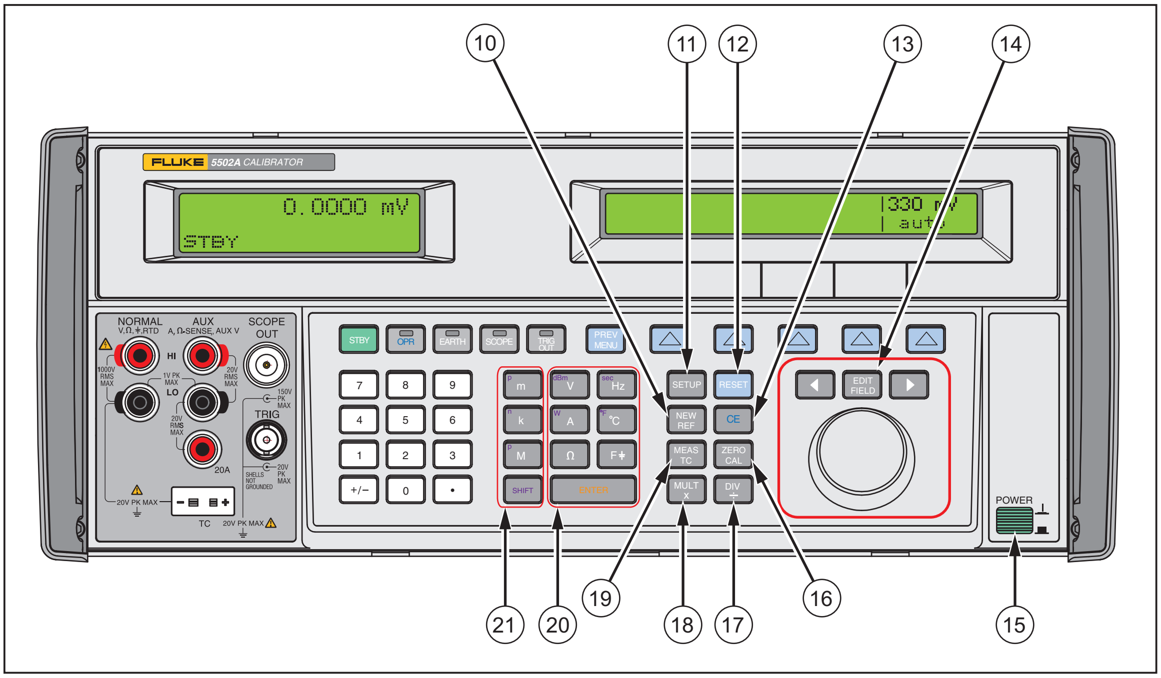

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Figure 3-1. Front-Panel Features (cont.)

Table 3-1. Front-Panel Features (cont.)

(10)	NEW REF The **NEW REF** (New Reference) key is active when error mode is in operation, and sets the current output value as a new reference for meter error computation.
(11)	SETUP The **SETUP** (Setup Menu) key puts the Calibrator into setup mode. The setup menu is shown in the Control Display. Choose Setup options with the softkeys below the Control Display.
(12)	RESET The **RESET** (Reset Calibrator) key aborts the Calibrators current operation and changes it to the power-up default condition, except when it is used by remote control.
(13)	CE The **CE** (Clear Entry) key clears a partially-completed keypad entry from the Control Display. If there is a partially-completed entry when CE is pushed, the output is unaffected.
(14)	◀ EDIT FIELD ▶ The **EDIT FIELD** (Edit Output Display Field) key and its left/right arrow keys provide step adjustment of the output signals. If any of these keys are pushed or the knob is rotated, a digit on the Output Display is highlighted and the output increments or decrements as the knob is rotated. If a digit goes past 0 or 9, the digit to its left or right is carried. An error shows on the Control Display. The difference between the original (reference) output and the new output is shown. The ◀ and ▶ keys adjust the magnitude of changes by moving the highlighted digit. EDIT FIELD lets you move from voltage or current to frequency and back. In practice, for voltage and current outputs, the knob and arrow keys are used to adjust output until the UUT reads correctly. The error display then shows the UUT deviation from the reference.

(15) The power switch turns on and off Calibrator power. The switch is a latching push-push type. When the switch is latched in, Calibrator power is on.

(16) [ZERO CAL]

The **ZERO CAL** key lets you do an ohms zero or a full-zero calibration.

(17) [DIV ÷]

The **DIV** (Divide) key immediately changes the output to 1/10th reference value (not necessarily the present output value) if the value is in performance limits. In the SCOPE mode, [DIV ÷] changes the output to the next lower range.

(18) [MULT X]

The **MULT** (Multiply) key immediately changes the output to 10X the reference value (not necessarily the present output value) if the value is in performance limits. This key sets the Calibrator to standby if this change is from <33 V. In the SCOPE mode, [MULT X] changes the output to the next higher range.

(19) [MEAS TC]

The **MEAS TC** (Measure Thermocouple) key starts the TC (Thermocouple) input connection and makes the Calibrator calculate a temperature derived from the voltage that is at the input.

(20) **Output Units Keys**

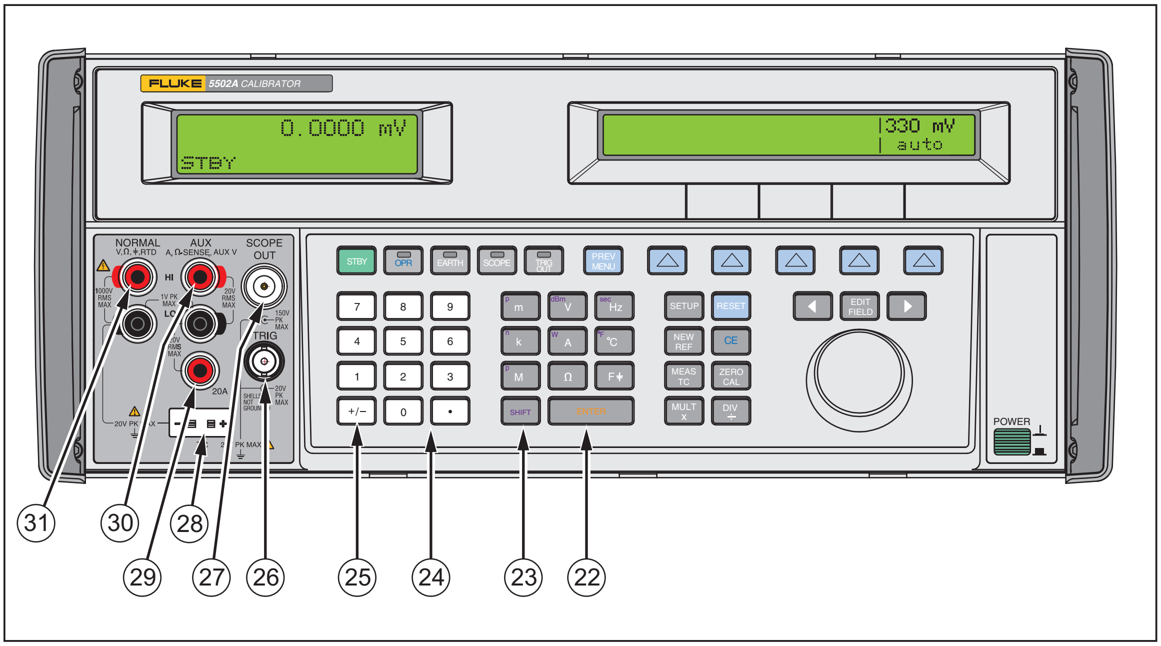
The output units keys choose the function of the Calibrator. Some keys have a secondary unit if [SHIFT] is pushed just before the units key. The output units are:

[dBm V]	Voltage or Decibels relative to 1 mW into 600 Ω (impedance changeable).
[W A]	Watts or Current
[Ω]	Resistance
[sec Hz]	Frequency or Seconds (seconds applies to the SCOPE functions only)
[F ⊣⊢]	Capacitance
[°F °C]	Temperature in Fahrenheit or Celsius

(21) **Multiplier Keys**

Select output value multipliers. Some keys have a secondary function if [SHIFT] is pushed just before the multiplier key. For example, if you record 33, then push [SHIFT], then [μ m], then [F ⊣⊢], and then [ENTER], the Calibrator output value is 33 μF. The multiplier keys are:

[μ m]	milli (10^{-3} or 0.001) or micro (10^{-6} or 0.000001)
[n k]	kilo (10^{3} or 1,000) or nano (10^{-9} or 0.000000001)
[p M]	mega (10^{6} or 1,000,000) or pico (10^{-12} or 0.000000000001)



gvx010.eps

Figure 3-1. Front-Panel Features (cont.)

Table 3-1. Front-Panel Features (cont.)

(22)	ENTER The **ENTER** key loads a newly-entered output value, shown on the Control Display, into the Calibrator, which shows on the Output Display. The new value can come from the numeric keypad. If you push ENTER without identifying the units for the entry, in most cases the Calibrator keeps the units that were last used. This lets you, for example, enter 1 mV, and then later enter 10 to get 10 V. (The "V" units were saved from the last entry, but not the multiplier, "m".) In the error (edit) mode, ENTER with no value puts the output to the value of the reference.
(23)	SHIFT The **SHIFT** key selects an alternative function of the units key and alternative multipliers of the multiplier keys. These alternative selections are named with small letters in the upper-left hand corner of the keys.
(24)	**Numeric Keypad** Use to record the digits of the output amplitude and frequency. The correct sequence to record a value is to push the digits of the output value, a multiplier key (if necessary), an output units key, and then ENTER. For example, to obtain an output of 20 mV, you would push this sequence of keys: 2 0 μ m dBm V. Push OPR to enable the output. If you push a digit key once the entry field is full, or push the decimal point key more than once in a single number, the beeper will sound.
(25)	+/- The +/- (Polarity) key changes the polarity of the output for dc voltage or dc current functions. Push the +/- key and then ENTER to toggle the output polarity.
(26)	The **SCOPE TRIG** (Scope Trigger) BNC connector is used to trigger the oscilloscope during oscilloscope calibration. This is active only when an oscilloscope option is installed.
(27)	The **SCOPE OUT** (Oscilloscope) A BNC connector is used for outputs during oscilloscope calibration. This is active only when an oscilloscope calibration option is installed.

Table 3-1. Front-Panel Features (cont.)

(28)	The **TC** (Thermocouple) minijackis used for thermocouple simulation during thermometer calibration, and thermocouple measurements. You must use the correct thermocouple wire and plug when you use this connector. For example, if you will simulate a type-K thermocouple, use type-K thermocouple wire and type-K plug to make connections.
(29)	The **20A** terminal is the source of current output when the 20 A range is selected (3 A to 20 A).
(30)	The **AUX (Auxiliary Output)** terminals are used for ac and dc current outputs, the second voltage output in dual-voltage modes, and ohms sense for 2-wire and 4-wire compensated resistance and capacitance measurements, and RTD simulation.
(31)	The **NORMAL** (Normal Output) terminals are used to source ac and dc voltage, ohms, and capacitance. The terminals are also used for Resistance Temperature Detector (RTD) simulation.

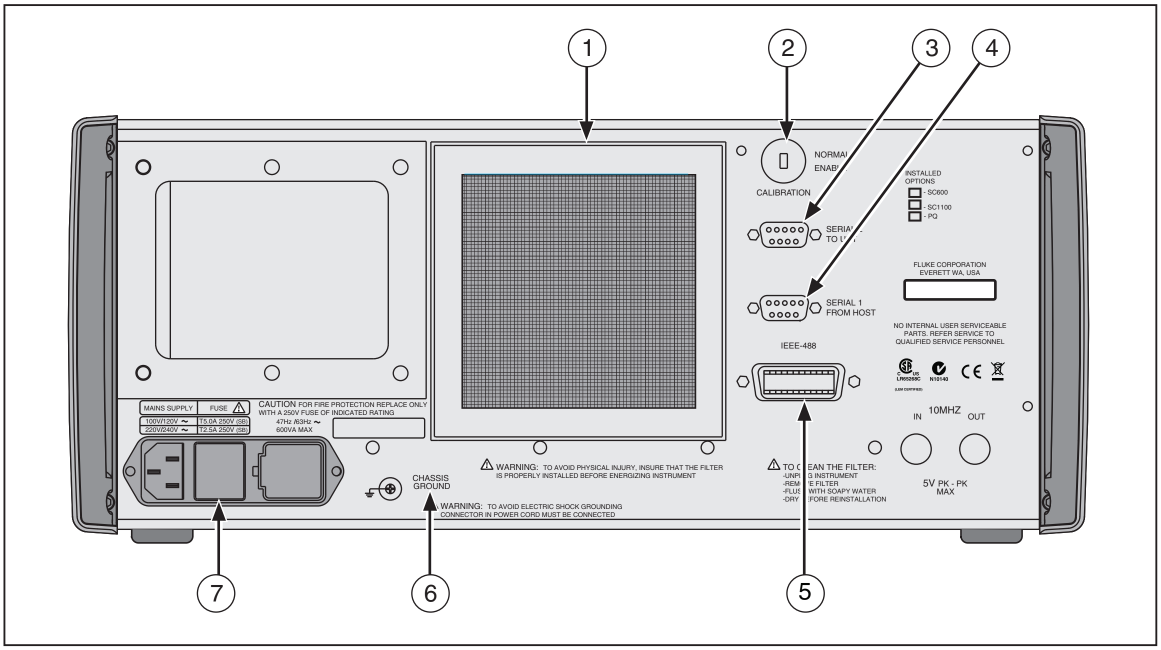


Figure 3-2. Rear-Panel Features

Table 3-2. Rear-Panel Features

1	The **Fan Filter**covers the air intake to keep dust and contamination out of the chassis air baffles. The fan supplies a constant cool air flow to the inner chassis. Instructions for fan filter maintenance are in Chapter 7.
2	The **CALIBRATION NORMAL/ENABLE** slide switch is used to write enable and disable the nonvolatile memory that stores calibration constants. Change to ENABLE to let changes be written into memory, and change to NORMAL to protect data in memory from being overwritten. The switch is recessed to let it to be covered with a calibration sticker to guarantee calibration integrity.
3	The **SERIAL 2 TO UUT** connector is used to transmit and receive RS-232 serial data between the Calibrator and a UUT. Chapter 6, “Remote Commands” tells you how to use the RS-232 serial interface for UUT communications.
4	The **SERIAL 1 FROM HOST** connector is for remote control of the Calibrator and for transmitting internal-constant RS-232 serial data to a printer, monitor, or host computer. Chapter 5, “Remote Operation” tells you how to use the RS-232 serial interface for remote control.
5	The **IEEE-488** connector**Error! Bookmark not defined.** is a standard parallel interface for operating the Calibrator in remote control as a Talker/Listener on the IEEE-488 bus. Refer to Chapter 5, “Remote Operation” for bus connection and remote programming instructions.

Table 3-2. Rear-Panel Features (cont.)

⑥	**⚠⚠ Warning** **To prevent possible electrical shock, fire, or personal injury:** • **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.** • **Make sure that the Product is grounded before use.** The **CHASSIS GROUND**terminal is internally grounded to the chassis. If the Calibrator is the location of the ground reference point in a system, this binding post can be used to connect other instruments to earth ground. Refer to the “Connect the Calibrator to a UUT” section in Chapter 4.
⑦	The **AC Power Input Module** gives you a grounded three-prong connector that takes the line power cord, a switch mechanism to select the line voltage, and a line power fuse. See the “Prepare for Operation” section in Chapter 2 for information on selecting the operating line voltage, and fuse rating and replacement information.

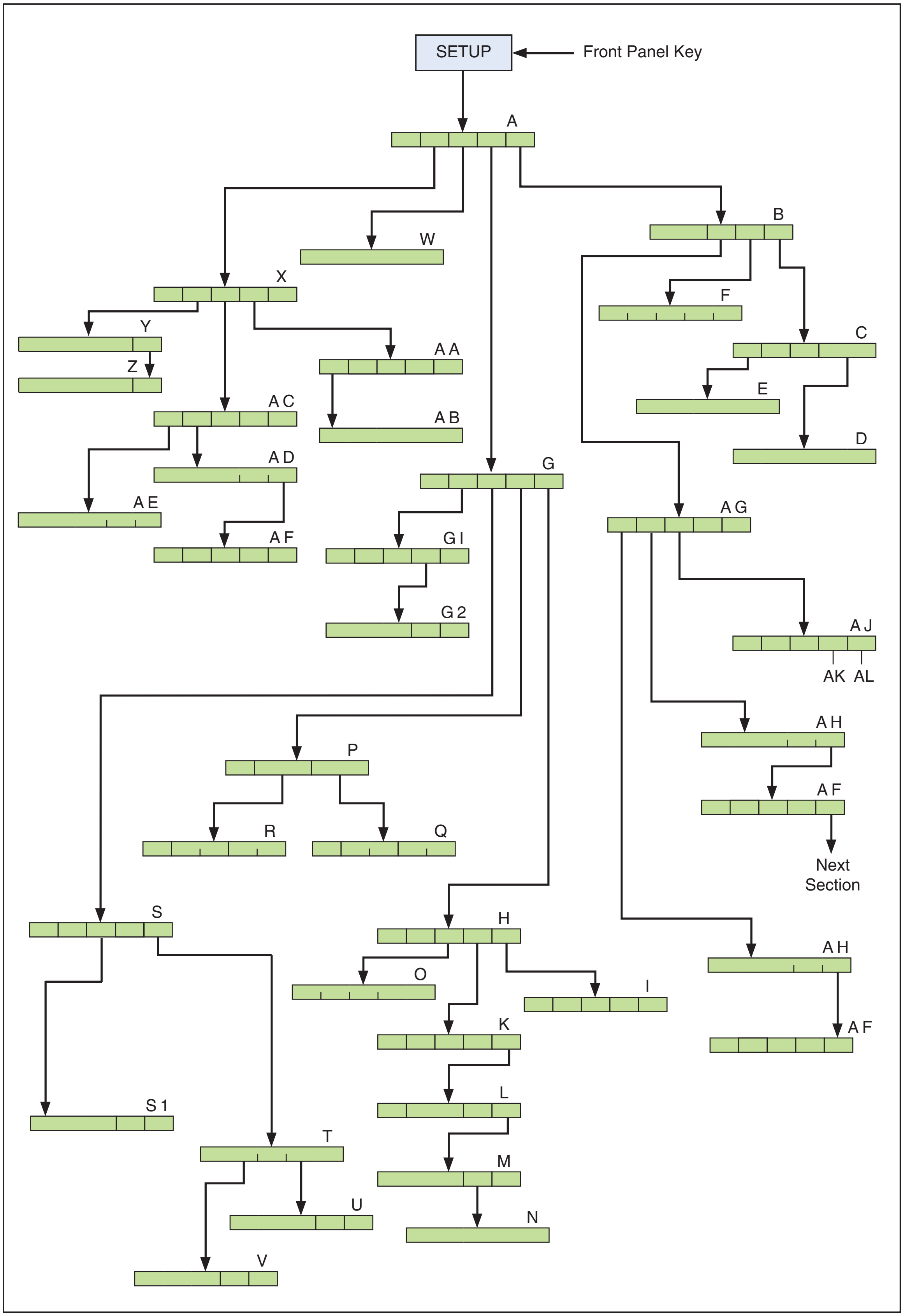


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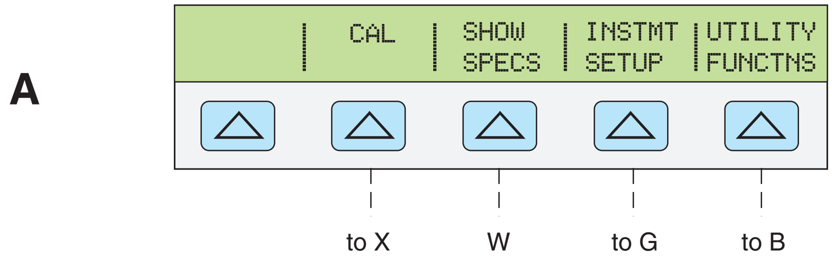
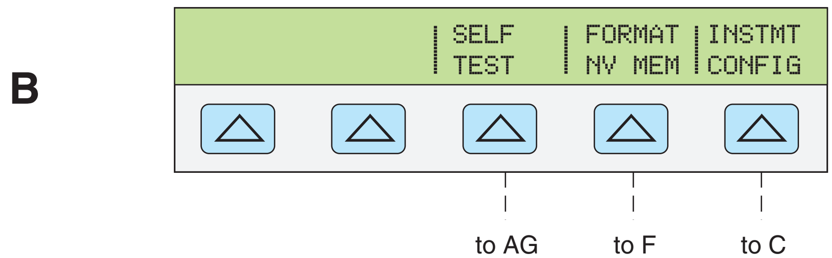
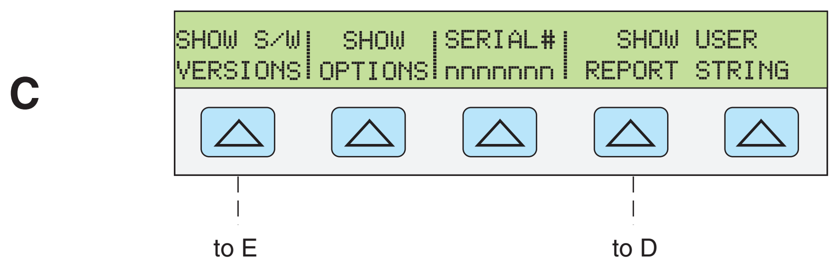
Figure 3-3. Setup Softkey Menu Tree



SHOW SPECS is an online summary of the programmed output specifications.



If self test does not pass, error codes are displayed. (See chapter 7, "Maintenance")



SERIAL # displays the serial number of the instrument. When corresponding with the factory, always include the serial number of the instrument.

USER REPORT STRING CONTENTS refer to a string of characters entered by the user for reporting purposes.

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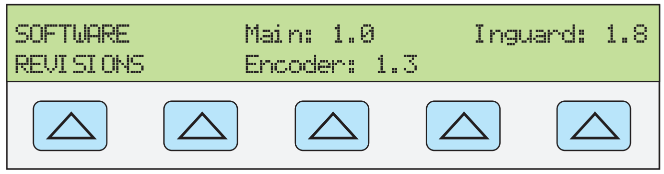
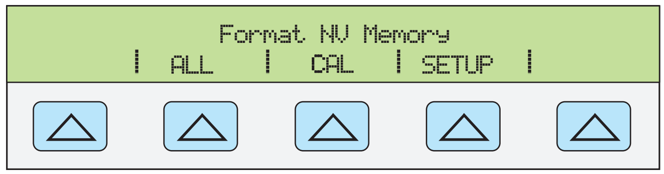
Figure 3-4. SETUP Softkey Menu Displays

E



Actual revision numbers replace the numbers in each of the above.

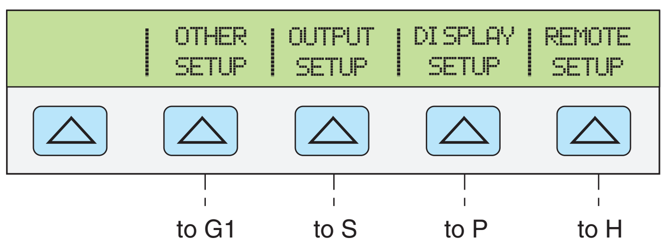
F



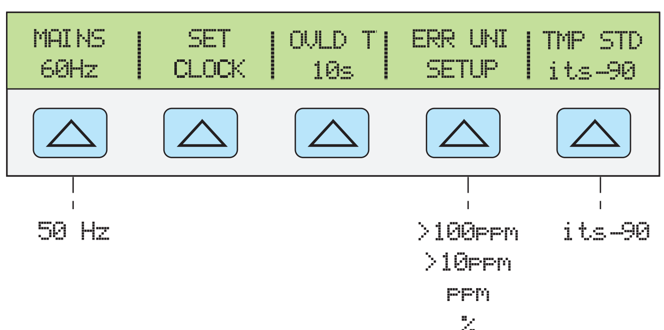
Format NV (non-volatile) Memory should be used with caution. Changes are non reversible. The softkeys function only when the rear-panel CALIBRATION switch is set to ENABLE, except for the softkey SETUP, which is not dependent on the CALIBRATION switch position.

All sets all calibration and setup constants to factory setting. **CAL** set only calibration constants to factory settings. **SETUP** resets instrument setup to factory default settings (see Table 3-3).

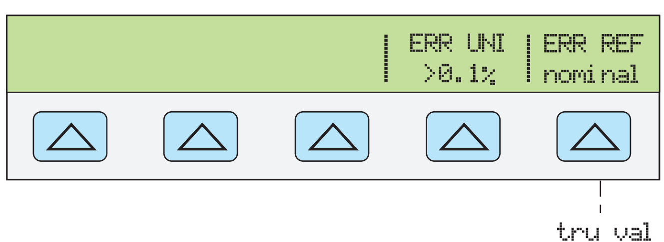
G



G1



G2



TMP STD (temperature degree standard) refers to ITS-90 (1990 International Temperature Standard) (factory default) and IPTS-68 (1968 International Provisional Temperature Standard).

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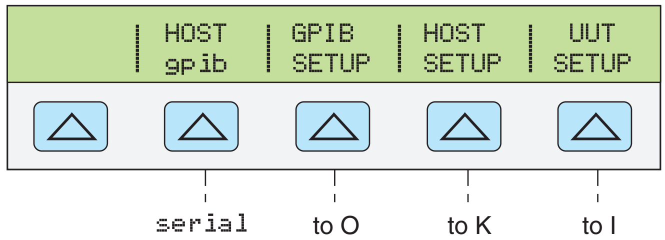
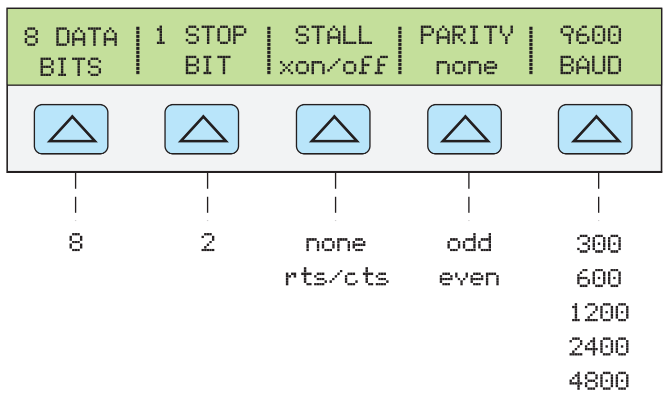
Figure 3-4. SETUP Softkey Menu Displays (cont.)

H



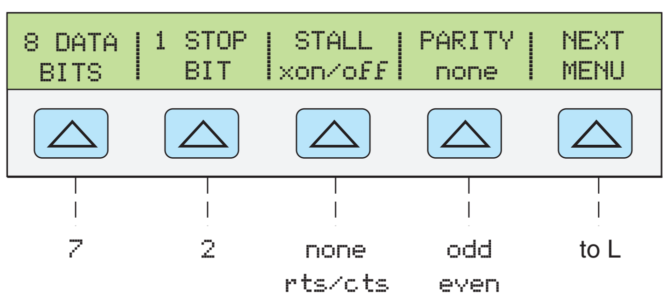
HOST selects the IEEE-488 (GPIB) (factory default) parallel port or RS-232 (serial) port. You cannot operate both IEEE-488 and RS-232 simultaneously.

I



STALL refers to the method of controlling data flow: software control (xon/off), hardware control (rts/cts) or none.

K

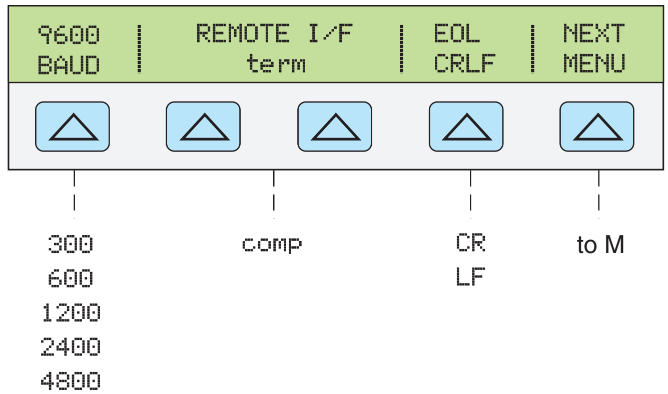


STALL refers to the method of controlling data flow: software control (xon/off), hardware control (rts/cts) or none.

gjh030.eps

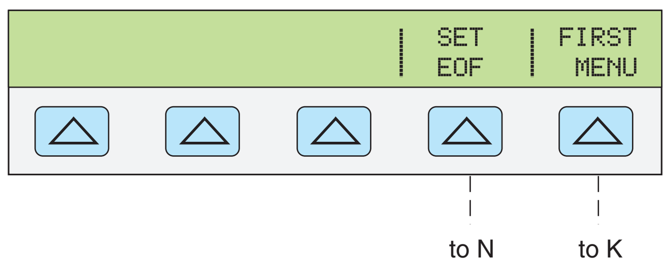
Figure 3-4. SETUP Softkey Menu Displays (cont.)

L



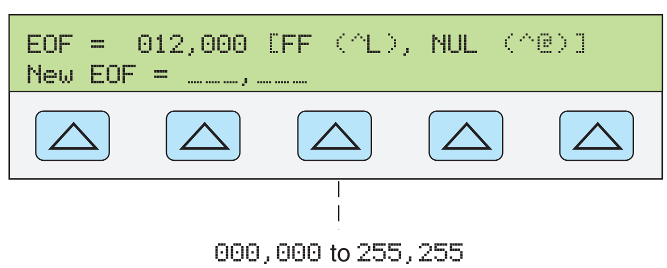
REMOTE I/F (Interface) has selections term (terminal) (factory default) and comp (computer). EOL (End of Line character) is either Carriage Return/Line Feed (CRLF), CR (Carriage Return) or LF (Line Feed).

M



EOF (End of File) indicates the action taken at the end of a file by entering one or two ASCII characters.

N



EOF (End of File) ASCII characters are entered with a range of 000 to 255 (first character) and 000 to 255 (second character). The factory defaults are 012,000, where the FF (form feed) character signals an advance to the next page, and the NULL (ignore) character holds position. When the NULL character is 000 (^@), then effectively the EOF is only the FF character, or ^L for the factory.

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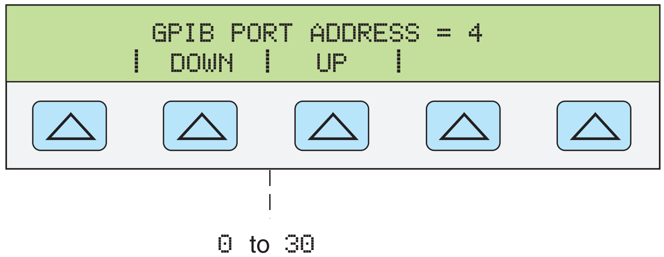
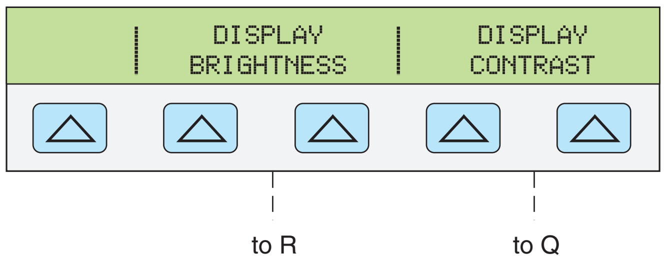
Figure 3-4. SETUP Softkey Menu Displays (cont.)

O



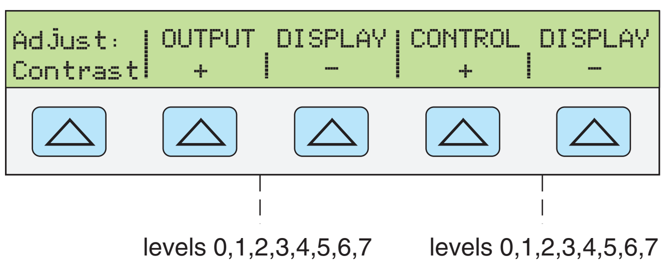
GPIB (General Purpose Interface Bus) selects the port address when using the IEEE-488 bus. The factory default is 4.

P



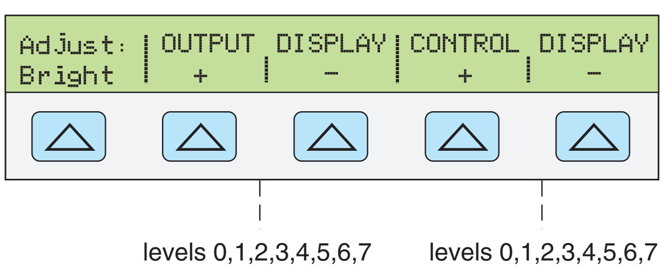
DISPLAY BRIGHTNESS and DISPLAY CONTRAST apply to both the Output Display and Control Display.

Q



There are eight levels of contrast, 0 to 7, for the Output Display and Control Display. Each may have its own level of contrast. The factory defaults are 7 and 7.

R



There are eight levels of brightness, 0 to 7, for the Output Display and Control Display. Each may have its own level of contrast. The factory defaults are 1 and 0.

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Figure 3-4. SETUP Softkey Menu Displays (cont.)

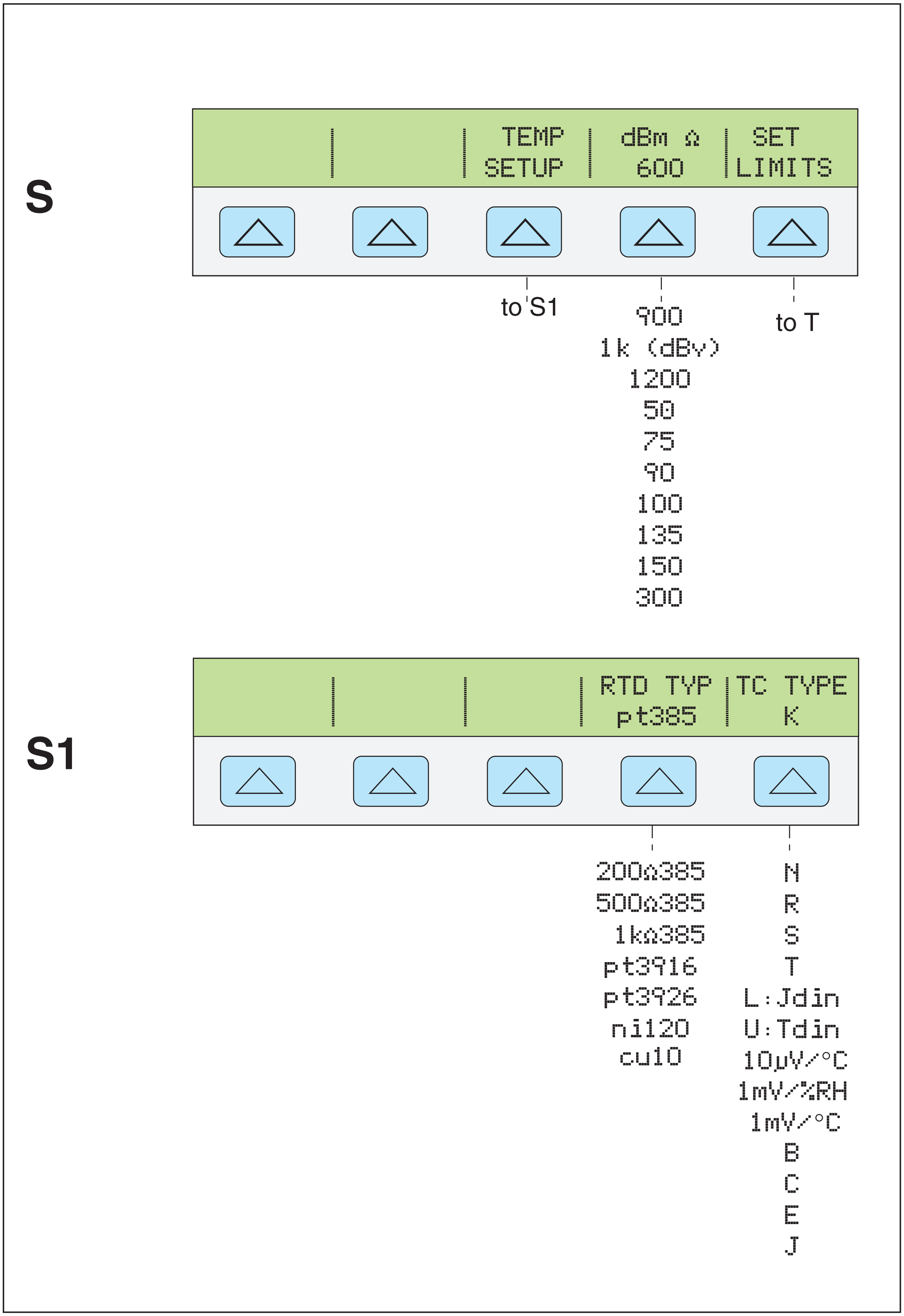


Figure 3-4. SETUP Softkey Menu Displays (cont.)

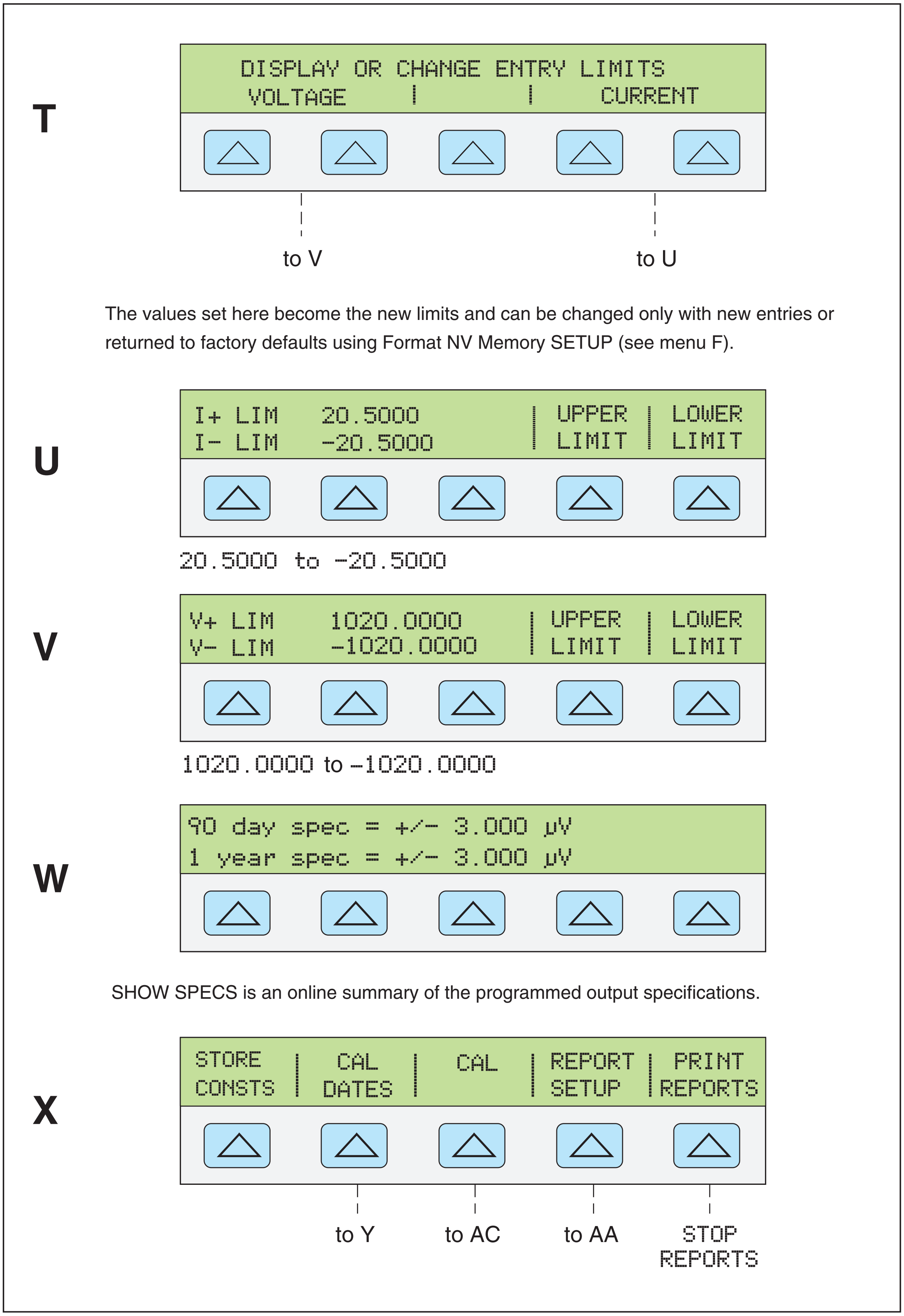
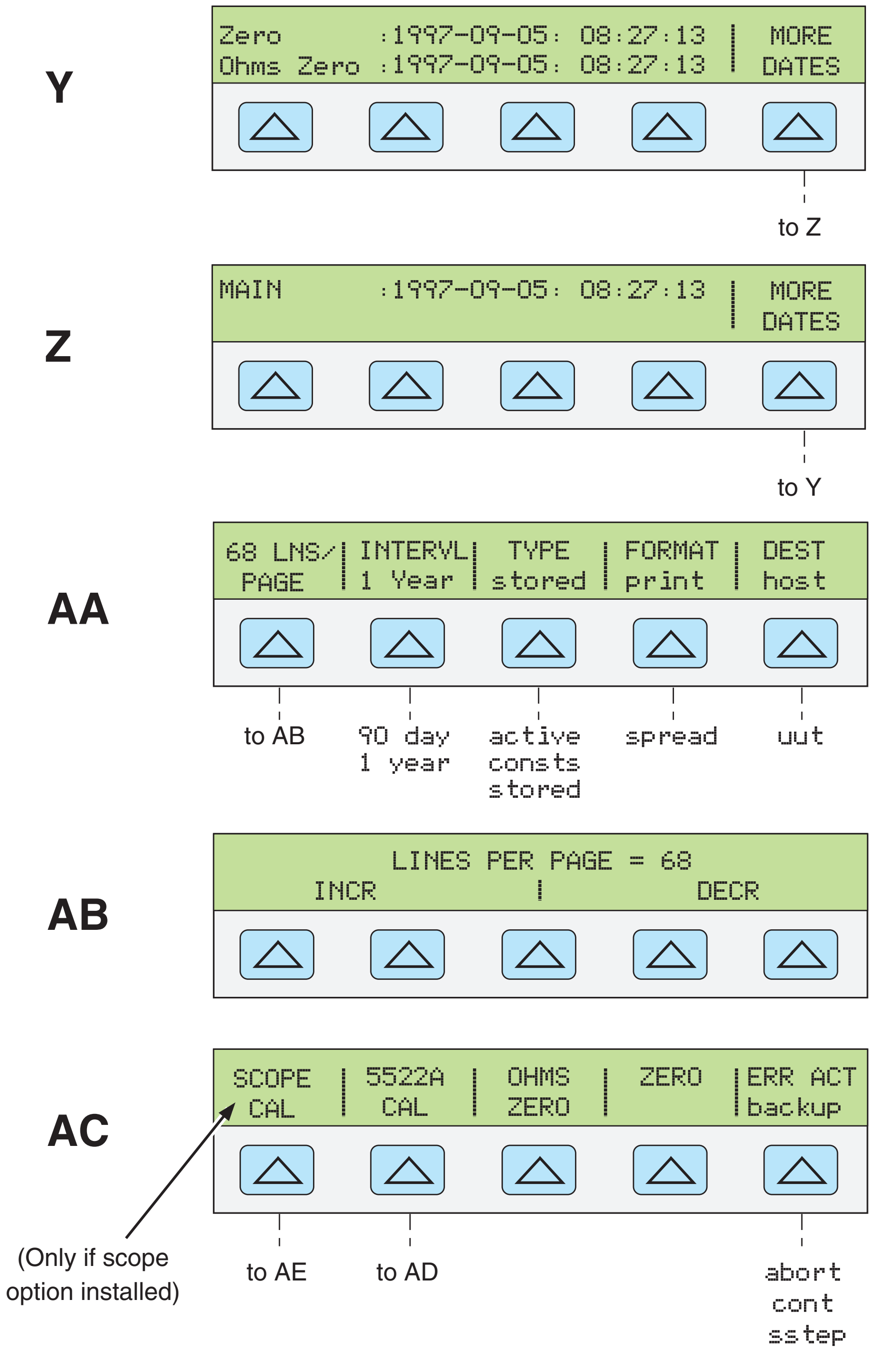


Figure 3-4. SETUP Softkey Menu Displays (cont.)

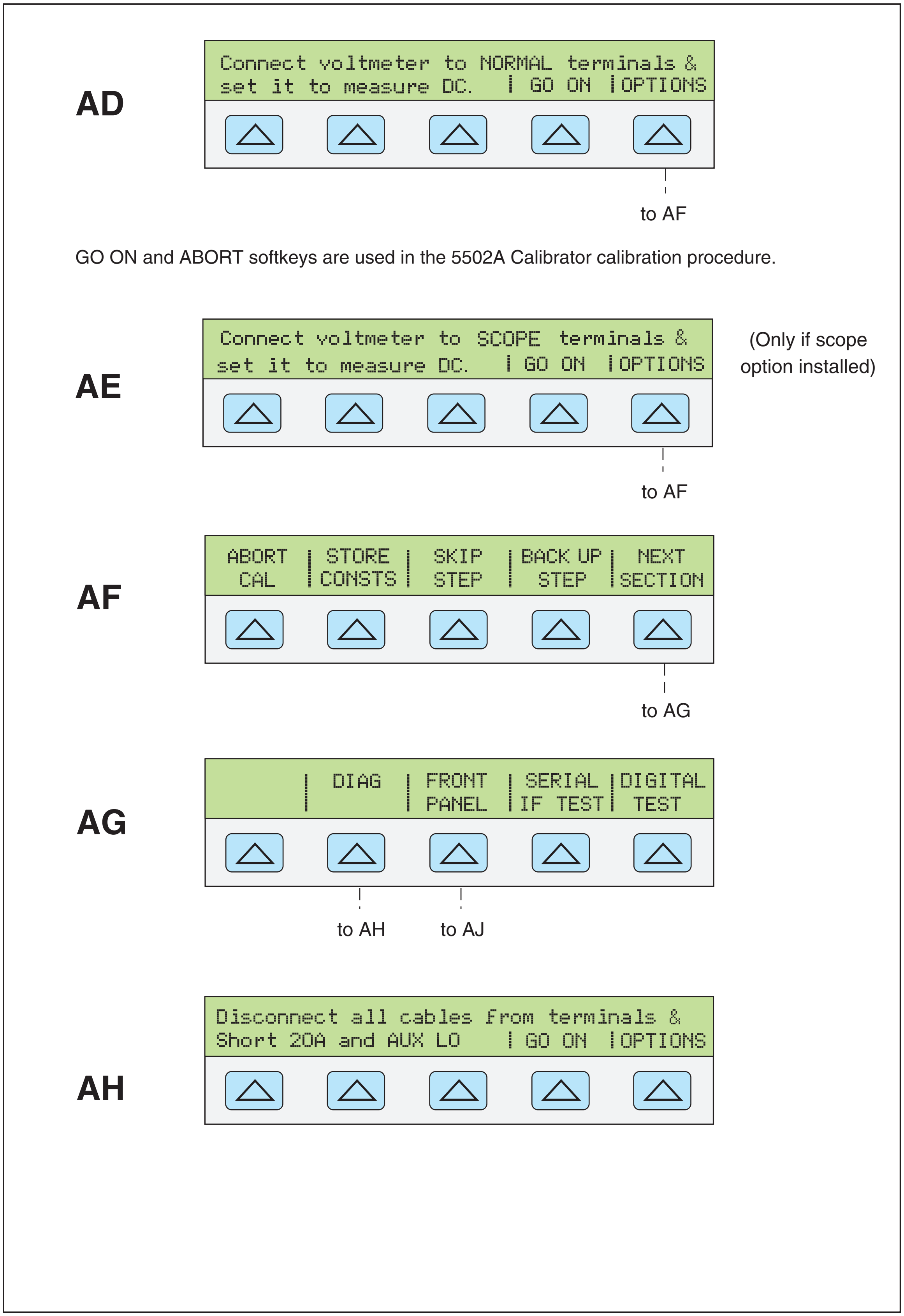
Select the desired CAL (Calibration) feature: CAL to calibrate the 5502A. CAL DATES to review when the 5502A Calibrator was last calibrated. CAL REPORTS to printout the calibration data.



5502A CAL opens the calibration menu. ZERO zeros the 5502A Calibrator. OHMS ZERO zeros the ohms portion of the 5502A Calibrator; ERR ACT (Error Action) set backup, abort, or cont (continue).

gjh013eps

Figure 3-4. SETUP Softkey Menu Displays (cont.)



gjh033.eps

Figure 3-4. SETUP Softkey Menu Displays (cont.)

Table 3-3. Factory Defaults for SETUP Menus Power-Up Defaults

Parameter	Setting	SETUP Menu (Figure 3-4)
User report string (*PUD string)	Cleared	D
Error units	> 0.1%	G1
SC-600 option overload test safety timeout	10 s	G1
Temperature standard	its-90	G1
Host interface	gpib (IEEE-488)	G1
UUT serial interface	8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud	I
Host serial interface	term, 8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud, CRLF, 012,000	K, L, M, N
GPIB Port Address	4	O
Display brightness (Note)	level 1,0	P
Display contrast (Note)	level 7,7	P
dBm impedance	600 Ω	S
RTD type	pt385	S1
Thermocouple type	K	S1
Current limits	±20.5 A	U
Voltage limits	±1020 V	V

Note:
Output Display and Control Display, respectively. There are 8 levels: 0,1,2,3,4,5,6, and 7

Chapter 4
Front-Panel Operation

Title **Page**

Introduction

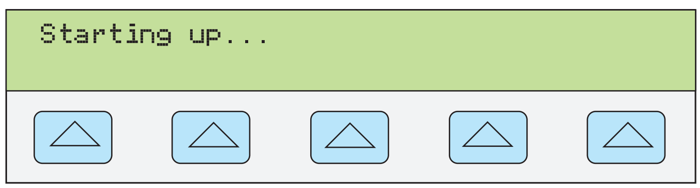
⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury, do not make connections to the output terminals when voltage is present. Standby mode is not sufficient to prevent shock hazard because OPR could be pushed accidently. Push RESET and make sure that the Calibrator is in standby before you make connections to the output terminals.

This chapter gives instructions to operate the Calibrator from the front panel. For a description of front-panel controls, displays, and terminals, see Chapter 3, "Features".

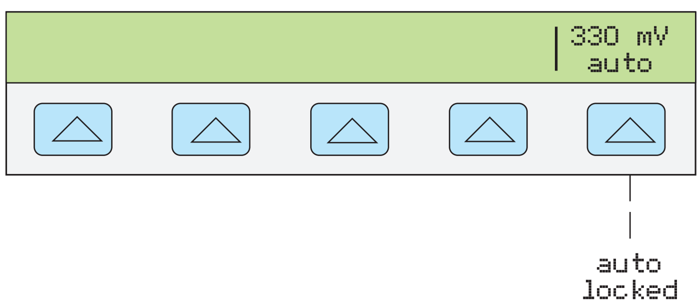
Turn on the Calibrator

When the Calibrator is on, the initial display is "Starting Up..." (see below) and it completes a self-test routine. If a self-test fails, the Control Display shows an error code. For a description of error codes, see Chapter 7, "Maintenance."



nn062f.eps

After self-test, the control display shows the reset condition (see below).



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For a discussion of the softkey selection shown above (auto/locked), see "Auto Range Versus Locked Range" in this chapter.

Warm up the Calibrator

When you turn on the Calibrator, let it warm up for 30 minutes to let the internal components become stable. Specifications given in Chapter 1 apply to a Calibrator that has completed its warm-up procedure.

If you turn off the Calibrator after warm up and then on again, give it a warm-up period of no less than two times the length of time it was turned off (maximum of 30 minutes). For example, if the Calibrator is turned off for 10 minutes and then on again, give it a warm-up period of no less than 20 minutes.

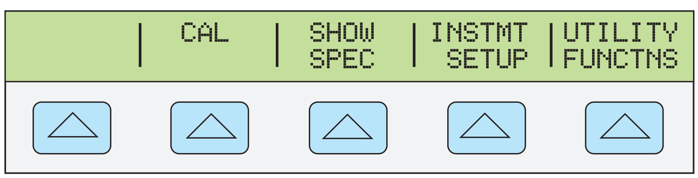
Use the Softkeys

The five keys to the right of PREV MENU are called softkeys. Softkey functions come from the name that shows directly above the key in the Control Display. Push a softkey to change a value or cause a submenu with new selections to be shown on the Control Display. Softkey menus are put in different levels, as given in the “Softkey Menu Tree” section in Chapter 3. You can move back through the menu selections with PREV MENU. Although RESET will return you to the top-level menu, it will also reset all volatile settings and return the Calibrator to 0 V dc in the standby mode. Use PREV MENU as your main navigation tool to move through the menu levels.

Use the Setup Menu

Push the front-panel SETUP key to access various operations and changeable parameters. Most parameters are nonvolatile. This means they will be stored during reset or when you turn off the power. Chapter 3 shows a map of the menu tree, the parameters, and has a table of factory-default values.

When you push SETUP from power-up, the display changes to:



nn064f.eps

This is the primary instrument setup menu. The list below tells you about the submenus that available through each softkey and tells you where you can find more information in the manuals.

- **CAL** (Calibration)

  Opens the calibration menu. You use softkeys in this menu to see the calibration dates, print a calibration report, calibrate, and to do the Zero calibration routine. Zero calibration is given in this chapter.

- **SHOW SPECS** (Show Specifications)

  Shows published Calibrator specifications for the output value that is currently selected.

- **INSTMT SETUP** (Instrument Setup)

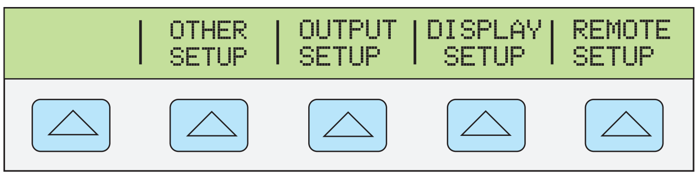
  Lets you change the power-up or reset default setting for different instrument parameters. Many of the same parameters in this menu can be changed during operation, but the changes you make during operation are volatile. Change them here to makes them nonvolatile. To set the Calibrator to its factory defaults, use the Format NV Memory menu in the UTILITY FUNCTNS menu.

- **UTILITY FUNCTNS** (Utility Functions)

  Lets you to start self-tests, format the nonvolatile memory (set the factory defaults), and examine the instrument configuration software versions and user report string. These features are given in the “Utilities Function Menu” section of this chapter.

Use the Instrument Setup Menu

The softkeys in the instrument setup menu (accessed by pressing INSTMT SETUP softkey in the Setup Menu) are shown below.



nn065f.eps

The list below gives submenus accessed by each softkey.

- **OTHER SETUP**

  Opens a menu that lets you toggle the degree reference between the 1968 International Provisional Temperature Standard (IPTS-68) and the 1990 International Temperature Standard (ITS-90) (factory default). This is also where you set the clock, and set the power-up and reset defaults for the SC-600 Oscilloscope Calibration Option Overload test safety timeout function (OVLD T), and shown error units. You can also configure the Calibrator for best operation with a 50 Hz line frequency.

- **OUTPUT SETUP**

  Opens a menu to change the power-up and reset defaults for current and voltage output limits, default thermocouple and RTD types, set the phase reference, internal or external phase reference source, and impedance for dBm display.

- **DISPLAY SETUP**

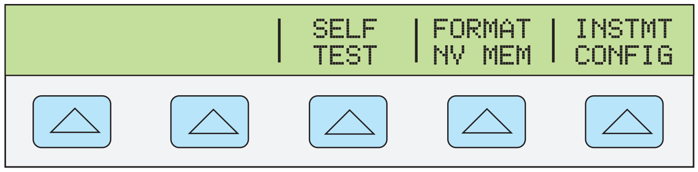
  Opens submenus to set the intensity and contrast of the Control and Output Displays.

- **REMOTE SETUP**

  Lets you change the configuration of the two RS-232 ports, SERIAL 1 FROM HOST and SERIAL 2 TO UUT, and IEEE-488 General Purpose Interface Bus (GPIB). (See Chapter 5, “Remote Operation”.)

Utility Functions Menu

The Setup Menu softkey UTILITY FUNCTNS (Utility Functions) gives access to Self Test, Format Nonvolatile Memory, and Instrument Configuration.



nn066f.eps

- **SELF TEST**

  This softkey opens a menu with Calibrator self-test selections.

- **FORMAT NV MEM** (Format Nonvolatile Memory)

  Opens a menu to put all or part of the data in the nonvolatile memory (EEPROM) to factory defaults.

- **INSTMT CONFIG** (Instrument Configuration)

  Lets you see the versions of software installed in the Calibrator as well as the user-entered report string.

Use the NV Memory Menu

⚠ Caution

The Format Nonvolatile Memory menu softkeys permanently erase calibration constants. If you push ALL or CAL, this will invalidate the condition of calibration of the 5502A.

Push FORMAT NV MEM in the utility functions menu to open:

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It is necessary that the rear-panel CALIBRATION switch to be in the ENABLE position for the ALL and CAL softkeys in this menu. The nonvolatile memory has calibration constants and dates, setup parameters, and the user report string. With calibration constants, factory defaults are the same for all calibrators. They are not the calibration constants received when the Calibrator was calibrated by the factory before shipment.

The softkeys are:

- **ALL**

  replaces all contents of the EEPROM with factory defaults. This is used by service personnel after they replace the EEPROM, for example. It is not typically necessary.

- **CAL**

  replaces all calibration constants with factory defaults but keeps the setup parameters unchanged. This is also not typically necessary.

- **SETUP**

  replaces the setup parameters with factory defaults (Table 3-3) but keeps the calibration unchanged. You do not have to break the calibration seal for this operation. Remote commands can also change the setup parameters. (See these commands in Chapter 6: SRQSTR, SPLSTR, *PUD, SP_SET, UUT_SET, TEMP_STD, DATEFMT, RTD_TYPE_D, TC_TYPE_D, LIMIT.)

Reset the Calibrator

When you use front panel-operation (not remote operation), you can put the Calibrator to the power-up condition with RESET, except after an error message, which is cleared by a push of the blue softkey.

Push RESET to:

- Put the Calibrator into the power-up condition: 0 V dc, standby, 330 mV range and all OUTPUT SETUP menus set to their most recent default values.
- Erases the stored values for limits and error mode reference.

Zero the Calibrator

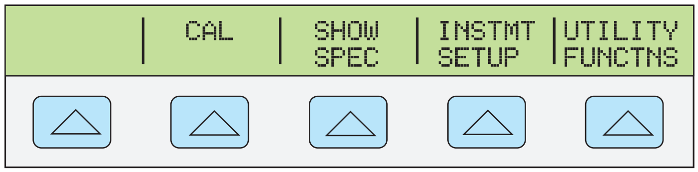
When you zero the Calibrator, the Calibrator recalibrates internal circuitry, most notably dc offsets in all ranges of operation. Zero the Calibrator each seven days to make sure the Calibrator outputs are not more or less than the limits of its specification, or when the Calibrator ambient temperature changes by more than 5 °C. The tightest ohms specifications are kept by a zero calibration each 12 hours within ±1 °C of use. The Calibrator shows a message when it is necessary to zero the Calibrator. To zero the Calibrator is very important when your calibration workload has 1 mΩ or 1 µV resolution, and when there has been a significant temperature change in the Calibrator work environment. There are two functions that zero the Calibrator: total instrument zero (ZERO) and ohms-only zero (OHMS ZERO).

Complete these procedures to zero the Calibrator.

Note

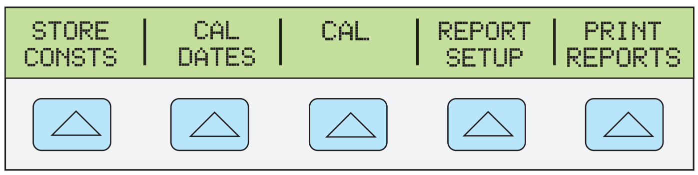
The Calibrator rear-panel CALIBRATION switch does not have to be enabled for this procedure.

1. Turn on the Calibrator and let it warm-up for no less than 30 minutes.
2. Push RESET.
3. Push SETUP. This opens the setup menu (see below).



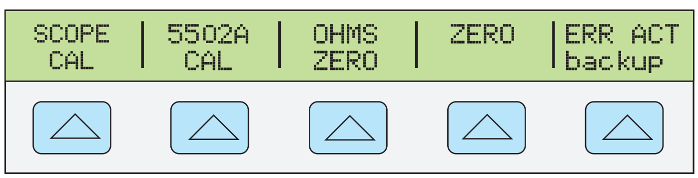
nn068f.eps

4. Push the CAL softkey. This opens the calibration information menu (see below).



nn069f.eps

5. Push the CAL softkey. This opens the calibration activity menu (see below). SCOPE CAL is shown as an option if it is installed:



gvx034.eps

6. Push the ZERO softkey to zero the Calibrator. Push the OHMS ZERO softkey to zero only the ohms function. After the zero routine is complete (several minutes), push RESET to reset the Calibrator. For a complete zero calibration, a short circuit that can pass 20 A must to be applied between the 20A and AUX LO terminals.

Operate and Standby Modes

When the OPERATE annunciator is illuminated and OPR is shown, the output value and function shown on the Output Display is live at the selected terminals. When STBY is shown in the Output Display, most of the Calibrator outputs are open-circuited. The front-panel thermocouple (TC) terminals are not open-circuited. To start the operate mode, push OPR. To put the Calibrator in standby, push SETUP.

If the Calibrator operates and these things occur, the Calibrator automatically goes to the standby mode:

- RESET is pushed.
- A voltage ≥33 V is selected when the previous output voltage was less than 33 V.
- Output function is changed between ac or dc voltage when the output voltage is ≥33 V, ac or dc current, temperature and any other function; resistance and any other function; capacitance and any other function.

- A p-p voltage output (square wave, triangle wave, or truncated sine wave) changes to rms voltage output ≥33 V (sine wave). For example, if a p-p output of 40 V is changed to rms output of 40 V by a change to the wave form with the WAVE softkey, the Calibrator goes to the standby mode.
- The output location for current is changed from AUX to 20 A, or from 20 A to AUX .
- An overload condition occurs.

Connect the Calibrator to a UUT

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury, do not make connections to the output terminals when voltage is present. Standby mode is not sufficient to prevent shock hazard because [OPR] could be pushed accidently. Push [RESET] and make sure that the Calibrator is in standby before you make connections to the output terminals.

The NORMAL (HI and LO) outputs are used to source voltages, resistances, capacitance, and simulate resistance temperature detector (RTD) outputs. The LO terminal connects to the analog signal ground in the guard shield. This signal line can or cannot be connected to the chassis ground. This depends on how [EARTH] is set. See "When to Use EARTH" in this chapter for more about these internal connections.

The AUX (HI and LO) outputs source current and low voltages in the dual voltage function. These outputs are also used for four-wire or remote sensing in the resistance, capacitance, and RTD functions.

When an oscilloscope calibration option is installed, the SCOPE OUT BNC connectors and TRIG give signals for oscilloscope calibration.

Use the TC socket to measure thermocouples and to supply simulated thermocouple outputs.

Recommended Cable and Connector Types

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury:

- **Do not use test leads if they are damaged. Examine the test leads for damaged insulation, exposed metal, or if the wear indicator shows. Check test lead continuity.**
- **Use only cables with correct voltage ratings.**
- **Connect the common test lead before the live test lead and remove the live test lead before the common test lead.**
- **Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.**

- **Properly terminate the sense leads to prevent exposure to hazardous voltages on the sense terminals. The voltage sense terminals are at output voltage when the two-wire function is set.**
- **Do not touch exposed metal on banana plugs, they can have voltages that could cause death.**
- **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.**
- **Make sure that the Product is grounded before use.**

Cables to the Calibrator are connected to the NORMAL and AUX terminals. To prevent errors caused by thermal voltages (thermal emfs), use connectors and conductors made of copper or materials that supply small thermal emfs when connected to copper. Do not use nickel-plated connectors. For best results use the Fluke Model 5440A-7002 Low Thermal EMF Test Leads, which are made of well-insulated copper wire and tellurium copper connectors. See Chapter 8, "Accessories."

When to Use EARTH

Figure 4-1 shows the internal connections made by EARTH.

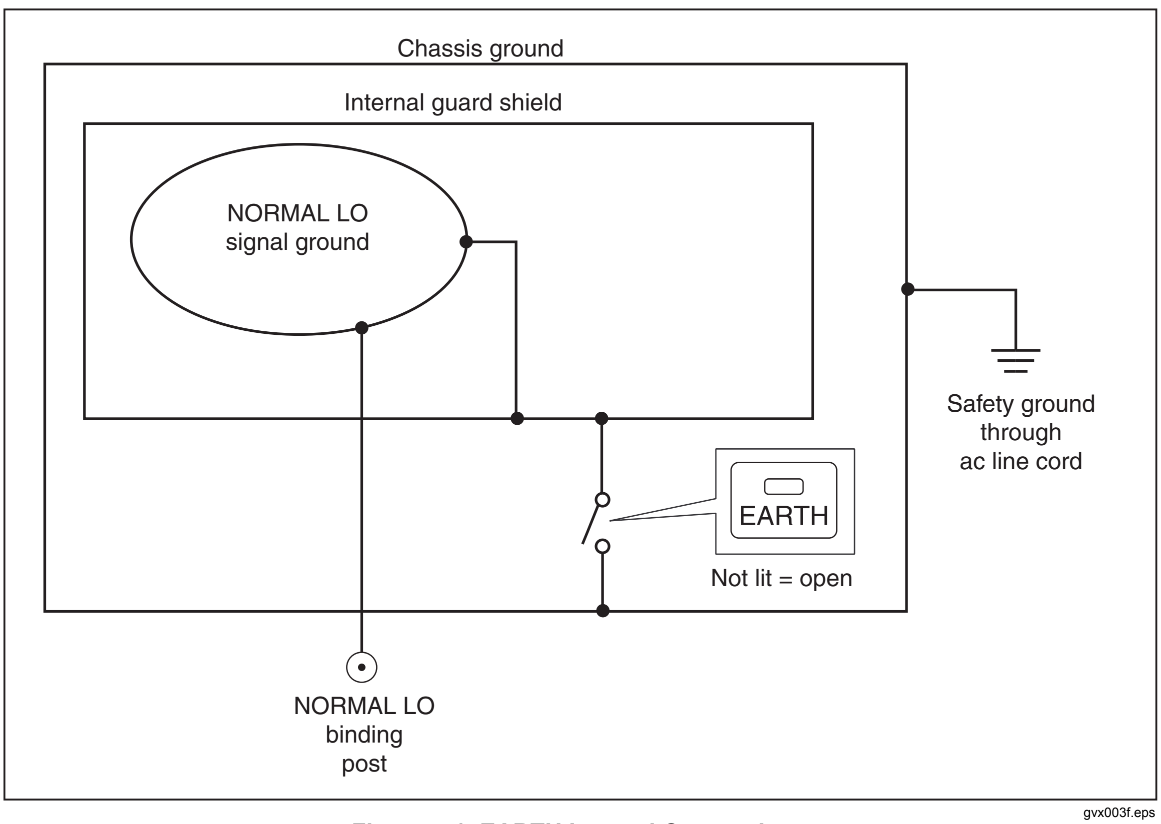


Figure 4-1. EARTH Internal Connections

The Calibrator front panel NORMAL LO terminal is typically isolated from earth (chassis) ground. When it is necessary to make a connection from the NORMAL LO terminal and earth ground, push the EARTH key, this lights the key annunciator. When the earth key is pushed, the NORMAL LO terminal is connected to earth ground through approximately 30 Ω.

To prevent ground loops and noise you must have only one earth ground-to-LO terminal connection in the system. Typically you make all signal ground connections at the UUT and make sure that the EARTH annunciator is off. In most cases, EARTH is on only for ac and dc volts where the UUT is isolated from earth ground. There must be a safety ground for the Calibrator. See "Connect to Line Power" in Chapter 2. When the sourced output is live, a softkey LO is shown, which lets you tie or open an internal connection from the NORMAL LO terminal to the AUX LO terminal. When tied and EARTH is on, then both LO terminals are tied to chassis ground.

Four-Wire versus Two-Wire Connections

Four-wire and two-wire connections are methods to connect the Calibrator to the UUT to cancel out test lead resistance to make sure the highest precision of the calibration output. Figures 4-2 through 4-4 show the connection configurations for resistance. Figures 4-5 and 4-6 show connection configurations for capacitance. The external-sensing function of the four- and two-wire compensated connections gives increased precision for resistance values less than 110 kΩ and capacitance values 110 nF and above. A part of the Calibrator output setup for resistance and capacitance includes selections for four-wire compensation (COMP 4-wire), two-wire compensation (COMP 2-wire) and two-wire no compensation (COMP off). (See "Set Resistance Output" and "Set Capacitance Output" in this chapter.) Note that compensated connections for capacitance are to compensate for lead and internal resistances, not for lead and internal capacitances.

Four-Wire Connection

The four-wire connection is typical for calibration of laboratory measurement equipment. Increased precision is supplied for resistance values less than 110 kΩ. For other values, the lead resistances do not degrade the calibration and the Calibrator changes the compensation to off (COMP off).

Two-Wire Compensation

The two-wire connection is typical for calibration of precision handheld Digital Multimeters (DMMs) with a two-wire input. Increased precision is supplied for resistance values less than 110 kΩ and capacitance values 110 nF and above. For other values, the Calibrator changes the compensation to off (COMP off).

Compensation Off

Compensation off is a typical connection for calibration of handheld analog meters or DMMs with a two-wire input. This connection is used for all values of resistance and capacitance and is typically selected when more precision is not necessary for the analog meter or DMM level of accuracy. This is the default condition when an ohms or capacitance output is made after an output that was not ohms or capacitance.

Cable Connections Instructions

Table 4-1 shows the figure names for each type of connection from a UUT to the Calibrator.

When you calibrate Resistance Temperature Detectors (RTDs) with the three-terminal connection shown in Figure 4-9, make sure the test leads have with resistances to cancel errors from lead resistance. This can be done, for example, with three test leads of the same length and with the same connector styles.

When you calibrate thermocouples, it is especially important to use the correct hookup wire and miniconnector between the Calibrator front panel TC terminal and the UUT. You must use the correct thermocouple wire and miniconnectors for the type of thermocouple. For example, if you simulate a temperature output for a type K thermocouple, use type K thermocouple wire and type K miniplugs for the hookup.

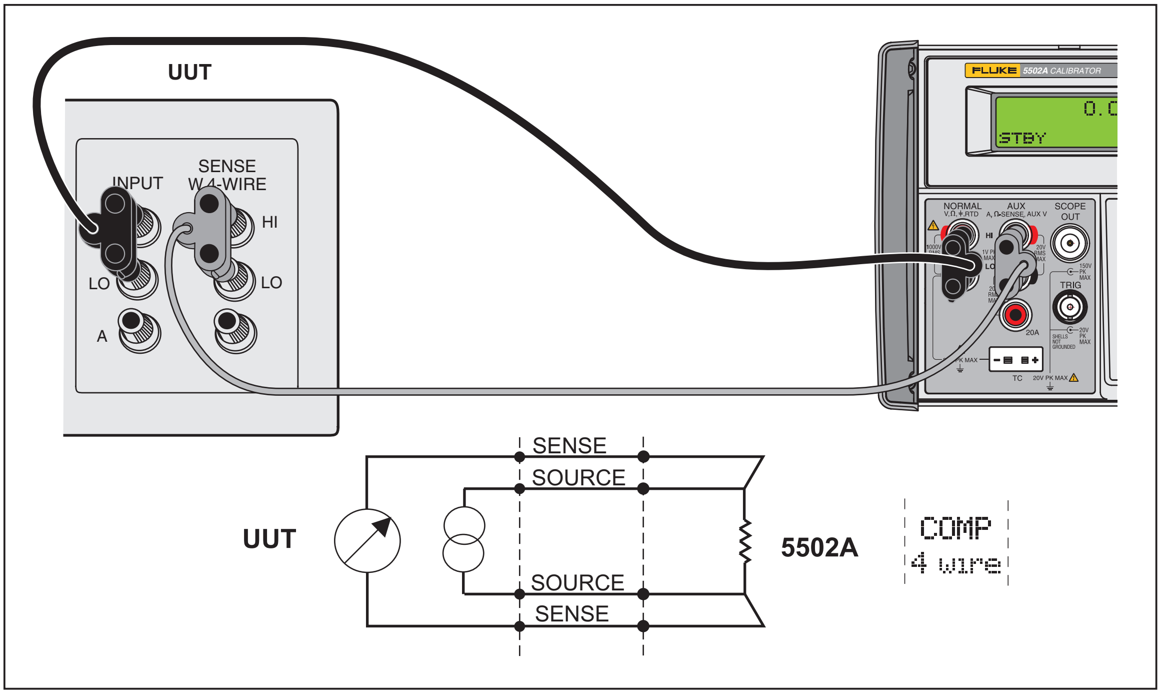
To connect the Calibrator to a UUT:

1. If the Calibrator is turned on, push RESET to remove the output from the Calibrator terminals.
2. Select the correct figure from Table 4-1 to make the connections to the UUT.
3. For capacitance outputs, connect the test leads to the UUT to null out stray capacitance. Put the cables (but do not connect them) to the Calibrator on a non-conductive surface. Null out the indication on the UUT with “rel,” “offset,” or “null,” (use the necessary method), and then connect the test leads to the Calibrator.

Table 4-1. UUT Connections

5502A Output	Figure Reference
Resistance	4-2 Resistance - four-wire compensation
	4-3 Resistance - two-wire compensation
	4-4 Resistance - compensation off
Capacitance	4-5 Capacitance - two-wire compensation
	4-6 Capacitance - compensation off
DC Voltage	4-7 DC Voltage/AC Voltage
AC Voltage	4-7 DC Voltage/AC Voltage
DC Current	4-8 DC Current/AC Current
AC Current	4-8 DC Current/AC Current
RTD Simulation	4-9 Temperature (RTD)
Thermocouple Simulation	4-10 Temperature (Thermocouple)

Note:
See the discussion under “Four-Wire versus Two-Wire Connections” above.



gvx014.eps

Figure 4-2. UUT Connection: Resistance (Four-Wire Compensation)

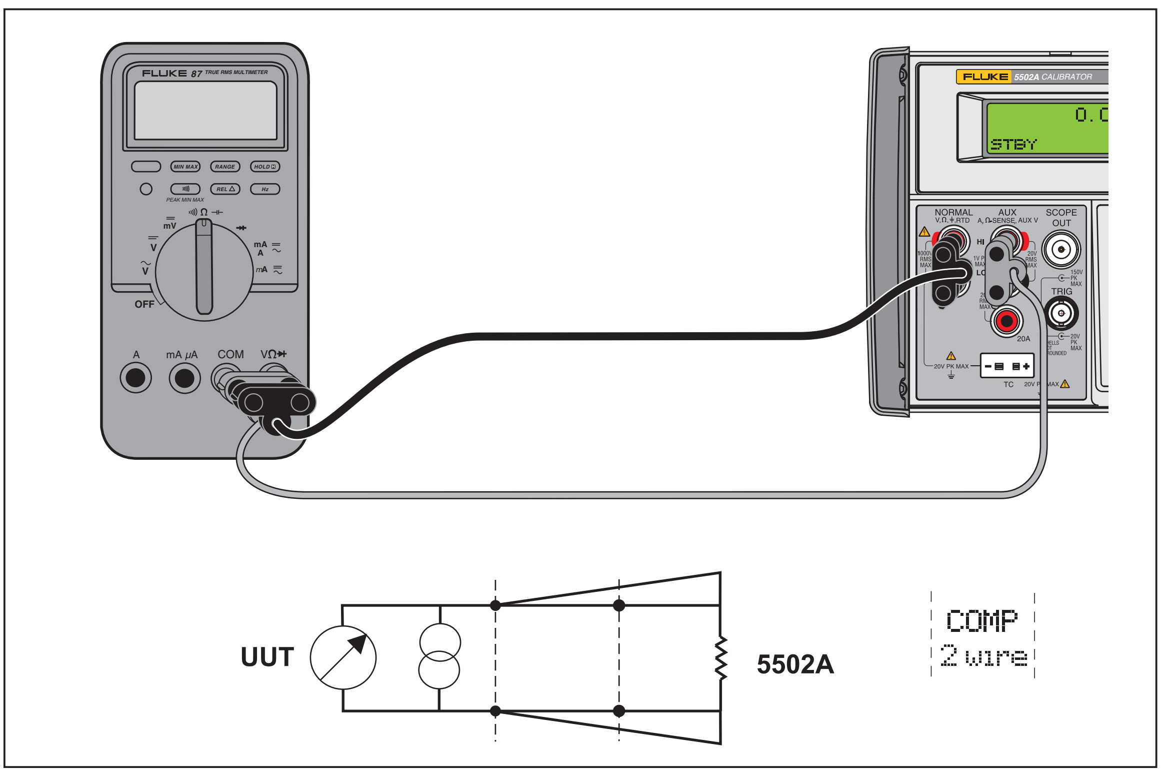


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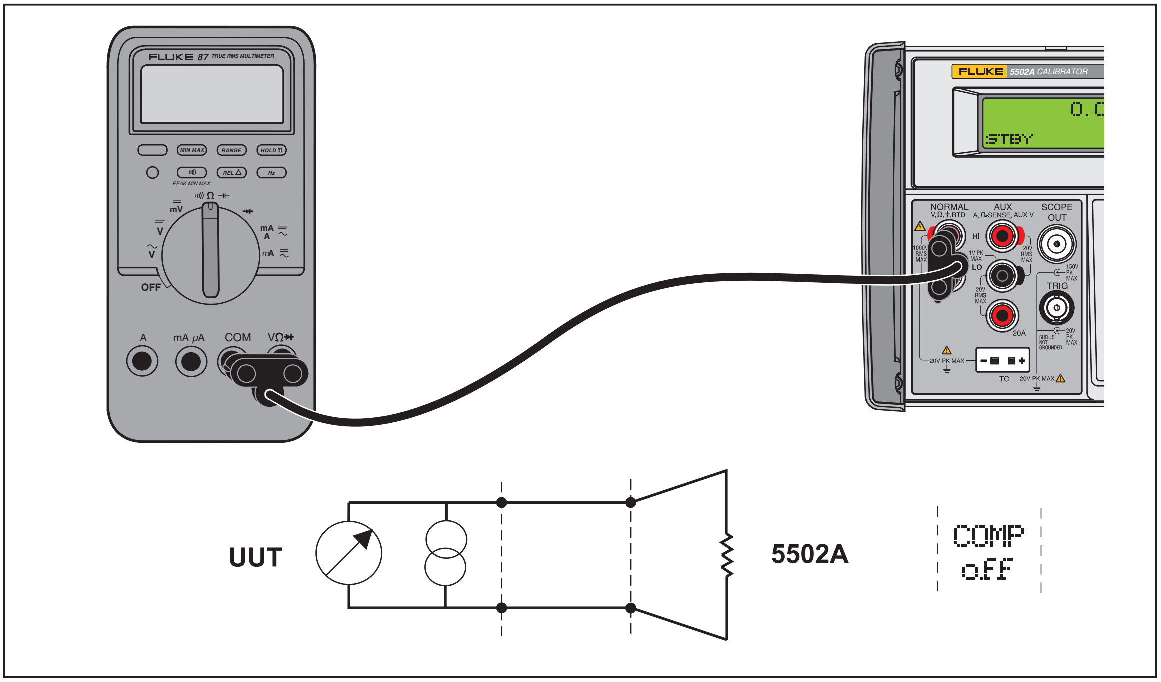
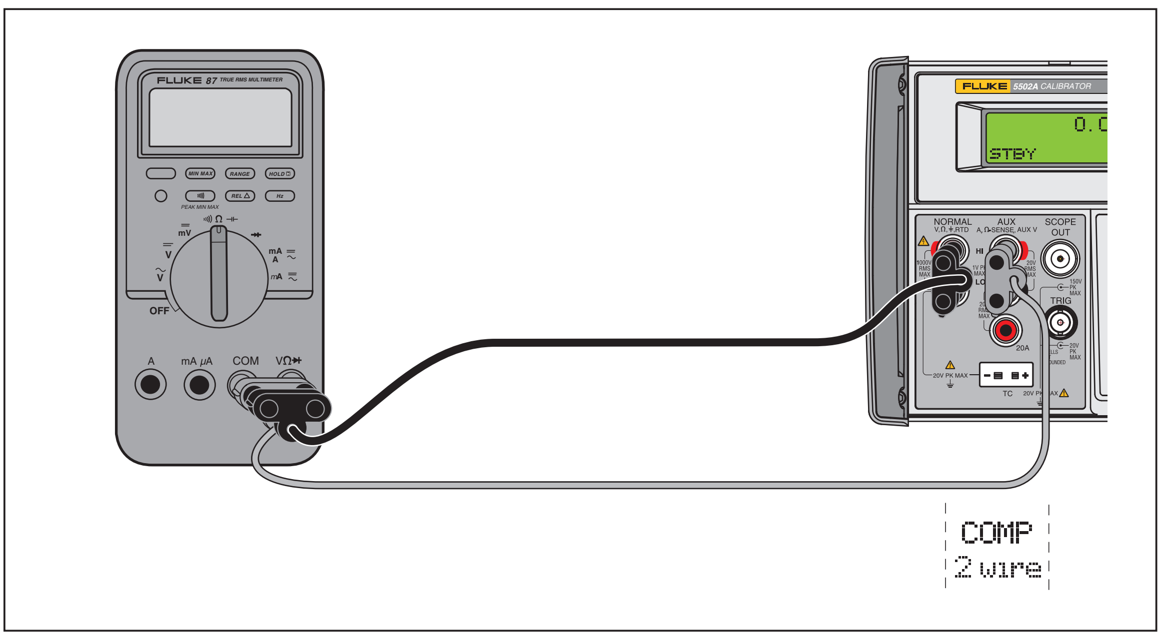
Figure 4-3. UUT Connection: Resistance (Two-Wire Compensation)



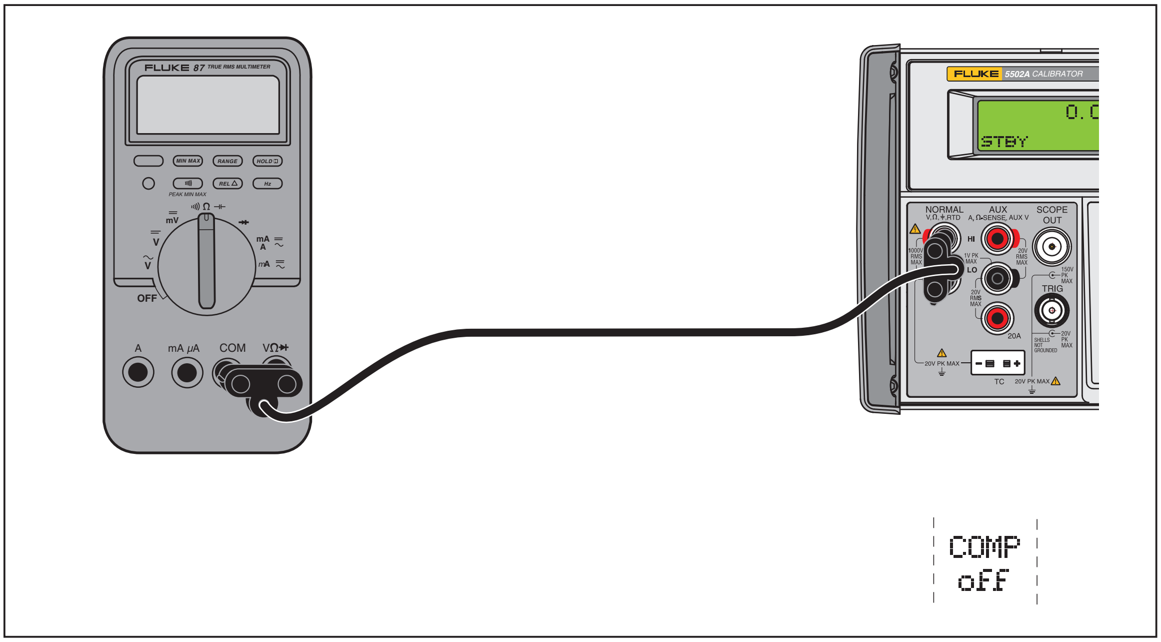
gvx016.eps

Figure 4-4. UUT Connection: Resistance (Compensation Off)



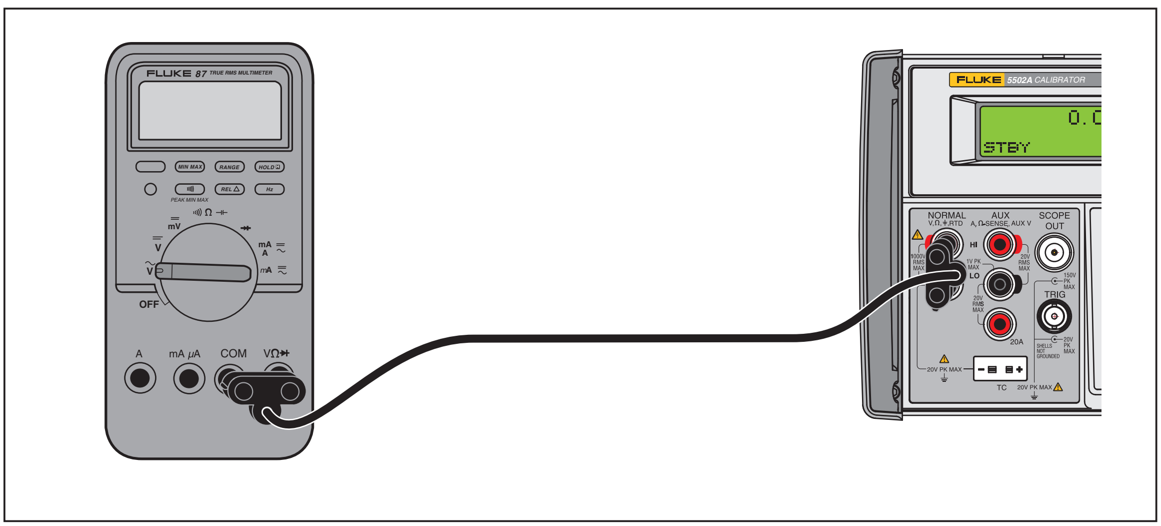
gvx017.eps

Figure 4-5. UUT Connection: Capacitance (Two-Wire Compensation)



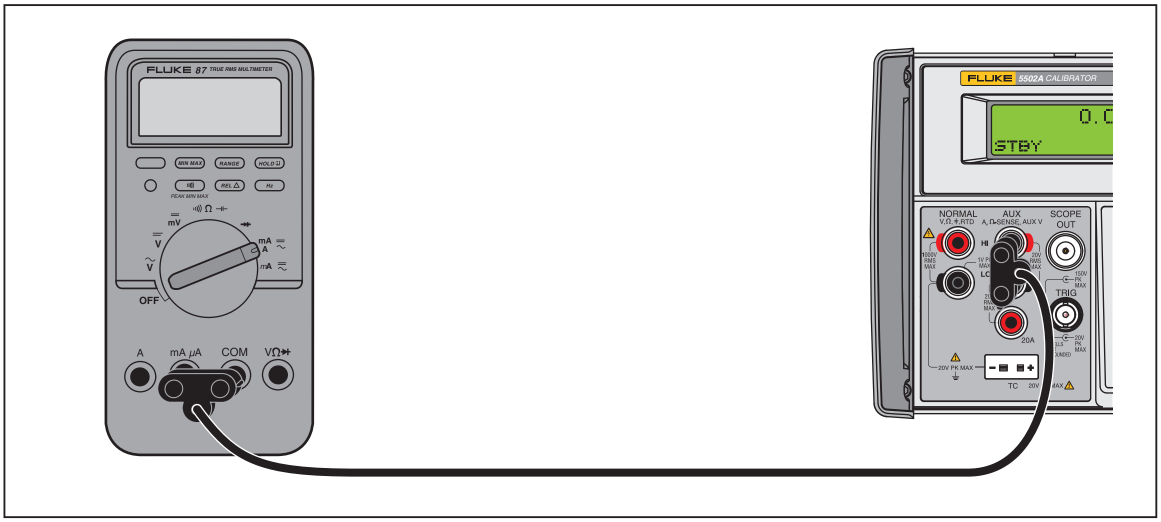
gvx018.eps

Figure 4-6. UUT Connection: Capacitance (Compensation Off)



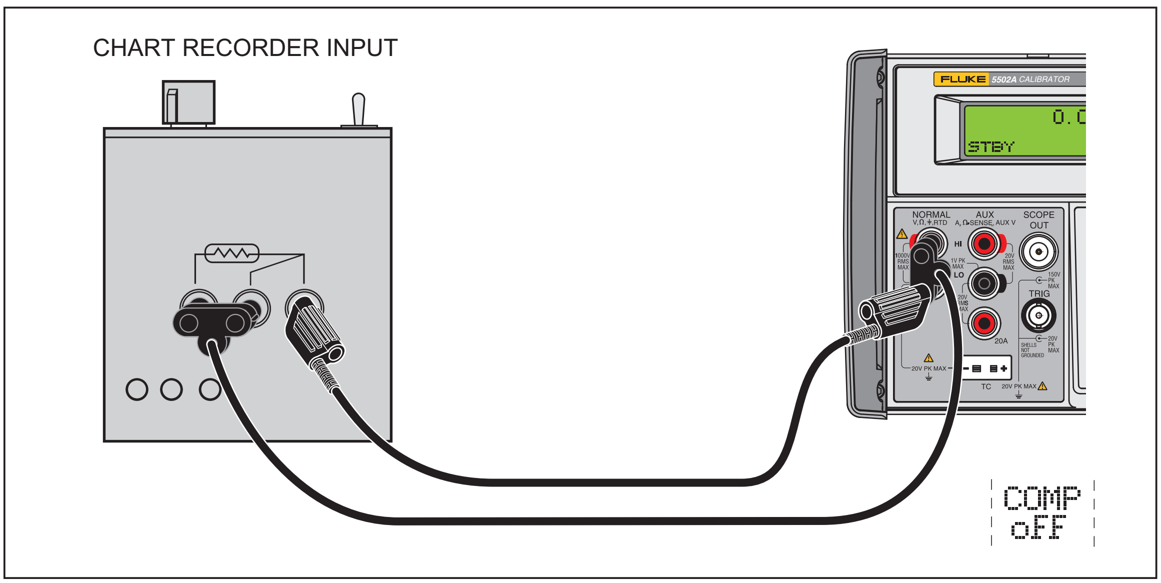
gvx019.eps

Figure 4-7. UUT Connection: DC Voltage/AC Voltage



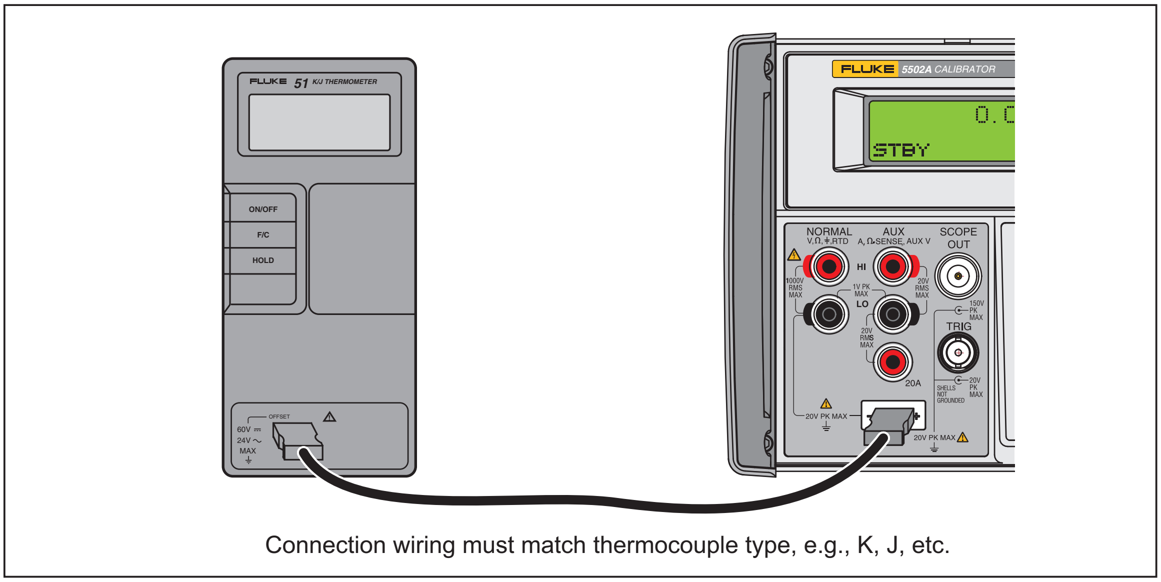
gvx020.eps

Figure 4-8. UUT Connection: DC Current/AC Current



gvx021.eps

Figure 4-9. UUT Connection: Temperature (RTD)



gvx022.eps

Figure 4-10. UUT Connection: Temperature (Thermocouple)

RMS Versus p-p Amplitude

The Calibrator ranges for sinusoidal ac functions are specified in rms (root-mean-square, the effective value of the wave form). For example, 1.0 to 32.999 mV, 33 to 329.999 mV, 0.33 to 3.29999 V, etc. The sine wave outputs are in rms, while the triangle wave, square wave, and truncated sine wave outputs are in p-p. The relationship between p-p and rms for the non-sine wave types are:

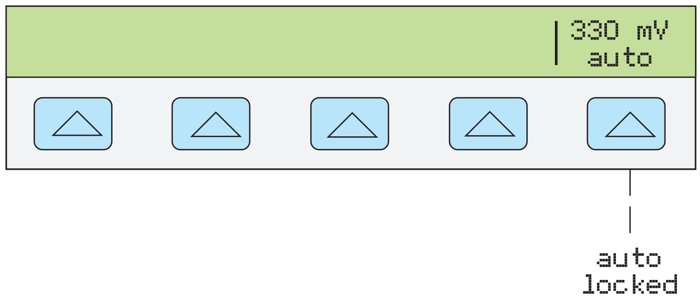
- Square wave p-p x 0.5000000 = rms
- Triangle wave p-p x 0.2886751 = rms
- Truncated Sine wave p-p x 0.2165063 = rms

While the ac function ranges are compatible for sine waves, the rms content of the other waveforms is less apparent. This quality leads to subtle Calibrator range changes. For example, if you record a sine wave voltage of 6 V (rms assumed), the selected range is 3.3 to 32.9999 V. If you then use the softkeys to change from a sine wave to a triangle wave, for example, the display changes from 6 V rms to 6 V p-p. This translates to 6 V p-p x 0.2886751 = 1.73205 V rms, and the range switches to 0.33 to 3.29999 V. The Output Display shows the range change because the sine wave voltage is shown as 6.0000, the resolution for the 3.3 to 32.9999 V range, while the triangle wave is shown as 6.00000, the resolution for the 0.33 to 3.29999 V range.

You must know the range in operation to record the correct values for voltage offset because the maximum offsets are specified to the range. For example, the maximum peak signal for the 3.3 to 32.9999 V range is 55 V while the maximum peak signal for the 0.33 to 3.29999 V range is 8 V. This means in the example above, the 6 V rms sine wave could have offsets applied to a maximum peak signal of 55 V because the current range is 3.3 to 32.9999 V, while the 6 V p-p triangle wave could have offsets applied to a maximum peak signal of 8 V because the current range is 0.93 to 9.29999 V. See “Specifications” in Chapter 1 and “Record a DC Offset” in this chapter for more about dc offset voltages.

Auto Range Versus Locked Range

A softkey is supplied to toggle between the ranging methods auto or locked. This feature is available only for single-output dc volts and dc current outputs.



nn063f.eps

When you select auto (the default), the Calibrator automatically selects the range that gives the best output resolution. When you select locked, the Calibrator locks the selected range and will not change ranges when you edit the output, or record new outputs. Values lower or higher than the locked range are not permitted. The locked selection is typically made to prevent range changes that can cause a small perturbation in the output, for example, when you measure the linearity of a given multimeter range.

Set Output

To set the Calibrator output, push the keys for the necessary values and then push a units key to identify which of the volts, amps, hertz, etc., that the values are for. The control display shows the value and units you select as you type them into the Calibrator. When you are satisfied with the value and units, push ENTER. If the output display shows STBY, push OPR to output the selection. A small "u" (unsettled) in the Output Display shows that the Calibrators internal circuitry must become stable.

For example, to set the output to 10 V dc, push:

1 → 0 → dBm V → ENTER → OPR

To set the output to 20 V ac at 60 Hz push:

2 → 0 → dBm V → 6 → 0 → sec Hz → ENTER → OPR

To change the output to dc, push:

0 → sec Hz → ENTER or +/- → ENTER

Step-by-step procedures are given for each output function:

- DC voltage
- AC voltage
- DC current
- AC current
- DC power
- AC power
- Dual DC voltage
- Dual AC voltage
- Capacitance
- Temperature - RTD
- Temperature - Thermocouple
- Resistance

Set DC Voltage Output

Do these procedures to set a dc voltage output from the front-panel NORMAL terminals. If you make an entry error, push CE to clear the display, then record the value again.

⚠ Caution

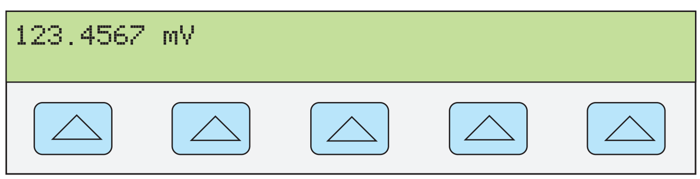
To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

1. Push RESET to clear outputs from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.
3. Set the UUT to measure dc voltage on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum seven numeric keys). For example, 123.4567.

Note

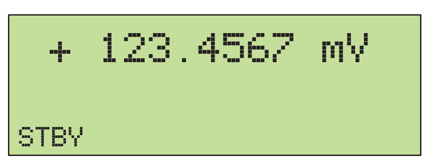
At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.

5. Push +/- to select the polarity of the voltage (default is +)
6. Push a multiplier key, if necessary. For example, push µ m.
7. Push dBm V.
8. The Control Display shows the amplitude of your entry. For example, 123.4567 mV (see below).



nn071f.eps

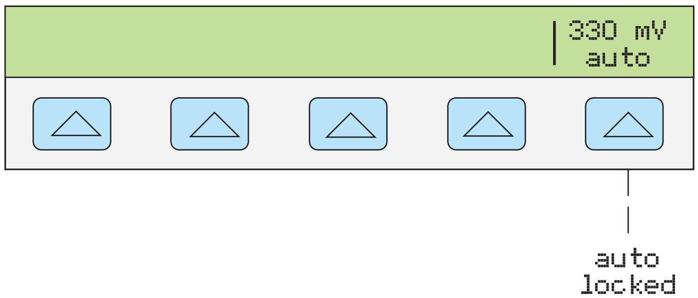
9. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn072f.eps

10. Push OPR to turn on the Calibrator output.

    A softkey name for range is shown on the Control Display in the dc voltage function:



Range (Operating Range) selects autorange (auto) or lock (locked) for the current range. When auto (the default) is selected, the Calibrator automatically selects the range that gives the best output resolution. When locked is selected, the Calibrator will not change ranges when you edit the output. The locked selection is typically made to prevent range changes that can cause a small agitation in the output, for example, when you measure the linearity of a given multimeter range.

Set AC Voltage Output

You can select an ac voltage output in volts or as a power output in dBm, where dBm is 10 log (Pout/.001), where Pout is shown in watts. The output range is 1 mV to 1000 V. When you select dBm outputs, the Calibrator calculates dBm at a selected impedance level. For this instance, the formula is:

20 log(V) - 10 log(Impedance * .001) = dBm.

Do this procedure to set an ac voltage output at the front panel NORMAL terminals. If you make an entry error, push CE to erase the display, then record the value again.

⚠ Caution

To prevent damage to the UUT, makes sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

1. Push RESET to clear output from the Calibrator.
1. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
2. Set the UUT to measure ac voltage on the necessary range.

   Output in volts:

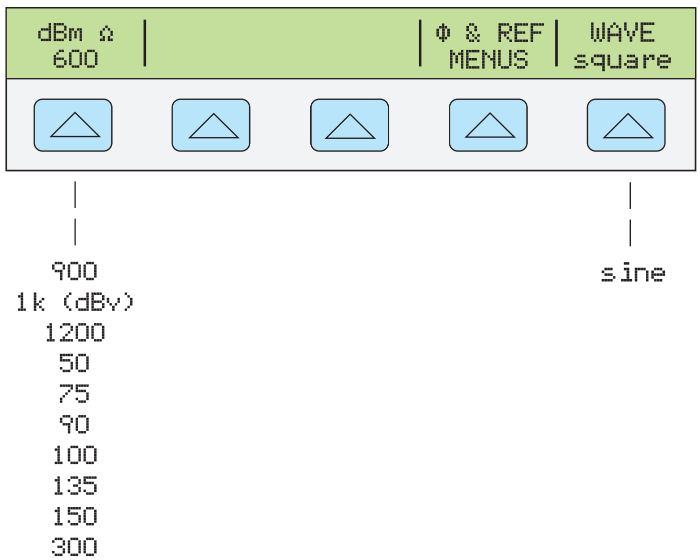
   Push the numeric keys and decimal point key to record the necessary voltage output (maximum six numeric keys). For example, 2.44949.

Output in dBm:

Push the numeric keys and decimal point key to record the necessary power output (maximum six numeric keys). For example, 10.0000. For a power output less than 1 mW (negative dBm values), push **+/-** to append the numeric entry with the negative (–) symbol.

When you push the dBm key, the right-most softkey turns on. This lets the dBm value and output impedance to be recorded as a unit.

When output is recorded in dBm, the Control Display changes to:



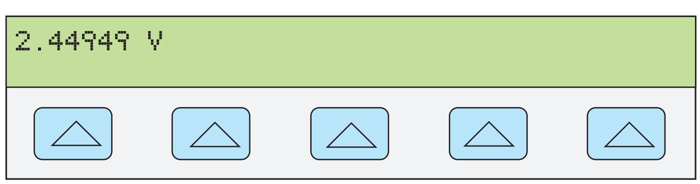
nn227f.eps

Note

At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.

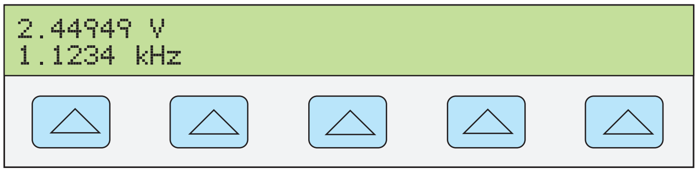
1. Push a multiplier key, if necessary. For example, push **μ m**.
2. Output in volts. Push **dBm V**.

   Output in dBm. Push **SHIFT** **dBm V**. Select an impedance for dBm from a list on the Control Display with the right-most softkey.
3. The Control Display shows the amplitude of your entry. For example, 2.44949 V (see below).



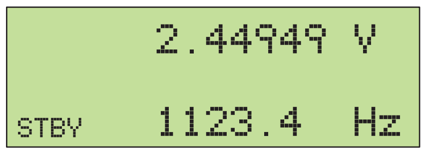
nn073f.eps

4. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key k. Then push the Hz key. For example, 1.1234 kHz (see below).



nn074f.eps

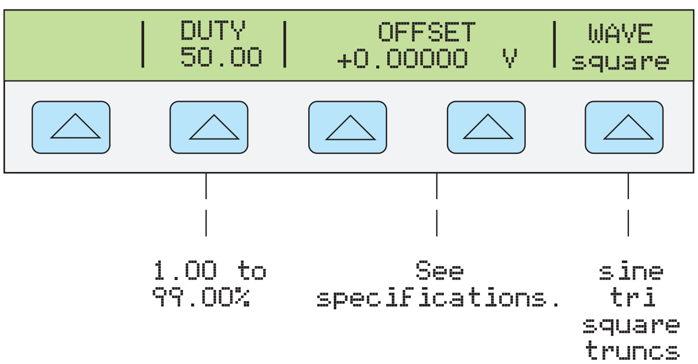
5. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn075f.eps

6. Push OPR to start the Calibrator output.

   Software names are shown on the Control Display in the ac voltage function, in reference to which waveform is selected: DUTY, OFFSET and WAVE.



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- **DUTY** (Duty Cycle) When the square wave is selected, DUTY shows and lets you change the duty cycle of the square wave. The range is 1.00 % to 99.00 %. The default is 50.00 %. The duty cycle must be 50.00 % if it is necessary to record an OFFSET (see below).
- **OFFSET** (Voltage Offset) shows when the necessary output is less than 33 V (sine waves), 65 V (square waves) or 93 V (triangle waves and truncated sine waves). This softkey lets you to add a positive or negative dc offset voltage to the ac output signal. See “Record a DC Offset” in this chapter for more information. When a voltage output is shown in dBm, voltage offset is not available. You can record an offset for a square wave output only when the duty cycle is 50.00 % (see DUTY above).
- **WAVE** (Waveform) lets you select one of four different types of waveforms: sine wave, triangle wave, square wave, and truncated sine wave. (See “Waveform Types” in this chapter). When a non-sinusoidal waveform is selected, the Output Display shows Pp (p-p). Output in dBm is sine wave only.

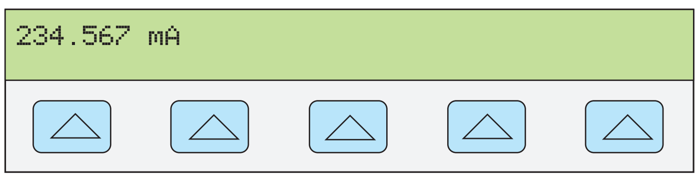
Set DC Current Output

Do the subsequent procedure to set a dc current output between AUX HI and LO or AUX 20A and LO. Choose the inputs for the current level selected. Current larger than ±3 A is sourced between the AUX 20A and LO terminals. If you make an entry error, push CE to clear the display, and then record the value again.

Note

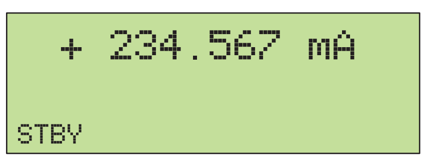
See the "Specifications" section in Chapter 1 for a chart that shows duration or duty-cycle limits for current larger than 11 A. If the Calibrator goes above the duration or duty cycle, the Calibrator will turn off. After a cool-off period, the Calibrator changes to usual operation.

1. Push RESET to clear output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.
3. Set the UUT to measure dc current on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
5. Push +/- to select the polarity of the current (default is +).
6. Push a multiplier key, if necessary. For example, μ m.
7. Push W A.
8. The Control Display shows the amplitude of the entry. For example, 234.567 mA.



nn077f.eps

9. Push ENTER. The Calibrator removes the entry from the Control Display and copies it into the Output Display (below is typical).



nn078f.eps

10. Push OPR to start the Calibrator output.

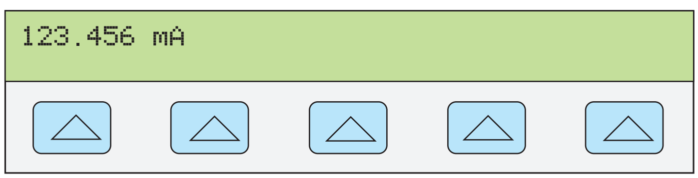
A range softkey is shown on the Control Display in the dc current function (operating range). This selects autorange (auto) or lock (locked) for the given range. When auto (the default) is selected, the Calibrator automatically selects the range that gives the best output resolution. When locked is selected, the Calibrator will not change ranges when you edit the output. The locked selection is typically made to prevent range changes that can cause a small agitation in the output, for example, when you measure the linearity of a given multimeter range.

A different softkey shows: OUTPUT. When you select 20 A for this parameter, or you select a current more than 3 A, the Calibrator switches to standby, and you must change the test lead to the 20A terminal and push OPR to activate the output.

Set AC Current Output

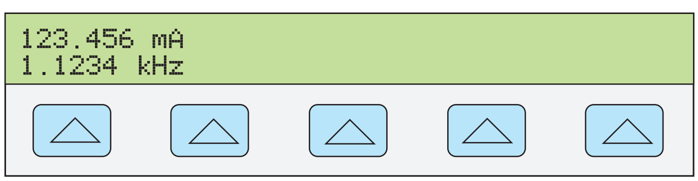
Do the subsequent procedure to set an ac current output at the AUX or 20A terminals. If you make an entry error, push CE to clear the display, then reenter the value.

1. Push RESET to clear any output from the Calibrator,
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
3. Set the UUT to measure ac current on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 123.456.
5. Push a multiplier key, if necessary. For example, push µ m.
6. Push W A.
7. The Control Display shows the amplitude of your entry. For example, 123.456 mA (see below).



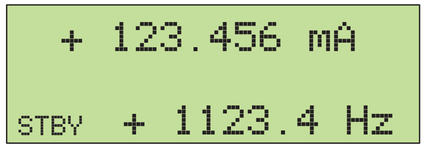
nn079f.eps

8. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key n k. Then push the sec Hz key. For example, 1.1234 kHz (see below).



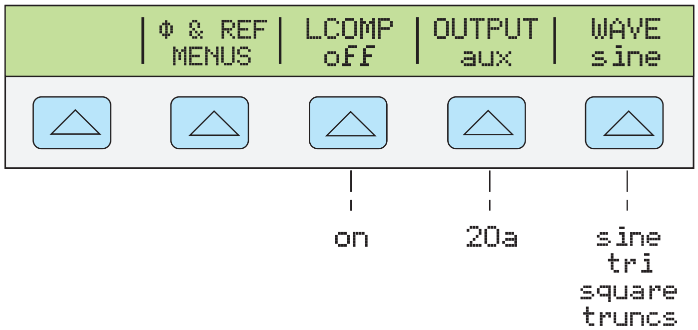
nn080f.eps

9. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn081f.eps

10. Push OPR to activate the Calibrator output.



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- **LCOMP** turns inductive compensation on and off. Inductive compensation is available for frequencies to a maximum of 1 kHz at outputs to a maximum of 239.999 mA, and for frequencies to a maximum of 440 Hz more than 239.999 mA.
- **OUTPUT** shows if the output is on the AUX or 20A terminals. Outputs 3 A or above are always on the 20A terminals.
- **WAVE** (waveform) selects one of four different types of waveforms: sine wave, triangle wave, square wave, and truncated sine wave. (See "Waveform Types" later in this chapter for more information). When a non-sinusoidal waveform is selected, the Output Display changes the RMS indication to p-p (P_P).

Set DC Power Output

Note

Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the "LO"s softkey selection "tied."

The Calibrator makes a dc power output by sourcing a dc voltage on the NORMAL outputs and a dc current on the AUX outputs. Complete the subsequent procedure to set a dc power output. If you make an entry error, push CE one or more times to clear the display, then reenter the value.

⚠ Caution

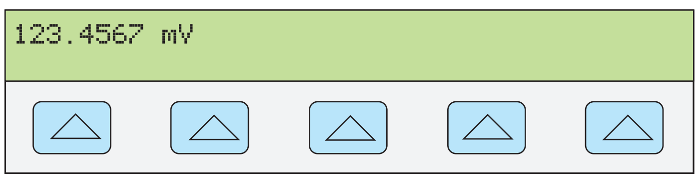
To prevent damage to the UUT, makes sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter. Change the voltage and current connections to this procedure.
3. Set the UUT to measure dc power on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum seven numeric keys). For example, 123.4567.

Note

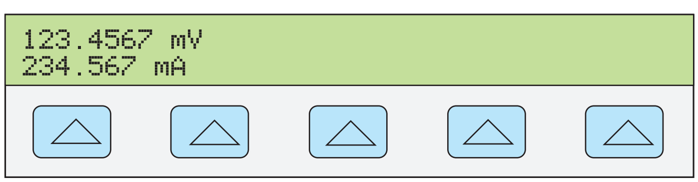
At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.

5. Push +/- to select the polarity of the voltage (default is +).
6. Push a multiplier key, if necessary. For example, push μ m.
7. Push dBm V.
8. The Control Display shows the amplitude of your entry. For example, 123.4567 mV (see below).



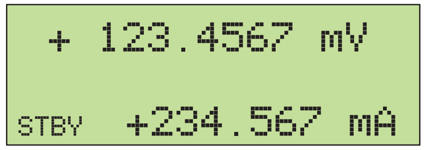
nn071f.eps

9. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
10. Push +/- to select the polarity of the current (default is +).
11. Push a multiplier key, if necessary. For example, push μ m.
12. Push W A.
13. The Control Display shows the amplitude of your entries. For example, 123.4567 mV and 234.567 mA (see below).



nn082f.eps

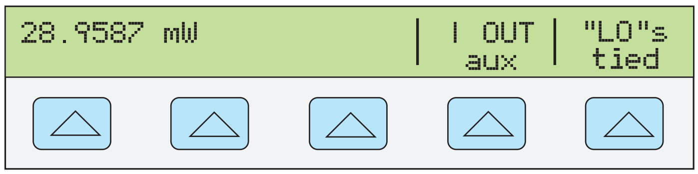
14. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn083f.eps

15. Push OPR to activate the Calibrator output. When you change the power output levels, you must reenter voltage and current (in either order).

(Record voltage or current and then a watts entry value with SHIFT W A. The remaining volts or current value is calculated and displayed.)



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- **I OUT** selects AUX or 20A terminals. Current outputs 3 A or above are always on the 20A terminals.
- **"LO"s** ties or opens a connection between front panel NORMAL LO and AUX LO terminals. The front panel NORMAL LO and AUX LO terminals must be tied together at the UUT or at the Calibrator. The default is tied.

Set AC Power Output

Note

Tie the terminals NORMAL LO and AUX LO together at the UUT, or at the Calibrator with the "LO"s softkey selection "tied." For optimum phase performance, tie the LO terminals at the UUT. At current levels >2.2 A, tie the terminals at the UUT. Use heavy gauge wire >10 mΩ resistance.

The Calibrator makes an ac power output by sourcing an ac voltage on the NORMAL outputs and an ac current on the AUX outputs.

See "Set AC Voltage Output" in this chapter for information about ac voltage output in dBm. This procedure that the ac voltage output is in volts.

Complete the subsequent procedure to set an ac power output. If you make an entry error, push CE one or more times to clear the display, then reenter the value.

⚠ Caution

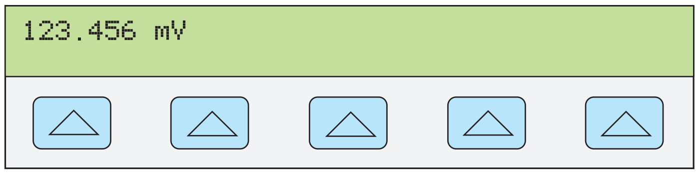
To prevent damage to the UUT, makes sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

1. Push RESET to erase output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter. (Change the voltage and current connections to suit your application.)
3. Set the UUT to measure ac power on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum six numeric keys). For example, 123.456.

Note

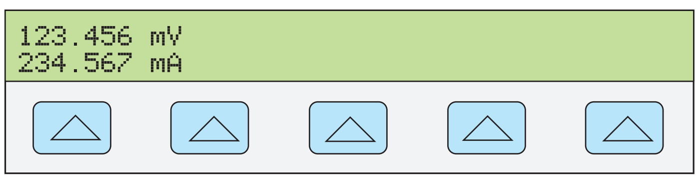
At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.

5. Push a multiplier key, if necessary. For example, push μ m.
6. Push dBm V.
7. The Control Display shows the amplitude of your voltage entry. For example, 123.456 mV (see below).



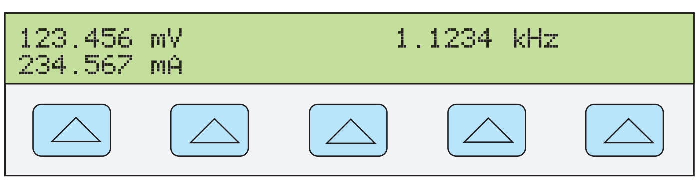
nn084f.eps

8. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
9. Push a multiplier key, if necessary. For example, push μ m.
10. Push W A.
11. The Control Display shows the amplitude of your voltage and current entries. For example, 123.456 mV and 234.567 mA (see below).



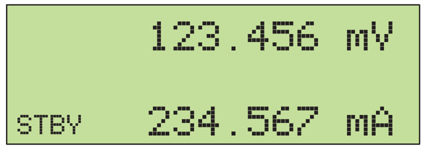
nn085f.eps

12. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key n k. Then push the sec Hz key. For example, 1.1234 kHz.
13. The Control Display shows your entries. For example, 123.456 mV and 234.567 mA at 1.1234 kHz (see below).



nn086f.eps

14. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).

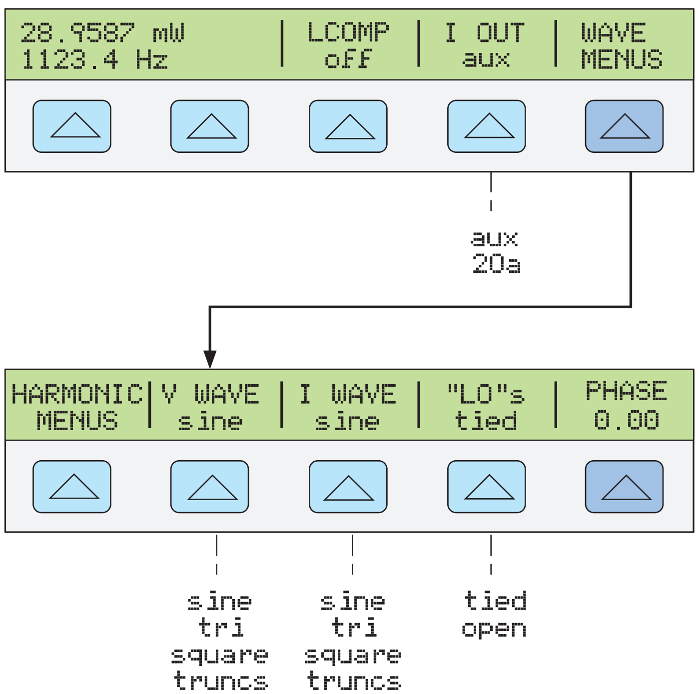


nn087f.eps

15. Push OPR to activate the Calibrator output. When you change power output levels, you must reenter voltage and current (in either order).

(Record voltage or current and then a watts entry value with ENTER W A. The remaining volts or current value is calculated and shown.)

Three softkey names show on the Control Display: WAVE MENUS, I OUT (AUX or 20A terminals), and LCOMP (off or on). The Control Display also shows the actual power output for sine waves. Power out is calculated as Power = Cosine Φ (Volts x Current) where Φ is the phase difference between the volts and current waveforms. Cosine Φ is also known as the Power Factor (PF) (see below)



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- **WAVE MENUS** (Waveform Menus) Opens submenus to select the type of harmonic, waveform, front panel LO terminal condition, and phase.
- **HARMONIC MENUS** (Harmonic Frequency Menus) Opens submenus to select harmonic outputs. See "Setting Harmonics" in this chapter.
- **V WAVE** (Voltage Waveform) Selects the waveform for the voltage output at the NORMAL terminals. See "Waveform Types" in this chapter.

- **I WAVE** (Current Waveform) Selects the waveform for the current output at the front panel AUX terminals. See "Waveform Types" in this chapter.
- **"LO"s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When tied at the UUT, select "open." The default is tied.
- **PHASE** Sets the phase difference between the NORMAL and AUX outputs. See "Adjusting the Phase" in this chapter.

Set a Dual DC Voltage Output

Note

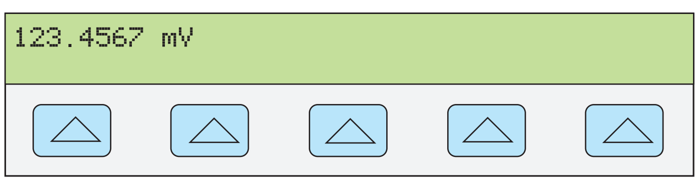
Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the "LO"s softkey selection "tied."

The Calibrator makes a dual dc voltage output by sourcing one dc voltage on the NORMAL outputs and a second on the AUX terminals. Complete the subsequent procedure to set a dual dc voltage output. If you make an entry error, push CE one or more times to clear the display, then enter the value again.

⚠ Caution

To prevent damage to the UUT, makes sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.
3. Set the UUT to measure dual dc voltage on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output at the NORMAL terminals (maximum seven numeric keys). For example, 123.4567.
5. Push +/- to select the polarity of the voltage (default is +).
6. Push a multiplier key, if necessary. For example, push μ m.
7. Push dBm V.
8. The Control Display shows the amplitude of your entry for the NORMAL terminals. For example, 123.4567 mV (see below).



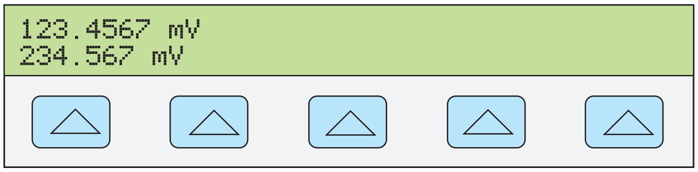
nn071f.eps

Note

Voltage on the AUX output is a maximum of 3.3 V.

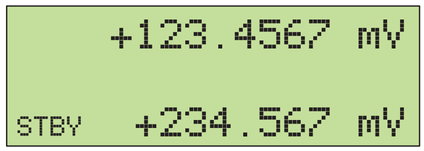
9. Push the numeric keys and decimal point key to record the necessary voltage output at the AUX terminals (maximum six numeric keys). For example, 234.567.
10. Push +/- to select the polarity of the voltage (default is +).
11. Push a multiplier key, if necessary. For example, push μ m.
12. Push dBm V.
13. The Control Display shows the amplitude of your entries for the NORMAL terminals

(upper reading) and AUX terminals (lower reading) (see below).



nn089f.eps

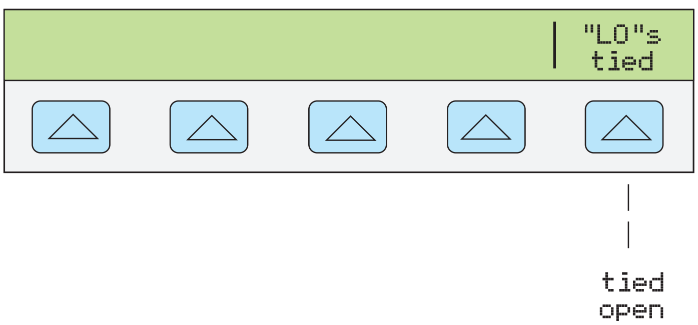
14. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn090f.eps

15. Push OPR to activate the Calibrator output.

A softkey named "LO"s shows on the Control Display (see below).



nn091f.eps

- **"LO"s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When the front panel NORMAL LO and AUX LO terminals are tied at the UUT, select "open" with the "LO"s softkey. If the NORMAL LO and AUX LO terminals are not tied at the UUT, select "tied" with the "LO"s softkey. The default is tied.

Set a Dual AC Voltage Output

Note

Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the "LO"s softkey selection "tied."

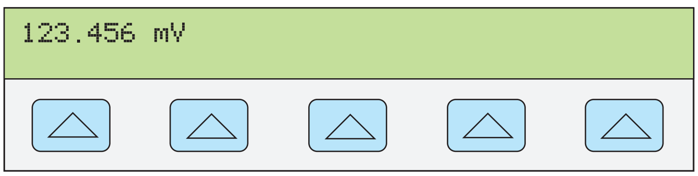
The Calibrator makes a dual ac voltage output by sourcing one ac voltage on the NORMAL outputs and a second on the AUX terminals.

Do the subsequent procedure to set a dual ac voltage output. If you make an entry error, push CE one or more times to clear the display, then enter the value again.

⚠ Caution

To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.

2. Push RESET to clear any output from the Calibrator.
3. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.
4. Set the UUT to measure dual ac voltage on the necessary range.
5. Push the numeric keys and decimal point key to record the necessary voltage output at the NORMAL terminals (maximum six numeric keys). For example, 123.456.
6. Push a multiplier key, if necessary. For example, push μ m.
7. Push dBm V.
8. The Control Display shows the amplitude of your voltage entry. For example, 123.456 mV (see below).

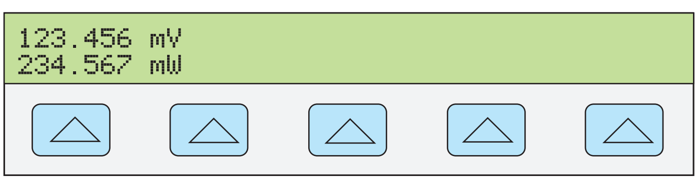


nn084f.eps

Note

The AUX output is 3.3 V rms maximum for sine waves, 6.6 V p-p for square waves, 9.3 V p-p for triangle and truncated sine waves.

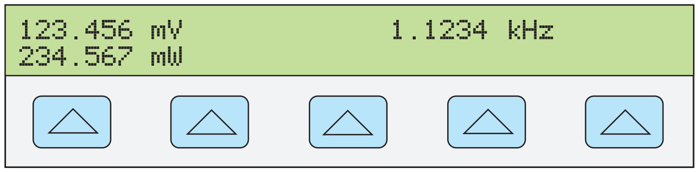
9. Push the numeric keys and decimal point key to record the necessary voltage output at the AUX terminals (maximum six numeric keys). For example, 234.567.
10. Push a multiplier key, if necessary. For example, push μ m.
11. Push dBm V.
12. The Control Display shows the amplitude of your entries for the NORMAL terminals (upper reading) and AUX terminals (lower reading) (below is typical).



nn092f.eps

13. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key n k. Then push the sec Hz key. For example, 1.1234 kHz.

14. The Control Display shows your voltage and frequency entries. For example, 123.456 mV and 234.567 mV at 1.1234 kHz (see below).



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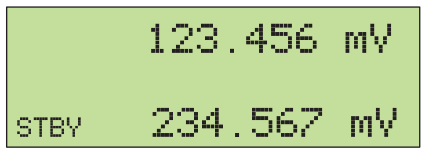
15. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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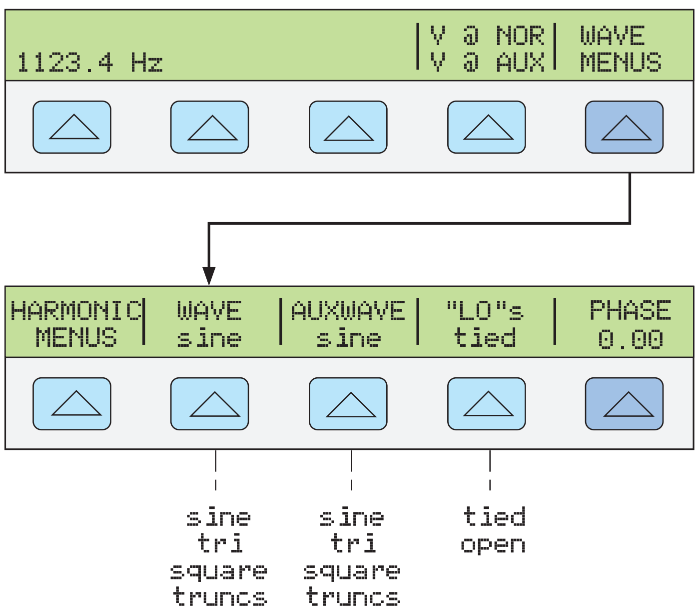
16. Push OPR to activate the Calibrator output.

Two softkey names show on the Control Display: V@NOR/V@AUX and WAVE MENUS (see below).



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- **V @ NOR** (Voltage at NORMAL Terminals) V @ AUX (Voltage at AUX Terminals) This is an information-only softkey position and does not have an related function. It shows the output function is dual ac voltage.

- **WAVE MENUS** (Waveform Menus) Opens submenus to select the type of harmonic, waveform, front panel LO terminal condition, and phase.
    - **HARMONIC MENUS** (Harmonic Frequency Menus) Opens submenus to select harmonic outputs. See "Set Harmonics" in this chapter.
    - **WAVE** (Normal Waveform) Selects the waveform for the voltage at the front panel NORMAL terminals. See "Waveform Types" in this chapter.
    - **AUXWAVE** (Auxiliary Waveform) Selects the waveform for the voltage at the front panel AUX terminals. See "Waveform Types" in this chapter.
    - **"LO"s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When the front panel NORMAL LO and AUX LO terminals are tied at the UUT, select "open" with the "LO"s softkey. If the NORMAL LO and AUX LO terminals are not tied at the UUT, select "tied" with the "LO"s softkey. The default is tied.
    - **Φ & REF MENUS** (Phase Difference and 10 MHz reference source.) Selects the phase difference between the NORMAL and AUX outputs, selects internal or external 10 MHz reference, and sets the phase difference between an external master 5502A (using 10 MHz IN/OUT) and the NORMAL output. See "Adjusting the Phase" and "Synchronizing the Calibrator using 10 MHz IN/OUT" in this chapter.

Set Resistance Output

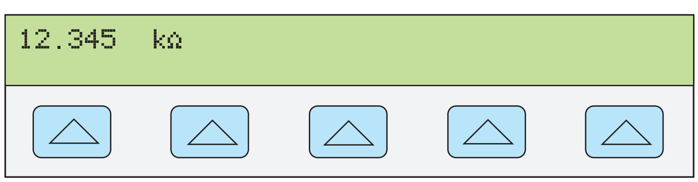
Complete the subsequent procedure to set a synthesized resistance output at the Calibrator front panel NORMAL terminals. If you make an entry error, push CE to clear the display, then enter the value again.

1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.

Note

Since this is a synthesized output, be sure the terminal connections from the Calibrator to the UUT are LO to LO and HI to HI.

3. Set the UUT to measure resistance on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary resistance output (maximum six numeric keys). For example, 12.345.
5. Push a multiplier key, if necessary. For example, push n k.
6. Push Ω.
7. The Control Display shows the amplitude of your resistance entry. For example, 12.345 kΩ (see below).



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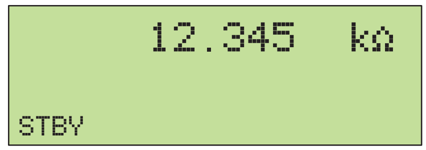
8. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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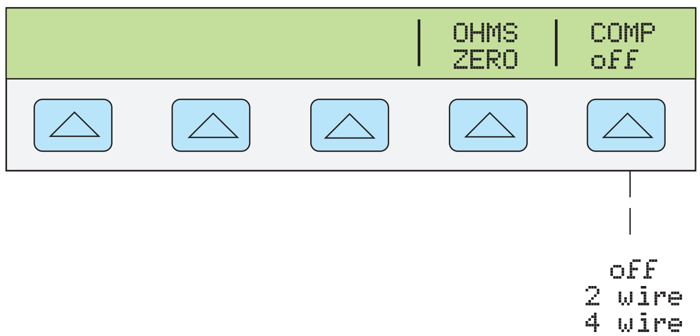
9. Push OPR to start the Calibrator output.

The softkeys let you select three lead-compensation settings and ohms zero (see below).



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- **OHMS ZERO** Push to recalibrate internal circuitry for the ohms function (allow several minutes).
- **COMP** (Compensation) Applies 4-wire compensation, 2-wire compensation or turns compensation off. Compensation is available for resistances to (but not including) 110 kΩ. See "Four-Wire versus Two-Wire Connections" in this chapter.

Set Capacitance Output

Complete the subsequent procedure to set a synthesized capacitance output at the front panel NORMAL terminals. If you make an entry error, push CE to clear the display, then reenter the value.

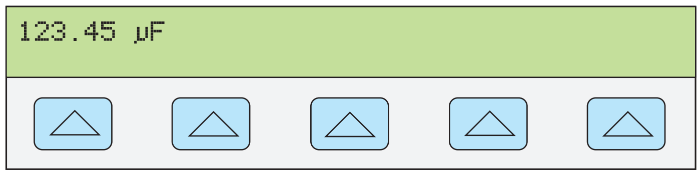
1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter. Also see "Cable Connection Instructions" for a procedure to null out stray capacitances due to the test cable connections.

Note

Since this is a synthesized output, be sure the terminal connections from the Calibrator to the UUT are LO to LO and HI to HI.

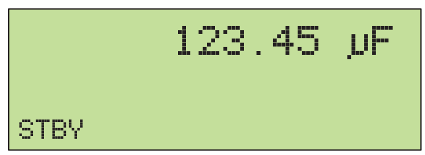
3. Set the UUT to measure capacitance on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary capacitance output (maximum five numeric keys). For example, 123.45.

5. Push a multiplier key (preceded with the SHIFT key) for the necessary output. For example, push SHIFT then μ m for μF. The other multiplier keys include p M for pF and n k for nF.
6. Push F ÷.
7. The Control Display shows the amplitude of your capacitance entry. For example, 123.45 μF (see below).



nn099f.eps

8. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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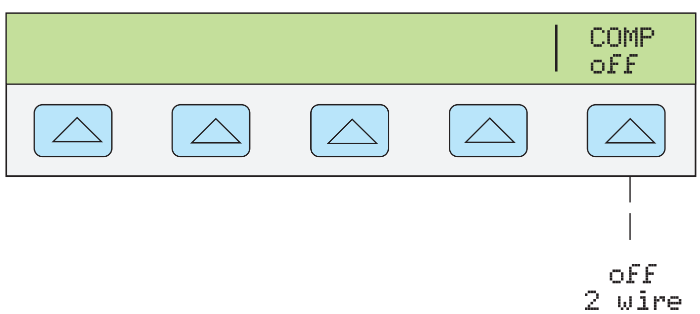
9. Push OPR to activate the Calibrator output.

The softkey in the Control Display named COMP lets you select one of three lead-compensation settings (see below).



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- **COMP** (Compensation). Applies 2-wire compensation or turns compensation off. Compensation refers to methods of connection the Calibrator to the UUT to cancel out test lead resistance (NOT capacitance). Compensation is available for capacitances of 110 nF and above. This softkey does not function in less than 110 nF. See “Four-Wire versus Two-Wire Connections” in this chapter.

Set Temperature Simulation (Thermocouple)

Note

Thermocouples have no electrical isolation. Make sure the thermocouple wire and plug are not changed by extraneous temperature sources. For example, do not put your fingers on the thermocouple plug or wire when you simulate a temperature.

Thermocouples generate a small dc voltage at specific temperatures. The simulated output is a small dc voltage that comes from the selected temperature and type of thermocouple that is simulated. To toggle the temperature reference between the 1968 International Provisional Temperature Standard (ipts-68) and the 1990 International Temperature Standard (its-90), see “Use the Instrument Setup Menu.”

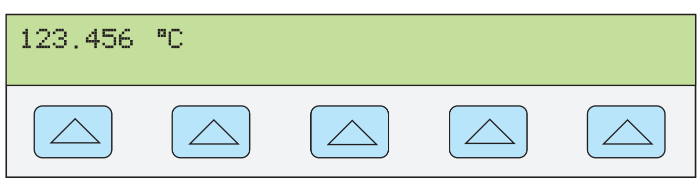
Complete the subsequent procedure to set a simulated thermocouple temperature output at the Calibrator front panel TC connector. If you make an entry error, push CE to clear the display, then enter the value again.

1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.

Note

You must use thermocouple wire and miniconnectors that agree with the type of thermocouple. For example, if you simulate a temperature output for a type-K thermocouple, use type-K thermocouple wire and type-K miniconnectors.

3. Set the UUT to measure temperature on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary temperature output (maximum six numeric keys). For example, 123.456.
5. For an output in °C, push °F °C. For an output in °F, push and then °F °C.
6. The Control Display shows the amplitude of your temperature output. For example, 123.456 °C (see below).



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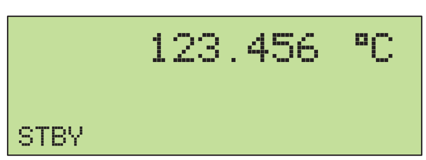
7. Push ENTER. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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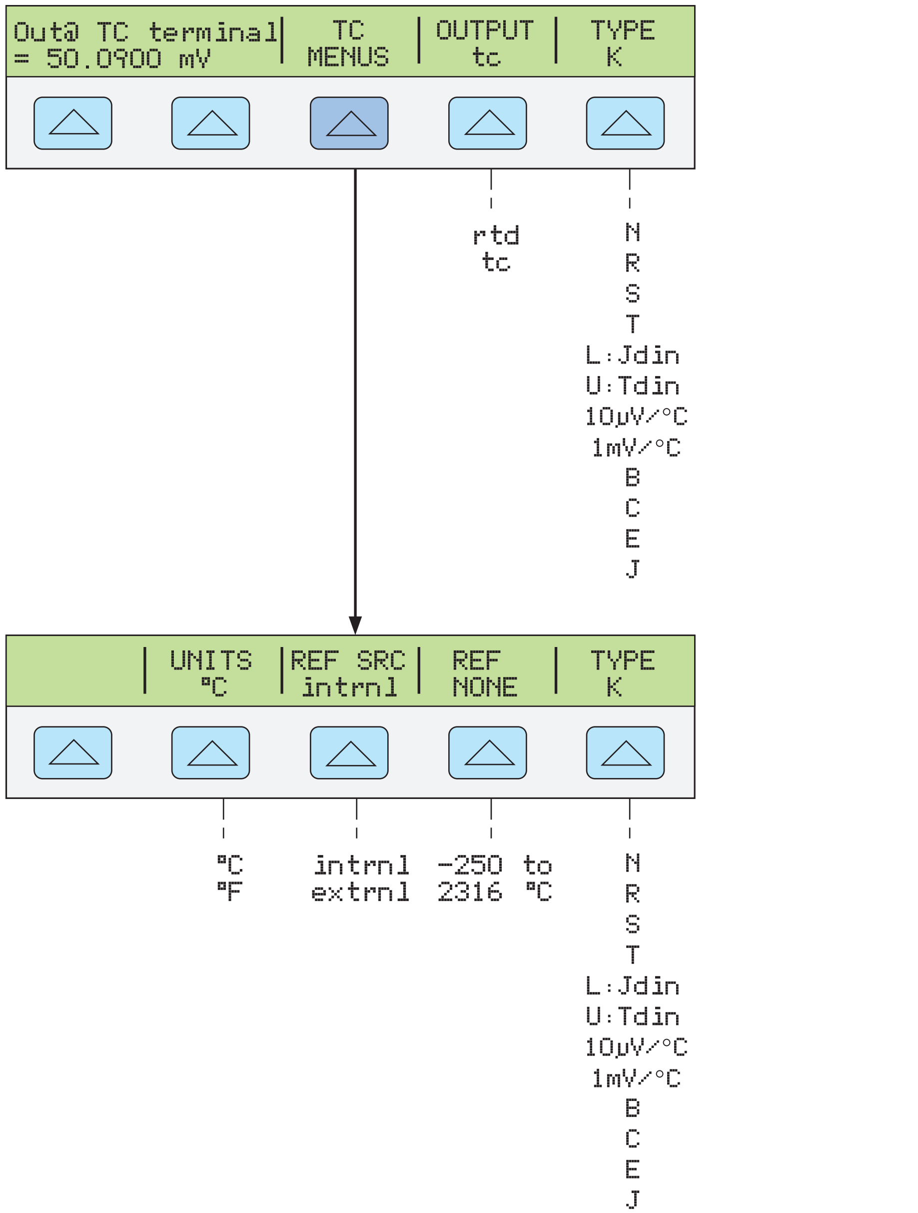
8. Push OPR to activate the Calibrator output. Four softkey names show on the Control Display (see below).

Note

The recorded temperature will be changed to 0 °C (32 °F) if you change between tc and rtd, or change the type of thermocouple (except for a type B thermocouple, which clears to 600 °C). If this occurs, select OUTPUT tc, the necessary thermocouple TYPE, and ten reenter the temperature.



- **Out@TC** terminal (Output at the front panel TC terminals) Shows the actual dc voltage at the front panel TC terminals. This is a display only, not a softkey function.
- **TC MENUS** (Thermocouple Menu) Shows submenus for thermocouple outputs.
  - **UNITS** (Temperature Units) Selects °C or °F as the temperature unit.
  - **REF SRC** (Reference Source) Selects intrnl (Internal) or extrnl (External) temperature reference source. Select intrnl when the selected thermocouple has alloy wires and you use the isothermal block internal to the Calibrator. Select extrnl when you use an external isothermal block, and when the selected thermocouple has copper wires. Push the REF softkey to record the value of the external temperature reference. The best accuracy is when you use extrnl and the external isothermal block is kept at 0 °C.
  - **REF** (Temperature Reference) Shows the value of the temperature reference. When the Reference Source is Internal, the display shows the internal reference, or NONE if the Calibrator is in Standby. When the Reference Source is External, the display shows the value you recorded for external reference.
  - **OUTPUT** (Temperature Output Device) Selects the temperature device: thermocouple (tc) or resistance temperature detector (rtd). Select tc.
  - **TYPE** (Thermocouple Type) Selects the thermocouple type simulated by the Calibrator. The default is type K. (The 10 µV/°C and 1 mV/°C settings are used as an accurate output voltage source for user-supplied linearizations.)

Note

The "u" indicator that occasionally shows in the Output Display shows an internal adjustment to the measured isothermal block temperature and is usual. If it shows for more than 10 seconds (nominal), or if it flashes continuously, make sure that you do not externally heat the thermocouple miniconnector or wires.

Set Temperature Simulation (RTD)

RTDs have a resistance quality at specified temperatures. The simulated output is a resistance value that comes from the selected temperature and type of RTD simulated. To toggle the degree reference between the 1968 International Provisional Temperature Standard (IPTS-68) and the 1990 International Temperature Standard (ITS-90), see "Use the Instrument Setup Menu" in this chapter.

Complete the subsequent procedure to set a simulated RTD temperature output at the front panel NORMAL terminals. If you make an entry error, push CE to clear the display, then enter the value again.

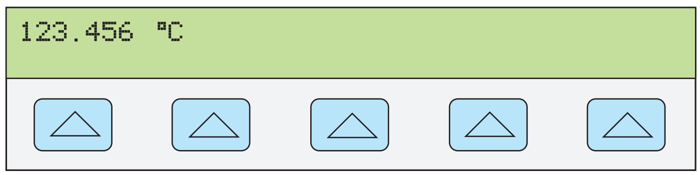
1. Push RESET to clear any output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter.

Note

When you calibrate Resistance Temperature Detectors (RTDs) with the three-terminal connection shown in Figure 4-9, make sure the test leads have the same resistances to cancel errors caused by lead resistance. This can be done, for example, with three of the same test lead lengths and the same connector styles.

3. Set the UUT to measure temperature in the necessary range.

4. Push the numeric keys and decimal point key to record the necessary temperature output (maximum six numeric keys). For example, 123.456.
5. For an output in °C, push [°F °C]. For °F, push [SHIFT] and then [°F °C].
6. The Control Display shows the amplitude of your temperature output. For example, 123.456 °C (see below).



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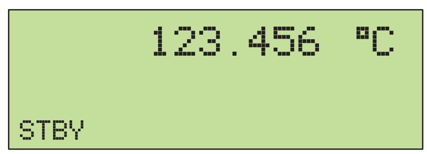
7. Push [ENTER]. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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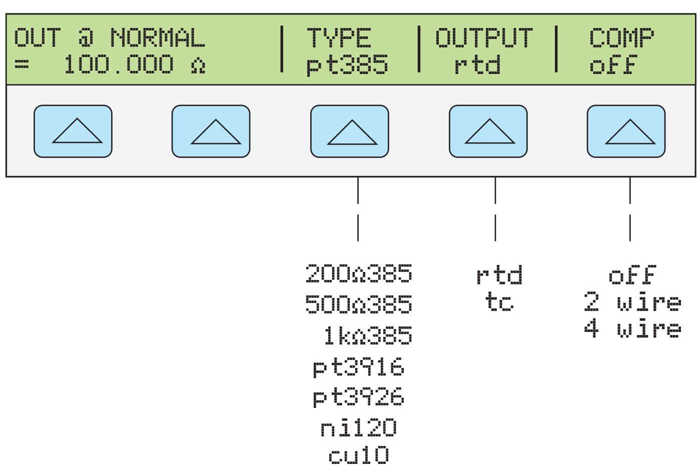
8. Push [OPR] to activate the Calibrator output.

Four softkey names show on the Control Display. Push the OUTPUT softkey to toggle the rtd selection, this shows the rtd setup menu and four softkey positions.

Note

The temperature you recorded above will be changed to 0 °C (32 °F) if you change between tc (thermocouple) and rtd (resistance temperature detector), or change the type of rtd. If this occurs, select OUTPUT rtd, the necessary rtd TYPE, and then record the temperature again. Follow steps 4 to 8.



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- **Out @ NORMAL** displays the location of the output terminals (always NORMAL) for rtd connections.
- **TYPE** (RTD Type) - Selects the rtd curve from a list.
- **OUTPUT** (Temperature Output Device) - Selects the temperature device: thermocouple (tc) or resistance temperature detector (rtd). Select rtd.
- **COMP** (Compensation) - Applies 4-wire compensation, 2-wire compensation or turns compensation off. Compensation refers to methods to connect the Calibrator to the UUT to cancel out test lead resistance. See "Four-Wire versus Two-wire Connections" in this chapter. For the 3-lead connection (Figure 4-9) select COMP off.

Measure Thermocouple Temperatures

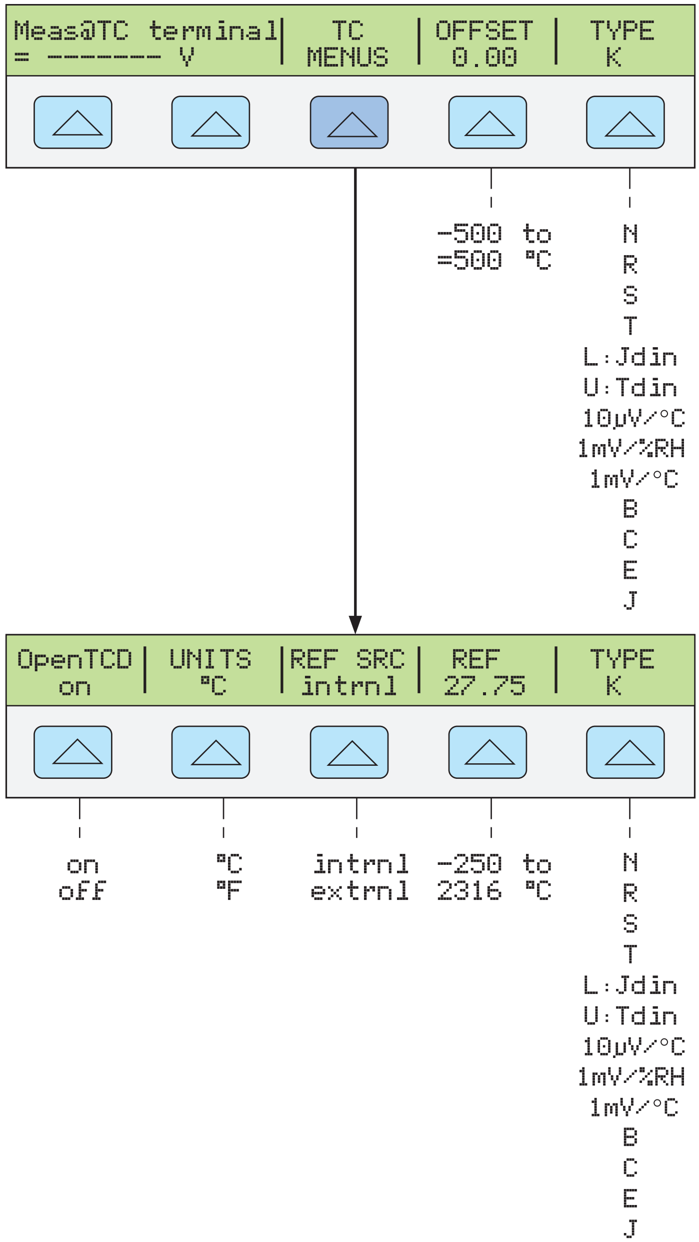
Complete the subsequent procedure to measure the output of a thermocouple connected to the TC input. If you make an entry error, push CE to clear the display, then reenter.

1. Push RESET to clear any output from the Calibrator.
2. Connect the thermocouple to the front panel TC connector.

Note

You must use thermocouple wire and miniconnectors that agree with the type of thermocouple. For example, if you simulate a temperature output for a type-K thermocouple, use type-K thermocouple wire and type-K miniconnectors.

3. Push [MEAS TC] to display the TC menus (see below).



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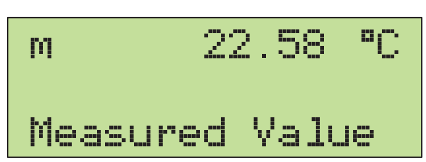
4. The measured temperature shows in the Output Display (below is typical). (The lower-case m blinks on when a measurement is being taken.)



nn107f.eps

- **Meas@TC** terminal (Measurement at the front panel TC terminals) Shows the actual dc voltage at the front panel TC terminals. This is a display only, not a softkey function.
- **TC MENUS** (Thermocouple Menus) Opens the thermocouple output submenus.
  - **Open TCD** (Open Thermocouple Detect) Selects on or off for the Open TCD feature. When Open TCD is on, a small electrical pulse checks for thermocouple continuity that, in most cases, will have no effect on the measurement. If you measure the thermocouple with the Calibrator in parallel with a different temperature-measure device, select off for Open TCD. When an open thermocouple is found, "Open TC" is shown in the TC menu as a positive identification of the fault.
  - **UNITS** (Temperature Units) Selects °C or °F as the temperature unit.
  - **REF SRC** (Reference Source) Selects intrnl (Internal) or extrnl (External) temperature reference source. The reference source shows the ambient temperature contribution to the thermocouple output, this is necessary to remember when you simulate an accurate temperature output. Select intrnl when the selected thermocouple has alloy wires and you use the isothermal block internal to the Calibrator. Select extrnl when you use an external isothermal block, and when the selected thermocouple has copper wires. Push the REF softkey to record the value of the external temperature reference.
  - **REF** (Temperature Reference) Shows the value of the temperature reference. When the Reference Source is Internal, the display shows the internal reference. When the Reference Source is External, the display shows the value you recorded for external reference.
  - **OFFSET** (Measurement Display Offset) Selects an offset value to be added or subtracted from the actual measurement. This is useful for differential measurements (temperatures above and below a necessary temperature).
  - **TYPE** (Thermocouple Type) Selects the thermocouple type used for measurement. The default is K. (The 10µV/°C setting is used for customer-supplied linearizations. 1 mV/%RH and 1 mV/°C settings are used for the Vaisala humidity/temperature probes.)

Waveform Types

AC voltage, ac current, dual ac voltage, and ac power functions supply a softkey to select between four different waveform types: sine wave (sine), triangle wave (tri), square wave (square), and truncated sine wave (truncs). When the Calibrator output is sine wave ac power or dual ac voltage, the Control Display shows more softkeys for harmonics and fundamental frequencies.

Sine Wave

When the wave selection is sine, a sine wave current or voltage signal is at the Calibrator outputs (Figure 4-11). The variables for the sine wave are amplitude, frequency, and dc offset voltage.

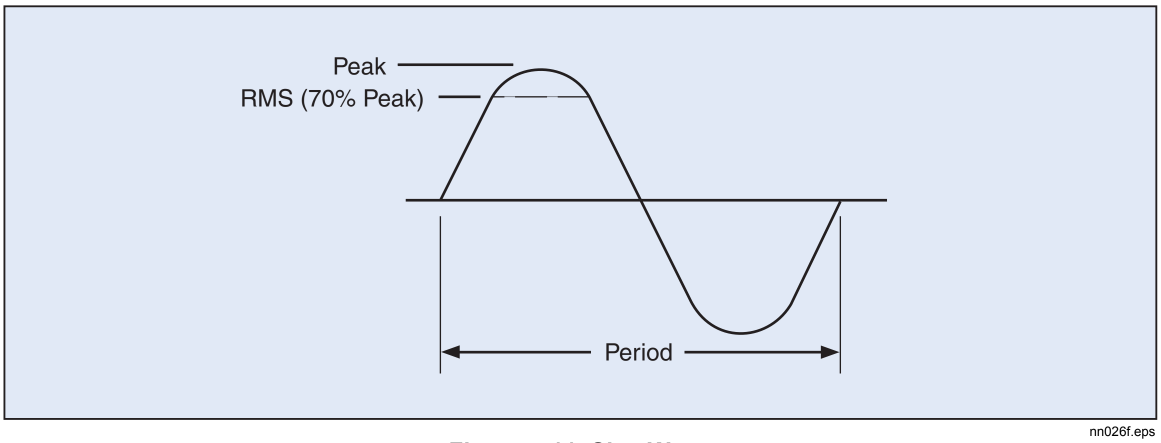


Figure 4-11. Sine Wave

Triangle Waves

When the wave selection is tri, the triangle wave is at the Calibrator outputs (Figure 4-12). The variables for the triangle wave are amplitude, frequency, and dc offset voltage. When a triangle wave is selected, the Output Display shows amplitudes in p-p units.

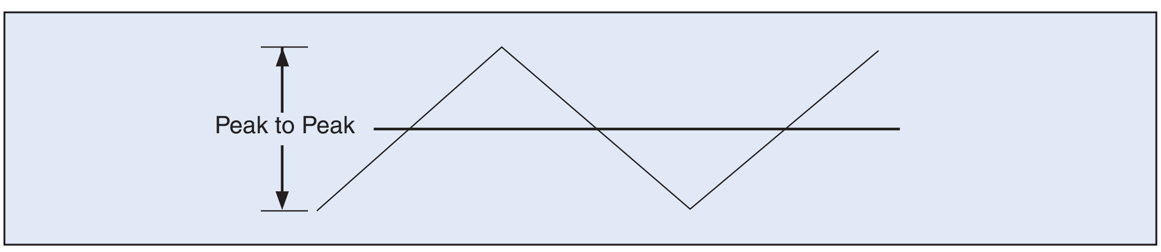


Figure 4-12. Triangle Wave

Square Wave

When the wave selection is square, a square wave current or voltage signal is at the Calibrator outputs (Figure 4-13). The variables for the square wave are duty cycle, amplitude, frequency, and dc offset voltage. When a square wave is selected, the Output Display shows amplitude in p-p units. If the Calibrator is set for one voltage or current output, the duty cycle of the signal can be set with the keypad. To record a new duty cycle, push the DUTY CYCLE softkey and a maximum of five numeric keys, then push ENTER. The negative-going edge of the square wave moves in relation to how the duty cycle is set.

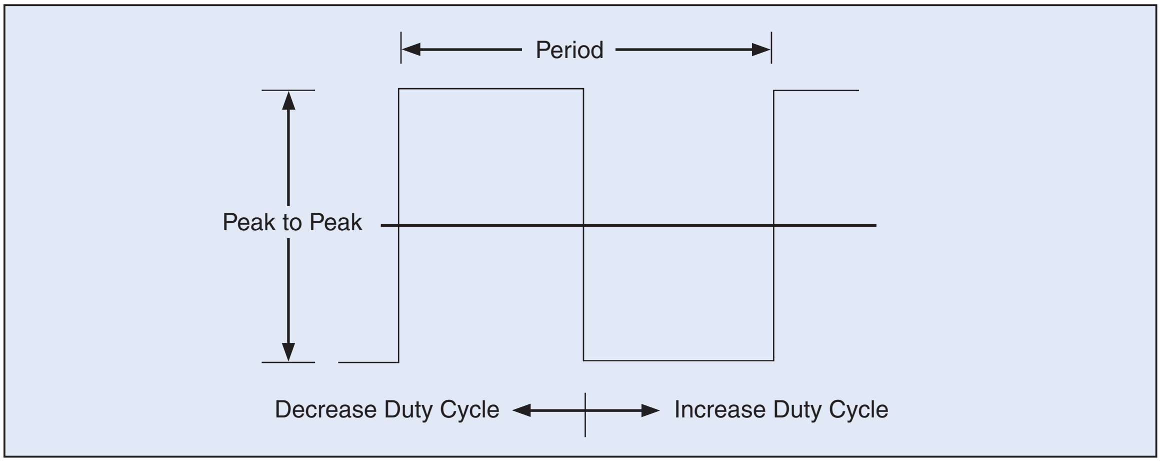


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Figure 4-13. Square Wave and Duty Cycle

Truncated Sine Wave

When the wave selection is truncs, a truncated sine wave current or voltage signal is at the Calibrator outputs (Figure 4-14). The variables for the truncated sine wave are amplitude and frequency. When a truncated sine wave is selected, the Output Display shows amplitudes in p-p units.

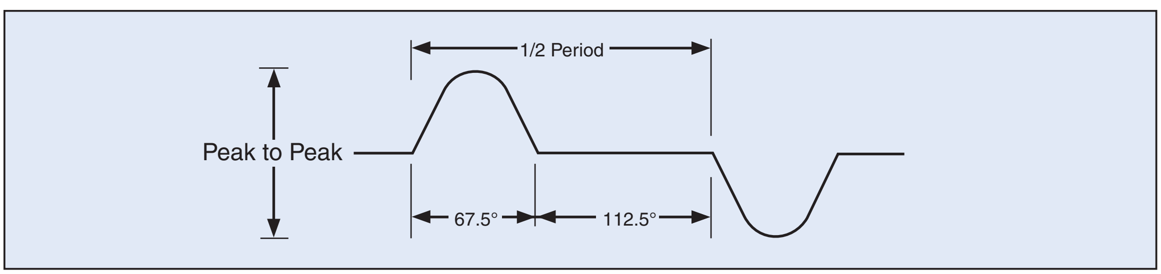

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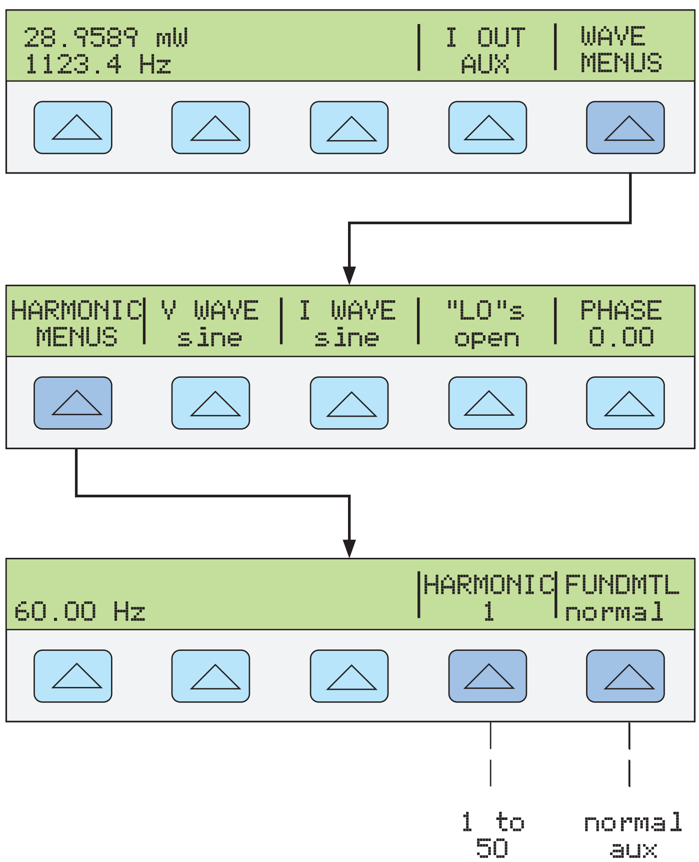
Figure 4-14. Truncated Sine Wav

Set Harmonics

When the Calibrator outputs dual ac voltages or ac power (sine waves only), the Calibrator sources two signals with adjustable harmonic difference, with a maximum harmonic frequency output of 10 kHz. For example, a 120 V, 60 Hz signal can be set on the front-panel NORMAL terminals, and a 1 V, 300 Hz (5th harmonic) output on the AUX terminals. The fundamental can be configured on the NORMAL or the AUX terminals, with the harmonic output on the opposite terminals. Note that the maximum AUX output is 3.3 V, while the maximum NORMAL output is 1000 V. Unless the fundamental and harmonic frequencies are permitted for the given amplitude, the output is not permitted.

Complete the subsequent procedure to record a harmonic output. For this procedure, you will have already sourced a dual ac voltage or ac power output.

1. Push the softkey WAVE MENUS to open the waveform menu.
2. Push the softkey HARMONIC MENUS to open the harmonic submenu (below is typical).



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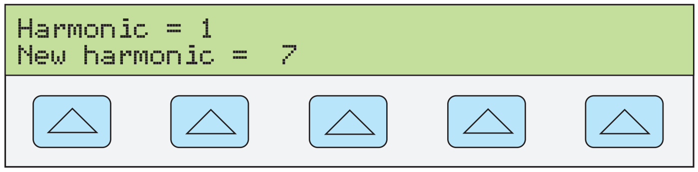
3. Push the softkey FUNDMTL to select the Calibrator front-panel terminals for the fundamental output (NORMAL or AUX). The harmonic shows on the AUX terminals.

4. Push the softkey HARMNIC to record the necessary harmonic (1 to 50), with a maximum frequency output of 10 kHz. For example, record the 7th harmonic (see below). When the control display shows the necessary value, push ENTER.



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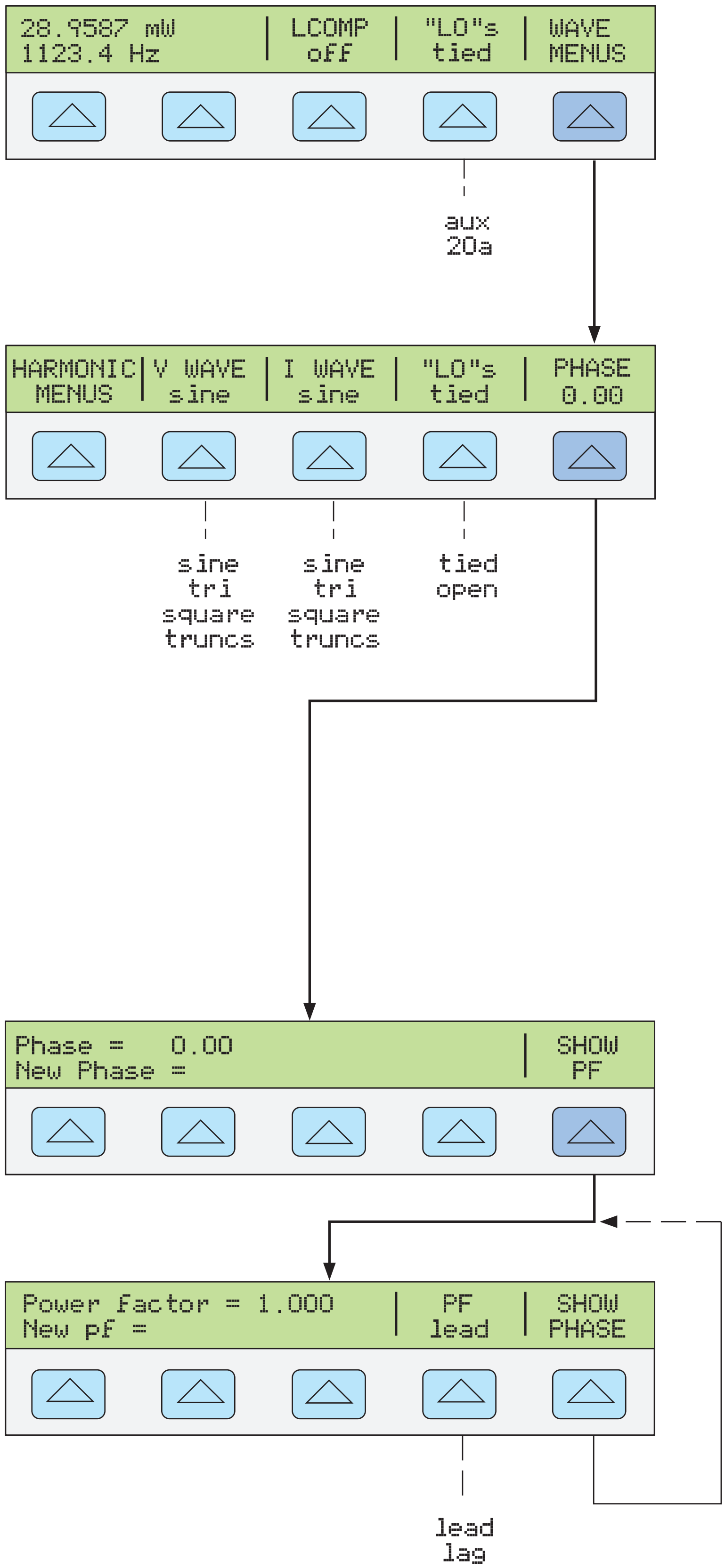
5. Push PREV MENU one or more times to return to previous menus.

Adjust the Phase

When in the dual ac voltage and ac power output modes, you can set the Calibrator to source two signals with adjustable phase difference. All phase adjustments move the AUX waveform in relation to the NORMAL waveform. Phase shift adjustments are recorded as degrees (0 to ±180.00) or as a power factor (PF). A leading or positive phase shift causes the AUX waveform to lead the NORMAL waveform. A lagging or negative phase shift causes the AUX waveform to lag the NORMAL waveform.

The softkey PHASE is available after you push the WAVE MENUS softkey that shows when outputting dual ac voltages or ac power (shown below for ac power output).



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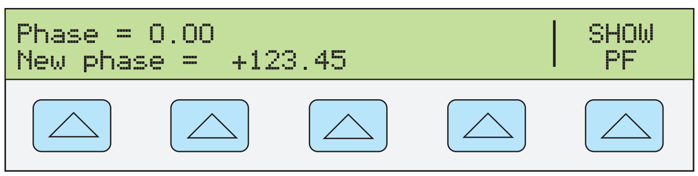
When one output is a harmonic of the other, the phase shift comes from the phase angle or power factor (cosine) of the harmonic signal. For example, when the AUX output is a 60-Hz signal, and the NORMAL output is a 120 Hz (2nd Harmonic) signal, a phase shift of 60 ° (PF of .5) moves the AUX signal 60 ° of 120 Hz (30 ° of 60 Hz).

Record a Phase Angle

If you have already sourced a dual ac voltage or ac power output, complete the subsequent procedure to record a phase shift in degrees.

1. Push the softkey WAVE MENUS to open the harmonic menu.
2. Push the softkey PHASE to open the phase entry menu.
3. Push the numeric keys and decimal point key to record the necessary phase angle (maximum five numeric keys). For example, 123.45.
4. Push **+/-** to select leading (+) or lagging (–) phase shift (default is +).
5. The Control Display shows the value of your entry. For example, a leading phase angle of 123.45 degrees (see below). (SHOW PF shows only for sine waves.)



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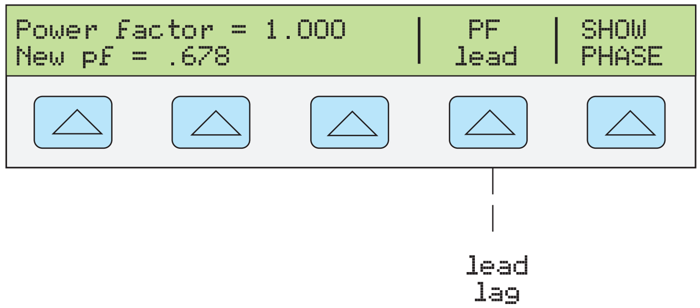
6. Push **ENTER**. The Calibrator erases your entry from the “New phase =” line and copies it to the “Phase =” line of the Control Display.
7. Push **CE** one or more times to return to previous menus.

Record a Power Factor

If you have already sourced a dual ac voltage or ac power output with sine waves as the waveform, complete the subsequent procedure to record a phase shift as a power factor (PF). PF = Cosine Φ, where Φ is the phase shift.

1. Push the softkey WAVE MENUS to open the waveform menu.
2. Push the softkey PHASE to open the phase entry menu.
3. Push the softkey SHOW PF to open the power factor entry menu.
4. Push the decimal point key and numeric keys to record the necessary power factor (maximum three numeric keys). For example, .678.
5. Push the softkey PF to toggle between a leading (lead) or lagging (lag) power factor (default is lead).
6. The Control Display shows the value of your entry. For example, a leading power factor of .678 (see below).



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7. Push ENTER. The Calibrator clears your entry from the "New pf=" line and copies it to the "Power Factor =" line of the Control Display.
8. Push PREV MENU one or more times to return to previous menus.

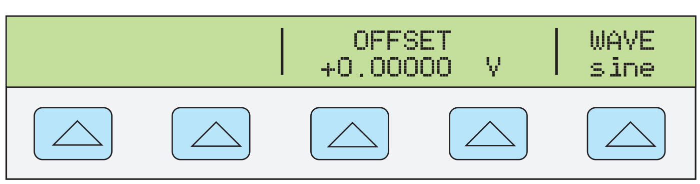
Record a DC Offset

When the Calibrator single output is an ac voltage of sine waves, triangle waves, square waves, or truncated sine waves, you can apply a +dc offset. When you apply an offset to square wave outputs, the duty cycle must be 50.00 % (default). The offset selection is recorded with the softkey OFFSET, which shows when the ac voltage output is less than 33 V (sine waves), 66 V p-p (square waves) or 93 V p-p (triangle waves and truncated sine waves). The softkey OFFSET will not show and offsets cannot be recorded when the output is a voltage sine wave measured in dBm.

The maximum offset value permitted is in relation to the maximum offset and maximum peak signal for each range. For example, a square wave output of 10 V p-p is in the range 6.6 V p-p to 65.9999 V p-p, a range with a maximum peak signal of 55 V. For this example, the square wave peak value is 5 V, this lets a maximum ±offset of 50 V for a maximum peak signal of 55 V.

Read the specifications in Chapter 1 for offset limits. If you use an offset voltage and you make the output move into a range where offset is not permitted (for example, above 33 V for a sine wave output), the Calibrator goes into the standby mode and the offset function will be disabled.

Complete the subsequent procedure to record a dc voltage offset. If you make an entry error, push CE to clear the display, then reenter the value. This procedure works if you have already sourced a single ac voltage output of a maximum of 33 V (sine waves), 65 V p-p (square waves) or 93 V p-p (triangle waves and truncated sine waves), this will show the softkey OFFSET (see below).



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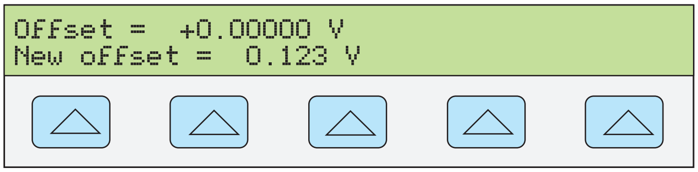
1. Push the softkey WAVE to select the necessary waveform: sine waves (sine), triangle waves (tri), square waves (square), or truncated sine wave (truncs).
2. Push the softkey OFFSET, opening the offset entry display. Record the necessary offset with the numeric keys and decimal point key. For example, 0.123 V (see below).



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3. Push the ENTER key to record the offset and then PREV MENU.

Edit and Error Output Settings

You can edit all Calibrator outputs with the front-panel Edit Field knob and ◀, ▶, and EDIT FIELD. Also, MULT X and DIV ÷ edit the output by decades. The difference in the initial output (reference) and edited output is shown as an "error" between the two positions. This lets you edit a value to get a correct measurement at the UUT and calculate an error in ±% or ppm (parts per million) if it is less than ±1000 ppm. Table 4-2 shows the actions that make the Calibrator exit the error mode and go to the initial reference output, or to output a new reference, as selected.

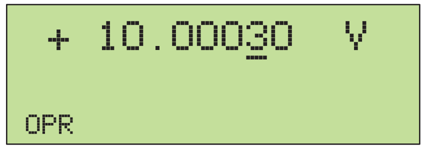
Table 4-2. Keys That Exit Error Mode

Keys	Action
ENTER	Shows to the reference value from before the current value.
+/- or ENTER	Establishes a new reference.
A new keypad entry + ENTER	Establishes a new reference.
NEW REF	Establishes the present output as a new reference.
MULT X	Sets the Calibrator to ten times the reference value and establishes a new reference.
DIV ÷	Sets the Calibrator to one-tenth the reference value and establishes a new reference.
RESET	Shows to the power-up condition.

Edit the Output Setting

When you initially source an output from the Calibrator, you record a value, for example, 10.00000 V dc. To edit the output value for your operation, turn the front-panel Edit Field knob clockwise to increase the value or counter-clockwise to decrease the value. (The Edit Field controls will not operate if you are in a setup function. Push PREV MENU one or more times to exit a setup function.)

To select a higher-order digit, use an Edit Field cursor key ◀ or ▶. The output digit in edit is always underlined (see below).



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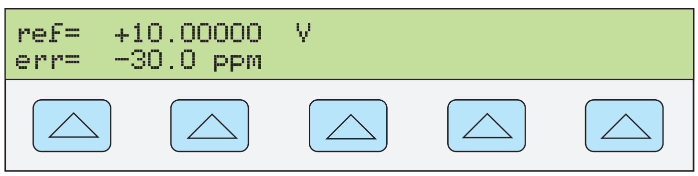
The short indication of the letter "u" on the Output Display when you edit during OPR (Operate) means "unsettled". The Calibrator output must become stable to a new value.

Show the UUT Error

When you edit the output value, the Control Display shows the difference in the reference value (the value you initially recorded) and the edit value (the value shown in the Output Display), shows the error difference in parts per million (ppm) or percent (%). For example, if ERR UNI is set to > 100 ppm, the error will be shown in ppm to a maximum of 99 and then the error will change to 0.0100 % at 100 ppm. This lets you edit the output so that the UUT shows the anticipated value and so give an indication of the UUT accuracy.



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For example, an edited difference of .00030 V for an output of 10.00000 V shows 0.00030/10.00000=0.000030, or 30 parts per million. The sign is negative (-30.0 ppm) because the output necessary to show 10.00000 at the UUT shows the UUT measurement is below the output value. When the reference is negative, the error sign is in relation to the magnitude. For example, if the reference is -10.00000 V and the output shown is -10.00030, the error is -30 ppm.

The Calibrator has two methods to show the UUT error. The first method is the "nominal" method that is used in the Fluke Calibration 5700A, 5720A, 5500A, 5520A, 5522A, and 5502A Calibrators. The second method is the "true value" method. Each method is used in this Calibrator.

The nominal method of error calculation uses the formula:

$$\frac{\text{reference value} - \text{edit value}}{\text{reference value}}$$

The nominal method is useful for measure the error of the Calibrator, when you verify its performance against a more accurate device.

The true-value method of error calculation uses the formula:

$$\frac{\text{Reference value} - \text{edit value}}{\text{edit value}}$$

With the nominal or true-value method, small changes in output value give you a calculated error that is the same. In the example above, the Control display will show the error as -30.0 ppm.

The true-value method is useful for large changes in output value. For example, if you apply 10.0000 V to an analog meter, and then adjust the Calibrator output to 11.0000 V so that the analog meter reads exactly 10 V, the true-value method will show

nominal= +10.0000 V

rel err= -9.0909 %

The -9.0909 % is the relative error of the analog meter when compared to the true value (11.0000 V in this case).

To select the UUT error calculation method:

1. Push SETUP.
2. Push the softkey INSTMT SETUP.
3. Push the softkey OTHER SETUP.
4. Push the softkey ERROR SETUP
5. Push the softkey ERR REF to toggle between “nominal” and “tru val”.

Use Multiply and Divide

The Calibrator output value (or reference value if you have edited the output) can be multiplied by a factor of 10 by the MULT X key. Similarly, the output value (or reference value if you have edited the output) can be divided a factor of 10 by the DIV ÷ key. The output is put in STBY (Standby) if the multiplied value is more than 33 V. Push OPR to continue if necessary. This feature is useful for UUTs with ranges organized in decades.

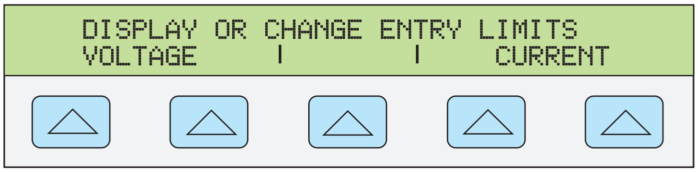
Set Output Limits

An output-limit feature is available to help prevent accidental damage to a UUT from overcurrent or overvoltage conditions. This feature lets you preset the maximum positive and negative voltage or current output. These entry limits prevent higher outputs entries from the front-panel keys or the output-adjustment controls. Positive limits for voltage and current set the limits for ac voltage and current. Your limit selections are kept in the nonvolatile memory. Voltage limits are shown as rms values, and voltage offsets are ignored.

To set voltage and current entry limits:

1. Push RESET to clear output from the Calibrator.
2. Push SETUP.
3. Push the softkey INSTMT SETUP to open the setup submenus.

4. Push the softkey OUTPUT SETUP to open the output setup submenus.
5. Push the softkey SET LIMITS to open the set limits menu (see below).



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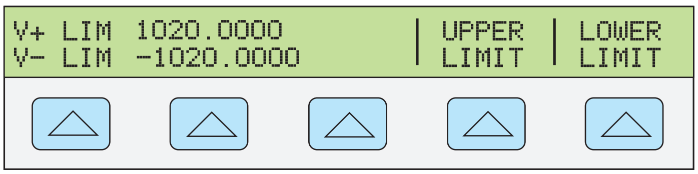
6. To Limit Voltage (applies to both dc and ac voltages), push a softkey below VOLTAGE to open the voltage limits menu (see below).



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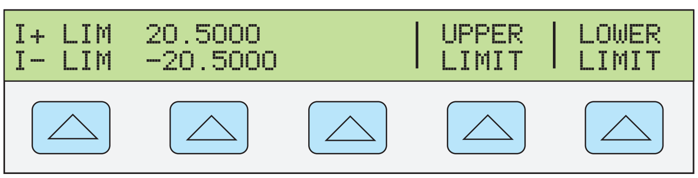
   a. Push the “Upper Limit” or the “Lower Limit” softkey, as necessary, and record the new limit.
   b. Push ENTER then PREV MENU one or more times to return to a previous menu.

7. To Limit Current (applies to both dc and ac currents). Push a softkey below CURRENT to open the current limits menu (see below).



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   a. Push the “Upper Limit” or the “Lower Limit” softkey, as necessary, and record the new limit.
   b. Push ENTER then PREV MENU one or more times to return to a previous menu.

Sample Applications

- Calibrate a Fluke 80 Series Digital Multimeter (DMM)
- Calibrate a Fluke Model 41 Power Harmonics Analyzer for Power and Harmonics
- Calibrate a Fluke Model 51 Digital Thermometer

How Calibrate an 80 Series Digital Multimeter

This example shows the steps necessary to calibrate a Fluke 80 Series DMM.

Note

These procedures are included here as an example. The 80 Series Service Manual contains the authoritative test and calibration procedures for 80 Series DMMs.

Two procedures are given. The first procedure tests each function and range for compliance to specifications. The second is the calibration procedure for the 80 Series meters. The 80 Series Service Manual gives instructions for disassembly and access to the pca (printed circuit assembly). It will be necessary to access the pca for the calibration procedure.

Before you connect the Calibrator to the 80 Series DMM, you must know what type of cables to use and if EARTH should be used. This is given in the “Cables” and “EARTH Connection” sections of this chapter.

Cables

Fluke 5440A-7002 Low-Thermal Cables are recommended for many calibrations connections, but they are not necessary for 80 Series calibration. Thermal emf errors that the Low-Thermal cables will prevent are not important when you calibrate a 3-1/2 digit meter. The cables work for the subsequent measurements:

- AC and dc voltages
- All resistances
- AC and dc currents to a maximum of 20 A

EARTH Connection

Because the 80 Series DMMs are battery operated, their inputs have no connection to earth ground. It will be necessary to start with the earth (chassis) ground of the Calibrator to LO. (Push EARTH so that the indicator is illuminates.)

Verify the Meter

You can use the error mode feature of the Calibrator of the meter (DMM) to make sure that all ranges of all functions are in specification limits:

1. Turn on the Calibrator and let it warm up.

⚠⚠ Warning

To prevent electrical shock, fire, or personal injury, make sure the Product is in standby mode before you make connections between the product and tester.

2. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-15.

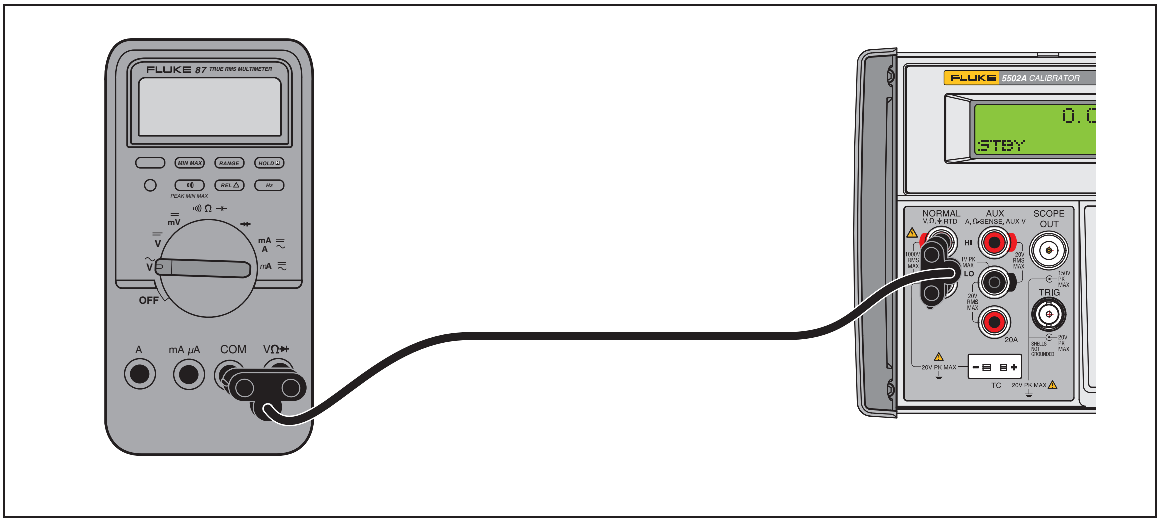

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Figure 4-15. Cable Connections to Verify 80 Series General Functions

3. Verify the dc voltage function:
   a. Turn on the DMM and set the function switch to V̄.
   b. Set the warmed-up Calibrator to 3.5 V dc.
   c. Push OPR.
   d. Use the output-adjustment controls to adjust the Calibrator output to measure +3.5000 on the DMM display.
   e. Make sure that the error shown on the control display is below the specification that is in the DMM Users Manual.
   f. Verify the DMM error at 35.0 V, -35.0 V, 350.0 V (use MULT X). Make sure the errors are in specification limits. When MULT X makes the output to go over 33 V, the Calibrator goes into standby. When this occurs, push OPR to operate.
   g. Verify the DMM error at 1000 V to make sure it is in specification limits.
   h. Set the output of the Calibrator to 350 mV and push OPR. Make sure that the errors are in specification limits.
4. Verify the ac voltage function:
   a. Push RESET on the Calibrator and set the DMM function switch to Ṽ.
   b. Set the output of the Calibrator to 350 mV at 60 Hz and push OPR. Make sure the errors are in specification limits.

c. Verify the error against specifications at the subsequent voltages and frequencies in Table 4-3.

Table 4-3. Verification Voltages and Frequencies

Voltage	Frequency
350 mV	60 Hz, 5 kHz, and 20 kHz
3.500 V	60 Hz, 5 kHz, and 20 kHz
35.00 V	60 Hz, 5 kHz, and 20 kHz
329.0 V	60 Hz, 5 kHz, and 20 kHz
100.0 V	20 kHz
200.0 V	20 kHz
300.0 V	20 kHz
1000 V	60 Hz and 5 kHz

5. Verify the frequency function:
   a. Push RESET on the Calibrator, set the DMM function switch to $\tilde{V}$, and push Hz on the DMM.
   b. Set the Calibrator to 150 mV at 19.0 kHz and push OPR. Make sure the error is in specification limits.
   c. Set the Calibrator to 150 mV at 190 kHz, push EDIT FIELD twice to move the cursor to the frequency measurement in the output display and push MULT X. Make sure the error is in specification limits.
6. Verify frequency sensitivity and trigger levels:
   a. Push RESET on the Calibrator.
   b. Set the DMM function switch to $\tilde{V}$ and push Hz on the DMM to choose the frequency mode.
   c. Set the Calibrator to 300 mV at 1 kHz and push OPR. Make sure the frequency error is in specification.
   d. Change the Calibrator output to 1.7 V. Make sure the frequency error is in specification.
   e. Change the Calibrator output to 1.0 V. Make sure that the DMM displays 000.0 frequency.
   f. Push RANGE to change the DMM range to 40 V. Change the Calibrator output to 6.0 V. Make sure the frequency error is in specification limits.
   g. Change the Calibrator output to 2.0 V. Verify that the DMM shows 000.0 frequency.

7. Verify the ohms function:
   a. Push RESET on the Calibrator and set the DMM function switch to ·))) Ω →|.
   b. Set the Calibrator to 190.0 Ω with 2-wire compensation (see Figure 4-3).
   c. Push OPR. Make sure the error is in specifications limits.
   d. Do the last step for 19.00 kΩ, 1.900 MΩ, and 19.00 MΩ. Make sure the errors are in specifications limits.
   e. Push RANGE on the DMM to record the 40 nS range. This range is for conductance tests of high resistances.
   f. Set the Calibrator output to 100 MΩ. Make sure the error is in specification limits.
8. Verify the capacitance function (use the REL feature of the 80 Series to subtract cable capacitance):
   a. Push RESET on the Calibrator and set the DMM function switch to ·))) Ω →|.
   b. Set the Calibrator output to 1.0 µF with compensation off.
   c. Push OPR. Make sure the error is in specification limits.
   d. Do this again with 0.470 µF, 0.047 µF, and 4.70 nF. Make sure the errors are in specification limits.
9. Verify the diode test function:
   a. Push RESET on the Calibrator and set the DMM function switch to →|.
   b. Set the Calibrator to 3.0 V dc and push OPR. Make sure the error is in specification limits.
10. Verify the ac and dc current function:
    a. Push RESET on the Calibrator and set the DMM function switch to **mA⎓**.
    b. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-16.

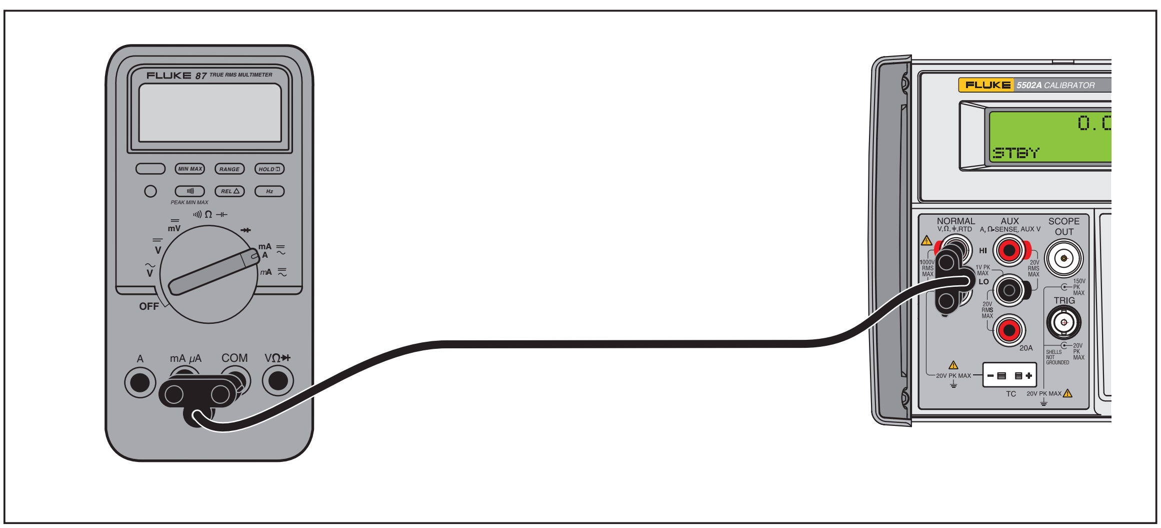

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Figure 4-16. Cable Connections to Verify an 80 Series Current Function

c. Set the Calibrator to 35.0 mA and push OPR.
d. Use the output adjustment controls to adjust the Calibrator output for a measurement of +35.00 mA on the DMM. Make sure that the error shown on the control display is in specification limits.
e. Do this step again with 350.0 mA. Make sure the error is in specification limits.
f. Push the blue key on the DMM to change to ac current measurement.
g. Set the Calibrator output to 35.0 mA at 60 Hz. Make sure the error is in specification limits.
h. Do this step again with the Calibrator set to:

AC Current	Frequency
35.0 mA	1.0 kHz
350.0 mA	60 Hz
350.0 mA	1.0 kHz

i. Push STBY on the Calibrator and switch the DMM function switch to **µA**⎓.
j. Set the Calibrator output to 350 µA at 0 Hz and push OPR. Make sure the error is in specification limits.
k. Do this again with 3500 µA at 0 Hz.
l. Push STBY on the Calibrator and push the blue key on the DMM to switch to ac measurements.
m. Change the Calibrator output to 350.0 µA at 60 Hz and push OPR. Make sure the error is in specification limits.
n. Do this step again with the Calibrator set to:

AC Current	Frequency
350.0 µA	1.0 kHz
3500.0 µA	60 Hz
3500.0 µA	1.0 kHz

11. Verify the high current function.
    a. Push RESET on the Calibrator.
    b. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-17.

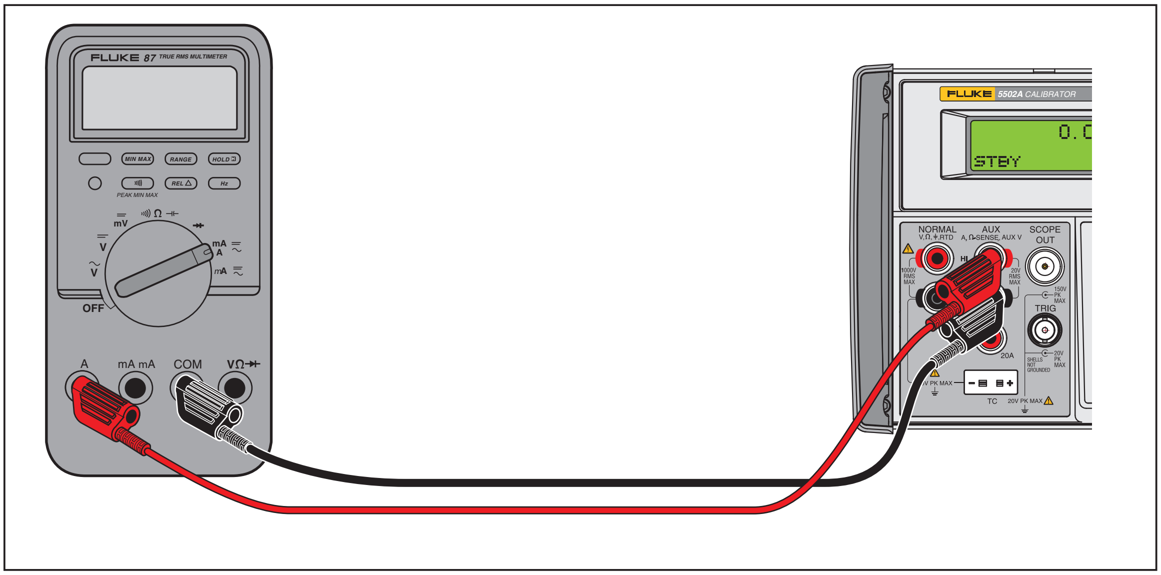

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Figure 4-17. Cable Connections to Verify an 80 Series High Amps Function

c. Set the Calibrator output to 3.5 A at 0 Hz and push OPR. Make sure the error is in specification limits.
d. Do this step again with 0 A at 0 Hz. Make sure the error is in specification limits.
e. Push STBY on the Calibrator and push the blue key on the DMM to change to ac measurements.
f. Set the Calibrator output to 3.5 A at 60 Hz and push OPR. Make sure the error is in specification limits.
g. Do this step again with the Calibrator set to:

AC Current	Frequency
3.5 A	1.0 kHz
10.0 mA	60 Hz
10.0 mA	1.0 kHz

Calibrate the Meter

Continue with calibration if there was a range that was out of tolerance in the verification procedure.

Note

To do the adjustment to calibrate the meter, it is necessary to disassemble the meter. Refer to the diagrams and access procedures in the 80 Series Service Manual.

1. Make sure that the Calibrator is set to 0 V dc in standby. Push RESET if necessary.
2. Turn on the 80 Series DMM, and set its function switch to V̅.
3. Connect a set of test leads to the DMM as shown in Figure 4-16.
4. Set the Calibrator to 3.5 V dc and push OPR.
5. The DMM shows 3.500 ±0.001. If necessary, adjust R21 to get the correct measurement.
6. Set the DMM function switch to Ṽ and set the Calibrator output to 3.500 V at 100 Hz.
7. The DMM shows 3.500 ±0.002. If necessary, adjust R34 to get the correct measurement.
8. Change the Calibrator output to 10 kHz.
9. The DMM shows 3.500 ±0.004. If necessary, adjust C2 to get the correct measurement.
10. Change the Calibrator output to 35.00 V at 10 kHz.
11. The DMM shows 35.00 ±0.04. If necessary, adjust C3 to get the correct measurement.

Verify a Model 41 Power Harmonics Analyzer

For the Model 41 Power Harmonics Analyzer, hereafter referred to as the Tester, two voltages with different phase relationships are necessary to verify the functionality of the power and harmonics features. The procedure included here is to demonstrate the operation of the dual-voltage function of the Calibrator.

Note

These procedures are included here as an example. The Model 41 Service Manual has the complete authoritative test and calibration procedures

Verify Watts, VA, VAR Performance

Do the subsequent procedure to verify the watts, VA, and VAR functions of the Tester. Refer to Table 4-4.

⚠⚠ Warning

To prevent electrical shock, fire, or personal injury, make sure the Product is in standby mode before you make connections between the product and Tester.

Table 4-4. Watts Performance, Text Screen

Calibrator Outputs			Performance Limits							
Normal V ac @ 60 Hz	Phase in DEG.	AUX mV ac @ 60 Hz	W/KW		VA/KVA		VAR/KVAR Model 41 Only		Phase Harmonics Screen	
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
5.0 V	0.0	30.0 mV	145	156	145	156	0	4	-2	2
8.0 V	0.0	30.0 mV	234	246	234	246	0	4	-2	2
100.0 V	157.0	150.0 mV	-14.3k	-13.3k	14.5k	15.6k	5.4k	6.3k	155	159
100.0 V	157.0	360.0 mV	-37k	-29k	32k	40k	10k	18k	155	159
10.0 V	46.0	1.40 V	9.2	10.2	13.5	14.5	9.6	10.6	44	48
100.0 V	46.0	1.40 V	92	102	135	145	96	106	44	48

1. Connect the Calibrator to the Model 41 as shown in Figure 4-18.

Note

Voltage is connected to the Model 41 amps input to simulate current clamp operation (1 mV = 1 A).

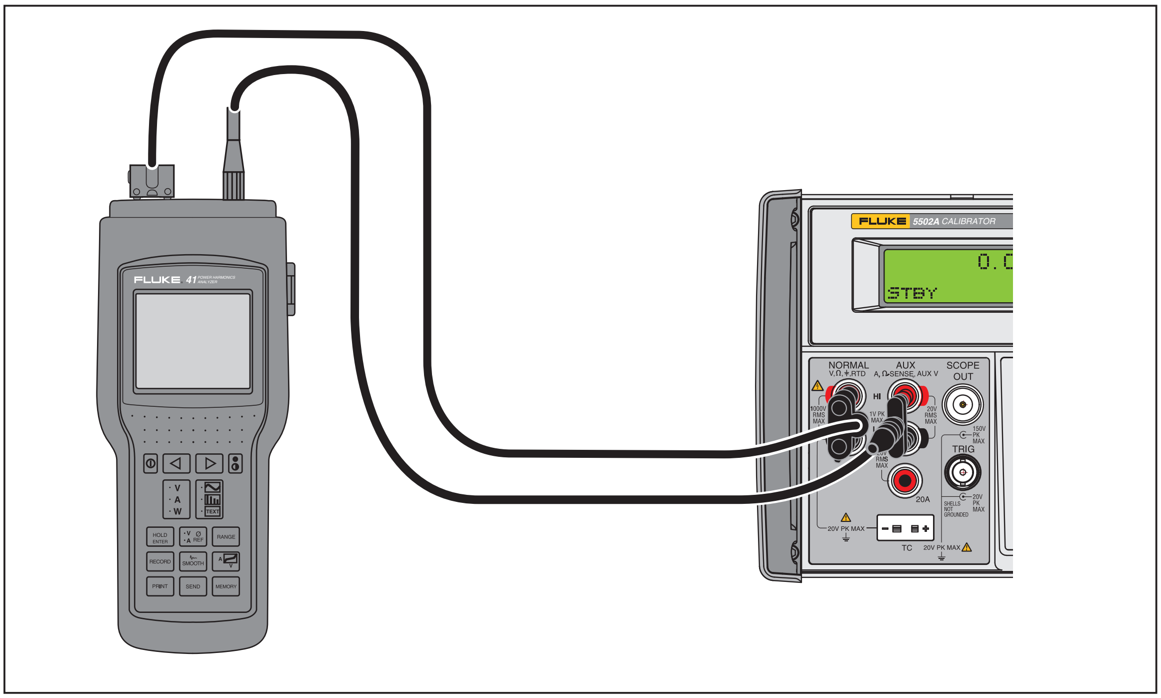

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Figure 4-18. Cable Connections to Verify a 40 Series Watts Function

2. Make sure that the EARTH indicator is illuminated. If not, push EARTH.
3. Set the Calibrator output to 5.0 V at 60 Hz on the NORMAL output and 30 mV at 60 Hz on the AUX output.
4. Push the WAVE MENUS, then the ϕ & REF MENUS softkey on the Calibrator. Make sure the AUX ϕ NRM angle is 0.00 degrees. Push OPR.
5. Select W from VAW on the Tester.
6. Push the mode button on the Tester for the text screen mode. Verify that the W/KW, VA/KVA, and VAR/KVAR indications are in the minimum and maximum limits specified in Table 4-4.
7. Push the mode button on the Tester for the harmonics screen mode. Verify that the fundamental frequency phase angle indications are between the minimum and maximum indications given in Table 4-4.
8. Do step 5, 6, and 7 again and use the Calibrator outputs and performance limits shown in Table 4-4.
9. Push STBY on the Calibrator to remove the voltage from the Tester.

Verify Harmonics Volts Performance

1. Push the mode button on the Tester for the harmonics screen.
2. Push the VAW button on the Tester until V is shown above the upper-right corner of the harmonics screen.
3. Push the VAϕ REF button on the Tester until AΦ is shown in the top status line.
4. Push the SMOOTH button on the Tester until ~20s is shown in the top status line.
5. Connect the Calibrator NORMAL output to the V and COM connectors on the Tester.
6. Connect the Calibrator AUX output to the Current Probe connector on the Tester.
7. Set the Calibrator output to 7.0 V at 60 Hz on the NORMAL output and 700 mV at 60 Hz on the AUX output. Push the WAVE MENUS, then the Φ & REF MENUS softkey and make sure the phase angle is -10.0 degrees. Push the HARMONIC MENU softkey and make sure the HARMONIC selection is set to “1” and the FUNDMTL selection is set to “aux.” Push OPR.
8. Move the Tester cursor to the necessary harmonic number.
9. Make sure that the harmonic amplitude and phase angle indications shown by the Tester are in the minimum and maximum limits shown in Table 4-5.

Note

The Tester will read a positive phase when the Calibrator output is a negative phase because, on the Calibrator, the polarity of the phase is relative to the NORMAL channel output.

10. Do steps 7, 8, and 9 again and use the values and limits in Table 4-5.

Table 4-5. Harmonics Performance for Volts, Harmonics Screen

5502A Normal Output			Fluke Tester	Performance Limits			
Amplitude	Harmonic	Phase	Harmonic cursor	Amplitude		Phase	
(V)	No.	(deg.)	No.	MIN	MAX	MIN	MAX
7.00	1	-10	1	6.7	7.3	8	12
7.00	3	-20	3	6.7	7.3	14	26
7.00	9	-30	9	6.7	7.3	21	39
7.00	13	-40	13	6.7	7.3	29	51
7.00	21	-50	21	6.5	7.5	35	65
7.00	31	-60	31	6.2	7.8	40	80

11. Push STBY to remove the voltage from the Tester.

Verify Harmonics Amps Performance

1. Push the VAW button on the Tester until A is shown above the top right corner of the harmonics display.
2. Push the VAϕ REF button on the Tester until Vϕ is shown in the top status line.
3. Push the SMOOTH button on the Tester until ~20s is shown in the top status line of the Tester.
4. Connect the Calibrator NORMAL output to the V and COM connectors on the Tester.
5. Connect the Calibrator AUX output to the Current Probe connector on the Tester.
6. Set the Calibrator output to 7.0 V at 60 Hz on the NORMAL output and 20 mV at 60 Hz on the AUX output. Push the WAVE MENUS, then the ϕ & REF MENUS softkey and make sure the phase angle is 10.00 degrees. Push the HARMONIC MENU softkey and make sure the HARMONIC selection is set to “1” and the FUNDMTL selection is set to “normal.” Push OPR.
7. See that the harmonic amplitude and phase angle indications shown by the Tester are in the minimum and maximum limits shown in Table 4-6.

Table 4-6. Harmonics Performance for Amps, Harmonics Screen

5502A AUX Output			Fluke Tester	Performance Limits			
Amplitude	**Harmonic**	**Phase**	**Harmonic cursor**	**Amplitude**		**Phase**	
(mV)	**No.**	**(deg.)**	**No.**	**MIN**	**MAX**	**MIN**	**MAX**
20.0	1	10	1	19.1	20.9	8	12
20.0	3	20	3	19.1	20.9	14	26
20.0	9	30	9	19.1	20.9	21	39
20.0	13	40	13	19.1	20.9	29	51
20.0	21	50	21	18.7	21.3	35	65
20.0	31	60	31	18.1	21.9	40	80

Calibrate a Fluke 51 Thermometer

The Fluke 51 Thermometer measures temperature with a type J or K thermocouple. The Calibrator simulates the two thermocouples. This simplifies the test and calibration. The subsequent section shows how the Calibrator is used to calibrate this thermometer.

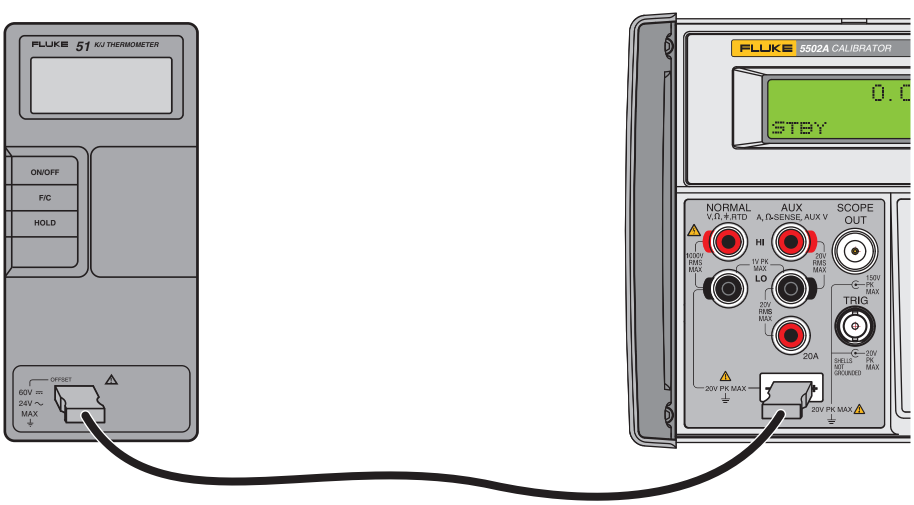
Note

These procedures are included here as an example. The Model 51 Service Manual has the authoritative test and calibration procedures.

Verify the Thermometer

The subsequent test is to be done only after the thermometer has had time to become stable to an ambient temperature of 23 °C ±5 °C (73 °F ±9 °F).

1. Connect the Fluke 51 Thermometer to the Calibrator with the correct connection cable (Figure 4-19). The connection cable and miniconnector material must be the same as the thermocouple type. For example, if you verify a K thermocouple, the cable and miniconnector are for a type-K thermocouple.



Connection wiring must match thermocouple type, for example, K, J, etc.

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Figure 4-19. Cable Connections to Verify a 50 Series Thermometer

2. Make sure that the EARTH indicator is on. If not, push EARTH.
3. Push 0 °F °C ENTER to set up the Calibrator. Make sure the softkey named OUTPUT shows “tc”. If not, push the OUTPUT softkey until it does.
4. Select the thermocouple type and reference source with the TC MENUS softkey. Make sure the REF SRC softkey selection shows “intrnl.” If not, push the REF SRC softkey. Make sure the TYPE softkey shows J or K. This will be the one that the 51 is set to. Continue to push the TYPE softkey until the selected thermocouple type is shown.
5. Record the Calibrator values shown in Table 4-7 and verify performance is not more or less than its specifications (see Chapter 1).

Table 4-7. Thermocouple Performance

Thermocouple Type [1]	5502A Setting	Display Readings	
		Degrees C	Degrees F
K	-182.0 °C	-182.0 ±(0.9)	-295.6 ±(1.6)
K	-80.0 °C	-80.0±(0.8)	-112.0 ±(1.4)
K	530.0 °C	530.0 ±(1.2)	986.0 ±(2.3)
K	1355.0 °C	1355.0 ±(2.1)	2471.0 ±(3.8)
J	-197.0 °C	-197.0 ±(1.0)	-322.6 ±(1.7)
J	258.0 °C	258.0 ±(1.1)	496.4 ±(1.9)
J	705.0 °C	705.0 ±(1.5)	1301.0 ±(2.7)

[1] When you change thermocouple types, be sure to also change the hookup wire that goes with the thermocouple. For example, K-type thermocouple wire changes to J-type thermocouple wire.

Calibrate the Thermometer

The subsequent procedure uses “UUT” (Unit Under Test) in place of “Fluke 51”. Use copper hookup wire for all connections other than steps 17 to 20.

⚠ Caution

To prevent damage to the Fluke 51 Thermometer, use only the elastomeric switch pad supplied when you short the switch grid on the circuit board.

1. Turn off the UUT and remove the top case. Keep the PCA in the bottom case.
2. Make sure the Calibrator is in standby and connect the UUT to the Calibrator as shown in Figure 4-19. When you make this connection with the UUT case top removed, make sure that the wide blade is on the same side as the wide case top hole.
3. At the same time, short the TP1 grid and short the ON/OFF switch grid to turn on the UUT. Hold the elastomeric switch pad on TP1 for a minimum of 3 seconds after turn on. This puts the UUT into the Thermocouple Calibration mode.
4. Select °C mode and T1 on the UUT.

Note

Specified voltages are necessary for the subsequent steps to be at the inputs of the Thermometer. With the 10 μV/ °C type thermocouple selection of the Calibrator, you can choose the output voltage on the TC terminals.

5. Push 0, °F °C, and ENTER. Make sure the softkey named OUTPUT shows “tc”. If not, push the OUTPUT softkey until it does.
6. Push the TYPE softkey until 10μV/°C is shown. This selection lets you choose the voltage on the TC terminal.
7. Push the TC MENU softkey.
8. Push REF SRC softkey until “external” is shown.
9. Push the REF softkey to record an external reference value.
10. Push 0 and ENTER to set the external reference to 0 °C.
11. Push PREV MENU to move to the last menu level.
12. Push OPR.
13. Let the UUT indication become stable and then adjust the T1 offset adjustment (R7) for in indication of 25.2 °C ±0.1 °C.
14. Change the Calibrator output to 5380.7 °C. This puts 53.807 mV on the tc terminals.
15. Let the UUT indication become stable and adjust R21 for a display indication of +1370.0 °C ±0.4 °C.
16. Push STBY on the Calibrator to remove voltage from the UUT. Disconnect the UUT from the Calibrator. Short the ON/OFF switch grid to turn off the UUT.
17. With an elastomeric switch pad in your left and right hands, use the left one to short out the TP2 grid, and use the right one to first turn on the instrument and then quickly short out the VIEW switch grid. Hold this position until the display is held in self-test. This puts the UUT into the Reference Junction Sensor calibration mode, and the VIEW procedure turns off a filter so that the indication was stable immediately.
18. With a type K thermocouple bead (supplied with the 5520A-525/LEADS test lead kit) and the Calibrator MEAS TC mode (push MEAS TC), measure the reference junction transistor temperature. To do this, put the K-bead into the middle hole of the isothermal block. The bead tip must be put into the well, against the body of Q1. To do this, cover the well and set the bead with a piece of tissue to help the bead stay in position. Do not hold the bead in position with your hands as this can introduce a measurement error. Let the temperature indication become stable.
19. Adjust R16 for a temperature indication on the UUT that is the same as shown on the Calibrator.
20. Power down the UUT and assemble it.

Chapter 5
Remote Operation

Title **Page**

Introduction

This chapter gives methods to operate the Calibrator by remote control.

⚠⚠ Warning

The 5502A Calibrator can output voltages to a maximum of 1020 V rms and must be programmed with caution to prevent hazardous voltage production without sufficient warning to the operator.

Write programs carefully and test them extensively to make sure of safe operation of the Calibrator. Fluke Calibration recommends that you include error-catching routines in your programs. These error-catching routines will help you find programming errors that can cause the Calibrator to act other than intended. You can program the Calibrator to cause an SRQ when an error is found by setting the Service Request Enable (SRQ) register. The subsequent skeleton program has error-catching code:

```
10     PRINT @4, "*CLS"                ! Clear status
20     PRINT @4, "*SRE 8"              ! Set SRE Error Available
30     ON SRQ GOTO 1000                ! Enable SRQ Function
100                                    ! Place body of program here

900    STOP                            ! End of program

1000   REM Start of SRQ Handler        ! Start routine
1010   PRINT @4, "FAULT?"              ! Request fault code
1020   INPUT @4, A%                    ! Input fault code
1030   PRINT @4, "EXPLAIN? ";A%        ! Request fault text
1040   INPUT @4, A$                    ! Input fault text
1050   PRINT "Fault ";A$" detected"    ! Print message
1060   PRINT @4, "STBY"                ! Place 5502A in standby
1070   STOP
```

Remote control can be interactive and you can control each step from a terminal, or with the control of a computer sequence that operates the Calibrator in an automated system. The Calibrator rear panel has three ports for remote operations: IEEE-488 parallel port (also known as a General Purpose Interface Bus, or GPIB port), and two RS-232 serial ports, SERIAL 1 FROM HOST and SERIAL 2 TO UUT.

IEEE-488 The IEEE-488 parallel port is usually used in larger control and calibration systems. An IEEE-488 system is more costly to set up, but can control multiple Calibrators and multiple UUTs. Also, parallel system throughput is faster than serial system throughput. The controller in an IEEE-488 system is typically a MS-DOS compatible personal computer (PC) that has one or more IEEE-488 ports. You can write your own computer sequences for system operation with the command set, or you can purchase optional Fluke Calibration software MET/CAL Plus. Typical IEEE-488 configurations are shown in Figure 5-1. The configuration that shows the PC with two IEEE-488 ports is used with MET/CAL. For this configuration, put the Units Under Test (UUTs) on isolated IEEE-488 port. You can also "piggy-back" the connectors on one IEEE-488 port.

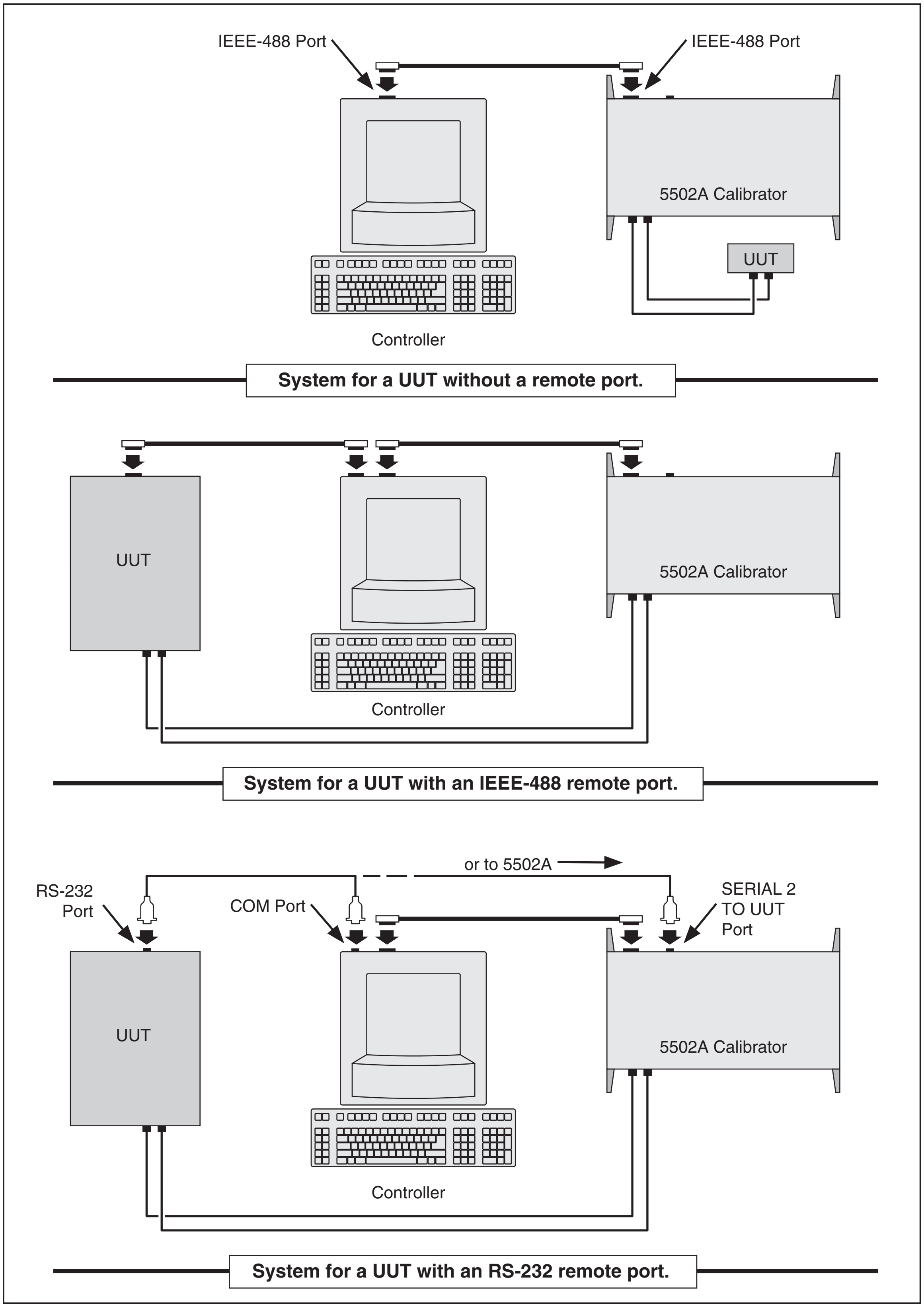


Figure 5-1. Typical IEEE-488 Remote Control Connections

RS-232 The SERIAL 1 FROM HOST serial port connects the PC and Calibrator, while the SERIAL 2 TO UUT serial port is used as a pass-through port for commands from the PC to UUT with the Calibrator. You can write your own computer programs with the command set, or use the PC as a terminal and enter individual commands, or you can purchase optional Fluke Calibration MET/CAL Plus software for RS-232 system operations. Typical RS-232 remote configurations are shown in Figure 5-2.

After you configure the IEEE-488 or RS-232 port for remote operation, you are prepared to start command set use. The operation of the command set is given in “Use Commands” in this chapter. A summary of remote commands is in Chapter 6, “Remote Commands.”

Set up the IEEE-488 Port for Remote Control

The Calibrator is fully programmable for to use on the IEEE Standard 488.1 interface bus. The IEEE-488 interface is also in compliance with supplemental standard IEEE-488.2, which gives more IEEE-488 features. Devices connected to the IEEE-488 bus are designated as talkers, listeners, talker/listeners, or controllers. The Calibrator operates as a talker/listener when it is remotely controlled by an instrument.

A PC with an IEEE-488 interface controls the Calibrator. Compatible software for IEEE-488 operation can be purchased from Fluke Calibration with MET/CAL Plus.

When you use the IEEE-488 remote control interface, there are two restrictions:

1. **Number of Devices** A maximum of 15 devices can be connected in one IEEE-488 bus system. For example, one instrument controller, one Calibrator, and thirteen UUTs.
2. **Cable Length** The total length of IEEE-488 cables used in one IEEE-488 system is 2 meters multiplied by the number of devices in the system, or 20 meters. Use that which is less. For example, if 8 devices are connected, the maximum cable length is 2 x 8 = 16 meters. If 15 devices are connected, the maximum cable length is 20 meters.

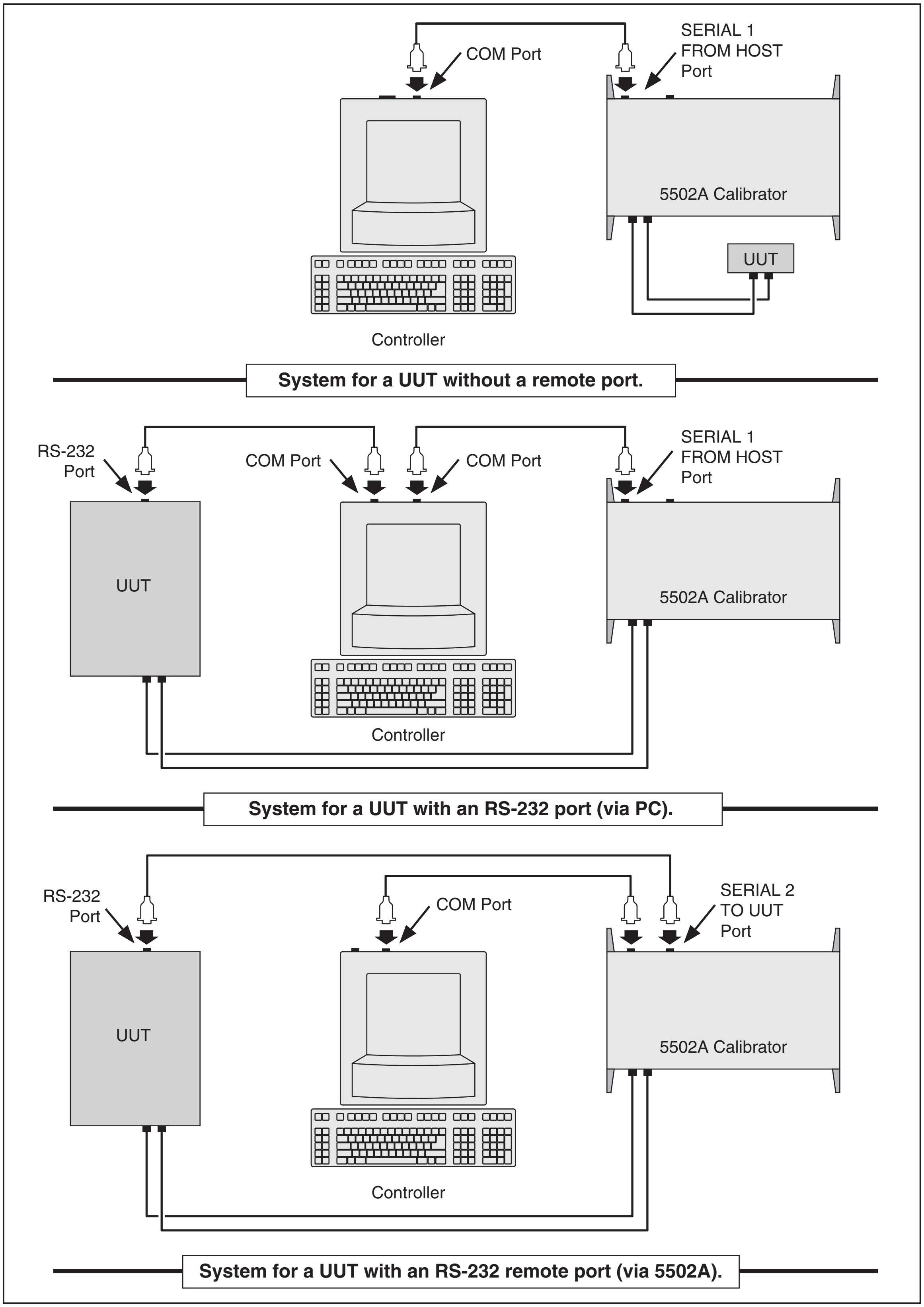
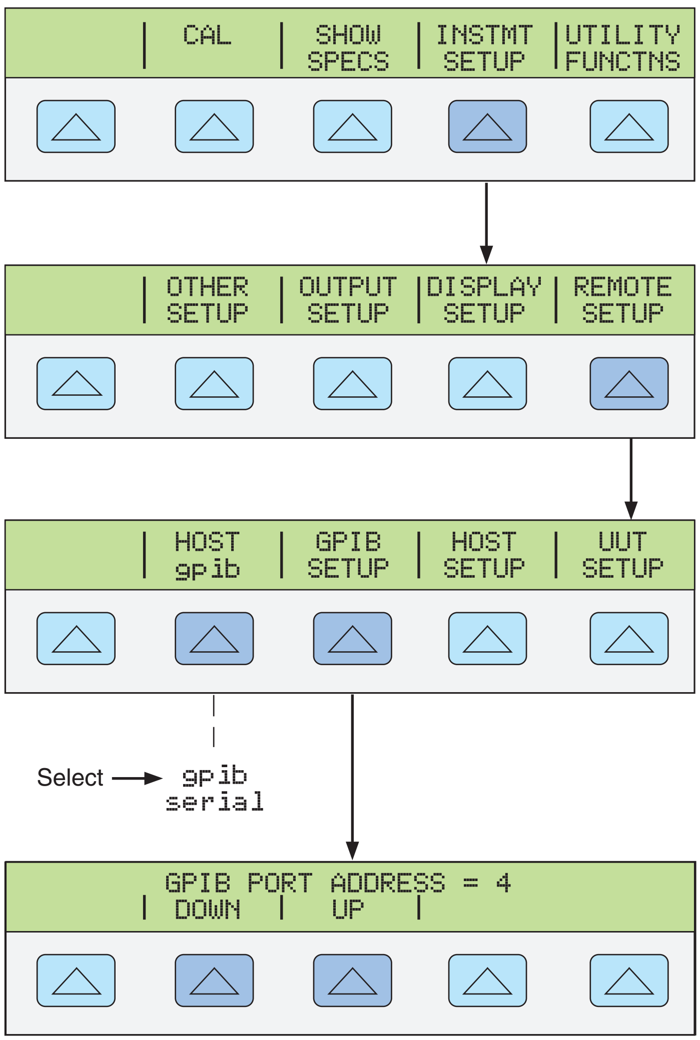


Figure 5-2. Typical RS-232 Remote Control Connections

IEEE-488 Port Setup Procedure

Complete the subsequent procedure to set up the Calibrator for remote operations with the IEEE-488 remote control port. This procedure selects GPIB as the interface and to select the GPIB address for the interface.

1. Turn the Calibrator power on. You can operate the Calibrator during warmup, but specifications are not guaranteed until the warmup is complete.
2. Push SETUP on the Calibrator front panel.
3. Navigate the softkey selections shown below. Verify the HOST port selection is GPIB. Select the necessary GPIB port address (0 to 30) with the UP/DOWN softkeys. The factory default is 4.



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4. Push PREV MENU (not ENTER) several times until the message STORE CHANGES/DISCARD CHANGES appears or, if there were no changes, the reset display. If you select STORE CHANGES, the GPIB and host port information are kept in the instrument non-volatile memory.

Verify the IEEE-488 Port

The subsequent procedure verifies IEEE-488 communications between the PC and the Calibrator with the Win32 Interactive Control utility. This utility is supplied with National Instruments interface cards for the PC, which are the recommended interfaces. (See Chapter 8, "Accessories.") A typical connection is shown in Figure 5-3.

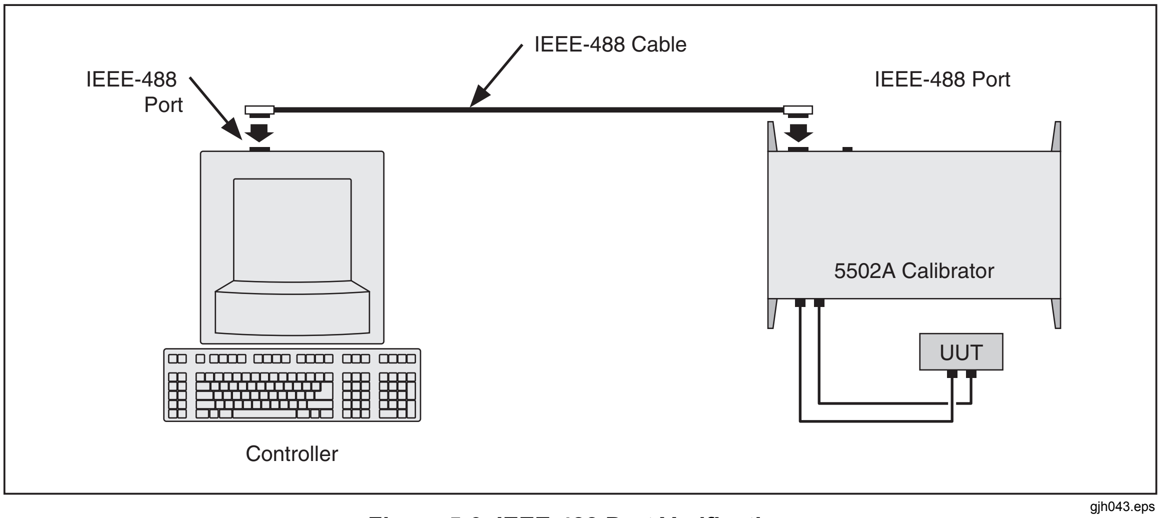
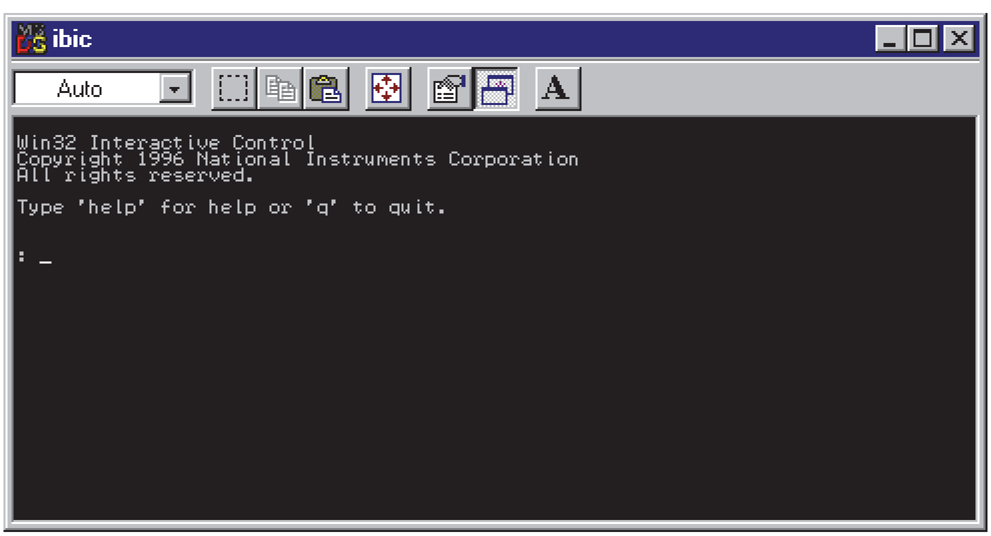


Figure 5-3. IEEE-488 Port Verification

Complete the subsequent procedure to verify IEEE-488 operation with Win32 Interactive Control.

1. Complete the "IEEE-488 Port Setup Procedure" in this chapter to set up the Calibrator for GPIB operation. Note the GPIB Address Port (default is 4).
2. Connect the PC and Calibrator IEEE-488 ports with a standard IEEE-488 cable. (See Chapter 8, "Accessories," for IEEE-488 cables available from Fluke Calibration.)
3. From the programs menu, select "NI-488.2M software for...(your operating system)".
4. From the NI488.2M software menu, select "Win32 interactive control".
5. A DOS window opens with a prompt as shown here:



6. At the prompt type the subsequent line to start the IEEE interface card:

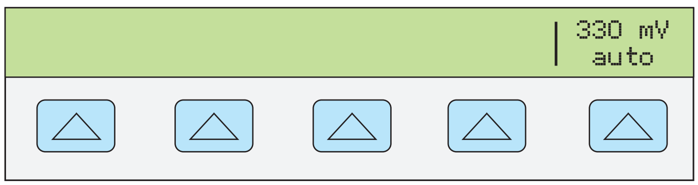
   `<ibdev 0 4 0 10 1 0>`

   The second number in this line is the primary address of the calibrator. If the address is changed from the factory default, change this line accordingly.

7. The prompt reads <ud0:>. From this prompt type <ibwrt "remote"> then push the ENTER (or RETURN) key.

8. Make sure that the calibrator is in remote control.

9. Select the Local command from the Control menu, then click OK in the Parameter Input Window. See the Calibrator Control Display changes to the reset condition (below).



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10. From the ud0: prompt, type <q> and then push the ENTER (or RETURN) key.

Set up the RS-232 Host Port for Remote Control

The Calibrator is fully programmable with an RS-232 connection with a PC the rear panel SERIAL 1 FROM HOST port (Figure 5-2). You can record individual commands from a terminal, write your own programs with, for example, a Windows-based language such as Visual Basic, or use optional Windows-based Fluke Calibration software such as MET/CAL Plus.

The RS-232 cable length for the port must not be more than 15 meters (50 feet), although longer cable lengths are permitted if the load capacitance measured at a connection point (including signal terminator) does not go more than 2500 pF.

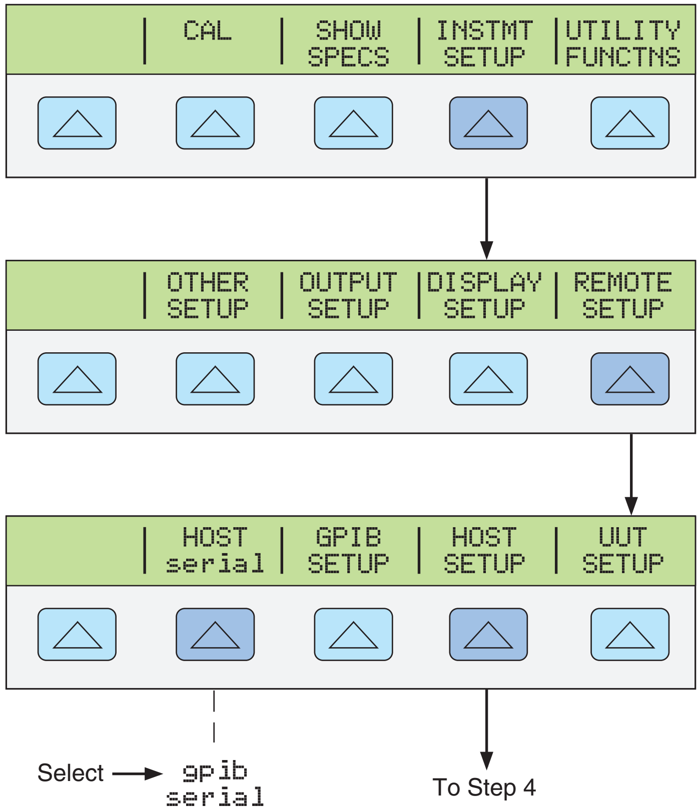
RS-232 Host Port Setup Procedure

Complete the subsequent procedure to set up the SERIAL 1 FROM HOST port. The RS-232 parameters that you select here must be the same parameters set for the PC COM port. The factory defaults (shown on the display below) are 9600 baud, 8 data bits, 1 stop bit, and no parity. Other parameters include flow control, EOL (end-of-line) character, and EOF (end-of-file) characters.

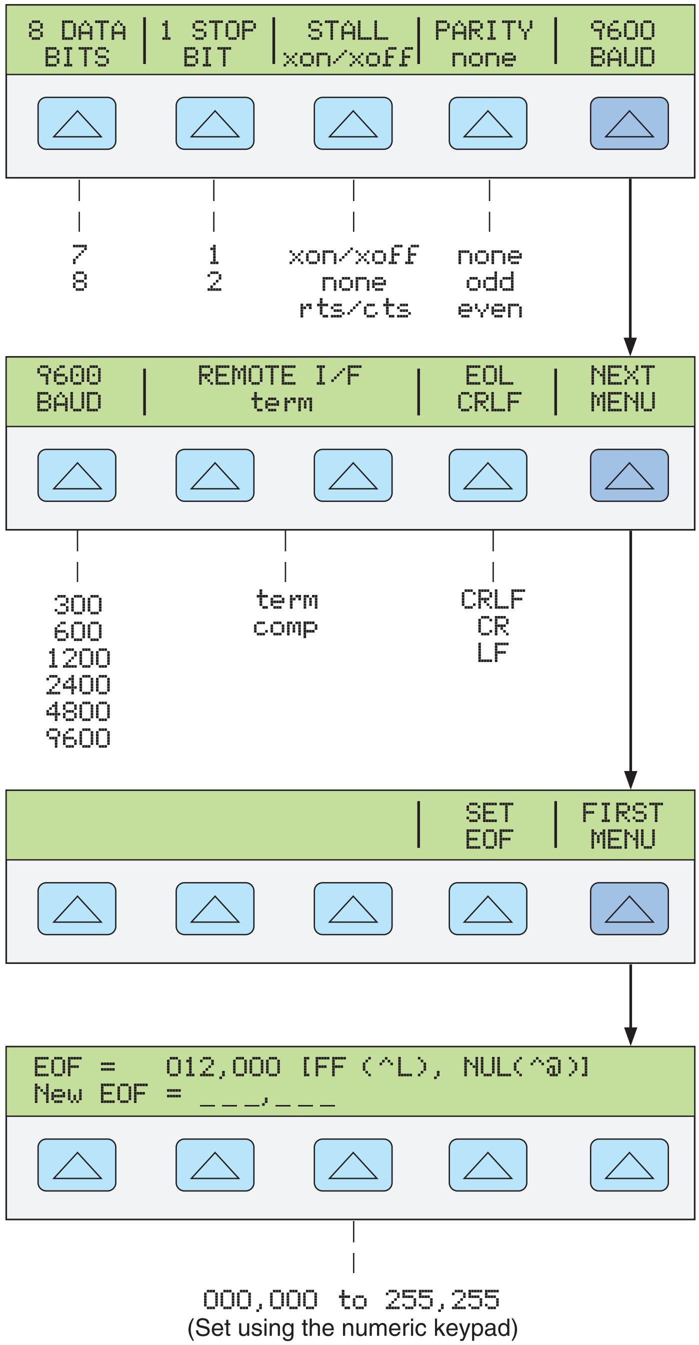
1. Turn on the Calibrator power. You can operate the Calibrator during warmup, but specifications are not guaranteed until warmup is complete.

2. Push SETUP on the Calibrator front panel.

3. Negotiate the softkey selections shown below to select the serial port for remote operation, then continue to Step 4.



4. Navigate the softkey selections shown below to select the HOST serial port parameters for the PC COM parameters. (Individual softkey functions are discussed in Chapter 3, "Features.") If operating the port with a computer program instead of individual commands from a terminal, select Remote I/F comp.



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5. Push PREV MENU (not ENTER) several times until the message STORE CHANGES/DISCARD CHANGES appears or, if there were no changes, the reset display. If you select STORE CHANGES, the serial and host port information are kept in the instrument non-volatile memory.

Verify the RS-232 Host Port

Choose or adapt one of the subsequent procedures to verify the Calibrator RS-232 Host port connected to a PC COM port. A typical connection is shown in Figure 5-4. Note that a null modem cable is used for connection. (See Appendix C for information about RS-232 cables and connectors.)

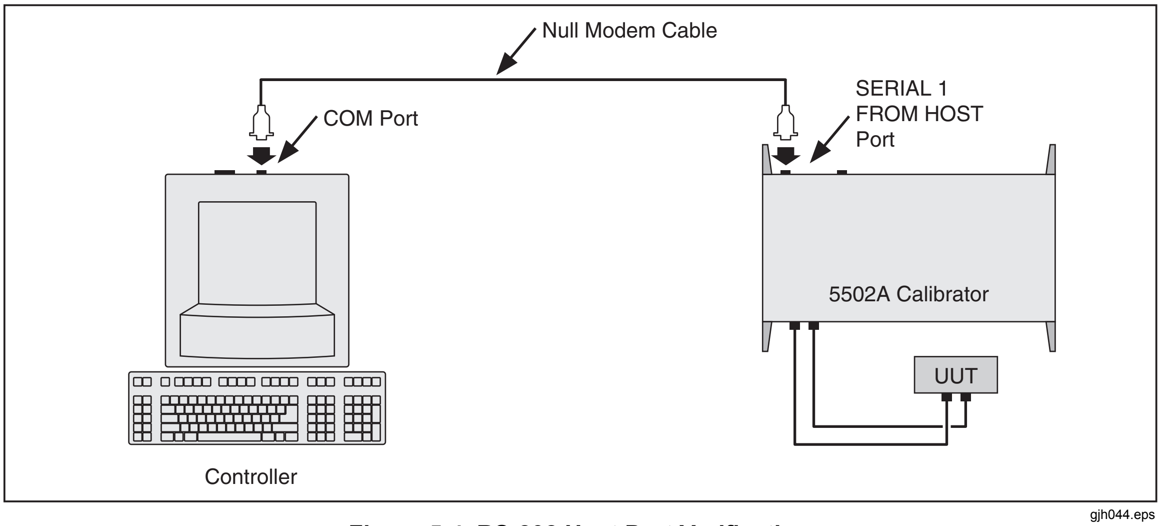


Figure 5-4. RS-232 Host Port Verification

Terminal This procedure uses the Terminal accessory supplied with Windows (or equal) to verify RS-232 Host port operation. To use this method, you must select term as the Remote I/F in Step 4 in the procedure "RS-232 Host Port Setup Procedure."

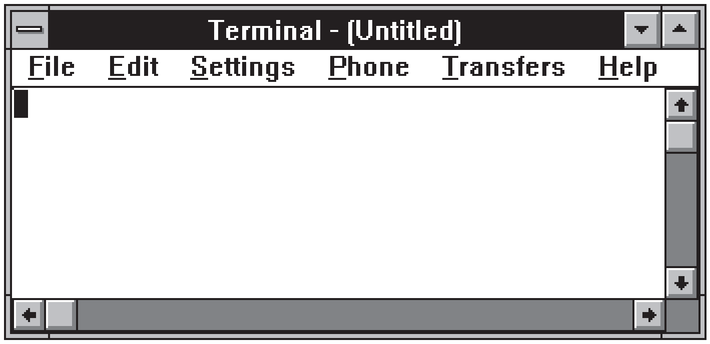
Visual Basic This procedure uses Visual Basic (see Appendix D) to verify RS-232 Host port and RS-232 UUT port operation.

Verify RS-232 Host Port Operation with a Terminal

Complete the subsequent procedure to verify RS-232 Host port operation with the Windows Terminal accessory (or equal).

1. Complete the "RS-232 Host Port Setup Procedure" before in this chapter to set up the Calibrator for RS-232 Host port operation. Write down the RS-232 Host port parameters that you selected in this procedure.
2. Connect the selected COM port on the PC to the Calibrator SERIAL 1 FROM HOST port with a standard null-modem RS-232 cable. (See Appendix C for information on RS-232 cables and connectors.)
3. Open Windows to the Program Manager screen on your PC.

4. Open Terminal from the Accessory group of Program Manager (below). If a terminal configuration file already exists, for example, host.trm, select the necessary file with the Open command from the File menu and go to Step 7. If not, go to Step 5.



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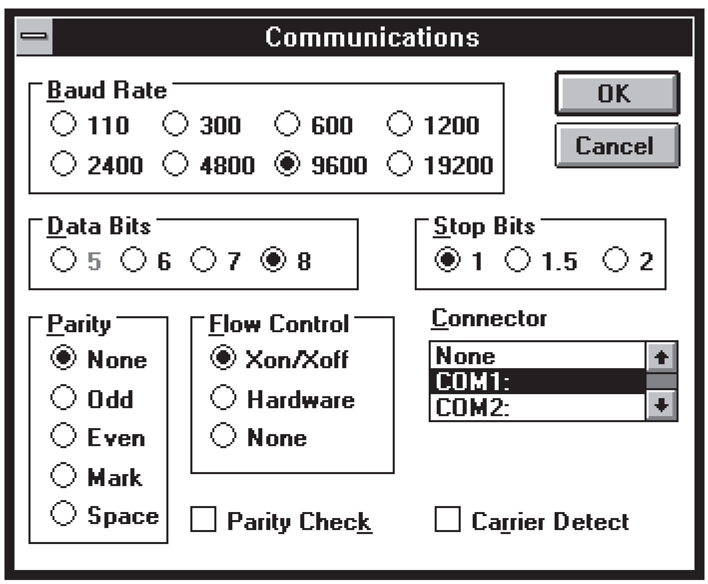
5. Select the Communications command from the Setting menu. Record the RS-232 parameters that match those selected at the Calibrator for the Host port. If you use the Calibrator factory defaults, you will see the Communications dialog box for COM1 as shown below. Select COM as necessary. Click OK.



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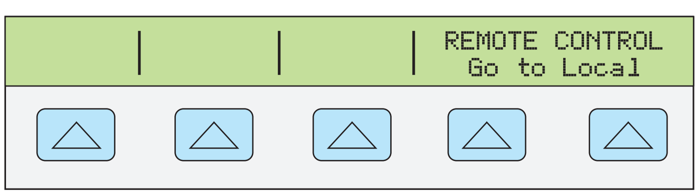
6. Verify the Calibrator is powered and in the reset condition. (If in doubt, push RESET on the Calibrator front panel.)

7. On the Terminal screen, type the command REMOTE and push <Enter>. See that the Calibrator Control Display changes to REMOTE CONTROL (see below).



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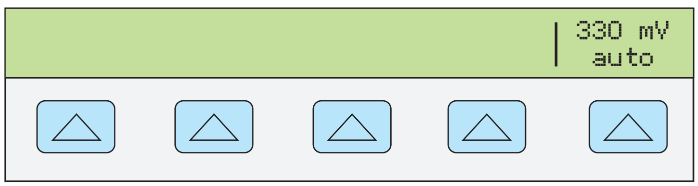
The characters REMOTE must have shown on the terminal screen as they were recorded. If they did not show on the screen, but the Control Display changed to REMOTE CONTROL, then see step 4 of the “RS-232 Host Port Setup Procedure” and change the REMOTE I/F setting from comp to term.

If nonsense characters showed on the screen, then there is a mismatch of RS-232 parameters. See step 4 of the “RS-232 Host Port Setup Procedure” procedure for the correct RS-232 settings and then do this procedure again. Start at Step 5.

If no characters showed on the screen, then see step 3 of the “RS-232 Host Port Setup Procedure” procedure to make sure that serial was selected for the Host port. Check that you used the correct RS-232 cable. It must be in a null-modem configuration where the RX and TX lines are reversed (see Appendix C). Also make sure that you have connected to the correct COM port on the PC.

8. Type the command LOCAL and push <Enter>. See that the Calibrator Control Display changes to the reset condition (below).



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To experiment with other commands in the command set, see Chapter 6, “Remote Commands.” When finished, select the Exit command from the File menu to close the Terminal accessory.

Hint: To keep the communication parameters in Terminal for future operations, first select Save from the File menu and then give a name, for example, host.trm.

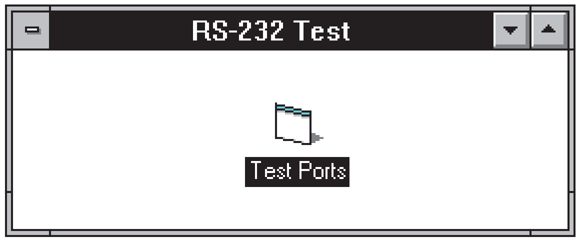
Verify RS-232 Host Port Operation with Visual Basic

Complete the subsequent procedure to verify RS-232 (Host) operation with the Windows-based programming language Visual Basic. This procedure is if you have completed Appendix D, “Creating a Visual Basic Test Program” to make the group RS-232 Test.

Complete the subsequent procedure to verify RS-232 operation with Visual Basic.

1. Complete the “RS-232 Host Port Setup Procedure” before in this chapter to set up the Calibrator for RS-232 Host port operation. Note the RS-232 Host port parameters that you selected in this procedure.

2. Connect the selected COM port on the PC to the Calibrator SERIAL 1 FROM HOST port with a standard null-modem RS-232 cable. (See Appendix C for information on RS-232 cables and connectors.)
3. To start the program, open the Test Ports icon from the RS-232 Test group (see below).



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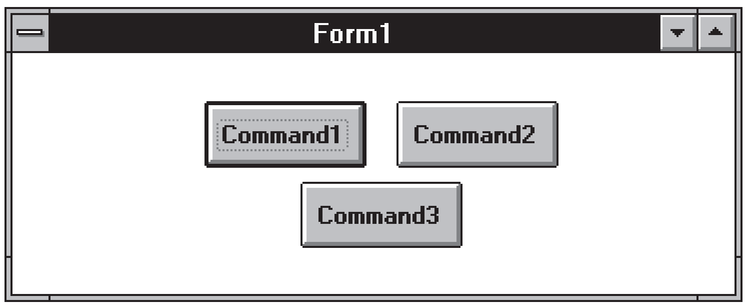
4. Verify the Calibrator is turned on and in the reset condition (if in doubt, push RESET), then click the Command1 button (see below).



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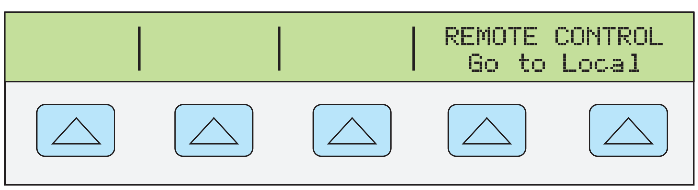
5. See that the Calibrator Control Display changes to REMOTE CONTROL (see below).



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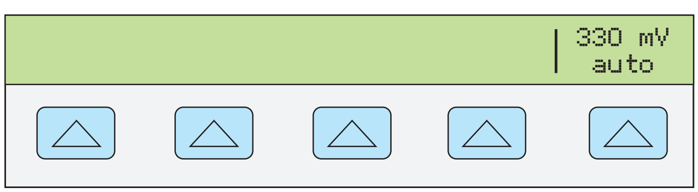
6. Click the Command2 button. See that the Calibrator Control Display changes to the reset condition (see below).

   (The Command3 button is used to verify the RS-232 UUT port later in this chapter.)



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7. Click on the top-left corner and close the program.

Set up the RS-232 UUT Port for Remote Control

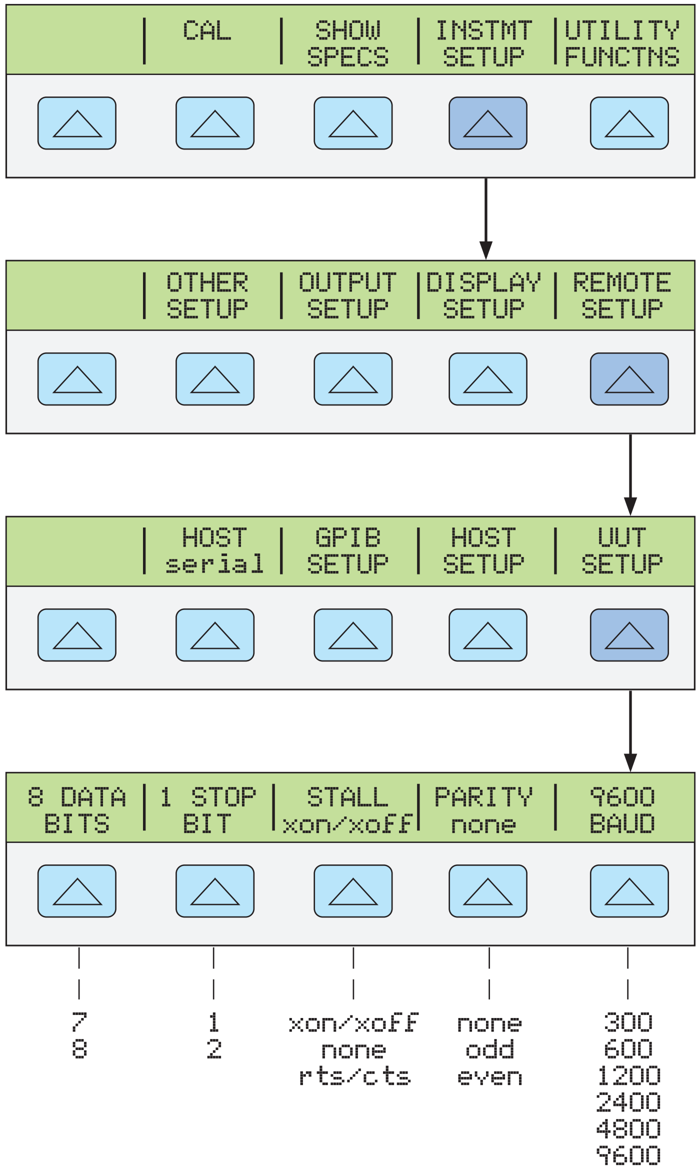
The SERIAL 2 TO UUT serial data port connects a UUT to a PC or terminal with the Calibrator (Figures 5-1 and 5-2). This “pass-through” configuration removes the requirement for two COM ports at the PC or Terminal. The UUT_* commands (see Chapter 6) are for the UUT port data flow.

The RS-232 cable length for each port must not be more than 15 meters, although longer cable lengths are permitted if the load capacitance measured at a connection point (including signal terminator) is not more than 2500 pF.

RS-232 UUT Port Setup Procedure

Complete the subsequent procedure to set up the SERIAL 1 FROM HOST port. The RS-232 parameters you select here must be the same as the parameters set for the PC COM port. The factory defaults (shown on the display below) are 9600 baud, 8 data bits, 1 stop bit, and no parity. Other parameters include flow control, EOL (end-of-line) character, and EOF (end-of-file) characters.

1. Turn on the Calibrator power. You can operate the Calibrator during warmup, but specifications are not guaranteed until warmup is complete.
2. Push RESET on the Calibrator front panel.
3. Navigate the softkey selections shown below to select the serial port for remote operation, then continue to Step 4.



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Verify the RS-232 UUT Port with RS-232 Host Port

Choose or adapt one of the subsequent test procedures to verify the Calibrator RS-232 UUT port with the RS-232 Host port. Connect the UUT and PC as shown in Figure 5-5. Note that a modem cable (NOT null modem) is used for UUT connection. (See Appendix C for information about RS-232 cables and connectors.)

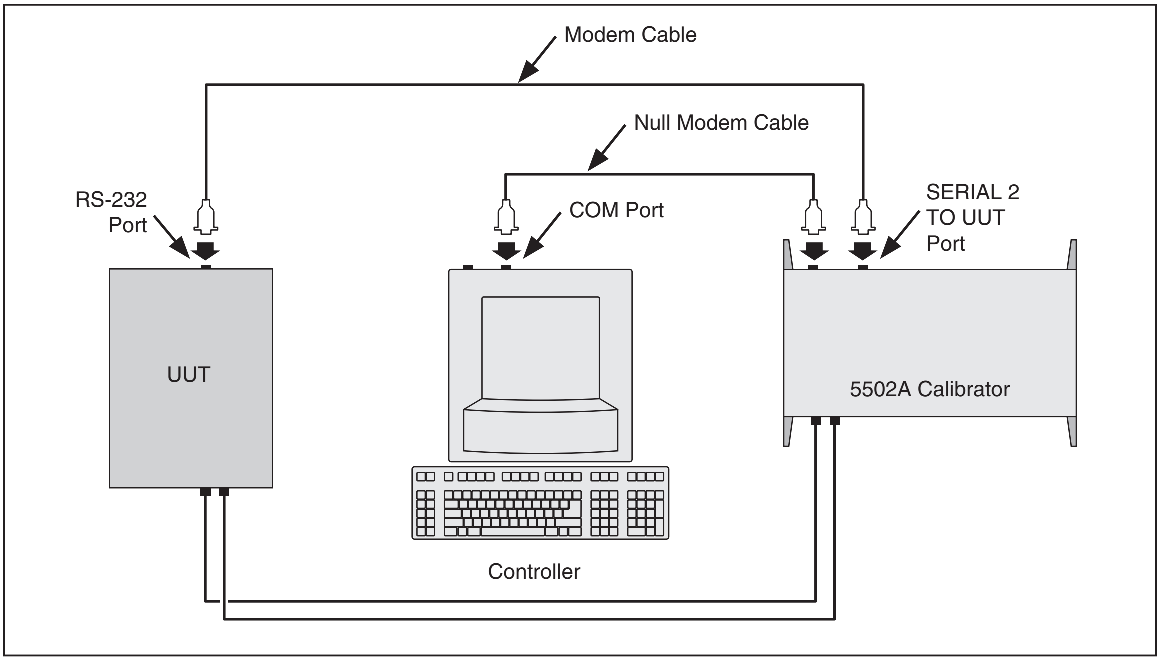


Figure 5-5. Testing the RS-232 UUT Port with RS-232 Host Port

Terminal This procedure uses the Terminal accessory supplied with Windows (or equal) to verify RS-232 UUT port operation.

Visual Basic This procedure uses Visual Basic (see Appendix D) to verify RS-232 Host port and RS-232 UUT port operation.

Test RS-232 UUT Port Operation with a Terminal

Complete the subsequent procedure to verify RS-232 UUT port operation with the RS-232 Host port with the Windows Terminal accessory (or equal).

1. Complete "RS-232 UUT Port Setup Procedure" to the Calibrator RS-232 UUT port to the same parameters of the UUT RS-232 port.
2. Complete "Test RS-232 Host Port Operation with a Terminal" to set up the Calibrator RS-232 Host port to the same parameters of the PC COM port. After Step 9, go to this procedure and continue to Step 3 below.
3. On the Terminal screen, type UUT_SEND "<uut command>" where <uut command> is the command you selected for the UUT response, then push <Enter>. See the UUT result. For example, to send the command REMS to a UUT, use UUT_SEND "REMS\n" and push <Enter>.

   Note that `\n` is used, which shows a Carriage Return (CR) as the end-of-line character. Other characters include `\r` (Line Feed), `\t` (Tab), `\b` (Backspace) and `\f` (Form Feed). If an end-of-line character is necessary for the UUT commands, select one or more of the above.

   The characters UUT_SEND "`<uut command>`" show as they are recorded. If they did not show on the screen, the RS-232 interface between the PC and Calibrator Host port is not in operation. Read the "RS-232 Host Port Setup Procedure" and correct the problem.
4. If the UUT command does not do what it must, see step 3 of the "RS-232 UUT Port Setup Procedure" to verify the RS-232 UUT port parameters. Also examine the cable for UUT connection was a modem (not null modem) cable. Make sure the command was recorded correctly and had the correct end-of-line character(s), if necessary.

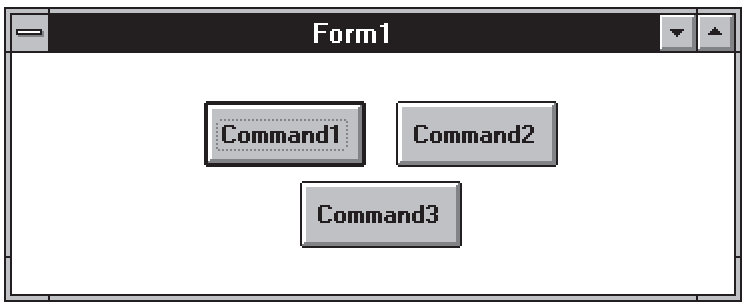
5. When you complete UUT commands tests, select the Exit command from the File menu to close the Terminal accessory.

Verify RS-232 UUT Port Operation with Visual Basic

Complete the subsequent procedure to verify RS-232 UUT port operation with the RS-232 Host port with a Visual Basic test program. For this procedure, complete Appendix D, “Creating a Visual Basic Test Program” to make the program used for this test.

Complete the subsequent procedure to verify RS-232 operation with Visual Basic.

1. Complete the “RS-232 UUT Port Setup Procedure” in this chapter to set up the Calibrator RS-232 UUT port to the same parameters of the UUT RS-232 port.
2. Complete “Verify RS-232 Host Port Operation with Visual Basic” to prepare the Calibrator RS-232 Host port. After Step 6, go to this procedure and continue to Step 3.
3. Click the Command3 button (below is typical). See that the UUT reacts to the command you used when you completed Appendix D, “Make a Visual Basic Test Program.”



nn311f.bmp

If the UUT did not react, make sure the RS-232 parameters are set for the Calibrator UUT port and set for the UUT port. Make sure you used a modem (not null modem) cable for the Calibrator to UUT connection. Examine the Visual Basic program to make sure the UUT command and the end-of-line character was recorded correctly.

4. To close the program, click the top-left corner and Close.

Verify the RS-232 UUT Port with IEEE-488 Port

This procedure uses the Win32 Interactive Control utility supplied by National Instruments with the recommended interface cards. Connect the UUT, Calibrator, and PC as shown in Figure 5-6. Note that a modem cable (NOT null modem) is used for the UUT connection. (See Appendix C for information about RS-232 cables and connectors.)

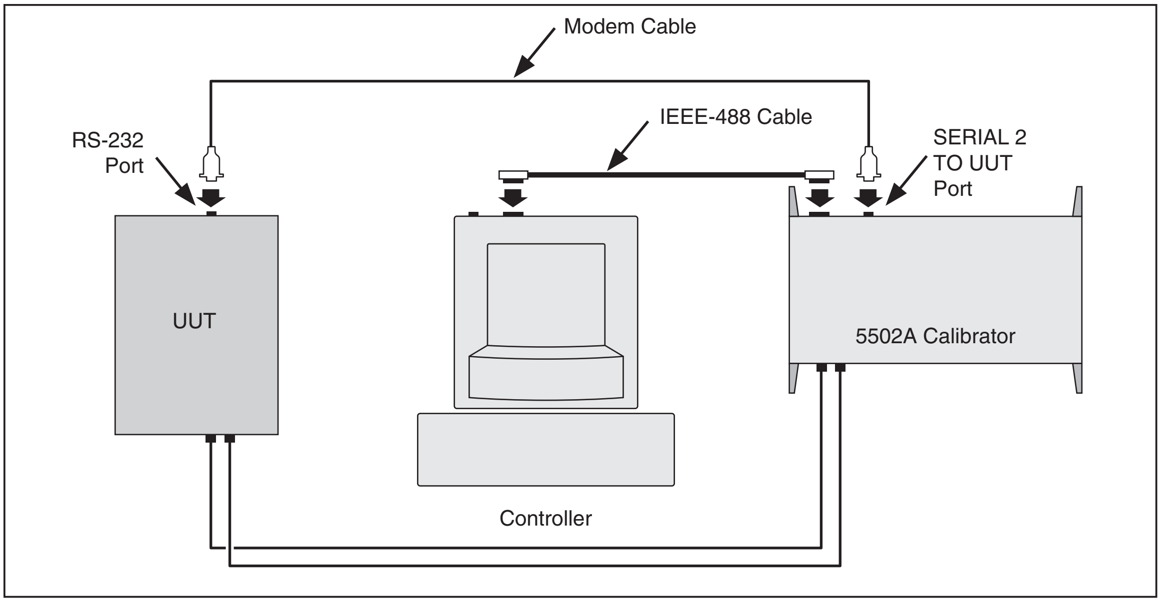
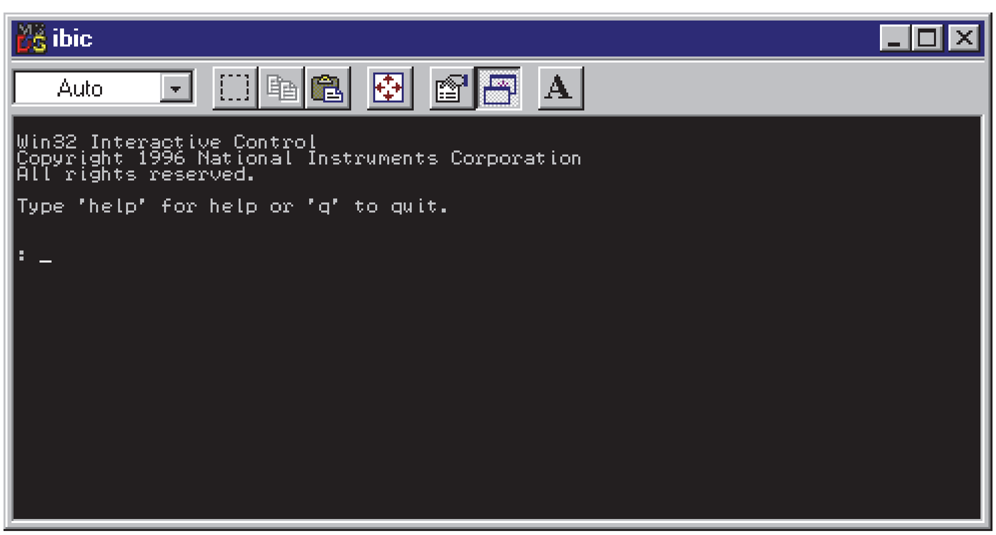


Figure 5-6. Verify the RS-232 UUT Port with IEEE-488 Port

Complete the subsequent procedure to verify RS-232 UUT port operation with the IEEE-488 port with the Win32 Interactive Control utility.

1. Complete the “IEEE-488 Port Setup Procedure” in this chapter to set up the Calibrator for GPIB operation.
2. Complete “Verify the IEEE-488 Port” to prepare the Calibrator IEEE-488 port to be verified. Before the last step, come to this procedure and continue to Step 3 below.
3. Go to Start then to the Programs menu.
4. Select "NI-488.2M software for... (your operating system)".
5. From the NI488.2M software menu, select "Win32 interactive control".
6. A DOS window opens with a prompt:



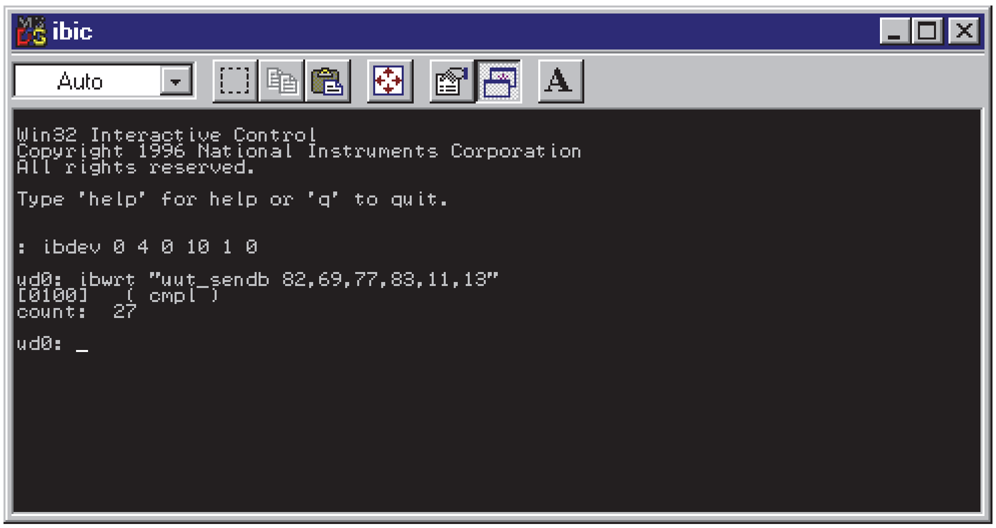
7. At the prompt, type the subsequent line to turn on the IEEE interface card:

    `<ibdev 0 4 0 10 1 0>`

8. The second number in this line is the primary address of the calibrator. If the address has changed from the factory default, change this line accordingly.
9. The prompt reads <ud0:>. From this prompt, type

    `<ibwrt "uut_sendb 82,69,77,83,11,13">`

10. Push the ENTER (or RETURN) key. This command will send REMS<CR><LF> to the UUT serial port. After the command is recorded, the Win32 Interactive Control shows the status of the command. If an error is found, examine the typing or consult the National Instruments manual regarding Win32 Interactive control. The count message is the quantity of characters sent through the bus (see below).



11. Verify that the UUT is in remote.
12. From the ud0: prompt type <q> then push the ENTER (or RETURN) key.

Change between Remote and Local Operation

With local mode (front-panel operation) and remote, the Calibrator can also be put into a local lockout condition by command of the controller. In combination, the local, remote, and lockout conditions give four possible operation conditions given as follows.

Local State

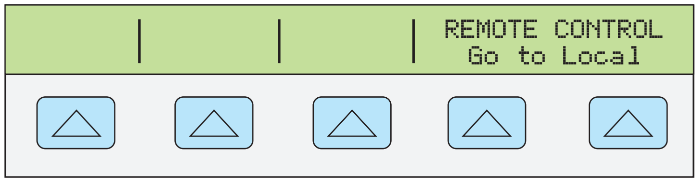
The Calibrator responds to local and remote commands. This is correct front-panel operation. All remote commands are can be used.

Local with Lockout State

Local with lockout is the same as local, but the Calibrator will change to the remote with lockout as an alternative to the remote condition when it gets a remote command.

Remote Condition

When the Calibrator is put in remote, with the RS-232 REMOTE command, or with IEEE-488 asserting the REN line, it goes to the remote condition. In the remote condition, the Output Display continues to show the output conditions or measurement as in local operation. The Control Display changes to:

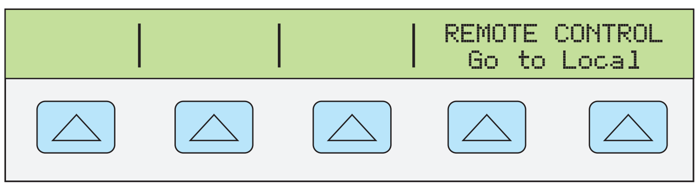


nn325f.eps

The left side of the Control Display shows data for the given output function, but front-panel operation is only for the power switch and the "Go To Local" softkeys. Push one of these softkeys, and use RS-232 to send the command LOCAL, or IEEE-488 to send the GTL (Go To Local) message will put the Calibrator to the local condition.

Remote with Lockout Condition

When the Calibrator is put in lockout with the RS-232 LOCKOUT command or with the IEEE-488 message LLO, the Calibrator front panel controls are totally locked out. In remote with lockout, the Control Display changes to:



nn325f.eps

The left side of the Control Display shows information regarding the given output function. Front-panel operation is only for the power switch. To change the Calibrator to the local with lockout condition, send the RS-232 LOCAL command or the IEEE-488 GTL (Go To Local) message.

Table 5-1 summarizes the possible Remote/Local condition changes. (For more information on IEEE-488 GPIB messages, see “IEEE-488 Overview.”

Table 5-1. Operation State Transitions

From	To	Front Panel	GPIB Message	Serial Command
Local	Remote		MLA (REN True)	REMOTE
	Local with Lockout		LLO	LOCKOUT
Remote	Local	Go to Local Softkey	GTL or REN False	LOCAL
	Remote with Lockout		LLO	LOCKOUT
Local with Lockout	Local		REN False	LOCAL
	Remote with Lockout		MLA (REN True)	REMOTE
Remote with Lockout	Local		REN False	REMOTE
	Local with Lockout		GTL	

RS-232 Interface Overview

The two Calibrator RS-232 ports are in accordance with EIA (Electronic Industries Association) standard RS-232. RS-232 is a serial binary data interchange that operates from 300 to 9600 baud (selectable), and distances to a maximum of 50 feet. The Calibrator rear panel SERIAL 1 FROM HOST port is configured as DTE (Data Terminal Equipment) while the SERIAL 2 TO UUT is configured as DCE (Data Communications Equipment). See Appendix C for RS-232 cable and connector information. For more information, see the EIA standard RS-232.

A summary of RS-232 terms, interface lines and mnemonics are shown in Table 5-2.

Table 5-2. RS-232 Interface Wiring

Mnemonic	Description
CTS	Clear to Send
DB-9	Type DB connector, 9 pins
DB-25	Type DB connector, 25 pins
DCD	Data Carrier Detect
DCE	Data Communications Equipment
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
GND	Ground
RI	Ring Indicator
RLSD	Received Line Signal Detector
RTD	Request to Send
RX	Receive Line
TX	Transmit Line

IEEE-488 Interface Overview

The IEEE-488 parallel interface sends commands as data and receives measurements and messages as data. The maximum data exchange rate is 1 Mbyte, with a maximum distance of 20 meters for the sum length of the connection cables. One cable must not be more than 4 meters in length. Some commands are kept for RS-232 serial operation because these functions must be implemented as IEEE messages per the IEEE Standards. For example, the command REMOTE could be sent as data with the IEEE-488 interface to put the Calibrator into remote, but it is not because the remote function to be sent to the device as the uniline message REN is necessary for the IEEE Standards. This is also correct for other commands and functions, as shown below, with their equivalent RS-232 emulation. A summary of IEEE-488 messages is shown in Table 5-3.

Table 5-3. RS-232 Emulation of IEEE-488 Messages

IEEE-488 Message	RS-232 Equivalent
GTL	LOCAL command
GTR	REMOTE command
LLO	LOCKOUT command
SDC, DCL	^C (<Cntl> C) character [clear the device]
GET	^T (<Cntl> T) character [execute a group trigger]
SPE, SPD	^P (<Cntl> P) character [print the serial poll string]
UNL, UNT	(not emulated on RS-232)

The IEEE-488 interface comes from the IEEE Standards 488.1 and 488.2. For more information, refer to the standards IEEE-488.1 and IEEE-488.2.

IEEE-488.1 IEEE-488.1 is the hardware piece of the interface. The parallel signal lines are divided into eight lines for the data bus, three lines for the handshake, and five lines for bus management. The handshake lines are for the timing for data interchange. The bus management lines control the operation of data interchange. The ATN line shows the operation of the DIO lines for addresses or messages (true), or for DIO data (false). The EOI line is used with the data lines to show the end of a message, and with the ATN line for polling. The SRQ line is used by the devices to show the controller that servicing is necessary. The IFC line is used by the controller to quickly get all the devices on the bus to stop talking and start listening. The REN line is used to implement the remote/local conditions.

IEEE-488.2 IEEE-488.2 is the software piece of the interface, specifying data formats, common commands, message interchange protocol and the status register implementation.

Use the subsequent items to decode the columns in Figure 5-7. Appendix C shows a typical IEEE-488 connector and pin assignments.

Type	M - Multiline U - Uniline	
Class	AC - Addressed Command AD - Address (Talk or listen) UC - Universal Command ST - Status	DD - Device Dependent HS - Handshake SE - Secondary
Other	B1, B2, etc. - Information Bits Blanks - Doesn’t Care condition	Logic Zero = 0 = False Logic One = 1 = True

MESSAGE DESCRIPTION				DATA BUS								HAND-SHAKE			BUS MANAGEMENT				
MNEM	MESSAGE NAME	TYPE	CLASS	DIO8	DIO7	DIO6	DIO5	DIO4	DIO3	DIO2	DIO1	DAV	NRFD	NDAC	ATN	EOI	SRQ	IFC	REN
ACG	Addressed Command Group	M	AC		0	0	0								1				
ATN	Attention	U	UC												1				
DAB	Data Byte	M	DD	B8	B7	B6	B5	B4	B3	B2	B1				0				
DAC	Data Accepted	U	HS											0					
DAV	Data Valid	U	HS									1							
DCL	Device Clear	M	UC		0	0	1	0	1	0	0				1				
END	End	U	ST												0	1			
EOS	End Of String	M	DD	B8	B7	B6	B5	B4	B3	B2	B1				0				
GET	Group Execute Trigger	M	AC		0	0	0	1	0	0	0				1				
GTL	Go To Local	M	AC		0	0	0	0	0	0	1				1				
IDY	Identify	U	UC													1			
IFC	Interface Clear	U	UC															1	
LAG	Listen Address Group	M	AD		0	1									1				
LLO	Local Lock Out	M	UC		0	0	1	0	0	0	1				1				
MLA	My Listen Address	M	AD		0	1	B5	B4	B3	B2	B1				1				
MTA	My Talk Address	M	AD		1	0	B5	B4	B3	B2	B1				1				
MSA	My Secondary Address	M	SE		1	1	B5	B4	B3	B2	B1				1				
NUL	Null Byte	M	DD		0	0	0	0	0	0	0								
OSA	Other Secondary Address	M	SE		(OSA = SCG and MSA-NOT)														
OTA	Other Talk Address	M	AD		(OTA = TAG and MTA-NOT)														
PCG	Primary Command Group	M	----		(PCG = ACG or UCG or LAG or TAG)														
PPC	Parallel Poll Configure	M	AC		0	0	0	0	1	0	1				1				
PPE	Parallel Poll Enable	M	SE		1	1	0	B4	B3	B2	B1				1				
PPD	Parallel Poll Disable	M	SE		1	1	1	B4	B3	B2	B1				1				
PPR1	Parallel Poll Response 1	U	ST								1				1	1			
PPR2	Parallel Poll Response 2	U	ST							1					1	1			
PPR3	Parallel Poll Response 3	U	ST						1						1	1			
PPR4	Parallel Poll Response 4	U	ST					1							1	1			
PPR5	Parallel Poll Response 5	U	ST				1								1	1			
PPR6	Parallel Poll Response 6	U	ST			1									1	1			
PPR7	Parallel Poll Response 7	U	ST		1										1	1			
PPR8	Parallel Poll Response 8	U	ST	1											1	1			
PPU	Parallel Poll Unconfigure	M	UC		0	0	1	0	1	0	1				1				
REN	Remote Enable	U	UC																1
RFD	Ready For Data	U	HS										0						
RQS	Request For Service	U	ST		1										0				
SCG	Secondary Command Group	M	SE		1	1									1				
SDC	Selected Device Clear	M	AC		0	0	0	0	1	0	0				1				
SPD	Serial Poll Disable	M	UC		0	0	1	1	0	0	1				1				
SPE	Serial Poll Enable	M	UC		0	0	1	1	0	0	0				1				
SRQ	Service Request	U	ST														1		
STB	Status Byte	M	ST	B8		B6	B5	B4	B3	B2	B1				0				
TCT	Take Control	M	AC		0	0	0	1	0	0	1				1				
TAG	Talk Address Group	M	AD		1	0									1				
UCG	Universal Command Group	M	UC		0	0	1								1				
UNL	Unlisten	M	AD		0	1	1	1	1	1	1				1				
UNT	Untalk	M	AD		1	0	1	1	1	1	1				1				

Figure 5-7. IEEE-488 Remote Message Coding

Use Commands

Communications between the controller and the Calibrator is made of commands, queries, and interface messages. Although the commands come from the 488.2 standard, they can be used on the IEEE-488 or RS-232 interface, but for some specified RS-232 commands given in "Commands for RS-232 Only." (For more about command structures, see the IEEE 488.2 standard.)

See Chapter 6, "Remote Commands" when more information about command references used this chapter are necessary.

All commands and units can be recorded in UPPER or lower case.

There are four remote control configurations that use commands, queries and interface messages: IEEE-488, RS-232 Terminal Mode, RS-232 Computer Mode, and RS-232 Pass-Through Mode. (set up and verify each mode is given in this chapter.)

IEEE-488 Mode The IEEE-488 mode is used when the Calibrator is operated by computer program. In this mode, necessary information is shown by query, and interface messages are queued and returned by command.

RS-232 Terminal Mode The RS-232 terminal mode is an interactive mode where an operator inputs commands, with immediate indications for requested information (queries) and interface messages.

RS-232 Computer Mode The RS-232 computer mode is used when the Calibrator is operated by computer program. In this mode, requested information is shown by query, and interface messages are queued and returned by command.

RS-232 Pass-Through Mode The RS-232 pass-through mode is used to move commands from the PC to a UUT, but with the Calibrator. This configuration is used when the UUT has an RS-232 port. Commands are sent to the UUT with the `UUT_SEND` command, shows use the `UUT_RECV?` query, and `UUT_FLUSH` cleans the UUT receive buffer in the Calibrator.

Types of Commands

The commands for the Calibrator can be grouped into one or more categories, depending on how they operate. Each category is given below.

Device-Dependent Commands

Device-dependent commands are unique to the Calibrator. An example of a device-dependent command is,

```
OUT 100 V, 1 A, 60 HZ
```

this tells the Calibrator to source 100 watts of ac power.

Common Commands

Common commands are specified by the IEEE 488.2 standard and are common to most bus devices. Common commands always start with an * character. Common commands are available is you use the IEEE-488 or RS-232 interface for remote control. An example of a common command is,

```
*IDN?
```

this tells the Calibrator to give the instrument identification string.

Query Commands

Query commands request information. That information is given as the command executes, or the information is put into a buffer until requested. An example of a query, which always completes with a question mark, is,

```
RANGE?
```

This shows the Calibrator primary and secondary outputs.

Interface Messages (IEEE-488)

Interface messages manage traffic on the IEEE-488 interface bus. Device addressing and clearing, data handshaking, and commands to put status bytes on the bus are all directed by interface messages. Some of the interface messages occur as condition changes of dedicated control lines. The remaining interface messages are sent with the data lines with the ATN signal true.

Note

All device-dependent and common commands are sent over the data lines with the ATN signal false.

An important thing about interface messages is that unlike device-dependent and common commands, interface messages are not sent literally (in a direct way). For example, when you send a device-dependent query to the Calibrator, the controller automatically sends the interface message MTA (My Talk Address).

IEEE-488 standards define interface messages. Table 5-4 shows the interface messages that the Calibrator accepts. Table 5-4 also shows the BASIC statement to make the interface message. Table 5-5 shows the interface messages that the Calibrator sends. The mnemonics shown in the tables are not sent in BASIC PRINT statements as commands are; this is how they are different from device-dependent and common commands.

Interface messages are controlled automatically in most cases. For example, handshake messages DAV, DAC, and RFD automatically occur with the direction of an interface of the instrument as each byte is sent over the bus.

Table 5-4. IEEE-488 Interface Messages (Received)

Mnemonic	Name	Function
ATN	Attention	A control line that, when asserted, tells all instruments on the bus that the subsequent data bytes are an interface message. When ATN is low, the subsequent data bytes are interpreted as device-dependent or common commands addressed to a specified instrument.
DAC	Data Accepted	Sets the handshake signal line NDAC low.
DAV	Data Valid	Asserts the handshake signal line DAV.
DCL	Device Clear	Clears the input/output buffers.
END	End	A message that occurs when the Controller asserts the EOI signal line before it sends a byte.
GET	Group Execute Trigger	Trigger a TC measurement and put the indication in the output buffer.
GTL	Go To Local	Transfer control of the Calibrator from one of the remote conditions to one of the local conditions, see Table 5-1.
LLO	Local Lockout	Transfers remote/local control of the Calibrator, see Table 5-1.
IFC	Interface Clear	A control line that sets the interface to a quiescent condition.
MLA	My Listen Address	Addresses a specified device on the bus as a listener. The controller sends MLA automatically when it tells a device-dependent or common command to a specified instrument.
MTA	My Talk Address	Addresses a specified device on the bus as a talker. The controller sends MTA automatically whenever it directs a device-dependent or common query to a specified instrument.
REN	Remote Enable	Transfer remote/local control of the Calibrator, see Table 5-1.
RFD	Ready For Data	Sets the handshake signal line NRFD low.
SDC	Selected Device Clear	Does the same thing as DCL, but only if the Calibrator is currently addressed as a listener.
SPD	Serial Poll Disable	Cancels the effect of a Serial Poll Enable.
SPE	Serial Poll Enable	After the Calibrator receives this message, it will show the Status Byte the next time it is addressed as a talker over the GPIB interface.
UNL	Unlisten	“Unaddresses” a specified device on the bus as a listener. The controller sends UNL automatically after the device has successfully received a device-dependent or common command.
UNT	Untalk	“Unaddresses” a specified device on the bus as a listener. The controller sends UNL automatically after the device has successfully received a device-dependent or common query.

Table 5-5. IEEE-488 Interface Messages (Sent)

Mnemonic	Name	Function
END	End	A message that occurs when the Calibrator asserts the EOI control line. The Calibrator asserts EOI while it transmits the ASCII character LF for its termination sequence or terminator.
DAC	Data Accepted	Set the handshake signal line NDAC low.
DAV	Data Valid	Asserts the handshake signal line DAV.
RFD	Ready for Data	Sets the handshake line NRFD low.
SRQ	Service Request	A control line that a device on the bus can assert to show that attention is necessary. Refer to “Check Calibrator Status”.
STB	Status Byte	The status byte is what the Calibrator sends when it replies to a serial poll (interface message SPE).

Compound Commands

A compound command is two or more commands in one command line. For example, the subsequent two commands could be recorded individually,

```
OUT 1 V, 60 HZ
OPER
```

where the Calibrator sources 1 V ac at 60 Hz, and then goes into operate, or they could be mixed into a compound command,

```
OUT 1 V, 60 HZ; OPER
```

with a semi-colon as a separator. Be careful when a compound command includes the coupled commands. (See “Coupled Commands.”)

Coupled Commands

A coupled command refers to two or more commands that are in a compound command (see “Compound Commands”) that do things that could interfere with each other and cause a fault. Commands in a compound command are disconnected with the; character. Compound commands with only coupled commands are not order-dependent.

In Chapter 6, the command shows a checkbox for coupled commands.

The coupled commands, but not the scope commands, are:

```
CUR_POST  DBMZ   DC_OFFSET     HARMONIC      OUT    WAVE
```

An example of the coupled command interference is the command

```
*RST; OUT 100V, 1kHZ; WAVE SINE
```

Followed by the commands

```
WAVE TRI
OUT 10V, 1kHZ
```

The `WAVE TRI` causes an error. At 100 V, only sine waves are permitted. The `WAVE` and `OUT` are coupled commands. So, the compound command

```
WAVE TRI; OUT 10V, 1kHZ
```

is successful. The `WAVE` and `OUT` are programmed together and at 10 V, triangle waves are permitted.

Overlapped Commands

Commands that start execution but slightly more time to complete is necessary are overlapped commands, because they can be overlapped by the subsequent command before they have completed execution.

In Chapter 6, the command shows a checkbox for overlapped commands.

The overlapped commands, but not the scope commands, are:

DBM	OPER	TSENS_TYPE
DC_OFFSET	OUT	WAVE
DPF	PHASE	ZCOMP
DUTY	RANGELCK	
EARTH	*RST	
HARMONIC	RTD_TYPE	
INCR	STBY	
LCOMP	TC_OFFSET	
LOWS	TC_OTCD	
MULT	TC_REF	
OLDREF	TC_TYPE	

You can use the command `*WAI` to wait until the overlapped command has completed execution before you do the subsequent command. For example,

```
OUT 1 V, 1 A, 60 HZ; *WAI
```

You can also use the status commands `*OPC` and `*OPC?` to find completion of overlapped commands. (See “Check 5502A Status.”)

Sequential Commands

Commands that start immediately are sequential commands.

In Chapter 6, the command shows a checkbox for sequential commands.

Most of the commands are sequential.

Commands where a Calibration Switch is Necessary

For the subsequent commands, the rear panel CALIBRATION switch must be in the ENABLE position:

`CLOCK` (when setting date but not time)
`FORMAT ALL`
`FORMAT CAL`
`*PUD`

If you try to use these commands with the CALIBRATION switch in the NORMAL position, an error is logged into the error queue. (Or it returns the error message if in the RS-232 Terminal Mode.)

Commands for RS-232 Only

The RS-232 checkbox shows RS-232 interface commands.

The IEEE-488 and RS-232 interfaces send commands to the Calibrator as data, but not those IEEE-488 functions that must be implemented as a message as specified in the IEEE-488 standards. For example, the RS-232 interface uses the command REMOTE to put the Calibrator in the remote mode. Although the IEEE-488 interface could also send a command REMOTE as data, it does not because this is one of the functions that must be implemented with the IEEE-488 Standards. The relationship between these IEEE-488 messages and the equivalent RS-232 emulation is shown in Table 5-6.

Table 5-6. Commands for RS-232 Only

IEEE-488 Message [1]	RS-232 Equivalent
GTL	LOCAL command
GTR	REMOTE command
LLO	LOCKOUT command
SRQ	SRQSTR command
SDC, DCL	^C (<Cntl> C) character [clear the device]
GET	^T (<Cntl> T) character [execute a group trigger]
SPE, SPD	^P (<Cntl> P) character [print the serial poll string]

[1] See “How IEEE-488 Operates” in this chapter.

With the commands and special characters that emulate the IEEE-488 functions shown above, there are more commands that are related to operation and control of the actual RS-232 Host port and these are unrelated to IEEE-488 operations. These include the subsequent six commands.

```
SP_SET     SPLSTR     SRQSTR
SP_SET?    SPLSTR?    SRQSTR?
```

Commands for IEEE-488 Only

The IEEE-488 checkbox shows commands that are used for the IEEE-488 interface. This is all the commands but those used for RS-232 operations. (See "Commands for RS-232 Only.") All commands are transferred over the IEEE-488 as data, except for the commands LOCAL, REMOTE, and LOCKOUT, which are implemented per IEEE Standards as messages (see Table 5-7).

Table 5-7. Commands for IEEE-488 Only

IEEE-488 Message [1]	Command Representation
GTL	LOCAL command
GTR	REMOTE command
LLO	LOCKOUT command
SRQ	SRQSTR command
SDC, DCL	Clear the device
GET	Execute a group trigger
SPE, SPD	Print the serial poll string

[1] See "How IEEE-488 Operates" in this chapter.

Command Syntax

The subsequent syntax rules apply to all the remote commands. Information about syntax of response messages is also given.

Parameter Syntax Rules

Table 5-8 shows the units accepted in command parameters and used in responses. All commands and units can be recorded in UPPER or lower case.

Table 5-8. Units Accepted in Parameters and Used in Responses

Units	Meaning
HZ	Frequency in units of hertz
KHZ	Frequency in units of kilohertz
MHZ	Frequency in units of megahertz
UV	Volts in units of microvolts
MV	Volts in units of millivolts
V	Volts in units of volts
KV	Volts in units of kilovolts
UA	Current in units of microamperes
MA	Current in units of milliamps
A	Current in units of amps
PCT	Percent
PPM	Parts-per-million
DBM	Volts in units of decibels referenced to 1 milliwatt into 600 Ω load

OHM	Resistance in units of ohms
KOHM	Resistance in units of kilohms
MOHM	Resistance in units of megohms
NF	Capacitance in units of nanofarads
PF	Capacitance in units of picofarads
UF	Capacitance in units of microfarads
MF	Capacitance in units of millifarads
F	Capacitance in units of farads
CEL	Temperature in degrees Celsius
FAR	Temperature in degrees Fahrenheit
NS	Period in units of nanoseconds
US	Period in units of microseconds
MS	Period in units of milliseconds
S	Period in units of seconds

General Rules The general rules for parameter use is:

1. When a command has more than one parameter, the parameters must be disconnected by commas. For example: `OUT 1V, 2A`.
2. Numeric parameters can have a maximum of 15 significant digits and their exponents can be in the range ±1.0E±20.
3. If you include too many or too few parameters, this causes a command error.
4. Null parameters cause an error, for example, the adjacent commas in `OUT 1V, ,2A`.
5. Expressions, for example `4+2*13`, are not permitted as parameters.
6. Binary Block Data can be in one of two ways: Indefinite Length and Definite Length format (both IEEE-488.2 standards).

Indefinite Length The Indefinite Length format accepts data bytes after the #0 until the ASCII Line Feed character is received with an EOI signal (for RS-232 just a line feed or carriage return will terminate the block).

Definite Length The Definite Length format specifies the number of data bytes. #n and an n-digit number come before the data bytes. The n-digit number identifies how many data bytes follow. For examples, see the UUT_SEND and *PUD command descriptions in Chapter 6.

Extra Space or Tab Characters

In the command descriptions in Chapter 6, parameters are shown disconnected by spaces. One space after a command is necessary (unless no parameters are necessary). All other spaces are optional. Spaces are put in for clarity in the manual and can be left in or ignored as necessary. You can put in more spaces or tabs between parameters as necessary. More spaces in a parameter are typically not permitted. They are permitted between a number and its related multiplier or unit. Chapter 6 has examples for commands where parameters or responses are not self-explanatory.

Terminators

Table 5-9 summarizes the terminator characters for the IEEE-488 and RS-232 remote interfaces.

Table 5-9. Terminator Characters

Terminator Function	ASCII Characters		Control Command Terminator	Language Command Terminator
	Number	Program		
Carriage Return (CR)	13	Chr(13)	<Cntrl> M	\n
Line Feed (LF)	10	Chr(10)	<Cntrl> J	\r
Backspace (BS)	8	Chr(8)	<Cntrl> H	\b
Form Feed (FF)	12	Chr(12)	<Cntrl> L	\f

Examples:	
RS-232 Terminal Mode	`OUT 1 V, 60 Hz` <Enter>
	`UUT SEND "REMS/n"` <Enter>
	`UUT_SEND #205REMS^M` <Enter> (^M means <cntrl>M)
RS-232 Computer Mode	`Comm1.Output = "OUT 1 V, 60 Hz" + Chr(10)`
(typical to Visual Basic)	`Comm1.Output = "UUT_SEND ""REMS/n"" " Chr(10)`
IEEE-488 Mode	`OUT 1 V, 60 Hz`
(command only)	`UUT_SEND "REMS\N"`

IEEE-488 Interface The Calibrator sends the ASCII character Line Feed with the EOI control line held high as the terminator for response messages. The calibrator recognizes these as terminators when found in incoming data.

- ASCII LF character
- All ASCII character sent with the EOI control line asserted

RS-232 Interface The Calibrator shows an EOL (End of Line) character with each response to the PC. This is selectable as Carriage Return (CR), Line Feed (LF) or CRLF. (See "RS-232 Host Port Setup Procedure" in this chapter.) Commands sent to the Calibrator must end in a CR, LF, or CRLF. (See Table 5-9.)

Incoming Character Processing

The Calibrator works with all incoming data as follows (except Binary Block Data as described under Parameter Syntax Rules):

1. The most significant data bit (DIO8) is ignored.
2. All data is read as 7-bit ASCII.
3. Lower-case or upper-case characters are accepted.
4. ASCII characters with decimal equivalents less than 32 (Space) are discarded. Characters 10 (LF) and 13 (CR) and in the `*PUD` command argument are not discarded. All characters in Binary Block Data arguments are permitted. Binary Block Data stops with a special procedure.

Response Message Syntax

The command descriptions in Chapter 6 tell you about the indications from the Calibrator where applicable. To know what type of data to read in, see the first part of the entry in the "Response" in the tables. The response is shown as one of the data types in Table 5-10.

Table 5-10. Response Data Types

Data Type	Description
Integer	Integers for some controllers or computers are decimal numbers in the range -32768 to 32768. Responses in this range are named Integer. Example: `*ESE 123; *ESE?` returns: `123`
Floating	Numbers that may have up to 15 significant figures plus an exponent that can range from ±E20. Example: `DC_OFFSET?` returns: `1.4293E+00`
String	ASCII characters with quotation mark delimiters. Example: `SRQSTR "SRQ from 5502A"; SRQSTR?` returns: `"SRQ from 5502A"`
Character Response Data (CRD)	This type of response is always a keyword. Example: `OUT 10V, 100HZ; FUNC?` returns: `ACV`
Indefinite ASCII (IAD)	ASCII characters followed by EOM. Queries with this type of response MUST be the last Query in a program message. Example: `*OPT?` returns: `SC600` CAL reports and lists that have Line Feeds are typically of this type.

Table 5-10. Response Data Types (cont.)

Data Type	Description
Binary Block Data	A special data type specified by the IEEE-488.2 standard. This type is used in *PUD? query. It is specified as follows: #(non-zero digit) (digits) (user data) The non-zero digit specifies the number of characters that in the <digits> field. Characters permitted in the digits field are 0 through 9 (ASCII 48 through 57 decimal). The value of the number in the <digits> field in decimal gives the number of user data bytes that follow in the <user data> field. The maximum response is 64 characters. Example: `*PUD "test1"; *PUD?` returns: `#205test1`

Check 5502A Status

The programmer has access to status registers, enable registers, and queues in the Calibrator to show various conditions in the instrument as shown in Figure 5-8. Some registers and queues are specified by the IEEE-488.2 standard. The remaining are specified to the Calibrator. In addition to the status registers, the Service Request (SRQ) control line, and a 16-element buffer named the Error Queue supply status information. Table 5-11 shows the status registers and gives the read/write commands and related mask registers.

Table 5-11. Status Register Summary

Status Register	Read Command	Write Command
Serial Poll Status Byte (STB)	*STB?	—
Service Request Enable Register (SRE)	*SRE?	*SRE
Event Status Register (ESR)	*ESR?	—
Event Status Enable Register (ESE)	*ESE?	*ESE
Instrument Status Register (ISR)	ISR?	—
Instrument Status Change Register (ISCR)	ISCR?	—
ISCR 1 to 0 transition	ISCR0?	—
ISCR 0 to 1 transition	ISCR1?	—
Instrument Status Change Enable Register (ISCE)	ISCE?	ISCE
ISCE 1 to 0 transition	ISCE0?	ISCE0
ISCE 0 to 1 transition	ISCE1?	ISCE1

Each status register and queue has a summary bit in the Serial Poll Status Byte. Enable registers are used to mask various bits in the status registers and supply summary bits in the Serial Poll Status Byte. For IEEE-488 interface operation, the Service Request Enable Register is used to assert the SRQ control line on detection of status condition or conditions the programmer chooses. For RS-232 interface operation, the SRQSTR string is sent over the serial interface when the SRQ line is set. (See the `SRQSTR` command description in Chapter 6.)

Serial Poll Status Byte (STB)

The Calibrator sends the serial poll status byte (STB) when it responds to a serial poll. This byte is set to 0 when the power is turned on. The STB byte is specified as shown in Figure 5-9. If you use the RS-232 as the remote control interface, transmitting the ^P character (in the Terminal mode, hold down the <Cntl> key and push P) gives the SPLSTR (Serial Poll String) and the status byte. Refer to the `*STB` command, and for RS-232 interface operation, the `SPLSTR` and `SPLSTR?` commands, in Chapter 6 for more information.

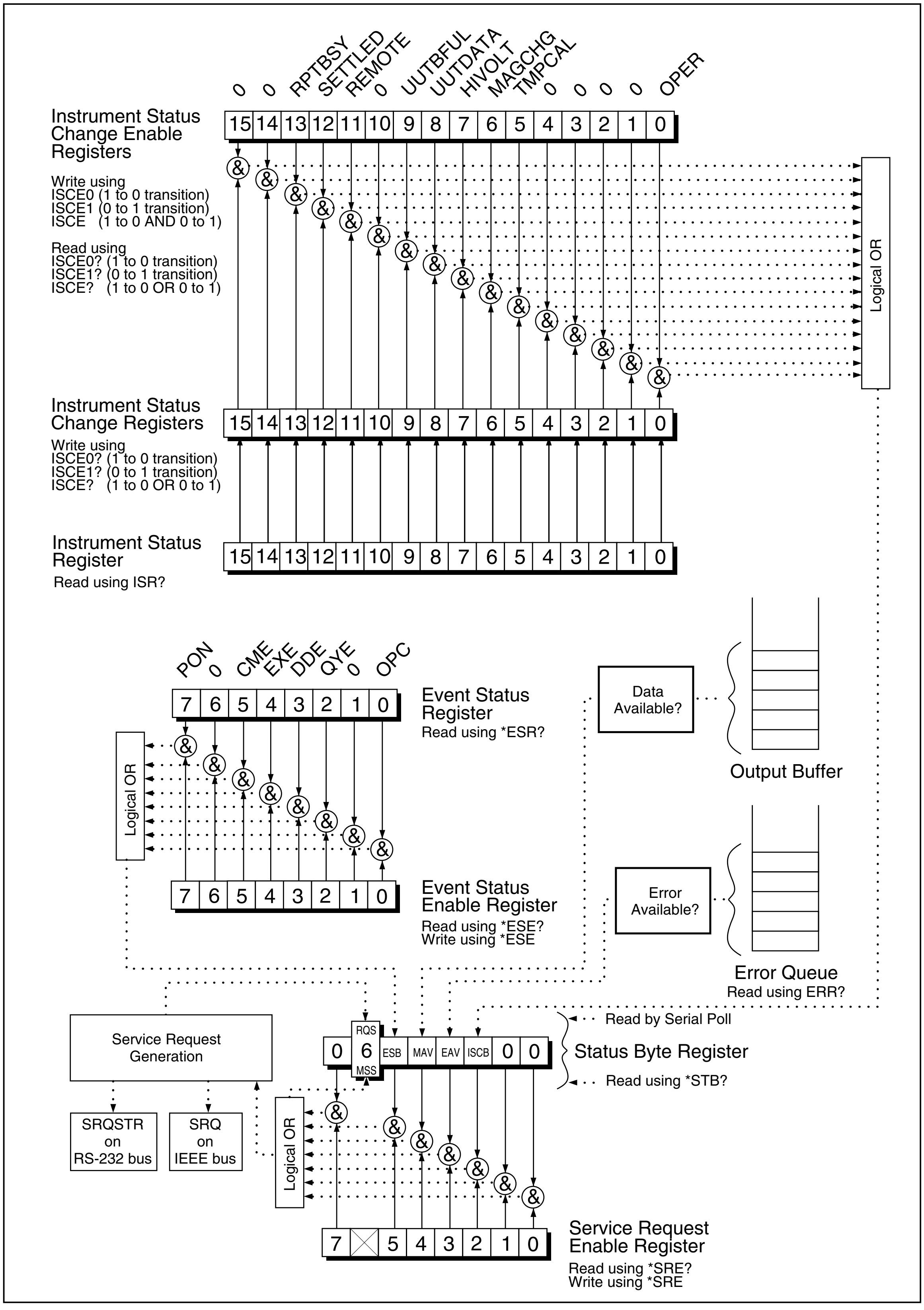


Figure 5-8. Status Register Overview

7	6	5	4	3	2	1	0
0	**RQS** / **MSS**	**ESB**	**MAV**	**EAV**	**ISCB**	**0**	**0**

RQS	Requesting service. The RQS bit is set to 1 whenever bits ESB, MAV, EAV, or ISCB change from 0 to 1 and are enabled (1) in the SRE. When RQS is 1, the 5502A asserts the SRQ control line on the IEEE-488 interface. You can do a serial poll to read this bit to see if the 5502A is the source of an SRQ.
MSS	Master summary status. Set to 1 whenever bits ESB, MAV, EAV, or ISCB are 1 and enabled (1) in the SRE. This bit can be read using the *STB? command in serial remote control in place of doing a serial poll.
ESB	Set to 1 when one or more enabled ESR bits are 1.
MAV	Message available. The MAV bit is set to 1 when data is available in the IEEE-488 interface output buffer of the 5502A.
EAV	Error available. An error has occurred and an error is available to be read from the error queue by using the ERR? query.
ISCB	One or more enabled ISCR bits are 1.

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Figure 5-9. Serial Poll Status Byte (STB) and Service Request Enable (SRE)

Service Request (SRQ) Line

IEEE-488 Service Request (SRQ) is an IEEE-488.1 bus control line that the Calibrator asserts to tell the controller that some type of service is necessary. Many instruments can be on the bus, but they all share a single SRQ line. To find which instrument set SRQ, the Controller typically does a serial poll of each instrument. The calibrator asserts SRQ when the RQS bit in its Serial Poll Status Byte is 1. This bit tells the controller that the Calibrator was the source of the SRQ.

RS-232 Remote operations with the RS-232 interface emulate the IEEE-488 SRQ line with an SRQSTR string sent with the serial interface when the SRQ line is set. (See the SRQSTR command description in Chapter 6 for more information.)

The Calibrator clears SRQ and RQS when the controller/host does a serial poll, sends *CLS, or when the MSS bit is cleared. The MSS bit is cleared only when ESB, MAV, EAV, and ISCB are 0, or they are disabled by their associated enable bits in the SRE register being set to 0.

Service Request Enable Register (SRE)

The Service Request Enable Register (SRE) enables or masks the bits of the Serial Poll Status Byte. The SRE is cleared at power up. Refer to Figure 5-9 for the bit functions.

Programming the STB and SRE

If you reset (to 0) the bits in the SRE, you can mask (disable) associated bits in the serial poll status byte. Bits set to 1 enable the associated bit in the serial poll status byte. The subsequent sample BASIC program enables the Error Available (EAV) bit.

```
10  ! THIS PROGRAM SETS EAV IN THE SRE
20  PRINT @6,"*SRE 8"                ! LOAD THE REGISTER
30  PRINT @6, "*SRE?"                ! ASK FOR THE SRE CONTENTS
40  INPUT @6, A%                     ! RETRIEVE THE REGISTER CONTENTS
50  PRINT "SRE = ";A%
60  RETURN
```

The subsequent BASIC program gives an error and verifies the Serial Poll Status Byte. Enable the EAV bit with the example above.

```
10  ! THIS PROGRAM GENERATES AN ERROR AND CHECKS IT
20  PRINT @6, "OUT 1300V"            ! 1300V IS OUT OF 5502A RANGE
30  A% = SPL(6)                      ! DO A SERIAL POLL
40  IF ((A% AND 72%)=0%)THEN PRINT "EAV and RQS should have been set"
50  PRINT @6, "*STB?"                ! RETRIEVE BYTE
60  INPUT @6, A%
70  IF ((A% AND 8%)=0%) THEN PRINT "EAV should have been set"
```

Event Status Register (ESR)

The Event Status Register is a two-byte register where the higher eight bits are 0 and the lower eight bits represent different conditions of the Calibrator. The ESR is cleared (set to 0) when you turn power on, and each time it is read.

Parameters are necessary for many of the remote commands. Incorrect use of parameters can make command errors. When a command error occurs, bit CME (5) in the Event Status Register (ESR) goes to 1 (if enabled in ESE register), and the error is recorded in the error queue.

Event Status Enable (ESE) Register

A mask register called the Event Status Enable register (ESE) lets the controller enable or mask (disable) each bit in the ESR. When a bit in the ESE is 1, the related bit in the ESR is enabled. When an enabled bit in the ESR is 1, the ESB bit in the Serial Poll Status Byte also goes to 1. The ESR bit stays 1 until the controller reads the ESR or does a device clear, a selected device clear, or sends the reset or `*CLS` command to the Calibrator. The ESE is cleared (set to 0) when the power is turned on.

Bit Assignments for the ESR and ESE

The bits in the Event Status Register (ESR) and Event Status Enable register (ESE) are given as shown in Figure 5-10.

15	14	13	12	11	10	9	8
0	0	0	0	0	0	0	0

7	6	5	4	3	2	1	0
PON	**0**	**CME**	**EXE**	**DDE**	**QYE**	**0**	**OPC**

PON	Power on. This bit is set to 1 if line power has been turned off and on since the last time the ESR was read.
CME	Command error. The IEEE-488 interface of the 5502A encountered an incorrectly formed command. (The command ERR? fetches the earliest error code in the error queue, which contains error codes for the first 15 errors that have occurred.)
EXE	Execution error. An error occurred while the 5502A tried to execute the last command. This could be caused, for example, by a parameter being out of range. (The command ERR? fetches the earliest error in the error queue, which contains error codes for the first 15 errors that have occurred.)
DDE	Device-dependent error. An error related to a device-dependent command has occurred.
QYE	Query error. The 5502A was addressed to talk when no response data was available or appropriate, or when the controller failed to retrieve data on the output queue.
OPC	Operation complete. All commands previous to reception of a *OPC c ommand have been executed, and the interface is ready to accept another message.

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Figure 5-10. Event Status Register (ESR) and Event Status Enable (ESE)

Program the ESR and ESE

To read the contents of the ESR, send the remote command, `*ESR?`. The ESR is cleared (set to 0) each time it is read. To read the contents of the ESE, send the remote command, `*ESE?`. The ESE is not cleared when it is read. When you read the registers, the Calibrator answers by sending a decimal number that when change to binary shows bits 0 through 15. The subsequent sample BASIC program gets the contents of each register:

```
10  ! THIS PROGRAM READS THE ESR AND THE ESE REGISTERS
20  PRINT @6, "*ESR?"        ! ASK FOR THE ESR CONTENTS
30  INPUT @6, A%             ! RETRIEVE THE REGISTER CONTENTS
40  PRINT @6, "*ESE?"        ! ASK FOR THE ESE CONTENTS
50  INPUT @6, B%             ! RETRIEVE THE REGISTER CONTENTS
60  PRINT "ESR = ";A%        ! DISPLAY THE ESR REGISTER CONTENTS VALUE
70  PRINT "ESE = ";B%        ! DISPLAY THE ESE REGISTER CONTENTS VALUE
80  END
```

Change the contents of variables A and B into binary, and you can read the status of the registers. For example if A is 32, its binary equal is: 00000000 00100000. Thus, bit 5 (CME) in the ESR is set (1) and the remaining of the bits are reset (0). This means that the Calibrator tried to do an incorrectly formed command.

If you set the bits in the ESE, you can mask (disable) the related bits in the ESR. For example, to prevent the occurrence of a command error from causing bit 5 (ESB) in the serial poll status byte to go to 1, you can reset (to 0) bit 5 in the ESE register. The subsequent sample program makes sure of the status of the CME bit, then toggles it if it is 1.

```
10  ! THIS PROGRAM RESETS BIT 5 (CME) IN THE ESE
20  PRINT @6,"*ESE 33"              ! INITIAL ESE IS CME + OPC
30  GOSUB 100                       ! GET AND PRINT INITIAL ESE
40  IF (A% AND 32%) THEN A% = A% - 32% ! CLEAR CME (BIT 5)
50  PRINT @6, "*ESE ";A%            ! LOAD ESE WITH NEW VALUE
60  GOSUB 100                       ! GET AND PRINT NEW ESE
70  END
100 PRINT @6, "*ESE?"               ! ASK FOR ESE CONTENTS
110 INPUT @6, A%                    ! RETRIEVE REGISTER CONTENTS
120 PRINT "ESE = ";A%
130 RETURN
```

Instrument Status Register (ISR)

The Instrument Status Register (ISR) gives the controller access to the condition of the Calibrator, including some of the information given to the operator on the Control Display and the display annunciators during local operation.

Instrument Status Change Registers

There are two registers that monitor changes in the ISR. These are the ISCR0 (Instrument Status 1-0 Change Register) and the ISCR1 (Instrument Status 0-1 Change Register). Each status change register has a related mask register. Each ISCR is cleared (set to 0) when your turn the Calibrator on, each time it is read, and at each `*CLS` (Clear Status) command.

Instrument Status Change Enable Registers

The Instrument Status Change Enable registers (ISCE0 and ISCE1) are mask registers for the ISCR0 and ISCR1 registers. If a bit in the ISCE is enabled (set to 1) and the related bit in the ISCR makes the correct change, the ISCB bit in the Status Byte is set to 1. If all bits in the ISCE are disabled (set to 0), the ISCB bit in the Status Byte does not go to 1. The contents of the ISCE registers are set to 0 at power-up.

Bit Assignments for the ISR, ISCR, and ISCE

The bits in the Instrument Status, Instrument Status Change, and Instrument Status Change Enable registers are given in Figure 5-11.

15	14	13	12	11	10	9	8
0	0	RPTBUSY	SETTLED	REMOTE	0	UUTBFUL	UUTDATA

7	6	5	4	3	2	1	0
HIVOLT	MAGCHG	TMPCAL	0	0	0	0	OPER

RPTBUSY	Set to 1 when a calibration report is being printed to the serial port.
SETTLED	Set to 1 when the output has stabilized to within speclfication or the TC measurement has settled and is available.
REMOTE	Set to 1 when the 5502A is under remote control.
UUTBFUL	Set to 1 when data from the UUT port has filled up the UUT buffer.
UUTDATA	Set to 1 when there ia data available from the UUT port.
HIVOLT	Set to 1 when the 5502A is programmed to a voltage above 33 Volts.
MAGCHG	Set to 1 when the output magnitude has changed as a result of another change (for example RTD_TYPE). This bit is always 0 in the ISR. It changes to 1 only in the ISCR0 and ISCR1 registers.
TMPCAL	Set to 1 when the 5502A is using temporary (non-stored) calibration data.
OPER	Set to 1 when the 5502A is in operate, 0 when it is in standby.

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Figure 5-11. Bit Assignments for the ISR, ISCEs and ISCR

Program the ISR, ISCR, and ISCE

To read the contents of the ISR, send the remote command, `ISR?`. To read the contents of the ISCR0 or 1, send the remote command, `ISCR0?`, or `ISCR1?`. To read the contents of the ISCE0 or 1, send the remote command, `ISCE0?`, or `ISCE1?`. The Calibrator sends a decimal number that represents bits 0 through 15 to answer. Each time you read the ISCR0 or 1, its contents are zeroed. The subsequent sample program reads all five registers:

```
10  ! THIS PROGRAM READS THE ISR, ISCR, AND ISCE REGISTERS
20  ! NOTE THAT THE ICSR? COMMANDS CLEAR THE ISCR CONTENTS
30  PRINT @6, “ISR?”     ! ASK ISR CONTENTS
40  INPUT @6,A%          ! RETRIEVE REGISTER CONTENTS FROM 5502A
50  PRINT @6, “ISCR0?”   ! ASK FOR AND CLEAR ISCR0 CONTENTS
60  INPUT @6, B%         ! RETRIEVE REGISTER CONTENTS FROM 5502A
70  PRINT @6, “ISCE0?”   ! ASK FOR ISCE0 CONTENTS
80  INPUT @6, C%         ! RETRIEVE REGISTER CONTENTS FROM 5502A
50  PRINT @6, “ISCR1?”   ! ASK FOR AND CLEAR ISCR1 CONTENTS
60  INPUT @6, D%         ! RETRIEVE REGISTER CONTENTS FROM 5502A
70  PRINT @6, “ISCE1?”   ! ASK FOR ISCE1 CONTENTS
80  INPUT @6, E%         ! RETRIEVE REGISTER CONTENTS FROM 5502A
90  PRINT “ISR =  “;A%   ! DISPLAY ISR
100 PRINT “ISCR0 = “;B%  ! DISPLAY ISCR0
110 PRINT “ISCE0 = “;C%  ! DISPLAY ISCE0
100 PRINT “ISCR1 = “;D%  ! DISPLAY ISCR1
110 PRINT “ISCE1 = “;E%  ! DISPLAY ISCE1
120 END
```

Change the returned variables into binary, and you can read the status of the instrument. For example if a register contains 128, its binary equivalent is: 00000000 10000000. Bit 7 (HIVOLT) is set (1) and the remaining of the bits are reset (0).

If you set the bits in an ISCE register, you can mask (disable) the related bits in the ISCR. For example, to cause an SRQ interrupt when the output has become stable, bit 12 (SETTLED) in the ISCE1 register must be 1. (The ISCB bit must also be enabled in the SRE.) The subsequent sample program loads a decimal 1024 into the ISCE, which sets bit 12 and resets the other bits:

```
10  ! THIS PROGRAM LOADS 00010000 00000000 BINARY INTO THE ISCE
20  PRINT @6, “ISCE 4096” ! LOAD DECIMAL 4096 INTO ISCE
30  PRINT @6, “ISCE?”     ! READ BACK ISCE VALUE
40  INPUT @6, A%          ! “
50  PRINT “ISCE = “;A%    ! PRINT IT, IT SHOULD BE 4096
60  END
```

Output Queue

The output queue is loaded when a query is done, and holds a maximum of 800 characters. The controller reads it with a statement like a BASIC INPUT statement, removes what it reads from the queue. If the queue is empty, the Calibrator does not answer to the INPUT statement from the controller. The Message Available (MAV) bit in the Serial Poll Status Byte is 1 if there is something in the output queue and 0 if the output queue is empty.

Error Queue

When a command error, execution error, or device-dependent error occurs, its error code is put in the error queue where it can be read by the `ERR?` command. (See Appendix E for error messages.) A procedure to decode an error code is to send the command, `EXPLAIN?`, which gives a description of an error code. If you read the first error with the `ERR?` command, this removes that error from the queue. A response of 0 means the error queue is empty. The Error Available (EAV) bit in the Serial Poll Status Byte shows if the queue is empty. The error queue is cleared when you turn off the power, and when you use the `*CLS` (Clear Status) common command.

The error queue has a maximum of 16 entries. If many errors occur, only the first 15 errors are kept in the queue. A 16th entry in the queue is an "error queue overflow" error, and all later errors are discarded until the queue is at minimum partially read. The first errors are kept, because if many errors occur before the user can acknowledge and read them, the earliest errors are the most likely to point to the problem. The later errors are typically repetitions or consequences of the initial problem.

Remote Program Examples

The subsequent programming examples show procedures to handle errors, to read measurements, get a number of successive indications, lock the range, and calibrate the Calibrator. These excerpts from programs are written in DOS BASIC.

Guidelines to Program the Calibrator

Commands are done one at a time as they are received. For some commands, a previous condition must be set before the command will be accepted by the Calibrator. For example, the waveform must be SQUARE before the DUTY command will be accepted. Use the subsequent programming guidelines to make sure that the output is programmed to the necessary condition.

- All external connections commands must be programmed first. The calibrator will be put in standby and the output can be changed to accommodate the new external connection. The setting can be set if the given output does not use the setting (for example, setting the current post while sourcing voltage).
- The output and output mode must be programmed subsequently with the OUT command.
- All other output parameters such as impedance compensation, offset, and waveforms must be programmed subsequently. The DUTY command must follow the WAVE command.
- The error status should be checked with the ERR? command. The calibrator will not do the OPER command if an unacknowledged error exists.
- Finally, the Calibrator must be put in operate with the OPER command.

First, it is necessary for a controller program to initialize the interface and the Calibrator. Refer to subsequent sample program:

```
10 INIT PORT 0 \ REMOTE @6       ! PUT THE 5502A INTO THE REMOTE STATE
20 PRINT @6, "*RST;OUT 10V;OPER" ! RESET THE 5502A, PROGRAM IT TO
```

If necessary, use SRQs, first use the `*SRE`, `*ESE`, and `ISCE` commands to enable the necessary event. Refer to "Checking 5502A Status."

You retrieve instrument parameters with a query (a programming command that ends with a question mark):

```
200 PRINT @6, "FUNC?"                ! RETRIEVE OUTPUT FUNCTION
210 INPUT LINE @6, A$
220 PRINT "Function is: ";A$
230 PRINT @6, "ONTIME?"            ! RETRIEVE ON TIME
240 INPUT LINE @6, A$
250 PRINT "The instrument has been on for ";A$;" minutes"
```

This program gives the subsequent sample output:

```
Function is: DCV
The instrument has been on for 134 minutes
```

Make sure that there are no for programming errors as in the subsequent sample programs. Verify the Error Available (EAV) bit in the serial poll register with a serial poll.

```
300 A = SPL(6)                              ! CHECK FOR ERRORS
310 IF (A AND 8) THEN PRINT "There was an error"
320 PRINT @6, "*CLS"                        ! CLEAR ERRORS
```

Get errors and explanations as follows. Since errors are accumulated in a queue, you must read the complete queue to get and clear all the errors.

```
400 PRINT @6, "ERR?"              ! CHECK FOR ERRORS
410 INPUT @6, A, A$               ! READ IN THE ERROR
420 IF (A = 0) THEN GOTO 500      ! NO MORE ERRORS
430 PRINT "Error# :"; A, A$        ! PRINT ERROR# AND EXPLANATION
440 GOTO 400
500 END
```

Write an SRQ and Error Handler

It is good to include fault (error) handling routines in your procedures. The subsequent sample program lines show a procedure to stop program execution on occurrence of an SRQ (Service Request) on the bus, see if the Calibrator is the source of the SRQ, get its fault messages, and act on the faults. You must change and extend this code as necessary for your procedure.

To use SRQs, first use the `*SRE`, `*ESE`, and `ISCE` commands to enable the necessary event. Refer to "Check the 5502A Status" for more information.

```
10   INIT PORT0                    ! IFC the bus
20   CLEAR PORT0                   ! DCL the bus
30   ! INITIALIZE THE 5502A SRQ HANDLER
40   PRINT @6, "*SRE 8"           ! Enable STB.EAV (error available)
50   ON SRQ GOTO 1100              ! Install SRQ handler
60   ! Body of the application goes here
1100  ! Bus SRQ handler
1110  CLEAR PORT0                  ! Make sure devices are not confused
1120  IF (SPL(6) AND 64) THEN GOSUB 1200   ! If (STB.RQS) call SRQ
1130  ! TEST OTHER DEVICES RQS BITS IF DESIRED
1140  RESUME
1200  ! 5502A SRQ handler
1210  IF (SPL(6) AND 8) THEN GOSUB 1300  ! If (STB.EAV) call handler
1220  ! Test other STB bits if desired here
1299  RETURN
1300  ! 5502A STB.EAV (error) handler
1320  PRINT @6, "ERR?"            ! Read and clear error
1330  INPUT @6, E%, E$             ! Read in error # and explanation
1340  PRINT "Error# :"; E, E$      ! Print error # and explanation
1350  IF (E% <> 0) THEN GOTO 1320 ! Until no more errors
1360  STOP                         ! Other commands for your app
1370  END
```

Verify a Meter on the IEEE-488 Bus

This program selects 10 V dc output, makes sure that the Calibrator is set to 10 V, then triggers a Fluke 45 to get a reading. It shows calibrator output, Fluke 45 indication, and the meter error in ppm. For this program, the Calibrator bus address is 4 and the Fluke 45 bus address is 1.

```
10 REM  THIS PROGRAM VERIFIES THE ACCURACY OF A FLUKE 45 AT 10V DC
20 INIT PORT 0                              ! INITIALIZE THE INTERFACE
30 CLEAR PORT 0                             ! "
40 PRINT @1, "VDC;RATE 5;AUTO;TRIGGER 2" ! SETS FLUKE 45 TO 10V DC
50 PRINT @1, "OUT 10 V; OPER;            ! SET THE 5502A TO 10V DC
60 PRINT @4, "*WAI; OUT?" ! WAIT FOR SETTLE, REQUEST THE OUTPUT VALUE
70 PRINT @4, V,U$,F,V2,U2$                  ! GET THE DATA FROM THE 5502A
80 PRINT @1, "*TRG;VAL?"                    ! TRIGGER 45 TO TAKE READING
90 INPUT @1, VM                             ! GET THE DATA FROM THE 45
100 ER = ABS(V - VM)/V * 1E6                ! COMPUTE ERROR
110 PRINT "5502 OUTPUT: ";V;U$              ! PRINT THE RESULTS
120 PRINT "45 MEASURED: ";VM;"V"
130 PRINT "ERROR:       ";ER;"PPM"
140 END
```

Verify a Meter on the RS-232 UUT Serial Port

This program selects 10 V dc output, makes sure that the Calibrator is set to 10 V, then triggers a Fluke 45 to get a reading. It shows Calibrator output, the Fluke 45 indication, and the meter error in ppm. For this program, the Calibrator uses the IEEE-488 interface with bus address 4 and the Fluke 45 is on the Calibrator SERIAL 2 TO UUT port.

```
10  REM  THIS PROGRAM VERIFIES THE ACCURACY OF A FLUKE 45 AT 10V DC
20  INIT PORT 0                              ! INITIALIZE THE INTERFACE
30  CLEAR PORT 0                             ! "
40  PRINT @4, "UUT_SEND `VDC;RATE S;AUTO;TRIGGER 2\n'" ! SET FLUKE 45
50  PRINT @4, "UUT_RECV"                    ! SEND THE FLUKE 45 PROMPT
60  PRINT @4, P$                             ! GET THE FLUKE 45 PROMPT
70  PRINT @4, "OUT 10 V; OPER"             ! SET THE 5502A TO 10 V DC
80  PRINT @4, "*WAI; OUT?"                  ! WAIT FOR SETTLE; GET VALUE
90  PRINT @4, "V,U$,F,V2,U2$"               ! GET THE DATA FROM 5502A
100 PRINT @4, "UUT_SEND `*TRG; VAL?\n'"     ! TRIGGER FLUKE 45 READING
110 PRINT @4, "UUT_RECV?"                   ! SEND 45 READING TO 5502A
120 INPUT @4, VM, P$                         ! GET 45 READING AND PROMPT
130 ER = ABS (V - VM)/V * 1E6                ! COMPUTE ERROR
140 PRINT "5502 OUTPUT: ";V;U$              ! PRINT THE RESULTS
150 PRINT "FLUKE 45 MEASURED: ";ER;"PPM"   ! PRINT THE RESULTS
160 END
```

Use *OPC?, *OPC, and *WAI

The *OPC?, *OPC, and *WAI commands let you keep control of the sequence of execution of commands that could be passed up by subsequent commands.

If you had sent an OUT command, you can make sure that the output has become stable by sending the query *OPC?. When the OUT command has completed (output settled), a "1" is shown in the output buffer. You must follow an *OPC? command with a read command. The read command makes the program execution pause until the addressed instrument answers. The subsequent sample program shows how you can use *OPC?.

```
10 PRINT @4, "OUT 100V,1KHZ/;/OPER/;/ *OPC?"     ! 5502A ADDRESS IS 4
20 INPUT @4, A                                   ! READ THE "1" FROM THE 5502A
30 !PROGRAM HALTS HERE UNTIL A "1" IS PUT INTO THE OUTPUT BUFFER
40 PRINT "OUTPUT SETTLED"
```

The *OPC command is like the *OPC? query in operation, except that it sets bit 0 (OPC for “Operation Complete”) in the Event Status Register to 1 as an alternative to sending a 1 to the output buffer. One simple use for *OPC is to put it in the program so that it gives an SRQ (Service Request). Then an SRQ handler written into the program can find the operation complete condition and respond correctly. You can use *OPC like *OPC?, except your program must read the ESR to find the finish of all operations. The subsequent sample program shows how you can use *OPC.

```
10 REMOTE
20 PRINT @4, “OUT 100V,1KHZ/;/OPER/;/*OPC”      ! 5502A ADDRESS IS 4
30 PRINT @4, “*ESR?”                            ! PUT THE ESR BYTE IN BUFFER
40 INPUT @4, A%                                 ! READ THE ESR BYTE
50 IF (A% AND 1%) = 0% GOTO 30                  ! TRY AGAIN IF NO OPC
60 PRINT “OUTPUT SETTLED”
70 END
```

The *WAI command makes the Calibrator stop until all commands are complete before it continues to the subsequent command, and does no more. Use *WAI as an easy procedure to stop operation until the commands before it are complete. The subsequent sample program shows how you can use *WAI.

```
10 REMOTE
20 PRINT @4, “OUT 100V,1KHZ/;/OPER/;/*WAI”      ! 5502A ADDRESS IS 4
30 PRINT @4, “OUT?”                             ! READ THE OUTPUT VALUE
40 PRINT @4, A$,B$,C$                           ! A$ CONTAINS THE OUTPUT
VALUE
50 PRINT “OUTPUT SETTLED”
60 PRINT “OUTPUT IS: “/;/A$/;/B$/;/” at “/;/C$
70 END
```

Get a Thermocouple Measurement

The subsequent program measures one temperature measurement at a time.

```
10 REM Set Bus Timeout to 20 seconds, Init IEEE Bus
20 TIMEOUT 20 * 1000
30 INIT PORT 0
40 CLEAR @6
100 REM Reset 5502A, TC measurement mode
110 PRINT @6,”*RST/;/ TC_TYPE J/;/ TC_MEAS FAR”
200 PRINT “Hit Carriage Return to take a Reading”
210 INPUTLINE A$
220 REM Request the measurement value
230 PRINT @6, “VAL?”
240 REM Read measurement, unit
250 INPUT @6, M,U$
260 GOTO 200
```

Use the RS-232 UUT Port to Control an Instrument

The SERIAL 2 TO UUT RS-232 port is used to send commands to a different instrument. For example, a meter that is being calibrated can have its RS-232 port connected to the Calibrator SERIAL 2 TO UUT serial port. Commands sent from a controller can go through the Calibrator’s UUT port and be received by the meter or UUT. There are seven special UUT_* commands that Calibrator can use to pass commands to an instrument that you connect to the UUT port. See to Chapter 6.

Input Buffer Operation

As the Calibrator receives each data byte from the controller, it puts the bytes in a part of memory the input buffer. The input buffer holds a maximum of 350 data bytes and operates with first in, first out protocol.

IEEE-488 The Calibrator sees the EOI IEEE-488 control line as an isolated data byte and puts it into the input buffer if it is met as part of a message terminator. Input buffer operation is transparent to the program on the controller. If the controller sends commands faster than the Calibrator can process them, the input buffer fills to capacity. When the input buffer is full, the Calibrator holds off the IEEE-488 bus with the NRFD (Not Ready For Data) handshake line. When the Calibrator has processed a data byte from the full input buffer, it completes the handshake, and lets the controller send a different data byte. The calibrator clears the input buffer on power-up and on receiving the DCL (Device Clear) or SDC (Selected Device Clear) messages from the controller.

RS-232 Under RS-232-C serial port remote control with ^S (<Cntl> S) XOFF protocol, the Calibrator gives a ^S XOFF when the input buffer becomes 80 % full. The Calibrator gives a ^Q (<Cntl> Q) when it has read a sufficient amount of the input buffer so that it is less than 40 % full. When you use RTS (Request to Send) protocol (selected as part of the "RS-232 Host Port Setup Procedure"), the serial interface asserts and unasserts RTS in response to same conditions as for XON/XOFF protocol.

Chapter 6
Remote Commands

Title	Page

Introduction

This chapter documents the IEEE-488/RS-232 remote commands for the Calibrator. Remote commands duplicate procedures that can be started from the front panel in local operation. After the summary table is a complete alphabetical listing of all commands complete with protocol information. Isolated headings in the alphabetical listing give the parameters and responses, plus an example for each command. For information on command use, see Chapter 5, “Remote Operation.”

Command Summary by Function

Tables 6-1 through 6-10 show and tell you about the command set for the Calibrator.

Table 6-1. Common Commands

Command	Description
*CLS	(Clear status.) Clears the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte. This command stops pending operation complete commands (*OPC or *OPC?).
*ESE	Puts a byte into the Event Status Enable register.
*ESE?	Shows the contents of the Event Status Enable register.
*ESR?	Shows the contents of the Event Status Register and clears the register.
*IDN?	Identification query. Shows instrument model number, serial number, and firmware revision levels for the main and front panel CPUs, and inguard PGA.
*OPC	Sets bit 0 (OPC for "Operation Complete") in the Event Status Register to 1 when all pending device operations are complete.
*OPC?	Shows a 1 after all pending operations are complete. This command makes program execution pause until all operations are complete. (See also *WAI.)
*OPT?	Shows the installed hardware and software options.
*PUD	Protected user data command. This command lets you keep a string of bytes in nonvolatile memory. This command works only when the CALIBRATION switch is in the ENABLE position.
*PUD?	Shows the contents of the *PUD (Protected User Data) memory.
*RST	Resets the condition of the instrument to the power-up condition. This command holds off execution of subsequent commands until it is complete. (Overlapped command.)
*SRE	Puts a byte into the Service Request Enable register (SRE).
*SRE?	Shows the byte from the Service Request Enable register.
*STB?	Shows the status byte.
*TRG	Changes the operation mode to thermocouple MEASURE, triggers a measurement, and shows the value of the measurement. This command is equal to sending "TC_MEAS;*OPC;VAL?".
*TST?	Starts a series of self-tests, then shows a "0" for pass or a "1" for fail. If faults are detected, they are kept into the fault queue where they can be read by the ERR? query.
*WAI	Keeps further remote commands from being done until all previous remote commands have finished.

Table 6-2. Error Mode Commands

Command	Description
EDIT	Sets the edit field. PRI is specified for the output value in single output functions and the primary output value in dual output functions.
EDIT?	Shows the edit field position.
ERR_REF	Selects the error reference source.
ERR_REF?	Shows the currently selected error reference source.
ERR_UNIT	Chooses how UUT error is shown.
ERR_UNIT?	Shows currently selected value of ERR_UNIT.
INCR	Increments or decrements the output (as selected by the edit field) and changes to error mode, the same as if you use the output adjustment knob in local operation.
MULT	Multiplies the reference magnitude (as selected by the edit field).
NEWREF	Sets the reference value to be the current Calibrator output value, the same as if you push the NEW REF key in local operation.
OLDREF	Sets the Calibrator output to the previously programmed reference value, the same as if you push the ENTER key in local operation.
OUT_ERR?	Shows the UUT error calculated after shifting the output with the INCR command.
REFOUT?	Shows the value of the reference, which is the output values of the Calibrator the last time a new reference was made with an OUT, NEWREF, or MULT.
EDIT	Sets the edit field. PRI is specified for the output value in single output functions and the primary output value in dual output functions.

Table 6-3. External Connection Commands

Command	Description
CUR_POST	Selects the live binding posts for current output. This applies to current and power outputs.
CUR_POST?	Shows the live binding posts for current output.
EARTH	Connects or disconnects the internal guard shield from earth (chassis) ground.
EARTH?	Shows if the internal guard shield is connected or disconnected from earth (chassis) ground.
LOWS?	Shows if or not the low terminals are internally open or connected together.
LOWS	Selects if or not the low terminals are internally open or connected together for dual outputs.
RTD_TYPE	Sets the Resistance Temperature Detector (RTD) type.

Table 6-3. External Connection Command (cont.)

Command	Description
RTD_TYPE?	Shows the Resistance Temperature Detector (RTD) type.
TC_REF	Sets if the internal temperature sensor or an external reference value is used for Thermocouple (TC) outputs and measurements.
TC_REF?	Shows the source and value of the temperature that is used as a reference for thermocouple simulation and measurement.
TC_TYPE	Sets the thermocouple (TC) temperature type.
TC_TYPE?	Shows the thermocouple (TC) type.
TSENS_TYPE	Sets temperature sensor type when output is set to a temperature with OUT command.
TSENS_TYPE?	Shows the temperature sensor type.

Table 6-4. Oscilloscope Commands

Commands	Description
OL_TRIP?	Shows the found condition of scope overload protection.
OUT_IMP	Sets the output impedance of the SCOPE BNC.
OUT_IMP?	Shows the output impedance of the SCOPE BNC.
RANGE	Sets the Calibrator range when in OVERLD, PULSE, or MEASZ scope modes.
SCOPE	Sets the calibrator output to an oscilloscope mode.
SCOPE?	Shows the current oscilloscope mode.
TDPULSE	Starts or deactivates the tunnel diode pulser drive for the –SC600 and –SC300 EDGE mode.
TDPULSE?	Shows whether the tunnel diode pulser drive for the –SC600 and –SC300 EDGE mode is active.
TLIMIT	Sets the time limit for –SC600 OVERLD mode to stay in operate.
TLIMIT?	Shows the time limit for –SC600 OVERLD mode to stay in operate.
TLIMIT_D	Sets the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.
TLIMIT_D?	Shows the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.
TMWAVE	Selects the waveform for MARKER mode.
TMWAVE?	Shows the timemark waveform setting for MARKER mode.
TRIG	Sets the frequency of the signal at the TRIG BNC.
TRIG?	Shows the frequency of the signal at the TRIG BNC.
VAL?	Shows the last thermocouple value, or, for the –SC600, impedance measurement value.
VIDEOFMT	Selects the format for VIDEO mode.
VIDEOFMT?	Shows the VIDEO mode format.
VIDEOMARK	Sets the VIDEO mode line marker location.

Table 6-4. Oscilloscope Commands (cont.)

Commands	Description
VIDEOMARK?	Shows the VIDEO mode line marker location.
ZERO_MEAS	Sets the zero offset for capacitance measurement with the -SC600.
ZERO_MEAS?	Shows the zero offset for the capacitance measurement with the -SC600.

Table 6-5. Output Commands

Command	Description
CFREQ?	Shows the optimum frequency value for stimulus for capacitance modes.
DBMZ	Sets the impedance used for dBm outputs (ac volts).
DBMZ?	Shows the impedance used for dBm outputs (ac volts).
DC_OFFSET	Applies a dc offset to an ac output voltage.
DPF	Sets the displacement power factor (phase angle) between the NORMAL and AUX terminals for ac power output only.
DPF?	Shows the displacement power factor (phase angle) between the NORMAL and AUX terminals.
DUTY	Sets the duty cycle of square wave outputs.
DUTY?	Shows the duty cycle of square wave outputs.
FUNC?	Shows the current output, measurement, or calibration function.
HARMONIC	Makes the frequency of one output be a harmonic (multiple) of the other output (named the fundamental).
HARMONIC?	Shows the current instrument harmonic and fundamental locations.
LCOMP	Starts or deactivates inductive load compensation for ac current output.
LCOMP?	Shows if inductive load compensation for ac current output is active.
OPER	Starts the Calibrator output if it is in standby.
OPER?	Shows the operate/standby setting.
OUT	Sets the output of the Calibrator and makes a new reference point for the error mode.
OUT?	Shows the output amplitudes and frequency of the Calibrator.
PHASE	Sets the phase difference between the NORMAL and AUX terminals for dual outputs. The NORMAL terminal output is the phase reference.
PHASE?	Shows the phase difference between the NORMAL and AUX terminals.
POWER?	Shows the equivalent power for dc and ac power output.
RANGE?	Shows the current output ranges.
RANGELCK	Locks in the currents range, or selects auto ranging.
RANGELCK?	Shows if or not the preset output range is locked.

Table 6-5. Output Commands (cont.)

Command	Description
STBY	Puts the Calibrator in standby.
WAVE	Sets the waveforms for ac outputs.
WAVE?	Shows the waveforms of the output.
ZCOMP	Starts (2-wire or 4-wire) or deactivates impedance compensation.
ZCOMP?	Shows if impedance compensation is active and if active, which type.

Table 6-6. RS-232 Host Port Commands

Command	Description
LOCAL	Puts the Calibrator into the local condition.
LOCKOUT	Puts the Calibrator into the lockout condition. This command duplicates the IEEE-488 LLO (Local Lockout) message.
REMOTE	Puts the Calibrator into the remote condition. This command duplicates the IEEE-488 REN (Remote Enable) message.
SPLSTR	Sets the serial remote mode Serial Poll response string.
SPLSTR?	Shows the string programmed for serial remote mode Serial Poll responses.
SRQSTR	Sets the serial remote mode SRQ (Service Request) response (up to 40 characters).
SRQSTR?	Shows the string programmed for Serial Mode SRQ response.
UUT_RECVB?	Shows binary data from the UUT serial port as integers.
UUT_SENDB	Sends binary data to the UUT serial port as integers.
^P (<cntl>p)	Control-P character prints the serial poll string. (See SPLSTR for string format.)
^C (<cntl>c)	Control-C character clears the device.
^T (<cntl>t)	Control-T character does a group trigger.

Table 6-7. RS-232 UUT Port Commands

Command	Description
UUT_FLUSH	Flush the UUT receive buffer.
UUT_RECV?	Shows data from the UUT serial port.
UUT_RECVB?	Shows binary data as integers from the UUT serial port.
UUT_SEND	Sends a string to the UUT serial port.
UUT_SET	Sets the UUT serial port communication parameters and keeps them in nonvolatile memory.
UUT_SET?	Shows the UUT serial port communication parameters contained in nonvolatile memory.

Table 6-8. Setup and Utility Commands

Command	Description
CLOCK	Sets the real-time clock.
CLOCK?	Queries the real-time clock.
DBMZ_D	Sets the power-up and reset default impedance used for dBm outputs (ac volts).
DBMZ_D?	Shows the power-up and reset default impedance used for dBm outputs (ac volts).
FORMAT	**Use with extreme care**. Restores the contents of the nonvolatile memory device to factory defaults.
LIMIT	Sets the maximum permitted output magnitudes, negative and positive.
LIMIT?	Shows the programmed output magnitude limits for voltage and current.
PR_RPT	Prints the Stored, Active or CAL-Constant CAL_Report through the HOST or UUT Serial Port.
RTD_TYPE_D	Set the default Resistance Temperature Detector (RTD) sensor type.
RTD_TYPE_D?	Shows the default Resistance Temperature Detector (RTD) sensor type.
SP_SET	Sets the HOST serial port communication parameters and saves them in nonvolatile memory.
SP_SET?	Shows the HOST serial port communication parameters contained in nonvolatile memory.
TC_TYPE_D	Sets the power-up and reset default thermocouple type.
TC_TYPE_D?	Shows the power-up and reset default thermocouple type.
TEMP_STD	Sets the temperature degree standard, IPTS -68 or its-90.
TEMP_STD?	Shows the temperature degree standard, IPTS -68 or its-90.
TLIMIT_D	Sets the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.
TLIMIT_D?	Shows the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.
UNCERT?	Shows specified uncertainties for the current output. If there are no specifications for an output, shows zero.

Table 6-9. Status Commands

Command	Description
ERR?	Shows the first error code with an explanation in the Calibrator error queue, and then removes that error code from the queue.
EXPLAIN?	Tells you about an error code. This command shows a string that tells you about the error code given as the parameter.
FAULT?	Shows the first error code contained in the Calibrator error queue, and then removes that error from the queue.
FUNC?	Shows the current output, measurement, or calibration function.
ISCE	Puts two bytes into both the Instrument Status 1 to 0 Change Enable register and the Instrument Status 0 to 1 Change Enable register.
ISCE?	Shows the OR of the contents of the Instrument Status 1 to 0 Change Enable register and the Instrument Status 0 to 1 Change Enable register.
ISCE0	Puts two bytes into the Instrument Status 1 to 0 Change Enable register.
ISCE0?	Shows the contents of the Instrument Status 1 to 0 Change Enable register.
ISCE1	Puts two bytes into the Instrument Status 0 to 1 Change Enable register.
ISCE1?	Shows the contents of the Instrument Status 0 to 1 Change Enable register.
ISCR?	Shows the OR of the contents of the Instrument Status 1 to 0 Change Register and the Instrument Status 0 to 1 Change Register and clears the registers.
ISCR0?	Shows and clears the contents of the Instrument Status 1 to 0 Change Register.
ISCR1?	Shows and clears the contents of the Instrument Status 0 to 1 Change Register.
ISR?	Shows the contents of the Instrument Status Register.

Table 6-10. Thermocouple (TC) Measurement Commands

Command	Description
TC_MEAS	Changes the operation mode to thermocouple measurement.
TC_OFFSET	Sets a temperature offset for the thermocouple measurement mode.
TC_OFFSET?	Shows the temperature offset when in the thermocouple measurement mode.
TC_OTCD?	Shows if the open thermocouple detection circuit is set.
TC_OTCD	Activates or deactivates the open thermocouple detection circuit in thermocouple measurement mode.
VAL?	Shows the last thermocouple value, or, for the -SC600, impedance measurement value.
VVAL?	Shows the last value of the thermocouple measurement in volts.

Commands

The subsequent text is an alphabetical listing of all Calibrator commands and queries. Common commands and device-dependent commands are shown as part of the listing. Each command title includes a graphic that shows remote interface applicability, IEEE-488 and RS-232, and command group: Sequential, Overlapped, and Coupled.

IEEE-488 (GPIB) and RS-232 Applicability [X] IEEE-488 [X] RS-232 Each command and query has a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations. For sorting, this list ignores the * character that comes before the common commands.

Sequential Commands [X] Sequential Commands done immediately as they occur in the data stream are named sequential commands. For more, see "Sequential Commands" in Chapter 5.

Overlapped Commands [X] Overlapped Commands where more time to execute is necessary. These commands are named overlapped commands because they can overlap the subsequent command before they complete execution. To be sure an overlapped command is not interrupted during execution, use the `*OPC`, `*OPC?`, and `*WAI` commands to find when the command is complete. For more, see "Overlapped Commands" in Chapter 5.

Coupled Commands [X] Coupled These are named coupled commands (examples: CUR_POST and OUT) because they "couple" in a compound command sequence. Precautions are necessary to make sure the action of one command does not disable the action of a second command and cause a fault. For more information, see "Coupled Commands" in Chapter 5.

CFREQ? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Capacitance Frequency query) Shows the optimal frequency for stimulus when you measure or calibrate capacitance output.

Response: <value> of the optimal frequency

Example: `CFREQ?` shows `1.0E+2`

Shows 100 Hz as the optimal frequency for the selected capacitance output (1.0 µF for this example). The indication is `0` if not sourcing capacitance.

CLOCK [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Real-Time Clock command) Sets the real time clock, time only, or date and time. To set the date, the CALIBRATION switch must be in the ENABLE position.

Parameters:
1. (optional) year in the format `YYYY`
2. (optional) month in the format `MM`
3. (optional) day in the format `DD`
4. hour in the format `HH`
5. minute in the format `MM`
6. second in the format `SS`

Examples: `CLOCK 1998,6,1,9,52,10`
sets clock to June 1, 1998, 9:52:10 AM

`CLOCK 13,10,10` sets clock time only to 1:10:10 PM

CLOCK? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Real_Time Clock query) Shows the date and time the real time clock.

Response: (character) 1. date in the format YYYY-MM-DD
(character) 2. time in the format HH:MM:SS

Example: `CLOCK?` shows `1998-12-04,13:03:50`

The clock is set to December 4, 1998, 13:03:50.

***CLS** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Clear Status command) Clears the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte. This command stops pending operation complete commands (*OPC or *OPC?).

Parameter: (None)

Example: `*CLS`

Clear the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte.

CUR_POST [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(Current Post command) Selects the binding posts for current output. This also applies to power outputs. The current post setting is kept until the power is turned off or the RESET button is pressed.

Parameters: `AUX` (selects the AUX terminals)
`A20` (selects the 20A terminals)

Example: `CUR_POST AUX`

Selects the Calibrator front panel AUX terminals for the output current.

CUR_POST? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Current Post query) Shows the active front panel binding post terminals used for current output: AUX or 20A.

Responses: `AUX` (AUX terminals are selected)
`A20` (20A terminals are selected)

Example: `CUR_POST?` shows `AUX`

Shows `AUX` when the AUX terminals are selected for output current.

DBMZ [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(dBm Impedance command) Sets the impedance used for dBm outputs (ac volts).

Parameters: `Z50` (50 ohms)
`Z75` (75 ohms)
`Z90` (90 ohms)
`Z100` (100 ohms)
`Z135` (135 ohms)
`Z150` (150 ohms)
`Z300` (300 ohms)
`Z600` (600 ohms)
`Z900` (900 ohms)

Z1000	(1000 ohms = dBv)
Z1200	(1200 ohms)

Example: `DBMZ Z600`

DBMZ? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(dBm Impedance query) Shows the impedance used for dBm outputs (ac volts).

Response: (character) Impedance keyword

Example: `DBMZ?` shows `Z600`

DBMZ_D [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(dBm Impedance Default command) Sets the power-up and reset default impedance used for dBm outputs (ac volts).

Parameters:

Z50	(50 ohms)
Z75	(75 ohms)
Z90	(90 ohms)
Z100	(100 ohms)
Z135	(135 ohms)
Z150	(150 ohms)
Z300	(300 ohms)
Z600	(600 ohms)
Z900	(900 ohms)
Z1000	(1000 ohms = dBv)
Z1200	(1200 ohms)

Example: `DBMZ_D Z600`

This setting only applies when single output AC voltages that are sourced. The dBm impedance is set to the default at power on, reset, and when you go into single output AC mode.

DBMZ_D? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(dBm Impedance Default query) Shows the power-up and reset default impedance used for dBm outputs (ac volts).

Response: (character) Impedance keyword

Example: `DBMZ_D?` shows `Z600`

DC_OFFSET [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(DC Voltage Offset command) Applies a dc offset to an ac output voltage (maximum six digits). This command applies only to single ac voltage outputs. If the selected offset is too large for the active ac voltage range, an error message is shown.

Parameter: <value> signed offset amplitude

Example: `DC_OFFSET +123.45 MV`

Install a dc offset of +123.45 mV to the ac output signal.

DC_OFFSET?
[X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(DC Voltage Offset query) shows the value of the dc offset voltage.

Response: <value> signed offset amplitude

Example: `DC_OFFSET? shows +1.44E-03`

Shows 1.44 mV as the value of the applied dc offset. If +0.00000E+00 is shown, the dc offset is zero.

DPF [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Displacement Power Factor command) Sets the displacement power factor (phase angle) between the Calibrator front panel terminals NORMAL and AUX (for sine waves output only). The NORMAL terminal output is the phase reference. The phase offset is expressed as the cosine of the phase offset (0.000 to 1.000) and a LEAD (default) or LAG term, which tells if the AUX output leads or lags the NORMAL output.

Parameters: <value>,`LEAD`
<value>,`LAG`

Example: `DPF .123,LEAD`

Set the current output on the Calibrator AUX terminals to lead the voltage output on the NORMAL terminals by 82.93 degrees. (Cosine of 82.93 degrees is 0.123, nominal.)

DPF? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Displacement Power Factor query) Shows the displacement power factor (cosine of the phase angle) between the Calibrator front panel NORMAL and AUX terminals for sine wave outputs.

Responses: <value>,`LEAD`
<value>,`LAG`

Example: `DPF?` shows `5.00E-01,LEAD`

Shows a leading power factor of .5 when the current output on the Calibrator AUX terminals leads the voltage output on the NORMAL terminals by 60 degrees. (Cosine of 60 degrees is 0.5.) 0 shows if power factor does not apply to the output.

DUTY [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Duty Cycle command) Sets the duty cycle of the square wave output. The duty cycle is the percentage of time the waveform is in the positive part of its cycle (1.00 to 99.00 percent). Duty cycle applies only to single-output square waves.

Parameter: <value> of duty cycle with optional `PCT` (percent) unit

Example: `DUTY 12.34 PCT`

Set the square wave duty cycle to 12.34 %.

DUTY? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Duty Cycle query) Shows the value of the square wave output duty cycle (1.00 to 99.00).

Response: <value> of duty cycle in percent

Example: `DUTY?` shows `1.234E+01`

Shows 12.34 % for the value of the square wave duty cycle.

EARTH [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Earth Ground command) Selects if the Calibrator front panel NORMAL LO terminal is tied to chassis (earth) ground. When set, the Calibrator keeps the earth setting until power off or reset.

Parameters: `OPEN` (disconnect front panel LO terminal from chassis ground)
`TIED` (connect front panel LO terminal to chassis ground)

Example: `EARTH TIED`

Load `TIED` to tie the Calibrator front panel NORMAL LO terminal to earth (the front panel EARTH key annunciator is on).

EARTH? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Earth Ground query) Shows if the Calibrator front panel NORMAL LO terminal is tied to chassis (earth) ground.

Responses: (character) `OPEN` (front panel LO terminal disconnected from chassis ground)

(character) `TIED` (front panel LO terminal connected to chassis ground)

Example: `EARTH?` shows `OPEN`

Shows `OPEN` when EARTH is not tied to the NORMAL LO terminal (the front panel EARTH key annunciator is off).

EDIT [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Edit command) Sets the edit field to the primary, secondary or frequency field.

Parameters: `PRI` (edit the value in single output functions and the primary output value in dual output functions)

`SEC` (edit the secondary value in dual output functions)

`FREQ` (edit the frequency value in single ac output functions)

`OFF` (edit is off, which is the same as with the NEWREF command)

Example: `EDIT FREQ`

Load `FREQ` into the edit field to edit frequency.

EDIT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Edit query) Shows the edit field setting.

Responses: (character) `PRI` (value in single output functions, and the primary output value in dual output functions is in edit)

(character) `SEC` (secondary value in dual output functions is in edit)

(character) `FREQ` (frequency value in single ac output functions is in edit)

(character) `OFF` (no value is in edit.)

Example: `EDIT?` shows `OFF`

Shows `OFF` when no value is in edit.

ERR? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Error query) Shows the first error code contained in the Calibrator error queue, and then removes that error code from the queue. After the error code is an explanation of the error code, like, but sometimes has more specified information, than the `EXPLAIN?` command. The explanation sent in response to this query can contain variables specified to a particular error event. See Appendix D for a list of error codes and error messages.

A zero value is shown when the error queue is empty. To read the full contents of the error queue, do `ERR?` until the response `0,"No Error"` is shown. For terminal users, the error queue Shows for `ERR?` is always `0,"No Error"` because error messages are shown as an alternative to queued.

Response: <value>, (error code value)
<string> (text string explaining the error)

Example: `ERR?` shows `0,"No Error"`

Shows `0,"No Error"` when the error queue is empty.

ERR_REF [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Chooses the error reference for error calculations.

Parameter: `NOMINAL` Sets the reference to the nominal value
`TRUVAL` Sets the reference to the output value

ERR_REF? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Shows the error reference for error calculations.

Response: `NOMINAL` The nominal value is used as the error reference
`TRUVAL` The output value is used as the error reference

ERR_UNIT [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Error Unit Thresh Hold command) Chooses how UUT error is shown (this is nonvolatile).

Parameter: `GT1000` UUT error is shown in % more than 1000 ppm, ppm below
`GT100` UUT error is shown in % more than 100 ppm, ppm below
`GT10` UUT error is shown in % more than 10 ppm, ppm below
`PPM` UUT error is shown in ppm always
`PCT` UUT error is shown in % always

ERR_UNIT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Error Unit Thresh Hold query) Shows currently selected values of ERR_UNIT.

Responses: `GT1000` UUT error is shown in % more than 1000 ppm, ppm below
`GT100` UUT error is shown in % more than 100 ppm, ppm below
`GT10` UUT error is shown in % more than 10 ppm, ppm below
`PPM` UUT error is shown in ppm always
`PCT` UUT error is shown in % always

***ESE** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled Error! Bookmark not defined.

(Event Status Enable command) Puts a byte into the Event Status Enable (ESE) register. (See "Event Status Enable Register (ESE)" in Chapter 5)

Parameter: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: `*ESE 140`

Load decimal 140 (binary `10001100`) to enable bits 7 (PON), 3 (DDE) and 2 (QYE).

***ESE?** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Event Status Enable query) Shows the contents of the Event Status Enable (ESE) register. (See “Event Status Enable Register (ESE)” in Chapter 5)

Response: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: `*ESE?` shows `133`

Shows decimal 133 (binary `10000101`) when bits 7 (PON), 2 (QYE), 1 (OPC) are enabled.

***ESR?** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Event Status Register query) Shows the contents of the Event Status Register (ESR) and clears the register. (See Event Status Register (ESR)” in Chapter 5)

Response: <value> (decimal equivalent of the ESR byte, 0 to 255)

Example: `*ESR?` shows `189`

Shows decimal 189 (binary `10111101`) when bits 7 (PON), 5 (CME), 4 (EXE), 3 (DDE), 2 (QYE) and 0 (OPC) are enabled.

EXPLAIN? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Explain Error query) Tells you about an error code. This command shows a string that tells you about the error code given as the parameter. The error code (same as the parameter) originally comes from sending the `FAULT?` query. (See the `ERR?` command, which shows both the error code and the explanation string.) See Appendix E for a list of error codes and error messages.

Parameter: <value> if the error code (an integer)

Response: <string> that tells you about the error code, with the parameter (if there is one) as a percent sign followed by d (integer parameter), f (floating point parameter), or s (string parameter)

Example: `EXPLAIN? 539` shows “`Can’t change compensation now.`”

Shows the explanation of error 539: “Can’t change compensation now.”

FAULT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Fault query) Shows the first error code contained in the Calibrator error queue, then remove that error from the queue. After you get the error code, use the `EXPLAIN?` command to see an explanation. A zero value is shown when the error queue is empty. To read the complete contents of the error queue, do `FAULT?` until the response is 0. (Only system errors appear in the error queue.)

Response: <value> of the error code

Example: `FAULT?` shows `539`

Shows the first error code in the error queue, number 539. To see an explanation of the error, record the command `EXPLAIN? 539`.

FORMAT [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Format command) **Use with extreme care.** Restores the contents of the nonvolatile memory device to factory defaults. The memory holds calibration constants and setup parameters. You lose all calibration data permanently. The CALIBRATION switch on the rear panel of the Calibrator must be set in the ENABLE position or an execution error occurs, except for `FORMAT SETUP`.

Parameter: `ALL` (replaces the whole contents with factory defaults)
`CAL` (replaces all cal constants with factory defaults)
`SETUP` (replaces setup parameters with factory defaults)

Example: `FORMAT SETUP`

Replace the setup parameters with the default setup values (below). (The `FORMAT ALL` command is the same as `FORMAT CAL` and then `FORMAT SETUP`.) The `FORMAT SETUP` command also clears the `*PUD` string (see the `*PUD` command) and `SRQSTR` is set to "SRQ: %02x %02x %04x %04x" (see the `SRQSTR` command) and `SPLSTR` is set to "SPL: %02x %02x %04x %04x" (see the `SPLSTR` command).

Features			
Temperature Standard	ITS-90	**Display Contrast***	level 7,7
Host Connection	GPIB (IEEE-488)	**Display Brightness***	level 1,0
GPIB Port Address	4	**RTD Power Up Default Type**	pt385
Serial Ports	8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud	**Thermocouple Power Up Default Type**	K
EOL (end of line)	CRLF	**Current Limits**	±20.5 A
EOF (end of file)	012,000	**Voltage Limits**	±1020 V
Remote I/F	term		
Remote Commands			
SRQSTR	`SRQ: %02x %02x %04x %04x`	***PUD string**	cleared
* Output Display and Control Display, respectively. There are 8 levels: 0,1,2,3,4,5,6,7.			
Defaults			
dBm Impedance	600 Ω		

FUNC? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Function query) Shows the current output, measurement, or calibration function. See the response below for output and measurement modes.

Responses: `DCV` (dc volts function)
`ACV` (ac volts function)
`DCI` (dc current function)
`ACI` (ac current function)
`RES` (ohms function)

`CAP`	(capacitance function)
`RTD`	(temperature with an rtd function)
`TC_OUT`	(temperature with a thermocouple function)
`DC_POWER`	(dc power function)
`AC_POWER`	(ac power function)
`DCV_DCV`	(dual dc volts function)
`ACV_ACV`	(dual ac volts function)
`TC_MEAS`	(measure temperature with a thermocouple)
`SACV`	(oscilloscope ac volts function)
`SDCV`	(oscilloscope dc volts function)
`MARKER`	(oscilloscope marker function)
`LEVSINE`	(oscilloscope leveled sine function)
`EDGE`	(oscilloscope edge function)
`VIDEO`	(-SC600 video trigger function)
`PULSE`	(-SC600 pulse output function)
`MEAS Z`	(-SC600 impedance measurement function)
`OVERLD`	(-SC600 overload test function)

Example: `FUNC?` shows `DCV_DCV`

Shows `DCV_DCV` when the Calibrator output function dual dc volts.

HARMONIC [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(Harmonic command) Makes the frequency of one output a multiple of a different output for the ac voltage or ac power functions (sine waves only). For example, in dual ac voltage, have the frequency of the voltage output on the Calibrator front panel NORMAL terminals at 60 Hz and the frequency of the voltage output on the AUX terminals at the 7th harmonic (420 Hz). The range for the harmonics is 1 to 50.

Parameters:
<value>, `PRI` (fundamental at 5502A NORMAL terminals)
<value>, `SEC` (fundamental at 5502A AUX terminals)

Example: `HARMONIC 5, PRI`

Put the fundamental frequency at the primary (PRI) output (NORMAL terminals), and the 5th harmonic frequency is at the secondary output (AUX terminals). For example, if the fundamental frequency output is 60 Hz, the harmonic frequency output is 300 Hz.

HARMONIC? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Harmonic query) Shows the current instrument harmonic property and location of the fundamental output PRI (primary, the NORMAL terminals) or SEC (secondary, the AUX terminals).

Response:
<value>, `PRI` (harmonic value, fundamental at primary output)
<value>, `SEC` (harmonic value, fundamental at secondary output)

Example: `HARMONIC?` shows `5, SEC`

Shows that the 5th harmonic frequency is selected, and the fundamental is at the secondary output (AUX terminals). This means that the harmonic frequency is at the primary, or NORMAL terminals.

***IDN?** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Identification query) Shows instrument model number, serial number, and firmware revision levels for the primary, encoder, and inguard CPUs.

Responses: (Indefinite ASCII) A message that has four fields separated by commas as follows:

1. Manufacturer
2. Model number
3. Serial number
4. Firmware revision levels for the Main CPU+Front Panel CPU+Inguard PGA

Example: `*IDN?` shows `FLUKE,5502A,5248000,1.0+1.3+1.8`

Shows Fluke manufacturer, model 5502A, serial number 5248000, main firmware version 1.0, encoder firmware 1.3, and inguard PGA 1.8.

INCR [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Increment command) Increments or decrements the output (as selected if you use the `EDIT` command, or defaults to the primary output) and records error mode; the same as if you use the Calibrator output adjustment knob in local operation.

Parameters: <+ value> (increment value) (optional unit matching edit field)
<–value> (decrement value)

Example: `INCR +.00001 mV`

Load the error mode and increment the selected edit field by .00001 mV.

ISCE [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Instrument Status Change Enable command) Puts two bytes into the two 16-bit ISCE mask registers (ISCE1 and ISCE0). (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE 6272`

Load decimal 6272 (binary `0001010001000000`) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT). This is equivalent to sending the commands `ISCE0 6272` and `ISCE1 6272` (see below).

ISCE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Instrument Status Change Enable query) Shows the two bytes from the two 16-bit ISCE mask registers (ISCE1 and ISCE0). (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISCE0 [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Instrument Status 1 to 0 Change Enable command) Puts the two bytes into the 16-bit ISCE0 register. (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE0 6272`

Load decimal 6272 (binary `0001010001000000`) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT).

ISCE0? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Instrument Status 1 to 0 Change Enable query) Shows the two bytes from the 16-bit ISCE0 register. (See "Instrument Status Change Enable Registers" in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE0?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISCE1 ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error! Bookmark not defined.

(Instrument Status 0 to 1 Change Enable command) Puts the two bytes into the 16-bit ISCE1 register. (See "Instrument Status Change Enable Registers" in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE1 6272`

Load decimal `6272` (binary `0001010001000000`) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT).

ISCE1? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error! Bookmark not defined.

(Instrument Status 0 to 1 Change Enable query) Shows the two bytes from the 16-bit ISCE1 register. (See "Instrument Status Change Enable Registers" in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCE1?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISCR? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error! Bookmark not defined.

(Instrument Status Change Register query) Shows and clears the contents of the Instrument Status 1 to 0 Change Register (ISCR0) and Instrument Status 0 to 1 Change Register (ISCR1). (See "Instrument Status Change Register" in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCR?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISCR0? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled Error! Bookmark not defined.

(Instrument Status 1 to 0 Change Register query) Shows and clears the contents of the Instrument Status 1 to 0 Change Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCRO?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISCR1? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled Error! Bookmark not defined.

(Instrument Status 0 to 1 Change Register query) Shows and clears the contents of the Instrument Status 0 to 1 Change Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISCR1?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

ISR? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled Error! Bookmark not defined.

(Instrument Status Register query) Shows contents of the Instrument Status Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: `ISR?` shows `6272`

Shows decimal `6272` (binary `0001010001000000`) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

LCOMP [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled Error! Bookmark not defined.

(Inductive compensation command) Activates or deactivates inductive load compensation for ac current output. For current output, compensation is permitted when the frequency is less than 440 Hz and the amplitude is less than 0.33 A. Compensation is also permitted when the frequency is less than 1 kHz and the amplitude is larger than or equal to 0.33 A.

Parameters: `OFF` (turns off the inductive load compensation circuitry)
`ON` (turns on the inductive load compensation circuitry

Example: `LCOMP ON`

LCOMP? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled Error! Bookmark not defined.

(Inductive compensation query) Shows if inductive load compensation for ac current output is active.

Responses: (character) `OFF` (Inductive load compensation circuitry is off)
(character) `ON` (Inductive load compensation circuitry is on)

Example: `LCOMP?` shows `ON`

LIMIT [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Limit command) Sets the maximum permitted output magnitude, negative and positive, for voltage and current, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) Negative and positive values must be recorded. When set, the Calibrator keeps the limit settings until another limit is recorded, or the `FORMAT SETUP` command resets the limits (and all other defaults) to the factory settings (±1020 V, ±20.5 A). See the `FORMAT` command.

The magnitude of the limit has this effect on different waveforms:

dc	magnitude of limit
ac (sine wave)	magnitude of limit (rms)
ac (non-sine wave)	magnitude of limit x 3 (peak-to-peak)
ac (with dc offset)	magnitude of limit x 2.4 (absolute peak) (volts only)

Parameters: <positive value>,<negative value>

Example: `LIMIT 100V, -100V`

Limit the voltage output to ±100 V dc, 100 V ac rms, 300 V peak-to-peak, 240 V peak.

Example: `LIMIT 1A, -1A`

Limit the current output to ±1 A dc, 1 A ac rms, 3 A peak-to-peak.

LIMIT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Limit query) Shows the programmed output magnitude limits for voltage and current.

Response: <positive value voltage>,<negative value voltage>,
<positive value current>,<negative value current>

Example: `LIMIT?`
shows `1020.0000,-1020.0000, 20.5000, –20.5000`

Shows the current value of the voltage and current limits (reset values shown).

LOCAL [ ] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Local command) Puts the Calibrator into the local condition, clearing the remote condition (see the `REMOTE` command) and front panel lockout (see the `LOCKOUT` command). This command duplicates the IEEE-488 GTL (Go To Local) message.

Parameter: (None)

Example: `LOCAL`

Set the instrument into the local condition, clearing the remote condition and front panel lockout (if enable).

LOCKOUT [ ] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Lockout command) Puts the Calibrator into the lockout condition when in remote control (see the `REMOTE` command). This means no local operation at the front panel is permitted during remote control. To clear the lockout condition, use the `LOCAL` command. This command duplicates the IEEE-488 LLO (Local Lockout) message.

Parameter: (None)

Example: `LOCKOUT`

Set the instrument into the front panel lockout condition. The front panel's controls cannot be used.

LOWS ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Low Potential Output Terminals command) Selects if the Calibrator front panel NORMAL LO terminal and AUX LO terminal are internally tied together (default) or are open. This feature is used for ac power, dc power, dual dc volts and dual ac volts outputs. When set, the Calibrator keeps the LO setting until power off or reset.

Parameter: `OPEN` (disconnect NORMAL LO and AUX LO terminals)

`TIED` (connect NORMAL LO and AUX LO terminals)

Example: `LOWS TIED`

Tie the front panel NORMAL LO and AUX LO terminals together.

LOWS? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Low Potential Output Terminals query) Shows if the Calibrator front panel NORMAL LO terminal and AUX LO terminal are internally tied together (default) or are open.

Response: `OPEN` (disconnected NORMAL LO and AUX LO terminals)

`TIED` (connected NORMAL LO and AUX LO terminals)

Example: `LOWS?` shows `OPEN`

Shows `OPEN` when the Calibrator front panel NORMAL LO and AUX LO terminals are not tied together.

MULT ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Multiply command) Multiplies the reference magnitude (as selected with the `EDIT` command or default to the primary output). The reference magnitude is the current reference in direct mode or in error mode.

Parameter: <value> (multiplier expressed as a floating point number)

Example: `MULT 2.5`

Multiply the reference that exists by 2.5, creating a new reference. For example, a reference that exists of 1 V is multiplied to 2.5 V.

NEWREF ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(New Reference command) Sets the new reference to the current Calibrator output value and exit the error mode (if selected). For example, you might edit the Calibrator output with the `EDIT` and `INCR` commands, and then use the `NEWREF` command to establish a new reference point and exit the error mode. This is the same as pressing the Calibrator front panel [NEW REF] key.

Parameter: (None)

Example: `NEWREF`

Set the reference value to the current Calibrator output value.

OLDREF ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Old Reference command) Sets the Calibrator output to the reference value and exit the error mode (if selected). If editing the output with the `EDIT` and `INCR` commands and you want to return to the reference value, use the `OLDREF` command. If editing the output and you want to make the edited value the new reference, use the `NEWREF` command.

Parameter: (None)

Example: `OLDREF`

Set the output to the reference value that exists, clearing editing changes.

ONTIME? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Calibrator On Time query) Shows the time in minutes since the Calibrator was most recently powered up.

Response: <minutes> (24-hour clock)

Example: `ONTIME?` shows `47`

Shows the time since the Calibrator was last powered up: 47 minutes.

***OPC** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operations Complete command) Sets bit 0 (OPC) of the Event Status Register to 1 when all pending device operations are complete. Also see the `*ESR?` command.

Parameter: (None)

Example: `*OPC`

Set bit 0 of the Event Status Register to 1 when all pending device operations are done.

***OPC?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operations Complete query) Shows a 1 after all pending operations are complete. This command causes program execution to pause until operations are complete. (See *WAI.)

Response: `1` (all operations are complete)

Example: `*OPC?` shows `1`

Shows `1` when all pending operations are complete.

OPER ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Operate command) Activates the Calibrator output if it is in standby. This is the same as pressing the Calibrator front panel [OPR] key. If there are errors in the error queue, the `OPER` command is inhibited for outputs 33 V and over. (Also see the `ERR?` command and `STBY` command.)

Parameter: (None)

Example: `OPER`

Connect the selected output to the Calibrator front panel terminals. Also lights the annunciator in the [OPR] key.

OPER? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operate query) Shows the operate/standby setting.

Response: `1` (Operate)

`0` (Standby)

Example: `OPER?` shows 1

Shows 1 when the Calibrator is in operate.

***OPT?** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Options command) Shows a list of the installed hardware and software options.

Responses: <option string>,<option string>,... (options list, separated by commas)

0 (no options are installed)

Example: `*OPT?` shows `SC600`

Shows `SC600` when the Oscilloscope Calibration Option is installed.

OUT [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(Output command) Sets the output of the Calibrator and establishes a new reference point for the error mode. If only one amplitude is supplied, the Calibrator sources a single output. If two amplitudes are supplied, the Calibrator sources two outputs. The second amplitude will be sourced at the AUX terminals for dual voltage outputs. If the frequency is not supplied, the Calibrator will use the frequency that is currently in use.

To source or measure a temperature, select the desired sensor and sensor parameters first. (See the `TSENS_TYPE, RTD_*`, and `TC_*` commands.)

To source a signal with the Calibrator scope options, refer to the `SCOPE` command.

If you change the frequency of an ac function and the harmonic output is not explicitly set at the same time with the `HARMONIC` command, the harmonic will be set to 1.

Use multipliers e.g., k, M, μ with the `OUT` command, as desired.

Parameters:

<value> V	Volts dc or update volts ac
<value> DBM	Volts ac dBm update
<value> V, <value> Hz	Volts ac or volts dc with 0 Hz
<value> DBM, <value> Hz	Volts ac in dBm
<value> A	Current dc or update current ac
<value> A, <value> Hz	Current ac
<value> OHM	Resistance
<value> F	Capacitance
<value> CEL	Temperature (Celsius)
<value> FAR	Temperature (Fahrenheit)
<value> HZ	Update frequency
<value> V, <value> A	Power dc or update power ac
<value> V, <value> A, <value> HZ	Power ac
<value> V, <value> V	Dual volts dc or update dual ac
<value> V, <value> V, <value> HZ	Dual volts ac in volts
<value>	For single output, changes amplitude keeping unit and frequency the same.

Examples:

`OUT 15.2 V`	(volts; 15.2 V @ same frequency)
`OUT 20 DBM`	(volts; 20 dBm @ same frequency)
`OUT 10 V, 60 Hz`	(volts ac; 10 V @ 60 Hz)
`OUT 10 DBM, 50 HZ`	(volts ac; 10 dBm @ 50 Hz)
`OUT 1.2 MA`	(current; 1.2 mA @ same frequency)
`OUT 1 A, 400 HZ`	(current ac; 1 A @ 400 Hz)

`OUT 1 KOHM`	(ohms; 1 kΩ)
`OUT 1 UF`	(capacitance; 1 μF)
`OUT 100 CEL`	(temperature; 100 °C)
`OUT 32 FAR`	(temperature; 32 °F)
`OUT 60 HZ`	(frequency update; 60 Hz)
`OUT 10 V, 1 A`	(power; 10 watts @ same frequency)
`OUT 1 V, 1 A, 60 HZ`	(power ac; 1 watts @ 60 Hz)
`OUT 1 V, 2 V`	(dual volts; 1 V, 2 V @ same freq.)
`OUT 10 MV, 20 MV, 60 HZ`	(dual volts; .01 V, .02 V @ 60 Hz)

Each example shows a value and unit, e.g., –15.2 V. If a value is recorded without a unit, the value of the output that exists is changed, when logically allowed.

OUT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Output query) Shows the output amplitudes and frequency of the Calibrator. Multipliers (e.g., K or M) are not used in the response.

Parameters:
- `V` (optional for ac voltage and TC modes)
- `DBM` (optional for ac voltage modes)
- `CEL` (optional for RTD and TC modes, Celsius)
- `FAR` (optional for RTD and TC modes, Fahrenheit)
- `OHM` (optional for RTD modes, ohms)

Response: <primary amplitude value>,<primary units>,
<secondary amplitude value>,<secondary units>,
<fundamental frequency value>

Examples:
```
OUT? shows -1.520000E+01,V,0E+00,0,0.00E+00
OUT? shows 1.88300E-01,A,0E+00,0,4.420E+02
OUT? shows 1.23000E+00,V,2.34000E+00,V,6.000E+01
OUT? shows 1.92400E+06,OHM,0E+00,0,0.00E+00
OUT? shows 1.52000E+01,V,1.88300E-01,A,4.420E+02
OUT? DBM shows 2.586E+01,DBM,0E+00,A,4.420E+02
OUT? shows 1.0430E+02,CEL,0E+00,0,0.00E+00
OUT? FAR shows 2.19740000E+02,FAR,0E+00,0,0.00E+00
OUT? V shows 4.2740E-03,V,0E+00,0,0.00E+00
OUT? OHM shows 1.40135E+02,OHM,0E+00,0,0.00E+00
```

The respective values for the above examples are:

–15.2 V
188.3 mA, 442 Hz
1.23 V, 2.34 V, 60 Hz
1.924 MΩ
15.2 V, 188.3 mA, 442 Hz
25.86 dBm, 442 Hz (25.86 dBm = 15.2 V at 600 Ω)
104.3 °C
219.74 °F (same value as 104.3 °C, in Fahrenheit)
4.274 mV (same value as 104.3 °C for a K-type thermocouple, in volts)
140.135 Ω (same value as 104.3 °C for a pt385 RTD, in ohms)

The primary and secondary units are: V, DBM, A, OHM, F, CEL, FAR. The units for the <frequency value> is always assumed to be Hz.

OUT_ERR? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Output Error query) Shows the UUT error and units computed by the Calibrator after shifting the output with the `INCR` command. The return units are `PPM` (parts per million), `PCT` (percent), `DB` (decibels) or `0` if there is no error. The UUT error is not computed when editing frequency.

Response: <value of error>,<units>

Example: `OUT_ERR?` shows `-1.00000E+01,PCT`

Shows –10% when the UUT is reading low by 10 %.

PHASE [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Phase Difference command) Sets a phase difference between the Calibrator front panel NORMAL and AUX or 20A terminals for ac power and ac dual voltage outputs. The NORMAL terminal output is the phase reference. The set range is 0.00 to ±180.00 degrees, with + for a leading phase difference and – for a lagging phase difference.

Parameter: <phase value> DEG (DEG, for degree, is optional)

Example: PHASE –60 DEG

Set the phase difference so the frequency output at the AUX terminals lags the frequency output at the NORMAL terminals by 60 degrees.

PHASE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Phase Difference query) Shows the phase difference between the Calibrator front panel NORMAL and AUX terminals for ac power and ac dual voltage outputs.

Response: <phase value>

Example: `PHASE?` shows `-6.000E+01`

Shows –60 when the frequency output at the AUX terminals is lagging the frequency output at the NORMAL terminals by 60 degrees.

POWER? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Calculate Power Output query) Shows the equivalent real power for ac and dc power outputs, based on the voltage and current settings, and power factor (ac only). If the output is not ac or dc power, the return is `0E+00` (zero) watts.

Response: <value> (in watts)

Example: `POWER?` shows `1.00000E+01`

Shows 10 when the output voltage is 10 V dc and output current 1 A dc, for 10 watts real power.

Example: `POWER?` shows `1.00000E+01`

Shows 10 when the output voltage is 10 V ac and output current 2 A ac and power factor is .5, for 10 watts real power.

PR_PRT [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Description: Prints a self calibration report out the selected serial port.

Parameters: 1. Type of report to print: **STORED**, **ACTIVE**, or **CONSTS**

2. Format of report: **PRINT** (designed to be read), **SPREAD** (designed to be loaded into a spreadsheet)
3. Calibration interval to be used for instrument specifications in the report: **I90D** (90 day spec), **I1Y** (I year spec)
4. Serial port through which to print: **HOST**, **UUT**

Example: `PR-PRT STORED, PRINT, i90D, HOST`

***PUD** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Protected User Data command) Stores a string of 64 characters (maximum), which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) This command works only when the CALIBRATION switch on the rear panel of the Calibrator is in the ENABLE position. Include a line feed (RS-232) character to stop the block data or End or Identify (EOI) command (IEEE-488).

Parameter:	#2<nn><nn characters string>	(definite length)
	#0<character string>	(indefinite length)
	"<character string>"	(character string)
	'<character string>'	(character string)

Example: `*PUD #0CAL LAB NUMBER 1`

Store the string `CAL LAB NUMBER 1` in the protected user data area with the indefinite length format.

Example: `*PUD #216CAL LAB NUMBER 1`

Store the string `CAL LAB NUMBER 1` in the protected user data area with the definite length format, where #2 means two digits follow which represent the number of text characters nn in `CAL LAB NUMBER 1` (including spaces=16).

Example: `*PUD "CAL LAB NUMBER 1"`

Store the string `CAL LAB NUMBER 1` in the protected user data area with the character string format.

***PUD?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Protected User Data query) Shows the contents of the *PUD (Protected User Data) memory in definite length format.

Response: #2nn<nn characters>

Example: `*PUD?` shows `#216CAL LAB NUMBER 1`

Shows #2 then 16 then 16 characters of text (with spaces) stored in the nonvolatile memory.

RANGE? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Range query) Shows the current output ranges. The primary output and secondary outputs are shown. If there is no secondary output, `0` is shown. Dual outputs are shown with `P` for primary output (front panel NORMAL terminals) and `S` for secondary output (front panel AUX terminals).

Response: <primary output>,<secondary output>

Examples: `DC330MV,0` (dc volts 330 mV range)

`DC33MA_A,0`	(dc current 33 mA range)
`AC3_3V,0`	(ac volts 3.3 V range)
`AC330MA_A,0`	(ac current 330 mA range)
`R110OHM,0`	(ohms 110 Ω range)
`C1_1UF,0`	(capacitance 1.1 μF range)
`TCSRC,0`	(temperature thermocouple source)
`RTD_110,0`	(temperature RTD 110 Ω range)
`DC3_3V_P,DC3A_AS`	(dc power 3.3 V, 3 A ranges)
`AC330V_P,AC20A_2S`	(ac power 330 V, 20 A ranges)
`DC330MV_P,DC3_3V_S`	(dual dc volts 330 mV, 3.3 V ranges)
`AC330V_P,AC3_3V_S`	(dual ac volts 330 V, 3.3 V ranges)

Shows the symbolic name of the single or first output, and show the symbolic name of the second output (0 if there is no second output).

RANGELCK ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Range Lock command) Locks in the current range, or selects auto ranging for dc voltage and dc current single outputs. The range automatically unlocks if the output function changes, for example from dc volts to dc current. When RANGELCK is on, this is equivalent to the softkey range lock that shows locked. When RANGELCK is off, this is equivalent to the softkey range lock that shows auto.

Parameter: `ON` (Locks the dc volts or dc current range)

`OFF` (Unlocks the dc volts or dc current range for autoranging)

Example: `RANGELCK OFF`

Set the range lock off to allow autoranging for dc volts or dc current.

RANGELCK? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Range Lock query) Shows if the preset dc volts or dc current single output range is locked.

Response: `ON` (range is locked and autoranging is not allowed)

`OFF` (range is not locked and autoranging is allowed)

Example: `RANGELCK?` shows `OFF`

Shows `OFF` when the range for dc volts or dc current is not locked (autoranging enabled).

REFOUT? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Reference Output query) Shows the current value of the reference when editing the output (error mode). If not editing the output with the `INCR` command, the return is 0 (`0E+00`). The reference value is set with the `OUT`, `NEWREF` or `MULT` commands. To find which quantity is being edited, use the `EDIT?` and `OUT?` commands.

Response: <reference value>

Example: `REFOUT?` shows `0E+00`

Shows 0 when the output is not being edited.

Example: `REFOUT?` shows `2.500000E-01`

Shows .250 when the output is being edited and the reference is, for example, 250 mV.

REMOTE ☐ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Remote command) Puts the Calibrator into the remote condition. This command duplicates the IEEE-488 REN (Remote Enable) message. When in the remote condition, the Control Display shows the softkey “REMOTE CONTROL Go to Local.” Push this softkey to change the Calibrator to local operation. If the front panel is locked out, the Control Display shows the softkey “REMOTE CONTROL LOCAL LOCK OUT.” (See the `LOCKOUT` command.) To unlock the front panel, use the LOCAL command, or cycle the Calibrator power switch.

Parameter: (None)

Example: `REMOTE`

Put the Calibrator in the remote condition and show this condition on the front panel Control Display with a softkey REMOTE CONTROL.

RPT_STR ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Report String command) Loads the user report string. The user report string can be read on the Control Display in local operation, and is shown on calibration reports. The CALIBRATION switch must be set to ENABLE. (Sequential command.)

Parameter: String of up to 40 characters

RPT_STR? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Report String query) Shows the user report string. The user report string can be read on the Control Display in local operation, and is shown on calibration reports. (Sequential command.)

Parameter: None

Response: (String) a maximum of 40 characters

***RST** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Reset Instrument command) Resets the Calibrator to the power-up condition. *RST holds off execution of subsequent commands until the reset operation is complete. This command is the same as if you push the front panel RESET key.

A reset gets the subsequent commands and values:

Command	Value	Command	Value
CUR_POST	AUX	RTD_TYPE	<RTD_TYPE_D value>
DBMZ	<DBMZ_D value>	SCOPE	OFF
DC_OFFSET	0V	STBY	(No output)
DUTY	50PCT	TC_OFFSET	0 CEL
EARTH	OPEN	TC_OTCD	ON
HARMONIC	1, PRI	TC_REF	INT
LCOMP	OFF	TC_TYPE	<TC_TYPE_D value>
LOWS	TIED	TRIG	OFF
OUT	0V,0HZ		
Command	**Value**	**Command**	**Value**
OUT_IMP	Z1M	WAVE	NONE,NONE
PHASE	0DEG	ZCOMP	OFF
RANGELCK	OFF	ZERO_MEAS	OFF
TSENS_TYPE	TC		

Changes made to the setup menus that are not kept in memory are discarded on reset.

Response: (None)

Example: *RST

Put the Calibrator in a reset condition, evoking the commands and values shown above.

RTD_TYPE [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Resistance Temperature Detector Type command) Sets the Resistance Temperature Detector (RTD) sensor type.

Before you use `RTD_TYPE`, select `RTD` with the `TSENS_TYPE` command. After you use `RTD_TYPE`, select the output temperature with the OUT command. Changes in temperature sensors changes the output to 0 °C. When set, the Calibrator keeps the RTD type until power off or reset.

Parameters:

`PT385`	(100-ohm RTD, curve α=0.00385 ohms/ohm/°C)
`PT385_200`	(200-ohm RTD, curve α=0.00385 ohms/ohm/°C)
`PT385_500`	(500-ohm RTD, curve α=0.00385 ohms/ohm/°C)
`PT385_1000`	(1000-ohm RTD, curve α=0.00385 ohms/ohm/°C)
`PT3926`	(100-ohm RTD, curve α=0.003926 ohms/ohm/°C)
`PT3916`	(100-ohm RTD, curve α=0.003916 ohms/ohm/°C)
`CU10`	(10-ohm RTD, empirical curve)
`NI120`	(120-ohm RTD, empirical curve)

Example: `RTD_TYPE PT3926`

Set the RTD type to a 100-ohm type, with the pt3926 curve (α=0.003926 ohms/ohm/°C). The resistance of 100 ohms refers to the ice point property, (the resistance of the RTD at 0 °C (32 °F)).

RTD_TYPE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Resistance Temperature Detector Type query) Shows the Resistance Temperature Detector (RTD) type used for RTD temperature simulations.

Responses:	`PT385`	(100-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_200`	(200-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_500`	(500-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_1000`	(1000-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT3926`	(100-ohm RTD, curve α=0.003926 ohms/ohm/°C)
	`PT3916`	(100-ohm RTD, curve α=0.003916 ohms/ohm/°C)
	`CU10`	(10-ohm RTD, empirical curve)
	`NI120`	(120-ohm RTD, empirical curve)

Example: `RTD_TYPE?` shows `PT3926`

Shows `PT3926` when a 100-ohm RTD with curve α=0.003926 ohms/ohm/°C is set as the RTD type.

RTD_TYPE_D [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Resistance Temperature Detector Type Default command) Sets the default Resistance Temperature Detector (RTD) at power on and reset, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.)

Parameters:	`PT385`	(100-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_200`	(200-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_500`	(500-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_1000`	(1000-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT3926`	(100-ohm RTD, curve α=0.003926 ohms/ohm/°C)
	`PT3916`	(100-ohm RTD, curve α=0.003916 ohms/ohm/°C)
	`CU10`	(10-ohm RTD, empirical curve)
	`NI120`	(120-ohm RTD, empirical curve)

Example: `RTD_TYPE_D PT3926`

Set the RTD default type to a 100-ohm RTD with curve α=0.003926 ohms/ohm/°C.

RTD_TYPE_D?
[X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Resistance Temperature Detector Type Default query) Shows the default Resistance Temperature Detector (RTD) used at power on and reset.

Responses:	`PT385`	(100-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_200`	(200-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_500`	(500-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT385_1000`	(1000-ohm RTD, curve α=0.00385 ohms/ohm/°C)
	`PT3926`	(100-ohm RTD, curve α=0.003926 ohms/ohm/°C)
	`PT3916`	(100-ohm RTD, curve α=0.003916 ohms/ohm/°C)
	`CU10`	(10-ohm RTD, empirical curve)
	`NI120`	(120-ohm RTD, empirical curve)

Example: `RTD_TYPE_D?` shows `PT3926`

Shows `PT3926` when the RTD default type is a 100-ohm RTD with curve α=0.003926 ohms/ohm/°C.

SP_SET [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Host Serial Port Set command) Sets the RS-232-C settings for the Calibrator rear panel SERIAL 1 FROM HOST serial port, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) (To set the parameters for the rear panel SERIAL 2 TO UUT serial port, see the `UUT_SET` command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the `FORMAT SETUP` command.)

The interface selection sets the command response, with command echo back for commands and error messages with TERM (terminal) or no echo back with COMP (computer).

Parameters:	<baud rate value>,	300, 600, 1200, 2400, 4800, **9600**
	<interface>,	**TERM** (terminal), COMP (computer)
	<flow control>,	**XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)
	<number data bits>,	DBIT7 (7 bits) or **DBIT8** (8 bits)
	<number stop bits>,	**SBIT1** (1 bit) or SBIT2 (2 bits)
	<parity>,	**PNONE** (none), PODD (odd),PEVEN (even)
	<end of line char.>	CR (carriage return), LF (line feed), **CRLF** (carriage return/line feed)

Example: `SP_SET 9600,TERM,XON,DBIT8,SBIT1,PNONE,CRLF`

Set the parameters for the rear panel SERIAL 1 FROM HOST serial port to the factory default values.

SP_SET? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Host Serial Port Set query) Shows the RS-232-C settings for the Calibrator rear panel SERIAL 1 FROM HOST serial port. (To return the parameters for the rear panel SERIAL 2 TO UUT serial port, see the `UUT_SET?` command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the `FORMAT SETUP` command.)

Responses:	<baud rate value>,	300, 600, 1200, 2400, 4800, **9600**
	<interface>,	**TERM** (terminal), COMP (computer)
	<flow control>,	**XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)
	<number data bits>,	DBIT7 (7 bits) or **DBIT8** (8 bits)
	<number stop bits>,	**SBIT1** (1 bit) or SBIT2 (2 bits)
	<parity>,	**PNONE** (none), PODD (odd),PEVEN (even)
	<end of line char.>	CR (carriage return), LF (line feed), **CRLF** (carriage return/line feed)

Example: `SP_SET?` shows `9600,TERM,XON,DBIT8,SBIT1,PNONE,CRLF`

Shows the parameters for the rear panel SERIAL 1 FROM HOST serial port, as shown, when set to the factory default values.

SPLSTR [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Serial Poll String command) Sets the Serial Poll String (string up to 40 characters) which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The SPLSTR is sent to the host over the serial interface when a ^P (<cntl> P) character is sent. The default format is:

```
SPL: %02x %02x %04x %04x
```

where the term %02x (8 bits) means print the value in hexadecimal with 2 hex digits, and %04x (16 bits) means print the value in hexadecimal with 4 hex digits. The string representations are:

```
SPL: (STB) (ESR) (ISCR0) (ISCR1)
```

See the commands `*STB?`, `*ESR?`, `ISCR0?`, and `ISCR1?`. A typical string in the default format sent to the host is: `SPL: 44 00 0000 1000`. This command is for format. For values instead of format, record a ^P (<cntl> p) character. Also see the `SRQSTR` command.

Parameter: `"<string>\n"` (`\n` represents the NEWLINE character, hex 0A)

Example: `SPLSTR "SPL: %02x %02x %04x %04x\n"`

Set the SPLSTR to the default values `SPL: %02x %02x %04x %04x\n`.

SPLSTR? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Serial Poll Response String query) Shows the string programmed for Serial Poll response. For values, record a ^P (<cntl> p) character. Also see the `SRQSTR` command.

Response: <string>

Example: `SRQSTR` shows `SRQ: %02x %02x %04x %04x\n`

Shows the SPLSTR string format (default settings in this example).

*SRE [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Service Request Enable command) Puts a byte into the Service Request Enable (SRE) register. (See "Service Request Enable Register (SRE)" in Chapter 5. Since bit 6 is not used (decimal value 64), the maximum entry is 255 – 64 = 191.

Parameter: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: `*SRE 56`

Enable bits 3 (EAV), 4 (MAV), and 5 (ESR).

*SRE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Service Request Enable query) Shows the byte in the Service Request Enable (SRE).

Response: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: `*SRE?` shows `56`

Shows `56` when bits 3 (EAV), 4 (MAV), and 5 (ESR) are enabled.

SRQSTR [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Service Request String command) Sets the Serial Mode SRQ (Service Request) response (up to 40 characters) in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The SRQSTR is sent to the host over the serial interface when the SRQ line is asserted (terminal mode only). Default format is:

```
SRQ: %02x %02x %04x %04x
```

where the term %02x (8 bits) means print the value in hexadecimal with 2 hex digits, and %04x (16 bits) means print the value in hexadecimal with 4 hex digits. The string representations are:

`SRQ: (STB) (ESR) (ISCR0) (ISCR1)`

See the commands `*STB?`, `*ESR?`, `ISCR0?`, and `ISCR1?` A typical string in the default format sent to the host is: `SRQ: 44 00 0000 1000`. This command is for format. See the `SPLSTR` command for the serial poll response.

Parameter: `"<string>\n"` (`\n` represents the Line Feed character, hex 0A)

Example: `SRQSTR "SRQ: %02x %02x %04x %04x\n"`

Set the SRQSTR to the default values `SRQ: %02x %02x %04x %04x\n`.

SRQSTR? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Service Request String query) Shows the string programmed for Serial Mode SRQ response. This is the format of the Service Request String; actual values come from the registers. Also see the `SPLSTR` command.

Response: <string>

Example: `SRQSTR` shows `SRQ: %02x %02x %04x %04x\n`

Shows the `SRQSTR` string format (default settings in this example).

***STB?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Status Byte Register query) Shows the byte for the Status Byte Register. (See "Status Byte Register (STB)" in Chapter 5.)

Response: <value> (the decimal equivalent of the STB byte, 0 to 255)

Example: `*STB?` shows `72`

Shows `72` if bits 3 (EAV) and 6 (MSS) are set.

STBY ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Standby command) Deactivates the Calibrator output if it is in operate. This is the same as if you push the Calibrator front panel STBY key.

Parameter: (None)

Example: `STBY`

Disconnect the selected output from the Calibrator front panel terminals.

TC_MEAS ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Measure command) Selects the measure thermocouple mode.

Parameters: `CEL` (Celsius) (optional)
`FAR` (Fahrenheit) (optional)

Example: `TC_MEAS CEL`

Measure the thermocouple temperature that is attached to the Calibrator TC terminals, in Celsius.

TC_OFFSET ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Temperature Measurement Offset command) Adds a temperature offset to thermocouple measurements (±500 °C). This command does not apply to thermocouple sourcing.

Parameters: <value> `CEL` (offset in Celsius) (optional)
<value> `FAR` (offset in Fahrenheit) (optional)

Example: `TC_OFFSET +10 CEL`

Add a temperature offset of +10 °C to the thermocouple measurements.

TC_OFFSET? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Temperature Measurement Offset query) Shows the temperature offset used for thermocouple measurements (±500 °C).

Responses: <value> `CEL` (offset in Celsius) (optional)

<value> `FAR` (offset in Fahrenheit) (optional)

Example: `TC_OFFSET?` shows `1.000E+01,CEL`

Shows 10 Celsius when a temperature offset of +10 °C has been added to the thermocouple measurements.

TC_OTCD ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Open Detection command) Activates or deactivates the open thermocouple detection circuit in thermocouple measurement mode. When set, the Calibrator keeps open thermocouple detection circuit setting until power off or reset.

Parameters: `ON` (turn on thermocouple detection circuit) (default)
`OFF` (turn off thermocouple detection circuit)

Example: `TC_OTCD ON`

Activate the open thermocouple detection circuit. If an open thermocouple is detected, this condition is shown on the front panel.

TC_OTCD? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Open Detection query) Shows the status of the open thermocouple detection circuit in thermocouple measurement mode.

Responses: `ON` (thermocouple detection circuit is on)
`OFF` (thermocouple detection circuit is off)

Example: `TC_OTCD?` shows `ON`

Shows `ON` when the open thermocouple detection circuit is activated.

TC_REF [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Thermocouple Reference command) Sets if the internal temperature sensor (INT) or an external reference value (EXT) is used for Thermocouple (TC) outputs and measurements. If the first parameter is EXT, the second parameter must be the temperature value to use as the reference for the thermocouple reference junction temperature. When set, the Calibrator keeps reference setting until power off or reset.

Parameters: `INT`
`EXT`, <value of external reference> `CEL` (or `FAR`)

Example: `TC_REF EXT, 25.6 CEL`

Set the thermocouple reference to external, with a value of 25.6 °C.

TC_REF? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Thermocouple Reference query) Shows the source and value of the temperature being used as a reference for thermocouple simulation and measurement (in Celsius, CEL, or Fahrenheit, FAR, depending on active units). The options are Internal reference (INT) or External reference (EXT).

If INT is shown, the reference temperature return is 0 unless you are in a thermocouple mode of operation and the Calibrator is in Operate.

Responses: `INT`, <value of reference temperature>,`CEL` (or `FAR`)
`EXT`, <value of reference temperature>,`CEL` (or `FAR`)

Example: `TC_REF?` shows `INT,2.988E+01,CEL`

Shows Internal, 29.88, Celsius, when the thermocouple reference is internal and at 29.88 °C. (If the temperature return for the internal reference is 0 (`0.00E+00`), the Calibrator is not in Operate, and/or the Calibrator is not in a thermocouple mode.)

TC_TYPE [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Thermocouple Type command) Sets the Thermocouple (TC) temperature sensor type. The TC type is used when the output is set to a temperature value with the `OUT` command and the temperature sensor type is set to `TC` with the `TSENS_TYPE` command. When the thermocouple type is changed while you simulate a temperature output, the temperature is changed to 0 °C. When set, the Calibrator keeps the TC type until power off or reset.

Parameters:

`B`	(B-type thermocouple)
`C`	(C-type thermocouple)
`E`	(E-type thermocouple)
`J`	(J-type thermocouple)
`K`	(K-type thermocouple) (default)
`N`	(N-type thermocouple)
`R`	(R-type thermocouple)
`S`	(S-type thermocouple)
`T`	(T-type thermocouple)
`X`	(10 µV/°C linear output)
`Y`	(% relative humidity)
`Z`	(1 mV/°C linear output)

Example: `TC_TYPE J`

Set the thermocouple type to simulate a temperature output to a J-type thermocouple.

TC_TYPE? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type query) Shows the Thermocouple (TC) temperature sensor type. When the thermocouple type is changed while you simulate a temperature output, the temperature is changed to 0 °C.

Responses:	B	(B-type thermocouple)
	C	(C-type thermocouple)
	E	(E-type thermocouple)
	J	(J-type thermocouple)
	K	(K-type thermocouple) (default)
	N	(N-type thermocouple)
	R	(R-type thermocouple)
	S	(S-type thermocouple)
	T	(T-type thermocouple)
	X	(10 µV/°C linear output)
	Y	(% relative humidity)
	Z	(1 mV/°C linear output)

Example: `TC_TYPE?` shows `K`

Shows `K` when the thermocouple type to simulate a temperature output is a K-type thermocouple.

TC_TYPE_D ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type Default command) Sets the default thermocouple (TC) sensor type, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The TC type is set to the default at power on and reset.

Responses:	B	(B-type thermocouple)
	C	(C-type thermocouple)
	E	(E-type thermocouple)
	J	(J-type thermocouple)
	K	(K-type thermocouple) (default)
	N	(N-type thermocouple)
	R	(R-type thermocouple)
	S	(S-type thermocouple)
	T	(T-type thermocouple)
	X	(10 µV/°C linear output)
	Y	(% relative humidity)
	Z	(1 mV/°C linear output)

Example: `TC_TYPE_D J`

Set the thermocouple type default to a type-J thermocouple.

TC_TYPE_D? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type Default query) Shows the default thermocouple (TC) sensor type.

Responses:
`B` (B-type thermocouple)
`C` (C-type thermocouple)
`E` (E-type thermocouple)
`J` (J-type thermocouple)
`K` (K-type thermocouple) (default)
`N` (N-type thermocouple)
`R` (R-type thermocouple)
`S` (S-type thermocouple)
`T` (T-type thermocouple)
`X` (10 µV/°C linear output)
`Y` (% relative humidity)
`Z` (1 mV/°C linear output)

Example: `TC_TYPE_D?` shows `K`

Shows `K` when the thermocouple type default is a type-K thermocouple.

TEMP_STD ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Temperature Degree Standard command) Selects the temperature standard IPTS -68 (1968 International Provisional Temperature Standard) or its-90 (1990 International Temperature Standard), which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The default is its-90.

Parameters:
`IPTS_68`
`ITS_90`

Example: `TEMP_STD ITS_90`

See the temperature standard to ITS-90.

TEMP_STD? ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Temperature Degree Standard command) Shows the temperature standard IPTS-68 (1968 International Provisional Temperature Standard) or ITS-90 (1990 International Temperature Standard).

Parameters:
`IPTS_68`
`ITS_90`

Example: `TEMP_STD?` shows `ITS_90`

Shows `ITS_90` when the temperature degree standard is the 1990 International Temperature Standard.

---

*TRG [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Trigger Thermocouple Measurement command) Triggers a thermocouple temperature measurement and shows the value of the measurement. Also changes the operating mode to thermocouple measurement if this is not already the operating mode. (This command is equivalent to sending `TC_MEAS;*WAI;VAL?`)

Responses:	<measurement value>,`CEL`	(value is in Celsius)
	<measurement value>,`FAR`	(value is in Fahrenheit)
	`0.00E+00,OVER`	(value is over or under capability)
	`0.00E+00,OPENTC`	(open thermocouple)
	`0.00E+00,NONE`	(wrong mode or no measurement)

Example: `*TRG shows +2.500E+01,CEL`

Trigger a thermocouple measurement and return 25.00 Celsius when the thermocouple temperature measurement is 25 °C.

TSENS_TYPE

[X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Temperature Sensor Type command) Sets the temperature sensor type to thermocouple (TC) or Resistance Temperature Detector (RTD) for temperature measurements. The Calibrator simulates the RTD temperature as a resistance output on the NORMAL terminals, and simulates the thermocouple temperature as a dc voltage output on the TC terminals. If the temperature sensor type is changed, the temperature output is reset to 0 degrees C. When set, the Calibrator keeps the temperature sensor type until power off or reset.

Parameters:	`TC`	(Thermocouple)
	`RTD`	(Resistance Temperature Detector)

Example: `TSENS_TYPE RTD`

Set the temperature sensor type to an RTD.

TSENS_TYPE?

[X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Temperature Sensor Type query) Shows the temperature sensor type thermocouple (TC) or Resistance Temperature Detector (RTD) for temperature measurements.

Responses:	`TC`	(Thermocouple)
	`RTD`	(Resistance Temperature Detector)

Example: `TSENS_TYPE? shows TC`

Shows `TC` when the temperature sensor type is a thermocouple.

*TST? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Self Test command) Start self-test and shows a `0` for pass or a `1` for fail. If faults are found, they are shown on screen (terminal mode) or are logged into the fault queue where they can be read by the ERR? query (computer mode).

Response:	`0` (pass self test)
	`1` (fail self test)

Example: `*TST? shows 1`

Shows `0` when self test is successful.

UNCERT? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Uncertainties command) Shows specified uncertainties for the current output. If there are no specifications for an output, shows zero.

Parameter: 1. (optional) Preferred unit of primary output uncertainty or PCT (default)

2. (optional) Preferred unit of secondary output uncertainty or PCT (default)

Response: 1. (float) 90-day specified uncertainty of primary unit

2. (float) 1-year specified uncertainty of primary output

3. (character) Unit of primary output uncertainty

4. (float) 90-day specified uncertainty of secondary unit

5. (float) 1-year specified uncertainty of secondary output

6. (character) Unit of secondary output uncertainty.

Example: `UNCERT?` shows `6.120E-01,6.150E-01,PCT,9.50E-02, 1.150E-01,PCT`

UUT_FLUSH [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Flush UUT Receive Buffer command) Flushes the UUT receive buffer for data received from the UUT over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Parameter: (None)

Example: `UUT_FLUSH`

Flush the Calibrator receive data buffer for the UUT.

UUT_RECV? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Receive Data query) Shows data from the UUT in IEEE-488.2 Standard format over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Response: <data> (binary block data in definite length format from UUT)

Example: `UUT_RECV?` shows `#211+1.99975E+0`

Shows (for example) a measurement from the UUT. The format is `#2` (two numbers follow) `11` (characters follow) `+1.99975E+0` (11 characters).

UUT_RECVB? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Receive Binary Data query) Shows binary data as integers from the UUT serial port. Use the UUT_RECV? command instead if receiving ASCII data.

Parameter: (Optional) Maximum number of integers per line

Response: (Indefinite ASCII) Comma separated integers as follows:

1. (integer) Number of data bytes shown that do not include the count

2. (integer) Data from the UUT serial port as series of comma separated integers

Example: `"=>"` followed by a carriage return and a line feed shows 4,61,62,13,10

UUT_SEND ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Send UUT Data command) Sends data to the UUT serial port in binary block or string data format over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation. Include a line feed (RS-232) character to stop the block data or End or Identify (EOI) command (IEEE-488).

Parameter: `#2`<nn><nn characters string> (definite length)
`#0`<character string> (indefinite length)
"<character string>" (character string)

Examples:

`UUT_SEND #206F1S2R0` (definite length format)

Sends the data `F1S2R0` to the UUT in definite length format. The format is #2 (two numbers follow) `06` (characters follow) `F1S2R0` (6 characters).

`UUT_SEND #0F1S2R0` (indefinite length format)

Sends the data `F1S2R0` to the UUT in indefinite length format. The format is #0 then the characters.

`UUT_SEND "F1S2R0"` (character string)

Sends the data `F1S2R0` to the UUT as a character string.

<u>Special Case</u> When the character string sent to a UUT must complete in a carriage return (CR) command or line feed (LF) command or both, you must use:

Definite Length Format Follow the instructions above and after the character string add a command ^J for CR or ^M for LF or both, where ^J means hold down the <Cntl> key and type the letter J. For example, if you send the string REMS in this format with both CR and LF, you can count 4 characters for REMS and 1 character each for ^J and ^M for a total of 6 characters. The command will be `UUT_SEND #206REMS^J^M` then <enter>. (The `^J` and `^M` "characters" actually perform the CR and LF functions.)

Indefinite Length Format This format cannot be used when CR and LF commands are necessary for the character string.

Character String Follow the instructions above and after the character string, add a \n for CR or \r for LF or both, where the alpha character is recorded in lower case. For example, in the terminal mode to send the string REMS in this format with CR and LF, the command will be `UUT_SEND "REMS\n\r"`. In the computer mode where commands are recorded as part of a command string, use double quotes to show embedded quotes. For example, `"uut_send "REMS\n\r"" "`.

The subsequent characters and commands can be implemented as described above:

Carriage Return	`^J`	`\n`
Line Feed	`^M`	`\r`
Tab	Tab	`\t`
Backspace	`^H`	`\b`
Form Feed	`^L`	`\f`

UUT_SENDB [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Send UUT Binary Data command) Send binary data to the UUT serial port (Calibrator rear panel SERIAL 2 to UUT serial port). Use the UUT_SEND command instead of sending ASCII data. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Parameter: Comma separated integers to send (maximum of 10)

Example: `UUT_SENDB 42,73,68,78,63,10`

Send the ASCII characters "*IDN?" followed by a new line (ASCII 10) to the UUT serial port.

UUT_SET [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Serial Port Set command) Sets the RS-232-C settings for the Calibrator rear panel SERIAL 2 TO UUT serial port, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) (To set the parameters for the rear panel SERIAL 1 FROM HOST serial port, see the `SP_SET` command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the `FORMAT SETUP` command.)

The interface selection sets the command response, with command echo back with TERM (terminal) and no echo back with COMP (computer).

Parameters:	<baud rate value>,	300, 600, 1200, 2400, 4800, **9600**
	<flow control>,	**XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)
	<number data bits>,	DBIT7 (7 bits) or **DBIT8** (8 bits)
	<number stop bits>,	**SBIT1** (1 bit) or SBIT2 (2 bits)
	<parity>	**PNON**E (none), PODD (odd),PEVEN (even)

Example: `UUT_SET 9600,XON,DBIT8,SBIT1,PNONE`

Set the parameters for the rear panel SERIAL 2 TO UUT serial port to the factory default values.

UUT_SET? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(UUT Serial Port Set query) Shows the RS-232-C settings for the Calibrator rear panel SERIAL 2 TO UUT serial port. (To return the parameters for the rear panel SERIAL 1 FROM HOST serial port, see the `SP_SET?` command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the `FORMAT SETUP` command.)

Responses:	<baud rate value>,	300, 600, 1200, 2400, 4800, **9600**
	<flow control>,	**XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)
	<number data bits>,	DBIT7 (7 bits) or **DBIT8** (8 bits)
	<number stop bits>,	**SBIT1** (1 bit) or SBIT2 (2 bits)
	<parity>	**PNONE** (none), PODD (odd),PEVEN (even)

Example: `UUT_SET? shows 9600,XON,DBIT8,SBIT1,PNONE`

Shows the parameters for the rear panel SERIAL 2 TO UUT serial port, as shown, when set to the factory default values.

VAL? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Measurement Value command) Shows the last value of the thermocouple temperature or scope impedance measurement. The unit shows the status of the indication.

Parameter: (Optional) Units to return

Responses: 1. (Float) Measured temperature
2. (Character) `CEL`, `FAR`, `OHM`, `F`,
`OVER` (value is over or under capability),
`OPENTC` (open thermocouple),
or `NONE` (wrong mode or no measurement)

Example: `VAL?` shows `0.00E+00,NONE`

Shows `0` and `NONE` when there is no recent measurement because the Calibrator is not in a measurement mode, or because no measurement was made.

VVAL? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Thermocouple Measurement Voltage command) Shows the last value of the thermocouple temperature measurement in volts. If the last measurement was an overload or open thermocouple condition, or there is no measurement, shows 0E+00.

Responses: <measurement value in volts> (valid measurement)
`0E+00` (overload, open TC, or no measurement)

Example: `VVAL?` shows `1.1047E-03` (1.1047 mV, equivalent to 50 °C with type K thermocouple and TC reference = 23.0 °C

***WAI** [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Wait-to-Continue command) Prevents more remote commands from being done until all previous remote commands have been done. For example, if you send an `OUT` command, you can cause the Calibrator to pause until the output has become stable before you continue on to the subsequent command if you follow `OUT` with a `*WAI` command. The `*WAI` command is useful with overlapped command. This prevents the Calibrator from processing other commands until the overlapped command is processed.

Example: `*WAI`

Process all commands that exist before you continue.

WAVE [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [X] Coupled

(Waveform command) Sets the waveforms for ac outputs. If the Calibrator is sourcing one output, one parameter is necessary. If the Calibrator is sourcing two outputs, two parameters are necessary or one parameter to set the waveform to the two outputs. Waveform selections are SINE (sine wave), TRI (triangle wave), SQUARE (square wave), TRUNCS (truncated sine wave), or NONE (waveform does not apply).

Parameter: <1st waveform> , (SINE, TRI, SQUARE, TRUNCS, NONE)
<2nd waveform> (SINE, TRI, SQUARE, TRUNCS, NONE)

Example: `WAVE SINE,SQUARE`

Set the waveforms for a dual output to Sine wave on the primary output (Calibrator front panel NORMAL terminals) and Square wave on the secondary output (front panel AUX or 20A terminals).

WAVE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Waveform query) Shows the waveform types for ac outputs. Waveform selections are SINE (sine wave), TRI (triangle wave), SQUARE (square wave), TRUNCS (truncated sine wave), or NONE (waveform does not apply).

Responses: <1st waveform> , (SINE, TRI, SQUARE, TRUNCS, NONE)
<2nd waveform> (SINE, TRI, SQUARE, TRUNCS, NONE)

Example: `WAVE?` shows `SQUARE,NONE`

Shows `SQUARE` when the ac primary output (Calibrator front panel NORMAL terminals) is a square wave and `NONE` when there is no secondary output on the front panel AUX terminals.

ZCOMP [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

(Impedance Compensation command) Activates or deactivates 2-wire or 4-wire impedance compensation. For resistance output, compensation is permitted when the resistance is less than 110 kΩ. For capacitance output, compensation is permitted when the capacitance is equal to or larger than 110 nF. For all other resistances and capacitances, the compensation is NONE and tries to use other parameters results in the error message “Can’t change compensation now.” For RTD temperature simulation, compensation is permitted for all temperatures.

Parameter: `NONE` (Turns off impedance compensation circuitry)
`WIRE2` (Turns on the 2-wire impedance compensation circuitry)
`WIRE4` (Turns on the 4-wire impedance compensation circuitry)

Example: `ZCOMP WIRE2`

Set 2-wire impedance compensation for the Calibrator UUT connection. (Resistance if the ohms value is less than 110 kΩ, capacitance if the farads value is 110 nF or more, or RTD temperature simulation, any value.)

ZCOMP? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

(Impedance Compensation query) Shows status of 2-wire or 4-wire impedance compensation.

Responses: `NONE` (impedance compensation is turns off)
`WIRE2` (2-wire impedance compensation is on)
`WIRE4` (4-wire impedance compensation is off)

Example: `ZCOMP?` shows `NONE`

Shows `NONE` when no impedance compensation is applied to the resistance, capacitance or RTD output.

ZERO_MEAS [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Sets the zero offset for capacitance measurement with the -SC600.

Parameter: 1. (boolean) ON
(boolean) OFF

Example: `ZERO_MEAS ON`

Sets the zero offset to the current measurement value.

ZERO_MEAS? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Shows the zero offset for capacitance measurements with the -SC600.

Parameter: (None)

Responses:	1. (character) OFF	(no zero in effect)
	(character) ON	(zero in effect)
	2. (float) offset value	
	3. (character) units	(F)

Example: `ZERO_MEAS?` shows `ON,-3.66E-02,F`

Chapter 7
Maintenance

Title **Page**

Introduction

This chapter tells you how to do the usual maintenance and calibration tasks necessary to keep the 5502A Calibrator in service.

See the Service Manual for intensive maintenance tasks like troubleshooting, calibration or repair, and all procedures where it is necessary to open the Calibrator cover. The Service Manual also has complete verification and calibration procedures.

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury:

- **Turn the Product off and remove the mains power cord. Stop for two minutes to let the power assemblies discharge before you open the fuse door.**
- **Replace a blown fuse with exact replacement only for continued protection against arc flash.**
- **Disconnect the mains power cord before you remove the Product covers.**
- **Use only specified replacement parts.**
- **Use only specified replacement fuses.**
- **Have an approved technician repair the Product.**

Replace the Mains Power Fuse

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury, replace a blown fuse with exact replacement only for continued protection against arc flash.

Access the line-power fuse on the rear panel. The fuse rating is 5 A/250 V slow blow fuse when the Calibrator is set to 100 V/120 V line voltage, 2.5 A/250 V slow blow when the Calibrator is set to 220 V/240 V line voltage. Fuses that are not user replaceable are shown in the "Maintenance" section of Chapter 7.

To examine or replace the fuse, see Figure 7-1 and continue as follows:

1. **Disconnect line power**.
2. Open the fuse compartment. Put a screwdriver blade into tab on the left side of the compartment and carefully pry until it can be removed with the fingers.
3. Remove the fuse from the compartment for replacement or verification. Be sure the correct fuse is installed.
4. Put the fuse compartment into the Calibrator. Push it into position until the tab locks.

Replace the Line Fuse

Access the line power fuse from the rear panel. The fuse rating information above the ac power input module shows the correct replacement fuse for each line voltage setting. Table 7-1 shows the fuse part numbers for each line voltage setting.

To verify or replace the fuse, refer to Figure 7-1 and do the subsequent steps:

1. **Disconnect line power**.
2. The line power fuse and line voltage switch are in a compartment on the right end of the ac input module. To open the compartment and remove the fuse, put the blade of a standard screwdriver to the left of the tab at the left side of the compartment cover.
3. Pull the tab out of the slot and the compartment cover will come part way out.
4. Remove the compartment cover.
5. The fuse comes out with the compartment cover and can be easily replaced.

To install the fuse, push the compartment cover back into the compartment until the tab locks with the ac input module.

Table 7-1. Replacement Line Fuses

Part Number	Fuse Description	Line Voltage Setting
⚠ 109215	5A/250 V Time Delay	100 V or 120 V
⚠ 851931	2.5A/250 V Time Delay	200 V or 240 V
⚠To ensure safety, use exact replacement only.		

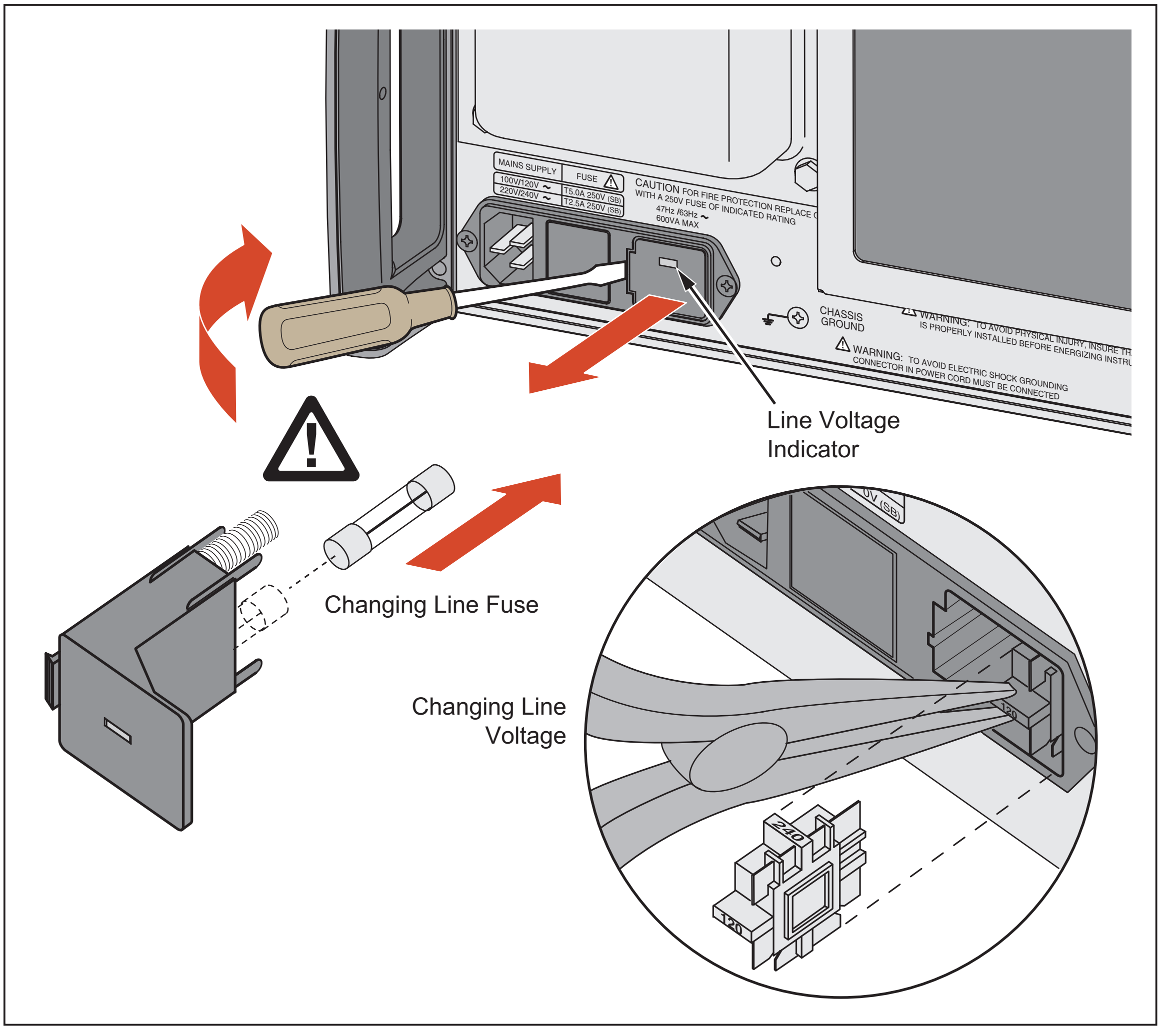

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Figure 7-1. Accessing the Fuse

Replace the Current Fuses

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury:

- **Replace a blown fuse with exact replacement only for continued protection against arc flash.**
- **Disconnect the mains power cord before you remove the bottom fuse cover.**
- **Use only specified replacement fuses.**
- **Have an approved technician repair the Product.**

Access the current fuses from the bottom of the Calibrator. These fuses are the 3A and 20A outputs protection from over-current. Table 7-2 shows the fuse part numbers for the two current fuses. To replace a current fuse:

1. Turn the Calibrator over on its top.
2. Remove the two screws with a Phillips head screwdriver as shown in Figure 7-2.

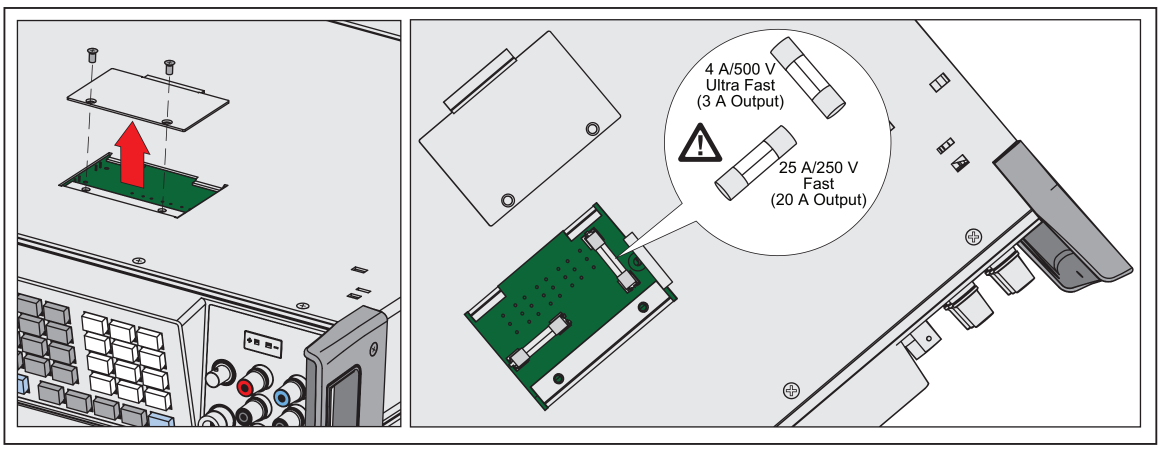

Figure 7-2. Current Fuse Replacement

3. Lift off the fuse door.
4. Remove the fuse and replace it with a new fuse of the same rating.

Table 7-2. Replacement Current Fuses

Part Number	Fuse Description
3674001	4A/500 V Ultra Fast
3470596	25A/250 V Fast
⚠To ensure safety, use exact replacement only.	

5. Replace the fuse door over the fuse compartment.
6. Install the two screws to hold the fuse door in position.

Clean the Air Filter

The air filter must be removed and cleaned each 30 days or more frequently if the calibrator is operated in a dusty environment. The air filter is accessed from the rear panel of the calibrator.

To clean the air filter, refer to Figure 7-3 and continue as follows:

1. Turn off the power, let the fan stop, and disconnect the ac line cord.
2. Remove the filter element.
   a. Hold the top and bottom of the air filter frame.
   b. Squeeze the edges of the frame to the middle to disengage the filter tabs from the slots in the calibrator.
   c. Pull the filter frame straight out from the calibrator.
3. Clean the filter element.
   a. Clean the filter element in soapy water.
   b. Flush the filter element.
   c. Shake out the unwanted water, and then let the filter element to dry before you install it.
4. Install the filter element. Do the filter removal steps in reverse.

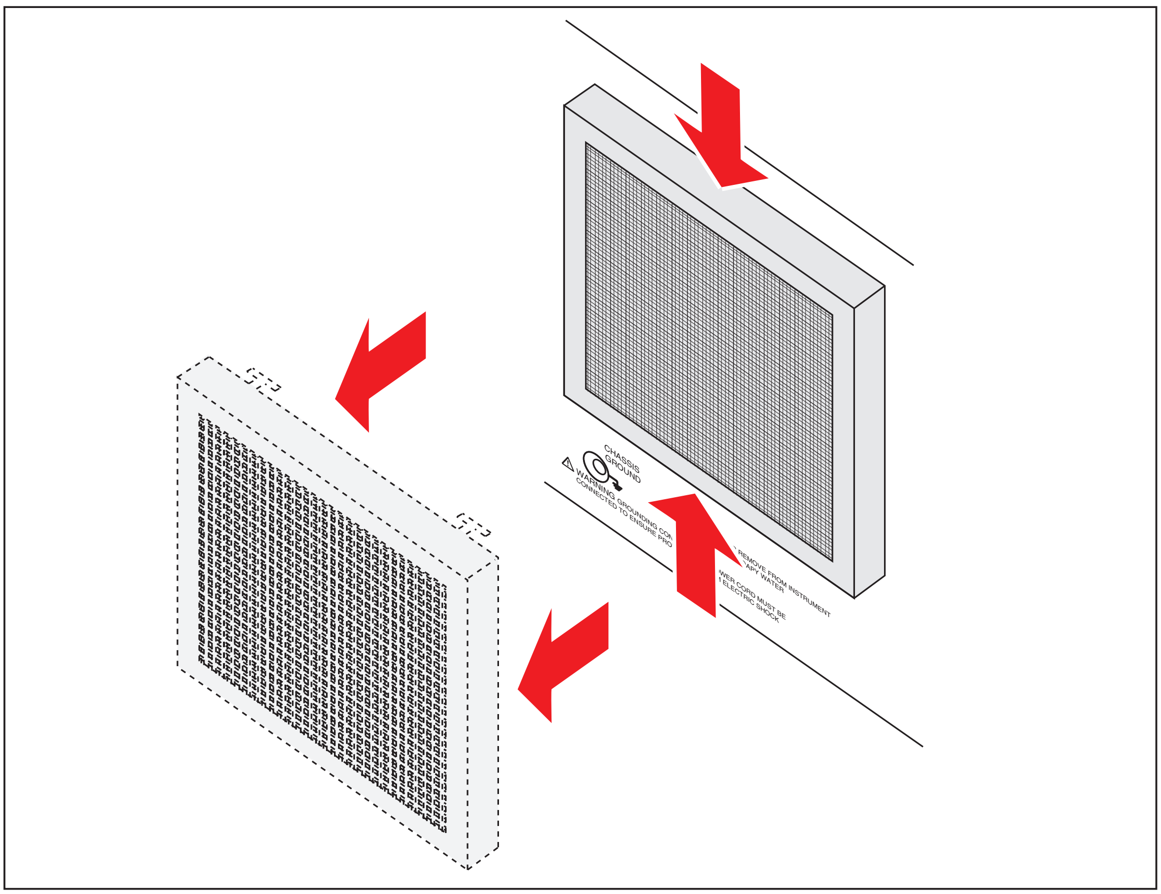

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Figure 7-3. Access the Air Filter

Clean the Calibrator

Clean the case, front panel keys, and display with a soft cloth dampened with water or a non-abrasive weak cleaning solution that will not harm plastics.

⚠ **Caution**

Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They can damage the plastic materials used in the calibrator.

Performance Tests

To make sure that the Product is in specification, use Tables 7-3 through 7-15. The tables are for approved metrology personnel who have access to a standards laboratory that has the correct equipment to test calibration equipment of this level of accuracy. The tables show the recommended test points and the permitted maximum and lower limits for each point. The limits were calculated by adding or subtracting the 90-day specification from the output value. There is no built-in factor for measurement uncertainty.

Table 7-3. Verification Tests for DC Voltage (Normal)

Range	Output	Lower Limit	Upper Limit
329.9999 mV	0.0000 mV	-0.0030 mV	0.0030 mV
329.9999 mV	329.0000 mV	328.9805 mV	329.0194 mV
329.9999 mV	-329.0000 mV	-329.0194 mV	-328.9805 mV
3.299999 V	0.000000 V	-0.000005 V	0.000005 V
3.299999 V	1.000000 V	0.9999855 V	1.000045 V
3.299999 V	-1.000000 V	-1.000045 V	-0.999955 V
3.299999 V	3.290000 V	3.2899863 V	3.290136 V
3.299999 V	-3.290000 V	-3.290136 V	-3.2898638 V
32.99999 V	0.00000 V	-0.00005 V	0.00005 V
32.99999 V	10.00000 V	9.99955 V	10.00045 V
32.99999 V	-10.00000 V	-10.00045 V	-9.99955 V
32.99999 V	32.90000 V	32.89863 V	-32.90136 V
32.99999 V	-32.90000 V	32.90136 V	-32.89863 V
329.9999 V	50.0000 V	49.9972 V	50.0027 V
329.9999 V	329.0000 V	328.9846 V	329.0153 V
329.9999 V	-50.0000 V	-50.0027 V	-49.9972 V
329.9999 V	-329.0000 V	-329.0153 V	-328.9846 V
1000.000 V	334.000 V	333.983 V	334.016 V
1000.000 V	900.000 V	899.958 V	900.042 V
1000.000 V	1020.000 V	1019.952 V	1020.047 V
1000.000 V	-334.000 V	-334.016V	-333.983 V
1000.000 V	-900.000 V	-900.042 V	-899.958 V
1000.000 V	-1020.000 V	-1020.047 V	-1019.952 V

Table 7-4. Verification Tests for DC Voltage (AUX)

Range	Output	Lower Limit	Upper Limit
329.999 mV	0.000 mV	-0.350 mV	0.350 mV
329.999 mV	329.000 mV	328.551 mV	329.449 mV
329.999 mV	-329.000 mV	-329.449 mV	-328.551 mV
3.29999 V	0.33000 V	0.32955 V	0.33045 V
3.29999 V	3.29000 V	3.28866 V	3.29134 V
3.29999 V	-3.29000 V	-3.29134 V	-3.28866 V
7.0000 V	7.0000 V	6.9976 V	7.0025 V
7.0000 V	-7.0000 V	-7.0025 V	-6.9976 V

Table 7-5. Verification Tests for DC Current (AUX)

Range	Output	Lower Limit	Upper Limit
329.999 µA	0.000 µA	-0.020 µA	0.020 µA
329.999 µA	190.000 µA	189.957 µA	190.043 µA
329.999 µA	-190.000 µA	-190.043 µA	-189.957 µA
329.999 µA	329.000 µA	328.941 µA	329.059 µA
329.999 µA	-329.000 µA	-329.059 µA	-328.941 µA
3.29999 mA	0.00000 mA	-0.00005 mA	0.00005 mA
3.29999 mA	1.90000 mA	1.89976 mA	1.90024 mA
3.29999 mA	-1.90000 mA	-1.90020 mA	-1.89980 mA
3.29999 mA	3.29000 mA	3.28969 mA	3.29031 mA
3.29999 mA	-3.29000 mA	-3.29031 mA	-3.28969 mA
32.9999 mA	0.0000 mA	-0.00025 mA	0.00025 mA
32.9999 mA	19.0000 mA	18.9982 mA	19.0018 mA
32.9999 mA	-19.0000 mA	-19.0018 mA	-18.9982 mA
32.9999 mA	32.9000 mA	32.8971 mA	32.9029 mA
32.9999 mA	-32.9000 mA	-32.9029 mA	-32.8971 mA
329.999 mA	0.000 mA	-0.0033 mA	0.0033 mA
329.999 mA	190.000 mA	189.982 mA	190.018 mA
329.999 mA	-190.000 mA	-190.018 mA	-189.982 mA
329.999 mA	329.000 mA	328.971 mA	329.029 mA
329.999 mA	-329.000 mA	-329.029 mA	-328.971 mA
2.99999 A	0.00000 A	-0.00004 A	0.00004 A

Table 7-5. Verification Tests for DC Current (AUX) (cont.)

Range	Output	Lower Limit	Upper Limit
2.99999 A	1.09000 A	1.08979 A	1.09021 A
2.99999 A	-1.09000 A	-1.09021 A	-1.08962 A
2.99999 A	2.99000 A	2.98906 A	2.99094 A
2.99999 A	-2.99000 A	-2.99094 A	-2.98906 A
20.5000 A	0.0000 A	-0.0005 A	0.0005 A
20.5000 A	11.0000 A	10.9953 A	11.0046 A
20.5000 A	-11.0000 A	-11.0046 A	10.9953 A
20.5000 A	20.0000 A	19.9833 A	20.0168 A
20.5000 A	-20.0000 A	-20.0168 A	-19.9833 A

Table 7-6. Verification Tests for Resistance

Range	Output	Lower Limit	Upper Limit
10.999 Ω	0.000 Ω	-0.0010 Ω	0.0010 Ω
10.999 Ω	2.000 Ω	1.9989 Ω	2.0011 Ω
10.999 Ω	10.900 Ω	10.8980 Ω	10.9019 Ω
32.999 Ω	11.900 Ω	11.8974 Ω	11.9025 Ω
32.999 Ω	19.000 Ω	18.9967 Ω	19.0032 Ω
32.999 Ω	30.000 Ω	29.9958 Ω	30.0042 Ω
109.999 Ω	33.000 Ω	32.9962 Ω	33.0037 Ω
109.999 Ω	109.000 Ω	108.9909 Ω	109.0090 Ω
329.999 Ω	119.000 Ω	118.9896 Ω	119.0103 Ω
329.999 Ω	190.000 Ω	189.9847 Ω	190.0153 Ω
329.999 Ω	300.000 Ω	299.9770 Ω	300.0230 Ω
1.09999 kΩ	0.33000 kΩ	0.329749 kΩ	0.330251 kΩ
1.09999 kΩ	1.09000 kΩ	1.089921 kΩ	1.090078 kΩ
3.29999 kΩ	1.19000 kΩ	1.189896 kΩ	1.190103 kΩ
3.29999 kΩ	1.9000 kΩ	1.899847 kΩ	1.900153 kΩ
3.29999 kΩ	3.00000 kΩ	2.999770 kΩ	3.000230 kΩ
10.9999 kΩ	3.3000 kΩ	3.29974 kΩ	3.30025 kΩ
10.9999 kΩ	10.9000 kΩ	10.89921 kΩ	10.90078 kΩ
32.9999 kΩ	11.9000 kΩ	11.89896 kΩ	11.90103 kΩ
32.9999 kΩ	19.0000 kΩ	18.99847 kΩ	19.00153 kΩ
32.9999 kΩ	30.0000 kΩ	29.99977 kΩ	30.00230 kΩ

Table 7-6. Verification Tests for Resistance (cont.)

Range	Output	Lower Limit	Upper Limit
109.999 kΩ	33.000 kΩ	32.9971 kΩ	33.0028 kΩ
109.999 kΩ	109.000 kΩ	108.9910 kΩ	109.0089 kΩ
329.999 kΩ	119.000 kΩ	118.9872 kΩ	119.0127 kΩ
329.999 kΩ	190.000 kΩ	189.9809 kΩ	190.0191 kΩ
329.999 kΩ	300.000 kΩ	299.9710 kΩ	300.0290 kΩ
1.09999 MΩ	0.33000 MΩ	0.329961 MΩ	0.330038 MΩ
1.09999 MΩ	1.09000 MΩ	1.089878 MΩ	1.090121 MΩ
3.29999 MΩ	1.19000 MΩ	1.189839 MΩ	1.190160 MΩ
3.29999 MΩ	1.90000 MΩ	1.899761 MΩ	1.900239 MΩ
3.29999 MΩ	3.00000 MΩ	2.999640 MΩ	3.000360 MΩ
10.9999 MΩ	3.3000 MΩ	3.29846 MΩ	3.30153 MΩ
10.9999 MΩ	10.9000 MΩ	10.89504 MΩ	10.90495 MΩ
32.9999 MΩ	11.9000 MΩ	11.88857 MΩ	11.91142 MΩ
32.9999 MΩ	19.0000 MΩ	18.98325 MΩ	19.01675 MΩ
32.9999 MΩ	30.0000 MΩ	29.99750 MΩ	30.02500 MΩ
109.999 MΩ	33.000 MΩ	32.8650 MΩ	33.1350 MΩ
109.999 MΩ	109.000 MΩ	108.5610 MΩ	109.4390 MΩ
329.999 MΩ	119.000 MΩ	118.4240 MΩ	119.5760 MΩ
329.999 MΩ	290.000 MΩ	288.7400 MΩ	291.2600 MΩ
1100.00 MΩ	400.00 MΩ	394.700 MΩ	405.300 MΩ
1100.00 MΩ	640.00 MΩ	631.820 MΩ	648.180 MΩ
1100.00 MΩ	1090.00 MΩ	1076.420 MΩ	1103.580 MΩ

Table 7-7. Verification Tests for AC Voltage (Normal)

Range	Output	Frequency	Lower Limit	Upper Limit
32.999 mV	3.000 mV	45 Hz	2.977 mV	3.022 mV
32.999 mV	3.000 mV	10 kHz	2.977 mV	3.022 mV
32.999 mV	30.000 mV	9.5 Hz	28.350 mV	31.650 mV,
32.999 mV	30.000 mV	10 Hz	29.944 mV	30.056 mV
32.999 mV	30.000 mV	45 Hz	29.956 mV	30.044 mV
32.999 mV	30.000 mV	1 kHz	29.956 mV	30.044 mV
32.999 mV	30.000 mV	10 kHz	29.956 mV	30.044 mV
32.999 mV	30.000 mV	20 kHz	29.944 mV	30.056 mV

Table 7-7. Verification Tests for AC Voltage (Normal) (cont.)

Range	Output	Frequency	Lower Limit	Upper Limit
32.999 mV	30.000 mV	50 kHz	29.932 mV	30.068 mV
32.999 mV	30.000 mV	100 kHz	29.877 mV	30.123 mV
32.999 mV	30.000 mV	450 kHz	29.715 mV	30.285 mV
329.999 mV	33.000 mV	45 Hz	32,970 mV	33.029 mV
329.999 mV	33.000 mV	10 kHz	32.970 mV	33.029 mV
329.999 mV	300.000 mV	9.5 Hz	283.350 mV	316.650 mV
329.999 mV	300.000 mV	10 Hz	299.917 mV	300.083 mV
329.999 mV	300.000 mV	45 Hz	299.893 mV	300.107 mV
329.999 mV	300.000 mV	1 kHz	299.983 mV	300.107 mV
329.999 mV	300.000 mV	10 kHz	299.983 mV	300.107 mV
329.999 mV	300.000 mV	20 kHz	299.782 mV	300.218 mV
329.999 mV	300.000 mV	50 kHz	299.702 mV	300.298 mV
329.999 mV	300.000 mV	100 kHz	299.311 mV	300.689 mV
329.999 mV	300.000 mV	500 kHz	298.470 mV	301.530 mV
3.29999 V	0.33000 V	45 Hz	0.32984 V	0.33015 V
3.29999 V	0.33000 V	10 kHz	0.32984 V	0.33015V
3.29999 V	3.00000 V	9.5 Hz	2.83500 V	3.16500 V
3.29999 V	3.00000 V	10 Hz	2.99868 V	3.00132 V
3.29999 V	3.00000 V	45 Hz	2.99910 V	3.00090 V
3.29999 V	3.00000 V	1 kHz	2.99910V	3.00090 V
3.29999 V	3.00000 V	10 kHz	2.99910 V	3.00090 V
3.29999 V	3.00000 V	20 kHz	2.99817 V	3.00183 V
3.29999 V	3.00000 V	50 kHz	2.99745 V	3.00255 V
3.29999 V	3.00000 V	100 kHz	2.99437 V	3.00563V
3.29999 V	3.00000 V	450 kHz	2.98659 V	3.01340 V
3.29999 V	3.29000 V	1 MHz	2.250 V [1]	
32.9999 V	3.3000 V	45 Hz	3.2985 V	3.3014 V
32.9999 V	3.3000 V	10 kHz	3.2985 V	3.3014 V
32.9999 V	30.0000 V	9.5 Hz	28.3500 V	31.6500 V
32.9999 V	30.0000 V	10 Hz	29.9866 V	30.0134V
32.9999 V	30.0000 V	45 Hz	29.9919 V	30.0081 V
32.9999 V	30.0000 V	1 kHz	29.9919 V	30.0081 V
32.9999 V	30.0000 V	10 kHz	29.9919 V	30.0081 V

Table 7-7. Verification Tests for AC Voltage (Normal) (cont.)

Range	Output	Frequency	Lower Limit	Upper Limit
32.9999 V	30.0000 V	20 kHz	29.9802 V	30.0198 V
32.9999 V	30.0000 V	50 kHz	29.9736 V	30.0264 V
32.9999 V	30.0000 V	90 kHz	29.9404 V	30.0596 V
329.999 V	33.000 V	45 Hz	32.984 V	33.015 V
329.999 V	33.000 V	10 kHz	32.969 V	33.030V
329.999 V	300.000 V	45 Hz	299.880 V	300.120 V
329.999 V	300.000 V	1 kHz	299.880 V	300.120 V
329.999 V	300.000 V	10 kHz	299.799 V	300.201 V
329.999 V	300.000 V	18 kHz	299.754 V	300.246 V
329.999 V	300.000 V	50 kHz	299.703 V	300.297 V
329.999 V	200.000 V	100 kHz	199.536 V	200.464 V
1020.00 V	330.00 V	45 Hz	329.84 V	330.15 V
1020.00 V	330.00 V	10 kHz	329.73 V	330.26 V
1020.00 V	1000.00V	45 Hz	999.56 V	1000.44 V
1020.00 V	1000.00 V	1 kHz	999.56 V	1000.44 V
1020.00 V	1000.00 V	5 kHz	999.349 V	1000.66 V
1020.00 V	1000.00 V	8 kHz	999.23 V	1000.77 V
1020.00 V	1020.00 V	1 kHz	1019.55 V	1020.44 V
1020.00 V	1020.00 V	8 kHz	1019.21 V	1020.78 V

[1] Typical specification is -24 dB at 2 MHz

Table 7-8. Verification Tests for AC Voltage (AUX)

Range	Output, AUX [1]	Frequency	Lower Limit	Upper Limit
329.999 mV	10.000 mV	45 Hz	9.622 mV	10.378 mV
329.999 mV	10.000 mV	1 kHz	9.622 mV	10.378 mV
329.999 mV	10.000 mV	5 kHz	9.535 mV	10.465 mV
329.999 mV	10.000 mV	10 kHz	9.520 mV	10.480 mV
329.999 mV	10.000 mV	30 kHz	8.700 mV	11.300 mV
329.999 mV	300.000 mV	9.5 Hz	283.500 mV	316.500 mV
329.999 mV	300.000 mV	10 Hz	299.180 mV	300.820 mV
329.999 mV	300.000 mV	45 Hz	299.390 mV	300.610 mV
329.999 mV	300.000 mV	1 kHz	299.390 mV	300.610 mV
329.999 mV	300.000 mV	5 kHz	299.100 mV	300.900 mV
329.999 mV	300.000 mV	10 kHz	298.650 mV	301.350 mV

Table 7-8. Verification Tests for AC Voltage (AUX) (cont.)

Range	Output, AUX [1]	Frequency	Lower Limit	Upper Limit
329.999 mV	300.000 mV	30 kHz	287.100 mV	312.900 mV
3.29999 V	3.00000 V	9.5 Hz	2.835 V	3.165V
3.29999 V	3.00000 V	10 Hz	2.99505 V	3.00495 V
3.29999 V	3.00000 V	45 Hz	2.99745 V	3.00255 V
3.29999 V	3.00000 V	1 kHz	2.99745 V	3.00255 V
3.29999 V	3.00000 V	5 kHz	2.99410 V	3.00590 V
3.29999 V	3.00000 V	10 kHz	2.98960 V	3.01040 V
3.29999 V	3.00000 V	30 kHz	2,87720 V	3.12280 V
5.00000 V	5.00000 V	9.5 Hz	4.72500 V	5.27500 V
5.00000 V	5.00000 V	10 Hz	4.99205 V	5.00795 V
5.00000 V	5.00000 V	45 Hz	4.99605 V	5.00395 V
5.00000 V	5.00000 V	1 kHz	4.99605 V	5.00395 V
5.00000 V	5.00000 V	5 kHz	4.99110 V	5.00890 V
5.00000 V	5.00000 V	10 kHz	4.98360 V	5.01640 V

[1] Set the NORMAL output to 300 mV.

Table 7-9. Verification Tests for AC Current

Range	Output	Frequency	Lower Limit	Upper Limit
329.99 µA	33.00 µA	1 kHz	32.87 µA	33.13 µA
329.99 µA	33.00 µA	10 kHz	32.60 µA	33.40 µA
329.99 µA	33.00 µA	30 kHz	32.20 µA	33.80 µA
329.99 µA	190.00 µA	45 Hz	189.71 µA	190.29 µA
329.99 µA	190.00 µA	1 kHz	189.71 µA	190.29 µA
329.99 µA	190.00 µA	10 kHz	188.66 µA	191.34 µA
329.99 µA	190.00 µA	30 kHz	187.32 µA	192.68 µA
329.99 µA	329.00 µA	10 Hz	328.37 µA	329.63 µA
329.99 µA	329.00 µA	45 Hz	328.57 µA	329.43 µA
329.99 µA	329.00 µA	1 kHz	328.57 µA	329.43 µA
329.99 µA	329.00 µA	5 kHz	328.03 µA	329.97 µA
329.99 µA	329.00 µA	10 kHz	326.83 µA	331.17 µA
329.99 µA	329.00 µA	30 kHz	324.65 µA	333.35 µA
3.2999 mA	0.3300 mA	1 kHz	0.3296 mA	0.3304 mA
3.2999 mA	0.3300 mA	5 kHz	0.3293 mA	0.3307 mA
3.2999 mA	0.3300 mA	30 kHz	0.3268 mA	0.3332 mA

Table 7-9. Verification Tests for AC Current (cont.)

Range	Output	Frequency	Lower Limit	Upper Limit
3.2999 mA	1.9000 mA	1 kHz	1.8983 mA	1.9017 mA
3.2999 mA	1.9000 mA	10 kHz	1.8921 mA	1.9079 mA
3.2999 mA	1.9000 mA	30 kHz	1.8842 mA	1.9158 mA
3.2999 mA	3.2900 mA	10 Hz	3.2846 mA	3.2954 mA
3.2999 mA	3.2900 mA	45 Hz	3.2872 mA	3.2928 mA
3.2999 mA	3.2900 mA	1 kHz	3.2872 mA	3.2928 mA
3.2999 mA	3.2900 mA	5 kHz	3.2845 mA	3.2955 mA
3.2999 mA	3.2900 mA	10 kHz	3.2765 mA	3.3035 mA
3.2999 mA	3.2900 mA	30 kHz	3.2631 mA	3.3169 mA
32.999 mA	3.3000 mA	1 kHz	3.297 mA	3.303 mA
32.999 mA	3.3000 mA	5 kHz	3.296 mA	3.304 mA
32.999 mA	3.3000 mA	30 kHz	3.285 mA	3.315 mA
32.999 mA	19.0000 mA	1 kHz	18.991 mA	19.009 mA
32.999 mA	19.0000 mA	10 kHz	18.967 mA	19.033 mA
32.999 mA	19.0000 mA	30 kHz	18.935 mA	19.065 mA
32.999 mA	32.9000 mA	10 Hz	32.849 mA	32.951 mA
32.999 mA	32.9000 mA	1 kHz	32.886 mA	32.914 mA
32.999 mA	32.9000 mA	5 kHz	32.877 mA	32.923 mA
32.999 mA	32.9000 mA	10 kHz	32.844 mA	32.956 mA
32.999 mA	32.9000 mA	30 kHz	32.791 mA	33.009 mA
329.99 mA	33.0000 mA	1 kHz	32.97 mA	33.03 mA
329.99 mA	33.0000 mA	5 kHz	32.92 mA	33.08 mA
329.99 mA	33.0000 mA	30 kHz	32.69 mA	33.31 mA
329.99 mA	190.0000 mA	1 kHz	189.91 mA	190.09 mA
329.99 mA	190.0000 mA	10 kHz	189.60 mA	190.40 mA
329.99 mA	190.0000 mA	30 kHz	189.19 mA	190.81 mA
329.99 mA	329.0000 mA	10 Hz	328.49 mA	329.51 mA
329.99 mA	329.0000 mA	45 Hz	328.86 mA	329.14 mA
329.99 mA	329.0000 mA	1 kHz	328.86 mA	329.14 mA
329.99 mA	329.0000 mA	5 kHz	328.69 mA	329.31 mA
329.99 mA	329.0000 mA	10 kHz	328.37 mA	329.63 mA
329.99 mA	329.0000 mA	30 kHz	327.75 mA	330.25 mA
2.99999 A	0.33000 A	1 kHz	0.32978 A	0.33022 A

Table 7-9. Verification Tests for AC Current (cont.)

Range	Output	Frequency	Lower Limit	Upper Limit
2.99999 A	0.33000 A	5 kHz	0.32735 A	0.33265 A
2.99999 A	0.33000 A	10 kHz	0.31840 A	0.34160 A
2.99999 A	1.09000 A	10 Hz	1.08827 A	1.09174 A
2.99999 A	1.09000 A	45 Hz	1.08951 A	1.09049 A
2.99999 A	1.09000 A	1 kHz	1.08951 A	1.09049 A
2.99999 A	1.09000 A	5 kHz	1.08355 A	1.09645 A
2.99999 A	1.09000 A	10 kHz	1.06320 A	1.11680A
2.99999 A	2.99000 A	10 Hz	2.98542 A	2.99459 A
2.99999 A	2.99000 A	45 Hz	2.98840 A	2.99160 A
2.99999 A	2.99000 A	1 kHz	2.98840 A	2.99160 A
2.99999 A	2.99000 A	5 kHz	2.97405 A	3.00595 A
2.99999 A	2.99000 A	10 kHz	2.92520 A	3.05480 A
20.5000 A	3.3000 A	500 Hz	3.2954 A	3.3046 A
20.5000 A	3.3000 A	1 kHz	3.2954 A	3.3046 A
20.5000 A	3.3000 A	5 kHz	3.2155 A	3.3845 A
20.5000 A	11.0000 A	45 Hz	10.9840A	11.0160 A
20.5000 A	11.0000 A	65 Hz	10.9840 A	11.0160A
20.5000 A	11.0000 A	500 Hz	10.9807 A	11.0193 A
20.5000 A	11.0000 A	1 kHz	10.9807 A	11.0193 A
20.5000 A	11.0000 A	5 kHz	10.7200 A	11.2800A
20.5000 A	20.0000 A	45 Hz	19.9750 A	20.0250 A
20.5000 A	20.0000 A	65 Hz	19.9750 A	20.0250 A
20.5000 A	20.0000 A	500 Hz	19.9690 A	20.0310 A
20.5000 A	20.0000 A	1 kHz	19.9690 A	20.0310 A
20.5000 A	20.0000 A	5 kHz	19.4950 A	20.5050 A

Table 7-10. Verification Tests for Capacitance

Range	Output	Test Frequency or Current	Lower Limit	Upper Limit
0.3999 nF	0.2200 nF	5 kHz	0.2192 nF	0.2308 nF
0.3999 nF	0.3500 nF	1 kHz	0.3387 nF	0.3613 nF
1.0999 nF	0.4800 nF	1 kHz	0.4682 nF	0.4918 nF
1.0999 nF	0.6000 nF	1 kHz	0.5877 nF	0.6123 nF
1.0999 nF	1.0000 nF	1 kHz	0.9862 nF	1.0138 nF

Table 7-10. Verification Tests for Capacitance (cont.)

Range	Output	Test Frequency or Current	Lower Limit	Upper Limit
3.299 nF	2.0000 nF	1 kHz	1.9824 nF	2.0176 nF
10.999 nF	7.0000 nF	1 kHz	6.9767 nF	7.0233 nF
10.999 nF	10.9000 nF	1 kHz	10.8693 nF	10.9307 nF
32.999 nF	20.000 nF	1 kHz	19.8620 nF	20.1380 nF
109.99 nF	70.00 nF	1 kHz	69.767 nF	70.233 nF
109.99 nF	109.00 nF	1 kHz	108.693 nF	109.307 nF
329.99 nF	200.00 nF	1 kHz	199.320 nF	200.680 nF
329.99 nF	300.00 nF	1 kHz	299.130 nF	300.870 nF
1.0999 µF	0.7000 µF	100 Hz	0.69767 µF	0.70233 µF
1.0999 µF	1.0900 µF	100 Hz	1.05929 µF.	1.12071 µF
3.2999 µF	2.0000 µF	100 Hz	1.99320 µF	2.00680 µF
3.2999 µF	3.0000 µF	100 Hz	2.99130 µF	3.00870 µF
10.999 µF	7.000 µF	100 Hz	6.9767 µF	7.0233 µF
10.999 µF	10.900 µF	100 Hz	10.8693 µF	10.9307 µF
32.999 µF	20.000 µF	100 Hz	19.9100 µF	20.0900 µF
32.999 µF	30.000 µF	100 Hz	29.8800 µF	30.1200 µF
109.99 µF	70.00 µF	50 Hz	69.662 µF	70.338 µF
109.99 µF	109.00 µF	50 Hz	108.529 µF	109.471 µF
329.99 µF	200.00 µF	54 µA dc	199.020 µF	200.980 µF
329.99 µF	300.00 µF	80 µA dc	298.680 µF	301.320 µF
1.0999 mF	0.3300 mF	90 µA dc	0.32788 mF	0.33212 mF
1.0999 mF	0.7000 mF	180 µA dc	0.69662 mF	0.70338 mF
1.0999 mF	1.0900 mF	270 µA dc	1.08529 mF	1.09471 mF
3.299 mF	1.100 mF	270 µA dc	1.0933 mF	1.1067 mF
3.299 mF	2.000 mF	540 µA dc	1.9902 mF	2.0098 mF
3.299 mF	3.000 mF	800 µA dc	2.9868 mF	3.0132 mF
10.999 mF	3.300 mF	900 µA dc	3.2788 mF	3.3212 mF
10.999 mF	10.900 mF	2.7 mA dc	10.8529 mF	10.9471 mF
32.999 mF	20.000 mF	5.4 mA dc	19.8300 mF	20.1700 mF
32.999 mF	30.000 mF	8.0 mA dc	29.7600 mF	30.2400 mF
110.00 mF	33.00 mF	9.0 mA dc	32.570 mF	33.430 mF
110.00 mF	110.00 mF	27.0 mA dc	108.800 mF	111.200 mF

Table 7-11. Verification Tests for Thermocouple Simulation

TC Type	Output, °C	Lower Limit, mV	Upper Limit, mV
10 µV/°C	0.00 °C (0.0000 mV)	-0.0030	0.0030
	100.00 °C (1.0000 mV)	0.99696	1.00304
	-100.00 °C (-1.0000 mV)	-1.00304	-0.99696
	1000.00 °C (10.0000 mV)	9.99660	10.00340
	-1000.00 °C (10.0000 mV)	-10.0034	-9.9966
	10000.00 °C (100.0000 mV)	99.9930	100.0070
	-10000.00 °C (-100.0000 mV)	-100.0070	-99.9930

Table 7-12. Verification Tests for Thermocouple Measurement

TC Type	Input, mV	Lower Limit, °C	Upper Limit, °C
10 µV/°C	0.00 °C (0,0000 mV)	-0.30	-0.30
	10000.00 °C (100.0000 mV)	9999.30	10000.70
	-10000.00 °C (-100.0000 mV)	-10000.70	-9999.30
	30000.00 °C (300.0000 mV)	29998.50	30001.50
	-30000.00 °C (-300.0000 mV)	-30001.50	-29998.50

Table 7-13. Verification Tests for Phase Accuracy, V and V

Range, Normal Output, V	Output, Normal V	Frequency	Range, AUX Output	Output, AUX	Phase °	Lower Limit°	Upper Limit °
3.29999	3.00000	65 Hz	3.29999 V	3.00000 V	0	-0.150	0.150
		400 Hz				-0.900	0.900
		1 kHz				-2.000	2.000
		5 kHz				-6.000	6.000
		10 kHz				-10.000	10.000
		30 kHz				-15.000	15.000
		65 Hz			60	59.850	60.150
		400 Hz				59.100	60.900
		1 kHz				58.000	62.000
		5 kHz				54.000	66.000
		10 kHz				50.000	70.000
		30 kHz				45.000	75.000
		65 Hz			90	89.850	90.150
		400 Hz				89.100	90.900
		1 kHz				88.000	92.000
		5 kHz				84.000	96.000
		10 kHz				80.000	100.000
		30 kHz				75.000	105.000
32.9999	30.0000	65 Hz				89.85	90.15
329.999	50.000	65 Hz				89.85	90.15

Table 7-14. Verification Tests for Phase Accuracy, V and I

Range, Normal Output, V	Output, Normal V	Frequency	Range, AUX Output	Output, AUX	Phase °	Lower Limit °	Upper Limit °
329.999 mV	30.000 mV	65 Hz	329.99 mA	300.00 mA	0	-0.15	0.15
		1 kHz	329.99 mA	300.00 mA		-2.00	2.00
		30 kHz	329.99 mA	300.00 mA		-15.00	15.00
	200.000 mV	65 Hz	2099999 A	2.00000 A		-0.15	0.15
	50.000 mV	65 Hz	20.5000 A	5.0000 A		-0.15	0.15
		400 Hz	20.5000 A	5.0000 A		-0.90	0.90
	30.000 mV	65 Hz	329.99 mA	300.00 mA	60	59.85	60.15
	200.000 mV	65 Hz	2.99999 A	2.00000 A		59.85	60.15
		65 Hz	20.5000 A	20.0000 A		59.85	60.15
		400 Hz	20.5000 A	20.0000 A		59.10	60.90
32.999 mV	3.3000 V	65 Hz	329.99 mA	300.00 mA	0	-0.15	0.15
		65 Hz	2.99999 A	2.00000 A		-0.15	0.15
		65 Hz	20.5000 A	5.0000 A		-0.15	0.15
		400 Hz	20.5000 A	5.0000 A		-0.90	0.90
		65 Hz	329.99 mA	300.00 mA	90	89.85	90.15
		65 Hz	2.99999 A	2.00000 A		89.85	90.15
		65 Hz	20.5000 A	20.0000 A		89.85	90.15
		400 Hz	20.5000 A	20.0000 A		89.10	90.90
329.999 V	33.000 V	65 Hz	329.99 mA	300.00 mA	0	-0.15	0.15
		65 Hz	2.99999 A	2.00000 A		-0.15	0.15
		65 Hz	20.5000 A	5.0000 A		-0.15	0.15
		400 Hz	20.5000 A	5.0000 A		-0.90	0.90
		65 Hz	329.99 mA	300.00 mA	90	89.85	90.15
		65 Hz	2.99999 A	2.00000 A		89.85	90.15
		65 Hz	20.5000 A	20.0000 A		89.85	90.15
		400 Hz	20.5000 A	20.0000 A		89.10	90.90

Table 7-15. Verification Tests for Frequency

Range, Normal Output, V	Output, Normal, V	Frequency	Lower Limit [1]	Upper Limit [1]
3.29999	3.00000	119.00 Hz	118.99602 Hz	119.00398 Hz
		120.0 Hz	119.99600 Hz	120.00400 Hz
		1000.0 Hz	999.974000 Hz	1000.026000 Hz
		100.00 kHz	99.99750000 Hz	100.00250000 Hz

[1] Frequency accuracy is specified for 1 year.

Chapter 8
Accessories

Title	Page

Introduction

Table 8-1 summarizes the available models, options, accessories, cables, and components.

Table 8-1. Options and Accessories

Model	Description
SC300	Oscilloscope Calibration Option
SC600	Oscilloscope Calibration Option
55XX/CASE	Transit Case
5522A/CARRYCASE	Carry Case with front/rear panels that you can remove.
5500A/HNDL	Side Handle
5500A/LEADS	Comprehensive Lead Set
109215	Replacement fuse; 5 A/250 V Time Delay (100 V or 120 V line voltage)
851931	Replacement fuse; 2.5 A/250 V Time Delay (200 V or 240 V line voltage)
3674001	Replacement fuse; 4 A/500 V, Ultra fast, 0.25 x 1.25, ceramic body
3470596	Replacement fuse; 25 A/250 V, Fast, 6.3 X 32 mm
MET/CAL Plus	Fluke Calibration Metrology Software
MET/CAL-IEEE USB	IEEE Interface Option.
884X-USB	USB to RS-232 Cable Adapter
⚠To ensure safety, use exact replacement only.	

Table 8-1. Options and Accessories (cont.)

Model	Description
Y5537	24 in. (61 cm) Rack Mount Kit for 5502A
Y8021	Shielded IEEE-488 Cable 0.5 m (1.64 ft)
Y8022	Shielded IEEE-488 Cable 2 m (6.56 ft)
Y8023	Shielded IEEE-488 Cable 4 m (13 ft)

Rack Mount Kit

The Y5537 rack mount kit supplies all the hardware necessary to install the 5502A on slides in a 24-inch (61 cm) equipment rack. Instructions are supplied in the kit. (To rack mount the 5725A Amplifier, order kit Y5735.)

IEEE-488 Interface Cable

Shielded IEEE-488 cables are available in three lengths (See Table 8-1). The cables attach to the 5502A to other IEEE-488 devices. Each cable has double 24-pin connectors at each end for stacking. Metric threaded installation screws are supplied with connectors. Appendix D shows the pinout for the IEEE-488 connector.

5500A/LEADS

The optional test lead kit, 5500A/LEADS, is a kit of test leads for voltage and current, thermocouple extension wires, thermocouple miniconnectors, and thermocouple measuring “beads.”

Chapter 9
SC600 Oscilloscope Calibration Option

Title	Page

Introduction

The SC600 Oscilloscope Calibration Option (the SC600 Option) has functions that help you keep your oscilloscope's accuracy by verifying and calibrating the subsequent oscilloscope qualities:

- Vertical deflection qualities are calibrated and verified. The VOLT function lets you compare the voltage gain to the graticule lines on the oscilloscope.
- Pulse transient response is examined and calibrated, verifying the accuracy of the measurement of pulse transitions of the oscilloscope with the EDGE function. Also, the Calibrator lets you do faster pulse response checks with an external tunnel diode pulser.
- Frequency response is examined by verifying the bandwidth with the leveled sine wave (LEVSINE) function. Vertical deflection is monitored until the -3 dB point is seen on the oscilloscope.
- Horizontal (time base) deflection qualities are calibrated and verified with the time MARKER function. This calibration procedure is like the one for verifying the vertical deflection qualities, but it examines the horizontal axis.
- The oscilloscope can show, hold, and measure pulse width. This is examined with the PULSE function. This function lets you to change the pulse width and the period.
- The oscilloscope can trigger on different waveforms. This is done with the wave generator (WAVEGEN) function.
- The oscilloscope can trigger on and capture complex TV trigger signals. This is done with the VIDEO function.
- The input qualities of the oscilloscope can be measured with the Input resistance and capacitance (MEAS Z) function.
- You can verify the oscilloscope input protection circuit with the overload (OVERLD) function.

The menus that implement these functions also include parameters to change how the output signal reacts to voltage, frequency, and time settings. This gives you control of the signal when you calibrate, and gives more methods to see signal qualities.

SC600 Oscilloscope Calibration Option Specifications

These specifications apply only to the SC600 Oscilloscope Calibration Option. General specifications that apply to the 5502A Calibrator can be found in Chapter 1. The specifications are correct given the 5502A is operated with the conditions specified in Chapter 1, and has completed a warm-up period of no less than two times the length of time the Calibrator was powered off, to a maximum of 30 minutes.

Voltage Function Specifications

Voltage Function	DC Signal		Square Wave Signal [1]	
	50 Ω Load	**1 MΩ Load**	**50 Ω Load**	**1 MΩ Load**
Amplitude Qualities				
Range	0 to ±6.599 V	0 to ±130 V	±1 mV to ±6.599 V p-p	±1 mV to ±130 V p-p
Resolution	Range 1 to 24.999 mV 25 to 109.99 mV 110 mV to 2.1999 V 2.2 to 10.999 V 11 to 130 V		Resolution 1 µV 10 µV 100 µV 1 mV 10 mV	
Adjustment Range	Continuously adjustable			
1-Year Absolute Uncertainty, tcal ±5 °C	±(0.25 % of output + 40 µV)	± 0.05 % of output + 40 µV)	±(0.25 % of output + 40 µV)	±(0.1 % of output + 40 µV) [2]
Sequence	1-2-5 (e.g., 10 mV, 20 mV, 50 mV)			
Square Wave Frequency Qualities				
Range	10 Hz to 10 kHz			
1-Year Absolute Uncertainty, tcal ±5 °C	±(2.5 ppm of setting)			
Typical aberration within 4 µs from 50 % of leading/trailing edge	<(0.5 % of output + 100 µV)			

[1] Selectable positive or negative, zero referenced square wave.
[2] For square wave frequencies above 1 kHz, ± (0.25 % of output + 40 µV).

Edge Specifications

Edge Qualities into 50 Ω Load		1-Year Absolute Uncertainty, tcal ± 5 °C
Rise Time	≤300 ps	(+0 ps / -100 ps)
Amplitude Range (p-p)	4.5 mV to 2.75 V	±(2 % of output + 200 µV)
Resolution	4 digits	
Adjustment Range	±10 % around each sequence value (indicated below)	
Sequence Values	5 mV, 10 mV, 25 mV, 50 mV, 60 mV, 80 mV, 100 mV, 200 mV, 250 mV, 300 mV, 500 mV, 600 mV, 1 V, 2.5 V	
Frequency Range [1]	900 Hz to 11 MHz	±(2.5 ppm of setting)
Typical Jitter, edge to trigger	<5 ps (p-p)	
Leading Edge Aberrations [2]	within 2 ns from 50 % of rising edge	<(3 % of output + 2 mV)
	2 to 5 ns	<(2 % of output + 2 mV)
	5 to 15 ns	<(1 % of output + 2 mV)
	after 15 ns	<(0.5 % of output + 2 mV)
Typical Duty Cycle	45 % to 55 %	
Tunnel Diode Pulse Drive	Square wave at 100 Hz to 100 kHz, with variable amplitude of 60 to 100 V p-p.	

[1] Above 2 MHz rise time specification <350 ps
[2] All edge aberration measurements made with Tektronix 11801 mainframe with SD26 input module.

Leveled Sine Wave Specifications

Leveled Sine Wave Qualities into 50 Ω	Frequency Range			
	50 kHz (reference)	**50 kHz to 100 MHz**	**100 to 300 MHz**	**300 to 600 MHz**
Amplitude Qualities (for measuring oscilloscope bandwidth)				
Range (p-p)	5 mV to 5.5 V			
Resolution	<100 mV: 3 digits ≥100 mV: 4 digits			
Adjustment Range	continuously adjustable			
1-Year Absolute Uncertainty, tcal ±5 °C	±(2 % of output + 300 μV)	±(3.5 % of output + 300 μV)	±(4 % of output + 300 μV)	±(6 % of output + 300 μV)
Flatness (relative to 50 kHz)	not applicable	±(1.5 % of output + 100 μV)	±(2 % of output + 100 μV)	±(4 % of output + 100 μV)
Short-Term Amplitude Stability	≤ 1 % [1]			
Frequency Qualities				
Resolution	1 kHz		10 kHz	
1-Year Absolute Uncertainty, tcal ±5 °C	±2.5 ppm [2]			
Distortion Qualities				
2nd Harmonic	≤ -33 dBc			
3rd and Higher Harmonics	≤ -38 dBc			

[1] Within 1 hour after reference amplitude setting, provided temperature varies no more than ±5 °C.
[2] With REF CLK set to ext, the frequency uncertainty of the Leveled Sine Wave is the uncertainty of the external 10 MHz clock ±0.3 Hz/gate time.

Time Marker Specifications

Time Maker into 50 Ω	5 s to 50 ms	20 ms to 100 ns	50 to 20 ns	10 ns	5 to 2 ns
1-Year Absolute Uncertainty at Cardinal Points, tcal ±5 °C	±(25 + t *1000) ppm [1]	±2.5 ppm	±2.5 ppm	±2.5 ppm	±2.5 ppm
Wave Shape	spike or square	spike, square, or 20 %-pulse	spike or square	square or sine	sine
Typical Output Level	>1 V p-p [2]	>1 V p-p [2]	>1 V p-p [2]	>1 V p-p [2]	>1 V p-p
Typical Jitter (rms)	<10 ppm	<1 ppm	<1 ppm	<1 ppm	<1 ppm
Sequence	5-2-1 from 5 s to 2 ns (e.g., 500 ms, 200 ms, 100 ms)				
Adjustment Range [3]	At least ±10 % around each sequence value indicated above.				
Amplitude Resolution	4 digits				

[1] t is the time in seconds.
[2] Typical rise time of square wave and 20 %-pulse (20 % duty cycle pulse) is < 1.5 ns.
[3] Time marker uncertainty is ±50 ppm away from the cardinal points.

Wave Generator Specifications

Wave Generator Qualities	Square Wave, Sine Wave, and Triangle Wave into 50 Ω or 1 MΩ
Amplitude	
Range	into 1 MΩ: 1.8 mV to 55 V p-p into 50 Ω: 1.8 mV to 2.5 V p-p
1-Year Absolute Uncertainty, tcal ±5 °C, 10 Hz to 10 kHz	±(3 % of p-p output + 100 μV)
Sequence	1-2-5 (e.g., 10 mV, 20 mV, 50 mV)
Typical DC Offset Range	0 to ± (≥40 % of p-p amplitude) [1]
Frequency	
Range	10 Hz to 100 kHz
Resolution	4 or 5 digits depending upon frequency
1-Year Absolute Uncertainty, tcal ±5 °C	±(25 ppm + 15 mHz)

[1] The DC offset plus the wave signal must not exceed 30 V rms.

Pulse Generator Specifications

Pulse Generator Qualities	Positive pulse into 50 Ω
Typical rise/fall times	<2 ns
Available Amplitudes	2.5 V, 1 V, 250 mV, 100 mV, 25 mV, 10 mV
Pulse Width	
Range	4 ns to 500 ns [1]
Uncertainty [2]	5 % of pulse width ±2 ns
Pulse Period	
Range	22 ms to 200 ns (45.5 Hz to 5 MHz)
Resolution	4 or 5 digits depending upon frequency and width
1-Year Absolute Uncertainty at Cardinal Points, tcal ±5 °C	±2.5 ppm

[1] Pulse width not to exceed 40 % of period.
[2] Pulse width uncertainties for periods below 2 μs are not specified.

Trigger Signal Specifications (Pulse Function)

Pulse Period	Division Ratio	Amplitude into 50 Ω (p-p)	Typical Rise Time
22 ms to 200 ns	off/1/10/100	≥1 V	≤2 ns

Trigger Signal Specifications (Time Marker Function)

Time Marker Period	Division Ratio	Amplitude into 50 Ω (p-p)	Typical Rise Time
2 to 9 ns	off/100	≥1 V	≤2 ns
10 to 749 ns	off/10/100	≥1 V	≤2 ns
750 ns to 34.9 ms	off/1/10/100	≥1 V	≤2 ns
35 ms to 5 s	off/1	≥1 V	≤2 ns

Trigger Signal Specifications (Edge Function)

Edge Signal Frequency	Division Ratio	Typical Amplitude into 50 Ω (p-p)	Typical Rise Time	Typical Lead Time
900 Hz to 11 MHz	off/1	≥1 V	≤2 ns	40 ns

Trigger Signal Specifications (Square Wave Voltage Function)

Voltage Function Frequency	Division Ratio	Typical Amplitude into 50 Ω (p-p)	Typical Rise Time	Typical Lead Time
10 Hz to 10 kHz	off/1	≥1 V	≤2 ns	1 μs

Trigger Signal Specifications

Trigger Signal Type	Parameters
Field Formats	Selectable NTSC, SECAM, PAL, PAL-M
Polarity	Selectable inverted or uninverted video
Amplitude into 50 Ω load	Adjustable 0 to 1.5 V p-p Ω, (±7 % accuracy)
Line Marker	Selectable Line Video Marker

Oscilloscope Input Resistance Measurement Specifications

Scope Input Selected	50 Ω	1 MΩ
Measurement Range	40 to 60 Ω	500 kΩ to 1.5 MΩ
Uncertainty	0.1 %	0.1 %

Oscilloscope Input Capacitance Measurement Specifications

Scope Input selected	1 MΩ
Measurement Range	5 to 50 pF
Uncertainty	±(5 % of input + 0.5 pF) [1]

[1] Measurement made within 30 minutes of capacitance zero reference. SC600 option must be selected for at least five minutes prior to capacitance measurement, including the zero process.

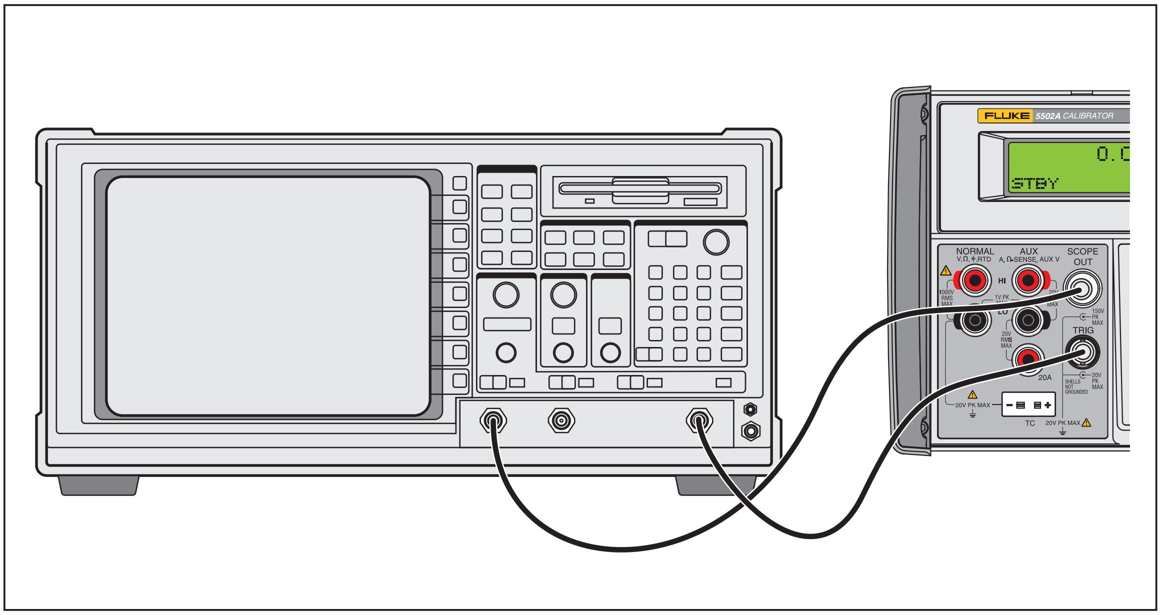
Overload Measurement Specifications

Source Voltage	Typical 'On' Current Indication	Typical 'Off' Current Indication	Maximum Time Limit DC or AC (1 kHz)
5 to 9 V	100 to 180 mA	10 mA	Setable 1 s to 60 s

Oscilloscope Connections

With the cable supplied with the SC600 Option, connect the SCOPE output on the Calibrator to one of the channel connectors on your oscilloscope (see Figure 9-1).

To use the external trigger, connect the TRIG output on the Calibrator to the external trigger connection on your oscilloscope. To use the external trigger and see its signal with the calibration signal, connect the TRIG output to A different channel. See your oscilloscope manual for instructions to connect and see an external trigger.

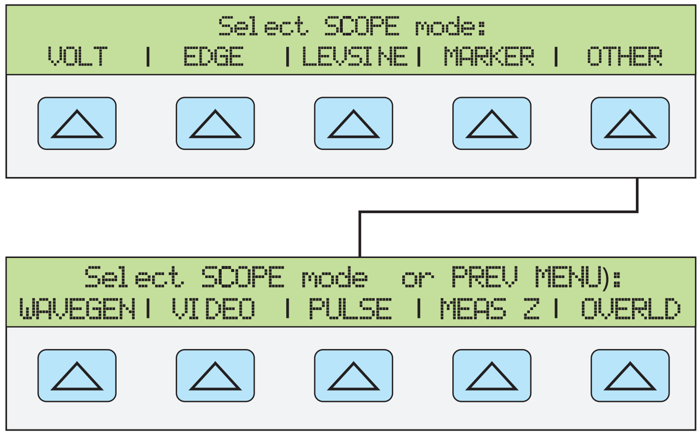


gvx036.eps

Figure 9-1. Oscilloscope Connection: Channel and External Trigger

Start the SC600 Option

Push SCOPE (LED on) to select the SC600 Option. The SCOPE menu, shown below, shows in the Control Display. You can push the first four softkeys to go directly to the VOLT, EDGE, LEVSINE, and MARKER calibration menus. Push the last softkey to go to the OTHER menu (also shown below), this lets you access to WAVEGEN, VIDEO, PULSE, Impedance/Capacitance measurement (MEAS Z), and Overload (OVERLD) menus. Push PREV MENU to return to the SCOPE menu from the OTHER menu. This chapter tells you about each of these menus.



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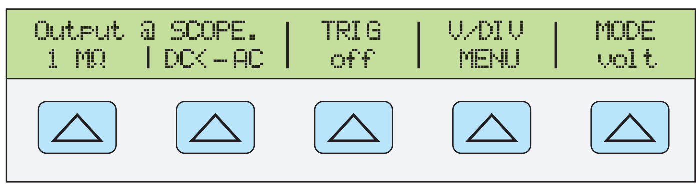
The Output Signal

If you have selected VOLT mode from the SCOPE menu, see the subsequent description. The Control Displays shows as follows with VOLT mode selected:



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The location of the output signal is shown on the Control Display (the display on the right side). If your Calibrator is connected, but the output does not show on the oscilloscope, you can have the Calibrator in standby mode. The settings for the output signal are indicated in the Output Display (the display on the left side).

If STBY is shown, push the OPR key. The Output Display will show OPR and the output should show on the oscilloscope.

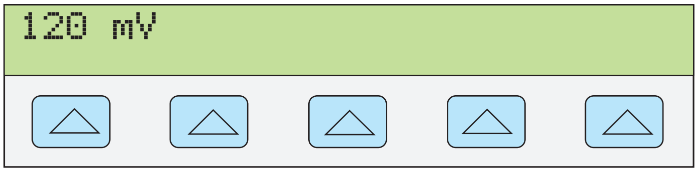
Adjust the Output Signal

The Calibrator has several ways to change the settings for the output signal during calibration. Since oscilloscope calibration requires many adjustments of the output signal, the three available methods for changing these settings for oscilloscope calibration are summarized below. These methods provide the means of jumping to a new value or sweeping through a range of values.

Key in a Value

The subsequent example is for use in the LEVSINE mode. To key a specific value directly into the Calibrator from its front panel:

1. Key in the value you want to record, including the units and prefixes. For example, to record 120 mV push [1] [2] [0] [µ m] [dBm V]. The control display shows:



gl002i.eps

Note

Units and prefixes printed in red in the upper-left corner of the keys are accessed through the [SHIFT] *key. For example, to record 200 µs, push* [2] [0] [0] [SHIFT] [µ m] [SHIFT] [sec Hz].

   If you make an error, push [CE] to clear the Control Display and return to the menu.

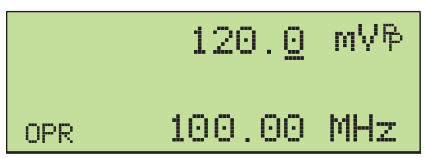
2. Push [ENTER] to activate the value and move it to the Output Display.

   Other settings in the display will remain unaltered unless you key in an entry and specify the units for that setting.

Adjust Values with the Rotary Knob

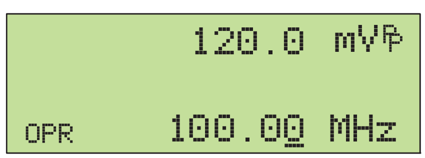
To adjust values in the Output Display with the rotary knob:

1. Turn the rotary knob. A cursor shows in the output display under the lowest digit and begins changing that digit. If you wish to place the cursor in the field without changing the digit, push [EDIT FIELD], see below.



gjh038.eps

2. To move the cursor between the voltage and frequency fields, push [EDIT FIELD], see below.

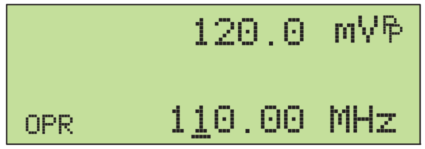


gjh039.eps

3. Use [▶] and [◀] to move the cursor to the digit you want to change.

4. Turn the rotary knob to change the value.

   When you use the rotary knob in Volt mode or Marker mode, the Control Display shows the new value's percent change from the reference value. This is useful for determining the percentage of error on the oscilloscope. You can set the reference value to the new value with NEW REF, see below.



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5. Push ENTER to remove the cursor from the Output Display and save the new value as the reference value.

Note

If you attempt to use the rotary knob to adjust a value to an amount that is invalid for the function you will use, or is outside the value's range limits, the value will not change and the 5502A will beep. If you need to reach a different range of values, turn the knob quickly to jump to the new range.

Use MULT X and DIV ÷

The MULT X and DIV ÷ keys cause the current value of the signal to jump to a predetermined cardinal value, whose amount is determined by the current function. These keys are given in more detail under the descriptions for each function.

Reset the Oscilloscope Option

You can reset all parameters in the 5502A to their default settings during front-panel operations. Push the RESET key on the front panel.

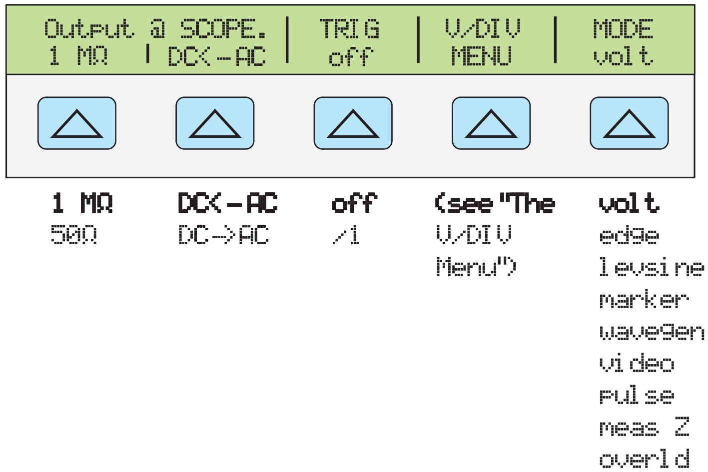
After resetting the 5502A, push SCOPE to return to the Oscilloscope Calibration Option (the Volt menu shows). Push OPR to connect the signal output.

Calibrate the Voltage Amplitude on an Oscilloscope

The oscilloscope voltage (vertical) gain is calibrated by applying a dc or low frequency square wave signal and adjusting its gain to meet the height specified for different voltage levels, designated by the graticule line divisions on the oscilloscope. The signal is applied from the 5502A in Volt mode. The specific voltages that you should use for calibration, and the graticule line divisions that need to be matched, vary for different oscilloscopes. See your oscilloscope's service manual.

The Volt Function

The Voltage gain is calibrated with the Volt function. This function is accessed through the Volt menu, which shows when you start the SCOPE option, or when you push the softkey below MODE to scroll through the oscilloscope calibration menus, see below.



gjh052.eps

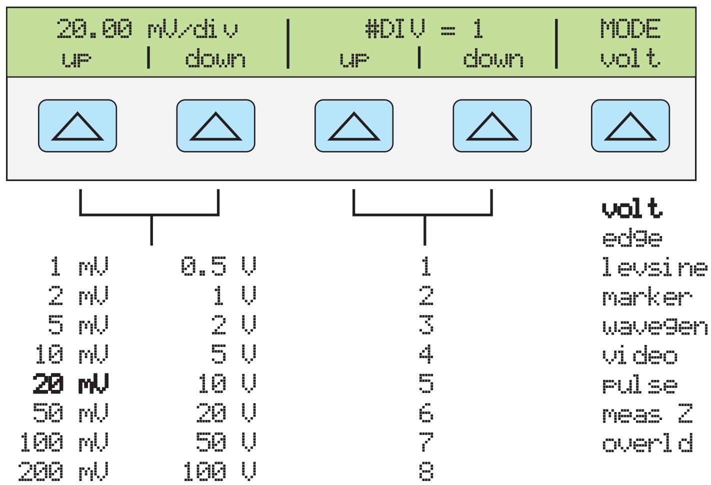
You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the SCOPE menu.

Each menu item is given below:

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **DC <-> AC** Toggles between a dc or ac signal. Push the softkey from the ac signal, to get the dc equivalent output.
- **1 MΩ** Toggles the output impedance setting of the Calibrator between 1 MΩ and 50 Ω.
- **TRIG** If you use a square wave to calibrate the external trigger, use this key to toggle the trigger off and on. When on, the reading will show "/1", which indicated that the external trigger is at the same frequency as the volt output. The external trigger can be useful for many oscilloscopes that have difficulty triggering on low amplitude signals. You can also toggle the trigger off and on. Push TRIG OUT.
- **V/DIV MENU** Opens the voltage scaling menu, which lets you select the scale of the signal in volts per division. This menu is given below in detail, under "The V/DIV Menu."
- **MODE** Shows you are in Volt mode. Use the softkey to change modes and open the corresponding menus for the other four oscilloscope calibration modes

The V/DIV Menu

The V/DIV menu, shown below, sets the number of volts denoted by each division on the oscilloscope. This menu gives alternative methods for changing the output amplitude that can be more convenient for certain oscilloscope applications. To access the V/DIV menu, push V/DIV from the Volt menu.



gjh053.eps

Each item in the V/DIV menu is given below.

- **V/div** Changes the scale of the output display by changing the number of volts that are represented by each division. The available settings, shown in the figure above, are provided in 1-2-5 step increments. Push the softkey below **UP** to increase the volts per division. Push the softkey below **DOWN** to decrease the volts per division.
- **# DIV** Specifies the number of divisions that establish the peak-to-peak value of the waveform. The value can be adjusted from one to eight divisions. The amount denoted by each division is shown in the V/div field. Push the softkey below UP to increase the signal's height, and push the softkey below DOWN to decrease it.

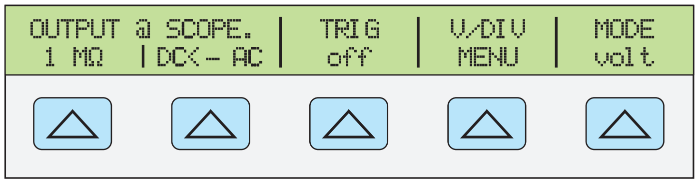
Shortcuts to Set the Voltage Amplitude

The [MULT ×] and [DIV ÷] keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the voltage is 40 mV, then push [MULT ×] to increase the voltage to the nearest cardinal point, which is 50 mV. Push [DIV ÷] to decrease the voltage to the nearest cardinal point, which is 20 mV.

Amplitude Calibration Procedure for an Oscilloscope

This example procedure tells you how to use the Volt menu to calibrate the oscilloscope's amplitude gain. During calibration, you will need to set different voltages and verify that the gain matches the graticule lines on the oscilloscope according to the specifications for your particular oscilloscope. See your oscilloscope manual for the recommended calibration settings and appropriate gain values.

Before you start this procedure, verify that you are running the oscilloscope option in Volt mode. If you are, the Control Display shows the subsequent menu.

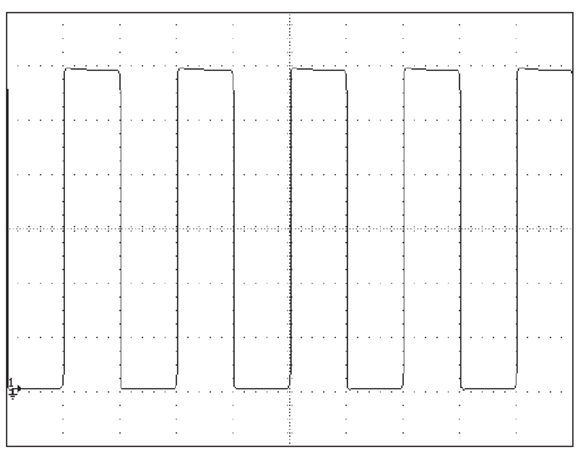


gjh054.eps

Do the subsequent sample procedure to calibrate the vertical gain.

1. Connect the Calibrator to Channel 1 on the oscilloscope, making sure the oscilloscope is terminated at the proper impedance (1 MΩ for this example). Verify that the OPR key on the 5502A is illuminated, indicating that the signal is connected.
2. Key in the voltage level that is recommended for your oscilloscope. For example to record 30 mV, push 3 0 µ m dBm V, then push ENTER. See "Keying in a Value" earlier in this chapter.
3. Adjust the oscilloscope as necessary. The waveform should be similar to the one shown below, with the gain at exactly the amount specified for the calibration settings for your oscilloscope.

   This example shows the gain at 30 mV to be 6 divisions, at 5 mV per division.



gl006i.bmp

4. Change the voltage to the next value recommended for calibrating your oscilloscope model, and repeat this procedure at the new voltage level, verifying the gain is correct according to the specifications in your manual.
5. Repeat the procedure for each channel.

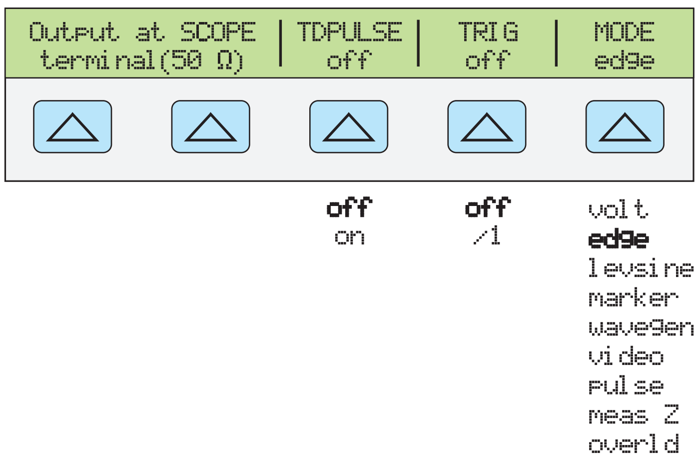
Calibrate the Pulse and Frequency Response on an Oscilloscope

The pulse response is calibrated with a square-wave signal that has a fast leading edge rise-time. With this signal, you adjust the oscilloscope as necessary until it meets its particular specifications for rise time and pulse aberrations.

Subsequent pulse verification, the frequency response is examined by applying a leveled sine wave and acquiring a frequency reading at the -3 dB point, when the amplitude drops approximately 30 %.

The Edge Function

The Edge function is used for calibrating the pulse response for your oscilloscope. To reach the Edge menu, push the softkey below MODE until "edge" shows.



gjh055.eps

You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the SCOPE menu.

Each option in the Edge menus is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.

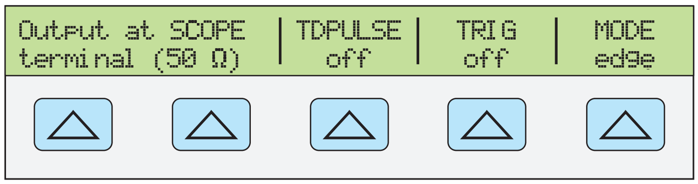
  You cannot change the output impedance in Edge mode.

- **TD PULSE** Push once to turn the Tunnel Diode Pulser drive signal on, again to turn the Pulser drive off. This signal sources up to 100 V p-p to drive a Tunnel Diode Pulser (Fluke Part Number 606522, Tektronix 067-0681-01, or equivalent.
- **TRIG** If you use the external trigger, use this key to toggle the trigger off and on. When on, the reading will show "/1" which shows that the external trigger is at the same frequency as the edge output. The external trigger can be useful for many digital storage oscilloscopes that have difficulty triggering on fast rise time signals. You can also toggle the trigger off and on by pushing the TRIG OUT key.
- **MODE** Shows you are in Edge mode. Use the softkey to change modes and open the corresponding menus for the other four oscilloscope calibration modes.

Pulse Response Calibration Procedure for an Oscilloscope

This sample procedure shows how to examine the oscilloscope's pulse response. Before you examine your oscilloscope, see your oscilloscope's manual for the recommended calibration settings.

Before you start this procedure, verify that you are running the oscilloscope option in Edge mode. If you are, the Control Display shows the subsequent menu.



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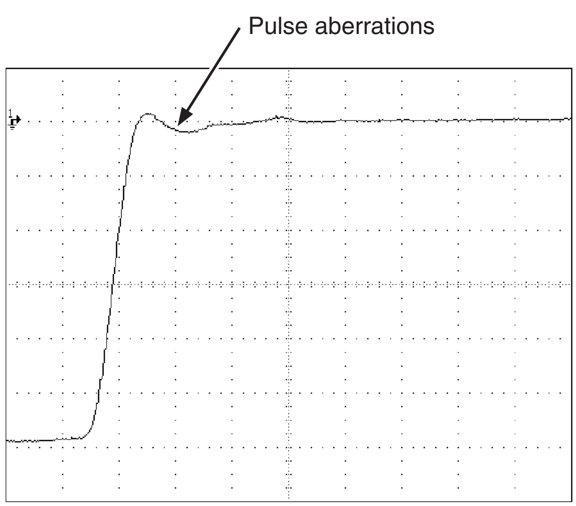
Do the subsequent sample procedure to calibrate the pulse response.

1. Connect the 5502A to Channel 1 on the oscilloscope. Select 50Ω impedance or use a 50Ω termination directly at the oscilloscope input. Verify that the OPR key is illuminated, indicating that the signal is connected.
2. Alter the voltage setting for the signal so it matches the amplitude value recommended by your oscilloscope manufacturer for calibrating the edge response. The default setting is 25 mV @ 1 MHz.

   For example, on a Fluke PM3392A oscilloscope, start with a signal of 1 V @ 1 MHz.
3. Adjust the scale on your oscilloscope to achieve a good picture of the edge. For example, on a Fluke PM3392A oscilloscope with a 1 V @ 1 MHz signal, use 200 mV/div.
4. Adjust the time base on your oscilloscope to the fastest position available (20.0 or 50.0 ns/div).



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5. Verify that your oscilloscope exhibits the proper rise time and pulse aberration qualities.
6. Push STBY to remove the input signal.

Pulse Response Calibration with a Tunnel Diode Pulser

You can use the Calibrator to drive a tunnel diode pulser. This lets you see pulse edge rise times as fast as 125 ps.

The Calibrator sources a maximum pulser drive signal of 100 V p-p at 100 kHz. The recommended (and default) output setting is 80 V p-p at 100 kHz.

Do the subsequent procedure to use a tunnel diode pulser:

1. Connect the Calibrator, tunnel diode pulser, and oscilloscope as shown in Figure 9-2.
2. With the SC600 Option in EDGE mode, push the TDPULSE softkey to “on”.
3. Push OPR.
4. Rotate the control on the pulser box to the minimum setting necessary to trigger a reading.

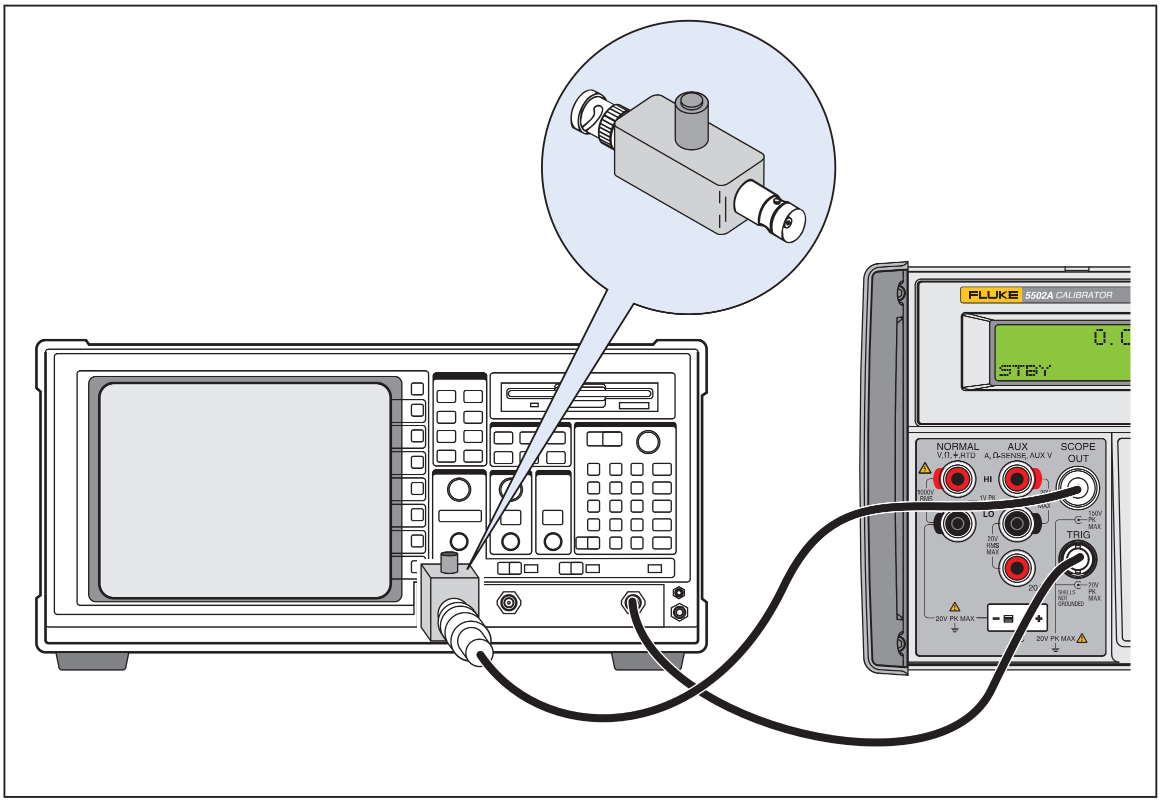

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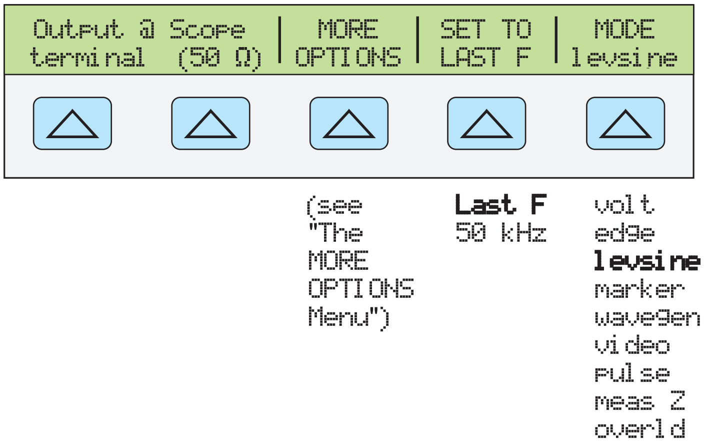
Figure 9-2. Tunnel Diode Pulser Connections

The Leveled Sine Wave Function

The Leveled Sine Wave (Levsine) function uses a leveled sine wave, whose amplitude remains relatively constant over a range of frequencies, to examine the bandwidth of the oscilloscope. When you examine your oscilloscope, you change the wave’s frequency until the amplitude shown on the oscilloscope drops 30 %, which is the amplitude that corresponds to the -3 dB point.

To access the Levsine menu, push the softkey below MODE until “levsine” shows.



gjh056.eps

You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the SCOPE menu.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY. You cannot change the impedance while you are in Levsine mode.
- **MORE OPTIONS** Opens more menu items, which are given in “The MORE OPTIONS Menu” section.
- **SET TO LAST F** Toggles between the current frequency setting and the reference value of 50 kHz. This option is useful for reverting to the reference to examine the output after you make adjustments at a different frequency.
- **MODE** Shows you are in Levsine mode. Use the softkey to change modes and open the related menus for the other four calibration modes.

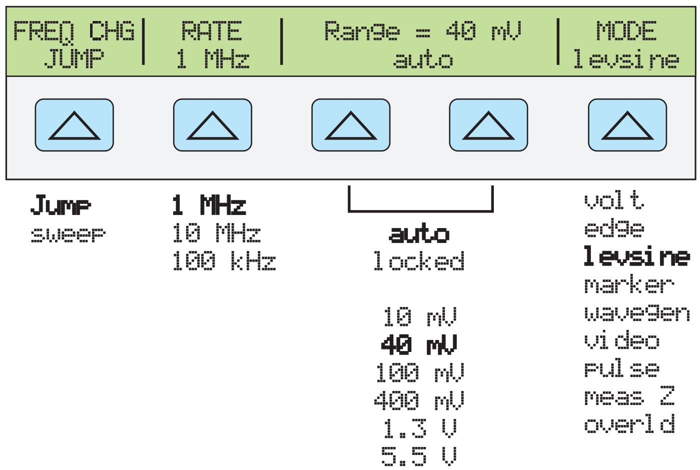
Shortcuts to Set the Frequency and Voltage

Three options are available to control the sine wave settings.

- **SET TO LAST F** toggles between the last frequency used and the reference frequency of 50 kHz, this lets you examine the output at the reference after you make adjustments at a different frequency.
- **MORE OPTIONS** lets you use an automatic frequency sweep and lock the voltage range, if necessary. The subsequent section gives more information on this menu.
- The MULT X and DIV ÷ keys step frequencies up or down in amounts that let you quickly access a new set of frequencies. For example, if the value is 250 kHz, MULT X changes it to 300 kHz, and DIV ÷ changes it to 200 kHz. For voltage values, MULT X and DIV ÷ step through cardinal point values in a 1.2-3-6 sequence.

The MORE OPTIONS Menu

When you select MORE OPTIONS, you open options that give you more control of the frequency and voltage. To access the MORE OPTIONS menu, push the softkey below MORE OPTIONS in the Levsine menu.



gjh057.eps

Each option in the MORE OPTIONS menu is given below.

- **FREQ CHANGE** Toggles between two settings that control how the output signal adjusts to a new frequency. This is the default setting.

  "Jump" causes the output signal to jump immediately to a new frequency setting. "Sweep" causes the signal to sweep through a series of frequency values, over a range you set. Use the sweep function to see the signal gradually change over a given bandwidth and see the point at which its amplitude changes. Sweep function instructions are given in the "Sweep Through a Frequency Range" section.

- **RATE** Used when FREQ CHANGE is set to "sweep" to select a sweep speed of 100 kHz, 1 MHz, or 10 MHz.

  A slower sweep rate lets you see the frequency change very slowly. After a faster sweep, you can pinpoint a specified frequency with a slower sweep over a subset of your previous frequency range.

- **Range** The softkeys toggle between two settings. The first setting ("auto") changes the range limit automatically in accordance with the voltage level. The second setting ("locked") freezes the current range limit. Subsequent changes in voltage level are then measured with this range limit.

  There are six range limits in levsine mode: 10 mV, 40 mV, 100 mV, 400 mV, 1.3 V, and 5.5 V. When set to "auto" the Calibrator uses your voltage setting to automatically set the range limit that gives the most accurate output. When set to "locked" the range limit stays set and you can decrease the voltage down to the bottom of the range.

  For example, if the range limit is 40 mV and you record 5 mV with "auto" selected, the Calibrator automatically changes the range limit to 10 mV and output 5 mV from the 10 mV range. If you start with the 40 mV range "locked" and then record 5 mV, the Calibrator outputs 5 mV from the 40 mV range.

The default range setting is “auto” which must always be used unless you are troubleshooting discontinuities in your oscilloscope’s vertical gain. The range setting will go to “auto” after you are out of levsine mode.

- **MODE** Shows that you are in levsine mode. Use the softkey to change modes and open the related menus for the other four calibration modes.

Sweep Through a Frequency Range

When you change frequencies with the sweep method, the output sine wave sweeps through a specified range of frequencies. This feature lets you identify the frequency at which the oscilloscope’s signal shows special behavior. You can quickly see the frequency response of the oscilloscope. Before you start this procedure, make sure you are in the MORE OPTIONS menu and the sine wave is shown on the oscilloscope.

Do the subsequent procedure to sweep through frequencies:

1. Make sure the output signal shows the frequency you will start with. If not, key in that frequency and push ENTER.
2. Toggle FREQ CHANGE to “sweep.” Toggle the RATE to “100 kHz” if you want to observe a very slow sweep over a small range.
3. Key in the end frequency; then push ENTER. After you push ENTER, the signal sweeps through frequencies between the two values you recorded, and the Sweep menu shows on the Control Display as shown below.
4. You can let the signal sweep through the full range, or you can stop the sweep if necessary to record the frequency at a specified point.

   To interrupt the sweep, push the softkey below HALT SWEEP. The current frequency will show on the Output Display and the MORE OPTIONS menu will show again on the Control Display.

Note

When you push HALT SWEEP and interrupt the frequency sweep, the FREQ CHANGE method changes to “jump.”

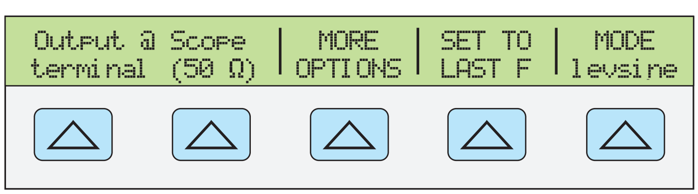
5. Do the procedure again if necessary. For example, if you did a fast sweep, you can pinpoint a specified frequency with a slow sweep over a subset of your previous frequency range.

Frequency Response Calibration Procedure for an Oscilloscope

This sample procedure, which verifies the frequency response on your oscilloscope, is usually done after the pulse response is verified.

This procedure examines the bandwidth by finding the frequency at the -3 dB point for your oscilloscope. The reference sine wave in this procedure has an amplitude of 6 divisions, so that the -3 dB point can be found when the amplitude drops to 4.2 divisions.

Before you start this example procedure, verify that you are have the oscilloscope option in Levsine mode. If you are, the Control Display shows the subsequent menu, see below.

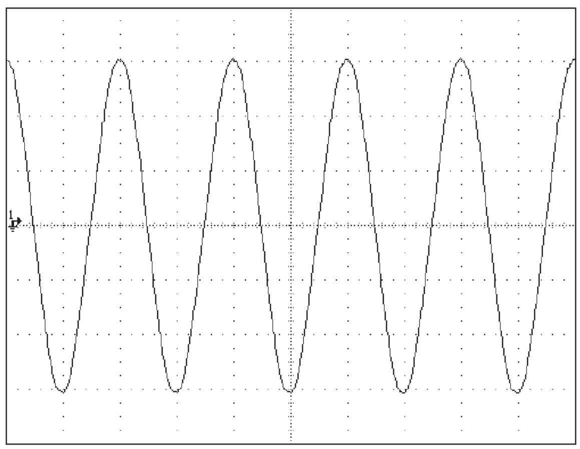


gjh058.eps

Do the subsequent sample procedure to calibrate the frequency response.

1. Push the OPR key on the 5502A to reconnect the signal. Select 50 Ω impedance or use a 50 Ω external termination directly at the oscilloscope input.
2. Adjust the sine wave settings in the Output Display. Refer to the calibration recommendations in your oscilloscope manual. For example, for the HP 54522C oscilloscope, start at 600 mV @ 1 MHz. To record 600 mV, push 6 0 0 m V; then push ENTER.
3. Adjust the oscilloscope as necessary. The sine wave must show at six divisions, peak-to-peak, as shown below.

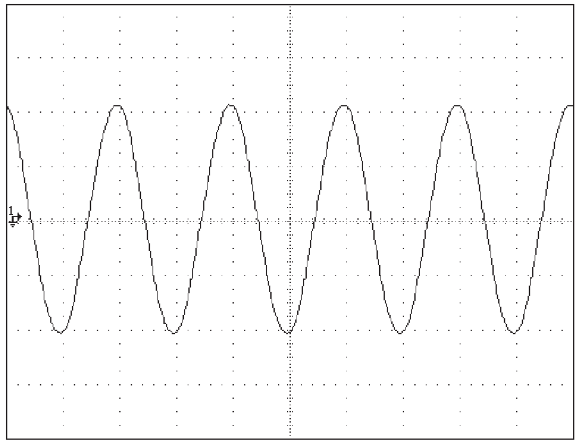
   If necessary, make small adjustments to the voltage amplitude until the wave gets to six divisions. To fine-tune the voltage, push EDIT FIELD to bring a cursor into the Output Display, move the cursor with the ◀ key, and turn the rotary knob to adjust the value.



gl009i.bmp

4. Increase the frequency to 400 MHz (for 500 MHz instruments), or 500 MHz (for 600 MHz instruments). To record 400 MHz, push 4 0 0 M Hz then push ENTER.
5. Continue to increase the frequency slowly until the waveform decreases to 4.2 divisions, as shown below.

   To increase the frequency slowly, fine-tune it with the rotary knob. To do this, push EDIT FIELD to place a cursor in the Output Display, push EDIT FIELD again to place it in the frequency field, and use the ◀ and ▶ keys to move it to the digit you want to change. Then turn the rotary knob to change the value. Continue with small increments in the frequency until the signal drops to 4.2 divisions. At 4.2 divisions, the signal is at the frequency that agrees to the -3 dB point, see below.



gl010i.bmp

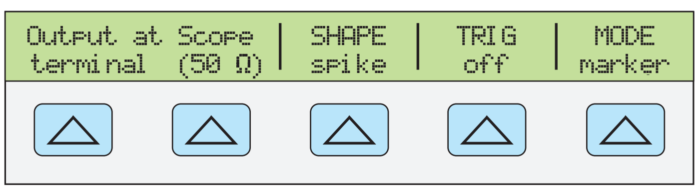
6. Push STBY to remove the input signal.
7. Do this procedure again for the remaining channels on your oscilloscope.

Calibrate the Time Base of an Oscilloscope

The horizontal deflection (time base) of an oscilloscope is calibrated with a method equivalent to the vertical gain calibration. A time marker signal is made from the Calibrator and the signal's peaks are aligned to the graticule line divisions on the oscilloscope.

The Time Marker Function

The Time MARKER function, which is available through the MARKER menu, lets you calibrate the timing response of your oscilloscope. To access the MARKER menu, push the softkey below MODE until "marker" shows.



gjh060.eps

You can push the MODE softkey to move through the functions as shown, or you can push PREV MENU to go directly to the SCOPE menu.

Each option in the Marker menu is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **SHAPE** Shows the type of waveform. With reference to the frequency setting, possible selections are sine, spike, square (50 % duty cycle square wave), and sq20% (20 % duty cycle square wave.) Note that selections available under SHAPE refer ton the selected marker period (frequency) as follows:

Selection	Period (Frequency)
Sine	10 ns – 2 ns (100 MHz – 500 MHz)
Spike	5 s – 20 ns (0.2 Hz – 50 MHz)
Square	5 s – 10 ns (0.2 Hz – 100 MHz)
Sq20%	20 ms – 100 ns (50 kHz – 10 MHz)

- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows on each 100 markers). You can also toggle the trigger off and on. Push the TRIG OUT key.
- **MODE** Shows you are in Marker mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

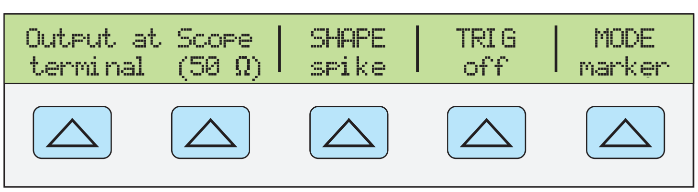
Default marker values are 1.000 ms, SHAPE = spike.

The MULT X and DIV ÷ keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the period is 1.000 ms, push MULT X to increase the period to the nearest cardinal point, which is 2.000 ms. Push DIV ÷ to decrease the voltage to the nearest cardinal point, which is 500 μs.

Time Base Marker Calibration Procedure for an Oscilloscope

This sample procedure uses the Time Marker function to examine the horizontal deflection (time base) of your oscilloscope. See the manual for your oscilloscope for the time base values recommended for calibration.

Before you start this procedure, verify that you are in Marker mode. If you are, the Control Display shows the subsequent menu, see below.



gjh060.eps

Do the subsequent sample procedure to calibrate the time base.

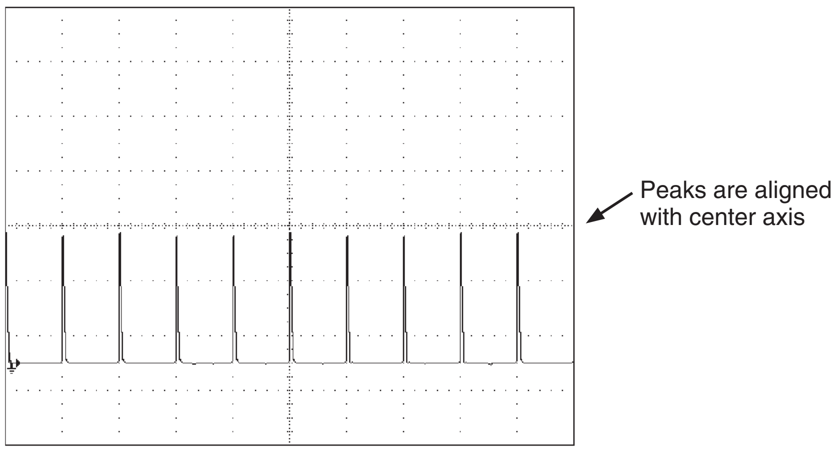
1. Connect the Calibrator to Channel 1 on the oscilloscope. Select 50 Ω impedance or use an external 50 Ω termination. Make sure the oscilloscope is dc-coupled.
2. Apply a time marker value. Refer to the recommended calibration settings in your oscilloscope manual. For example, to record 200 ns, push 2 0 0 SHIFT n k SHIFT sec Hz, then push ENTER.

Note

You can record the equivalent frequency as an alternative to the time marker value. For example, you can record 5 MHz for 200 ns.

3. Set the time base of your oscilloscope to show 10 time markers. The time markers must align with the oscilloscope divisions, as shown in the example below.

   For an accurate indication, align the peaks of the signal with the horizontal center axis.



gl011i.eps

4. Do this procedure again for all time marker values recommended for your oscilloscope. Do this procedure again for digital and analog mode as necessary. It can be necessary, for some oscilloscopes, to change the magnification while you calibrate in analog mode.
5. Push STBY to remove the input signal.

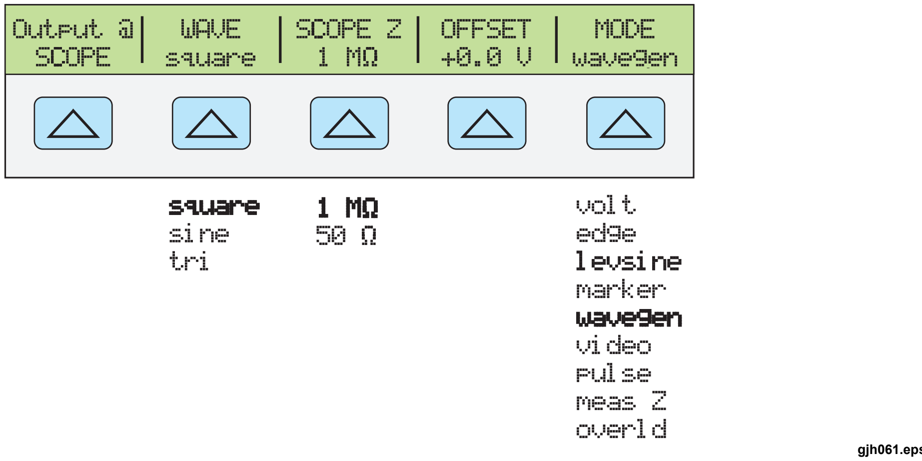
Test the Trigger SC600 Option

The oscilloscope can trigger on different waveforms. This can be tested with the wave generator. When the wave generator is used, a square, sine, or triangle wave is transmitted and the wave output impedance, offset, and voltage can be changed to test the trigger function at different levels.

Note

The wave generator must not be used to verify the accuracy of your oscilloscope.

The wave generator is available through the Wavegen menu, shown below. To access this menu, push the softkey below MODE until “wavegen” shows, see below.



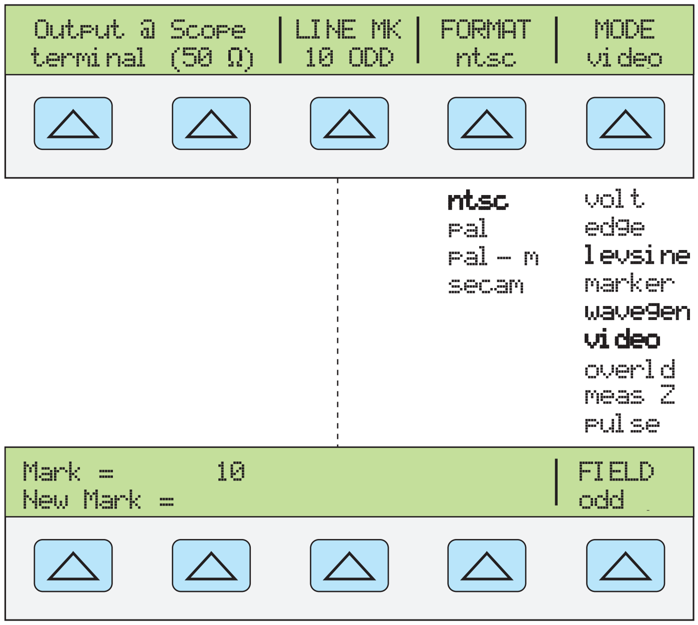
You can push the MODE softkey to go through the functions in the sequence shown, or you can push PREV MENU to return directly to the OTHER modes menu.

Each option in the Wavegen menu is given below.

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **WAVE** Scrolls through the three types of waveforms that are available. You can select a square, sine, or triangle wave as the output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 50 Ω and 1 MΩ.
- **OFFSET** Shows the offset of the given wave. To change the offset, record the new value, and push ENTER. The rotary knob does not change the offset. The rotary knob changes the voltage output.

  When you change the offset, you must stay in specified limits to prevent clipping the peaks. The limit comes from the peak-to-peak value of the wave. The maximum peak excursion is equal to the offset plus half of the wave’s peak-to-peak value. See “Wave Generator Specifications” at the start of this chapter.
- **MODE** Shows you are in Wavegen mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

Test Video Triggers



gjh062.eps

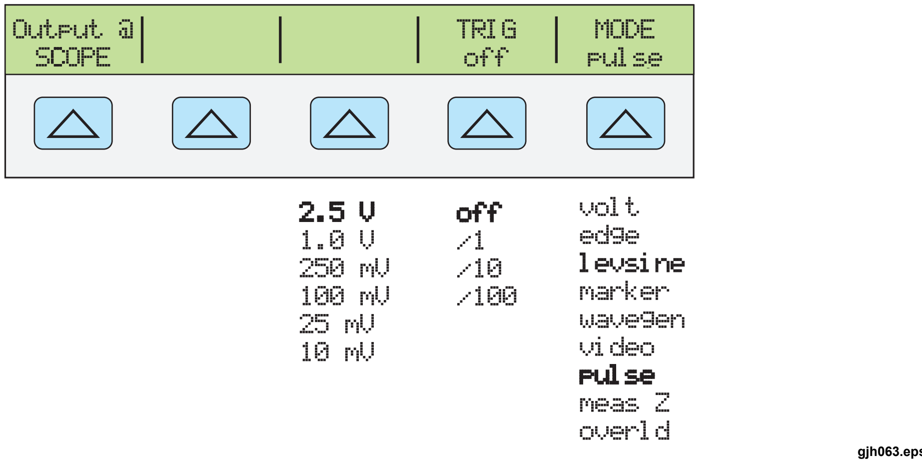
You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the OTHER modes menu.

Each option in the Video menu is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **LINE MK** Lets you to select the marker line number. For ntsc and pal-m formats, you can also select field ("odd" or "even"). For pal and secam formats, the field ("ODD" or "EVEN") is selected automatically in reference to the marker line number.
- **FORMAT** Scrolls through the available formats. You can select ntsc, pal, pal-m, and secam.
- **MODE** Shows you are in VIDEO mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

Default video settings are +100 %, format = NTSC, and videomark = 10.

Verify Pulse Capture



You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the OTHER modes menu.

Each option in the PULSE menu is given below.

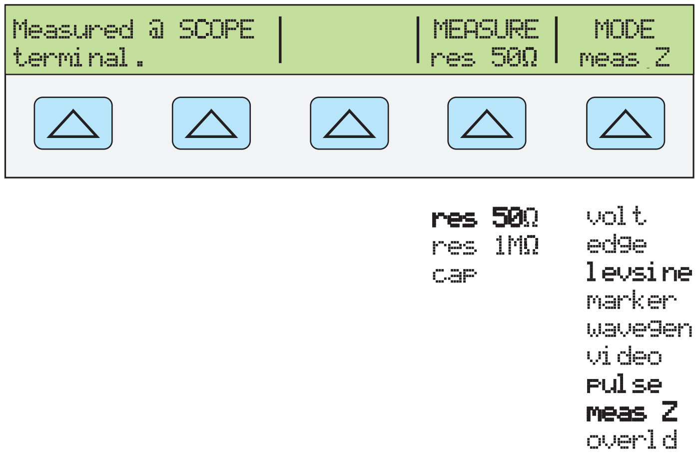
- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **AMPL** Shows the output level. You can select 2.5 V, 1.0 V, 250 mV, 100 mV, 25 mV, or 10 mV.
- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows on each 100 markers). You can also toggle the trigger off and on. Push TRIG OUT.
- **MODE** Shows you are in PULSE mode. Use the softkey to change modes and open the menus for the other oscilloscope calibration modes.

Default Pulse settings are 100.0 ns width and 1.000 ms period. To change these values, you have some options. Usually, you will record values for pulse width and period. To do this, record the pulse width value with units first, followed immediately by the period value and units, followed by ENTER. For example, you could record a pulse width of 50 ns and a period of 200 ns with the subsequent sequence:

5 0 SHIFT n k SHIFT sec Hz 2 0 0 SHIFT n k SHIFT sec Hz ENTER.

To change only the pulse width, record a value in seconds. You can record this value with units (for example, 200 ns) or without units (for example, 0.0000002). To change only the period, record a frequency with units (for example, 20 MHz, this changes the period to 50 ns).

Measure Input Resistance and Capacitance



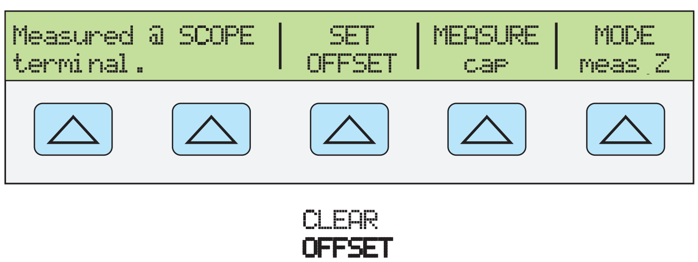
gjh064.eps

You can push the MODE softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the OTHER modes menu.

Each option in the Impedance/Capacitance (MEAS Z) menu is given below.

- **Measured @ SCOPE terminal** Shows the location of the measured input.
- **MEASURE** Shows the type of test. You can select res 50 Ω or res 1 MΩ termination (for impedance) or cap (capacitance).
- **MODE** Shows the Calibrator is in MEAS Z mode. Use the softkey to change modes and open the menus for the other oscilloscope calibration modes.

If you have selected Capacitance measurement, the menu shows as follow:



gjh065.eps

- **SET OFFSET** With the cable disconnected at the oscilloscope but still connected at the Calibrator, push **SET OFFSET** to cancel the capacitance of the Calibrator and cable. Push again (**CLEAR OFFSET**) to cancel the offset.

Input Impedance Measurement

With MEAS Z mode selected, do the subsequent procedure to measure the input impedance of an oscilloscope:

1. Use the MEASURE softkey to select "res 50Ω" or "res 1 MΩ" termination.
2. Connect the SCOPE terminal on the Calibrator to Channel 1 on the oscilloscope.
3. Push OPR to initiate the measurement.

Input Capacitance Measurement

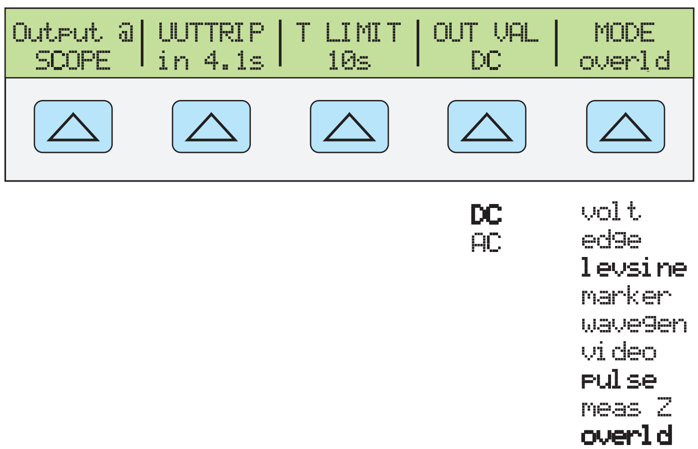
With MEAS Z mode selected, do the subsequent procedure to measure the input capacitance of an oscilloscope:

1. Set the oscilloscope for 1 MΩ input impedance. Note that input capacitance tests cannot be done with 50 Ω input impedance.
2. Use the MEASURE softkey to select “cap”.
3. With the output cable connected to the Calibrator but not connected to the oscilloscope, push the SET OFFSET softkey to cancel stray capacitances.
4. Connect the output cable to Channel 1 on the oscilloscope.
5. Push OPR to initiate the measurement.

Test Overload Protection

⚠ Caution

This test examines the power handling capability of the 50 Ω input of your oscilloscope. Before proceeding, ensure that the power rating of your oscilloscope can handle the voltages and currents that this test can output. Failing to do so could damage your oscilloscope.



gjh066.eps

You can push the **MODE** softkey to move through the functions in the sequence shown, or you can push PREV MENU to return directly to the OTHER modes menu.

Each option in the OVERLD menu is given below.

- **OUTPUT @ SCOPE** Shows the location of the signal output.
- **UUTTRIP** Shows test results. “NO” shows if the overload protection did not trip during the selected time limit. A value in seconds shows (for example, “4.1s”) if the overload protection has tripped during the time limit.
- **T LIMIT** Shows the selected time limit to apply the output value. Push this softkey to key in or edit a different time limit (1s to 60s.)
- **OUT VAL** Shows the output voltage type. You can select DC or AC and a value ranging from 5 V to 9 V (shown in Output Display). Key in or edit this value.
- **MODE** Shows you are in OVERLD (Overload) mode. Use the softkey to change modes and open menus for other oscilloscope calibration modes.

Default overload settings are +5.000 V and DC.

You can also set the overload time limit with SETUP, **INSTMT SETUP** softkey, **OTHER SETUP** softkey, **TLIMDEF** softkey, then choose 1s to 60s.

Do the subsequent procedure to verify the overload protection of an oscilloscope:

1. Connect the Calibrator to Channel 1 on the oscilloscope.
2. Select the voltage type (DC or AC) with the OUT VAL softkey.
3. Key in the voltage level. (The default value is 5 V.)
4. If necessary, change the time. (Refer to the procedure given above.) The default time is 10s.
5. Look for test results shown with the UUTTRIP softkey.

Remote Commands and Queries

This section tells you commands and queries that are exclusive to the SC600 Option. Each command description shows if it can be used with IEEE-488 and RS-232 remote interfaces and identifies it as a Sequential, Overlapped, or Coupled command.

IEEE-488 (GPIB) and RS-232 Applicability Each command and query has a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations.

Sequential Commands Commands done immediately as they are found in the data stream are referred to as sequential commands. For more information, see "Sequential Commands" in Chapter 5.

Overlapped Commands Commands `SCOPE`, `TRIG`, and `OUT_IMP` are designated as overlapped commands because they can be overlapped (interrupted) by the subsequent command before they have completed execution. When an overlapped command is interrupted, it can take longer to do while it stops for other commands to be completed. To prevent an overlapped command interruption during execution, use `*OPC`, `*OPC?`, or `*WAI`, which prevent interruptions until they sense command completion. For more information, see "Overlapped Commands" in Chapter 5.

Coupled Commands `SCOPE` and `OUT_IMP` are coupled commands because they can be coupled (combined) with other commands to make a compound command sequence. Precautions are necessary to make sure that commands are not coupled so that they disable each other, since a fault can be the result. For more information, see "Coupled Commands" in Chapter 5.

General Commands

Table 9-1 is a list of Scope command parameters.

Table 9-1. SCOPE Command Parameters

Parameter	Description/Example
OFF	Turns the oscilloscope hardware off. Programs 0 V, 0 Hz, output at the NORMAL terminals, standby.
VOLT	Oscilloscope ac and dc VOLT mode. Programs 20 mV peak-to-peak, 1 kHz, output at the SCOPE BNC, output impedance 1 MΩ, standby if from OFF or if in standby. FUNC? Shows SACV (for ac) or SDCV (for dc).
	Example: SCOPE VOLT; OUT 4 V, 1 kHz (ac voltage, 4 V peak-to-peak, 1 kHz.)

Table 9-1. SCOPE Command Parameters (cont.)

Parameter	Description/Example	
EDGE	Oscilloscope EDGE mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows EDGE.	
	Example:	SCOPE EDGE; OUT 0.5 V, 5 kHz (Edge, 0.5 V peak-to-peak, 5 kHz.)
LEVSINE	loscope LEVSINE mode. Programs 30 mV peak-to-peak, 50 kHz, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows LEVSINE.	
	Example:	SCOPE LEVSINE; OUT 1 V, 50 kHz (Leveled sine wave, 1 V peak-to-peak, 50 kHz.)
MARKER	Oscilloscope MARKER mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows MARKER.	
	Example:	SCOPE MARKER; OUT 2 MS (Marker, period of 2 ms.)
WAVEGEN	Oscilloscope WAVEGEN mode. Programs 20 mV peak-to-peak, square wave, 1 kHz, no offset, output impedance 1 MΩ, standby if from OFF or previously in standby. FUNC? shows WAVEGEN.	
	Example:	SCOPE WAVEGEN; OUT 1 V, 1 kHz (Wave Generator, 1 V peak-to-peak, 1 kHz.)
VIDEO	Oscilloscope VIDEO mode. Programs 100% output (1 V p-p), line marker 10, format NTSC. FUNC? shows VIDEO.	
	Examples:	SCOPE VIDEO; OUT 90 (Video, 90% output) SCOPE VIDEO; OUT -70 (Video, -70% output, inverse video)
PULSE	Oscilloscope PULSE mode. Programs 100 ns pulse width, 1.000 µs period, 2.5 V range. FUNC? shows PULSE.	
	Example:	SCOPE PULSE; OUT 50 ns, 500 ns; RANGE TP8DB (Pulse, 50 ns pulse width, 500 ns period, 1.5 V range)
MEASZ	Oscilloscope Impedance/Capacitance measurement (MEAS Z) mode. Programs 50Ω range. FUNC? shows MEASZ.	
	Example:	SCOPE MEASZ; RANGE TZCAP (MEAS Z mode, capacitance range)
OVERLD	Oscilloscope Overload mode. Programs 5 V dc range. FUNC? shows OVERLD.	
	Example:	SCOPE OVERLD; OUT 7 V; RANGE TOLAC (Overload, 7 V output, ac range)

SCOPE

(IEEE-488, RS-232, Sequential)

Programs the SC600 oscilloscope calibration option hardware, if installed. The instrument settings are determined by this command's parameter. Once in SCOPE mode, use the OUT command to program new output.

OPER, STBY, *OPC, *OPC?, and *WAI all operate as given in Chapter 6. The state of the oscilloscope's output while in SCOPE mode is reflected by the bit in the ISR that is assigned to SETTLED.

The FUNC? query shows SDCV, SACV, LEVSINE, MARKER, EDGE, and WAVEGEN for the corresponding oscilloscope modes.

Parameters:	`OFF`	Turns the oscilloscope hardware off. Programs 0V,0 Hz, output at the NORMAL terminals, standby.
	`VOLT`	AC and dc voltage mode of the oscilloscope. Programs 20 mV peak-to-peak, 1 kHz, output at the SCOPE BNC, output impedance 1 MΩ, standby if from OFF or previously in standby.
	`EDGE`	Oscilloscope Edge mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from OFF or previously in standby.
	`LEVSINE`	Oscilloscope-leveled sine mode. Programs 30 mV peak-to-peak, 50 kHz, output at the SCOPE BNC, standby if from OFF or previously in standby.
	`MARKER`	Oscilloscope Marker mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from OFF or previously in standby.
	`WAVEGEN`	Oscilloscope Wavegen mode. Programs 20 mV peak-to-peak, square wave, 1 kHz, no offset, output impedance 1 MΩ, standby if from OFF or previously in standby.
	`VIDEO`	Oscilloscope video trigger mode. Programs 100 % output; ntsc format, mark line 10, odd field.
	`PULSE`	Oscilloscope pulse mode. Programs 100 nanosecond width pulses every 1 microsecond.
	`MEASZ`	Oscilloscope impedance measurement mode.
	`OVERLD`	Oscilloscope overload test mode. Programs a 5 V dc output with a 10 second time limit.

Example:	`SCOPE VOLT;`	`OUT -2V, 0 Hz`	(dc voltage, -2 V)
	`SCOPE VOLT;`	`OUT 4V, 1 kHz`	(ac voltage, 4 V peak-to-peak, 1 kHz.)
	`SCOPE EDGE;`	`OUT 0.5V, 5 kHz`	(Edge, 0.5 V peak to peak, 5 kHz.)
	`SCOPE LEVSINE;`	`OUT 1V, 20 kHz`	(Leveled sine wave, 2 V peak-to-peak, 20 kHz.)
	`SCOPE MARKER;`	`OUT 2 MS`	(Marker, period of 2 ms.)

`SCOPE WAVEGEN; OUT 1V, 1 kHz`	(Wave Generator, 1 V peak-to-peak, 1 kHz.)
`SCOPE VIDEO; OUT 100PCT`	(Video trigger; 100% amplitude)
`SCOPE PULSE; OUT 100NS,1US`	(Pulse output, 100ns width pulses every 1 microsecond)
`SCOPE MEASZ`	(Impedance measurement mode)
`SCOPE OVERLD; OUT 5V`	(Overload test mode; output 5V)

SCOPE?

(IEEE-488, RS-232, Sequential)

Shows the oscilloscope's current mode of operation. Shows `OFF` if the oscilloscope is off.

Parameters: None

Response: <character> (Shows `OFF`, `VOLT`, `EDGE`, `LEVSINE`, `MARKER`, `WAVEGEN`, `VIDEO`, `PULSE`, `MEASZ`, `or OVERLD`)

TRIG

(IEEE-488, RS-232, Sequential)

Programs the oscilloscope's trigger output BNC.

Parameters:

`OFF`	(Turns the trigger output off.)
`DIV1`	(Turns the trigger output on. Frequency is the same as the signal at SCOPE output.)
`DIV10`	(Turns the trigger output on. Frequency is 1/10 of the signal at SCOPE output.)
`DIV100`	(Turns the trigger output on. Frequency is 1/100 of the signal at SCOPE output.)

TRIG?

(IEEE-488, RS-232, Sequential)

Shows the output setting of the oscilloscope's trigger.

Parameters: (None)

Response: <character> (Shows `OFF`, `DIV1`, `DIV10`, or `DIV100`.)

OUT_IMP

(IEEE-488, RS-232, Sequential)

Programs the oscilloscope's output impedance.

Parameters:

`Z50`	(Programs the oscilloscope output impedance to 50 Ω.)
`Z1M`	(Programs the oscilloscope output impedance to 1 MΩ.)

OUT_IMP?

(IEEE-488, RS-232, Sequential)

Shows the impedance setting of the oscilloscope's output.

Parameters: (None)

RANGE

Programs the instrument range in PULSE, MEAS Z, and OVERLD modes.

Parameters:	`TP0DB`	Sets the range to 2.5 V in pulse mode.
	`TP8DB`	Sets the range to 1.0 V in pulse mode.
	`TP20DB`	Sets the range to 250 mV in pulse mode.
	`TP28DB`	Sets the range to 100 mV in pulse mode.
	`TZ50OHM`	Sets the impedance to 50 Ω in Meas Z mode.
	`TZ1MOHM`	Sets the impedance to 1 MΩ in Meas Z mode.
	`TZCAP`	Sets the impedance to cap in Meas Z mode.
	`TOLDC`	Sets the instrument to DC in Overload mode.
	`TOLAC`	Sets the impedance to AC in Overload mode.

Example: `RANGE TP20DB`

Edge Function Commands

TDPULSE

(IEEE-488, RS-232, Sequential)

Turns tunnel diode pulse drive on/off in EDGE mode.

Parameters: `ON` (or non-zero) or `OFF` (or zero)

Example: `TDPULSE ON`

Shows the tunnel diode pulse drive setting in EDGE mode.

Parameters: None

Response: 1 if ON, 0 if OFF.

Marker Function Commands

TMWAVE

(IEEE-488, RS-232, Sequential)

Selects the waveform for MARKER mode.

Parameters:	`SINE`	Sine wave (2 ns to 15 ns)
	`SPIKE`	Triangular/sawtooth pulse (15 ns to 5s)
	`SQUARE`	Square wave (50% duty cycle) (4 ns to 5s)
	`SQ20PCT`	Square wave (20% duty cycle) (85 ns to 5s)

Example: `TMWAVE SPIKE`

TMWAVE?

(IEEE-488, RS-232, Sequential)

Shows the MARKER mode waveform setting.

Parameters: None

Response: <character> (Shows `SINE`, `SPIKE`, `SQUARE`, or `SQ20PCT`.)

Video Function Commands

VIDEOFMT

(IEEE-488, RS-232, Sequential)

Selects the format for VIDEO mode.

Parameters: `NTSC`, `PAL`, `PALM` (for PAL-M), or `SECAM`

Example: `VIDEOFMT SECAM`

VIDEOFMT?

(IEEE-488, RS-232, Sequential)

Shows the VIDEO mode format.

Parameters: None

Response: `NTSC`, `PAL`, `PALM` (for PAL-M), or `SECAM`

VIDEOMARK

(IEEE-488, RS-232, Sequential)

Programs the VIDEO mode line marker location.

Parameters: Line marker number.

Example: `VIDEOMARK 10`

VIDEOMARK?

(IEEE-488, RS-232, Sequential)

Shows the VIDEO mode line marker setting.

Parameters: None.

Response: <character> `SINE`, `SPIKE`, `SQUARE` or `SQ20PCT`

Overload Function Commands

OL_TRIP?

(IEEE-488, RS-232, Sequential)

Shows the found state of scope overload protection.

Parameters: None

Response: Shows the number of seconds before protection was tripped. Shows 0 if protection has not tripped or if OVERLD mode not active.

TLIMIT

(IEEE-488, RS-232, Sequential)

Sets the OPERATE time limit for the OVERLD mode signal. The Calibrator automatically goes to STANDBY if the UUT protection trips during this interval or at the end of this interval if the protection has not tripped.

Parameters: 1 to 60 (seconds)

Example: `TLIMIT 30`

TLIMIT?

(IEEE-488, RS-232, Sequential)

Shows the programmed OPERATE time limit for the OVERLD mode signal.

Response: <Integer> Time limit in seconds.

TLIMIT_D

(IEEE-488, RS-232, Sequential)

Sets the default OPERATE time limit for the OVERLD mode signal.

Parameters: 1 to 60 (seconds)

Example: `TLIMIT_D 15`

TLIMIT_D?

(IEEE-488, RS-232, Sequential)

Shows the default overload time limit.

Response: <Integer> Default time limit in seconds.

Impedance/Capacitance Function Commands

ZERO_MEAS

(IEEE-488, RS-232, Sequential)

Sets the measurement offset to the capacitance value.

Parameters: (boolean) ON or OFF.

*TRG

(IEEE-488, RS-232, Sequential)

Triggers and shows a new impedance measurement value when used with the SC600 option in MEAS Z mode. (See Chapter 6 for *TRG use in all cases except MEAS Z mode with the SC600 option.)

Responses:	<measurement value>, OHM	(input impedance value in ohms)
	<measurement value>, F	(input capacitance value in farads)
	<measurement value>, NONE	(no measurement is available)

Example: `*TRG` shows `1.00E+03,OHM` (1 kΩ input impedance).

Note

*You can also use the VAL? query to show an impedance measurement value with the SC600 option. VAL? shows the last measurement, whereas *TRG gets a new measurement. Responses are the same as shown above for the *TRG command. (See Chapter 6 for VAL? use with thermocouple measurements.)*

Verification Tables

The verification test points are supplied here as a guide when verification to 1-year specifications is necessary.

Table 9-2. SC600 Option DC Voltage Verification

(1 MΩ output impedance unless noted)			
Nominal Value (V dc)	**Measured Value (V dc)**	**Deviation (V dc)**	**1-Year Spec. (V dc)**
0			0.00004
0.00125			0.000040625
-0.00125			0.000040625
0.00249			0.000041245
-0.00249			0.000041245
0.0025			0.00004125
-0.0025			0.00004125
0.00625			0.000043125
-0.00625			0.000043125
0.0099			0.00004495
-0.0099			0.00004495
0.01			0.000045
-0.01			0.000045
0.0175			0.00004875
-0.0175			0.00004875
0.0249			0.00005245
-0.0249			0.00005245
0.025			0.0000525
-0.025			0.0000525
0.0675			0.00007375
-0.0675			0.00007375
0.1099			0.00009495
-0.1099			0.00009495
0.11			0.000095
-0.11			0.000095
0.305			0.0001925
-0.305			0.0001925
0.499			0.0002895

Table 9-2. SC600 Option DC Voltage Verification (cont.)

(1 MΩ output impedance unless noted)			
Nominal Value (V dc)	**Measured Value (V dc)**	**Deviation (V dc)**	**1-Year Spec. (V dc)**
-0.499			0.0002895
0.5			0.00029
-0.5			0.00029
1.35			0.000715
-1.35			0.000715
2.19			0.001135
-2.19			0.001135
2.2			0.00114
-2.2			0.00114
6.6			0.00334
-6.6			0.00334
10.99			0.005535
-10.99			0.005535
11			0.00554
-11			0.00554
70.5			0.03529
-70.5			0.03529
130			0.06504
-130			0.06504
6.599 (50 Ω)			0.0165375

Table 9-3. SC600 Option AC Voltage Amplitude Verification

(1 MΩ output impedance unless noted)				
Nominal Value (V p-p)	**Frequency (Hz)**	**Measured Value (V p-p)**	**Deviation (V p-p)**	**1-year Spec. (V p-p)**
0.001	1000			0.000041
-0.001	1000			0.000041
0.01	1000			0.00005
-0.01	1000			0.00005
0.025	1000			0.000065
-0.025	1000			0.000065
0.11	1000			0.00015

Table 9-3. SC600 Option AC Voltage Amplitude Verification (cont.)

(1 MΩ output impedance unless noted)				
Nominal Value (V p-p)	**Frequency (Hz)**	**Measured Value (V p-p)**	**Deviation (V p-p)**	**1-year Spec. (V p-p)**
-0.11	1000			0.00015
0.5	1000			0.00054
-0.5	1000			0.00054
2.2	1000			0.00224
-2.2	1000			0.00224
11	1000			0.01104
-11	1000			0.01104
130	1000			0.13004
-130	1000			0.13004
6.599 (50 Ω)	1000			0.0165375

Table 9-4. AC Voltage Frequency Verification

(1 MΩ output impedance unless noted)				
Nominal Value (V p-p)	**Frequency (Hz)**	**Measured Value (Hz)**	**Deviation (Hz)**	**1-year Spec. (Hz)**
2.1	10			0.000025
2.1	100			0.00025
2.1	1000			0.0025
2.1	10000			0.025

Table 9-5. SC600 Option Wave Generator Amplitude Verification (1 MΩ output impedance)

Wave Shape	Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
square	0.0018	1000			0.000154
square	0.0119	1000			0.000457
square	0.0219	1000			0.000757
square	0.022	1000			0.00076
square	0.056	1000			0.00178
square	0.0899	1000			0.002797
square	0.09	1000			0.0028
square	0.155	1000			0.00475

Table 9-5. SC600 Option Wave Generator Amplitude Verification (1 MΩ output impedance) (cont.)

Wave Shape	Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
square	0.219	1000			0.00667
square	0.22	1000			0.0067
square	0.56	1000			0.0169
square	0.899	1000			0.02707
square	0.9	1000			0.0271
square	3.75	1000			0.1126
square	6.59	1000			0.1978
square	6.6	1000			0.1981
square	30.8	1000			0.9241
square	55	10			1.6501
square	55	100			1.6501
square	55	1000			1.6501
square	55	10000			1.6501
sine	0.0018	1000			0.000154
sine	0.0219	1000			0.000757
sine	0.0899	1000			0.002797
sine	0.219	1000			0.00667
sine	0.899	1000			0.02707
sine	6.59	1000			0.1978
sine	55	1000			1.6501
triangle	0.0018	1000			0.000154
triangle	0.0219	1000			0.000757
triangle	0.0899	1000			0.002797
triangle	0.219	1000			0.00667
triangle	0.899	1000			0.02707
triangle	6.59	1000			0.1978
triangle	55	1000			1.6501

Table 9-6. SC600 Option Wave Generator Amplitude Verification (50 Ω output impedance)

Wave Shape	Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
square	0.0018	1000			0.000154
square	0.0064	1000			0.000292
square	0.0109	1000			0.000427
square	0.011	1000			0.00043
square	0.028	1000			0.00094
square	0.0449	1000			0.001447
square	0.045	1000			0.00145
square	0.078	1000			0.00244
square	0.109	1000			0.00337
square	0.11	1000			0.0034
square	0.28	1000			0.0085
square	0.449	1000			0.01357
square	0.45	1000			0.0136
square	0.78	1000			0.0235
square	1.09	1000			0.0328
square	1.1	1000			0.0331
square	1.8	1000			0.0541
square	2.5	10			0.0751
square	2.5	100			0.0751
square	2.5	1000			0.0751
square	2.5	10000			0.0751
sine	0.0018	1000			0.000154
sine	0.0109	1000			0.000427
sine	0.0449	1000			0.001447
sine	0.109	1000			0.00337
sine	0.449	1000			0.01357
sine	1.09	1000			0.0328
sine	2.5	1000			0.0751
triangle	0.0018	1000			0.000154
triangle	0.0109	1000			0.000427
triangle	0.0449	1000			0.001447

Table 9-6. SC600 Option Wave Generator Amplitude Verification (50 Ω output impedance) (cont.)

Wave Shape	Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
triangle	0.109	1000			0.00337
triangle	0.449	1000			0.01357
triangle	1.09	1000			0.0328
triangle	2.5	1000			0.0751

Table 9-7. SC600 Option Leveled Sine Wave Verification: Amplitude

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.005	50 kHz			0.0004
0.0075	50 kHz			0.00045
0.0099	50 kHz			0.000498
0.01	50 kHz			0.0005
0.025	50 kHz			0.0008
0.039	50 kHz			0.00108
0.04	50 kHz			0.0011
0.07	50 kHz			0.0017
0.099	50 kHz			0.00228
0.1	50 kHz			0.0023
0.25	50 kHz			0.0053
0.399	50 kHz			0.00828
0.4	50 kHz			0.0083
0.8	50 kHz			0.0163
1.2	50 kHz			0.0243
1.3	50 kHz			0.0263
3.4	50 kHz			0.0683
5.5	50 kHz			0.1103

Table 9-8. SC600 Option Leveled Sine Wave Verification: Frequency

Nominal Value (V p-p)	Frequency	Measured Value (Hz)	Deviation (Hz)	1-Year Spec. (Hz)
5.5	50 kHz			0.125
5.5	500 kHz			1.25
5.5	5 MHz			12.5
5.5	50 MHz			125
5.5	500 MHz			1250

Table 9-9. SC600 Option Leveled Sine Wave Verification: Harmonics

Harmonic	Nominal Value (V p-p)	Frequency	Measured Value (dB)	Deviation (dB)	1-Year Spec. (dB)
2nd harmonic	0.0399	50 kHz			-33
3rd+ harmonic	0.0399	50 kHz			-38
2nd harmonic	0.099	50 kHz			-33
3rd+ harmonic	0.099	50 kHz			-38
2nd harmonic	0.399	50 kHz			-33
3rd+ harmonic	0.399	50 kHz			-38
2nd harmonic	1.2	50 kHz			-33
3rd+ harmonic	1.2	50 kHz			-38
2nd harmonic	5.5	50 kHz			-33
3rd+ harmonic	5.5	50 kHz			-38
2nd harmonic	5.5	100 kHz			-33
3rd+ harmonic	5.5	100 kHz			-38
2nd harmonic	5.5	200 kHz			-33
3rd+ harmonic	5.5	200 kHz			-38
2nd harmonic	5.5	400 kHz			-33
3rd+ harmonic	5.5	400 kHz			-38
2nd harmonic	5.5	800 kHz			-33
3rd+ harmonic	5.5	800 kHz			-38
2nd harmonic	5.5	1 MHz			-33
3rd+ harmonic	5.5	1 MHz			-38
2nd harmonic	5.5	2 MHz			-33
3rd+ harmonic	5.5	2 MHz			-38

Table 9-9. SC600 Option Leveled Sine Wave Verification: Harmonics (cont.)

Harmonic	Nominal Value (V p-p)	Frequency	Measured Value (dB)	Deviation (dB)	1-Year Spec. (dB)
2nd harmonic	5.5	4 MHz			-33
3rd+ harmonic	5.5	4 MHz			-38
2nd harmonic	5.5	8 MHz			-33
3rd+ harmonic	5.5	8 MHz			-38
2nd harmonic	5.5	10 MHz			-33
3rd+ harmonic	5.5	10 MHz			-38
2nd harmonic	5.5	20 MHz			-33
3rd+ harmonic	5.5	20 MHz			-38
2nd harmonic	5.5	40 MHz			-33
3rd+ harmonic	5.5	40 MHz			-38
2nd harmonic	5.5	80 MHz			-33
3rd+ harmonic	5.5	80 MHz			-38
2nd harmonic	5.5	100 MHz			-33
3rd+ harmonic	5.5	100 MHz			-38
2nd harmonic	5.5	200 MHz			-33
3rd+ harmonic	5.5	200 MHz			-38
2nd harmonic	5.5	400 MHz			-33
3rd+ harmonic	5.5	400 MHz			-38
2nd harmonic	5.5	600 MHz			-33
3rd+ harmonic	5.5	600 MHz			-38

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.005	50 kHz		na	na
0.005	30 MHz			0.000175
0.005	70 MHz			0.000175
0.005	120 MHz			0.0002
0.005	290 MHz			0.0002
0.005	360 MHz			0.0003
0.005	390 MHz			0.0003
0.005	400 MHz			0.0003

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.005	480 MHz			0.0003
0.005	570 MHz			0.0003
0.005	580 MHz			0.0003
0.005	590 MHz			0.0003
0.005	600 MHz			0.0003
0.0075	50 kHz		na	na
0.0075	30 MHz			0.0002125
0.0075	70 MHz			0.0002125
0.0075	120 MHz			0.00025
0.0075	290 MHz			0.00025
0.0075	360 MHz			0.0004
0.0075	390 MHz			0.0004
0.0075	400 MHz			0.0004
0.0075	480 MHz			0.0004
0.0075	570 MHz			0.0004
0.0075	580 MHz			0.0004
0.0075	590 MHz			0.0004
0.0075	600 MHz			0.0004
0.0099	50 kHz		na	na
0.0099	30 MHz			0.0002485
0.0099	70 MHz			0.0002485
0.0099	120 MHz			0.000298
0.0099	290 MHz			0.000298
0.0099	360 MHz			0.000496
0.0099	390 MHz			0.000496
0.0099	400 MHz			0.000496
0.0099	480 MHz			0.000496
0.0099	570 MHz			0.000496
0.0099	580 MHz			0.000496
0.0099	590 MHz			0.000496
0.0099	600 MHz			0.000496

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.01	50 kHz		na	na
0.01	30 MHz			0.00025
0.01	70 MHz			0.00025
0.01	120 MHz			0.0003
0.01	290 MHz			0.0003
0.01	360 MHz			0.0005
0.01	390 MHz			0.0005
0.01	400 MHz			0.0005
0.01	480 MHz			0.0005
0.01	570 MHz			0.0005
0.01	580 MHz			0.0005
0.01	590 MHz			0.0005
0.01	600 MHz			0.0005
0.025	50 kHz		na	na
0.025	30 MHz			0.000475
0.025	70 MHz			0.000475
0.025	120 MHz			0.0006
0.025	290 MHz			0.0006
0.025	360 MHz			0.0011
0.025	390 MHz			0.0011
0.025	400 MHz			0.0011
0.025	480 MHz			0.0011
0.025	570 MHz			0.0011
0.025	580 MHz			0.0011
0.025	590 MHz			0.0011
0.025	600 MHz			0.0011
0.039	50 kHz		na	na
0.039	30 MHz			0.000685
0.039	70 MHz			0.000685
0.039	120 MHz			0.00088
0.039	290 MHz			0.00088
0.039	360 MHz			0.00166

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.039	390 MHz			0.00166
0.039	400 MHz			0.00166
0.039	480 MHz			0.00166
0.039	570 MHz			0.00166
0.039	580 MHz			0.00166
0.039	590 MHz			0.00166
0.039	600 MHz			0.00166
0.04	50 kHz		na	na
0.04	30 MHz			0.0007
0.04	70 MHz			0.0007
0.04	120 MHz			0.0009
0.04	290 MHz			0.0009
0.04	360 MHz			0.0017
0.04	390 MHz			0.0017
0.04	400 MHz			0.0017
0.04	480 MHz			0.0017
0.04	570 MHz			0.0017
0.04	580 MHz			0.0017
0.04	590 MHz			0.0017
0.04	600 MHz			0.0017
0.07	50 kHz		na	na
0.07	30 MHz			0.00115
0.07	70 MHz			0.00115
0.07	120 MHz			0.0015
0.07	290 MHz			0.0015
0.07	360 MHz			0.0029
0.07	390 MHz			0.0029
0.07	400 MHz			0.0029
0.07	480 MHz			0.0029
0.07	570 MHz			0.0029
0.07	580 MHz			0.0029
0.07	590 MHz			0.0029

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.07	600 MHz			0.0029
0.099	50 kHz		na	na
0.099	30 MHz			0.001585
0.099	70 MHz			0.001585
0.099	120 MHz			0.00208
0.099	290 MHz			0.00208
0.099	360 MHz			0.00406
0.099	390 MHz			0.00406
0.099	400 MHz			0.00406
0.099	480 MHz			0.00406
0.099	570 MHz			0.00406
0.099	580 MHz			0.00406
0.099	590 MHz			0.00406
0.099	600 MHz			0.00406
0.1	50 kHz		na	na
0.1	30 MHz			0.0016
0.1	70 MHz			0.0016
0.1	120 MHz			0.0021
0.1	290 MHz			0.0021
0.1	360 MHz			0.0041
0.1	390 MHz			0.0041
0.1	400 MHz			0.0041
0.1	480 MHz			0.0041
0.1	570 MHz			0.0041
0.1	580 MHz			0.0041
0.1	590 MHz			0.0041
0.1	600 MHz			0.0041
0.25	50 kHz		na	na
0.25	30 MHz			0.00385
0.25	70 MHz			0.00385
0.25	120 MHz			0.0051
0.25	290 MHz			0.0051

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.25	360 MHz			0.0101
0.25	390 MHz			0.0101
0.25	400 MHz			0.0101
0.25	480 MHz			0.0101
0.25	570 MHz			0.0101
0.25	580 MHz			0.0101
0.25	590 MHz			0.0101
0.25	600 MHz			0.0101
0.399	50 kHz		na	na
0.399	30 MHz			0.006085
0.399	70 MHz			0.006085
0.399	120 MHz			0.00808
0.399	290 MHz			0.00808
0.399	360 MHz			0.01606
0.399	390 MHz			0.01606
0.399	400 MHz			0.01606
0.399	480 MHz			0.01606
0.399	570 MHz			0.01606
0.399	580 MHz			0.01606
0.399	590 MHz			0.01606
0.399	600 MHz			0.01606
0.4	50 kHz		na	na
0.4	30 MHz			0.0061
0.4	70 MHz			0.0061
0.4	120 MHz			0.0081
0.4	290 MHz			0.0081
0.4	360 MHz			0.0161
0.4	390 MHz			0.0161
0.4	400 MHz			0.0161
0.4	480 MHz			0.0161
0.4	570 MHz			0.0161
0.4	580 MHz			0.0161

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.4	590 MHz			0.0161
0.4	600 MHz			0.0161
0.8	50 kHz		na	na
0.8	30 MHz			0.0121
0.8	70 MHz			0.0121
0.8	120 MHz			0.0161
0.8	290 MHz			0.0161
0.8	360 MHz			0.0321
0.8	390 MHz			0.0321
0.8	400 MHz			0.0321
0.8	480 MHz			0.0321
0.8	570 MHz			0.0321
0.8	580 MHz			0.0321
0.8	590 MHz			0.0321
0.8	600 MHz			0.0321
1.2	50 kHz		na	na
1.2	30 MHz			0.0181
1.2	70 MHz			0.0181
1.2	120 MHz			0.0241
1.2	290 MHz			0.0241
1.2	360 MHz			0.0481
1.2	390 MHz			0.0481
1.2	400 MHz			0.0481
1.2	480 MHz			0.0481
1.2	570 MHz			0.0481
1.2	580 MHz			0.0481
1.2	590 MHz			0.0481
1.2	600 MHz			0.0481
1.3	50 kHz		na	na
1.3	30 MHz			0.0196
1.3	70 MHz			0.0196
1.3	120 MHz			0.0261

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
1.3	290 MHz			0.0261
1.3	360 MHz			0.0521
1.3	390 MHz			0.0521
1.3	400 MHz			0.0521
1.3	480 MHz			0.0521
1.3	570 MHz			0.0521
1.3	580 MHz			0.0521
1.3	590 MHz			0.0521
1.3	600 MHz			0.0521
3.4	50 kHz		na	na
3.4	30 MHz			0.0511
3.4	70 MHz			0.0511
3.4	120 MHz			0.0681
3.4	290 MHz			0.0681
3.4	360 MHz			0.1361
3.4	390 MHz			0.1361
3.4	400 MHz			0.1361
3.4	480 MHz			0.1361
3.4	570 MHz			0.1361
3.4	580 MHz			0.1361
3.4	590 MHz			0.1361
3.4	600 MHz			0.1361
5.5	50 kHz		na	na
5.5	30 MHz			0.0826
5.5	70 MHz			0.0826
5.5	120 MHz			0.1101
5.5	290 MHz			0.1101
5.5	360 MHz			0.2201
5.5	390 MHz			0.2201
5.5	400 MHz			0.2201
5.5	480 MHz			0.2201
5.5	570 MHz			0.2201

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

Nominal Value (V p-p)	Frequency	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
5.5	580 MHz			0.2201
5.5	590 MHz			0.2201
5.5	600 MHz			0.2201

Table 9-11. SC600 Option Edge Verification: Amplitude

Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
0.005	1 kHz			0.0003
0.005	10 kHz			0.0003
0.005	100 kHz			0.0003
0.01	100 kHz			0.0004
0.025	100 kHz			0.0007
0.05	100 kHz			0.0012
0.1	100 kHz			0.0022
0.25	100 kHz			0.0052
0.5	100 kHz			0.0102
1	100 kHz			0.0202
2.5	100 kHz			0.0502
2.5	10 kHz			0.0502
2.5	1 kHz			0.0502

Table 9-12. SC600 Option Edge Verification: Frequency

Nominal Value (V p-p)	Frequency	Measured Value (Hz)	Deviation (Hz)	1-Year Spec. (Hz)
2.5	1 kHz			0.0025
2.5	10 kHz			0.025
2.5	100 kHz			0.25
2.5	1 MHz			2.5
2.5	10 MHz			25

Table 9-13. SC600 Option Edge Verification: Duty Cycle

Nominal Value (V p-p)	Frequency	Measured Value (%)	Deviation (from 50%)	1-Year Spec. (%)
2.5	1 MHz			5

Table 9-14. SC600 Option Edge Verification: Rise Time

Nominal Value (V p-p)	Frequency	Measured Value (s)	Deviation (ns)	1-Year Spec. (ns)
0.25	1 kHz			0.3 ns
0.25	100 kHz			0.3 ns
0.25	10 MHz			0.3 ns
0.5	1 kHz			0.3 ns
0.5	100 kHz			0.3 ns
0.5	10 MHz			0.3 ns
1	1 kHz			0.3 ns
1	100 kHz			0.3 ns
1	10 MHz			0.3 ns
2.5	1 kHz			0.3 ns
2.5	100 kHz			0.3 ns
2.5	10 MHz			0.3 ns

Table 9-15. SC600 Option Tunnel Diode Pulser Verification

Nominal Value (V p-p)	Frequency (Hz)	Measured Value (V p-p)	Deviation (V p-p)	1-Year Spec. (V p-p)
11	100			0.2202
11	10000			0.2202
55	100			1.1002
55	10000			1.1002
100	100			2.0002
100	10000			2.0002

Table 9-16. SC600 Option Marker Generator Verification

Period (s)	Measured Value (s)	Deviation (s)	1-Year Spec. (s)
5			0.0251 s
2			0.00405 s
0.05			3.75E-06 s
0.02			5E-8
0.01			2.5E-8
1e-7			2.5E-13
5e-8			1.25E-13
2e-8			5E-14
1e-8			2.5E-14
5e-9			1.25E-14
2e-9			5E-15

Table 9-17. SC600 Option Pulse Generator Verification: Period

Nominal Value (V p-p)	Pulse Width (s)	Period (s)	Measured Value (s)	Deviation (s)	1-Year Spec. (s)
2.5	8E-08	2E-06			5E-12
2.5	0.0000005	0.01			2.5E-08
2.5	0.0000005	0.02			5E-08

Table 9-18. SC600 Option Pulse Generator Verification: Pulse Width

Nominal Value (V p-p)	Pulse Width (s)	Period (s)	Measured Value (s)	Deviation (s)	1-Year Spec. typical (s)
2.5	4.0E-09	2.0E-06			6.2E-9
2.5	4.0E-09	2.0E-05			6.2E-9
2.5	4.0E-09	2.0E-04			6.2E-9
2.5	4.0E-08	2.0E-03			4.4E-8

Table 9-19. SC600 Option Input Impedance Verification: Resistance

Nominal Value (Ω)	Measured Value (Ω)	Deviation (Ω)	1-Year Spec. (Ω)
40 Ω			0.04 Ω
50 Ω			0.05 Ω
60 Ω			0.06 Ω
600000 Ω			600 Ω
1000000 Ω			1000 Ω
1500000 Ω			1500 Ω

Table 9-20. SC600 Option Input Impedance Verification: Capacitance

Nominal Value (pF)	Measured Value (pF)	Deviation (pF)	1-Year Spec. (pF)
5 pF			0.75 pF
29 pF			1.95 pF
49 pF			2.95 pF

Chapter 10

SC300 Oscilloscope Calibration Option

Contents **Page**

Introduction

The SC300 Oscilloscope Calibration Option (the SC300 Option) has functions that help you keep your oscilloscope's accuracy by verifying and calibrating the subsequent oscilloscope qualities:

- Vertical deflection qualities are calibrated and verified. The VOLT function lets you compare the voltage gain to the graticule lines on the oscilloscope.
- Pulse transient response is examined and calibrated, verifying the accuracy of the measurement of pulse transitions of the oscilloscope with the EDGE function.
- Frequency response is examined by verifying the bandwidth with the leveled sine wave (LEVSINE) function. Vertical deflection is monitored until the -3 dB point is seen on the oscilloscope.
- Horizontal (time base) deflection qualities are calibrated and verified with the time MARKER function. This calibration procedure is like the one for verifying the vertical deflection qualities, but it examines the horizontal axis.
- The power to trigger on different waveforms is verified with the wave generator function of the oscilloscope.

The menus that implement these functions also include parameters to change how the output signal reacts to voltage, frequency, and time settings. This gives you control of the signal at calibration, and gives more methods to see the properties of the signal.

SC300 Oscilloscope Calibration Option Specifications

These specifications apply only to the SC300 Oscilloscope Calibration Option. General specifications that apply to the 5502A Calibrator can be found in Chapter 1. The specifications are correct given the 5502A is operated with the conditions specified in Chapter 1, and has completed a warm-up period of no less than two times the length of time the Calibrator was powered off, to a maximum of 30 minutes.

Volt Function Specifications

Volt Function	DC Signal		Square Wave Signal	
	Into 50 Ω	**Into 1 MΩ**	**Into 50 Ω**	**Into 1 MΩ**
Amplitude Characteristics				
Range	0 V to ± 2.2 V	0 V to ± 33 V	1.8 mV to 2.2 V p-p	1.8 mV to 105 V p-p [1]
Resolution	<100 V: 4 digits or 10 µV, whichever is greater ≥100 V: 5 digits			
Adjustment Range	Continuous [1]			
1-Year Absolute Uncertainty, tcal ± 5°C	± (0.25% of output + 100 µV)[2] [3]			
Sequence	1-2-5 (for example 10 mV, 20 mV, 50 mV)			
Square Wave Frequency Characteristics				
Range	10 Hz to 10 kHz			
1-Year Absolute Uncertainty, tcal ± 5°C	± (25 ppm of setting + 15 mHz)			
Typical Aberration within 20 µs from leading edge	< (2% of output + 100 µV)			

[1] The square wave signal into 1 MΩ is a positive square wave from 1.8 mV to 55 V p-p. From 95 V to 105 V, its output is a square wave-like signal that alternates between the negative peak and the positive peak, with the centerline at –10 V. Signals between 55 V and 95 V p-p are not available.

[2] The uncertainty for 50 Ω loads does not include the input impedance uncertainty of the oscilloscope. Square wave signals below 4.5 mV p-p have an uncertainty of ± (0.25% of output + 200 µV).

[3] Signals from 95 to 105 V p-p have an uncertainty of 0.5% of output in the frequency range 100 Hz to 1 kHz. Typical uncertainty is 1.5% of output for 95 V to 105 V p-p signals in the frequency range 10 Hz to 100 Hz, and 0.5% of output in the frequency range 1 kHz to 10 kHz.

Edge Function Specifications

Edge Characteristics into 50 Ω		1-Year Absolute Uncertainty, tcal ± 5°C
Amplitude		
Range (p-p)	4.5 mV to 2.75 V	±(2 % of output + 200 µV)
Resolution	4 digits	
Adjustment Range	±10 % around each sequence value (shown below)	
Sequence	5 mV, 10 mV, 25 mV, 50 mV, 100 mV, 250 mV, 500 mV, 1 V, 2.5 V	
Other Edge Characteristics		
Frequency Range	1 kHz to 1 MHz	±(25 ppm of setting + 15 mHz)
Rise Time	< 400 ps	
Leading Edge Aberrations	within 10 ns	<(3% of output + 2 mV)
	10 to 30 ns	<(1% of output + 2 mV)
	after 30 ns	<(0.5% of output + 2 mV)
Typical Duty Cycle	45 % to 55 %	

Leveled Sine Wave Function Specifications

Leveled Sine Wave	Frequency Range		
Characteristics into 50 Ω	**50 kHz Reference**	**50 kHz to 100 MHz**	**100 to 300 MHz [1]**
Amplitude Characteristics			
Range (p-p)	5 mV to 5.5 V[1]		
Resolution	<100 mV: 3 digits ≥100 mV: 4 digits		
Adjustment Range	continuously adjustable		
1-Year Absolute Uncertainty, tcal ± 5 °C	±(2% of output + 200 µV)	±(3.5% of output + 300 µV)	± (4% of output + 300 µV)
Flatness (relative to 50 kHz)	not applicable	±(1.5% of output + 100 µV)	± (2.0% of output + 100 µV)
Short-term Stability	≤ 1%[2]		
Frequency Characteristics			
Resolution	10 Hz	10 kHz[3]	10 kHz
1-Year Absolute Uncertainty, tcal ± 5 °C	±(25 ppm + 15 mHz)	±25 ppm[4]	± 25 ppm
Distortion Characteristics			
2nd Harmonic	≤-35 dBc		
3rd and Higher Harmonics	≤-40 dBc		

[1] Extended frequency range to 350 MHz is provided, but flatness is not specified. Amplitude is limited to 3 V for frequencies above 250 MHz.

[2] Within one hour after reference amplitude setting, provided temperature varies no more than ± 5°C.

[3] At frequencies below 120 kHz, the resolution is 10 Hz. For frequencies between 120 kHz and 999.9 kHz, the resolution is 100 Hz.

[4] ±(25 ppm + 15 mHz) for frequencies of 1 MHz and below.

Time Marker Function Specifications

Time Marker into 50 Ω	5 s to 100 μs	50 μs to 2 μs	1 μs to 20 ns	10 ns to 2 ns
1-Year Absolute Uncertainty, tcal ± 5 °C	±(25 + t *1000) ppm [1]	±(25 + t *15,000) ppm [1]	±25 ppm	±25 ppm
Wave Shape	pulsed sawtooth	pulsed sawtooth	pulsed sawtooth	sine
Typical Output Level	> 1 V pk	> 1 V pk	> 1 V pk	> 2 V p-p [2]
Sequence	5-2-1 from 5 s to 2 ns (for example, 500 ms, 200 ms, 100 ms)			
Adjustment Range	At least ±10 % around each sequence value shown above.			
Resolution	4 digits			

[1] t is the time in seconds.

[2] The 2 ns time marker is typically > 0.5 V p-p.

Wave Generator Specifications

Wave Generator Characteristics	Square Wave, Sine Wave, and Triangle Wave into 50 Ω or 1 MΩ
Amplitude	
Range	into 1 MΩ: 1.8 mV to 55 V p-p into 50 Ω: 1.8 mV to 2.2 V p-p
1-Year Absolute Uncertainty, tcal ± 5 °C, 10 Hz to 10 kHz	±(3 % of p-p output + 100 μV)
Sequence	1-2-5 (for example, 10 mV, 20 mV, 50 mV)
Typical DC Offset Range	0 to ±(≥40% of p-p amplitude) [1]
Frequency	
Range	10 Hz to 100 kHz
Resolution	4 or 5 digits depending upon frequency
1-Year Absolute Uncertainty, tcal ± 5 °C	±(25 ppm + 15 mHz)

[1] The DC offset plus the wave signal must not exceed 30 V rms.

Trigger Signal Specifications for the Time Marker Function

Time Marker Period	Division Ratio [1]	Amplitude into 50 Ω (p-p)	Typical Rise Time
5 to 1s	off/1	≥1 V	≤2 ns
0.5 to 0.1s	off/1/10	≥1 V	≤2 ns
50 ms to 100 ns	off/1/10/100	≥1 V	≤2 ns
50 to 10 ns	off/10/100	≥1 V	≤2 ns
5 to 2 ns	off/100	≥1 V	≤2 ns

[1] Divider is internally limited to prevent trigger output from frequencies that are either lower than 0.2 Hz (5s period) or higher than 10 MHz.

Trigger Signal Specifications for the Edge Function

Edge Signal Frequency	Division Ratio	Amplitude into 50 Ω (p-p)	Typical Rise Time
1 kHz to 1 MHz	off/1	≥1 V	≤2 ns

Oscilloscope Connections

Use the cable supplied with the Oscilloscope Calibration Option to connect the SCOPE connector on the 5502A to one of the channel connectors on your oscilloscope (see Figure 8-3).

To use the external trigger, connect the TRIG connector on the 5502A to the external trigger connection on your oscilloscope. To use the external trigger and see its signal with the calibration signal, connect the TRIG connector to a different channel. See your oscilloscope manual for information about connections and how to see an external trigger.

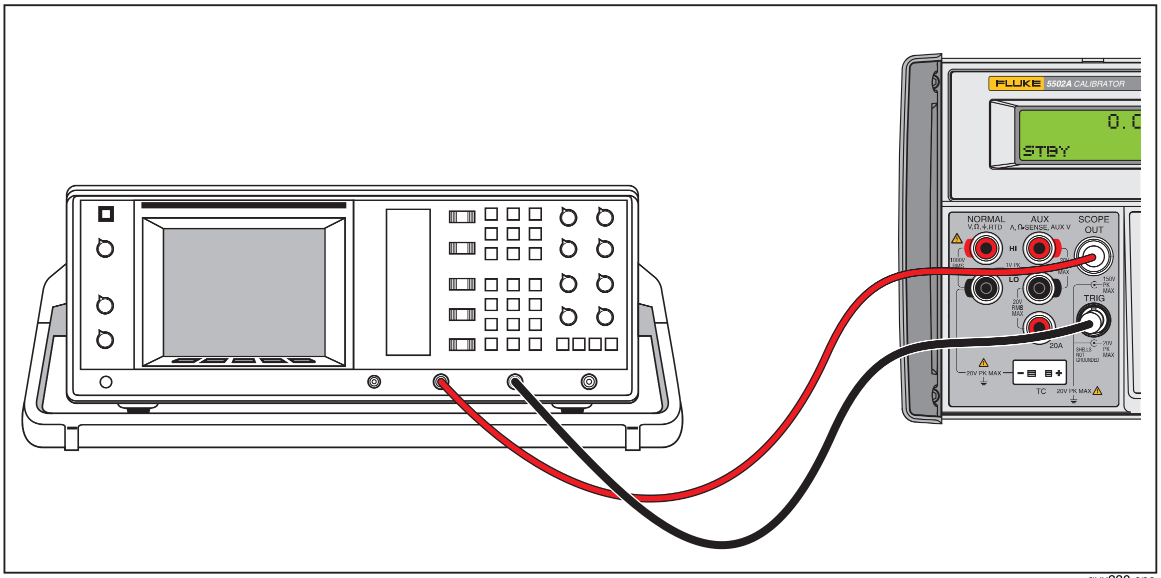
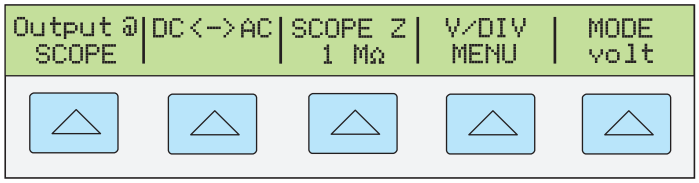


Figure 10-3. Oscilloscope Connection: Channel and External Trigger

Start the Oscilloscope Calibration Option

Push SCOPE to start the Oscilloscope Calibration Option. The Control Display opens the volt menu, shown below, which contains options to calibrate the vertical gain on your oscilloscope. This is the first of five calibration menus, which you can scroll through. Push the softkey below MODE. Each menu is given in this chapter, see below.

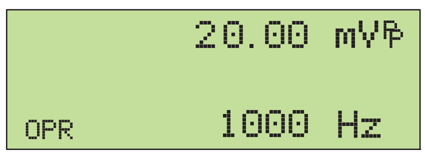


gl021i.eps

The Output Signal

The location of the output signal is shown on the Control Display (the display on the right side). If your 5502A is connected, but the output does not show on the oscilloscope, you can have the 5502A in standby mode.

The settings for the output signal are shown in the Output Display (the display on the left side). The subsequent example shows the default settings for volt mode, which are set when you start the Oscilloscope Calibration Option, see below.



gl022i.eps

If STBY is shown, push the OPR key. The Output Display will show OPR and the output will show on the oscilloscope.

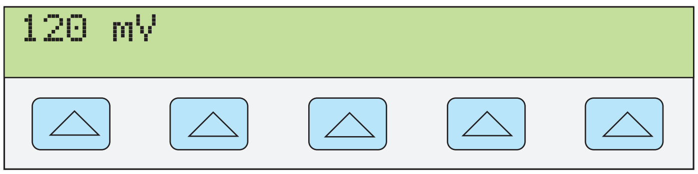
Adjust the Output Signal

The 5502A gives different methods to change the settings for the output signal during calibration. Since many adjustments of the output signal are necessary for oscilloscope calibration, the three available methods to change these settings for oscilloscope calibration are summarized below. These methods give the means of jumping to a new value or sweep through a range of values.

Key in a Value

To key a special value directly into the 5502A from its front panel:

1. Key in the value and include the units and prefixes. For example to key in 120 mV push 1 2 0 µ m dBm V. The Control Display will show:



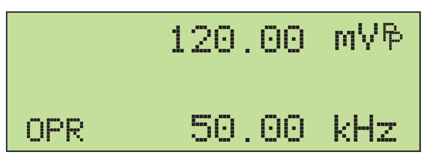
gl002i.eps

Note

Units and prefixes printed in purple in the top left corner of the keys are accessed through the SHIFT *key. For example, to record 200 µs, push* 2 0 0 SHIFT µ m SHIFT sec Hz.

If you make an error, push CE to clear the Control Display and go to the menu.

2. Push ENTER to start the value and move it to the Output Display, see below.



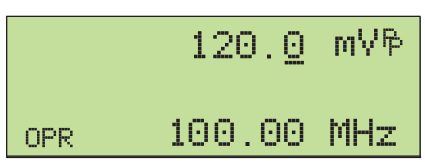
gl023i.eps

Other settings in the display will stay unaltered unless you key in an entry and specify the units for that setting.

Adjust Values with the Rotary Knob

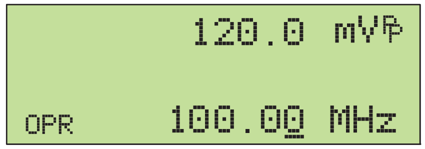
To adjust values in the Output Display with the rotary knob:

1. Turn the rotary knob. A cursor shows in the output display below the lowest digit and starts to change that digit. If you wish to put the cursor in the field without a digit change, push EDIT FIELD, see below.



gl003i.eps

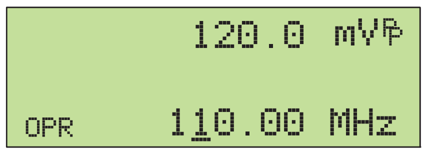
2. To move the cursor between the voltage and frequency fields, push [EDIT FIELD], see below.



gl004i.eps

3. Use the [◄] and [►] keys to move the cursor to the digit that you will change.
4. Turn the rotary knob to change the value.

   When you use the rotary knob in volt mode or marker mode, the Control Display shows the percentage change of the new value from the reference value. This is useful to learn the percentage of error on the oscilloscope. You can set the reference value to the new value. Push [NEW REF], see below.



gl005i.eps

5. Push [ENTER] to remove the cursor from the Output Display and save the new value as the reference value.

Note

If you try to use the rotary knob to adjust a value to an quantity that is invalid for the function that you use, or is out of the range limit of the value, the value will not change and the 5502A will beep. If it is necessary to go to a different range of values, turn the knob quickly to jump to the new range.

Use [MULT X] and [DIV ÷]

The [MULT X] and [DIV ÷] keys cause the current value of the signal to jump to a predetermined cardinal value. The current function determines this value. These keys are explained more under the descriptions for each function.

Reset the Oscilloscope Option

You can reset all parameters in the 5502A to their default settings during front panel operations. Push [RESET] on the front panel.

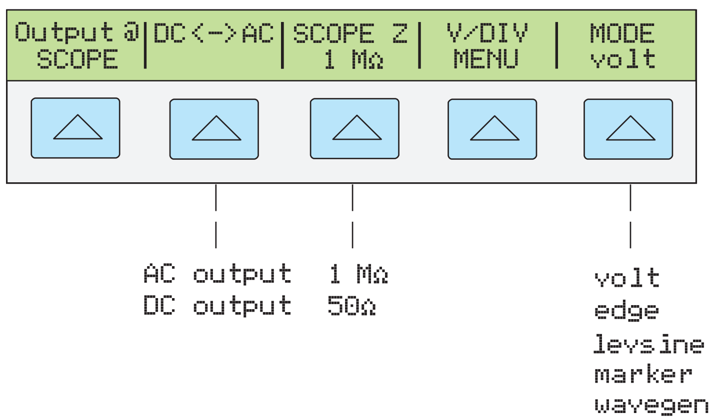
After you reset the 5502A, push [SCOPE] to go to the Oscilloscope Calibration Option (the Volt menu shows). Push [OPR] to connect the signal output.

Calibrate the Voltage Amplitude on an Oscilloscope

To calibrate oscilloscope voltage gain, apply a low frequency square wave signal and adjust its gain to the height specified for different voltage levels, designated by the graticule line divisions on the oscilloscope. Apply the signal from the 5502A in Volt mode. The voltages that you must use for calibration, and the graticule line divisions that are necessary to be matched, can be different for different oscilloscopes. These are specified in your service manual for your oscilloscope.

The Volt Function

The Voltage gain is calibrated with the volt function. This function is accessed through the Volt menu, which shows when you start the SCOPE option, or when you push the softkey below MODE to scroll through the oscilloscope calibration menus, see below.



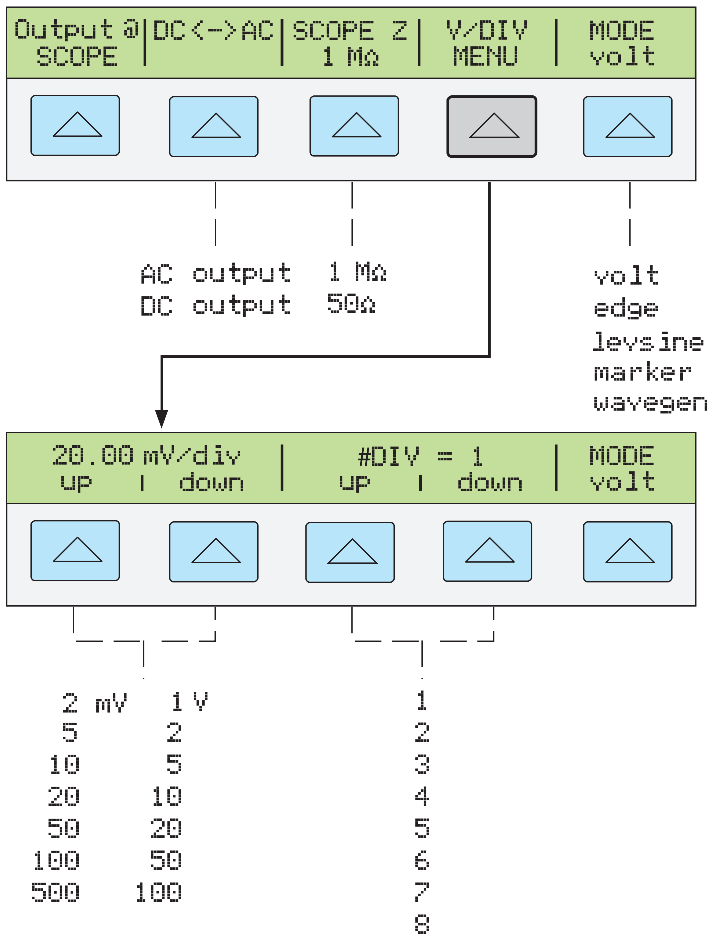
gl024i.eps

Each menu item is described below:

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **DC <-> AC** Toggles between a dc and ac signal. Push the softkey from the ac signal to make the dc equivalent output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 1 MΩ and
  50 Ω.
- **V/DIV MENU** Opens the voltage scaling menu, which lets you select the scale of the signal in volts per division. This menu is shown below in the “The V/DIV Menu” section.
- **MODE** Shows you are in volt mode. Use the softkey to change modes and open its menus for the other four oscilloscope calibration modes.

The V/DIV Menu

The V/DIV menu, shown below, sets the number of volts shown by each division on the oscilloscope. This menu gives alternative methods to change the output amplitude that can be more convenient for special oscilloscope uses. To access the V/DIV menu, push V/DIV from the Volt menu, see below.



gl025i.eps

Each item in the V/DIV menu is given below.

- **V/div** Changes the scale of the output display with a change to the number of volts that are shown by each division. The available settings, shown in the figure above, are given in 1-2-5 step increments. Push the softkey below UP to increase the volts per division. Push the softkey below DOWN to decrease the volts per division.
- **# DIV** Specifies the number of divisions that make the p-p value of the waveform. The value can be adjusted from one to eight divisions. The quantity shown by each division is shown in the V/div field. Push the softkey below UP to increase the height of the signal, and push the softkey below DOWN to decrease it.

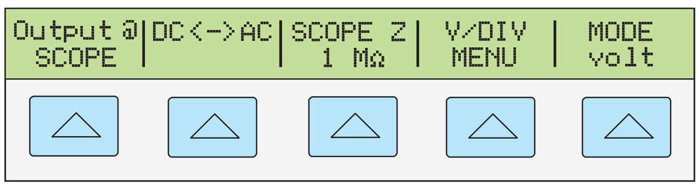
Shortcuts to Set the Voltage Amplitude

The MULT × and DIV ÷ keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the voltage is 40 mV, then push MULT × to increase the voltage to the nearest cardinal point, which is 50 mV. Push DIV ÷ to decrease the voltage to the nearest cardinal point, which is 20 mV.

Amplitude Calibration Procedure for an Oscilloscope

This example procedure tells you how to use the Volt menu to calibrate the amplitude gain of the oscilloscope. When you calibrate the oscilloscope, it will be necessary to set different voltages and verify that the gain matches the graticule lines on the oscilloscope with reference to the specifications for your oscilloscope. See your oscilloscope manual for the recommended calibration settings and correct gain values.

Before you start this procedure, verify that you are running the oscilloscope option in Volt mode. If you are, the Control Display shows the subsequent menu, see below.

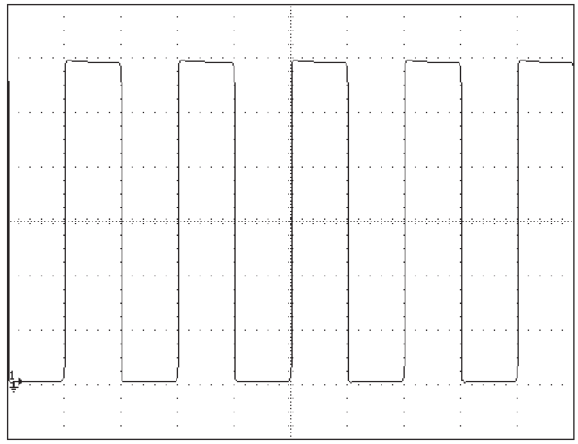


gl026i.eps

Do the subsequent sample procedure to calibrate the vertical gain.

1. Connect the Calibrator to Channel 1 on the oscilloscope. Make sure the oscilloscope is terminated at the correct impedance (1 MΩ for this example). Make sure that the OPR key on the 5502A is lit. This shows that the signal is connected.
2. Key in the voltage level that is recommended for your oscilloscope. For example to record 20 mV, push 2 0 µ m dBm V, then push ENTER. See “Keying in a Value” in this chapter.
3. Adjust the oscilloscope as necessary. The waveform must be similar to the one shown below, with the gain set as specified for the calibration settings for your oscilloscope.

The example below shows the gain at 20 mV to be 4 divisions, at 5 mV per division.



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4. Change the calibration voltage to the subsequent value that is recommended for your oscilloscope model, and do this procedure again at the new voltage level. Make sure that the gain is correct with reference to the specifications in your manual.
5. Do the procedure again for each channel.

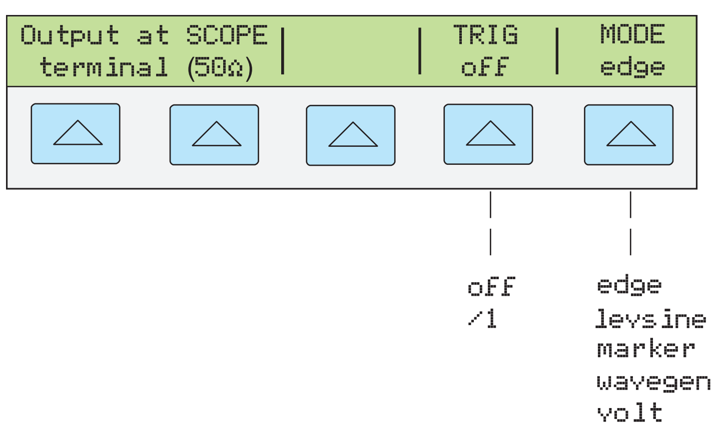
Calibrate the Pulse and Frequency Response on an Oscilloscope

The pulse response is calibrated with a square-wave signal that has a fast leading edge rise-time. With this signal, you adjust the oscilloscope as necessary until it is in specification for rise time and pulse aberrations.

After pulse verification, the frequency response is verified with a leveled sine wave applied and by a frequency indication at the -3 dB point, when the amplitude drops approximately 30 %.

The Edge Function

The Edge function is used to calibrate the pulse response for your oscilloscope. To get to the Edge menu, push the softkey below MODE until "edge" shows, see below.



gl027i.eps

Each option in the Edge menu is shown below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.

  You cannot change the output impedance in Edge mode.

- **TRIG** If you use the external trigger, use this key to toggle the trigger off and on. When on, the indication will show "/1" which shows that the external trigger is at the same frequency as the edge output.

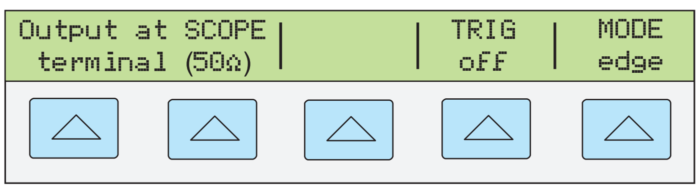
  You can also toggle the trigger off and on with TRIG OUT. The external trigger can be useful for many digital storage oscilloscopes where triggering on fast rise time signals cannot be done easily.

- **MODE** Shows you are in Edge mode. Use the softkey to change modes and open the related menus for the other three oscilloscope calibration modes.

Pulse Response Calibration Procedure for an Oscilloscope

This sample procedure shows how to verify the pulse response of the oscilloscope. Before you verify your oscilloscope, see the oscilloscope manual for the recommended calibration settings.

Before you start this procedure, make sure that you use the oscilloscope option in Edge mode. If you are, the Control Display shows the subsequent menu.



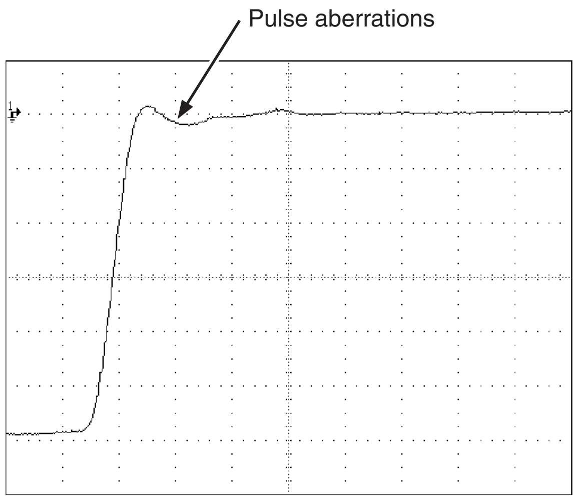
gl028i.eps

Do the subsequent sample procedure to calibrate the pulse response.

1. Connect the 5502A to Channel 1 on the oscilloscope. Select 50Ω impedance or use a 50 Ω termination at the oscilloscope input. Make sure that the OPR key is lit. This shows that the signal is connected.
2. Change the voltage adjustment for the signal so it agrees with the amplitude value recommended by your oscilloscope manufacturer to calibrate the edge response. The default is 25 mV @ 1 MHz.

   For example, on a Fluke PM3392A oscilloscope, start with a signal of 1 V @ 1 MHz.
3. Adjust the scale on your oscilloscope to get a good picture of the edge. For example, on a Fluke PM3392A oscilloscope with a 1 V @ 1 MHz signal, use 200 mV/div.

4. Adjust the time base on your oscilloscope to the fastest position available (20.0 or 50.0 ns/div), see below.



gl007i.eps

5. Make sure that your oscilloscope shows the correct rise time and pulse aberration properties.
6. To remove the input signal, push STBY.

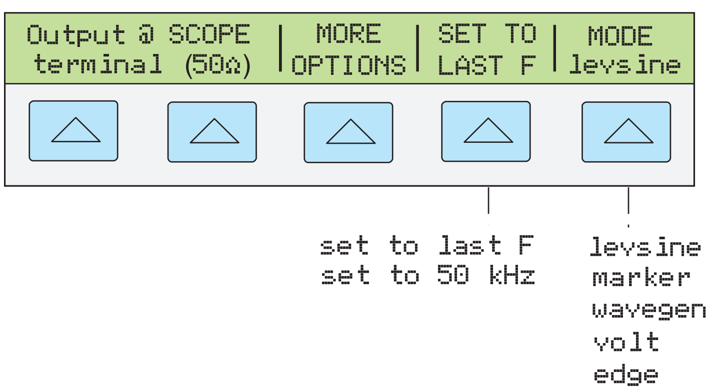
The Leveled Sine Wave Function

The Leveled Sine Wave (Levsine) function uses a leveled sine wave, whose amplitude stays relatively constant over a range of frequencies, to verify the bandwidth of the oscilloscope. When you verify your oscilloscope, you change the frequency of the wave until the amplitude shown on the oscilloscope drops 30%, which is the amplitude that refers to the -3 dB point.

To access the Levsine menu, push the softkey below MODE until “levsine” shows, see below.

Note

Make sure there is no cable connected to TRIG while you use the Levsine function.



gl029i.eps

Each option in the Levsine menu is shown below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push [OPR]. To disconnect the signal, push [STBY]. You cannot change the impedance while you are in Levsine mode.
- **MORE OPTIONS** Opens more menu items, which are given in the "The MORE OPTIONS Menu" section.
- **SET TO LAST F** Toggles between the current frequency setting and the reference value of 50 kHz. This option is useful for reverting to the reference to examine the output after you make adjustments at A different frequency.
- **MODE** Shows you are in Levsine mode. Use the softkey to change modes and open the corresponding menus for the other four calibration modes.

Note

If a question mark shows in the Output Display, then no specifications are available for the frequency that is used. This will occur at frequencies more than 250 MHz.

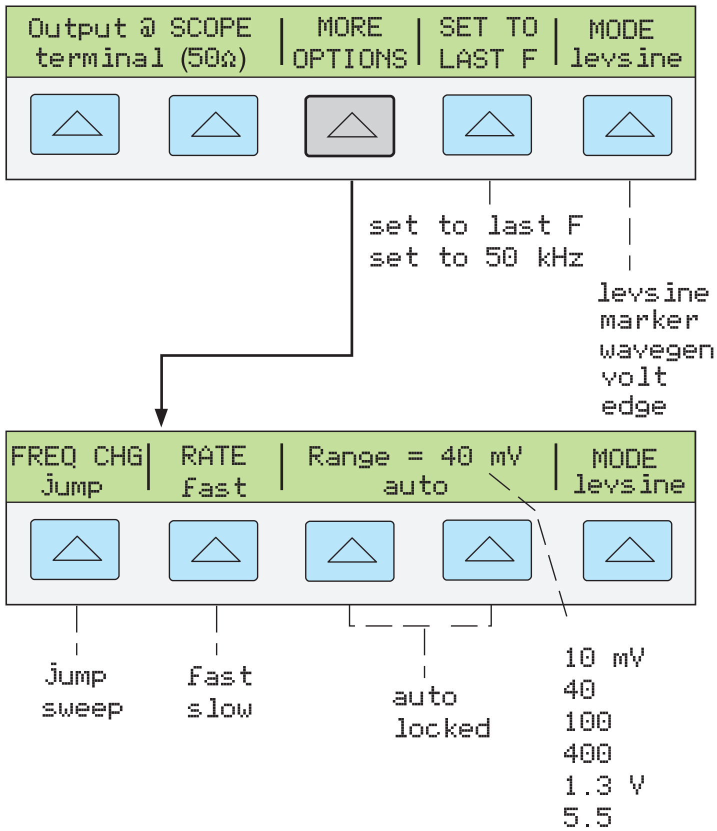
Shortcuts to Set the Frequency and Voltage

Three options are available to control the sine wave settings.

- **SET TO LAST F** Toggles between the last frequency used and the reference frequency of 50 kHz. This lets you examine the output at the reference after you make adjustments at a different frequency.
- **MORE OPTIONS** Lets you use an automatic frequency sweep and lock the voltage range, if necessary. The subsequent section gives details about this menu.
- **The [MULT X] and [DIV ÷] keys** step frequencies up or down to let you quickly access a new set of frequencies. For example, if the value is 250 kHz, [MULT X] changes it to 300 kHz, and [DIV ÷] changes it to 200 kHz. For voltage values, [MULT X] and [DIV ÷] step through cardinal point values in a 1.2-3-6 sequence.

The MORE OPTIONS Menu

When you select MORE OPTIONS, you open options that give you more control over the frequency and voltage. To access the MORE OPTIONS menu, push the softkey below MORE OPTIONS in the levsine menu, see below.



gl030i.eps

Each option in the MORE OPTIONS menu is given below.

- **FREQ CHANGE** Toggles between two settings that control the way the output signal adjusts to a new frequency. This is the default setting.

  "Jump" causes the output signal to jump immediately to a new frequency setting. "Sweep" causes the signal to sweep through a series of frequency values, over a range you set. Use the sweep function to monitor the signal gradually change over a given bandwidth and see the point at which its amplitude changes. More about the sweep function is given in the "Sweeping Through a Frequency Range" section.

- **RATE** Used when FREQ CHANGE is set to "sweep" to toggle the sweep speed between "fast" and "slow." The slow speed is one tenth the fast speed.

  The slow sweep rate lets you monitor the frequency change very slowly. After a fast sweep, it can be necessary to pinpoint a special frequency with a slow sweep over a subset of your previous frequency range.

- **RANGE** The softkeys toggle between two settings: "auto," which adjusts the range limit automatically in accordance with the voltage level, and "locked," which sets the available voltages to one range.

  There are six range limits in Levsine mode: 10 mV, 40 mV, 100 mV, 400 mV, 1.3 V, and 5.5 V. When set to "auto" the Calibrator uses your voltage setting to automatically set the range limit that gives the most accurate output. When set to "locked" the range limit stays fixed and you can decrease the voltage down to 0 V for all range limits.

  For example, if the range limit is 40 mV. If you set the 40 mV range to "auto" and then key in 1 mV, the Calibrator will adjust the range limit to 10 mV and will output 1 mV from the 10 mV range. If you set the 40 mV range to "locked" and then key in 1 mV, the Calibrator will output 1 mV from the 40 mV range.

  The default range setting is "auto," which must be used unless you are troubleshooting discontinuities in the vertical gain of your oscilloscope. The range setting will always go to "auto" after you go out of Levsine mode.

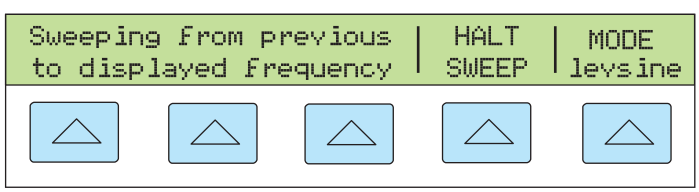
Sweep through a Frequency Range

When you change frequencies with the sweep method, the output sine wave sweeps through a specified range of frequencies. This lets you identify the frequency at which the signal of the oscilloscope shows special behavior (e.g., changes amplitude). Before you start this procedure, make sure you are in the MORE OPTIONS menu and the sine wave is shown on the oscilloscope.

Do the subsequent procedure to sweep through frequencies.

1. Make sure the output signal shows the starting frequency. If not, key in the starting frequency and then push ENTER.
2. Toggle FREQ CHANGE to "sweep." Toggle the RATE to "slow" to see a very slow sweep over a small range.
3. Key in the end frequency and then push ENTER.

After you push ENTER, the signal sweeps through frequencies between the two values you recorded, and the Sweep menu shows on the Control Display as shown below.



gl031i.eps

4. You can let the signal sweep through the complete range, or you can stop the sweep if necessary to record the frequency at a certain point.

   To interrupt the sweep, push the softkey below HALT SWEEP. The current frequency will show on the Output Display and the MORE OPTIONS menu will show again on the Control Display.

Note

When you interrupt the frequency sweep by a HALT SWEEP softkey push, the FREQ CHANGE method changes to "jump."

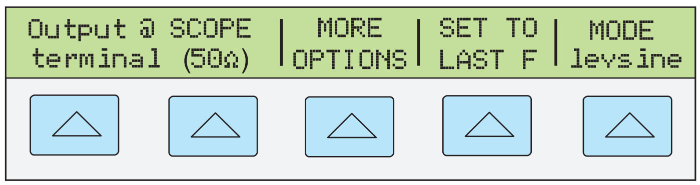
5. Do the procedure again if necessary. For example, if you did a fast sweep, it can be necessary to pinpoint a special frequency with a slow sweep over a subset of your previous frequency range.

Frequency Response Calibration Procedure for an Oscilloscope

This sample procedure, which verifies the frequency response on your oscilloscope, is usually done after the pulse response is verified.

To verify the bandwidth, this procedure finds the frequency at the -3 dB point for your oscilloscope. The reference sine wave in this procedure has an amplitude of 6 divisions, so that the -3 dB point can be found when the amplitude drops to 4.2 divisions.

Before you start this example procedure, verify that you run the oscilloscope option in Levsine mode. If you are, the Control Display shows the subsequent menu, see below.

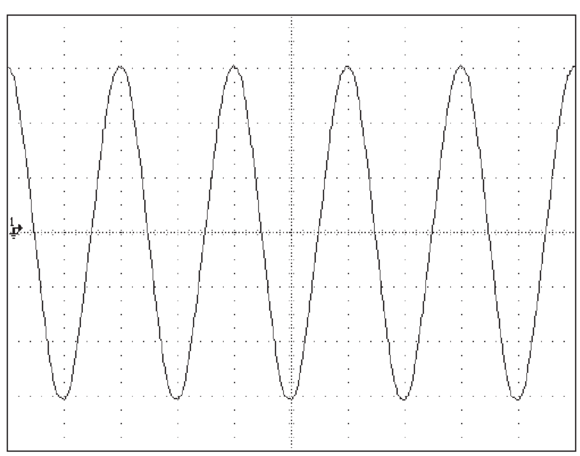


gl032i.eps

Do the subsequent sample procedure to calibrate the frequency response.

1. Push the [OPR] key on the 5502A to reconnect the signal. Select 50 Ω impedance or use a 50 Ω external termination directly at the oscilloscope input
2. Adjust the sine wave settings in the Output Display to the calibration recommendations in your oscilloscope manual. For example, for the Fluke PM3392A oscilloscope, start at 120 mV @ 50 kHz. To key in 120 mV, push [1] [2] [0] [μ m] [dBm V], and then push [ENTER].
3. Adjust the oscilloscope as necessary. The sine wave must show at six divisions, p-p, as shown below.

   If necessary, make small adjustments to the voltage amplitude until the wave gets to exactly six divisions. To fine-tune the voltage, push [EDIT FIELD] to move a cursor into the Output Display, move the cursor with the [◄] key, and turn the rotary knob to adjust the value. (See "Fine-Tuning Values" earlier in this chapter.)



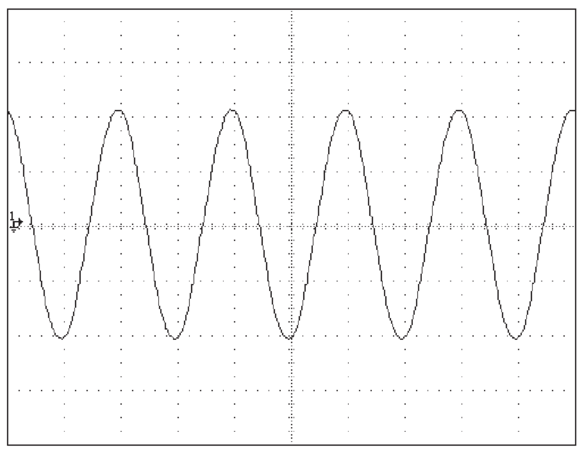
gl009i.bmp

4. Increase the frequency to 60 MHz (for 100 MHz instruments), or 150 MHz (for 200 MHz instruments). To key in 60 MHz, push [6] [0] [M] [Hz] and then push [ENTER].

5. Continue to increase the frequency slowly until the waveform decreases to 4.2 divisions, as shown below.

   To increase the frequency slowly, fine-tune it with the rotary knob. To do this, push [EDIT FIELD] to put a cursor in the Output Display. Push [EDIT FIELD] again to put it in the frequency field, and use the [◀] and [▶] keys to move it to the digit you will change. Then turn the rotary knob to change the value.

   Continue to make small adjustments in the frequency until the signal drops to 4.2 divisions. At 4.2 divisions, the signal is at the frequency that corresponds to the -3 dB point, see below.



gl010i.bmp

6. Push [STBY] to remove the input signal.

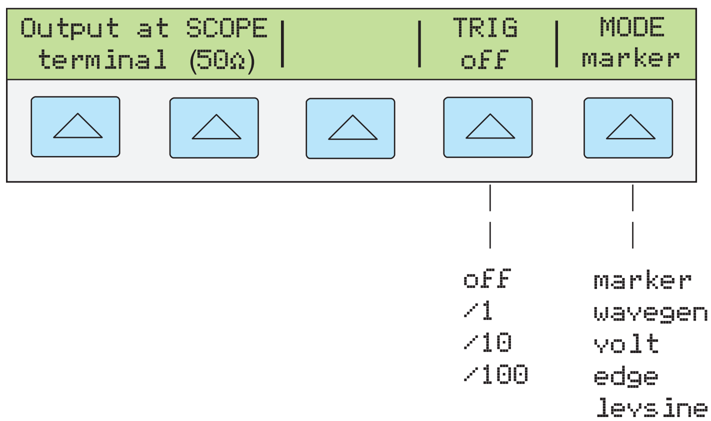
7. Do this procedure again for the channels on your oscilloscope that have not been done.

Calibrate the Time Base of an Oscilloscope

The horizontal deflection (time base) of an oscilloscope is calibrated with a method not unlike the vertical gain calibration. A time marker signal is made from the Calibrator and the peaks of the signal are aligned to the graticule line divisions on the oscilloscope.

The Time Marker Function

The Time Marker function, which is available through the Marker menu, lets you calibrate the timing response of your oscilloscope. To access the Marker menu, push the softkey below MODE until “marker” shows, see below.



gl033i.eps

Each option in the Marker menu is shown below.

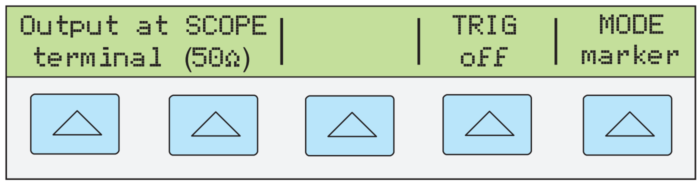
- **OUTPUT @ SCOPE terminal** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows at every 100th marker).

  You can also toggle the trigger off and on with TRIG OUT.
- **MODE** Shows you are in Marker mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

Time Base Marker Calibration Procedure for an Oscilloscope

This sample procedure uses the Time Marker function to verify the horizontal deflection (time base) of your oscilloscope. See your manual for the oscilloscope for the time base values recommended for calibration.

Before you start this procedure, make sure that you are in Marker mode. If you are, the Control Display shows the subsequent menu, see below.



gl034i.eps

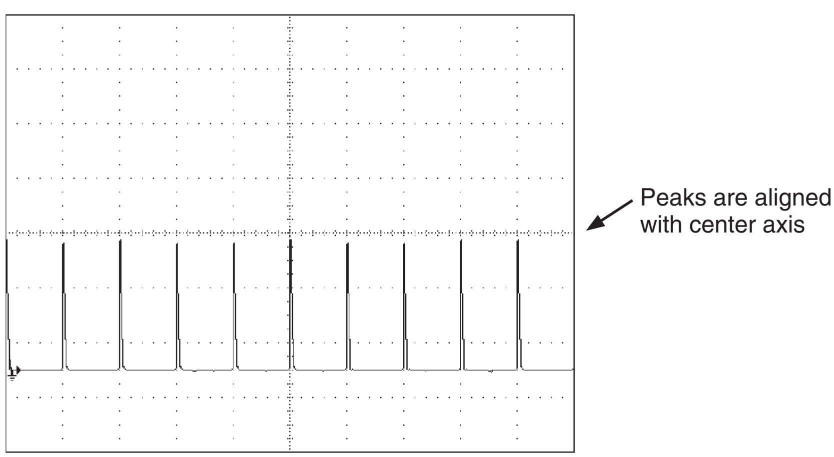
Do the subsequent sample procedure to calibrate the time base.

1. Connect the Calibrator to Channel 1 on the oscilloscope. Select 50Ω impedance or use an external 50 Ω termination. Make sure the oscilloscope is dc-coupled.
2. Apply a time marker value. Refer to the recommended calibration settings in your oscilloscope manual. For example, to key in 200 ns, push 2 0 0 SHIFT n K SHIFT sec Hz, and then push ENTER.

Note

You can record the equivalent frequency as an alternative to the time marker value. For example, as an alternative to 200 ns, you can record 5 MHz.

3. Set the time base of your oscilloscope to show 10 time markers. The time markers must align with the oscilloscope divisions, as shown in the example below. For an accurate indication, align the peaks of the signal with the horizontal center axis, see below.



gl011i.eps

4. Do this procedure again for all time marker values recommended for your oscilloscope. Do this again for digital and analog mode as necessary. It can be necessary to change some oscilloscopes magnification while you calibrate in analog mode.
5. Remove the signal with STBY.

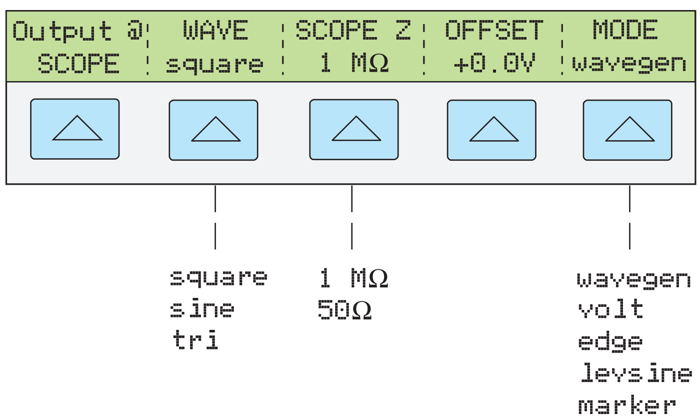
Test the Trigger

The oscilloscope can trigger on different waveforms. This can be verified with the wave generator. When the wave generator is used, a square, sine, or triangle wave is transmitted and the output impedance of the wave, offset, and voltage can be changed to examine the trigger function at different levels.

Note

The wave generator must not be used to verify the accuracy of your oscilloscope. The question mark in the Output Display shows the amplitude values are not sufficiently accurate for this function.

The wave generator is available through the Wavegen menu, shown below. To access this menu, push the softkey below MODE until "wavegen" shows, see below.



gl035i.eps

Each option in the Wavegen menu is given below.

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push OPR. To disconnect the signal, push STBY.
- **WAVE** Moves through the three types of waveforms that are available. You can select a square, sine, or triangle wave as the output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 50Ω and 1 MΩ.
- **OFFSET** Shows the offset of the generated wave. To change the offset, key in the new value, and push ENTER. The rotary knob does not change the offset, it changes the actual voltage output.

  When you change the offset, you must stay between specified limits to prevent clipping the peaks. The limit depends on the p-p value of the wave. The maximum peak excursion is equal to the offset plus half of the p-p value of the wave. See “Wave Generator Specifications” in this chapter.
- **MODE** Shows that you are in Wavegen mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

Summary of Commands and Queries

This section tells you about commands and queries that are used only for the oscilloscope calibration option. Each command description shows if it can be used with IEEE-488 and RS-232 remote interfaces and identifies it as a Sequential, Overlapped, or Coupled command.

IEEE-488 (GPIB) and RS-232 Applicability [X] IEEE-488 [X] RS-232 Each command and query have a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations.

Sequential Commands [X] Sequential Commands done immediately as occur in the data stream are named sequential commands. For more information, see “Sequential Commands” in Chapter 5.

Overlapped Commands [X] Overlapped Commands `SCOPE`, `TRIG`, and `OUT_IMP` are overlapped commands because they can be overlapped (interrupted) by the subsequent command before they are complete. When an overlapped command is interrupted, it can take longer to do the command while it stops for other commands to complete. To prevent an overlapped command from interruption during execution, use `*OPC`, `*OPC?`, or `*WAI`. These commands prevent interruptions until they sense that the command is complete. For more information, see “Overlapped Commands” in Chapter 5.

Coupled Commands [X] Coupled `SCOPE` and `OUT_IMP` are coupled commands because they can be coupled (combined) with other commands to make a compound command sequence. Precautions are necessary to make sure that commands are not coupled so that they can cause them to disable each other, since this can end in a fault. For more information, see “Coupled Commands” in Chapter 5.

SCOPE

☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Programs the oscilloscope calibration option hardware, if installed. The instrument settings are sensed by this parameter of this command. When in SCOPE mode, use the OUT command to program new output.

`OPER`, `STBY`, `*OPC`, `*OPC?`, and `*WAI` all operate as given in Chapter 6. The condition of the oscilloscope output while in SCOPE mode is reflected by the bit in the ISR that is assigned to SETTLED.

The `FUNC?` query shows `SDCV`, `SACV`, `LEVSINE`, `MARKER`, `EDGE`, and `WAVEGEN` for the related oscilloscope modes.

Parameters:

Parameters:	`OFF`	Turns off the oscilloscope hardware. Programs 0 V, 0 Hz, output at the NORMAL terminals, standby.
	`VOLT`	Oscilloscope ac and dc voltage mode. Programs 20 mV p-p, 1 kHz, output at the SCOPE BNC, output impedance 1 MΩ, standby if from `OFF` or in standby before.
	`EDGE`	Oscilloscope Edge mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from `OFF` or in standby before.
	`LEVSINE`	Oscilloscope-leveled sine mode. Programs 30 mV p-p, 50 kHz, output at the SCOPE BNC, standby if from `OFF` or in standby before.
	`MARKER`	Oscilloscope Marker mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from `OFF` or in standby before.
	`WAVEGEN`	Oscilloscope Wavegen mode. Programs 20 mV p-p, square wave, 1 kHz, no offset, output impedance 1 MΩ, standby if from `OFF` or in standby before.

Example:	`SCOPE VOLT;`	`OUT -2 V, 0 Hz`	(dc voltage, -2 V)
	`SCOPE VOLT;`	`OUT 4 V, 1 kHz`	(ac voltage, 4 V peak-to-peak, 1 kHz.)
	`SCOPE EDGE;`	`OUT 0.5 V, 5 kHz`	(Edge, 0.5 V p-p, 5 kHz.)
	`SCOPE LEVSINE;`	`OUT 1 V, 20 kHz`	(Leveled sine wave, 2 V p-p, 20 kHz.)
	`SCOPE MARKER;`	`OUT 2 MS`	(Marker, period of 2 ms.)
	`SCOPE WAVEGEN;`	`OUT 1 V, 1 kHz`	(Wave Generator, 1 V p-p, 1 kHz.)

SCOPE? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Shows the current mode of operation for the oscilloscope. Shows `OFF` if the oscilloscope is off.

Parameter:	(None)	
Response:	<character>	(Shows `OFF`, `VOLT`, `EDGE`, `LEVSINE`, `MARKER`, or `WAVEGEN`.)

TRIG [X] IEEE-488 [X] RS-232 [ ] Sequential [X] Overlapped [ ] Coupled

Programs the trigger output BNC of the oscilloscope.

Parameters:	`OFF`	(Turns off the trigger output.)
	`DIV1`	(Turns on the trigger output. Frequency is the same as the signal at `SCOPE` output.)
	`DIV10`	(Turns on the trigger output. Frequency is 1/10 of the signal at `SCOPE` output.)
	`DIV100`	(Turns on the trigger output. Frequency is 1/100 of the signal at `SCOPE` output.)

TRIG? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Shows the trigger output setting of the oscilloscope.

Parameters:	(None)	
Response:	<character>	(Shows `OFF`, `DIV1`, `DIV10`, or `DIV100`.)

OUT_IMP [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Programs the output impedance of the oscilloscope.

Parameters:	`Z50`	(Programs the output impedance of the oscilloscope to 50Ω.)
	`Z1M`	(Programs the output impedance of the oscilloscope to 1 MΩ.)

OUT_IMP? [X] IEEE-488 [X] RS-232 [X] Sequential [ ] Overlapped [ ] Coupled

Shows the output impedance setting of the oscilloscope.

Parameters:	(None)	
Response:	<character>	(Shows `Z50` or `Z1M`.)

Verification Tables

At the Fluke Calibration factory, the SC300 Option is verified to its specifications at the subsequent test points. The verification test points are given here as a guide when verification is necessary.

Table 10-1. Voltage Function Verification: AC Voltage into a 1 MΩ Load

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
5.0 mV	10 Hz			0.11 mV
5.0 mV	100 Hz			0.11 mV
5.0 mV	1 kHz			0.11 mV
5.0 mV	5 kHz			0.11 mV
5.0 mV	10 kHz			0.11 mV
10.0 mV	10 kHz			0.12 mV
20.0 mV	100 Hz			0.15 mV
20.0 mV	1 kHz			0.15 mV
20.0 mV	10 kHz			0.15 mV
50.0 mV	10 kHz			0.23 mV
89.0 mV	10 Hz			0.32 mV
89.0 mV	10 kHz			0.32 mV
100.0 mV	10 kHz			0.35 mV
200.0 mV	100 Hz			0.60 mV
200.0 mV	1 kHz			0.60 mV
200.0 mV	10 kHz			0.60 mV
500.0 mV	10 kHz			1.35 mV
890.0 mV	10 Hz			2.32 mV
890.0 mV	10 kHz			2.32 mV
1.0 V	100 Hz			2.60 mV
1.0 V	1 kHz			2.60 mV
1.0 V	10 kHz			2.60 mV
2.0 V	10 kHz			5.10 mV
5.0 V	10 Hz			12.60 mV
5.0 V	10 kHz			12.60 mV
10.0 V	10 kHz			25.10 mV
20.0 V	10 kHz			50.10 mV

Table 10-1. Voltage Function Verification: AC Voltage into a 1 MΩ Load (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
50.0 V	10 Hz			125.10 mV
50.0 V	100 Hz			125.10 mV
50.0 V	1 kHz			125.10 mV
50.0 V	10 kHz			125.10 mV
105.0 V	100 Hz			262.60 mV
105.0 V	1 kHz			262.60 mV

Table 10-2. Voltage Function Verification: AC Voltage into a 50 Ω Load

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
5.0 mV	10 Hz			0.11 mV
5.0 mV	100 Hz			0.11 mV
5.0 mV	1 kHz			0.11 mV
5.0 mV	5 kHz			0.11 mV
5.0 mV	10 kHz			0.11 mV
10.0 mV	100 Hz			0.12 mV
10.0 mV	1 kHz			0.12 mV
10.0 mV	10 kHz			0.12 mV
20.0 mV	10 kHz			0.15 mV
44.9 mV	10 Hz			0.21 mV
44.9 mV	10 kHz			0.21 mV
50.0 mV	10 kHz			0.23 mV
100.0 mV	100 Hz			0.35 mV
100.0 mV	1 kHz			0.35 mV
100.0 mV	10 kHz			0.35 mV
200.0 mV	10 kHz			0.60 mV
449.0 mV	10 Hz			1.22 mV
449.0 mV	10 kHz			1.22 mV
500.0 mV	10 kHz			1.35 mV
1.0 V	100 Hz			2.60 mV
1.0 V	1 kHz			2.60 mV
1.0 V	10 kHz			2.60 mV
2.0 V	10 Hz			5.10 mV

Table 10-2. Voltage Function Verification: AC Voltage into a 50 Ω Load (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
2.0 V	100 Hz			5.10 mV
2.0 V	1 kHz			5.10 mV
2.0 V	5 kHz			5.10 mV
2.0 V	10 kHz			5.10 mV

Table 10-3. Voltage Function Verification: DC Voltage into a 50 Ω Load

Nominal Value (dc)	Measured Value (dc)	Deviation (mV)	1-Year Spec.
0.0 mV			0.10 mV
5.0 mV			0.11 mV
-5.0 mV			0.11 mV
10.0 mV			0.12 mV
-10.0 mV			0.12 mV
22.0 mV			0.15 mV
-22.0 mV			0.15 mV
25.0 mV			0.16 mV
-25.0 mV			0.16 mV
55.0 mV			0.24 mV
-55.0 mV			0.24 mV
100.0 mV			0.35 mV
-100.0 mV			0.35 mV
220.0 mV			0.65 mV
-220.0 mV			0.65 mV
250.0 mV			0.72 mV
-250.0 mV			0.72 mV
550.0 mV			1.47 mV
-550.0 mV			1.47 mV
700.0 mV			1.85 mV
-700.0 mV			1.85 mV
2.2 V			5.60 mV
-2.2 V			5.60 mV

Table 10-4. Voltage Function Verification: DC Voltage into a 1 MΩ Load

Nominal Value (dc)	Measured Value (dc)	Deviation (mV)	1-Year Spec.
0.0 mV			0.10 mV
5.0 mV			0.11 mV
-5.0 mV			0.11 mV
22.0 mV			0.15 mV
-22.0 mV			0.15 mV
25.0 mV			0.16 mV
-25.0 mV			0.16 mV
45.0 mV			0.21 mV
-45.0 mV			0.21 mV
50.0 mV			0.23 mV
-50.0 mV			0.23 mV
220.0 mV			0.65 mV
-220.0 mV			0.65 mV
250.0 mV			0.72 mV
-250.0 mV			0.72 mV
450.0 mV			1.22 mV
-450.0 mV			1.22 mV
500.0 mV			1.35 mV
-500.0 mV			1.35 mV
3.3 V			8.35 mV
-3.3 V			8.35 mV
4.0 V			10.10 mV
-4.0 V			10.10 mV
33.0 V			82.60 mV
-33.0 V			82.60 mV

Table 10-5. Edge Function Verification

Nominal Value (p-p)	Frequency	Pulse Response Time (ηs)	1-Year Spec.
25.0 mV	1 MHz		400 ps
250.0 mV	1 MHz		400 ps
250.0 mV	10 kHz		400 ps
250.0 mV	100 kHz		400 ps
250.0 mV	1 MHz		400 ps
2.5 V	1 MHz		400 ps

Table 10-6. Wave Generator Function Verification: 1 MΩ Load

Waveform	Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
Square	5.0 mV	10 kHz			0.25 mV
Square	20.0 mV	10 kHz			0.70 mV
Square	89.0 mV	10 kHz			2.77 mV
Square	219.0 mV	10 kHz			6.67 mV
Square	890.0 mV	10 kHz			26.80 mV
Square	6.5 V	10 kHz			195.10 mV
Square	55.0 V	10 kHz			1.65 V
Sine	5.0 mV	10 kHz			0.25 mV
Sine	20.0 mV	10 kHz			0.70 mV
Sine	89.0 mV	10 kHz			2.77 mV
Sine	219.0 mV	10 kHz			6.67 mV
Sine	890.0 mV	10 kHz			26.80 mV
Sine	6.5 V	10 kHz			195.10 mV
Sine	55.0 V	10 kHz			1.65 V
Triangle	5.0 mV	10 kHz			0.25 mV
Triangle	20.0 mV	10 kHz			0.70 mV
Triangle	89.0 mV	10 kHz			2.77 mV
Triangle	219.0 mV	10 kHz			6.67 mV
Triangle	890.0 mV	10 kHz			26.80 mV
Triangle	6.5 V	10 kHz			195.10 mV
Triangle	55.0 V	10 kHz			1.65 V

Table 10-7. Wave Generator Function Verification: 50 Ω Load

Waveform	Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
Square	5.0 mV	10 kHz			0.25 mV
Square	10.9 mV	10 kHz			0.43 mV
Square	44.9 mV	10 kHz			1.45 mV
Square	109.0 mV	10 kHz			3.37 mV
Square	449.0 mV	10 kHz			13.57 mV
Square	1.1 V	10 kHz			32.50 mV
Square	2.2 V	10 kHz			66.10 mV
Sine	5.0 mV	10 kHz			0.25 mV
Sine	10.9 mV	10 kHz			0.43 mV
Sine	44.9 mV	10 kHz			1.45 mV
Sine	109.0 mV	10 kHz			3.37 mV
Sine	449.0 mV	10 kHz			13.57 mV
Sine	1.1 V	10 kHz			32.50 mV
Sine	2.2 V	10 kHz			66.10 mV
Triangle	5.0 mV	10 kHz			0.25 mV
Triangle	10.9 mV	10 kHz			0.43 mV
Triangle	44.9 mV	10 kHz			1.45 mV
Triangle	109.0 mV	10 kHz			3.37 mV
Triangle	449.0 mV	10 kHz			13.57 mV
Triangle	1.1 V	10 kHz			32.50 mV
Triangle	2.2 V	10 kHz			66.10 mV

Table 10-8. Leveled Sine Wave Function Verification: Amplitude

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
5.0 mV	50 kHz			0.300 mV
10.0 mV	50 kHz			0.400 mV
20.0 mV	50 kHz			0.600 mV
40.0 mV	50 kHz			1.000 mV
50.0 mV	50 kHz			1.200 mV
100.0 mV	50 kHz			2.200 mV
200.0 mV	50 kHz			4.200 mV

Table 10-8. Leveled Sine Wave Function Verification: Amplitude (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
400.0 mV	50 kHz			8.200 mV
500.0 mV	50 kHz			1.200 mV
1.3 V	50 kHz			26.200 mV
2.0 V	50 kHz			40.200 mV
5.5 V	50 kHz			110.200 mV

Table 10-9. Leveled Sine Wave Function Verification: Flatness

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
5.0 mV	500 kHz			0.17 mV
5.0 mV	1 MHz			0.17 mV
5.0 mV	1 MHz			0.17 mV
5.0 mV	2 MHz			0.17 mV
5.0 mV	5 MHz			0.17 mV
5.0 mV	10 MHz			0.17 mV
5.0 mV	20 MHz			0.17 mV
5.0 mV	50 MHz			0.17 mV
5.0 mV	100 MHz			0.17 mV
5.0 mV	125 MHz			0.20 mV
5.0 mV	160 MHz			0.20 mV
5.0 mV	200 MHz			0.20 mV
5.0 mV	220 MHz			0.20 mV
5.0 mV	235 MHz			0.20 mV
5.0 mV	250 MHz			0.20 mV
10.0 mV	500 kHz			0.25 mV
10.0 mV	1 MHz			0.25 mV
10.0 mV	1 MHz			0.25 mV
10.0 mV	2 MHz			0.25 mV
10.0 mV	5 MHz			0.25 mV
10.0 mV	10 MHz			0.25 mV
10.0 mV	20 MHz			0.25 mV
10.0 mV	50 MHz			0.25 mV
10.0 mV	100 MHz			0.25 mV
10.0 mV	125 MHz			0.30 mV

Table 10-9. Leveled Sine Wave Function Verification: Flatness (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
10.0 mV	160 MHz			0.30 mV
10.0 mV	200 MHz			0.30 mV
10.0 mV	220 MHz			0.30 mV
10.0 mV	235 MHz			0.30 mV
10.0 mV	250 MHz			0.30 mV
40.0 mV	500 kHz			0.70 mV
40.0 mV	1 MHz			0.70 mV
40.0 mV	1 MHz			0.70 mV
40.0 mV	2 MHz			0.70 mV
40.0 mV	5 MHz			0.70 mV
40.0 mV	10 MHz			0.70 mV
40.0 mV	20 MHz			0.70 mV
40.0 mV	50 MHz			0.70 mV
40.0 mV	100 MHz			0.70 mV
40.0 mV	125 MHz			0.90 mV
40.0 mV	160 MHz			0.90 mV
40.0 mV	200 MHz			0.90 mV
40.0 mV	220 MHz			0.90 mV
40.0 mV	235 MHz			0.90 mV
40.0 mV	250 MHz			0.90 mV
100.0 mV	500 kHz			1.60 mV
100.0 mV	1 MHz			1.60 mV
100.0 mV	1 MHz			1.60 mV
100.0 mV	2 MHz			1.60 mV
100.0 mV	5 MHz			1.60 mV
100.0 mV	10 MHz			1.60 mV
100.0 mV	20 MHz			1.60 mV
100.0 mV	50 MHz			1.60 mV
100.0 mV	100 MHz			1.60 mV
100.0 mV	125 MHz			2.10 mV
100.0 mV	160 MHz			2.10 mV
100.0 mV	200 MHz			2.10 mV

Table 10-9. Leveled Sine Wave Function Verification: Flatness (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
100.0 mV	220 MHz			2.10 mV
100.0 mV	235 MHz			2.10 mV
100.0 mV	250 MHz			2.10 mV
400.0 mV	500 kHz			6.10 mV
400.0 mV	1 MHz			6.10 mV
400.0 mV	1 MHz			6.10 mV
400.0 mV	2 MHz			6.10 mV
400.0 mV	5 MHz			6.10 mV
400.0 mV	10 MHz			6.10 mV
400.0 mV	20 MHz			6.10 mV
400.0 mV	50 MHz			6.10 mV
400.0 mV	100 MHz			6.10 mV
400.0 mV	125 MHz			8.10 mV
400.0 mV	160 MHz			8.10 mV
400.0 mV	200 MHz			8.10 mV
400.0 mV	220 MHz			8.10 mV
400.0 mV	235 MHz			8.10 mV
400.0 mV	250 MHz			8.10 mV
1.3 V	500 kHz			19.60 mV
1.3 V	1 MHz			19.60 mV
1.3 V	1 MHz			19.60 mV
1.3 V	2 MHz			19.60 mV
1.3 V	5 MHz			19.60 mV
1.3 V	10 MHz			19.60 mV
1.3 V	20 MHz			19.60 mV
1.3 V	50 MHz			19.60 mV
1.3 V	100 MHz			19.60 mV
1.3 V	125 MHz			26.10 mV
1.3 V	160 MHz			26.10 mV
1.3 V	200 MHz			26.10 mV
1.3 V	220 MHz			26.10 mV
1.3 V	235 MHz			26.10 mV

Table 10-9. Leveled Sine Wave Function Verification: Flatness (cont.)

Nominal Value (p-p)	Frequency	Measured Value (p-p)	Deviation (mV)	1-Year Spec.
1.3 V	250 MHz			26.10 mV
5.5 V	500 kHz			82.5 mV
5.5 V	1 MHz			82.5 mV
5.5 V	1 MHz			82.5 mV
5.5 V	2 MHz			82.5 mV
5.5 V	5 MHz			82.5 mV
5.5 V	10 MHz			82.5 mV
5.5 V	20 MHz			82.5 mV
5.5 V	50 MHz			82.5 mV
5.5 V	100 MHz			82.5 mV
5.5 V	125 MHz			110.00 mV
5.5 V	160 MHz			110.00 mV
5.5 V	200 MHz			110.00 mV
5.5 V	220 MHz			110.00 mV
5.5 V	235 MHz			110.00 mV
5.5 V	250 MHz			110.00 mV

Table 10-10. Leveled Sine Wave Function Verification: Frequency

Nominal Value (p-p)	Frequency	Measured Frequency	Deviation	1-Year Spec.
1.3 V	50 kHz			0.0013 kHz
1.3 V	10 MHz			0.0003 MHz
1.3 V	250 MHz			0.0063 MHz

Table 10-11. Marker Generator Function Verification

Nominal Interval	Measured Interval	Deviation	1-Year Spec.
5s			25.12 ms
2.00s			4.05 ms
1s			1.03 ms
500.00 ms			262.50 µs
200.00 ms			45.00 µs
100.00 ms			12.50 µs
50.00 ms			3.75 µs
20.00 ms			900.000 ns
10.00 ms			350.00 ns
5.00 ms			150.00 ns
2.00 ms			54.000 ns
1.00 ms			26.000 ns
500.00 µs			12.750 ns
200.00 µs			5.040 ns
100.00 µs			2.510 ns
50.00 µs			1.287 ns
20.00 µs			0.506 ns
10.00 µs			0.252 ns
5.00 µs			0.125 ns
2.00 µs			0.050 ns
1.00 µs			0.025 ns
500.000 ns			0.013 ns
200.000 ns			5.000 ps
100.000 ns			2.500 ps
50.000 ns			1.250 ps
20.000 ns			0.500 ps
10.000 ns			0.250 ps
5.000 ns			0.125 ps
2.000 ns			0.050 ps

Appendix A
Glossary

adc (analog-to-digital converter)
A device or circuit that changes an analog signal to digital signals.

absolute uncertainty
Uncertainty specifications that include the error contributions made by all equipment and standards used to calibrate the instrument. Absolute uncertainty is the numbers to compare with the UUT to verify uncertainty ratio.

accuracy
The degree to which the measured value of a quantity agrees with the correct value of that quantity. For example, an instrument specified to $\pm$1% uncertainty is 99% accurate.

apparent power
The power value that you get when you multiply the ac current by the ac voltage on a circuit without consideration of phase relationships between the two waveforms. (See "true power" for comparison.)

assert
To cause a digital signal to go into a logic true condition.

af (audio frequency)
The frequency range of human hearing, typically 15,000 - 20,000 Hz.

artifact standard
An object that makes or embodies a physical quantity to be standardized, for example a Fluke Calibration 732A DC Voltage Reference Standard.

base units
Units in the SI system that are dimensionally independent. All other units are derived from base units. The only base unit in electricity is the ampere.

buffer

1. An area of digital memory for temporary storage of data.
2. An amplifier stage before the final amplifier.

burden voltage

The maximum sustainable voltage across the terminals of a load.

compliance voltage

The maximum voltage a constant-current source can supply.

control chart

A chart made to monitor one or more procedures to sense the radical deviation from a necessary value of a component or procedure.

crest factor

The ratio of the peak voltage to the rms voltage of a waveform (with the dc component removed).

dac (digital-to-analog converter)

A device or circuit that changes a digital waveform to an analog voltage.

dBm

A reference power level of 1 mW expressed in decibels.

derived units

Units in the SI system that are derived from base units. Volts, ohms, and watts are derived from amperes and other base and derived units.

displacement power factor

Refers to the displacement component of power factor; the ratio of the active power of the fundamental wave, in watts, to the apparent power of the fundamental wave, in volt-amperes.

distortion

Undesired changes in the waveform of a signal. Harmonic distortion disturbs the initial relationship between a frequency and other frequencies naturally related to it. Intermodulation distortion (imd) introduces new frequencies by the mixing of two or more initial frequencies. Other types of distortion are phase distortion and transient distortion.

errors

The different types of errors given in this glossary are “offset error,” “linearity error,” “random error,” “scale error,” “systematic errors,” and “transfer error.”

flatness

A measure of the variation of the actual output of an ac voltage source at different frequency points when set to the same nominal output level. A flat voltage source shows very little error in its frequency range.

floor

The part of the uncertainty specification of an instrument that is typically a set offset plus noise. Floor can be shown as units, such as microvolts or counts of the least significant digit. For the 5502A, the floor specification is combined with set range errors in one term to find total uncertainty.

full scale

The maximum indication of a range of a meter, analog-to-digital converter, or other measurement device, or the maximum attainable output on a range of a calibrator.

gain error

Same as scale error. Scale or gain error results when the slope of the response curve of the meter is not exactly 1. A meter with only gain error (no offset or linearity error), will read 0 V with 0 V applied, but something other than 10 V with 10 V applied.

ground

The voltage reference point in a circuit. Earth ground is a connection through a ground rod or other conductor to the earth, usually accessible through the ground conductor in an ac power receptacle.

ground loops

Undesirable currents induced when there is more than one chassis ground potential in a system of instruments. Ground loops can be minimized by connecting all instruments in a system to ground to one point.

guard

See “voltage guard”.

harmonics

A waveform that is an integral multiple of the fundamental frequency. For example, a waveform that is two times the frequency of a fundamental is called the second harmonic.

IPTS-68

Refers to the International Provisional Temperature Standard (1968), replaced by the International Temperature Standard (1990). This specifies the definition of the °C temperature standard.

ITS-90

Refers to the International Temperature Standard (1990), which replaced the International Provisional Temperature Standard (1968). This specifies the definition of the °C temperature standard.

International Systems of Units

Same as “SI System of Units,” the accepted system of units. See also “units,” “base units,” and “derived units.”

legal units

The highest echelon in a system of units, for example the U.S. National Bureau of Standards volt.

life-cycle cost

The consideration of all elements that contribute to the cost of an instrument through its useful life. This includes initial purchase cost, service and maintenance cost, and the cost of support equipment.

linearity

The relationship between two quantities when a change is the first quantity is directly proportional to a change in the second quantity.

linearity error

Linearity error occurs when the response curve of a meter is not exactly a straight line. This type of error is measured by fixing two points on the response curve, drawing a line through the points, then measuring how far the curve deviates from the straight line at different points in the response curve.

MAP (Measurement Assurance Program)

A program for measurement process. A MAP provides information to demonstrate that the total uncertainty of the measurements (data), that includes random error and systematic components of error relative to national or other designated standards is quantified, and sufficiently small to meet requirements.

MTBF (Mean Time Between Failures)

The time interval in operating hours that can be expected between failure of equipment. MTBF can be calculated from direct observation or mathematically derived through extrapolation.

MTTF (Mean Time To Fail)

The time interval in operating hours that can be expected until the first failure of equipment. MTTF can be calculated from direct observation or mathematically derived through extrapolation.

MTTR (Mean Time to Repair)

The average time in hours necessary to repair failed equipment.

metrology

The science of, and the field of knowledge concerned with measurement.

minimum use specifications

A compilation of specifications that satisfies the calibration requirements of a measurement system or device. The minimum use specifications are usually determined by maintaining a specified test uncertainty ratio between the calibration equipment and the unit under test.

noise

A signal that contains no useful information that is superimposed on a necessary or expected signal.

normal mode noise

An undesired signal that shows between the terminals of a device.

offset error

Same as zero error. The indication shown on a meter when an input value of zero is applied is its offset or zero error.

parameters

Independent variables in a measurement procedure such as temperature, humidity, test lead resistance, etc.

power factor

The ratio of actual power used in a circuit, shown in watts, to the power which is apparently pulled from the source, expressed in volt-amperes.

precision

The precision of a measurement procedure is the coherence, or the closeness to the one result, of all measurement results. High precision, for example, completes in a tight pattern of arrow hits on a target, without respect to where on the target the tight pattern falls.

predictability

A measure of how accurately the output value of a device can be assumed after a known time after calibration. If a device is highly stable, it is also predictable. If a device is not highly stable, but its value changes at the same rate each time after calibration, its output has a higher degree of predictability than a device that exhibits random change.

primary standard

A standard specified and maintained by some authority and used to calibrate all other secondary standards.

process metrology

When the accuracy drift of calibration and other equipment is monitored with statistical analysis to correction factors received during calibration.

random error

All errors which can change in an unpredictable manner in absolute value and in sign when measurements of the same value of a quantity are made under effectively the same conditions.

range

The stated maximum end of a measurement span of a device. Typically, a measurement device can measure quantities for a specified percentage overrange. (The absolute span that includes overrange capability is named “scale.”) In the 5502A, range and scale are identical.

reference standard

The highest-echelon standard in a laboratory. The standard that is used to maintain working standards that are used in regular calibration and comparison procedures.

relative uncertainty

5502A uncertainty specifications that exclude the effects of external dividers and standards, for use when range constants are adjusted. Relative uncertainty includes only the stability, temperature coefficient, noise, and linearity specifications of the 5502A itself.

reliability

A measure of the “uptime” of an instrument.

repeatability
The degree of agreement among independent measurements of a quantity under the same conditions.

resistance
A property of a conductor that finds the amount of current that will flow when a given amount of voltage exists across the conductor. Resistance is measured in ohms. One ohm is the resistance through which one volt of potential will cause one ampere of current to flow.

resolution
The smallest change in quantity that can be sensed by a measurement system or device. For a given parameter, resolution is the smallest increment that can be measured, generated, or shown.

rf (radio frequency)
The frequency range of radio waves; from 150 kHz to the infrared range.

rms (root-mean-square)
The value given to an ac voltage or current that ends in the same power dissipation in a resistance as a dc current or voltage of equal value.

rms sensor
A device that changes ac voltage to dc voltage with very good accuracy. RMS sensors operate by measuring the heat caused by a voltage through a known resistance (i.e., power). They sense true rms voltage.

resistance temperature detector (RTD)
A resistance device that gives a proportional resistance output for a temperature of the device. Most RTDs are characterized by their resistance at 0 °C, called the ice point. The most common ice point is 100 Ω at 0 °C. The curve of resistance vs. temperature can be one of several: pt385 (0.00385 ohms/ohm/°C) and pt3926 (0.003926 ohms/ohm/°C) are examples.

scale
The absolute span of the reading range of a measurement device that includes overrange capability.

scale error
Same as gain error. Scale or gain error results when the slope of the meter’s response curve is not exactly 1. A meter with only scale error (no offset or linearity error), will read 0V with 0V applied, but something other than 10V with 10V applied.

secondary standard
A standard maintained by comparison against a primary standard.

sensitivity
The degree of response of a measuring device to the change in input quantity, or a figure of merit that expresses the ability of a measurement system or device to respond to an input quantity.

shield
A grounded covering device that is made to protect a circuit or cable from electromagnetic interference.

SI System of Units
The accepted International System of Units. See also “units,” “base units,” and “derived units.”

specifications
An accurate statement of the set of requirements satisfied by a measurement system or device.

stability
A measure of the freedom from drift in value over time and over changes in other variables such as temperature. Note that stability is not the same as uncertainty.

standard
A device that is used as an exact value for reference and comparison.

standard cell
A primary cell that serves as a standard of voltage. The term “standard cell” often refers to a “Weston normal cell,” which is a wet cell with a mercury anode, a cadmium mercury amalgam cathode, and a cadmium sulfate solution as the electrolyte.

systematic errors
Errors in repeated measurement results that stay constant or change in a predictable way.

temperature coefficient
A factor per °C deviation from a nominal value or range that the uncertainty of an instrument increases. This specification is necessary to account for the thermal coefficients of analog circuitry in the Calibrator.

test uncertainty ratio
The numerical ratio of the uncertainty of the measurement system or device being calibrated to the uncertainty of the measurement system or device used as the calibrator. (Also called “test accuracy ratio.”)

thermal emf
The voltage made when two dissimilar metals connected together are heated.

thermocouple
Two dissimilar metals that, when welded together, develop a small voltage dependent on the relative temperature between the hotter and colder junction.

traceability
The power to show individual measurement results to national standards or nationally accepted measurement systems through an unbroken chain of comparisons, i.e., a calibration “audit trail.”

Measurements, measurement systems or devices have traceability to the designated standards if and only if scientifically rigorous evidence is given on a continuing basis to show that the measurement procedure is producing measurement results for which the total measurement uncertainty relative to national or other designated standards is qualified.

transfer error
The sum of all new errors induced in the process of comparing one quantity against A different quantity.

transfer standard
A working standard used to compare a measurement process, system, or device at one location or level with a different measurement process, system, or device at a different location or level.

transport standard
A transfer standard that is rugged enough for shipment by common carrier to a different location.

true power
The actual power (real power) used to cause heat or work. Compare to “apparent power.”

true value
Also named legal value, the accepted, consensus, for example, the correct value of the quantity that is measured.

uncertainty
The maximum difference between the accepted, consensus, or true value and the measured value of a quantity. Uncertainty is typically shown in units of ppm (parts per million) or as a percentage.

units
Symbols or names that specify the measured quantities. Examples of units are: V, mV, A, kW, and dBm. See also “SI System of Units.”

UUT (Unit Under Test)
An abbreviated name for an instrument that is verified or calibrated.

var
Symbol for voltampere reactive, the unit of reactive power, as opposed to real power in watts.

verification
When the functional performance and uncertainty of an instrument or standard is examined without adjustments or changes to its calibration constants.

volt
The unit of emf (electromotive force) or electrical potential in the SI system of units. One volt is the difference of electrical potential between two points on a conductor that transmitts one ampere of current, when the power being dissipated between these two points is equal to one watt.

voltage guard
A shield that floats around voltage measurement circuitry inside an instrument. The voltage guard gives a low-impedance path to ground for common-mode noise and ground currents. This removes errors introduced by such interference.

watt
The unit of power in the SI system of units. One watt is the power necessary to do work at the rate of one joule/second. In terms of volts and ohms, one watt is the power dissipated by one ampere that flows through a one-ohm load.

working standard
A standard that is used in routine calibration and comparison procedures in the laboratory and is maintained by comparison to reference standards.

zero error
Same as offset error. The indication shown on a meter when an input value of zero is applied is its zero or offset error.

Appendix B
ASCII and IEEE-488 Bus Codes

ASCII CHAR.	DECIMAL	OCTAL	HEX	BINARY 7654 3210	DEV. NO.	MESSAGE ATN=TRUE		ASCII CHAR.	DECIMAL	OCTAL	HEX	BINARY 7654 3210	DEV. NO.	MESSAGE ATN=TRUE	
NUL	0	000	00	0000 0000			ADDRESSED COMMANDS	@	64	100	40	0100 0000	0	MTA	TALK ADDRESSES
SQH	1	001	01	0000 0001		GTL		A	65	101	41	0100 0001	1	MTA	
STX	2	002	02	0000 0010				B	66	102	42	0100 0010	2	MTA	
ETX	3	003	03	0000 0011				C	67	103	43	0100 0011	3	MTA	
EOT	4	004	04	0000 0100		SDC		D	68	104	44	0100 0100	4	MTA	
ENQ	5	005	05	0000 0101		PPC		E	69	105	45	0100 0101	5	MTA	
ACH	6	006	06	0000 0110				F	70	106	46	0100 0110	6	MTA	
BELL	7	007	07	0000 0111				G	71	107	47	0100 0111	7	MTA	
BS	8	010	08	0000 1000		GET		H	72	110	48	0100 1000	8	MTA	
HT	9	011	09	0000 1001		TCT		I	73	111	49	0100 1001	9	MTA	
LF	10	012	0A	0000 1010				J	74	112	4A	0100 1010	10	MTA	
VT	11	013	0B	0000 1011				K	75	113	4B	0100 1011	11	MTA	
FF	12	014	0C	0000 1100				L	76	114	4C	0100 1100	12	MTA	
CR	13	015	0D	0000 1101				M	77	115	4D	0100 1101	13	MTA	
SO	14	016	0E	0000 1110				N	78	116	4E	0100 1110	14	MTA	
SI	15	017	0F	0000 1111				O	79	117	4F	0100 1111	15	MTA	
DLE	16	020	10	0001 0000			UNIVERSAL COMMANDS	P	80	120	50	0101 0000	16	MTA	
DC1	17	021	11	0001 0001		LLO		Q	81	121	51	0101 0001	17	MTA	
DC2	18	022	12	0001 0010				R	82	122	52	0101 0010	18	MTA	
DC3	19	023	13	0001 0011				S	83	123	53	0101 0011	19	MTA	
DC4	20	024	14	0001 0100		DCL		T	84	124	54	0101 0100	20	MTA	
NAK	21	025	15	0001 0101		PPU		U	85	125	55	0101 0101	21	MTA	
SYN	22	026	16	0001 0110				V	86	126	56	0101 0110	22	MTA	
ETB	23	027	17	0001 0111				W	87	127	57	0101 0111	23	MTA	
CAN	24	030	18	0001 1000		SPE		X	88	130	58	0101 1000	24	MTA	
EM	25	031	19	0001 1001		SPD		Y	89	131	59	0101 1001	25	MTA	
SUB	26	032	1A	0001 1010				Z	90	132	5A	0101 1010	26	MTA	
ESC	27	033	1B	0001 1011				[	91	133	5B	0101 1011	27	MTA	
FS	28	034	1C	0001 1100				\	92	134	5C	0101 1100	28	MTA	
GS	29	035	1D	0001 1101				]	93	135	5D	0101 1101	29	MTA	
RS	30	036	1E	0001 1110				^	94	136	5E	0101 1110	30	MTA	
US	31	037	1F	0001 1111				_	95	137	5F	0101 1111		UNT	
SPACE	32	040	20	0010 0000	0	MLA	LISTEN ADDRESSES	‘	96	140	60	0111 0000	0	MSA	SECONDARY ADDRESSES
!	33	041	21	0010 0001	1	MLA		a	97	141	61	0111 0001	1	MSA	
"	34	042	22	0010 0010	2	MLA		b	98	142	62	0111 0010	2	MSA	
#	35	043	23	0010 0011	3	MLA		c	99	143	63	0111 0011	3	MSA	
$	36	044	24	0010 0100	4	MLA		d	100	144	64	0111 0100	4	MSA	
%	37	045	25	0010 0101	5	MLA		e	101	145	65	0111 0101	5	MSA	
&	38	046	26	0010 0110	6	MLA		f	102	146	66	0111 0110	6	MSA	
'	39	047	27	0010 0111	7	MLA		g	103	147	67	0111 0111	7	MSA	
(	40	050	28	0010 1000	8	MLA		h	104	150	68	0111 1000	8	MSA	
)	41	051	29	0010 1001	9	MLA		i	105	151	69	0111 1001	9	MSA	
*	42	052	2A	0010 1010	10	MLA		j	106	152	6A	0111 1010	10	MSA	
+	43	053	2B	0010 1011	11	MLA		k	107	153	6B	0111 1011	11	MSA	
,	44	054	2C	0010 1100	12	MLA		l	108	154	6C	0111 1100	12	MSA	
—	45	055	2D	0010 1101	13	MLA		m	109	155	6D	0111 1101	13	MSA	
.	46	056	2E	0010 1110	14	MLA		n	110	156	6E	0111 1110	14	MSA	
/	47	057	2F	0010 1111	15	MLA		o	111	157	6F	0111 1111	15	MSA	
0	48	060	30	0011 0000	16	MLA		p	112	160	70	0111 0000	16	MSA	
1	49	061	31	0011 0001	17	MLA		q	113	161	71	0111 0001	17	MSA	
2	50	062	32	0011 0010	18	MLA		r	114	162	72	0111 0010	18	MSA	
3	51	063	33	0011 0011	19	MLA		s	115	163	73	0111 0011	19	MSA	
4	52	064	34	0011 0100	20	MLA		t	116	164	74	0111 0100	20	MSA	
5	53	065	35	0011 0101	21	MLA		u	117	165	75	0111 0101	21	MSA	
6	54	066	36	0011 0110	22	MLA		v	118	166	76	0111 0110	22	MSA	
7	55	067	37	0011 0111	23	MLA		w	119	167	77	0111 0111	23	MSA	
8	56	070	38	0011 1000	24	MLA		x	120	170	78	0111 1000	24	MSA	
9	57	071	39	0011 1001	25	MLA		y	121	171	79	0111 1001	25	MSA	
:	58	072	3A	0011 1010	26	MLA		z	122	172	7A	0111 1010	26	MSA	
;	59	073	3B	0011 1011	27	MLA		{	123	173	7B	0111 1011	27	MSA	
<	60	074	3C	0011 1100	28	MLA		|	124	174	7C	0111 1100	28	MSA	
=	61	075	3D	0011 1101	29	MLA		}	125	175	7D	0111 1101	29	MSA	
>	62	076	3E	0011 1110	30	MLA		~	126	176	7E	0111 1110	30	MSA	
?	63	077	3F	0011 1111		UNL			127	177	7F	0111 1111		UNS	

fb-01.eps

Appendix C
RS-232/IEEE-488 Cables and Connectors

IEEE-488 Connector

The IEEE-488 connector on the rear panel connects with an IEEE-488 standard cable. The pin assignments of the rear-panel IEEE-488 connector are shown in Figure C-1. IEEE-488 connection cables are available from Fluke Calibration as shown in Table C-1. See Chapter 8, “Accessories,” for order information.

Table C-1. IEEE-488 Connection Cables

IEEE-488 Connection Cable	Fluke Calibration Part Number
1 m (3.28 feet)	Y8021
2 m (6.56 feet)	Y8022

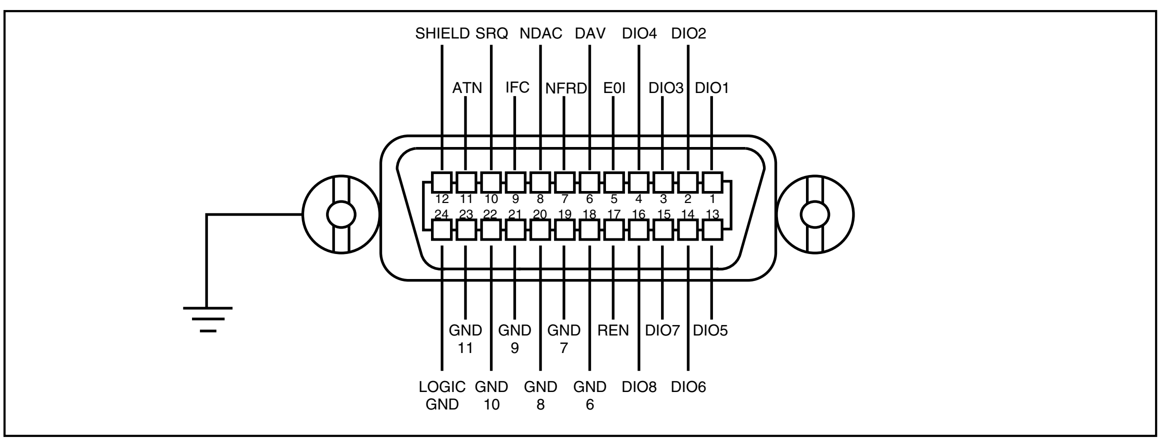


Figure C-1. IEEE-488 Connector Pinout (connection side)

Serial Connectors

The two 9-pin serial connectors on the rear panel of the 5502A Calibrator are used to interface with a computer, or controller, and an instrument serial port. The pin assignments of the rear-panel serial connectors are in conformance to EIA/TIA-574 standard and are shown in Figures C-2 (Host) and C-3 (UUT).

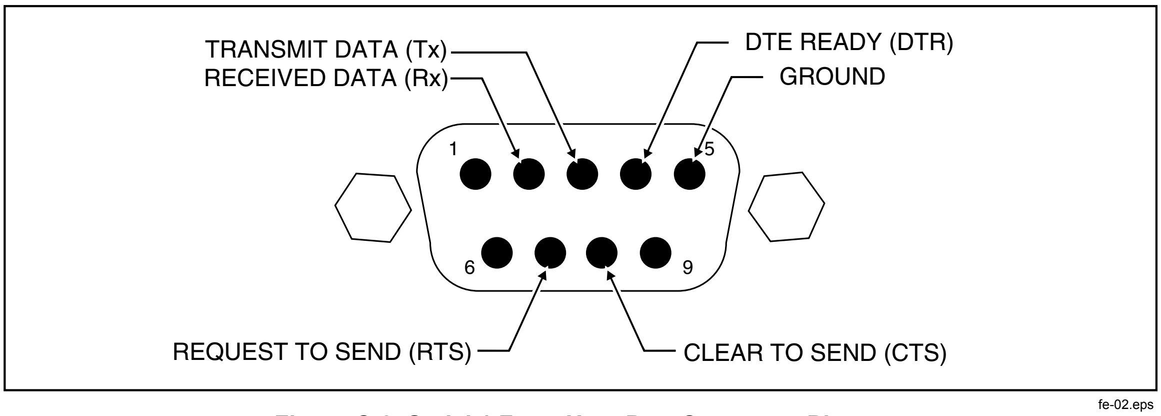


Figure C-2. Serial 1 From Host Port Connector Pinout

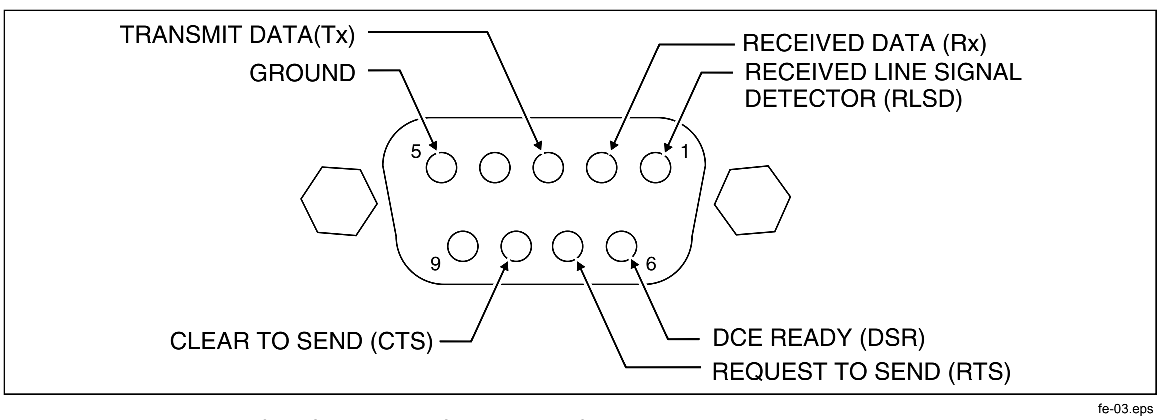


Figure C-3. SERIAL 2 TO UUT Port Connector Pinout (connection side)

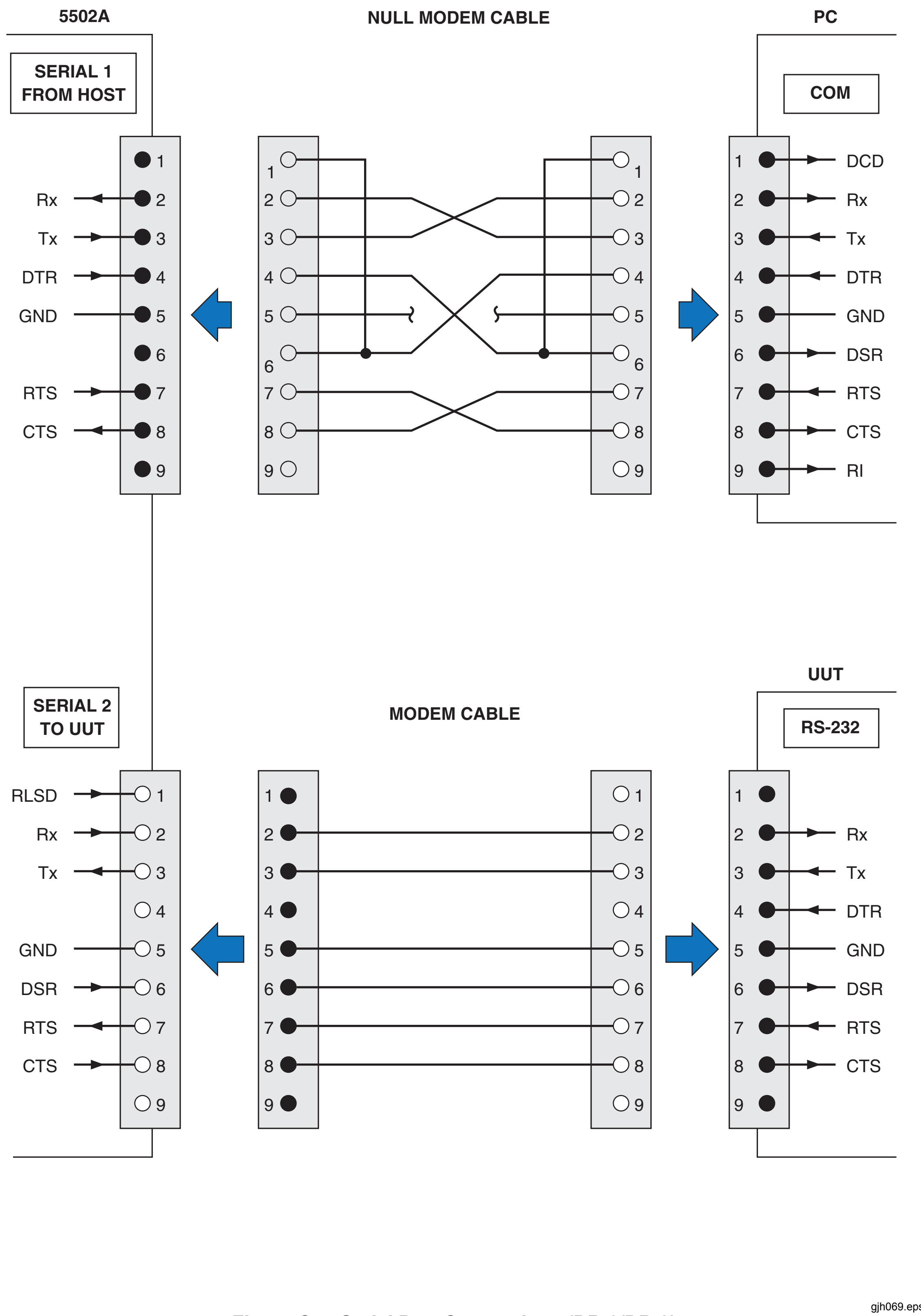


Figure C-4. Serial Port Connections (DB-9/DB-9)

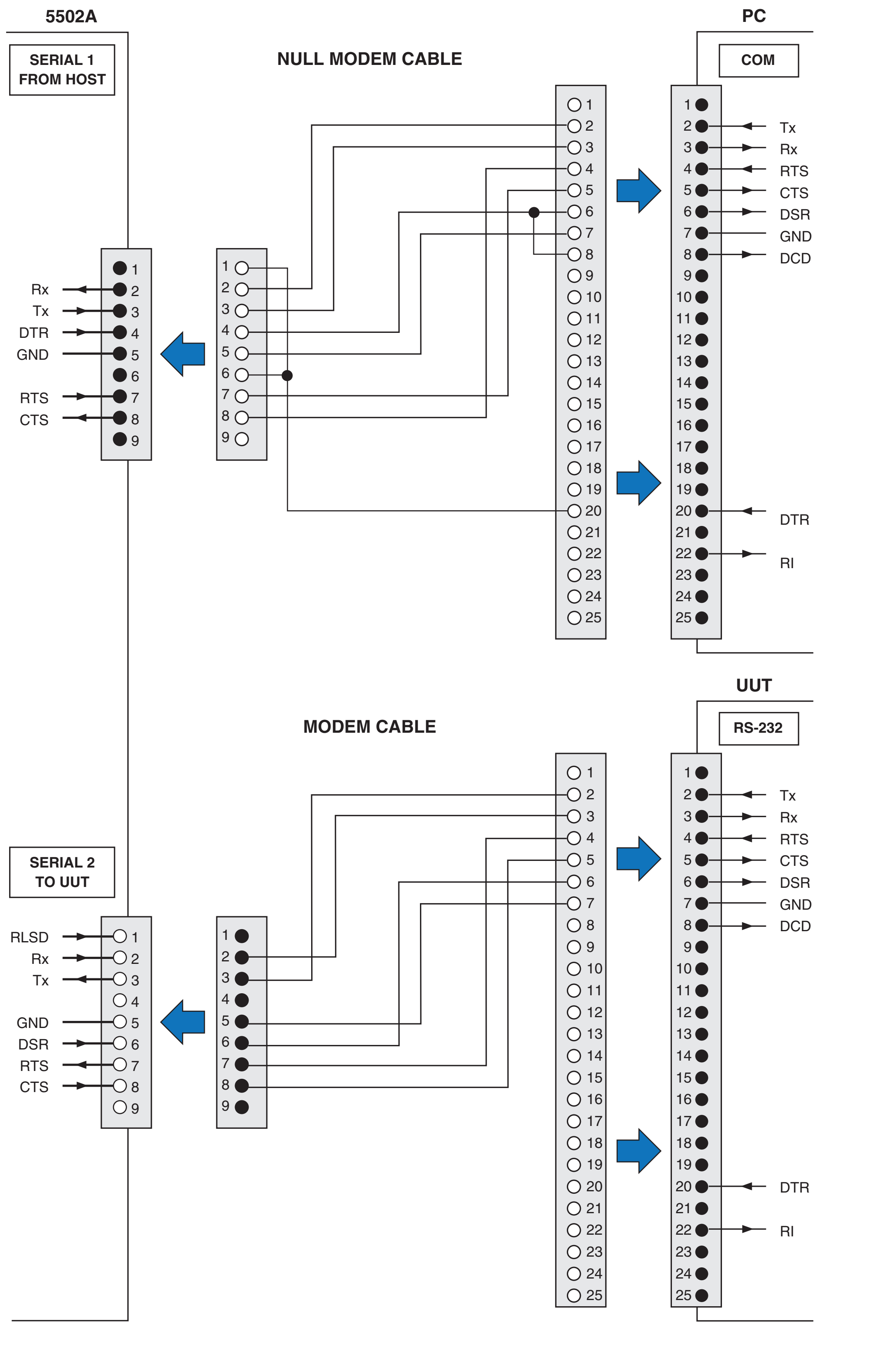


Figure C-5. Serial Port Connections (DB-9/DB-25)

Appendix D
Error Messages

Error Messages

The subsequent is a list of the Calibrator error messages. The error message format is shown in Table D-1.

Table D-1. Error Messages Format

Error Number	(Message Class :	Description)	Text Characters
0 to 65535	**QYE** Query Error, caused by a full input buffer, unterminated procedure or interrupted procedure	**F** Error is shown on the front panel as it occurs	To a maximum of 36 text characters
	DDE Device-Specific Error, caused by the 5502A because of some condition, for example, overrange	**R** Error is queued to the remote interface as it occurs	
	EXE Execution Error, caused by an element that is inconsistent with the 5502A functions	**S** Error causes instrument to go to Standby	
	CME Command Error, caused by incorrect command syntax, unrecognized header, or parameter of the incorrect type	**D** Error causes instrument to go to the power up condition	
		(none) Error is given to the initiator only (i.e., local initiator or remote initiator)	

0	(QYE:)	No Error
1	(DDE:FR)	Error queue overflow
100	(DDE:FR D)	Inguard not responding (send)
101	(DDE:FR D)	Inguard not responding (recv)
102	(DDE:FR D)	Lost sync with inguard
103	(DDE:FR)	Invalid guard xing command
104	(DDE:FR D)	Hardware relay trip occurred
105	(DDE:FR D)	Inguard got impatient

106	(DDE:FR D)	A/D fell asleep
107	(DDE:FR D)	Inguard watchdog timeout
108	(DDE:FR)	Inguard is obsolete
109	(DDE:FR D)	Inguard parity error
110	(DDE:FR D)	Inguard overrun error
111	(DDE:FR D)	Inguard framing error
112	(DDE:FR D)	Inguard fault error
113	(DDE:FR D)	Inguard fault input error
114	(DDE:FR D)	Inguard fault detect error
115	(DDE:FR D)	Inguard read/write error
116	(DDE:FR D)	Received unexpected data (IG)
200	(DDE:DR D)	Cannot download waveform
300	(DDE:)	Invalid procedure number
301	(DDE:)	No such step in procedure
302	(DDE:)	Cannot change that while busy
303	(DDE:)	Cannot begin/resume cal there
304	(DDE:)	Wrong unit for reference
305	(DDE:)	Entered value out of bounds
306	(DDE:)	Not waiting for a reference
307	(DDE:)	Continue command ignored
308	(DDE:FR)	Cal constant outside limits
309	(DDE:FR)	Cal try to null failed
310	(DDE:FR D)	Sequence failed during cal
311	(DDE:FR D)	A/D measurement failed
312	(DDE:FR)	Invalid cal step parameter
313	(DDE:)	Cal switch must be ENABLED
314	(DDE:FR)	Divide by zero encountered
315	(DDE:FR)	Must be in OPER at this step
316	(DDE:FR)	Open thermocouple for RJ cal
317	(DDE:FR)	Bad reference Z or entry
318	(DDE:FR)	Cal takes DAC over top limit
319	(DDE: R)	Zero cal needed every 7 days
320	(DDE: R)	Ohms zero needed every 12 hours
398	(QYE:F)	Unusual cal fault %d
399	QYE:F)	Fault during %s
400	(DDE:FR D)	Encoder not responding VERS
401	(DDE:FR D)	Encoder not responding COMM
402	(DDE:FR D)	Encoder not responding STAT
403	(DDE:FR)	Encoder self-test failed
405	(DDE:FR)	Message over display R side
406	(DDE:FR)	Unmappable character #%d
407	(DDE:FR)	Encoder did not reset
408	(DDE:FR)	Encoder got invalid command
409	(DDE:FR D)	Encoder unexpectedly reset
500	(DDE:)	Internal state error
501	(DDE:)	Invalid keyword or choice
502	(DDE:)	Harmonic must be 1 - 50
503	(DDE:)	Frequency must be >= 0
504	(DDE:)	AC magnitude must be > 0
505	(DDE:)	Impedance must be >= 0
506	(DDE:)	Function not available
507	(DDE:)	Value not available

508	(DDE:)	Cannot enter watts by itself
509	(DDE:)	Output exceeds user limits
510	(DDE:)	Duty cycle must be 1.0-99.0
511	(DDE:)	Power factor must be 0.0-1.0
512	(DDE:)	Cannot select that field now
513	(DDE:)	Edit digit out of range
514	(DDE:)	Cannot switch edit field now
515	(DDE:)	Not editing output now
516	(DDE:)	dBm only for single sine ACV
517	(DDE:)	Freq too high for non-sine
518	(DDE:)	Value outside locked range
519	(DDE:)	Must specify an output unit
520	(DDE:)	Cannot do two frequencies at once
521	(DDE:)	Cannot source 3 values at once
522	(DDE:)	Temp must be degrees C or F
523	(DDE:)	Cannot do that now
526	(DDE:)	Limit too small or large
527	(DDE:)	No changes except RESET now
528	(DDE:)	Offset out of range
529	(DDE:)	Cannot edit to or from 0 Hz
530	(DDE:)	Bad state image - not loaded
531	(DDE:)	TC offset limited to +/-500 C
532	(DDE:)	Cannot go to STBY in Meas TC
533	(DDE:)	Cannot set an offset now
534	(DDE:)	Cannot lock this range
535	(DDE:)	Cannot set phase or PF now
536	(DDE:)	Cannot set wave now
537	(DDE:)	Cannot set harmonic now
538	(DDE:)	Cannot change duty cycle now
539	(DDE:)	Cannot change compensation now
540	(DDE:FR)	Current OUTPUT moved to 5725A
541	(DDE:)	TC ref must be valid TC temp
542	(DDE:)	Cannot turn EARTH on now
543	(DDE: D)	STA couldn't update OTD
544	(DDE:)	Cannot enter W with non-sine
545	(DDE:)	Cannot edit now
546	(DDE:)	Cannot set trigger to that now
547	(DDE:)	Cannot set output imp. now
548	(DDE:FR)	Compensation is now OFF
549	(DDE:)	Period must be >= 0
550	(DDE:)	A report is already printing
551	(DDE:)	ScopeCal option not installed
552	(DDE:)	Not a ScopeCal function
553	(DDE:)	Cannot set marker shape now
554	(DDE:)	Cannot set video parameter now
555	(DDE:)	Marker location out of range
556	(DDE:)	Pulse width must be 1 - 255
557	(DDE:)	Cannot set range directly now
558	(DDE:)	Not a range for this function
559	(DDE:)	Cannot set TD pulse now
560	(DDE:)	ZERO_MEAS only for C
561	(DDE:FR)	That requires a -SC option

562	(DDE:FR)	That requires a -SC600 option
563	(DDE:)	Time limit must be 1s-60s
564	(DDE:)	Cannot set ref. phase now
565	(DDE:)	ZERO_MEAS reading not valid
568	(DDE:)	Slave cannot send SYNCOUT
569	(DDE: FR)	That takes a -SC1100 option
570	(DDE:)	Invalid harmonic number
571	(DDE:)	Invalid harmonic amplitude
572	(DDE:)	Duplicate harmonic number
573	(DDE:)	No trig unless OPER & settled
574	(DDE:)	Max 15 harmonics in CHwave
575	(DDE:)	Square or sine flicker only
578	(DDE:)	Cannot set that now
579	(DDE:)	Parameter setting too big
600	(DDE:FR D)	Outguard watchdog timeout
601	(DDE:FR)	Power-up RAM test failed
602	(DDE:FR)	Power-up GPIB test failed
700	(DDE: R)	Saving to NV memory failed
701	(DDE: R)	NV memory invalid
702	DDE: R)	NV invalid so default loaded
703	(DDE: R)	NV obsolete so default loaded
800	(DDE:FR)	Serial parity error %s
801	(DDE:FR)	Serial framing error %s
802	(DDE:FR)	Serial overrun error %s
803	(DDE:FR)	Serial characters dropped %s
900	(DDE:FR)	Report timeout - aborted
1000	(DDE:FR)	Sequence failed during diag
1200	(DDE:FR)	Sequence name too long
1201	(DDE:FR)	Sequence RAM table full
1202	(DDE:FR)	Sequence name table full
1300	(CME: R)	Bad syntax
1301	(CME: R)	Unknown command
1302	(CME: R)	Bad parameter count
1303	(CME: R)	Bad keyword
1304	(CME: R)	Bad parameter type
1305	(CME: R)	Bad parameter unit
1306	(EXE: R)	Bad parameter value
1307	(QYE: R)	488.2 I/O deadlock
1308	(QYE: R)	488.2 interrupted query
1309	(QYE: R)	488.2 unterminated command
1310	(QYE: R)	488.2 query after indefinite response
1311	(DDE: R)	Invalid from GPIB interface
1312	(DDE: R)	Invalid from serial interface
1313	(DDE: R)	Service only
1314	(EXE: R)	Parameter too long
1315	(CME: R)	Invalid device trigger
1316	(EXE: R)	Device trigger recursion
1317	(CME: R)	Serial buffer full
1318	(EXE: R)	Bad number
1319	(EXE: R)	Service command failed
1320	(CME: R)	Bad binary number
1321	(CME: R)	Bad binary block

1322	(CME: R)	Bad character
1323	(CME: R)	Bad decimal number
1324	(CME: R)	Exponent magnitude too large
1325	(CME: R)	Bad hexadecimal block
1326	(CME: R)	Bad hexadecimal number
1328	(CME: R)	Bad octal number
1329	(CME: R)	Too many characters
1330	(CME: R)	Bad string
1331	(DDE: R)	OPER not allowed while error pending
1332	(CME:FR)	Cannot change UUT settings now
1500	(DDE:FRS)	Compliance voltage exceeded
1501	(DDE:FRS)	Shunt amp over or underload
1502	(DDE:FRS)	Current Amp Thermal Limit Exceeded
1503	(DDE:FRS)	Output current limit exceeded
1504	(DDE:FRS)	Input V or A limit exceeded
1505	(DDE:FRS)	VDAC counts out of range
1506	(DDE:FRS)	IDAC counts out of range
1507	(DDE:FRS)	AC scale dac counts out of range
1508	(DDE:FRS)	DC scale dac counts out of range
1509	(DDE:FRS)	Frequency dac counts out of range
1510	(DDE:FRS)	IDAC counts (DC OFFSET) out of range
1511	(DDE:FRS)	ZDAC counts out of range
1515	(DDE:FR D)	Cannot load waveform for scope mode
1516	(DDE:FRS)	Peak or avg amplitude too high
1600	(DDE:FR D)	OPM transition error
1601	(DDE:FR D)	TC measurement fault
1602	(DDE:FR D)	Z measurement fault
65535	(DDE:FR)	Unknown error %d