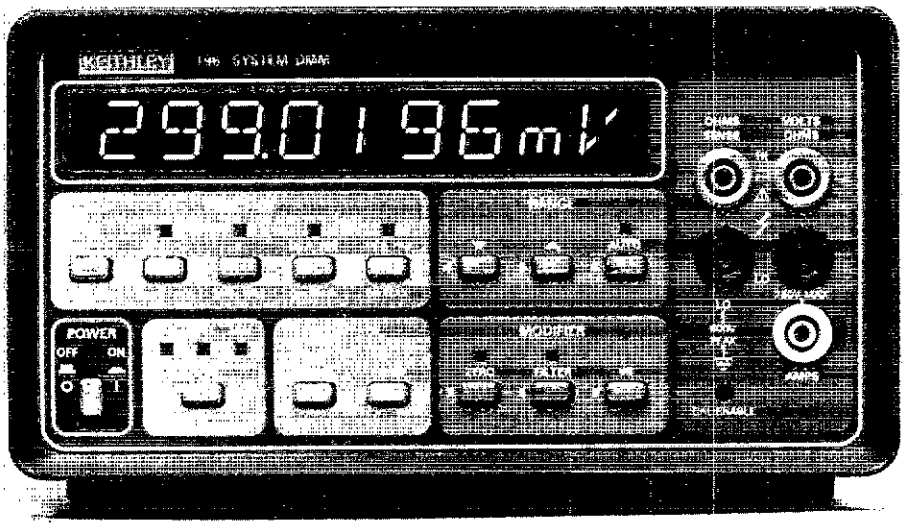
Model 196
System DMM

Instruction Manual



Contains Operating and Servicing Information

KEITHLEY

SPECIFICATIONS

DC VOLTS
(6½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY[1] ±(%rdg + counts) 24 Hr.,[2] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18° & 28°-50°C
300 mV	100 nV	>1 GΩ	0.0020 + 20[3]	0.005 + 20[3]	0.008 + 20[3]	0.0006 + 10
3 V	1 μV	>1 GΩ	0.0013 + 10	0.003 + 20	0.0038 + 20	0.0004 + 1
30 V	10 μV	11 MΩ	0.0015 + 10	0.006 + 20	0.008 + 30	0.0013 + 3
300 V	100 μV	10.1 MΩ	0.003 + 10	0.009 + 20	0.009 + 30	0.0013 + 1

[1]For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300mV range). For 3½-digit accuracy, count error is 5.
[2]Relative to calibration standards.
[3]When properly zeroed.

ANALOG SETTLING TIME: <1ms (<2ms on 300mV range), to 0.01% of step change.

CMRR: >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 10ppm of range for 3V-300V ranges; 15ppm of range for 300mV range; at 23°C ±1°C.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

TRMS AC VOLTS
(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20Hz-50Hz[2]	50Hz-200Hz[2]	200Hz-10kHz[2]	10kHz-20kHz[2]	20kHz-100kHz[3]
300 mV	1 μV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	2.0 + 300
3 V	10 μV	2 + 100	0.3 + 100	0.15 + 100	0.3 + 200	1.5 + 300
30 V	100 μV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300

[1]For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for inputs >200Hz.
[2]For sinewave inputs >2,000 counts.
[3]For sinewave inputs >20,000 counts.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NONSINUSOIDAL INPUTS: For fundamental frequencies <1kHz, crest factor <3, add 0.25% of reading to specified accuracy for 300mV and 3V ranges; add 0.6% of reading to specified accuracy for 30V and 300V ranges.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

3dB BANDWIDTH: 300kHz typical.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, 10^7 V·Hz, whichever is less.

SETTLING TIME: 1 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C below 20kHz, ±(0.2x) for 20kHz to 100kHz.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

dB (Ref. = 1V):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-20kHz	20kHz-100kHz	RESOLUTION
−34 to +49 dB (20mV to 300V)	0.2	0.4	0.01 dB
−54 to −34 dB (2mV to 20mV)	1.1	3[1]	0.01 dB

[1]Typical.

OHMS
(6½ Digits)

RANGE	RESOLUTION	NOMINAL I-SHORT	ACCURACY[1] ±(%rdg + counts) 24 Hr.,[5] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18° & 28°-50°C
300 Ω[2]	100 μΩ	1.7 mA	0.0025 + 20[3]	0.008 + 20[3]	0.010 + 20[3]	0.001 + 7
3 kΩ[2]	1 mΩ	1.7 mA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
30 kΩ[2]	10 mΩ	160 μA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
300 kΩ	100 mΩ	50 μA	0.006 + 20	0.020 + 20	0.021 + 20	0.004 + 1
3 MΩ	1 Ω	5 μA	0.007 + 20	0.020 + 20	0.021 + 20	0.004 + 1
30 MΩ	10 Ω	0.5 μA	0.06 + 50	0.1 + 50	0.1 + 50	0.030 + 1
300 MΩ[4]	1 kΩ	0.5 μA	2.0 + 5	2.0 + 5	2.0 + 5	0.30 + 1

[1]For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range). For 3½-digit accuracy, count error is 5.
[2]4-wire accuracy, 300Ω-30kΩ ranges.
[3]When properly zeroed.
[4]Resolution on 300MΩ range is limited to 5½ digits.
[5]Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire. Offset compensation available on 300Ω-30kΩ ranges, requires proper zeroing. Allowable compensation of ±10mV on 300Ω range and ±100mV on 3kΩ and 30kΩ ranges.

MAX. ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: 5.5V maximum.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 300Ω-30kΩ ranges, at 23°C ±1°C.

DC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	0.09 + 20	0.4 V
3 mA	10 nA	0.05 + 10	0.4 V
30 mA	100 nA	0.05 + 10	0.4 V
300 mA	1 μA	0.05 + 10	0.5 V
3 A	10 μA	0.09 + 10	2 V

[1]4½-digit count error is 20. 3½-digit count error is 5.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V), accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C):
$< \pm(0.1 \times$ applicable accuracy specification$)/°C$.

TRMS AC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] 1 Year, 18°-28°C 20Hz-45Hz	45Hz-10kHz	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	2 + 100	0.9 + 100	0.4V
3 mA	10 nA	2 + 100	0.6 + 100	0.4V
30 mA	100 nA	2 + 100	0.6 + 100	0.4V
300 mA	1 μA	2 + 100	0.6 + 100	0.5V
3 A	10 μA	2 + 100	0.6 + 100	2 V

[1] For sinewave inputs >2000 counts. For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for sinewave inputs >200Hz.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at ⅔ full scale.

NONSINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz, crest factor <3.

SETTLING TIME: 1 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V) accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C):
$< \pm(0.1 \times$ applicable accuracy specification$)/°C$.

dB (Ref. = 1mA): INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-10kHz	RESOLUTION
−34 to +69 dB (20μA to 3A)	0.2	0.01 dB
−54 to −34 dB (2μA to 20μA)	0.9	0.01 dB

MAXIMUM READING RATES[1]

DCV, DCA, ACV, ACA READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	1000	1000	237	80	112	58
4½-Digit	333	333	145	63	91	49
5½-Digit	35 (29)	9 (7.5)	40 (33)	9 (7.5)	35 (29)	9 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

OHMS READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	53	25	57	25	37	23
4½-Digit	43	20	47	21	30	19
5½-Digit	16 (13)	9.5 (7.5)	18 (15)	9.5 (7.5)	15 (12.5)	9.5 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

Offset Compensated Ohms: Rates are 0.5× normal mux on ohms rates.

[1]Reading rates are for on-range on-scale readings with internal filter off, for 3V, 3kΩ, and 3mA ranges. 6½- and 5½-digit rates are for 60Hz operation. Values in parentheses are for 50Hz operation.
[2]Internal filter on.

IEEE-488 BUS IMPLEMENTATION

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

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

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Reading Storage, Calibration, Display, Multiplex, Status, Service Request, Self Test, Output Format, TRANSLATOR.

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 3029999 counts in 6½-digit mode.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

WARMUP: 2 hours to rated accuracy.

DISPLAY: 10, 0.5-in. alphanumeric LED digits with decimal point and polarity. Function and IEEE-488 bus status also indicated.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5×10^5 max. V·Hz product. $>10^9\Omega$ paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 readings/second (2/second on 30MΩ and 300MΩ ranges).

FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

OPERATING ENVIRONMENT: 0°-50°C, 0%-80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°C-50°C (0%-60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: −25° to +65°C.

POWER: 105-125V or 210-250V, rear panel switch selected, 50Hz or 60Hz, 30VA max. 90-110V and 180-220V versions available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.7kg (8 lbs.).

ACCESSORIES AVAILABLE:

Model 1019A-1: 5¼-in. Single Fixed Rack Mounting Kit
Model 1019A-2: 5¼-in. Dual Fixed Rack Mounting Kit
Model 1019S-1: 5¼-in. Single Slide Rack Mounting Kit
Model 1019S-2: 5¼-in. Dual Slide Rack Mounting Kit
Model 1651: 50-Ampere Shunt
Model 1681: Clip-On Test Lead Set
Model 1682A: RF Probe
Model 1685: Clamp-On Current Probe
Model 1751: General Purpose Test Leads
Model 1754: Universal Test Lead Kit
Model 5806: Kelvin Clip Leads
Model 7007-1: Shielded IEEE-488 Cable, 1m
Model 7007-2: Shielded IEEE-488 Cable, 2m
Model 7008-3: IEEE-488 Cable, 3 ft. (0.9m)
Model 7008-6: IEEE-488 Cable, 6 ft. (1.8m)

Prices and specifications subject to change without notice.

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Keithley Model 196 System DMM is a five function autoranging digital multimeter. At 6½ digit resolution, the LED display can display ±3,030,000 counts. The range of this analog-to-digital (A/D) converter is greater than the normal ±1,999,999-count A/D converter used in many 6½ digit DMMs. The built-in IEEE-488 interface makes the instrument fully programmable over the IEEE-488 bus. The Model 196 can make the following basic measurements:

1. DC voltage measurements from 100nV to 300V.
2. Resistance measurements from 100μΩ to 300MΩ.
3. TRMS AC voltage measurements from 1μV to 300V.
4. DC current measurements from 1nA to 3A.
5. TRMS AC current measurements from 1nA to 3A.

In addition to the above mentioned measurement capabilities, the Model 196 can make AC dB voltage and current measurements.

1.2 FEATURES

Some important Model 196 features include:

- 10 Character Alphanumeric Display—Easy to read 14-segment LEDs used for readings and front panel messages.
- High Speed Measurement Rate—1000 readings per second.
- Zero—Used to cancel offsets or establish baselines. A zero value can be programmed from the front panel or over the IEEE-488 bus.
- Filter—The weighted average digital filter can be set from the front panel or over the bus.
- Data Store—Can store up to 500 readings and is accessible only over the bus.
- Digital Calibration—The instrument may be digitally calibrated from either the front panel or over the bus.
- User Programmable Default Conditions—Any instrument measurement configuration can be established as the power-up default conditions.
- Translator Software—User defined words (stored in non-volatile memory) can be used to replace standard command strings over the IEEE-488 bus.
- Offset Compensated Ohms—Used to correct for small error voltages in the measurement circuit.

1.3 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. Should it become necessary to exercise the warranty, contact your Keithley representative or the factory to determine the proper course of action. Keithley Instruments maintains service facilities in the United States, United Kingdom and throughout Europe. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of these locations. Check the inside front cover for addresses.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with the manual. Be sure to review these changes before attempting to operate or service the instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual or found on the Model 196.

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

The ⚡ on the instrument denotes that a potential of 300V or more may be present on the terminal(s). Standard safety practices should be observed when such dangerous levels are encountered.

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

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

1.6 SPECIFICATIONS

Detailed Model 196 specifications may be found preceding the Table of Contents of this manual.

1.7 INSPECTION

The Model 196 System DMM was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent. Retain and use the original packing materials in case reshipment is necessary. The following items are shipped with every Model 196 order:

Model 196 System DMM
Model 196 Instruction Manual
Safety Test Leads (Model 1751)
Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 196-901-00). The manual package includes an instruction manual and any applicable addenda.

1.8 USING THE MODEL 196 MANUAL

This manual contains information necessary for operating and servicing the Model 196 System DMM. The information is divided into the following sections:

- Section 1 contains general information about the Model 196 including that necessary to inspect the instrument and get it operating as quickly as possible.
- Section 2 contains detailed operating information on using the front panel controls and programs, making connections and basic measuring techniques for each of the available measuring functions.
- Section 3 contains the information necessary to connect the Model 196 to the IEEE-488 bus and program operating modes and functions from a controller.
- Section 4 contains performance verification procedures for the instrument. This information will be helpful if you wish to verify that the instrument is operating in compliance with its stated specifications.
- Section 5 contains a description of operating theory. Analog, digital, power supply, and IEEE-488 interface operation is included.
- Section 6 contains information for servicing the instrument. This section includes information on fuse replacement, line voltage selection, calibration and troubleshooting.
- Section 7 contains replaceable parts information.

1.9 GETTING STARTED

The Model 196 System DMM is a highly sophisticated instrument with many capabilities. To get the instrument up and running quickly use the following procedure. For complete information on operating the Model 196 consult the appropriate section of this manual.

Power Up

1. Plug the line cord into the rear panel power jack and plug the other end of the cord into an appropriate, grounded power source. See paragraph 2.2.1 for more complete information.
2. Press in the POWER switch to apply power to the instrument. The instrument will power up in the 300V DC range.

Making Measurements

1. Connect safety shrouded test leads to the front panel VOLTS HI and LO input terminals. Make sure the INPUT switch on the rear panel is in the in (FRONT) position.
2. To make a voltage measurement, simply connect the input leads to a DC voltage source (up to 300V) and take the reading from the display.
3. To change to a different measuring function, simply press the desired function button. For example, to measure resistance, press the OHMS button.

Using Front Panel Programs

Program selection is accomplished by pressing the PRGM button followed by the button(s) that corresponds to the program number or name. For example, to select Program 31 (IEEE), press the PRGM button and then the 3 and 1 buttons. Table 2-7 lists and briefly describes the available front panel programs. Once a program is selected the following general rules will apply:

1. A displayed program condition can be entered by pressing the ENTER button.
2. Program conditions that prompt the user with a flashing digit can be modified using the data buttons (0 through 9 and ±).
3. Programs that contain alternate conditions can be displayed by pressing one of the range buttons. Each press of one of these buttons toggles the display between the two available conditions.

4. A program will be executed when the ENTER button is pressed.
5. A program can be exited at any time and thus not executed, by pressing the PRGM button.

Paragraph 2.7 provides the detailed information for using the front panel programs.

1.10 ACCESSORIES

The following accessories are available to enhance the Model 196s, capabilities.

Models 1019A and 1019S Rack Mounting Kits—The Model 1019A is a stationary rack mounting kit with two front panels provided to enable either single or dual side-by-side mounting of the Model 196 or other similar Keithley instruments. The Model 1019S is a similar rack mounting kit with a sliding mount configuration.

Model 1301 Temperature Probe—The Model 1301 is a rugged low cost temperature probe designed to allow temperature measurements from −55 to 150°C.

Model 1600B High Voltage Probe—The Model 1600B extends DMM measurements to 40kV.

Model 1651 50-Ampere Current Shunt—The Model 1651 is an external 0.001Ω ±1% 4-terminal shunt, which permits current measurements from 0 to 50A AC or DC.

Model 1681 Clip-On Test Lead Set—The Model 1681 contains two leads, 1.2m (4 ft.) long terminated with banana plugs and spring action clip probes.

Model 1682A RF Probe—The Model 1682A permits voltage measurements from 100kHz to 250MHz. AC to DC transfer accuracy is ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in RMS of a sine wave.

Model 1685 Clamp-On AC Probe—The Model 1685 measures AC current by clamping on to a single conductor. Interruption of the circuit is unnecessary. The Model 1685 detects currents by sensing the changing magnetic field produced by the current flow.

Model 1751 Safety Test Leads—Finger guards and shrouded banana plugs help minimize the chance of making contact with live circuitry.

Model 1754 Universal Test Lead Kit—The Model 1754 is a 12 piece test lead kit, with interchangeable plug-in accessories. Included in the kit is one set of test leads (1-red, 1-black), two spade lugs, two standard banana plugs, two phone tips (0.06 DIA.), two hooks and miniature alligator clips (with boots).

Model 5804 Test Lead Set—The Model 5804, used for 4-terminal measurements, includes: two test probes with spring-loaded plunger clip adapters to fit test probes, two spring-loaded plunger test clips with in-line banana jacks, and four solid copper alligator clips with insulator boots.

Model 5805 Kelvin Probes—The Model 5805 includes two spring-loaded Kelvin test probes (one red, one black), with 48-inch banana plug cable assemblies. A set of eight replacement contacts for the Model 5805 Kelvin test probes is also available (Keithley P/N CS-551).

Model 5806 Kelvin Clip Lead Set—The Model 5806 includes two Kelvin clip test lead assemblies with banana plug termination (one red, one black). A set of eight replacement rubber bands for the Model 5806 is also available (Keithley P/N GA-22).

Model 7007 IEEE-488 Shielded Cables—The Model 7007 connects the Model 196 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter in length and has a EMI shielded IEEE-488 connector at each end. The Model 7007-2 is identical to the Model 7007-1, but is two meters in length.

Model 7008 IEEE-488 Cables—The Model 7008 connects the Model 196 to the IEEE-488 bus. The Model 7008-3 is 0.9m (3 ft.) in length and has a standard IEEE-488 connector at each end. The Model 7008-6 cable is identical to the Model 7008-3, but is 1.8m (6 ft.) in length.

Model 8573A IEEE-488 Interface—The Model 8573A is an IEEE-488 standard interface designed to interface the IBM PC or XT computers to Keithley instrumentation over the IEEE-488 bus. The interface system contains two distinctive parts: an interface board containing logic to perform the necessary hardware functions and the handler software (supplied on disk) to perform the required control functions. These two important facets of the Model 8573A join together to give the IBM advanced capabilities over IEEE-488 interfaceable instrumentation.