

**Instruction Manual  
Model 196  
System DMM**

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# SECTION 1

## GENERAL INFORMATION

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### 1.1 INTRODUCTION

The Keithley Model 196 System DMM is a five function autoranging digital multimeter. At  $6\frac{1}{2}$  digit resolution, the LED display can display  $\pm 3,030,000$  counts. The range of this analog-to-digital (A/D) converter is greater than the normal  $\pm 1,999,999$ -count A/D converter used in many  $6\frac{1}{2}$  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  $100\mu\Omega$  to 300M $\Omega$ .
3. TRMS AC voltage measurements from 1 $\mu$ V 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  $\pm$ ).
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  $150^{\circ}\text{C}$ .

**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  $0.001\Omega \pm 1\%$  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  $\pm 1\text{dB}$  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.

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## SECTION 2

# BASIC DMM OPERATION

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### 2.1 INTRODUCTION

Operation of the Model 196 can be divided into two general categories: front panel operation and IEEE-488 bus operation. This section contains information necessary to use the instrument from the front panel. These functions can also be programmed over the IEEE-488 bus, as described in Section 3.

### 2.2 POWER UP PROCEDURE

#### 2.2.1 Line Power

Use the following procedure to connect the Model 196 to line power and power up the instrument.

1. Check that the instrument is set to correspond to the available line power. When the instrument leaves the factory, the internally selected line voltage is marked on the rear panel. Ranges are 105V-125V or 210V-250V 50/60Hz AC. If the line voltage setting of the instrument needs to be changed, refer to Section 6, paragraph 6.2 for the procedure. If the line frequency setting of the instrument needs to be checked and/or changed, utilize front panel Program 32 (see paragraph 2.7.8) after the instrument completes the power up sequence.
2. Connect the female end of the power cord to the AC receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded AC outlet.

#### WARNING

**The Model 196 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.**

#### CAUTION

**Be sure that the power line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage.**

#### 2.2.2 Power Up Sequence

The instrument can be turned on by pressing in the front panel POWER switch. The switch will be at the inner most position when the instrument is turned on. Upon power up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E<sup>2</sup>PROM). If RAM or ROM fails, the instrument will lock up. If E<sup>2</sup>PROM FAILS, the message "UNCAL" will be displayed. See paragraph 6.7.2 for a complete description of the power up self test and recommendations to resolve failures.

#### 2.2.3 Default Conditions

Default conditions can be defined as setup conditions that the instrument will return to when a particular feature or command is asserted. The Model 196 will return to either factory default conditions or user saved default conditions.

##### Factory Default Conditions

At the factory, the Model 196 is set up so that the instrument is configured to certain setup conditions on the initial power up. These factory default conditions are listed in Tables 2-1 and 3-7 (located in Section 3). If alternate setup conditions are saved (see User Saved Default Conditions), the instrument can be returned to the factory default conditions by running Program 37 (Reset). To retain the factory default conditions as power-up default conditions, run Program 30 (Save) immediately after executing Program 37 (Reset).

Sending device-dependent command L0 over the IEEE-488 bus is equivalent to running Program 37 (Reset) and then Program 30 (Save).

Table 2-1. Factory Default Conditions

Control/Feature	Default Condition
Function	DCV
Range	300V
Resolution (Program 2)	6½ Digits
Zero	Disabled
Zero Value (Program ZERO)	000.0000
dB	Disabled
dB Reference Value (Program dB)	1.000000
Filter	Disabled
Filter Value (Program FILTER)	10
MX+B Status (Program 4)	Disabled
MX+B Parameters (Program 34)	M=1.000000 B=000.0000
Multiplexer (Program 6)	Enabled
HI/LO/PASS (Program 5)	Disabled
HI/LO Limits (Program 35)	+3.030000, -3.030000
Ohms Compensation (Program Ω)	Disabled

NOTE: The Model 196 is initially set for an IEEE address of 7. The line frequency is set to 50 or 60Hz.

**User Saved Default Conditions**

Each function of the Model 196 “remembers” the last measurement configuration that it was set up for (such as range, zero value, filter value, etc). Switching back and forth between functions will not affect the unique configuration of each function. However, the instrument will “forget” the configurations on power-down unless they are saved.

Unique setup conditions can be saved by running front panel Program 30 (Save) or by sending device-dependent command L1 over the IEEE-488 bus. These user saved default conditions will prevail over the factory default conditions on power-up, or when a DCL or SDC is asserted over the bus.

**IEEE Address and Line Frequency**

Any IEEE address and line frequency setting can be saved as default conditions by running Program 30 (Save) or by sending L1 over the bus. See paragraph 2.7 for complete information on Programs 31 (IEEE Address) and 32 (Line Frequency).

**NOTE**

An “UNCAL” error will set the IEEE address to 7 and the line frequency to 60Hz.

**2.3 FRONT PANEL FAMILIARIZATION**

The front panel layout of the Model 196 is shown in Figure 2-1. The following paragraphs describe the various components of the front panel in detail.

**2.3.1 Display and Indicators**

**Display**—The 10 character, alphanumeric, LED display is used to display numeric conversion data, range and function mnemonics (i.e. mV) and messages.

**Function Indicators**—The indicator that is on identifies which of the five operating functions is currently selected.

**Range Indicator**—When the instrument is in autorange the AUTO indicator light will be on.

**Modifier Indicators**—When the zero feature is enabled, the ZERO indicator will turn on. When filter is enabled, the FILTER indicator will turn on.

**IEEE Status Indicators**—These three indicators apply to instrument operation over the IEEE-488 bus. The RMT indicator shows when the instrument is in the IEEE-488 remote state. The TLK and LSN indicators show when the instrument is in the talk and listen states respectively. See Section 3 for detailed information on operation over the bus.

**2.3.2 Controls**

All front panel controls, except the POWER and CAL ENABLE switches, are momentary contact switches. Indicators are located above certain buttons to show that they are enabled. Some buttons have secondary functions that are associated with front panel program operation. See paragraph 2-7 for detailed information on front panel programs.

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

**B FUNCTION GROUP**

**DCV**—The DCV button places the instrument in the DC volts measurement mode. The secondary function of this button is to enter the ± sign. See paragraph 2.6.4 for DCV measurements.



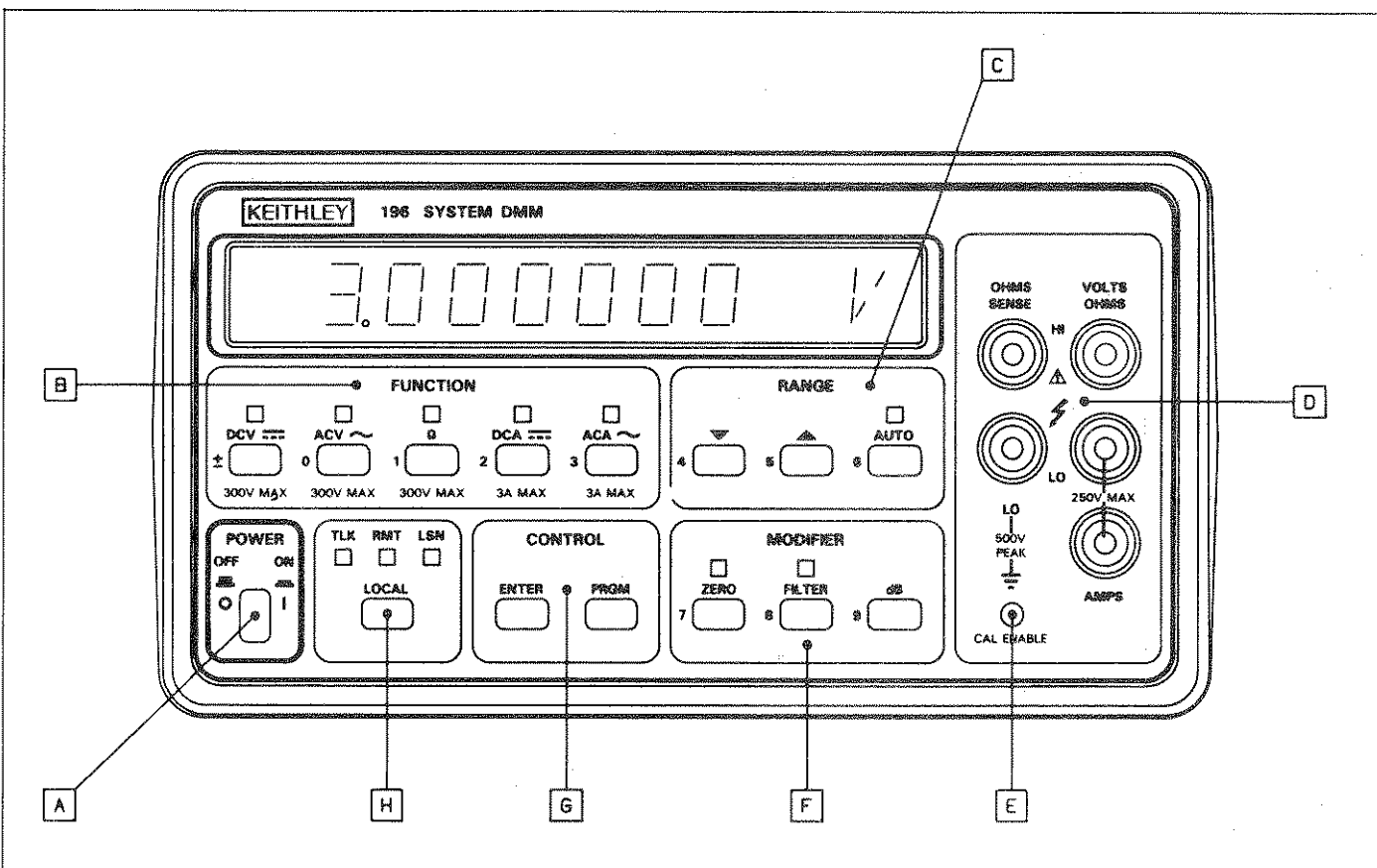


Figure 2-1. Model 196 Front Panel

**ACV**—The ACV button places the instrument in the AC volts measurement mode. The secondary function of this button is to enter the number 0. See paragraph 2.6.7 for ACV measurements.

**Ω**—The Ω button places the instrument in the ohms measurement mode. The secondary function of this button is to enter the number 1. See paragraph 2.6.6 for resistance measurements.

**DCA**—The DCA button places the instrument in the DC amps measurement mode. The secondary function of this button is to enter the number 2. See paragraph 2.6.8 for DCA measurements.

**ACA**—The ACA button places the instrument in the AC amps measurement mode. The secondary function of this button is to enter the number 3. See paragraph 2.6.8 for ACA measurements.

### **C** RANGE GROUP

**Manual**—Each time the ▲ button is pressed, the instrument will move up one range, while the ▼ button will move

the instrument down one range each time it is pressed. Pressing either of these buttons will cancel autorange, if it was previously selected. The secondary functions of these buttons are to enter the number 4 (▼) and number 5 (▲).

**AUTO**—The AUTO button places the instrument in the autorange mode. While in this mode, the instrument will go to the best range to measure the applied signal. Autoranging is available for all functions and ranges. Autoranging may be cancelled by pressing the AUTO button or one of the manual range buttons. The secondary function of this button is to enter the number 6.

### **F** MODIFIER GROUP

**ZERO**—The ZERO button turns on the ZERO indicator and causes the displayed reading to be subtracted from subsequent readings. This feature allows for zero correction or storage of baseline values. The secondary function of this button is to select the ZERO program and enter the number 7. Refer to paragraph 2.6.2 for detailed information on the zero feature.

**FILTER**—The **FILTER** button turns on the **FILTER** indicator and causes the instrument to start weighted averaging (1 to 1/99) the readings. The factory default weighted average is 1/10, but may be changed using the **FILTER** program (see paragraph 2.7.16). See paragraph 2.6.3 for filter operation. Selecting the **FILTER** program is one of the secondary functions of this button. The other secondary function is to enter the number 8.

**dB**—The **dB** button places the instrument in the **dB** measurement mode and may be used with the **ACV** and **ACA** functions. Under factory default conditions, measurements are referenced to 1V or 1mA. However, the **dB** program may be used to change the reference level. The secondary function of this button is to select the **dB** program and enter the number 9. See paragraph 2.6.9 for **dB** measurements.

### **G** CONTROL GROUP

**PRGM**—This button is used to enter the front panel program mode.

**ENTER**—This button is used to enter program parameters. This button will also trigger a reading when the instrument is in a one-shot trigger mode.

**H** **LOCAL**—When the instrument is in the IEEE-488 remote state (**RMT** indicator on), the **LOCAL** button will return the instrument to front panel operation. However, if local lockout (**LLO**) was asserted over the IEEE-488 bus,

the **LOCAL** button will be inoperative. See Section 3 for information on operating the instrument over the IEEE-488 bus.

### 2.3.3 Input Terminals **D**

The input terminals are intended to be used with safety shrouded test leads to help minimize the possibility of contact with live circuits. Note that the terminals are duplicated sideways on the rear panel and that the **INPUT** switch (also located on the rear panel) determines which set of terminals is active.

**VOLTS OHMS HI and LO**—The **VOLTS OHMS HI** and **LO** terminals are used for making DC volts, AC volts and two-wire resistance measurements.

**AMPS and LO**—The **AMPS** and **LO** terminals are used for making DC current and AC current measurements.

**OHMS SENSE HI and LO**—The **OHMS SENSE HI** and **LO** terminals are used with the **VOLTS OHMS HI** and **LO** terminals to make four-wire resistance measurements.

### 2.3.4 Calibration Enable Switch **E**

Calibration of the Model 196 can only be done if the **CAL ENABLE** switch is in the enable position. See paragraph 6.4 for details.

## 2.4 REAR PANEL FAMILIARIZATION

The rear panel of the Model 196 is shown in Figure 2-2.

### 2.4.1 Controls

**G** LINE VOLTAGE—This switch matches the instrument to the available line voltage. See paragraph 6.2 for the procedure to set this switch.

**A** INPUT—The INPUT switch connects the instrument to either the front panel input terminals or the rear panel input terminals. This switch operates in same manner as the power switch. The front panel input terminals are selected when the switch is in the “in” position and the rear panel input terminals are selected when the switch is in the “out” position.

### 2.4.2 Connectors and Terminals

**D** AC Receptacle—Power is applied through the supplied power cord to the 3-terminal AC receptacle. Note that the selected supply voltage is marked on the rear panel near the line voltage switch.

**C** Input Terminals—The rear panel input terminals perform the same functions as the front panel input terminals. Paragraph 2.3.3 contains the description of the input terminals.

**H** IEEE-488 Connector—This connector is used to connect the instrument to the IEEE-488 bus. IEEE interface functions are marked below the connector.

**I** EXTERNAL TRIGGER Input—This BNC connector is used to apply pulses to trigger the Model 196 to take one or more readings, depending on the selected trigger mode.

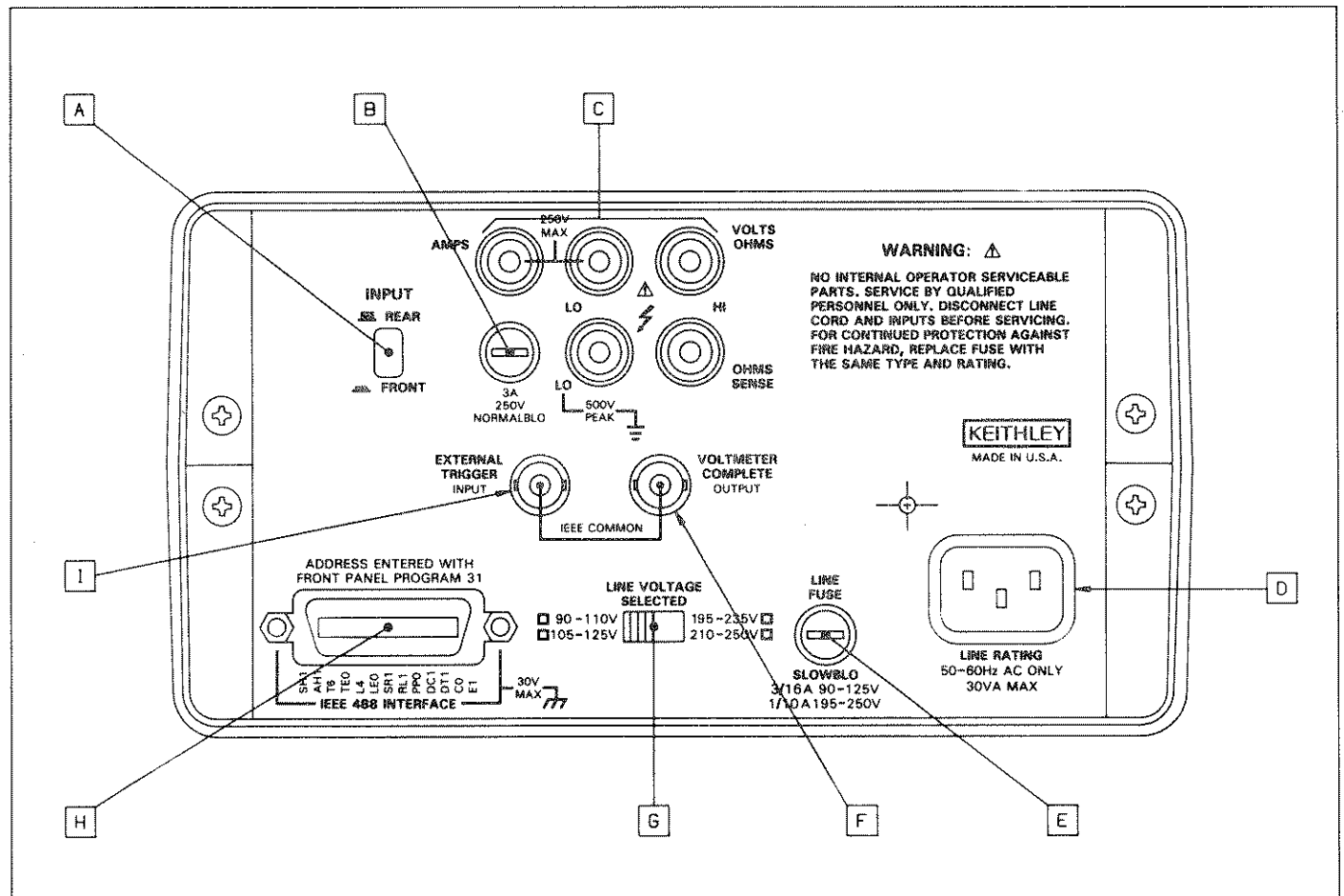


Figure 2-2. Model 196 Rear Panel

**F** VOLTMETER COMPLETE Output—This BNC output connector provides a TTL-compatible negative-going pulse when the Model 196 has completed a reading. It is useful for triggering other instrumentation.

**2.4.3. Fuses**

**E** LINE FUSE—The line fuse provides protection for the AC power line input. Refer to paragraph 6.3.1 for the line fuse replacement procedure.

**B** CURRENT FUSE—The 3A current fuse provides protection for the current measurement circuits of the instrument. Refer to paragraph 6.3.2 for the current fuse replacement procedure.

**2.5 ERROR DISPLAY MESSAGES**

Table 2-2 lists and explains the various display messages associated with incorrect front panel operation of the Model 196.

**Table 2-2. Error Messages**

Message	Explanation
UNCAL	E <sup>2</sup> PROM failure on power up. See paragraph 6.7.2.
NO PROGRAM	Invalid entry while trying to select program.
O.VERFLO KΩ	Overrange-Decimal point position and mnemonics define function and range (3kΩ range shown). The number of characters in the "OVERFLO" message defines the display resolution (6½d resolution shown).
TRIG-ERROR	Trigger received while still processing reading from last trigger.
AC ONLY	Selecting dB with instrument not in ACV or ACA.
NO RANGE	Pressing a range button while in ACV dB or ACA dB.
CONFLICT	196 in invalid state (i.e. dB function), when entering calibration program.

**2.6 BASIC MEASUREMENTS**

The following paragraphs describe the basic procedures for making voltage, resistance, current, and dB measurements.

**High Energy Circuit Safety Precautions**

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

**WARNING**

**Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury or death. If the meter is connected to a high energy circuit when set to a current range, low resistance range or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can also result when the meter is set to a voltage range if the minimum voltage spacing is reduced.**

When making measurements in high energy circuits use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g. alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. This diminishes arc protection and creates a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device such as the circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated leads for this application.
3. Set the DMM to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the DMM.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

**WARNING**

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

## 2.6.1 Warm Up Period

The Model 196 is usable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least two hours to achieve rated accuracy.

## 2.6.2 Zero

The zero feature serves as a means of baseline suppression by allowing a stored offset value to be subtracted from subsequent readings. When the ZERO button is pressed, the instrument takes the currently displayed reading as a baseline value. All subsequent readings represent the difference between the applied signal level and the stored baseline.

A baseline level can be established for any or all measurement functions and is remembered by each function. For example, a 10V baseline can be established on DCV, a 5V baseline can be established on ACV and a 10k $\Omega$  baseline can be established on OHMS. These levels will not be cancelled by switching back and forth between functions. Once a baseline is established for a measurement function, that stored level will be the same regardless of what range the Model 196 is on. For example, if 1V is established as the baseline on the 3V range, then the baseline will also be 1V on the 30V through 300V ranges. A zero baseline level can be as large as full range.

### NOTE

The following discussion on dynamic range is based on a display resolution of 6½ digits. At 5½d resolution, the number of counts would be reduced by a factor of 10. At 4½d resolution, counts would be reduced by a factor of 100 and 3½d resolution would reduce counts by a factor of 1000.

By design, the dynamic measurement range of the Model 196, at 6½-digit resolution, is 6060000 counts. With zero disabled, the displayed reading range of the instrument is  $\pm 3030000$  counts. With zero enabled, the Model 196 has the capability to display  $\pm 6060000$  counts. This increased display range ensures that the dynamic measurement range of the instrument is not reduced when using a zero baseline value. The following two examples will use the maximum allowable zero values (3030000 counts and  $-3030000$  counts) to show that dynamic measurement range will not be reduced. It is important to note that the increased display range does not increase the maximum allowable input level to the instrument. For example, on the 3V range, the Model 196 will always overrange when more than  $\pm 3.03V$  is connected to the input.

**Example 1**—The instrument is set to the 3V DC range and a maximum  $-3.030000V$  is established as the zero value. When  $-3.030000V$  is connected to the input of the Model 196, the display will read 0.000000V. When  $+3.030000V$  is connected to the input, the display will read  $+6060000V$ . Thus, the dynamic measurement range of the Model 196 is 0V to 6.06V, which is 6060000 counts.

**Example 2**—The instrument is still set to the 3V DC range, but a maximum  $+3.030000V$  is the zero level. When  $+3.030000V$  is connected to the input of the Model 196, the display will read 0.000000V. When  $-3.030000V$  is connected to the input, the display will read  $-6.060000V$ . Thus the dynamic measurement range of the instrument is  $-6.06V$  to 0V, which is still 6060000 counts.

**Zero Correction**—The Model 196 must be properly zeroed when using the 300mV DC or the 300 $\Omega$  range in order to achieve rated accuracy specifications. To use ZERO for zero correction, perform the following steps:

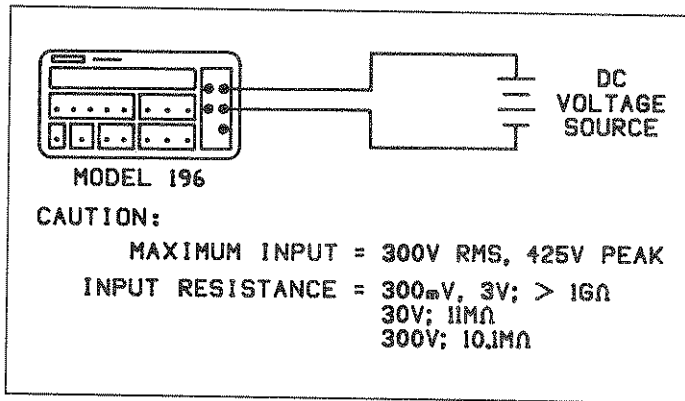
1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select the 300mV DC or the 300 $\Omega$  range.
3. Connect the test leads to the input of the Model 196 and short them together. If four-wire resistance measurements are to be made, connect and short all four leads together. Allow any thermals to stabilize.  
Note: At 5½ and 6½-digit resolution, low level measurement techniques need to be employed. Use Kelvin test leads or shielded test leads. See paragraph 2.6.5 for low level measurement considerations.
4. Press the ZERO button. The display will read zero.
5. Remove the short and connect the test leads to the signal or resistance to be measured.

Note: Test lead resistance is also compensated for when zeroing the 300 $\Omega$  range with the above procedure.

**Baseline Levels**—Baseline values can be established by either applying baseline levels to the instrument or by setting baseline values with the front panel ZERO program. Paragraph 2.7.15 contains the complete procedure for using the ZERO program. To establish a baseline level by applying a level to the Model 196, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select a function and range that is appropriate for the anticipated measurement.
3. Connect the desired baseline level to the input of the Model 196 and note that level on the display.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-3.
5. Take the reading from the display.



**Figure 2-3. DC Voltage Measurements**

### 2.6.5 Low-Level Measurement Considerations

**Accuracy Considerations**—For sensitive measurements, other external considerations besides the Model 196 will affect the accuracy. Effects not noticeable when working with higher voltages are significant in nanovolt and microvolt signals. The Model 196 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors which affect accuracy, noise, source resistance, thermal emfs and stray pick-up.

**Noise and Source Resistance**—The limit of sensitivity in measuring voltages with the Model 196 is determined by the noise present. The noise voltage at the Model 196 input increases with source resistance.

For high impedance sources, the generated noise can become significant when using the most sensitive range (300mV, 6½d) of the Model 196. As an example of determining  $e_r$  (noise voltage generation due to Johnson noise of the source resistance), assume that the Model 196 is connected to a voltage source with an internal resistance of 1MΩ. At a room temperature of 20°C, the p-p noise voltage generated over a bandwidth of 1Hz will be:

$$e_r = 6.35 \times 10^{-10} \sqrt{R \times f}$$

$$e_r = 6.35 \times 10^{-10} \sqrt{(1 \times 10^6) (1)}$$

$$e_r = 0.635\mu\text{V}$$

Thus, an  $e_r$  of 0.635μV would be displayed at 6½d resolution as an additional six digits of noise on the Model 196. To compensate for the displayed noise, use digital filtering and then zero out the settled offset.

**Shielding**—AC voltages which are extremely large compared with the DC signal may erroneously produce a DC output. Therefore, if there is AC interference, the circuit should be shielded with the shield connected to the Model 196 input LO (particularly for low-level sources). Improper shielding can cause the Model 196 to behave in one or more of the following ways:

1. Unexpected offset voltages.
2. Inconsistent readings between ranges.
3. Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 196 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

**Thermal EMFs**—Thermal emfs (thermoelectric potentials) are generated by thermal differences between the junction of dissimilar metals. These can be large compared to the signal which the Model 196 can measure. Thermal emfs can cause the following problems:

1. Instability or zero offset is much higher than expected.
2. The reading is sensitive to (and responds to) temperature changes. This can be demonstrated by touching the circuit, by placing a heat source near the circuit or by a regular pattern of instability (corresponding to heating and air-conditioning systems or changes in sunlight).
3. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the Model 196. A banana plug is generally suitable and generates just a few microvolts. A clean copper conductor such as #10 bus wire is about the best for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to Shielding.
4. Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant temperatures to minimize these thermal emfs. A cardboard box around the circuit under test also helps by minimizing air currents.
5. The ZERO control can be used to null out constant offset voltages.

## 2.6.6 Resistance Measurements

The Model 196 can make resistance measurements from  $100\mu\Omega$  to  $300M\Omega$ . The Model 196 provides automatic selection of 2-terminal or 4-terminal resistance measurements. This means that if the ohms sense leads are not connected, the measurement is done 2-terminal. If the sense leads are connected, the measurement is done 4-terminal. For 4-terminal measurements, rated accuracy can be obtained as long as the maximum lead resistance does not exceed the values listed in Table 2-3. For best results on the  $300\Omega$ ,  $3k\Omega$  and  $30k\Omega$  ranges, it is recommended that 4-terminal measurements be made to eliminate errors caused by the voltage drop across the test leads which will occur when 2-terminal measurements are made. The Model 5806 Kelvin Test Lead Set is ideal for low resistance 4-terminal measurements.

**Offset-Compensated Ohms**—Offset-compensated ohms is used to compensate for voltage potentials (such as thermal EMFs) across the device under test. This feature eliminates errors due to a low level external voltage source configured in series with the unknown resistor. Offsets up to  $10mV$  on the  $300\Omega$  range and up to  $100mV$  on the other ranges can be corrected with offset-compensation. This feature can be used for both 2-terminal and 4-terminal resistance measurements up to  $30k\Omega$ . Offset-compensation is selected through front panel Program  $\Omega$  (see paragraph 2.7.14).

During ohms offset compensated resistance measurements, the Model 196 performs the following steps for each conversion:

1. Makes a normal resistance measurement of the device. In general, this consists of sourcing a current through the device, and measuring the voltage drop across the device.
2. Turns off the internal current source and again measures the voltage drop across the device. This is the voltage caused by an external source.
3. Calculates and displays the corrected resistance value.

Offset-Compensated ohms not only corrects for small error voltages in the measurement circuit, but also compensates for thermal voltages generated within the Model 196. In normal ohms, these thermal EMF offsets are accounted for during calibration. Therefore, enabling offset-compensation will cause these offsets to appear in the readings,

especially the  $300\Omega$  range. After offset-compensation is enabled, the Model 196 should be properly zeroed.

To make resistance measurements, proceed as follows:

1. Select the ohms function by pressing the  $\Omega$  button.
2. Select a range consistent with the expected resistance or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Turn offset-compensation on or off as needed, using Program  $\Omega$ .

### NOTE

If offset-compensation is being used, the  $300\Omega$ ,  $3k\Omega$  and  $30k\Omega$  ranges require zero to be set in order to achieve the best accuracy. The zero correction procedure is located in paragraph 2.6.2.

5. For 2-terminal measurements connect the resistance to the instrument as shown in Figure 2-4. For 4-terminal measurements connect the resistance to the instrument as shown in Figure 2-5.

### CAUTION

The maximum input voltage between the HI and LO input terminals is  $425V$  peak or  $300V$  RMS. Do not exceed these values or instrument damage may occur.

6. Take the reading from the display.

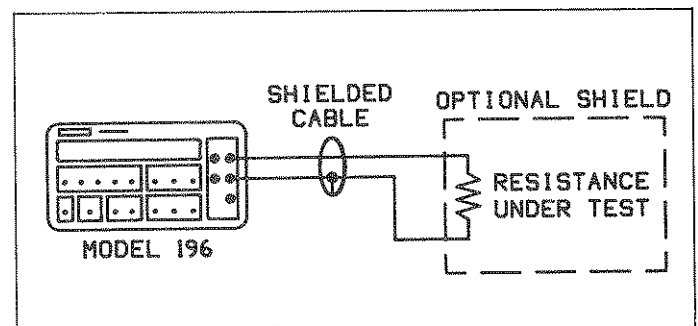


Figure 2-4. Two-Terminal Resistance Measurements

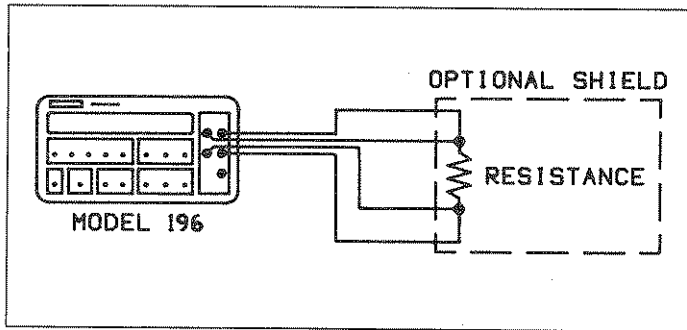


Figure 2-5. Four-Terminal Resistance Measurements

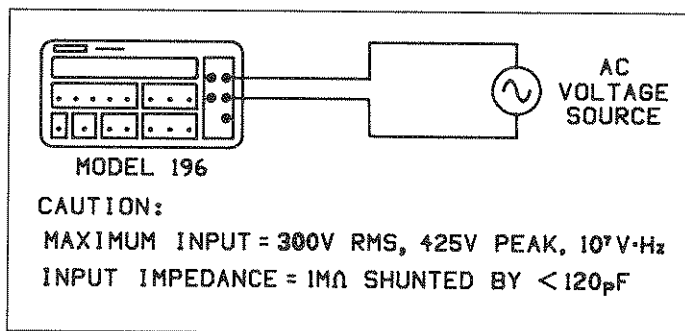


Figure 2-6. TRMS AC Voltage Measurement

Notes:

1. With ohms compensation active (Progam Ω), the Ω indicator light will blink when the ohms function is selected.
2. Table 2-3 shows the current output for each resistance range.
3. It helps to shield resistance greater than 100kΩ to achieve a stable reading. Place the resistance in a shielded enclosure and electrically connect the shield to the LO input terminal of the instrument.
4. Diode Test—The 3kΩ range can be used to test diodes as follows:
  - A. Select the 3kΩ range.

- B. Forward bias the diode by connecting the red terminal of the Model 196 to positive side of the diode. A good diode will typically measure between 300Ω to 1kΩ.
- C. Reverse bias the diode by reversing the connections on the diode. A good diode will overrange the display.

Table 2-3. Resistance Ranges

Range	6 <sup>1</sup> / <sub>2</sub> d Resolution	Nominal I-Short	Maximum Test Lead Resistance (Ω) for <1 Count Error (6 <sup>1</sup> / <sub>2</sub> d)
300 Ω	100 μΩ	1.7mA	1
3kΩ	1mΩ	1.7mA	3
30 kΩ	10mΩ	160μA	10
300 kΩ	100mΩ	50μA	30
3MΩ	1 Ω	5μA	100
30MΩ	10 Ω	0.5μA	300
300MΩ	1 kΩ*	0.5μA	3k

\*5<sup>1</sup>/<sub>2</sub>d resolution only

NOTE: Typical open circuit voltage is 5V.

### 2.6.7 TRMS AC Voltage Measurements

The instrument can make TRMS AC voltage measurements from 1μV to 300V. To measure AC volts, proceed as follows:

1. Select the AC volts function by pressing the ACV button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.

**NOTE**

There is a small amount of offset (typically 150 counts at 5<sup>1</sup>/<sub>2</sub>d) present when using the ACV function. Do not zero this level out. Paragraph 2.6.10 provides an explanation of AC voltage offset.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-6.
5. Take the reading from the display.



### 2.6.1 Warm Up Period

The Model 196 is usable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least two hours to achieve rated accuracy.

### 2.6.2 Zero

The zero feature serves as a means of baseline suppression by allowing a stored offset value to be subtracted from subsequent readings. When the ZERO button is pressed, the instrument takes the currently displayed reading as a baseline value. All subsequent readings represent the difference between the applied signal level and the stored baseline.

A baseline level can be established for any or all measurement functions and is remembered by each function. For example, a 10V baseline can be established on DCV, a 5V baseline can be established on ACV and a 10k $\Omega$  baseline can be established on OHMS. These levels will not be cancelled by switching back and forth between functions. Once a baseline is established for a measurement function, that stored level will be the same regardless of what range the Model 196 is on. For example, if 1V is established as the baseline on the 3V range, then the baseline will also be 1V on the 30V through 300V ranges. A zero baseline level can be as large as full range.

#### NOTE

The following discussion on dynamic range is based on a display resolution of 6½ digits. At 5½d resolution, the number of counts would be reduced by a factor of 10. At 4½d resolution, counts would be reduced by a factor of 100 and 3½d resolution would reduce counts by a factor of 1000.

By design, the dynamic measurement range of the Model 196, at 6½-digit resolution, is 6060000 counts. With zero disabled, the displayed reading range of the instrument is  $\pm 3030000$  counts. With zero enabled, the Model 196 has the capability to display  $\pm 6060000$  counts. This increased display range ensures that the dynamic measurement range of the instrument is not reduced when using a zero baseline value. The following two examples will use the maximum allowable zero values (3030000 counts and  $-3030000$  counts) to show that dynamic measurement range will not be reduced. It is important to note that the increased display range does not increase the maximum allowable input level to the instrument. For example, on the 3V range, the Model 196 will always overrange when more than  $\pm 3.03$ V is connected to the input.

**Example 1**—The instrument is set to the 3V DC range and a maximum  $-3.030000$ V is established as the zero value. When  $-3.030000$ V is connected to the input of the Model 196, the display will read 0.000000V. When  $+3.030000$ V is connected to the input, the display will read  $+6060000$ V. Thus, the dynamic measurement range of the Model 196 is 0V to 6.06V, which is 6060000 counts.

**Example 2**—The instrument is still set to the 3V DC range, but a maximum  $+3.030000$ V is the zero level. When  $+3.030000$ V is connected to the input of the Model 196, the display will read 0.000000V. When  $-3.030000$ V is connected to the input, the display will read  $-6.060000$ V. Thus the dynamic measurement range of the instrument is  $-6.06$ V to 0V, which is still 6060000 counts.

**Zero Correction**—The Model 196 must be properly zeroed when using the 300mV DC or the 300 $\Omega$  range in order to achieve rated accuracy specifications. To use ZERO for zero correction, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select the 300mV DC or the 300 $\Omega$  range.
3. Connect the test leads to the input of the Model 196 and short them together. If four-wire resistance measurements are to be made, connect and short all four leads together. Allow any thermals to stabilize.  
Note: At 5½ and 6½-digit resolution, low level measurement techniques need to be employed. Use Kelvin test leads or shielded test leads. See paragraph 2.6.5 for low level measurement considerations.
4. Press the ZERO button. The display will read zero.
5. Remove the short and connect the test leads to the signal or resistance to be measured.

Note: Test lead resistance is also compensated for when zeroing the 300 $\Omega$  range with the above procedure.

**Baseline Levels**—Baseline values can be established by either applying baseline levels to the instrument or by setting baseline values with the front panel ZERO program. Paragraph 2.7.15 contains the complete procedure for using the ZERO program. To establish a baseline level by applying a level to the Model 196, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select a function and range that is appropriate for the anticipated measurement.
3. Connect the desired baseline level to the input of the Model 196 and note that level on the display.

- Press the ZERO button. The display will zero and the ZERO indicator will be enabled. The previously displayed reading will be the stored baseline. The zero baseline value will also be stored in Program ZERO, replacing the previous zero value.

**WARNING**

With ZERO enabled, a hazardous voltage baseline level ( $\pm 40V$  or more), not displayed, may be present on the input terminals. If not sure what is applied to the input, assume that a hazardous voltage is present.

- Disconnect the stored signal from the input and connect the signal to be measured in its place. Subsequent readings will be the difference between the stored value and the applied signal.

Notes:

- Disabling zero cancels the zero baseline value on that selected function. However, since the zero value is automatically stored in Program ZERO, the zero baseline value can be retrieved by using the program as long as the ZERO button is not again pressed (see paragraph 2.7.15 for details). Pressing the ZERO button, thus enabling zero, will wipe out the previous baseline value in Program ZERO. Baselines established on other functions are not affected.
- To store a new baseline on a selected function, zero must first be disabled and then enabled again. The new value will be stored with the first triggered conversion. The baseline value will also be stored as the zero value in Program ZERO, cancelling the previously stored value.
- Setting the range lower than the suppressed value will overrange the display; the instrument will display the overrange message under these conditions.
- When the ZERO button is pressed to enable zero, the ZERO indicator light will blink until an on scale reading is available to use as a zero level.

**2.6.3 Filter**

The Model 196 incorporates two filters; a digital filter controlled from either the front panel or over the IEEE-488 bus, and an internal filter controlled exclusively from over the bus.

**Digital Filter**—The Model 196 utilizes a digital filter to attenuate excess noise present on input signals. This filter is a weighted average type.

The factory default filter weighting is 1/10, but can be changed to a weighting from 1 (1/1) to 1/99 with the use of the FILTER program. While in the program, the Model 196 will only display the denominator of the filter weighting. For example, if the current filter weighting is 1/10, the FILTER program will display it as the value 10. Thus, filter value as used in this discussion refers to the values displayed by the Model 196 when in the FILTER program.

A filter value can be set for any or all measurement functions and is remembered by each function. For example, a filter value of 20 can be set for DCV and a filter value of 55 can be set for ACV. These filter values will not be cancelled by switching back and forth between functions.

An advantage of using the filter is to stabilize the reading of a noisy input level. A consideration of filter usage is that the larger the weighting, the longer the response time of the display. Perform the following procedure to use the filter:

- If it is desired to check and/or change the filter value, utilize Program FILTER as explained in paragraph 2.7.16.
- Press the FILTER button. The FILTER indicator will turn on.

Notes:

- When the filter is enabled, readings will be filtered before being displayed. See Digital Filter Theory.
- Pressing the FILTER button a second time will disable the filter.
- After a reading is triggered (continuous or one-shot), the FILTER indicator light will blink for three time constants. A time constant is measured in readings. The number of readings in one time constant is equal to the filter value. For example, for a filter value of 10, one time constant is equal to 10 readings and three time constants would be equal to 30 readings. The blinking duration will be shorter in the 3½d mode since that has the fastest reading rate.
- In a continuous trigger mode, a reading that is outside the filter window will cause the FILTER indicator to blink for one time constant.

**Digital Filter Theory**—The mathematical representation of the weighted average digital filter is as follows:

$$AVG(t) = AVG(t-1) + \frac{(\text{new reading} - AVG(t-1))}{F}$$

Where,

AVG(t) = displayed average

AVG(t-1) = old displayed average

F = weighting factor (filter value)

As with any filter, the Model 196 digital filter will affect reading response time. The step response for this filter is of the form:

$$\text{step response} = 1 - K^{(n+1)}$$

Where,

"K" is a constant based on the filter weighting factor

$$K = 1 - \left( \frac{1}{F} \right)$$

"n" is the reading number.

The step occurs when n=0. n=1 is the first reading after the step, n=2 is the second reading, etc.

Therefore:

$$\text{step response} = 1 - \left( 1 - \frac{1}{F} \right)^{n+1}$$

Example:

F = 10

n = 5

$$1 - \left( 1 - \frac{1}{10} \right)^6$$

Five readings after the step occurs, the display will be at  $\approx 47\%$  of the step change. After 10 readings (n=10), the display will be at  $\approx 68\%$  and after 20 readings, the display will be at  $\approx 88\%$ . The more the readings, the closer the display will be to the step change.

To speed the response to large step changes, the Model 196 digital filter employs a "window" around the displayed average. As long as new readings are within this window, the displayed value is based on the weighted average equation. If a new reading is outside of this window, the

displayed value will be the new reading, and weighted averaging will start from this point. The step response was one reading to this change. The window in the Model 196 filter is 10,000 counts for  $6\frac{1}{2}$ d resolution, 1000 counts for  $5\frac{1}{2}$ d, 100 counts for  $4\frac{1}{2}$ d and 10 counts for  $3\frac{1}{2}$ d.

**Internal Filter**—In addition to the front panel digital filter, an internal running average digital filter is used when making high resolution and high sensitivity measurements. The enable/disable status of the filter is controlled over the IEEE bus. However, under factory default conditions, the instrument powers up with the filter enabled. When enabled, this filtering only occurs when the instrument is in the  $5\frac{1}{2}$  or  $6\frac{1}{2}$ -digit resolution mode.

Notes:

1. The front panel FILTER indicator light does not turn on when the internal filter is activated. The indicator is only used with the front panel digital filter.
2. Controlling the internal filter (on/off) over the IEEE bus is explained in paragraph 3.9.22.
3. In a one-shot trigger mode, the Model 196 will not output a reading until both filters have settled. Three time constants are used to allow the filters to settle. A time constant is measured in readings. The number of readings in one time constant is equal to the filter value. For example, for a filter value of 10, three time constants would be equal to 30 readings. If both the internal filter and the front panel filter are in use, the time constant is the sum of both filter values.
4. Filter windows for the internal filter function in the same manner as the windows for the front panel filter. However, the window sizes of the internal filter are much smaller than the front panel filter window sizes.

## 2.6.4 DC Voltage Measurements

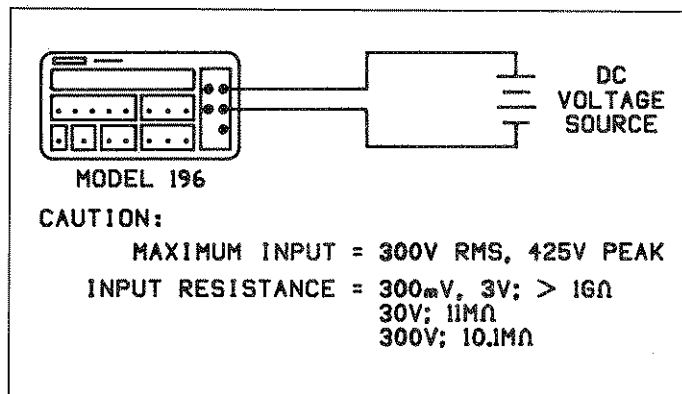
The Model 196 can be used to make DC voltage measurements in the range of  $\pm 100$ nV to  $\pm 300$ V. Use the following procedure to make DC voltage measurements.

1. Select the DC volts function by pressing the DCV button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals with the INPUT switch.

### NOTE

The 300mV DC range requires zero to be set in order to achieve rated accuracy. The zero correction procedure can be found in paragraph 2.6.2.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-3.
5. Take the reading from the display.



**Figure 2-3. DC Voltage Measurements**

### 2.6.5 Low-Level Measurement Considerations

**Accuracy Considerations**—For sensitive measurements, other external considerations besides the Model 196 will affect the accuracy. Effects not noticeable when working with higher voltages are significant in nanovolt and microvolt signals. The Model 196 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors which affect accuracy, noise, source resistance, thermal emfs and stray pick-up.

**Noise and Source Resistance**—The limit of sensitivity in measuring voltages with the Model 196 is determined by the noise present. The noise voltage at the Model 196 input increases with source resistance.

For high impedance sources, the generated noise can become significant when using the most sensitive range (300mV, 6½d) of the Model 196. As an example of determining  $e_n$  (noise voltage generation due to Johnson noise of the source resistance), assume that the Model 196 is connected to a voltage source with an internal resistance of 1MΩ. At a room temperature of 20°C, the p-p noise voltage generated over a bandwidth of 1Hz will be:

$$e_n = 6.35 \times 10^{-10} \sqrt{R \times f}$$

$$e_n = 6.35 \times 10^{-10} \sqrt{(1 \times 10^6) (1)}$$

$$e_n = 0.635\mu V$$

Thus, an  $e_n$  of 0.635μV would be displayed at 6½d resolution as an additional six digits of noise on the Model 196. To compensate for the displayed noise, use digital filtering and then zero out the settled offset.

**Shielding**—AC voltages which are extremely large compared with the DC signal may erroneously produce a DC output. Therefore, if there is AC interference, the circuit should be shielded with the shield connected to the Model 196 input LO (particularly for low-level sources). Improper shielding can cause the Model 196 to behave in one or more of the following ways:

1. Unexpected offset voltages.
2. Inconsistent readings between ranges.
3. Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 196 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

**Thermal EMFs**—Thermal emfs (thermoelectric potentials) are generated by thermal differences between the junction of dissimilar metals. These can be large compared to the signal which the Model 196 can measure. Thermal emfs can cause the following problems:

1. Instability or zero offset is much higher than expected.
2. The reading is sensitive to (and responds to) temperature changes. This can be demonstrated by touching the circuit, by placing a heat source near the circuit or by a regular pattern of instability (corresponding to heating and air-conditioning systems or changes in sunlight).
3. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the Model 196. A banana plug is generally suitable and generates just a few microvolts. A clean copper conductor such as #10 bus wire is about the best for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to Shielding.
4. Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant temperatures to minimize these thermal emfs. A cardboard box around the circuit under test also helps by minimizing air currents.
5. The ZERO control can be used to null out constant offset voltages.

## 2.6.6 Resistance Measurements

The Model 196 can make resistance measurements from  $100\mu\Omega$  to  $300M\Omega$ . The Model 196 provides automatic selection of 2-terminal or 4-terminal resistance measurements. This means that if the ohms sense leads are not connected, the measurement is done 2-terminal. If the sense leads are connected, the measurement is done 4-terminal. For 4-terminal measurements, rated accuracy can be obtained as long as the maximum lead resistance does not exceed the values listed in Table 2-3. For best results on the  $300\Omega$ ,  $3k\Omega$  and  $30k\Omega$  ranges, it is recommended that 4-terminal measurements be made to eliminate errors caused by the voltage drop across the test leads which will occur when 2-terminal measurements are made. The Model 5806 Kelvin Test Lead Set is ideal for low resistance 4-terminal measurements.

**Offset-Compensated Ohms**—Offset-compensated ohms is used to compensate for voltage potentials (such as thermal EMFs) across the device under test. This feature eliminates errors due to a low level external voltage source configured in series with the unknown resistor. Offsets up to  $10mV$  on the  $300\Omega$  range and up to  $100mV$  on the other ranges can be corrected with offset-compensation. This feature can be used for both 2-terminal and 4-terminal resistance measurements up to  $30k\Omega$ . Offset-compensation is selected through front panel Program  $\Omega$  (see paragraph 2.7.14).

During ohms offset compensated resistance measurements, the Model 196 performs the following steps for each conversion:

1. Makes a normal resistance measurement of the device. In general, this consists of sourcing a current through the device, and measuring the voltage drop across the device.
2. Turns off the internal current source and again measures the voltage drop across the device. This is the voltage caused by an external source.
3. Calculates and displays the corrected resistance value.

Offset-Compensated ohms not only corrects for small error voltages in the measurement circuit, but also compensates for thermal voltages generated within the Model 196. In normal ohms, these thermal EMF offsets are accounted for during calibration. Therefore, enabling offset-compensation will cause these offsets to appear in the readings,

especially the  $300\Omega$  range. After offset-compensation is enabled, the Model 196 should be properly zeroed.

To make resistance measurements, proceed as follows:

1. Select the ohms function by pressing the  $\Omega$  button.
2. Select a range consistent with the expected resistance or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Turn offset-compensation on or off as needed, using Program  $\Omega$ .

### NOTE

If offset-compensation is being used, the  $300\Omega$ ,  $3k\Omega$  and  $30k\Omega$  ranges require zero to be set in order to achieve the best accuracy. The zero correction procedure is located in paragraph 2.6.2.

5. For 2-terminal measurements connect the resistance to the instrument as shown in Figure 2-4. For 4-terminal measurements connect the resistance to the instrument as shown in Figure 2-5.

### CAUTION

The maximum input voltage between the HI and LO input terminals is  $425V$  peak or  $300V$  RMS. Do not exceed these values or instrument damage may occur.

6. Take the reading from the display.

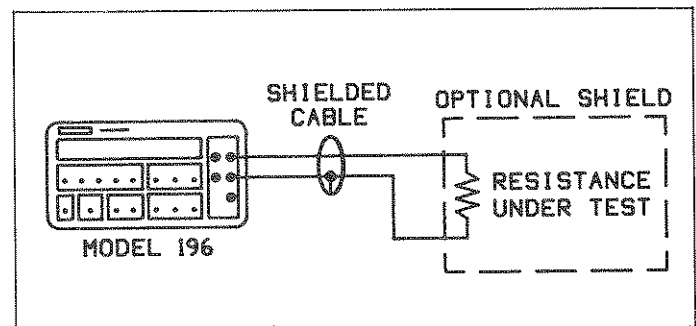


Figure 2-4. Two-Terminal Resistance Measurements

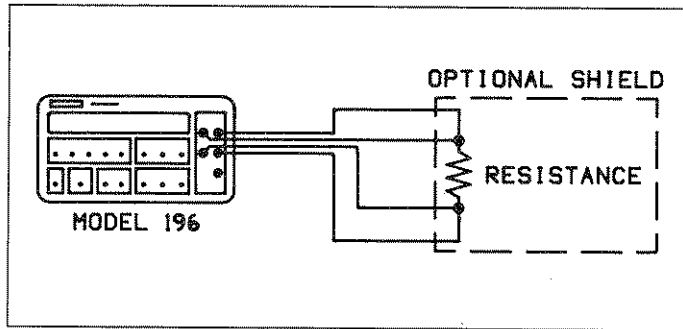


Figure 2-5. Four-Terminal Resistance Measurements

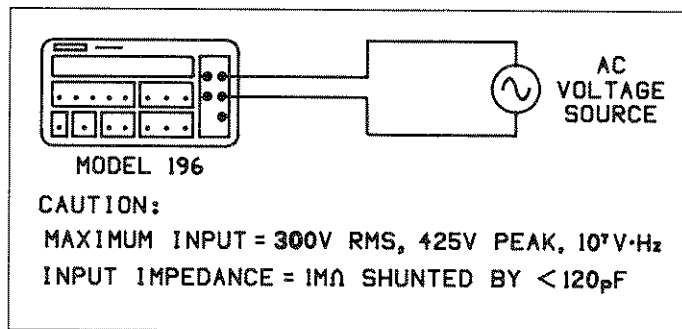


Figure 2-6. TRMS AC Voltage Measurement

Notes:

1. With ohms compensation active (Program Ω), the Ω indicator light will blink when the ohms function is selected.
2. Table 2-3 shows the current output for each resistance range.
3. It helps to shield resistance greater than 100kΩ to achieve a stable reading. Place the resistance in a shielded enclosure and electrically connect the shield to the LO input terminal of the instrument.
4. Diode Test—The 3kΩ range can be used to test diodes as follows:
  - A. Select the 3kΩ range.

- B. Forward bias the diode by connecting the red terminal of the Model 196 to positive side of the diode. A good diode will typically measure between 300Ω to 1kΩ.
- C. Reverse bias the diode by reversing the connections on the diode. A good diode will overrange the display.

Table 2-3. Resistance Ranges

Range	6 <sup>1/2</sup> d Resolution	Nominal I-Short	Maximum Test Lead Resistance (Ω) for <1 Count Error (6 <sup>1/2</sup> d)
300 Ω	100 μΩ	1.7mA	1
3kΩ	1mΩ	1.7mA	3
30 kΩ	10mΩ	160μA	10
300 kΩ	100mΩ	50μA	30
3MΩ	1 Ω	5μA	100
30MΩ	10 Ω	0.5μA	300
300MΩ	1 kΩ*	0.5μA	3k

\*5<sup>1/2</sup>d resolution only

NOTE: Typical open circuit voltage is 5V.

### 2.6.7 TRMS AC Voltage Measurements

The instrument can make TRMS AC voltage measurements from 1μV to 300V. To measure AC volts, proceed as follows:

1. Select the AC volts function by pressing the ACV button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.

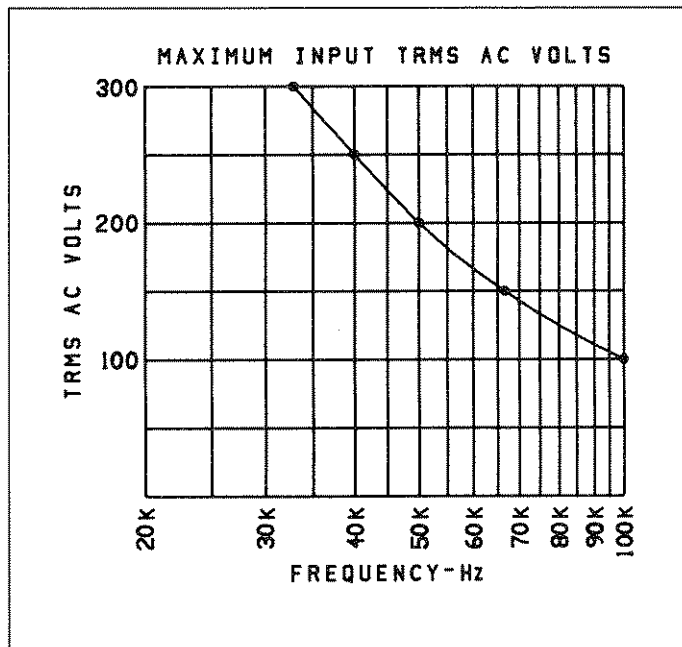
**NOTE**

There is a small amount of offset (typically 150 counts at 5<sup>1/2</sup>d) present when using the ACV function. Do not zero this level out. Paragraph 2.6.10 provides an explanation of AC voltage offset.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-6.
5. Take the reading from the display.

## Clarifications of TRMS ACV Specifications:

**Maximum Allowable Input**—The following graph summarizes the maximum input based on the  $10^7 \text{V} \cdot \text{Hz}$  specification.



**Settling Time**—1sec to within 0.1% of change in reading. This time specification is for analog circuitry to settle and does not include A/D conversion time.

## Notes:

- See paragraph 2.6.10 for TRMS measurement considerations.
- When making TRMS AC voltage measurements below 45Hz, enable the front panel filter modifier to obtain stable readings. A filter value of 10 is recommended.
- To make low frequency AC measurements in the range of 10Hz to 20Hz:
  - The ACV function must be selected.
  - Digital filtering must be used to obtain a stable reading.
  - Allow enough settling time before taking the reading.

## 2.6.8 Current Measurements (DC or TRMS AC)

The Model 196 can make DC or TRMS AC current measurements from 1nA (at  $5\frac{1}{2}$ d resolution) to 3A. Use the following procedure to make current measurements.

- Select the DC current or AC current function by pressing the DCA or ACA button respectively.
- Select a range consistent with the expected current or use autorange.
- Select the front or rear panel input terminals using the INPUT switch.
- Connect the signal to be measured to the selected input terminals as shown in Figure 2-7.
- Take the reading from the display.

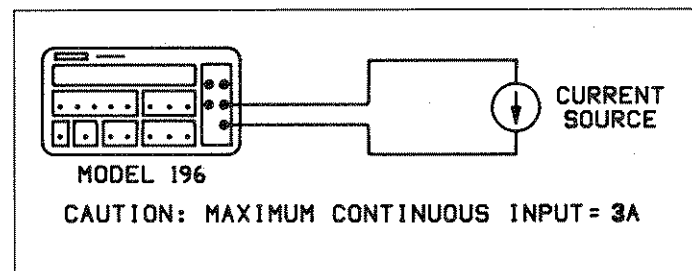


Figure 2-7. Current Measurements

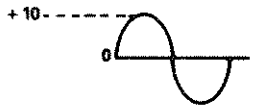
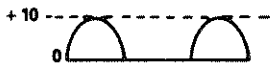



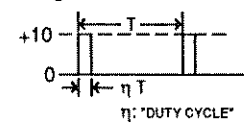
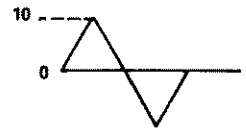
## 2.6.9 dB Measurements

The dB measurement mode makes it possible to compress a large range of measurements into a much smaller scope. AC dB measurements can be made with the instrument in the ACV or ACA function. The relationship between dB and voltage and current, can be expressed by the following equations:

$$\text{dB} = 20 \log \left( \frac{V_{in}}{V_{ref}} \right)$$

$$\text{dB} = 20 \log \left( \frac{I_{in}}{I_{ref}} \right)$$

Table 2-5. Comparison of Average and TRMS Meter Readings

Waveform	Ac Coupled Peak Value	RMS Value	Average Responding Meter Reading	Ac Coupled TRMS Meter Reading	Averaging Meter Percent Error
Sine 	10V	7.07V	7.07V	7.07V	0%
Half-Wave Rectified Sine 	10V	5.00V	3.53V	5.00V	29.4%
Full-Wave Rectified Sine 	10V	7.07V	7.07V	7.07V	0%
Square 	10V	10.00V	11.10V	10.00V	11%
Rectified Square Wave 	10V	5.00V	5.55V	5.00V	11%
Rectangular Pulse  <p style="text-align: center;"><math>\eta</math>: "DUTY CYCLE"</p>	10V	$10V \cdot \sqrt{\eta}$	$11.1V \cdot \eta$	$10V \cdot \sqrt{\eta}$	$(1.11 \sqrt{\eta} - 1) \times 100\%$
Triangular Sawtooth 	10V	5.77V	5.55V	5.77V	3.8%



### 2.6.11 dB Applications

**Measuring Circuit Gain/Loss**—Any point in a circuit can be established as the 0dB point. Measurements in that circuit are then referenced to that point expressed in terms of gain (+dB) or loss (−dB). To set the zero dB point proceed as follows:

1. Place the Model 196 in ACV and dB.
2. Connect the Model 196 to the desired location in the circuit.
3. Press the ZERO button. The display will read 0dB.
4. Gain/loss measurements can now be made referenced to the 0dB point.

**Measuring Bandwidth**—The Model 196 can be used to determine the bandwidth of an amplifier as follows:

1. Connect a signal generator and a frequency counter to the input of the amplifier.
2. Set the Model 196 to ACV and autorange.
3. Connect the Model 196 to the load of the amplifier.
4. Adjust the frequency of the signal generator until a peak AC voltage reading is measured on the Model 196. This is the center frequency.
5. Press the dB button and then press the ZERO button. The 0dB point is now established.
6. Increase the frequency input until the Model 196 reads −3.00dB. The frequency measured on the frequency counter is the high-end limit of the bandwidth.
7. Decrease the frequency input until the dB reading again falls to −3.00dB. The frequency measured on the signal generator is the low-end limit of the bandwidth.

Note: The bandwidth of the Model 196 is typically 300kHz. Do not use this application to check amplifiers that exceed the bandwidth of the Model 196.

**Determining Q**—The Q of a tuned circuit can be determined as follows:

1. Determine the center frequency and bandwidth as explained in the previous application (Measuring Bandwidth).
2. Calculate Q by using the following formula:  

$$Q = \text{Center Frequency} / \text{Bandwidth}$$

## 2.7 FRONT PANEL PROGRAMS

There are 17 programs available from the front panel of the Model 196. These programs are listed in Table 2-6. The following paragraphs describe and explain the operation of each program.

Table 2-6. Front Panel Programs

Program	Description
0 (Menu)	Display software level and list available front panel programs.
2 (Resolution)	Change display resolution (3½d, 4½d, 5½d or 6½d).
4 (MX+B)	Enable MX+B program.
5 (HI/LO/Pass)	Enable/disable HI/LO/Pass program.
6 (Mux)	Recall status, enable/disable multiplexer.
30 (Save)	Save current instrument set up.
31 (IEEE Address)	Recall/modify IEEE address.
32 (Line Frequency)	Recall/modify line frequency setting (50/60Hz).
33 (Self Test)	Enter self-test program.
34 (MX+B Parameters)	Recall/modify MX+B program values.
35 (HI/LO Limits)	Recall/modify HI/LO limits.
36 (Calibration)	Enter digital calibration mode.
37 (Reset)	Returns 196 to factory default conditions.
Ω	Recall status, enable/disable offset compensation.
ZERO	Recall/modify zero value.
FILTER	Recall/modify filter value.
dB	Recall/modify dB reference value.

**Program Selection**—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 Address), press the PRGM button and then the “3” and “1” buttons.

**Data Entry**—Program data is applied from the front panel using the data buttons. The data buttons consist of the buttons labeled with the ± polarity sign and numbers 0 through 9. Data entry is accomplished by pressing the appropriate number button at each cursor location. Cursor location is indicated by the bright, flashing display digit. The cursor moves one digit to the right every time a number is entered. After entering a number at the least significant display digit, the cursor will move back to the most significant digit. Polarity (± button) can be changed with the cursor at any display character. Plus (+) is implied and thus, not displayed.

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 (cursor) can be modified using the data buttons (0 through 9). Polarity ( $\pm$  button) can be changed with the cursor on any character. Plus (+) is implied and thus, not displayed.
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 pressed ENTER button causes the instrument to exit the program.
5. A program can be exited at any time and thus not executed, by pressing the PRGM button.

### 2.7.1 Program 0 (Menu)

This program displays the software revision level of the Model 196 and lists the available front panel programs. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Enter the number 0 by pressing the "0" button. The software level of the instrument will be displayed. For example, if the software level is B1, the following message will be displayed:

SOFTREV B1

3. Use the manual Range buttons to scroll through the front panel programs. The  $\blacktriangle$  range button scrolls forward while the  $\blacktriangledown$  range button scrolls backward.
4. To exit from the menu, press the PRGM button. The instrument will return to the previous operating state.

### 2.7.2 Program 2 (Resolution)

Program 2 selects the number of display resolution digits. The resolution available is dependent on function and range. Table 2-7 lists the display resolution available for the various function/range combinations. Display resolution can be set for each function and is remembered by each function as long as the instrument remains powered up. Resolution can be remembered after power-down by running Program 30 (Save). To change the display resolution, perform the following procedure:

1. Set the instrument to the desired function and range.
2. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

3. Enter the number 2 by pressing the "2" button. The current resolution status will then be displayed. For example, if the selected function is currently set for 6½ digits of resolution, the following message will be displayed:

6½ d

4. If an altered resolution is desired, use the manual Range buttons to display the resolution. The  $\blacktriangledown$  Range button decreases resolution, while the  $\blacktriangle$  Range button increases resolution.
5. With the desired resolution displayed, press the ENTER button. The instrument will return to the previously selected function and range.

**Table 2-7. Display Resolution**

Function	Range	Available Resolution
DCV	All	3½d, 4½d, 5½d, 6½d
ACV	All	3½d, 4½d, 5½d
$\Omega$	300 $\Omega$ , 3k $\Omega$ , 30k $\Omega$ , 300k $\Omega$ 3M $\Omega$ , 30M $\Omega$ 300M $\Omega$	3½d, 4½d, 5½d, 6½d 5½d, 6½d 5½d
DCA	All	3½d, 4½d, 5½d
ACA	All	3½d, 4½d, 5½d

### 2.7.3 Program 4 (MX+B)

This program allows the operator to automatically multiply normal display readings (X) by a constant (M) and add a constant (B). The result (Y) will be displayed in accordance with the formula,  $Y=MX + B$ . This program is useful when slope calculations are required for a series of measurements. The values of M and B can be changed by utilizing Program 34. Perform the following steps to enable the MX + B feature:

1. Set the Model 196 to the desired function and range.
2. Connect the signal to be measured (X) to the input of the Model 196.

- If the values of M and B need to be checked or changed, do so using Program 34.
- Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

- Enter the number 4 by pressing the "4" button. The current status of the MX+B program will be displayed. For example, if the MX+B is currently disabled, the following message will be displayed:

MX+B OFF

- Any range button will toggle the display to the alternate MX+B status. Therefore, press a Range button and the following message will be displayed:

MX+B ON

- With the message "MX+B ON" displayed, press the ENTER button to enable MX+B. The instrument will return to the function initially set.
- All subsequent readings (Y) will be the result of the equation:  $Y=MX+B$ .

#### Notes:

- The MX+B feature can be disabled by again running Program 4. While in the program, press a range button until the message "MX+B OFF" is displayed and then press the ENTER button.
- Once MX+B has been enabled, the Model 196 will show the value of Y. If the value of Y is larger than can be handled by the particular range, the overrange message will be displayed, indicating the instrument must be switched to a higher range.
- User selected values of M and B will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever, X+B is enabled. Note however, that the value of B is scaled according to the range in use. Example: A value of 19.00000 entered for B is actually 19.00000V with the instrument on the 30V range and 190.0000V with the instrument on the 300.0000V range.
- An example of readings that will be obtained when MX+B is enabled is shown in Table 2-8. Each of the obtained values for Y assumes the following constants:  $M=+1.5$ ;  $B=+5$ .

Table 2-8. Example MX + B Readings

196 Range and Function	Normal Reading (X)	MX + B* Reading (Y)
30VDC	8.00000VDC	17.00000VDC
30VDC	-5.00000VDC	-2.50000VDC
30VAC	6.30000VAC	14.45000VAC
30k $\Omega$	4.00000k $\Omega$	11.00000k $\Omega$

\*where  $M = +1.5$  and  $B = +5$ .

### 2.7.4 Program 5 (HI/LO/Pass)

Program 5 is used to enable the HI/LO/PASS program. With this program, the Model 196 will indicate whether or not a specific reading falls within a prescribed range. The factory default LO limit is a negative full scale reading, with the actual value dependent on function and range. Conversely, the factory default HI limit is a positive full scale reading. With these  $\pm$  full scale limits, the Model 196 will display the HI or LO message for overrange readings and the PASS message for on-range readings. The HI and LO limits can be set to any on-range value with Program 35 (HI/LO Limits).

This feature is especially useful for component evaluation, where certain component tolerances must be observed. Once the limits are programmed into the instrument, the operator need only monitor the display messages to determine the integrity of the device. Perform the following procedure to enable Program 5:

- Select the desired function and range, and zero the instrument, if desired. These operating parameters cannot be changed once the program is active without exiting the program.
- If the limits need to be checked or changed, do so using Program 35.
- Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

- Enter the number 5 by pressing the "5" button. The following message will be displayed briefly:

HI LO PASS

5. At this point, the instrument will run the program. No numeric readings will be displayed. Instead, one of the following messages will be displayed:

A. If the measured value is less than the low limit, the following message will be displayed:

LO

B. If the measured value is greater than the high limit, the following message will be displayed:

HI

C. If the measured value falls within the high and low limits, the following message will be displayed:

PASS

6. To disable the program, press the function button that has the indicator light on. This will disable the program without changing the measurement parameters (i.e. function, range, etc.) of the instrument.

**Notes:**

1. Limits can be set using Program 35 with or without Program 5 enabled.
2. User selectable values of L and H will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever HI/LO/PASS is enabled. Note however, that the value of L and H are scaled according to the range in use.
3. Pressing any of the front panel controls, except dB (unless in AC), ENTER, and LOCAL, will disable the program and select the feature associated with that button.

**2.7.5 Program 6 (Multiplexer, Auto/Cal)**

The multiplexer auto/cal routines may be defeated by running Program 6. Using the Model 196 with the auto zero/cal defeated increases measurement speed and is useful for making high impedance DC voltage measurements which can be affected by the input multiplexing. Perform the following steps to run this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Enter the number 6 by pressing the "6" button. The current multiplexer status will then be displayed. For example, if the multiplexer is on, the following message will be displayed:

MUX ON

3. If the alternate multiplexer status is desired, press one of the range buttons. The alternate status will be displayed as follows:

MUX OFF

4. To enter the displayed multiplexer status, press the ENTER button. The instrument will return to the previous operating state.

**NOTE**

With the auto/cal multiplexer disabled, the internal zero and calibration are affected by changing the nominal input level, especially on ohms and the 300VDC range. Whenever the applied input level changes, press the selected function button to perform an auto/cal routine, otherwise substantial errors will result. Zero and calibration may also be affected by time. Thus, it is recommended that the selected function button be pressed periodically.

**2.7.6 Program 30 (Save)**

Program 30 saves current instrument conditions set up by the user. These user programmed conditions will then replace the previously saved default conditions on power up. Also, an SDC or DCL asserted over the IEEE-488 bus will return the instrument to these saved conditions.

The following instrument operating parameters are saved by this program:

- Function
- Range
- Resolution
- Zero status (on/off) and value
- Filter status (on/off) and value
- ACdB status (on/off) and reference value
- IEEE address
- Line frequency setting
- MX+B status (on/off) and values
- HI/LO limits
- Ohms compensation status (on/off)

Perform the following procedure to use the save program:

1. Set up the instrument as desired or run Program 37 (Reset) to return the instrument to the factory default conditions.

2. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

3. Enter the number 30 by pressing the "3" and "0" buttons. The following message will be displayed briefly:

SAVE

4. The following message will then be displayed:

ENTER ?

5. To save the instrument set up conditions, press the ENTER button. The following message will be displayed briefly:

ENTERED

6. The instrument will return to the conditions set up in step 1 and will now power up to those conditions.

#### Notes:

1. To exit the program without changing the previous default conditions, press any front panel button except the ENTER button. The instrument will return to the operating states set up in step 1.
2. To return the instrument to the factory power up default conditions, use Program 37 (Reset) and save the conditions using Program 30.
3. When using this program, make sure that the rest of the instrument is in the desired operating state.

### 2.7.7 Program 31 (IEEE Address)

Program 31 allows the user to check and/or modify the address of the IEEE-488 interface. The interface can be set to any primary address from 0 to 30. Detailed information on the IEEE-488 bus is provided in Section 3. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Enter the number 31 by pressing the "3" and "1" buttons. The IEEE address value will be displayed. Example: If the current primary address of the instrument is 7, the following message will be displayed:

07 IE

3. If it is desired to retain the displayed status value, proceed to step 4. To change the status value, enter the address number (0 to 30).

4. With a valid status displayed, press the ENTER button. The instrument will return to the previously defined state.

#### Notes:

1. If an invalid number is entered, the instrument will exit from the program with the IEEE primary address being set to 30.
2. To change the default address of the instrument, select the desired IEEE address using this program and then Program 30 (or L1 over the IEEE bus) to save it. Cycling power, Program 37 (Reset), or an SDC, DCL or L0 sent over the bus will not have any affect on the new default address.
3. If the IEEE address is changed but not saved:
  - A. Cycling power will return the instrument to the default address.
  - B. Program 37 (Reset), or an SDC or DCL sent over the bus will not have any affect on the current address.
  - C. Sending L0 over the bus will not change the current IEEE address, and will save that address as the power up default address.
4. An "UNCAL" error will default the IEEE address to 7 and the line frequency setting to 60Hz.

### 2.7.8 Program 32 (Line Frequency)

The Model 196 does not automatically detect the power line frequency upon power up. This program allows the user to check the line frequency setting of the instrument and to select the alternate frequency. The instrument can be set to either 50Hz or 60Hz. Perform the following steps to check and/or change the line frequency setting of the Model 196.

1. Press the PRGM button. The following prompt will be displayed.

PROGRAM ?

2. Enter the number 32 by pressing the "3" and "2" buttons. The current line frequency setting will then be displayed. If the instrument is currently set to 60Hz, the following message will be displayed:

FREQ=60Hz

- If the displayed frequency setting matches the available line frequency, proceed to step 4. If the alternative line frequency setting is needed, press one of the Range buttons. The display will toggle to the alternate frequency setting as shown:

FREQ=50Hz

- With the correct frequency setting displayed, press the ENTER button. The instrument will return to the previous operating state.

**Notes:**

- To change the default line frequency setting of the instrument, select the desired setting using this program and then Program 30 (or L1 over the IEEE bus) to save it. Cycling power, Program 37 (Reset), or an SDC, DCL or L0 sent over the bus will not have any affect on the new default setting.
- If the line frequency setting is changed but not saved:
  - Cycling power, or sending an SDC or DCL over the bus will return the instrument to the default setting.
  - Program 37 (Reset) will not have any affect on the current setting.
  - Sending L0 over the bus will not change the current line frequency setting, and will save that setting as the default setting.
- An "UNCAL" error will default the IEEE address to 7 and the line frequency setting to 60Hz.

**2.7.9 Program 33 (Diagnostic)**

Program 33 is a diagnostic program designed to switch on various switching FET's, relays and logic levels to allow signal tracing through the instrument. Also, tests on the display and memory are performed. Refer to paragraph 6.7.3 in the maintenance section to use this program to troubleshoot the instrument.

**2.7.10 Program 34 (MX+B Parameters)**

This program allows the operator to check/change the M and B values for the MX+B feature (Program 4) of the Model 196. The factory power up default value of M is 1.000000 and the value of B is 0000000. To check/change the values of M and B, proceed as follows:

- Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

- Enter the number 34 by pressing the "3" and "4" buttons. The current value of M will now be displayed. If the factory default value is the current value of M, then the following message will be displayed:

1.000000 M

- If it is desired to retain the displayed M value, proceed to step 4. If it is desired to modify the M value, do so using the data buttons. Note that valid M values are in the range of -9.999999 to +9.999999.
- With a M value displayed, press the ENTER button.
- The current B value will now be displayed. If the factory default value is the current B value, the following message will be displayed:

0000.000 B

Decimal point position is determined by the range that the instrument was on when this program was selected.

- If it is desired to retain the displayed B value, proceed to step 7. If it is desired to modify the value of M, do so using the data keys. Note that the B value range is from  $\pm 0.0001 \times 10^{-3}$  to  $\pm 9999.999$  (including zero).
- With a valid B value displayed, press the ENTER button. The instrument will return to the previously defined state of operation.

**Notes:**

- User selected values of M and B will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever MX+B is enabled. Note however, that the value of B is scaled according to the range in use. Example: A value of 19.00000 entered for B is actually 19.00000V with the instrument on the 30V range and 190.0000V with the instrument in the 300V range.
- The user can set the values for M and B as the power up default values by running Program 30.

**2.7.11 Program 35 (HI/LO Limits)**

Program 35 is used to set the high and low limits for the HI/LO/PASS program (Program 5). The factory default limits are +3030000 counts (HI limit) and -3030000 counts (LO limit). The actual value of the limits is dependent on the range. For example, the factory default HI limit on the 3V range is 3.030000V, while the factory default HI limit on the 30V range is 30.30000V. Perform the following procedure to set HI and LO limits:

1. Place the Model 196 in the function and range that the HI/LO/PASS program (Program 5) will be used.
2. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

3. Enter the number 35 by pressing the "3" and "5" buttons. The current LO limit will be displayed. For example, if the LO limit is the factory default value, the following message will be displayed:

-303.0000 LO

Decimal point position is determined by the range that the instrument was on when this program was selected.

4. If it is desired to retain the displayed LO limit, proceed to step 5. Otherwise, modify the displayed value using the data buttons. The LO limit must be in the range of -3030000 to +3030000 counts.
5. With the desired LO limit displayed, press the ENTER button. The current HI limit will be displayed. For example, if the LO limit is the factory default value, the following message will be displayed:

303.0000 HI

Decimal point position is determined by the range that the instrument was on when this program was selected.

6. If it is desired to retain the displayed HI limit, proceed to step 7. Otherwise, modify the displayed value using the data buttons. The HI limit must be in the range of -3030000 to +3030000 counts.
7. With the desired HI limit displayed, press the ENTER button. The instrument will return to the previous operating state.

#### Notes:

1. User selected limits will be stored in the Model 196 until power is turned off (unless saved by Program 30). These constants will be used whenever Program 5 (HI/LO/PASS) is enabled.
2. Limits set by the user will become the power up default limits by running Program 30 (Save).
3. Entering an invalid value will result with the instrument using the power up default limit.

## 2.7.12 Program 36 (Calibration)

The user can easily perform front panel digital calibration by applying accurate calibration signals using Program 36. The calibration signals can be either prompted default values or numbers entered from the front panel. Paragraph 6.4.5 describes the basic steps for using this program, while paragraphs 6.4.7 through 6.4.12 provide the complete front panel calibration procedure.

## 2.7.13 Program 37 (Reset)

Program 37 resets instrument set up parameters back to factory default conditions. The factory default conditions are listed in Tables 2-1 and 3-7. Perform the following steps to run this program.

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Enter the number 37 by pressing the "3" and "7" buttons. The following message will be displayed briefly:

RESET

3. The following prompt will then be displayed:

ENTER?

4. Press the ENTER button. The following message will be displayed briefly and the instrument will return to the factory default conditions.

ENTERED

#### Notes:

1. Program 37 (Reset) can be aborted by pressing any front panel button, except the ENTER button, when the prompt "ENTER?" is displayed. The instrument will return to the previous operating state.
2. Once the instrument is reset to the factory default conditions with this program, Program 30 must be run if it is desired to have the factory default conditions on subsequent power ups.
3. Program 37 (Reset) will have no affect on the current IEEE address and line frequency setting.

### 2.7.14 Program $\Omega$

The ohms offset compensation program is used to compensate for voltage potentials (such as thermal EMFs) across the resistance to be measured. This feature can be used for both 2-terminal and 4-terminal resistor measurements up to 30k $\Omega$ . Additional information on ohms offset compensation can be found in paragraph 2.6.6. Perform the following steps to use the ohms offset compensation program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Press the  $\Omega$  button. The current status of ohms compensation will be displayed. For example, if compensation is currently disabled, the following message will be displayed:

COMP OFF

3. If the alternate status is desired, press one of the Range buttons. The alternate status will be displayed as follows:

COMP ON

4. With the desired compensation status displayed, press the ENTER button.
  - A. If ohms offset compensation was enabled, the instrument will be placed in the ohms function with the  $\Omega$  indicator light flashing.
  - B. If ohms offset compensation was disabled, the instrument will return to the previous operating state. When the ohms function is selected, the  $\Omega$  indicator light will not flash.

Notes:

1. The  $\Omega$  indicator light reveals the status of ohms offset compensation. With the ohms function selected, a flashing  $\Omega$  light indicates that compensation is enabled, and conversely, a non-flashing  $\Omega$  light indicates that compensation is disabled.
2. The status of ohms offset compensation can be saved as a power up default condition by running Program 30.

### 2.7.15 Program ZERO

Program ZERO allows the user to check or modify the zero value. A complete explanation of the zero modifier can be found in paragraph 2.6.2. Once a zero value is set on a measurement function, that zero level is the same on all

the ranges. Example: If 1V DC is set to the zero value of the 3V DC range, the zero value in the program will be displayed as 1.000000. On the 30V DC range the zero value will still be 1V DC, but will be expressed as 01.00000 in the program.

Perform the following procedure to implement Program ZERO.

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Press the ZERO button. The current zero value will then be displayed. Example: If the instrument is on the 30V DC range and the current zero value is +3V DC, the following message will be displayed:

03.00000 Z

3. If it is desired to retain the displayed zero value, press the ENTER button. The instrument will return to the previous operating state with the zero modifier enabled. The displayed reading will reflect the entered zero value.
4. To modify the zero value, enter the new value and press the ENTER button. The instrument will return to the previously defined state with the zero modifier enabled using the newly entered zero value.

Note: The factory default power up zero value is 0000.000. If it is desired to have a different zero value displayed on power up, modify the zero value using Program ZERO followed by Program 30 to save it.

### 2.7.16 Program FILTER

Program FILTER allows the user to modify the weighting of the digital filter. Valid filter values are from 1 to 99. More information concerning the filter can be found in paragraph 2.6.3.

Perform the following steps to check and/or modify the filter value.

1. Select the desired function.
2. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?



3. Press the FILTER button. The current filter value will then be displayed. Example: If the filter value is 5, the following message will be displayed:

05      F

4. If it is desired to retain the displayed filter value, proceed to step 5. If it is desired to modify the filter value, do so using the data buttons.
5. With the desired filter value displayed, press the ENTER button. The instrument will return to the previously defined state when the filter is enabled.
6. To check or change the filter value of another function, select the function and repeat steps 2 through 5.

#### Notes:

1. The factory default power up filter value is 10. If it is desired to have a different filter value on power up, change the filter value using Program FILTER followed by Program 30 to save it.
2. Entering a filter value of 00 will default the filter value back to the previous value and return the instrument to the previously defined state with the filter disabled.

### 2.7.17 Program dB

Program dB allows the user to check and/or modify the dB reference. The programmable voltage reference can be up to 9.999999V and the programmable current reference can be up to 9.999999mA. Detailed information on dB measurements is provided in paragraph 2.6.9. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Press the dB button. The current reference level will be displayed. Example: If the reference is 1V or 1mA, the following message will be displayed:

1.000000dB

3. Modify, if desired, the dB reference level and press the ENTER button. The recommended reference range is 10 $\mu$ V to 9.999999V and 10nA to 9.999999mA. The instrument will return to the previously defined state.

ENTERED

Note: The factory default power up voltage reference is 1.000000V with the instrument in ACV and 1.000000mA with ACA selected. If it is desired, to have a different

reference on power up, modify the reference using Program dB followed by Program 30 to save it.

## 2.8 FRONT PANEL TRIGGERING

With the instrument properly configured over the IEEE-488 bus, readings can be triggered from the front panel using the ENTER button. The following paragraphs provide general procedures for one-shot front panel triggering and front panel triggering into data store.

#### NOTE

The procedures in this section require IEEE-488 bus programming. Refer to Section 3, particularly paragraphs 3.9.7 (Triggering) and 3.9.9 (Data Store) for details on programming the instrument over the bus.

### 2.8.1 One-Shot Triggering

On power up, the instrument is in the continuous trigger mode with the conversion rate determined by the internal time base. To place the instrument in a state where each press of the ENTER button will trigger one reading, perform the following general procedure:

1. Place the instrument in the desired function and range.
2. Place the instrument in "one-shot on external trigger" by sending T7 over the IEEE-488 bus.
3. Press the LOCAL button to return control to the front panel.
4. Each press of the ENTER button will trigger one reading.

### 2.8.2 Triggering Readings Into Data Store

The front panel ENTER button can be used to trigger reading into data store. In the one-shot trigger mode, each press of the ENTER button will store one reading in the buffer. In the continuous trigger mode, the ENTER button will start the storage process at the rate that was programmed over the IEEE-488 bus. Perform the following general procedure to trigger readings into data store from the front panel:

1. Place the instrument in the desired function and range.
2. Place the instrument in the appropriate trigger mode:
  - A. To store one reading in the buffer after each press of the ENTER button, send T7 (one-shot on external trigger) over the bus.
  - B. To store a series of readings in the buffer after the ENTER button is pressed, send T6 (continuous on external trigger) over the bus.

3. Configure the storage interval and buffer size of the data store by sending the appropriate Qn and I commands over the bus (see paragraph 3.9.9).
4. Press the LOCAL button to return control to the front panel.
5. Press the ENTER key to either store one reading in the buffer or to start storage of a series of readings.

## 2.9 EXTERNAL TRIGGERING

The Model 196 has two external BNC connectors on the rear panel associated with instrument triggering. The EXTERNAL TRIGGER INPUT connector allows the instrument to be triggered by other devices, while the VOLTMETER COMPLETE OUTPUT connector allows the instrument to trigger other devices.

### 2.9.1 External Trigger

The Model 196 may be triggered on a continuous or one-shot basis. For each of these modes, the trigger stimulus will depend on the selected trigger mode. In the continuous trigger mode, the instrument takes a continuous series of readings. In the one-shot mode, only a single reading is taken each time the instrument is triggered.

The external trigger input requires a falling edge pulse at TTL logic levels, as shown in Figure 2-8. Connections to the rear panel EXTERNAL TRIGGER INPUT jack should be made with a standard BNC connector. If the instrument is in the external trigger mode, it will be triggered to take readings while in either a continuous or one-shot mode when the negative-going edge of the external trigger pulse occurs.

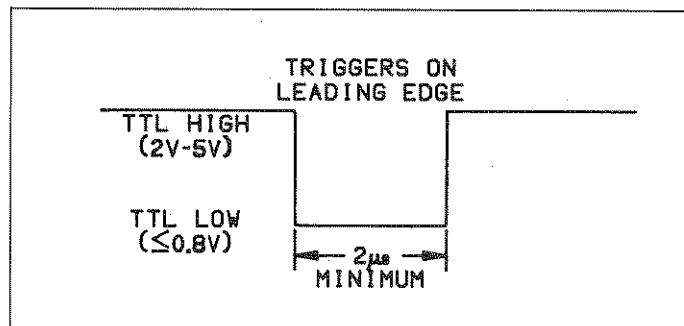


Figure 2-8. External Trigger Pulse Specifications

To use the external trigger, proceed as follows:

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

#### CAUTION

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

2. Place the instrument in the "one-shot on external trigger" (T7) or "continuous on external trigger" (T6) as explained in paragraph 3.9.7.
3. To trigger the instrument, apply a pulse to the external trigger input. The instrument will process a single reading each time the pulse is applied (one-shot), or start a continuous series of readings.

Note: External triggering can be used to control the fill rate in the data store mode with the data store enabled and one-shot mode selected, each trigger will cause a reading to be stored.

### 2.9.2 Voltmeter Complete

The Model 196 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible negative-going pulse (see Figure 2-9) will appear at the VOLTMETER COMPLETE OUTPUT jack each time the instrument completes a reading. To use the voltmeter complete output, proceed as follows:

1. Connect the Model 196 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 196.

#### CAUTION

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

2. Select the desired function, range, trigger mode, and other operating parameters, as desired.
3. In a continuous trigger mode, the instrument will output pulses at the conversion rate; each pulse will occur after the Model 196 has completed a conversion.
4. In a one-shot trigger mode, the Model 196 will output a pulse once each time it is triggered.

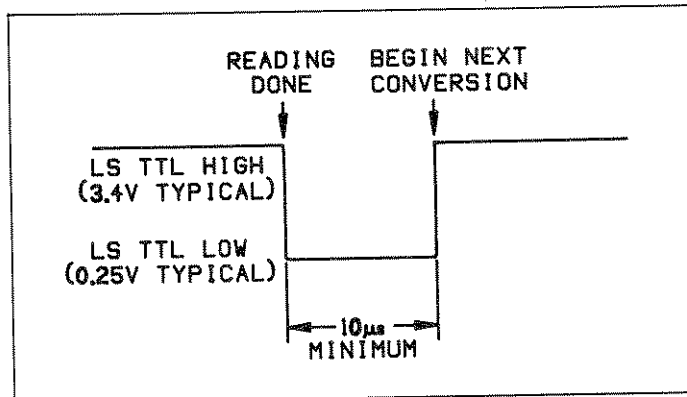


Figure 2-9. Voltmeter Complete Pulse Specifications

### 2.9.3 Triggering Example

As an example of using both the external trigger input and the meter complete output, assume that the Model 196 is to be used in conjunction with a Keithley Model 705 Scanner to allow the Model 196 to measure a number of different signals, which are to be switched by the scanner. The Model 705 can switch up to 20 2-pole channels (20 single-pole channels with special cards such as the low-current card). In this manner, a single Model 196 could monitor up to 20 measurement points.

By connecting the triggering inputs of the two instruments together, a complete automatic measurement sequence could be performed. Data obtained from each measurement point could be stored using the data store of the Model 196.

Once the Model 705 is programmed for its scan sequence, the measurement procedure is set to begin. When the Model 705 closes the selected channel, it triggers the Model 196 to scan to the next channel. The process repeats until all channels have been scanned.

To use the Model 196 with the Model 705, proceed as follows:

1. Connect the Model 196 to the Model 705 as shown in

Figure 2-10. Use shielded cables with BNC connectors. The Model 196 VOLTMETER COMPLETE OUTPUT jack should be connected to the Model 705 EXTERNAL TRIGGER INPUT jack. The Model 196 EXTERNAL TRIGGER INPUT jack should be connected to the Model 705 CHANNEL READY OUTPUT. Additional connections, which are not shown on the diagram, will also be necessary to apply signal inputs to the scanner and the Model 196.

2. Place the Model 196 in "one-shot on external trigger" (T7) as explained in paragraph 3.9.7.
3. Program the Model 705 scan parameters such as first and last channel as required. Place the instrument in the single scan mode.
4. Install the desired scanner cards and make the required input and output signal connections. See the Model 705 Instruction Manual for details.
5. Begin the measurement sequence by pressing the Model 705 START/STOP button. The Model 705 will close the first channel and trigger the Model 196 to take a reading. When the Model 196 completes the reading, it will trigger the Model 705 to go to the next channel. The process repeats until all programmed channels have been scanned.

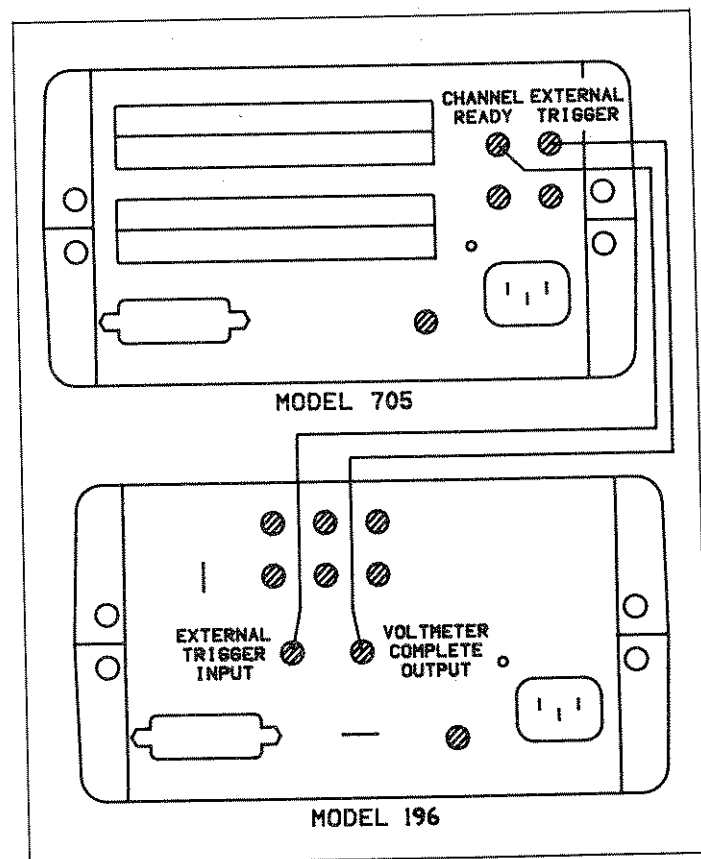
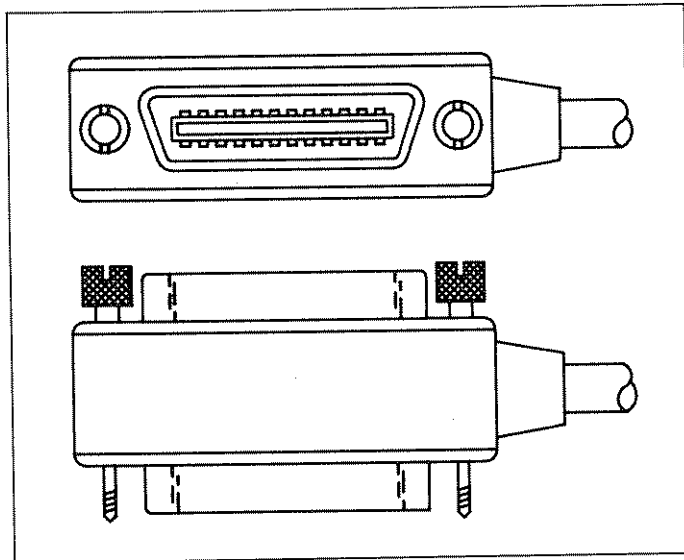


Figure 2-10. External Triggering Example

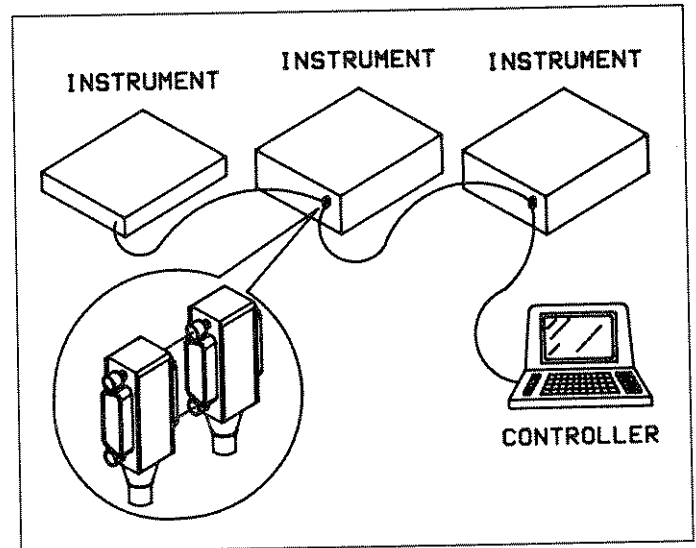
### 3.3 BUS CONNECTIONS

The Model 196 is intended to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 3-2. The connector is designed to be stacked to allow a number of parallel connections at one instrument. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark colored screws. Earlier versions had different screws, which were silver colored. Do not attempt to use these type of connectors on the Model 196, which is designed for metric threads.



**Figure 3-2. IEEE-488 Connector**

A typical connecting scheme for a multiple-instrument test set up is shown in Figure 3-3. Although any number of connectors can be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.



**Figure 3-3. IEEE-488 Connections**

Connect the Model 196 to the IEEE-488 bus as follows:

1. Line up the cable connector with the connector located on the rear panel of the instrument. The connector is designed so that it will fit only one way. Figure 3-4 shows the location of the IEEE-488 connector on the instrument.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make certain that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. Consult the instruction manual for your controller for the proper connecting method.

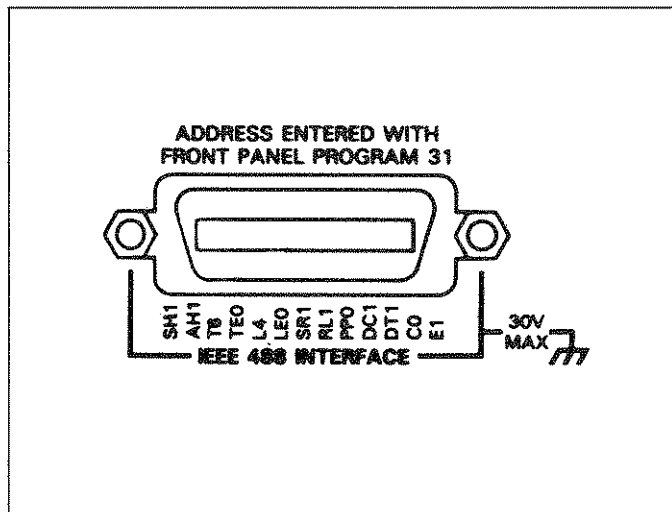


Figure 3-4. IEEE-488 Connector Location

#### NOTE

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

Custom cables may be constructed by using the information in Table 3-2 and Figure 3-5. Table 3-2 lists the contact assignments for the bus, and Figure 3-5 shows the contact configuration.

#### CAUTION

IEEE-488 common is connected to chassis ground and cannot be floated.

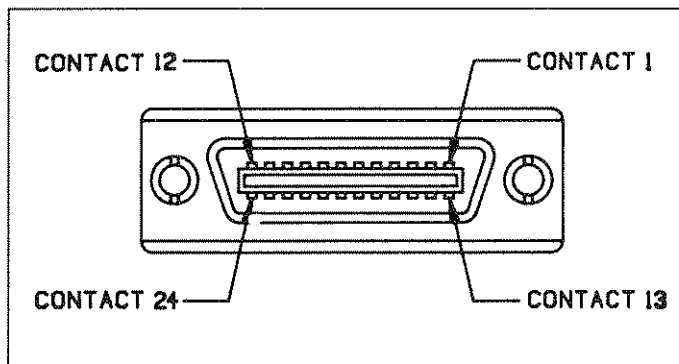


Figure 3-5. Contact Assignments

Table 3-2. IEEE Contact Designation

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

\*Numbers in parentheses refer to signal ground return of referenced contact number. EOI and REN signal lines return on contact 24.

### 3.4 INTERFACE FUNCTION CODES

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions, and they should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 196 are listed in Table 3-3 and are listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 196 capabilities as follows:

SH (Source Handshake)—SH1 defines the ability of the Model 196 to properly handshake data or command bytes when the unit is acting as a source.

AH (Acceptor Handshake)—AH1 defines the ability of the Model 196 to properly handshake the bus when it is acting as an acceptor of data or commands.

T (Talker)—The ability of the Model 196 to send data over the bus to other devices is defined by the T function. Model 196 talker capabilities exist only after the instrument has been addressed to talk.

L (Listener)—The L function defines the ability of the Model 196 to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen.

SR (Service Request)—The SR function defines the ability of the Model 196 to request service from the controller.

RL (Remote-Local)—The RL function defines the capability of the Model 196 to be placed in the remote or local modes.

PP (Parallel Poll)—The Model 196 does not have parallel polling capabilities.

DC (Device Clear)—The DC function defines the ability of the Model 196 to be cleared (initialized).

DT (Device Trigger)—The ability for the Model 196 to have its readings triggered is defined by the DT function.

C (Controller)—The Model 196 does not have controller capabilities.

TE (Extended Talker)—The Model 196 does not have extended talker capabilities.

LE (Extended Listener)—The Model 196 does not have extended listener capabilities.

E (Bus Driver Type)—The Model 196 has open-collector bus drivers.

**Table 3-3. Model 196 Interface Function Codes**

Code	Interface Function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T6	Talker (Basic talker, Serial poll, Unaddressed to talk on LAG)
L4	Listener (Basic listener, Unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker capabilities
LE0	No Extended Listener capabilities

### 3.5 PRIMARY ADDRESS SELECTION

The Model 196 must receive a listen command before it will respond to addressed commands over the bus. Similarly, the instrument must receive a talk command before it will transmit its data. These listen and talk commands are derived from the primary address of the instrument, which is set to 7 at the factory. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples in this manual assume the instrument is programmed for that address.

The primary address can be programmed for any value between 0 and 30. However, each device on the bus must have a unique primary address-- a factor that should be kept in mind when setting the primary address of the Model 196. Most controllers also use a primary address; consult the controller instruction manual for details. Whatever address is used, it must be the same as the value specified as part of the controller's programming language.

To check the presently programmed primary address, or to change to a new one, proceed as follows:

1. Press PRGM, 3, 1. The current primary address will be displayed. For example, if the current address is 7, the following message will be displayed:

07 IE

2. To modify the address, key in a new value (0-30) with the numeric data buttons.
3. With the desired address value displayed, press the ENTER button. The address will be programmed and the instrument will return to the previous operating state.
4. To store the address as the power up address, run Program 30.

Note: For detailed information on using Programs 30 and 31, refer to paragraph 2.7.

### 3.6 CONTROLLER PROGRAMMING

A number of IEEE-488 controllers are available, each of which has its own programming language. In this section, we will discuss the programming language for the Hewlett-Packard HP-85.

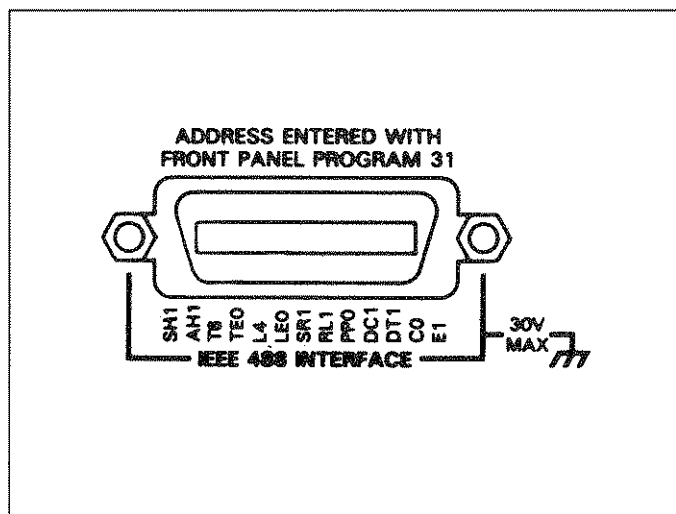


Figure 3-4. IEEE-488 Connector Location

#### NOTE

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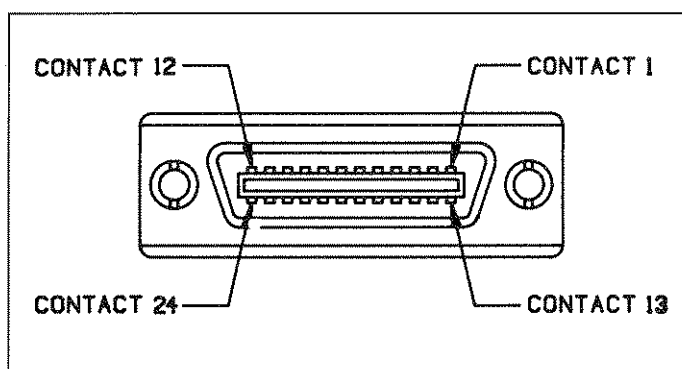


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15	DIO7	Data
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Note: For detailed information on using Programs 30 and 31, refer to paragraph 2.7.

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L4	Listener (Basic listener, Unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker capabilities
LE0	No Extended Listener capabilities



**NOTE**

Programming information for using the IBM PC/XT equipped with a Model 8573A IEEE-488 interface is contained in Appendix B.

**3.6.1 Controller Handler Software**

Before a specific controller can be used over the IEEE-488 bus, it must have IEEE-488 handler software installed. With some controllers like the HP-85, the software is located in an optional I/O ROM, and no software installation is necessary on the part of the user. In other cases, software must be loaded from a diskette and initialized, as is the case with the Model 8573A interface.

Other small computers that can be used as IEEE-488 controllers may not support all IEEE-488 functions. With some, interface programming may depend on the particular interface being used. Many times, little "tricks" are necessary to obtain the desired results.

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

**3.6.2 BASIC Interface Programming Statements**

The programming instructions covered in this section include examples written in HP-85 BASIC. This computer was chosen for the examples because of its versatility in controlling the IEEE-488 bus. A partial list of statements for the HP-85 is shown in Table 3-4.

HP-85 statements have a one or three digit argument that must be specified as part of the statement. The first digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address. In the examples shown, the default Model 196 address (7) is shown. For a different address, you would of course change the corresponding digits in the programming statement.

Some of the statements have two forms, with the exact configuration depending on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command over the bus, while CLEAR 707 sends the SDC command to a device with a primary address of 7.

**Table 3-4. BASIC Statements Necessary to Send Bus Commands**

Action	HP-85 Statement
Transmit string to device 7.	OUTPUT 707; A#
Obtain string from device 7.	ENTER 707; A#
Send GTL to device 7.	LOCAL 707
Send SDC to device 7.	CLEAR 707
Send DCL to all devices.	CLEAR 7
Send remote enable.	REMOTE 7
Cancel remote enable.	LOCAL 7
Serial poll device 7.	SPOLL (707)
Send Local Lockout.	LOCAL LOCKOUT
Send GET to device.	TRIGGER 707
Send IFC.	ABORTIO 7

**3.7 FRONT PANEL ASPECTS OF IEEE-488 OPERATION**

The following paragraphs discuss aspects of the front panel that are part of IEEE-488 operation, including front panel error messages, IEEE-488 status indicators, and the LOCAL key.

**3.7.1 Front Panel Error Messages**

The Model 196 has a number of front panel error messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that may occur when sending device-dependent commands to the instrument, as summarized in Table 3-5.

The following paragraphs discuss each of these messages in detail. Note that the instrument may be programmed to generate an SRQ (paragraph 3.9.13), and the U1 error word can be checked for specific error conditions (paragraph 3.9.16) if any of these errors occur.

**Table 3-5. Front Panel IEEE-488 Messages**

Message	Description
NO REMOTE	Instrument programmed with REN false.
IDDC IDDCO	Illegal Device-dependent Command Illegal Device-dependent Command Option
TRIG ERROR	Instrument triggered while it is still processing a previous trigger.
SHORT TIME	Instrument cannot store readings at programmed interval. Readings will be stored as fast as the instrument can run.
BIG STRING	Programmed display message exceeds 10 characters.
CAL LOCKED	Calibration command sent with calibration switch in the disable position.
CONFLICT	Data Store—Instrument cannot store readings at a high speed interval (1 to 14ms) while in an invalid state. Storage will not occur.  Calibration—Calibration command is ignored when instrument is in an invalid state (i.e. dB function).

NOTE: Error messages associated with translator software are located in paragraph 3.10.

#### No Remote Error

A no remote error will occur if the instrument receives a device-dependent command and the REN (Remote Enable) line is false. In this instance, the following error message will be displayed on the front panel:

NO REMOTE

The error condition can be corrected by placing the REN line true before attempting to program the instrument.

**HP-85 Programming Example**—To demonstrate the NO REMOTE error message, type in the following lines:

```
LOCAL 7
OUTPUT 707; "R1X"
```

Note that the NO REMOTE error message is briefly displayed when the second statement above is executed.

#### IDDC (Illegal Device-Dependent Command) Error

An IDDC error occurs when the unit receives an invalid command over the bus. For example, the command string E1X includes an illegal command because the letter E is not part of the instrument's programming language. When an illegal command is received, the instrument will briefly display the following error message:

IDDC

To correct the error condition, send only valid commands. Refer to paragraph 3.9 for device-dependent command programming details.

**HP-85 Programming Example**—To demonstrate an IDDC error, use the following statements:

```
REMOTE 707
OUTPUT 707; "E1X"
```

Note that the IDDC error message is briefly displayed when the second statement above is executed.

#### IDDCO (Illegal Device-Dependent Command Option) Error

Sending the instrument a legal command with an illegal option that cannot be automatically scaled within bounds will result in the following front panel error message:

IDDCO

For example, the command Y9X has an illegal option (9) that is not part of the instrument's programming language. Thus, although the command (Y) itself is valid, the option (9) is not, and the IDDCO error will result.

To correct this error condition, use only valid command options, as discussed in paragraph 3.9.

**HP-85 Programming Example**—Demonstrate an IDDCO error with the following statements:

```
REMOTE 707
OUTPUT 707; 'Y9X'
```

Note that the IDDCO error message is briefly displayed when the second statement above is executed.

### Trigger Overrun Error

A trigger overrun error occurs when the instrument receives a trigger while still processing a reading from a previous trigger. Note that only the overrun triggers are ignored. These overrun triggers will not affect the instrument except to generate the message below. When a trigger overrun occurs, the following front panel message will be displayed for approximately one second:

```
TRIG ERROR
```

**HP-85 Programming Example**—To demonstrate a trigger overrun error, enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707; 'T3X'
TRIGGER 707 @ TRIGGER 707
```

Note that the trigger overrun message is displayed after the END LINE key is pressed a third time.

### Big String Error

A big string error occurs when trying to display a message (using the D command) that exceeds 10 characters. Blank display digits used in the message count as characters. The invalid message is ignored and the following message is displayed briefly when a big string error occurs:

```
BIG STRING
```

**HP-85 Programming Example**—Enter the following statements into the computer to demonstrate a big string error:

```
REMOTE 707
OUTPUT 707; 'DH0W@ARE@YOU?X'
```

When END LINE is pressed the second time the big string error will occur because the message is made up of 12 characters.

### Cal Locked Error

A cal locked error occurs when trying to calibrate the instrument over the bus with the front panel calibration switch in the disable position. Calibration commands will be ignored and the following message will be displayed briefly:

```
CAL LOCKED
```

### Short Time Error

A short time error occurs when the instrument cannot store readings in the data store at the programmed interval (Q command). However, the instrument will continue to store readings as fast as it can run. The following message is displayed briefly when a short time error occurs:

```
SHORT TIME
```

**HP-85 Programming Example**—To demonstrate a short time error, enter the following statements into the computer:

```
REMOTE 707
OUTPUT 707; 'Q100F2T2X'
TRIGGER 707
```

When END LINE is pressed the third time, the instrument will start storing readings in the buffer. However, since the instrument cannot make resistance measurements (F2) at the selected interval (Q100), short period errors will occur.

### Conflict Error

A conflict error occurs when trying to store readings at a high speed interval (1ms to 14ms) while the instrument is in an invalid state. After sending a command string that contains the interval command (Q), the following message is displayed briefly when a conflict error occurs:

```
CONFLICT
```

The entire command string will be ignored and the data store will not start.

Valid instrument states for high speed data storage are listed in Table 3-11.

A conflict error also occurs when trying to send a calibration command over the bus while the instrument is in an invalid state, such as the dB function. The entire command string is ignored when a conflict error occurs.

**HP-85 Programming Example**—Enter the following statements into the computer to demonstrate a CONFLICT error:

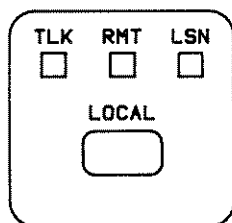
```
REMOTE 707
OUTPUT 707; 'Q1F2X'
```

When END LINE is pressed the second time, a conflict error will occur because data cannot be stored at the high speed interval of 1ms (Q1) with the instrument in the ohms function (F2). The entire command string will be ignored.

### 3.7.2 IEEE-488 Status Indicators and LOCAL Key

The TLK, RMT, and LSN indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.

#### STATUS INDICATORS



**TALK**—The TLK indicator will be on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TLK will be off when the unit is in the talker idle state. The instrument is placed in the talker idle state by sending it an UNT (Untalk) command, addressing it to listen, or with the IFC (Interface Clear) command.

**REMOTE**—The RMT indicator shows when the instrument is in the remote mode. Note that RMT does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the RMT indicator will turn on. When the instrument is in remote, all front panel keys except for the LOCAL key will be locked out. When RMT is turned off, the instrument is in the local mode.

**LISTEN**—The LSN indicator will be on when the Model 196 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSN will be off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

**LOCAL**—The LOCAL key cancels the remote mode and restores local operation of the instrument.

Since all front panel keys except LOCAL are locked out when the instrument is in remote, this key provides a convenient method of restoring front panel operation. Pressing LOCAL will also turn off the RMT indicator and return the display to the normal mode if user messages were previously displayed with the D command.

Note that the LOCAL key will also be inoperative if the LLO (Local Lockout) command is in effect.

**Table 3-6. General Bus Commands and Associated BASIC Statements**

Command	HP-85 Statement	Affect on Model 196
REN	REMOTE 7	Goes into remote when next addressed.
IFC	ABORTIO 7	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	Front panel controls locked out.
GTL	LOCAL 707	Cancel remote.
DCL	CLEAR 7	Returns to default conditions.
SDC	CLEAR 707	Returns to default conditions.
GET	TRIGGER 707	Triggers reading in T2 and T3 modes.

### 3.8 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general purpose regardless of the instrument. Commands supported by the Model 196 are summarized in Table 3-6, which lists HP-85 statements necessary to send each command. Note that commands requiring a primary address assume that the Model 196 primary address is set to 7 (its factory default address).

#### 3.8.1 REN (Remote Enable)

REN is a uniline command that must be asserted by the controller to place the Model 196 in the remote mode. Simply setting REN true will not actually place the instrument in remote; instead, the unit must be addressed to listen after REN is set true.

Generally, remote enable should be asserted before attempting to program the instrument over the bus. Once the instrument is in remote, all front panel controls except LOCAL will be inoperative. Normal front panel operation can be restored by pressing the LOCAL key.

To place the Model 196 in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 196 to listen.

**HP-85 Programming Example**—Place the Model 196 in remote with the following statement:

```
REMOTE 707
```

When the END LINE key is pressed, the Model 196 should be in the remote mode as indicated by the RMT annunciator light. If not, check to see that proper bus connections are made, and that the instrument is programmed for the correct primary address (7).

Note that all front panel controls except LOCAL (and, of course, POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL button.

#### 3.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the

Model 196 in the talker and listener idle states. The unit will respond to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100 $\mu$ sec.

**HP-85 Programming Example**—Before demonstrating the IFC command, place the instrument in the talker active state with the following statements:

```
REMOTE 707
ENTER 707;A#
```

At this point, the RMT and TLK indicators should be on.

The IFC command can be sent by typing in the following statement:

```
ABORTIO 7
```

Note that the TLK indicator turns off when the END LINE key is pressed.

#### 3.8.3 LLO (Local Lockout)

The LLO command is used to lock out operation of the LOCAL key, thereby completely locking out front panel operation of the instrument (recall that the remaining controls are locked out when the instrument is placed in remote).

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

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

To cancel local lockout and return control to the front panel, REN must be set false by sending the LOCAL 7 command to the instrument.

**HP-85 Programming Example**—To verify LLO operation, enter the following statements:

```
REMOTE 707
LOCAL LOCKOUT 7
```

After the second statement is executed, the LOCAL key will be locked out. it does not set REN false.

To cancel LLO, type in the following statement:

LOCAL 7

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

REMOTE 707

When END LINE is pressed, control to the front panel will be restored.

Verify that the instrument is in remote.

Send GTL as follows:

### 3.8.4 GTL (Go To Local)

LOCAL 707

The GTL command is used to take the instrument out of the remote mode and restore operation of the front panel keys.

Note that the instrument goes into the local mode, and that operation of the front panel keys has now been restored.

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

### 3.8.5 DCL (Device Clear)

1. Set ATN true.
2. Address the Model 196 to listen.
3. Place the GTL command byte on the data lines.

The DCL command may be used to clear the Model 196 and return it to its default conditions. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 196 receives a DCL command, it will return to either the factory default conditions listed in Tables 2-1 and 3-7 or to the user saved default conditions.

The GTL command will not cancel LLO (local lockout) since

**Table 3-7. Factory Default Conditions**

Mode	Command	Status
Multiplex	A1	Enabled
Reading	B0	A/D converter
Function	F0	DC volts
Data Format	G0	Send prefix with reading
Self-Test	J0	Clear
EOI	K0	Enable EOI and bus hold-off on X
SRQ	M0	Disabled
Internal Digital Filter	N1	Enabled
Filter	P0	Disabled
Data Store Interval	Q0	One-shot into buffer
Data Store Size	I1	One reading
Range	R4	300V
Rate	S3	6½d, line cycle integration
Trigger	T6	Continuous on external trigger
Delay	W0	No delay
Terminator	Y0	CR LF
Zero	Z0	Disabled

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

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

Notes:

1. DCL will return the instrument to the default line frequency setting.
2. DCL will not have any affect on the current IEEE address.

**HP-85 Programming Example**—Place the unit in an operating mode that is not a default condition. Now enter the following statement into the HP-85 keyboard:

```
CLEAR 7
```

When the END LINE key is pressed, the instrument returns to the default conditions.

### 3.8.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only a single, selected instrument instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 196 receives the SDC command, it will return to either the factory default conditions listed in Tables 3-7 and 2-1 or to the user saved default conditions.

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

1. Set ATN true.
2. Address the Model 196 to listen.
3. Place the SDC command byte on the data bus.

Notes:

1. SDC will return the instrument to the default line frequency setting.
2. SDC will not have any affect on the current IEEE address.

**HP-85 Programming Example**—Using several front panel controls, alter instrument states from the default configuration. Send SDC with the following statement:

```
CLEAR 707
```

When the above statement is executed, the instrument returns to the default configuration.

### 3.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 196 measurement sequence if the instrument is placed in the appropriate trigger mode (see paragraph 3.9). Once triggered, the instrument will perform the measurement sequence in accordance with previously selected rate and sample parameters.

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

1. Set ATN low.
2. Address the Model 196 to listen.
3. Place the GET command byte on the data bus.

**HP-85 Programming Example**—Type in the following statements to place the instrument in the correct trigger mode for purposes of this demonstration:

```
REMOTE 707
OUTPUT 707; 'T3X'
```

Now trigger the measurement sequence by sending GET with the following statement:

```
TRIGGER 707
```

When the END LINE key is pressed, the measurement sequence will be triggered.

### 3.8.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 196 serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 3.9.13. The serial polling sequence can also be used by the controller to determine which instrument on the bus has asserted SRQ (Service Request).

The serial polling sequence is generally conducted as follows:

1. The controller sets ATN true.
2. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll enabled mode and waiting to be addressed.

3. The Model 196 is then addressed to talk.
4. The controller sets ATN false.
5. The instrument places its serial poll byte on the data bus to be read by the controller.
6. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

Once instruments are in the serial poll mode, steps 3 through 5 above can be repeated by sending the correct talk address for each instrument.

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

```
REMOTE 707
S= SPOLL (707)
DISP S
```

When the above statements are executed, the Model 196 is serial polled, and the decimal value of the serial poll byte is displayed on the computer CRT.

### 3.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 196 to control various operating modes such as function, range, trigger mode and data format. Each command is made up of a single ASCII letter followed by a number representing an option of that command. For example, a command to control the measuring function is programmed by sending an ASCII "F" followed by a number representing the function option. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

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

Commands that affect instrument operation will trigger a reading when the command is executed. These bus commands affect the Model 196 much like the front panel controls. Note that commands are not necessarily executed in the order received; instead, they will be executed in alphabetical order. Thus to force a particular command sequence, you would follow each command with the execute character (X), as in the example string, L0XF2X, which will reset the instrument to factory default conditions and then select the ohms function.

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

F0X—Single command string.  
F0K1P0R0X—Multiple command string.  
T6 X—Spaces are ignored.

Typical invalid command strings include:

E1X—Invalid command, as E is not one of the instrument commands.  
F15X—Invalid command option because 15 is not an option of the F command.

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

Device-dependent commands that control the Model 196 are listed in Table 3-8. These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands with the HP-85.

#### NOTE

Programming examples assume that the Model 196 is at its factory default value of 7.

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

1. Set ATN true.
2. Address the Model 196 to listen.
3. Set ATN false.
4. Send the command string over the bus one byte at a time.



Table 3-8. Device-Dependent Command Summary

Mode	Command	Description	Paragraph																																																																																	
Execute	X	Execute other device-dependent commands.	3.9.1																																																																																	
Function	F0 F1 F2 F3 F4 F5 F6 F7	DC volts AC volts Ohms DC current AC current ACV dB ACA dB Offset compensated ohms	3.9.2																																																																																	
Range		<table border="1"> <thead> <tr> <th></th> <th>DCV</th> <th>ACV</th> <th>DCA</th> <th>ACA</th> <th>Ohms</th> <th>ACV dB</th> <th>ACA dB</th> <th>Offset Compensated Ohms</th> </tr> </thead> <tbody> <tr> <td>R0</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> <td>Auto</td> </tr> <tr> <td>R1</td> <td>300mV</td> <td>300mV</td> <td>300 <math>\mu</math>A</td> <td>300 <math>\mu</math>A</td> <td>300 <math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>300 <math>\Omega</math></td> </tr> <tr> <td>R2</td> <td>3 V</td> <td>3 V</td> <td>3mA</td> <td>3mA</td> <td>3 k<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>3k <math>\Omega</math></td> </tr> <tr> <td>R3</td> <td>30 V</td> <td>30mV</td> <td>30mA</td> <td>30mA</td> <td>30 k<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>30 k<math>\Omega</math></td> </tr> <tr> <td>R4</td> <td>300 V</td> <td>300 V</td> <td>300mA</td> <td>300mA</td> <td>300 k<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>30 k<math>\Omega</math></td> </tr> <tr> <td>R5</td> <td>300 V</td> <td>300 V</td> <td>3 A</td> <td>3 A</td> <td>3M<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>30 k<math>\Omega</math></td> </tr> <tr> <td>R6</td> <td>300 V</td> <td>300 V</td> <td>3 A</td> <td>3 A</td> <td>30M<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>30 k<math>\Omega</math></td> </tr> <tr> <td>R7</td> <td>300 V</td> <td>300 V</td> <td>3 A</td> <td>3 A</td> <td>300M<math>\Omega</math></td> <td>Auto</td> <td>Auto</td> <td>30 k<math>\Omega</math></td> </tr> </tbody> </table>		DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms	R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	R1	300mV	300mV	300 $\mu$ A	300 $\mu$ A	300 $\Omega$	Auto	Auto	300 $\Omega$	R2	3 V	3 V	3mA	3mA	3 k $\Omega$	Auto	Auto	3k $\Omega$	R3	30 V	30mV	30mA	30mA	30 k $\Omega$	Auto	Auto	30 k $\Omega$	R4	300 V	300 V	300mA	300mA	300 k $\Omega$	Auto	Auto	30 k $\Omega$	R5	300 V	300 V	3 A	3 A	3M $\Omega$	Auto	Auto	30 k $\Omega$	R6	300 V	300 V	3 A	3 A	30M $\Omega$	Auto	Auto	30 k $\Omega$	R7	300 V	300 V	3 A	3 A	300M $\Omega$	Auto	Auto	30 k $\Omega$	3.9.3
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Filter	P0 Pn	Filter disabled Filter on with a value of n (n=1 to 99)	3.9.5																																																																																	
Rate		<table border="1"> <thead> <tr> <th></th> <th colspan="8">Resolution</th> </tr> <tr> <th></th> <th>DCV</th> <th>ACV</th> <th>DCA</th> <th>ACA</th> <th>OHMS</th> <th>ACV dB</th> <th>ACA dB</th> <th>Offset Compensated Ohms</th> </tr> </thead> <tbody> <tr> <td>S0</td> <td>3<math>\frac{1}{2}</math>d</td> <td>3<math>\frac{1}{2}</math>d</td> <td>3<math>\frac{1}{2}</math>d</td> <td>3<math>\frac{1}{2}</math>d</td> <td>3<math>\frac{1}{2}</math>d(R1-R4) 5<math>\frac{1}{2}</math>d(R5-R7)</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> </tr> <tr> <td>S1</td> <td>4<math>\frac{1}{2}</math>d</td> <td>4<math>\frac{1}{2}</math>d</td> <td>4<math>\frac{1}{2}</math>d</td> <td>4<math>\frac{1}{2}</math>d</td> <td>4<math>\frac{1}{2}</math>d(R1-R4) 5<math>\frac{1}{2}</math>d(R5-R7)</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> </tr> <tr> <td>S2</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> </tr> <tr> <td>S3</td> <td>6<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>6<math>\frac{1}{2}</math>d(R1-R6) 5<math>\frac{1}{2}</math>d(R7)</td> <td>5<math>\frac{1}{2}</math>d</td> <td>5<math>\frac{1}{2}</math>d</td> <td>6<math>\frac{1}{2}</math>d</td> </tr> </tbody> </table> <p>Integration period: 3<math>\frac{1}{2}</math>d=318<math>\mu</math>sec, 4<math>\frac{1}{2}</math>d=2.59msec, 5<math>\frac{1}{2}</math>d and 6<math>\frac{1}{2}</math>d=Line cycle</p>		Resolution									DCV	ACV	DCA	ACA	OHMS	ACV dB	ACA dB	Offset Compensated Ohms	S0	3 $\frac{1}{2}$ d	3 $\frac{1}{2}$ d	3 $\frac{1}{2}$ d	3 $\frac{1}{2}$ d	3 $\frac{1}{2}$ d(R1-R4) 5 $\frac{1}{2}$ d(R5-R7)	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	S1	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d(R1-R4) 5 $\frac{1}{2}$ d(R5-R7)	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	S2	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	S3	6 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	6 $\frac{1}{2}$ d(R1-R6) 5 $\frac{1}{2}$ d(R7)	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	6 $\frac{1}{2}$ d	3.9.6																											
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S1	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d	4 $\frac{1}{2}$ d(R1-R4) 5 $\frac{1}{2}$ d(R5-R7)	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d																																																																												
S2	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d																																																																												
S3	6 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	6 $\frac{1}{2}$ d(R1-R6) 5 $\frac{1}{2}$ d(R7)	5 $\frac{1}{2}$ d	5 $\frac{1}{2}$ d	6 $\frac{1}{2}$ d																																																																												
Trigger Mode	T0 T1 T2 T3 T4 T5 T6 T7	Continuous on Talk One-shot on Talk Continuous on GET One-shot on GET Continuous on X One-shot on X Continuous on External Trigger One-shot on External Trigger	3.9.7																																																																																	

Table 3-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Reading Mode	B0	Readings from A/D converter	3.9.8
	B1	Readings from data store	
Data Store Size	I0	Continuous data store mode	3.9.9
	In	Data store of n (n=1 to 500)	
Data Store Interval	Q0	One-shot into buffer	3.9.9
	Qn	n=interval in milliseconds (1msec to 999999msec)	
Value	V±nn.nnnn or V±n.nnnnnnE+n	Calibration value, zero value	3.9.10
Calibration	C0	Calibrate first point using value (V)	3.9.10
	C1	Calibrate second point using value (V)	
Default Conditions	L0	Restore factory default conditions and save (L1)	3.9.11
	L1	Save present machine states as default conditions	
Data Format	G0	Reading with prefixes.	3.9.12
	G1	Reading without prefixes.	
	G2	Buffer readings with prefixes and buffer locations.	
	G3	Buffer readings without prefixes and with buffer locations.	
	G4	Buffer readings with prefixes and without buffer locations.	
	G5	Buffer readings without prefixes and without buffer locations.	
SRQ	M0	Disable	3.9.13
	M1	Reading overflow	
	M2	Data store full	
	M4	Data store half full	
	M8	Reading done	
	M16	Ready	
	M32	Error	
EOI and Bus Hold-off	K0	Enable EOI and bus hold-off on X	3.9.14
	K1	Disable EOI, enable bus hold-off on X	
	K2	Enable EOI, disable bus hold-off on X	
	K3	Disable both EOI and bus hold-off on X	
Terminator	Y0	CR LF	3.9.15
	Y1	LF CR	
	Y2	CR	
	Y3	LF	
Status	U0	Send machine status word	3.9.16
	U1	Send error conditions	
	U2	Send translator word	
	U3	Send buffer size	
	U4	Send average reading in buffer	
	U5	Send lowest reading in buffer	
	U6	Send highest reading in buffer	
	U7	Send current value	
	U8	Send input switch status (front/rear)	
Multiplex	A0	Auto/Cal multiplex disabled	3.9.17
	A1	Auto/Cal multiplex enabled	

Table 3-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Delay	Wn	n=delay period in milliseconds, (0msec to 60000msec)	3.9.18
Self-test	J0	Test, ROM, RAM, E <sup>2</sup> PROM	3.9.19
Hit Button	Hn	Hit front panel button number n	3.9.20
Display	Da D	Display up to 10 character message. a=character Cancel display mode	3.9.21
Exponential Filter	N0 N1	Internal filter off Internal filter on	3.9.22

**NOTE**

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

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

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

```
OUTPUT 707;A$
```

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

**3.9.1 Execute (X)**

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 196 to execute other device-dependent commands such as F (function) or R (range). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain circumstances where it is desirable to send a command string at one time, and then send the execute character later on. Command strings sent without the execute character will be stored within an internal command buffer for later execution. When the X character is finally transmitted, the stored commands will be executed, assuming that all commands in the previous string were valid.

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

```
REMOTE 707
OUTPUT 707;''X''
```

When the END LINE key is pressed the second time, the

**3.9.2 Function (F)**

The function command allows the user to select the type of measurement made by the Model 196. When the instrument responds to a function command, it will be ready to take a reading once the front end is set up. The function may be programmed by sending one of the following commands:

```
F0 = DC Volts
F1 = AC Volts
F2 = Ohms
F3 = DC Current
F4 = AC Current
F5 = ACV dB
F6 = ACA dB
F7 = Offset Compensated Ohms
```

Upon power up, or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

**HP-85 Programming Example**—Place the instrument in the ohms function by pressing the OHMS button and enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''F0X''
```

When END LINE is pressed the second time, the instrument changes to DC volts.

### 3.9.3 Range (R)

The range command gives the user control over the sensitivity of the instrument. This command, and its options, perform essentially the same functions as the front panel Range buttons. Range command parameters and the respective ranges for each measuring function are summarized in Table 3-9. The instrument will be ready to take a reading after the range is set up when responding to a range command.

Upon power up, or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

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

```
REMOTE 707
OUTPUT 707; 'R3X'
```

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

### 3.9.4 Zero (Z)

Over the bus, the zero modifier can be controlled in the same way that it is controlled from the front panel. Refer to paragraphs 2.6.2 and 2.7.15 (zero program) for a complete description of the zero modifier. The zero modifier is controlled by sending one of the following zero commands over the bus:

- Z0 = Zero disabled.
- Z1 = Zero enabled.
- Z2 = Zero enabled using a zero value (V).

Sending Z1 has the same effect as pressing the ZERO button. Zero will enable, and the display will zero with the input signal becoming the zero baseline level. The baseline will be stored in Program ZERO.

The Z2 command is used when a zero value, using the V command, has already been established. When the Z2 command is sent, subsequent readings represent the difference between the input signal and the value of V. Also, the value of V is stored in Program ZERO. For example, with 0.5V on the input, sending the command strings V2XZ2X will result with zero being enabled and the instrument reading -1.5V ( $0.5 - 2.0 = -1.5$ ).

Sending the Z2 command without a V value established is the same as sending the Z1 command. See paragraph 3.9.10 for more information on using the V command.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition. The value of V will reset to zero.

**HP-85 Programming Example**—Set the instrument to the 3V DC range. With the front panel ZERO button disable the zero mode, if enabled, and enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707; 'V1X'
OUTPUT 707; 'Z2X'
```

**Table 3-9. Range Command Summary**

Command	Range							Offset Compensated Ohms
	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	300 $\mu$ A	300 $\mu$ A	300 $\Omega$	Auto	Auto	300 $\Omega$
R2	3 V	3 V	3mA	3mA	3 k $\Omega$	Auto	Auto	3 k $\Omega$
R3	30 V	30 V	30mA	30mA	30 k $\Omega$	Auto	Auto	30 k $\Omega$
R4	300 V	300 V	300mA	300mA	300 k $\Omega$	Auto	Auto	30 k $\Omega$
R5	300 V	300 V	3 A	3 A	3M $\Omega$	Auto	Auto	30 k $\Omega$
R6	300 V	300 V	3 A	3 A	30M $\Omega$	Auto	Auto	30 k $\Omega$
R7	300 V	300 V	3 A	3 A	300M $\Omega$	Auto	Auto	30 k $\Omega$

After the END LINE key is pressed the third time, the ZERO indicator will turn on with a zero baseline level of 1V DC. The zero value will also be stored in Program ZERO.

When the END LINE key is pressed the second time, the filter will turn on and have a filter value of 20.

### 3.9.5 Filter (P)

The filter command controls the amount of filtering applied to the input signal. The Model 196 filters the signal by taking the weighted average of a number of successive reading samples. Since noise is mostly random in nature, it can be largely cancelled out with this method. The number of readings averaged (filter value) can be from 1 to 99. The filter value can be programmed by sending one of the following commands:

P0 = Filter disabled.

Pn = Filter on with a value of n. Where n can be from 1 to 99.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

Notes:

1. A filter value sent over the bus is stored in Program FILTER, replacing the previous filter value.
2. Keep in mind that each function can have its own unique filter value.

**HP-85 Programming Example**—With the front panel FILTER indicator off, enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707; 'P20X'
```

### 3.9.6 Rate (S)

The rate command controls the integration period and the usable resolution of the Model 196. Table 3-10 lists the usable resolution on each function for the four S modes. The integration period is dependent on usable resolution as follows:

3½d resolution = 318µsec

4½d resolution = 2.59msec

5½d resolution = Line cycle\*

6½d resolution = Line cycle\*

\*20msec for 50Hz, 16.6msec for 60Hz.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

**HP-85 Programming Example**—From the front panel, set the display of the Model 196 for DCV at 6½d resolution. Now enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707; 'S1X'
```

When END LINE is pressed the second time, the S1 rate will be selected.

**Table 3-10. Rate Command Summary**

Command	Resolution							Offset Compensated Ohms
	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	
S0	3½d	3½d	3½d	3½d	3½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S1	4½d	4½d	4½d	4½d	4½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S2	5½d	5½d	5½d	5½d	5½d	5½d	5½d	5½d
S3	6½d	5½d	5½d	5½d	6½d(R1-R6) 5½d(R7)	5½d	5½d	6½d
Integration period: 3½d=318µsec, 4½d=2.59msec, 5½d and 6½d=Line cycle.								

### 3.9.7 Trigger Mode (T)

Triggering provides a stimulus to begin a reading conversion within the instrument. Triggering may be done in two basic ways: in a continuous mode, a single trigger command is used to start a continuous series of readings; in a one-shot trigger mode, a separate trigger stimulus is required to start each conversion. The Model 196 has eight trigger commands as follows:

T0 = Continuous on Talk  
 T1 = One-shot on Talk  
 T2 = Continuous on GET  
 T3 = One-shot on GET  
 T4 = Continuous on X  
 T5 = One-shot on X  
 T6 = Continuous on External Trigger  
 T7 = One-shot on External Trigger

The trigger modes are paired according to the type of stimulus that is used to trigger the instrument. In the T0 and T1 modes, triggering is performed by addressing the Model 196 to talk. In the T2 and T3 modes, the IEEE-488 multiline GET command performs the trigger function. The instrument execute (X) character provides the trigger stimulus in the T4 and T5 modes. External trigger pulses provide the trigger stimulus in the T6 and T7 modes.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

#### NOTE

With the instrument in the T6 and T7 trigger modes, the front panel ENTER button can be used to trigger readings. See paragraph 2.8 for details.

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

```
REMOTE 707
OUTPUT 707; 'T1X'
```

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

```
ENTER 707; A#
DISP A#
```

In this example, the ENTER statement addresses the Model 196 to talk, at which point a single reading is triggered. When the reading has been processed, it is sent out over to the bus to the computer, which then displays the result.

### 3.9.8 Reading Mode (B)

The reading mode command parameters allow the selection of the source of data that is transmitted over the IEEE-488 bus. Through this command, the user has a choice of data from the A/D converter (normal DMM readings) or the buffer (data store). The reading mode commands are as follows:

B0 = A/D converter readings  
 B1 = Data Store readings

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

When in B0, normal A/D readings will be sent. In a continuous trigger mode, readings will be updated at the conversion rate. The B1 command is used to access readings from the buffer. When the B1 command is sent, subsequent readings will be taken from consecutive buffer locations beginning with the first memory location (001). Once all readings have been requested, the unit will cycle back and begin again.

**HP-85 Programming Example**—Enter the following statements into the computer to send a reading over the bus and display it on the computer CRT.

```
REMOTE 707
OUTPUT 707; 'B0X'
ENTER 707; A#
DISP A#
```

The second statement above sets the instrument to the A/D converter reading mode. The third and fourth statements acquire the reading and display it on the CRT.

### 3.9.9 Data Store Interval (Q) and Size (I)

The data store is controlled by the interval command (Q) and the size command (I).

## Interval

With the Q command, the user can select the interval that the instrument will store readings or select the one-shot mode. In one-shot, one reading will be stored each time the instrument is triggered. The Q command is in the following form:

Q0=One-shot into buffer.

Qn=Set storage interval in millisecc (1msec to 999999msec).

To use the data store in the one-shot mode (Q0), the instrument must be in a one-shot trigger mode (T1, T3, T5 or T7). In the Q0T1 mode, one reading will be stored each time the instrument is addressed to talk. In the Q0T3 mode, each GET command will cause one reading to be stored. In the Q0T5 mode, each instrument execute character (X) will cause a reading to be stored. Finally, in the Q0T7 mode, each external trigger pulse will cause a reading to be stored. If the instrument is in a continuous trigger mode (T0, T2, T4 or T6), an IDDC error will occur.

### NOTE

With the instrument in the T7 trigger mode, the front panel ENTER button can be used to manually store readings into the buffer. Each press of the ENTER button will store one reading in the buffer. See paragraph 2.8 for details.

To store readings at a selected interval (Qn), the instrument must be in a continuous trigger mode (T0, T2, T4, T6). When the selected trigger occurs, the storage process will commence.

### NOTE

With the instrument in the T6 trigger mode, the front panel ENTER button can be used to start a series of readings to be stored in the buffer. The storage interval and buffer size are determined by the Qn and I commands respectively. See paragraph 2.8 for details.

## Size

The size of the data store can be controlled by one of the following I commands.

I0=Continuous storage mode.

In=Set data store size to n (1 to 500).

In the continuous data storage mode (I0), storage will not stop after the buffer is filled (500 readings), but will proceed back to the first memory location and start overwriting data. With the Innn command, the storage process will stop when the defined number of readings have been stored. In this case the buffer is considered to be full.

### Notes:

1. When the Q or I command is sent, "-----" will be displayed until the first trigger occurs.
2. The data store can be disabled by sending the F command. Storage will again resume when the appropriate trigger occurs.
3. The instrument must be in a valid operating state (see Table 3-11) in order to use the high speed data store capabilities. The high speed intervals are 1msec through 14msec. The instrument display will blank while the instrument is storing readings at high speed. If the instrument is not in a valid operating state for high speed storage, a conflict error will be displayed briefly and storage will not occur.
4. The short time error message indicates that the instrument cannot store readings at the programmed interval rate. Instead, readings will be stored as fast as the instrument can run.
5. With S2 or S3 asserted, the fastest valid storage interval (I) is 31msec and 35msec respectively. A shorter interval will result in a short time error when the storage process is started. Readings will be stored as fast as the instrument can run.
6. Either during or after the storage process, readings may be recalled by using the B1 command as described in the previous paragraph. Also, the highest, lowest and average reading in a full buffer can be recalled by sending the appropriate U commands. See paragraph 3.9.16 for information on using the U commands.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

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

PROGRAM	COMMENTS
10 DIM A# [25]	
20 REMOTE 707	Send remote enable.
30 OUTPUT 707; " 'T0300I100X' "	Set trigger mode, and storage parameters.
40 TRIGGER 707	Start storage process.
50 OUTPUT 707; " 'B100X' "	Set read mode to data store.
60 FOR I=1 TO 100	Set counter for 100 loops.
70 ENTER 707; A#	Get a reading.
80 DISP A#	Display reading.
90 NEXT I	Loop back for next reading.
100 END	

In this example, note that only as many significant digits as necessary need be sent. In this case, the exact value is assumed to be 30.00000 even though only the first two digits were actually sent.

Digital Calibration—When performing digital calibration, two points must be calibrated on each range. The first calibration value should be approximately full range and the second calibration value should be approximately zero. After the second calibration value is sent over the bus, permanent storage of the two values will occur.

In order to send calibration values over the bus, the calibration command (C) must be sent after the value command (V) is sent. The calibration command takes on the following form:

- C0=Calibrate first point using value (V)
- C1=Calibrate second point using value (V)

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

The following example first sends a calibration value of 3 and then a calibration of 0.

### 3.9.10 Value (V) and Calibration (C)

V3XC0X  
V0XC1X

One advanced feature of the Model 196 is its digital calibration capabilities. Instead of the more difficult method of adjusting a number of potentiometers, the user need only apply an appropriate calibration signal and send the calibration value over the bus.

If the calibration value is greater than 3030000 counts (at 6½d resolution) an IDDCO error message will be displayed on the Model 196.

The V command is also used to program a zero value (see paragraph 3.9.4).

#### CAUTION

**Precision calibration signals must be connected to the instrument before attempting calibration, otherwise instrument accuracy will be affected. See Section 6 for complete details on calibrating the instrument either from the front panel or over the bus.**

The value command may take on either of the following forms:

Vnn.nnnnn  
Vn.nnnnnnE+n

Thus, the following two commands would be equivalent:

V30  
V3.0E+1

Table 3-11. High Speed Data Store

Data Store Interval	Valid Reading Rates	Valid Functions	Valid Ranges*	Valid Date Store Size*
Q1, Q2	S0	F0, F1, F3, F4	R1-R7	I1-I500
Q3-Q14	S0, S1	F0, F1, F3, F4	R1-R7	I1-I500

\*Data store size I0 (continuous) and R0 (autorange) cannot be used in the high speed data store mode.





- G0 = Send single reading with prefixes. Examples:  
NDCV-1.234567E+0 (A/D reading)  
NDCV-1.234567E+0,B001 (buffer reading)
- G1 = Send single reading without prefixes. Examples:  
-1.234567E+0 (A/D reading)  
-1.234567E+0,001 (buffer reading)
- G2 = Send all buffer readings, separated by commas, with prefixes and buffer memory locations. Examples:  
NDCV-1.234567E+0,B001,NDCV-1.765432E+0,B002, etc...
- G3 = Send all buffer readings, separated by commas, without prefixes and with buffer memory locations. Example: -1.234567E+0,001,-1.765432E+0,002, etc...
- G4 = Send all buffer readings, separated by commas, with reading prefixes and without memory buffer locations. Example:  
NDCV-1.234567E+0,NDCV-1.765432E+0,etc...
- G5 = Send all buffer readings, separated by commas, without reading prefixes and without buffer memory locations. Example:  
-1.234567E+0,-1.765432E+0, etc...

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

Notes:

1. The B command affects the source of the data. In the B0 mode, the bus data will come from the A/D converter. In the B1 mode, the data will come from the buffer.
2. The B1 command must be asserted when using the G2 through G5 modes.
3. Programmed terminator and EOI sequences appear at the end of each reading in the G0 and G1 modes, but are transmitted only at the end of the buffer in the G2 through G5 modes. No terminator is sent if in G2 through G5 modes while in B0 (data from A/D).

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

```
REMOTE 707
OUTPUT 707;''B0XG1X''
ENTER 707;A#
DISP A#
```

When the second statement is executed, the instrument will change to the G1 mode. The last two statements acquire data from the instrument and display the reading string on the CRT. Note that no prefix or suffix appears on the data string.

**3.9.13 SRQ Mask (M) and Serial Poll Byte Format**

The SRQ command controls which of a number of conditions within the Model 196 will cause the instrument to request service from the controller by asserting an SRQ. Once an SRQ is generated, that serial poll byte can be checked to determine if the Model 196 was the instrument that asserted the SRQ, and if so, what conditions can be checked by using the U1 command, as described in paragraph 3.9.13.

The Model 196 can be programmed to generate an SRQ under one or more of the following conditions:

1. When a reading is completed or an overrange condition occurs.
2. If a bus error occurs.
3. When the data store is full.
4. When the data store is 1/2 full.
5. If a trigger overrun error occurs.
6. When the bus is ready.

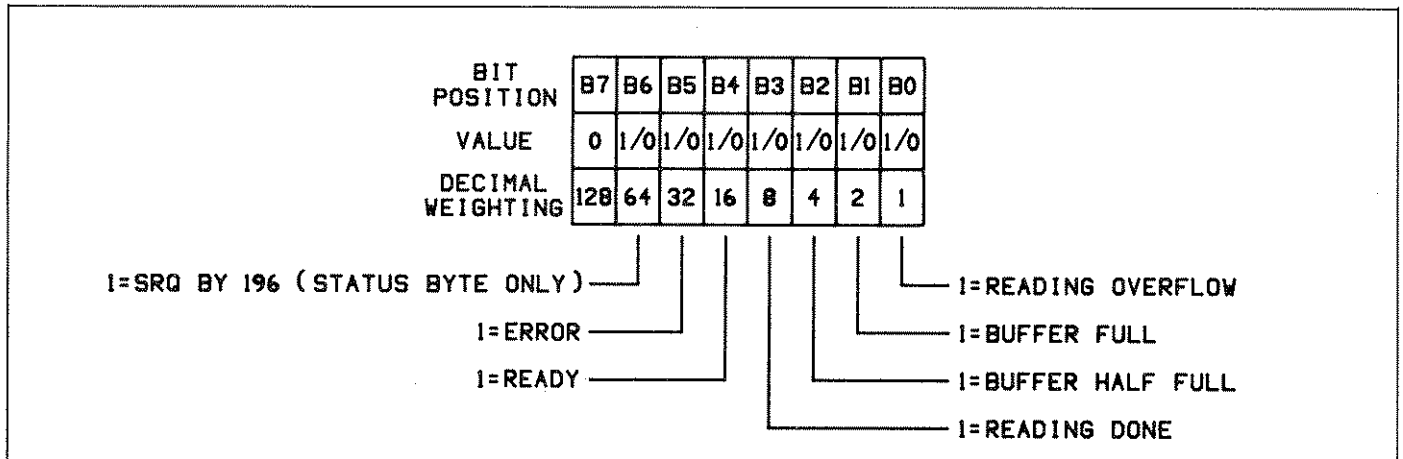


Figure 3-7. SRQ Mask and Serial Poll Byte Format

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

**SRQ Mask**—The Model 196 uses an internal mask to determine which conditions will cause an SRQ to be generated. Figure 3-7 shows the general format of this mask.

SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit in the SRQ mask. Decimal values for the various bits are summarized in Table 3-12. Note that the instrument may be programmed for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under reading overflow and buffer full conditions, send M3X. To disable SRQ, send M0X. This command will clear all bits in the SRQ mask.

**Table 3-12. SRQ Command Parameters**

Command	Condition to Generate SRQ
M0	Disable
M1	Reading overflow
M2	Data store full
M4	Data store half full
M8	Reading done
M16	Ready
M32	Error

**Serial Poll Byte Format**—The serial poll byte contains information relating to data and error conditions within the instrument. The general format of the serial poll byte (which is obtained by using the serial polling sequence, as described in paragraph 3.8.8) is shown in Figure 3-7.

The bits in the serial poll byte have the following meanings:

**Bit 0 (Reading Overflow)**—Set when an overrange input is applied to the instrument.

**Bit 1 (Buffer Full)**—Set when the defined buffer size is full.

**Bit 2 (Buffer 1/2 Full)**—Set when half the defined buffer size is full.

**Bit 3 (Reading Done)**—Set when the instrument has completed the present reading conversion.

**Bit 4 (Ready)**—Set when the instrument has processed all previously received commands and is ready to accept additional commands over the bus.

**Bit 5 (Error)**—Set when one of the following errors have occurred:

1. Trigger Error
2. Short Time
3. Big String
4. Uncalibrated
5. Cal Locked
6. Conflict
7. No Remote
8. IDDC
9. IDDCO
10. Translator

The nature of the error can be determined with the U1 command as explained in paragraph 3.9.16. An explanation of each error can also be found in paragraph 3.9.16.

**Bit 6 (SRQ)**—Provides a means to determine if an SRQ was asserted by the Model 196. If this bit is set, service was requested by the instrument.

**Bit 7**—Not used and always set to zero.

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

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

PROGRAM	COMMENTS
10 REMOTE 707 @ CLEAR 7	Set up for remote operation, clear instrument.
20 OUTPUT 707;''M32X''	Program for SRQ on IDDCO.
30 OUTPUT 707;''K5X''	Attempt to program illegal option.
40 S=SPOLL(707)	Serial poll the instrument.
45 IF NOT BIT(S,5) THEN 40	Wait for SRQ error.
50 DISP ''B7 B6 B5 B4 B3 B2 B1 B0''	Identify the bits.
60 FOR I=7 TO 0 STEP -1	Loop eight times.
70 DISP BIT(S,I);	Display each bit position.
80 NEXT I	
90 DISP	
100 END	

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

### 3.9.14 EOI and Bus Hold-off Modes (K)

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

- K0 = Send EOI with last byte; hold off bus until commands processed on X.
- K1 = Do not send EOI with last byte; hold off bus until 7 commands processed on X.
- K2 = Send EOI with last byte; do not hold off bus on X.
- K3 = Send no EOI with last byte; do not hold off bus on X.

Upon power up, or after the instrument receives a DCL or SDC command, the instrument will return to the default condition.

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

The bus hold off mode allows the instrument to temporarily hold up bus operation when it receives the X character until it processes all commands sent in the command string. The purpose of the hold off is to ensure that the front end FETs and relays are properly configured before taking a reading. Keep in mind that all bus operation will cease—not just activity associated with the Model 196. The advantage of this

mode is that no bus commands will be missed while the instrument is processing commands previously received.

The hold off period depends on the commands being processed. Table 3-13 lists hold off times for a number of different commands. Since a NRFD hold off is employed, the handshake sequence for the X character is complete.

**NOTE**

With K0 or K1 asserted, hold-off will also occur on an EOI and a terminator. These delays allow for proper operation of the Translator software, since "X" cannot be used in Translator words.

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

```
REMOTE 707
OUTPUT 707; '*K2X'
```

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

**Table 3-13. Bus Hold-off Times (Typical)**

Commands	Bus Held-off on X for:
Function (F)	100msec on DCV (F0), Ohms (F2) and Compensated Ohms (F7) 630msec on ACV (F1), ACA (F4), DBV (F5) and DBA (F6) 160msec on DCA (F3)
Range (R)	100msec on most range commands 170msec on 30MΩ (F2R6) and 300MΩ (F2R7) ranges 638msec per range command on ACV (F2) and ACA (F4)
Calibrate (C)	9sec on most functions 18.5sec on 30MΩ (F2R6) and 300MΩ (F2R7) ranges
Others	94msec to 110msec depending on command sent 1sec for selftest (J0) command

### 3.9.15 Terminator (Y)

The terminator sequence that marks the end of the instrument's data string or status word can be programmed by sending the Y command followed by an appropriate character. The default terminator sequence is the commonly used carriage return, line feed (CR LF) sequence (Y0). The terminator will assume this default value upon power up, or after the instrument receives a DCL or SDC command. Programmable terminators include:

Y0 = CR LF  
 Y1 = LF CR  
 Y2 = CR  
 Y3 = LF  
 Y4 = No terminator

**HP-85 Programming Example**—To reserve the default (CR LF) terminator sequence, type the following lines into the computer.

```
REMOTE 707
OUTPUT 707; 'Y0X'
```

When the second statement is executed, the normal terminator sequence will be reserved; the instrument will terminate each data string or status word with a (CR LF).

### 3.9.16 Status (U)

The status command allows access to information concerning various operating modes and conditions of the Model 196. Status commands include:

U0 = Send machine status word.  
 U1 = Send error conditions.  
 U2 = List Translator words.  
 U3 = Send a value indicating the buffer size.  
 U4 = Send the average reading in the data store.  
 U5 = Send the lowest reading in the data store.  
 U6 = Send the highest reading in the data store.  
 U7 = Send the present value (V).  
 U8 = Send input switch status (front/rear).

When the command sequence U0X is transmitted, the instrument will transmit the status word instead of its normal data string the next time it is addressed to talk. The status word will be transmitted only once each time the U0 command is given. To make sure that correct status is transmitted, the status word should be requested as soon as possible after the command is transmitted.

The format of U0 status is shown in Figure 3-8. Note that the letters correspond to modes programmed by the respective device-dependent commands. The default values in the status word are also shown in Figure 3-8. Note that all returned values except for those associated with the terminator correspond to the programmed numeric values. For example, if the instrument is presently in the R3 range, the second (R) byte in the status word will correspond to an ASCII 3.

The U1 command allows access to Model 196 error conditions in a similar manner. Once the sequence U1X is sent, the instrument will transmit the error conditions with the format shown in Figure 3-9 the next time it is addressed to talk in the normal manner. The error condition word will be sent only once each time the U1 command is transmitted. Note that the error condition word is actually a string of ASCII characters representing binary bit positions. An error condition is also flagged in the serial poll byte, and the instrument can be programmed to generate an SRQ when an error condition occurs. See paragraph 3.9.13. Note that all bits in the error condition word and the serial poll byte error bit will be cleared when the word is read. In addition, SRQ operation will be restored after an error condition by reading U1.

The various bits in the error condition word are described as follows:

**TRIG ERROR**—Set when the instrument receives a trigger while it is still processing a reading from a previous trigger.

**SHORT TIME**—Set when the instrument cannot run as fast as the selected data store interval.

**BIG STRING**—Set if more than a 10 character message is sent using the display (D) command.

**UNCAL**—Set when E<sup>2</sup>PROM memory fails the self test. Instrument calibration is invalid.

**CAL LOCKED**—Set when trying to calibrate the instrument with the calibration switch in the disable position.

**CONFLICT**—Set when trying to calibrate the instrument while it is in an improper state. (i.e. dB function).

**Translator Error (TRANSERR)**—Set when any one of ten possible Translator errors occur. Table 3-15 in paragraph 3.10 lists and describes the Translator errors.

**NO REMOTE**—Set when a programming command is received when REN is false.

**IDDC**—Set when an illegal device-dependent command (IDDC), such as E1X is received ("E" is illegal).

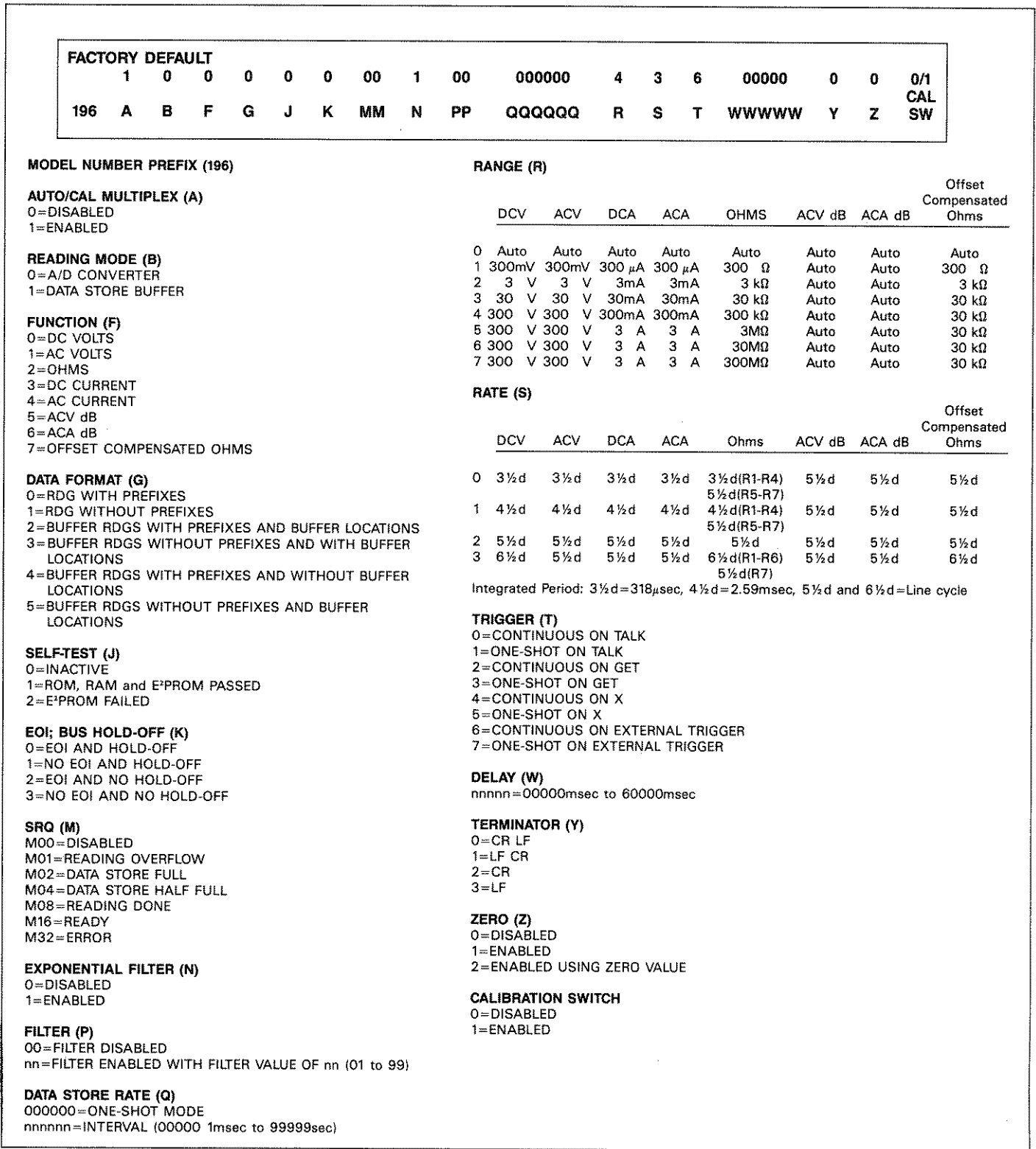


Figure 3-8. U0 Machine Status Word and Default Values

IDDCO—Set when an illegal device-dependent command option (IDDCO) such as T9X is received ("9" is illegal).

#### NOTE

The complete command string will be ignored if an IDDC, IDDCO or no remote error occurs.

The U2 command lists the Translator words that have been defined by the operator. The list will be transmitted only once each time the command is received.

The U3 command allows the user to find out the current defined size of the buffer. The buffer size is controlled by the I command. When this command is transmitted, the instrument will transmit the value the next time it is addressed to talk. This information will be transmitted only once each time the command is received. The U3 value will not be cleared when read; thus, the U3 value is always current.

The U4 command sends the average of all the readings that are in the data store. The U5 command sends the lowest reading in the data store and the U6 command sends the highest. When any of these commands are transmitted, the instrument will send the appropriate reading the next time the instrument is addressed to talk. A reading will only be sent once each time the appropriate command is received. Transmission of U4, U5 and U6 will not occur until the buffer is full.

The U7 command sends the present value. The value can be a calibration value, or a zero value.

The U8 command sends a value that defines the status of the input switch. A value of 0 indicates that the front panel input terminals are selected, while a value of 1 indicates that the rear panel input terminals are selected.

**HP-85 Programming Example**—Enter the following statements into the computer to obtain and display the machine status word (U0).

PROGRAM	COMMENTS
10 REMOTE 707	Send remote enable.
20 DIM A\$(40)	
30 OUTPUT 707: "U0X"	Send U0 command.
40 DISP "mdlABFGJKMMN PPQQQQQRRSTWWWWWY Z*"	
50 ENTER 707:A\$	Obtain U0 status from instrument.
60 DISP A\$	Display U0 status word.
70 ENTER 707:A\$	Get normal reading.
80 DISP A\$	Display normal reading.
90 END	

After entering the program, run it by pressing the HP-85 RUN key. The machine conditions of the Model 196 will be listed on the CRT display. To show that status is transmitted only once, a normal reading is requested and displayed last.

### 3.9.17 Auto/Cal Multiplex (A)

The Model 196 has built-in multiplex routines that automatically calibrate and zero the instrument, so as to maintain its high accuracy. The multiplex routines can be defeated, either through front panel Program 6 (paragraph 2.7.5) or through one of the following commands:

A0 = Disable multiplex  
A1 = Enable multiplex

Upon power up or after a DCL or SDC command, the instrument will return to the default condition.

**HP-85 Programming Example**—Disable multiplex by entering the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707: "A0X"
```

When the END LINE key is pressed the second time, the multiplexer routines will be disabled.





### 3.9.18 Delay (W)

The delay command controls the time interval that occurs from the point the instrument is triggered until it begins integration of the input signal. This feature is useful in situations where a specific time period must transpire to allow an input signal to settle before measurement. During the delay period, the input multiplexing FETs are switched on so the instrument is set to begin integration upon conclusion of the programmed delay period. A delay period can be programmed using the following command:

Wn

Here, n represents the delay value in milliseconds. The range of programmable delay values is from 0msec to 60000msec.

Examples: For a delay of 0.002sec send W2X.  
For a delay of 30.05sec send W30050X.  
For a delay of 60sec send W60000X.

Upon power up or after receiving a DCL or SDC command, the instrument will return to the default condition.

**HP-85 Programming Example**—To program a 250msec delay period into the instrument, enter the following statements into the computer:

```
REMOTE 707
OUTPUT 707; 'W250X'
```

After the END LINE key is pressed the second time, the instrument will wait for 250msec after each triggered conversion before executing the next conversion period.

### 3.9.19 Self-Test (J)

The J command causes the instrument to perform tests it automatically performs upon power up. When the self-test command is given, the Model 196 performs the following tests:

1. ROM Test
2. RAM Test
3. E<sup>2</sup>PROM Test

J command parameters include:

J0 = Perform self-test.

If the self-test is successful, the J byte in the U0 status word will be set to 1. If E<sup>2</sup>PROM fails, the message "UNCAL" will be displayed and the J byte in the U1 status word will be set to 2. An E<sup>2</sup>PROM failure is also flagged in the U1 status word. If ROM and RAM fails, the instrument will lock up.

See paragraph 6.7.2 for more information on these tests and recommendations to resolve a failure.

**HP-85 Programming Example**—Enter the following statements into the computer to perform the Model 196 self-test:

```
REMOTE 707
OUTPUT 707; 'J0X'
```

When the END LINE key is pressed the second time, the instrument performs the self-test. If successful, the self-test byte (J) in the U0 status word will be set to 1.

### 3.9.20 Hit Button (H)

The hit button command allows the user to emulate virtually any front panel control sequence. Through the use of the H command, the front panel programs may be entered through commands given over the bus. The H command is sent by sending the ASCII letter followed by a number representing a front panel control. These control numbers are shown in Figure 3-10.

Examples:

H3X—Selects the ACA function.  
H0X—Selects the ACV function.

**HP-85 Programming Example**—Enter the following statements into the computer to place the instrument in the ohms function:

```
REMOTE 707
OUTPUT 707; 'H1X'
```

When the END LINE key is pressed the second time, the instrument is placed in the ohms function.

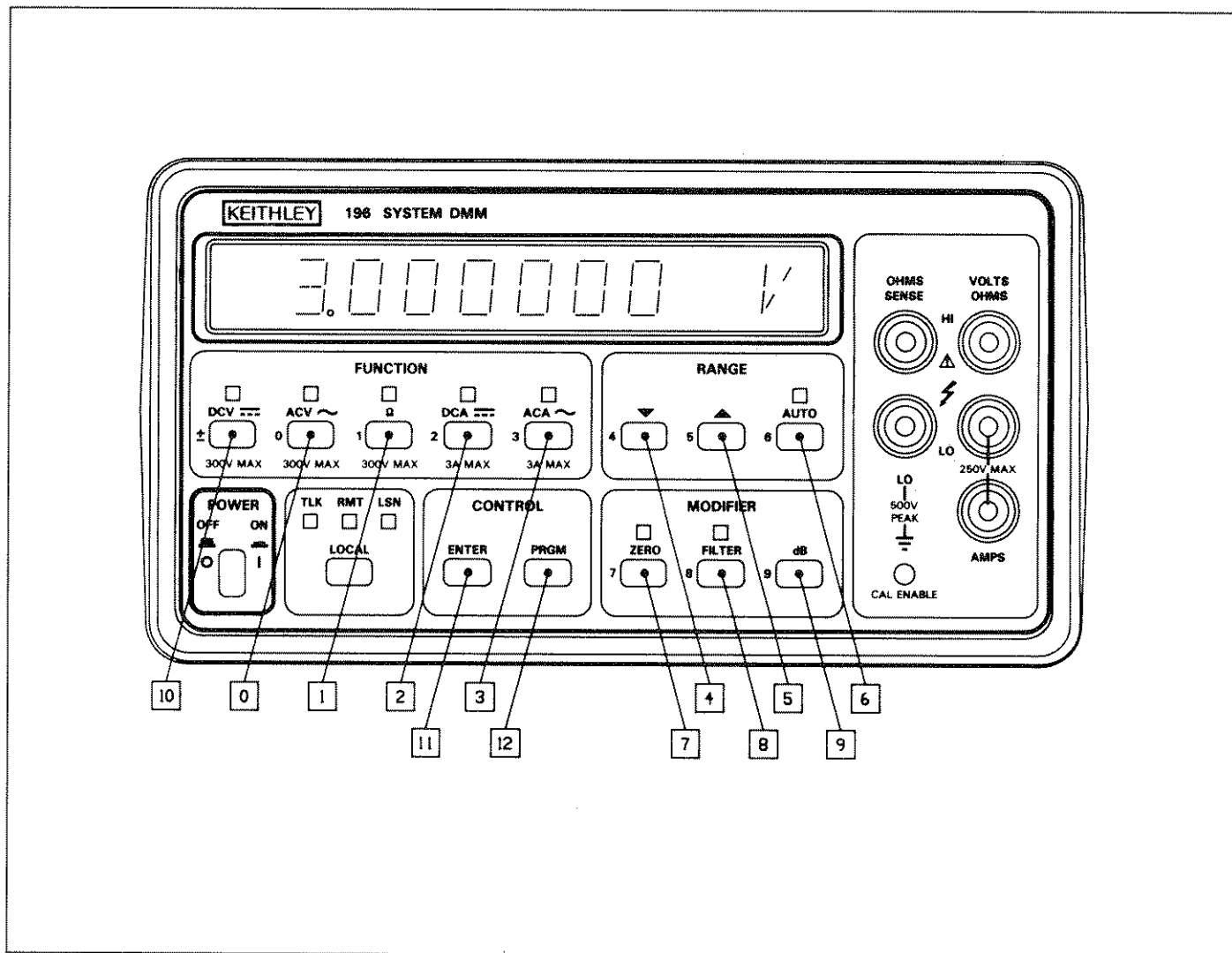


Figure 3-10. Hit Button Command Numbers

### 3.9.21 Display (D)

The display command controls the ASCII messages that can be placed onto the Model 196 display. Messages are controlled with the following commands:

Da = DIspay character "a", where "a" represents a printable ASCII character. Up to 10 characters (including blanks) may be sent.

D = Restores display back to normal.

#### Notes:

1. In order to have spaces preceding the beginning of the message and between message words, use the @ symbol to represent each space. For example, to display the message "Model 196" starting at the second display character (one space), send the following command string:

```
''@MODEL@196X''
```

2. Spaces in a command string are ignored.
3. Sending a message that exceeds 10 characters will result with the big string error message being displayed.

**HP-85 Programming Example**—Enter the following statements into the computer to display the message "MODEL 196":

```
REMOTE 707
OUTPUT 707; '*D@MODEL@196 X' '
```

When the END LINE key is pressed the second time the instrument model number will be displayed. Display operation may be returned to normal by entering the following statement:

```
OUTPUT 707; '*DX' '
```

### 3.9.22 Internal Filter (N)

In addition to the digital filter (P), a running average filter is used to provide additional filtering when making high resolution and high sensitivity measurements. The internal filter is controlled by the following commands:

N0 = Internal filter off.

N1 = Internal filter on.

The factory default condition of the internal filter is N1 (enabled).

**HP-85 Programming Example**—Enter the following statements into the computer to turn the internal filter off:

```
REMOTE 707
OUTPUT 707; '*N0X' '
```

When the END LINE key is pressed the second time, the internal filter will be disabled.

## 3.10 TRANSLATOR SOFTWARE

The built in Translator software allows the user to define his own words in place of Keithley's defined device-dependent commands. One word can replace a single command or a string of commands. For example, the word ACV can be sent in place of F1, and the word SETUP1 can be sent in place of F3R1T2S0Z1U0M2P15. Also, Keithley commands can be translated to emulate functions of other units. For example, the word RA, which is used by H-P to select autorange, can be sent in place of R0. There are certain words and characters that cannot be used as defined Translator words. These reserved words and character make up the Translator software syntax and are listed in Table 3-14.

**Table 3-14. Translator Reserved Words and Character**

Word/Character	Description
ALIAS	Used at the beginning of a command string to define Translator words.
;	Used to terminate the Translator string (one space must precede it).
\$	Used to define wild card Translator words. Values sent with a wild card Translator word select options of the equivalent DDC.
NEW	Tells the Model 196 to recognize Translator words.
OLD	Tells the Model 196 to only recognize the Keithley device-dependent commands.
SAVE	Saves Translator words as power up default.
LIST	Used to list the Translator words.
FORGET	Used to purge Translator words from memory.

### 3.10.1 Translator Format

The basic format for defining a Translator word is shown in the following example command string, which defines the word SETUP1 as a substitute for F1R0X.

```
"ALIAS SETUP1 F1R0X ;"
```

Where:

ALIAS is a reserved word that precedes the Translator word.

SETUP1 is the desired Translator word.

F1R0X is the Keithley command string.

; is a reserved character necessary to terminate the Translator string.

(spaces) must be used to separate words and the ";" character.

When SETUP1 is sent over the IEEE-488 bus, the instrument will go to the ACV function (F1) and enable autorange (R0).

Translator words that contain conflicting device-dependent commands, such as F1 and F2, can be defined. When sending the command word over the bus, the device-dependent command that was last entered will prevail. For example, sending a Translator word in place of F0F1X will place the instrument in the F1 function.

Notes:

1. Trying to define a Translator word that already exists will cause an error message to be displayed briefly. That Translator word will retain its original definition.
2. A Translator word cannot exceed 31 characters.
3. The Translator buffer can hold approximately 100 18-character Translator words.
4. The character X and \$ cannot be used in Translator words.
5. The Model 196 will not recognize an undefined Translator word sent over the bus.
6. A valid Translator word sent over the bus while the instrument is in the OLD mode will not be recognized. However, the instrument will try to execute (on the next X) the letters and numbers of the word as if they were device-dependent commands. To avoid this problem, it is recommended that NEW be sent before trying to execute Translator words. See paragraph 3.10.3 for an explanation of NEW and OLD.
7. Translator error messages are listed and described in Table 3-15.

**HP-85 Programming Example**—Enter the following program into the computer to define a Translator word (SETUP1) to emulate the command string F1R0X:

```
REMOTE 707
OUTPUT 707; "ALIAS SETUP1 F1R0X ;"
OUTPUT 707; "SETUP1"
```

**Table 3-15. Translator Error Messages**

Display Message	Explanation	Example Error String
TRANSERR 9 TRANSERR14 TRANSERR15	No more memory left for Translator words. Use of more than one ALIAS in a definition. Translator word exceeds 31 characters.	— "ALIAS TEST1 F1X ALIAS TEST2 R1X ;" "ALIAS ITHINKTHISISTHIRTYTWOCHARACTERS! F1X ;"
TRANSERR16 TRANSERR17	Use of an X in a Translator word. Trying to define a Translator word that already exists. The second string in the example is the error string.	"ALIAS XRAY F1X ;" "ALIAS SETUP F1X ;" "ALIAS SETUP R1X ;"
TRANSERR18 TRANSERR19	Use of a \$ in a Translator word. Sending the ; character.	"ALIAS \$200 F1X ;" ";"
TRANSERR20 TRANSERR21 TRANSERR23	Use of LIST in a Translator definition. Use of FORGET in a Translator definition. Use of SAVE in a Translator definition.	"ALIAS DOG F1X LIST ;" "ALIAS DOG F1X FORGET ;" "ALIAS DOG F1X SAVE ;"

When END LINE is pressed the second time, the Translator word will be defined to emulate the Keithley command string. When END LINE is pressed the third time, the instrument will go to the ACV function (F1) and enable autorange (R0).

### 3.10.2 Wild Card (\$)

An advanced feature of Translator software is its wild card capabilities. By using the reserved character "\$", the same basic Translator word can be used to select all options of a command. With this feature, a DDC option number is sent with the wild card Translator word. The format for using the wild card is shown in the following example, which defines the word FUNCTION as a substitute for the F command:

```
"ALIAS FUNCTION F$X ;"
"FUNCTION 1"
"FUNCTION 2"
```

The first statement defines FUNCTION as the wild card Translator word for the F command. The wild card (\$) will allow any valid option number of the F command (0 through 8) to be sent with the word. The second statement which is the substitute for the F1 command, will place the instrument in the ACV function. The third statement is a substitute for the F2 command, and will place the instrument in the ohms function.

#### Notes:

1. When sending a wild card Translator word over the bus, there must be a space between the Translator word and the option number.
2. If a wild card Translator word is sent without an option number, the instrument will default to option 0.

**HP-85 Programming Example**—Enter the following program to define a wild card Translator word to emulate the P (filter) command.

```
REMOTE 707
OUTPUT 707; ' 'ALIAS FILTER P$X ;' '
OUTPUT 707; ' 'FILTER 20' '
```

The second statement defines FILTER as the wild card Translator word for the P command. The third statement enables the filter with a filter value of 20.

### 3.10.3 NEW and OLD

NEW is a reserved word that tells the instrument that the ensuing commands may be defined Translator words. The instrument will then respond to the Translator words as well as Keithley device-dependent commands. The reserved word ALIAS automatically places the instrument in the NEW mode. NEW is also used to combine Translator words and is explained in paragraph 3.10.4.

OLD is a reserved word that prevents the instrument from responding to the defined Translator words. In this mode, only the Keithley device-dependent commands will be recognized over the bus.

**HP-85 Programming Example**—Enter the following statements into the computer to place the instrument in the NEW mode:

```
REMOTE 707
OUTPUT 707; ' 'NEW' '
```

When END LINE is pressed the second time, the instrument will go into the NEW mode.

### 3.10.4 Combining Translator Words

Existing Translator words can be combined resulting in a Translator word that contains the commands of the two (or more) combined words. For example, existing Translator words SETUP1 and SETUP2 can be combined and named SETUP3. When SETUP3 is sent over the bus, the commands of both SETUP1 and SETUP2 will be executed. The format for combining Translator words is shown in the following example:

```
"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 ;"
```

Where:

SETUP3 is the new Translator word.

SETUP1 and SETUP2 are words to be combined.

NEW is a reserved word that tells the instrument that SETUP1 and SETUP2 are Translator words and not Keithley device-dependent commands.

Even though the two words were combined to form SETUP3, SETUP1 and SETUP2 still exist as valid Translator words.

Wild card Translator words can also be combined with other Translator words. The option number used with the new word will apply only to the first wild card word in the string. For example, assume that FILTER (emulating the P command) and FUNCTION (emulating the F command) are wild card Translator words that are to be combined with the normal Translator word SETUP1. The format might look like this:

```
"ALIAS TEST NEW SETUP1 NEW FUNCTION
NEW FILTER ;"
```

The new Translator word is TEST. Whenever TEST is sent, the option value sent with that word will only affect function since FUNCTION is the first wild card command in the string. For example, TEST might be sent over the bus in the following format:

```
"TEST 3"
```

The "3" in the command string will only affect the FUNCTION command. In this example the instrument will be placed in the DCA function (F3). Since the FILTER command does not have an assigned option value (due to its position in the string), it will default to 0 (disable).

**HP-85 Programming Example**—The following program will create two Translator words and then combine them to form a third Translator word:

```
REMOTE 707
OUTPUT 707;''ALIAS SETUP1 F1X;''
OUTPUT 707;''ALIAS SETUP2 R0X;''
OUTPUT 707;''ALIAS SETUP3 NEW SETUP1 NEW
SETUP2;''
```

The second and third program statements define the two Translator words. When END LINE is pressed a fourth time, the two words combine to form the new word (SETUP3).

### 3.10.5 Combining Translator Words With Keithley IEEE-488 Commands

One or more existing Translator words (including wild card words) can be combined with Keithley IEEE commands resulting in a Translator word that contains the commands of the Translator words and the Keithley IEEE commands. The format for combining Translator words with Keithley IEEE commands is shown in the following example:

```
"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 P1Z1X ;"
```

Where:

SETUP3 is the new Translator word.

SETUP1 and SETUP2 are the existing words.

P1Z1X is the Keithley IEEE command string.

NEW tells the instrument that SETUP1 and SETUP2 are Translator words.

When the Translator word SETUP3 is asserted over the bus, the commands of the two Translator words and the Keithley IEEE command string will be executed.

**HP-85 Programming Example**—The following program will create two Translator words and then combine them with a Keithley IEEE command string to form a new Translator word:

```
REMOTE 707
OUTPUT 707;''ALIAS SETUP1 F1X;''
OUTPUT 707;''ALIAS SETUP2 R0X;''
OUTPUT 707;''ALIAS SETUP3 NEW SETUP1
NEW SETUP2 P1Z1X;''
```

The second and third statements create two Translator words. When END LINE is pressed the fourth time, the two Translator words are combined to form the word SETUP3.

### 3.10.6 Executing Translator Words and Keithley IEEE Commands

Translator words (including wild card words) and Keithley IEEE commands can be executed in the same command string. The format for doing this is demonstrated in the following examples:

```
"SETUP1 P1Z1X"
"FUNCTION 2 P1Z1X"
```

When the first command string is sent over the bus, the commands in SETUP1 and the Keithley IEEE commands will be executed. When the second string is sent, the second option of the wild card FUNCTION command and the Keithley IEEE commands will be executed.

**HP-85 Programming Example**—The following program will assert the commands of an existing Translator word and the standard Keithley IEEE commands over the bus:

```
REMOTE 707
OUTPUT 707;''SETUP1 P1Z1X;''
```

When END LINE is pressed the second time, the commands of SETUP1 and the Keithley IEEE commands (P1Z1X) will be sent over the bus.

### 3.10.7 SAVE

Translator words can be remembered by the instrument as power up default words by sending the reserved word SAVE. If SAVE is not sent, Translator words will be lost when the instrument is turned off, Program 37 (Reset) is run, or an SDC, DCL or L0 is sent over the bus.

When SAVE is sent, the instrument also remembers if it was in NEW or OLD. If the instrument is in NEW when SAVE is sent, it will power up in NEW. If the instrument is in OLD when SAVE is sent, it will power up in OLD.

**HP-85 Programming Example**—With one or more Translator words already defined, enter the following statements into the computer to retain them as power up default words:

```
REMOTE 707
OUTPUT 707; 'SAVE'
```

When END LINE is pressed the second time, current Translator words will become power up default words.

### 3.10.8 LIST

LIST is a reserved word that can be used to list the existing Translator words stored in temporary memory. The most recent defined word will be listed first.

Notes:

1. The U2 command can also be used to list the Translator words (see paragraph 3.9.16).
2. If there are no Translator words in memory, nothing will be displayed when the list is requested.

**HP-85 Programming Example**—With Translator words already defined, enter the following program statements to list them:

```
REMOTE 707
OUTPUT 707; 'LIST'
ENTER 707; A#
DISP A#
```

The second and third statements will send the word list to the computer. When END LINE is pressed a fourth time, the Translator words will be displayed.

### 3.10.9 FORGET

FORGET is a reserved word that is used to purge all Translator words from temporary memory. However, Translator words that were saved in E<sup>2</sup>PROM by the SAVE command will again be available after power to the instrument is cycled, Program 37 (Reset) is RUN, or DCL, SDC or L0 is sent over the bus.

To purge Translator words from E<sup>2</sup>PROM, first send the FORGET command and then send the SAVE command.

**HP-85 Programming Example**—Enter the following statements into the computer to purge all Translator words from temporary memory:

```
REMOTE 707
OUTPUT 707; 'FORGET'
```

When END LINE is pressed the second time, the Translator words are purged from temporary memory.

## 3.11 BUS DATA TRANSMISSION TIMES

A primary consideration is the length of time it takes to obtain a reading once the instrument is triggered to make a conversion. The length of time will vary somewhat depending on the selected function and trigger mode. Table 3-16 gives typical times.

**Table 3-16. Trigger To Reading-Ready Times (DCV Function)**

Configuration*	Mode	Time (typical)
S0A0G1N0T1X	Maximum Reading Rate (3½d)	6msec
S1A0G1N0T1X	4½d	8msec
S2A0G1N0T1X	5½d	24msec
S3A1G1N0T1X	6½d (internal filter off)	106msec
S3A1G1N1T1X	6½d (internal filter on)	3.3sec

\*Commands not listed are at factory default.





# SECTION 4 PERFORMANCE VERIFICATION

---

## 4.1 INTRODUCTION

The procedures outlined in this section may be used to verify that the instrument is operating within the limits stated in the specifications at the front of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

### NOTE

If the instrument is still under warranty (less than 1 year from the date of shipment), and its performance falls outside the specified range, contact your Keithley representative or the factory to determine the correct course of action.

## 4.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at 18 - 28°C (65 - 82°F) and at less than 80% relative humidity.

## 4.3 INITIAL CONDITIONS

The Model 196 must be turned on and allowed to warm up for at least two hours before beginning the verification procedures. If the instrument has been subject to extremes of temperature (outside the range specified in paragraph 4.2), additional time should be allowed for internal temperatures to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

## 4.4 RECOMMENDED TEST EQUIPMENT

Table 4-1 lists all test equipment required for verification. Alternate equipment may be used as long as the substitute equipment has specifications at least as good as those listed in the table.

### NOTE

The verification limits in this section do not include test equipment tolerance.

**Table 4-1. Recommended Test Equipment**

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	300mV, 3V, 30V, 300V ranges $\pm 15$ ppm.
Fluke	5200A	AC Voltage Calibrator	300mV, 3V, 30V ranges; 20Hz $\pm 0.1\%$ ; 50Hz-20kHz 0.02%; 100kHz $\pm 0.33\%$ .
Fluke	5215A	AC Power Amplifier	300V range: 20Hz $\pm 0.12\%$ ; 50Hz-20kHz $\pm 0.04\%$ ; 100kHz $\pm 0.1\%$
Fluke	5450A	Resistance Calibrator	300 $\Omega$ -3M $\Omega$ ranges $\pm 15$ ppm; 30M $\Omega$ $\pm 32$ ppm; 300M $\Omega$ range $\pm 225$ ppm
Valhalla	2500E	AC-DC Current Calibrator	300 $\mu$ -3A ranges $\pm 0.03\%$ DC, $\pm 0.1\%$ AC to 5kHz (at full scale output)

### 4.5 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying the one year accuracy specifications of the instrument, at 5½d resolution, for each of the five measuring functions: DC volts, TRMS AC volts, ohms, TRMS AC amps, and DC amps. These procedures are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications and not under warranty, refer to Section 6 for calibration procedures.

**WARNING**

The maximum common-mode voltage (voltage between input low and chassis ground) is 500V. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose the user to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

#### 4.5.1 DC Volts Verification

With the Model 196 set to 5½d resolution, verify the DC volts function as follows:

**CAUTION**

Do not exceed 300V between the input HI and LO terminals or damage to the instrument may occur.

1. Select the DCV function and autorange.
2. Connect the DC voltage calibrator to the Model 196 as shown in Figure 4-1.
3. Set the calibrator to 0V and enable zero on the Model 196. Verify that the display is reading 000.000mV ±2 counts.

**NOTE**

Low measurement techniques should be used when checking the 300mV DC range. Refer to paragraph 2.6.5 for low level measurement considerations.

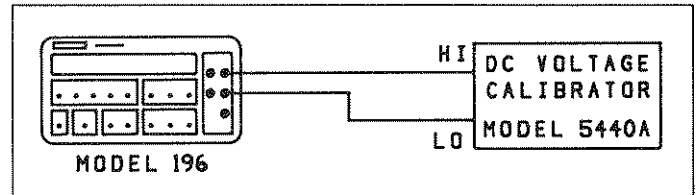
4. Set the calibrator to output +300mV and verify that the reading is within the limits listed in Table 4-2.
5. Disable zero and leave it disabled for the remainder of the DCV verification procedure.
6. Check the 3V, 30V, and 300V ranges by applying the respective DC voltage levels listed in Table 4-2. Verify to

see that the reading for each range is within the limits listed in the table.

7. Repeat the procedure for each of the ranges with negative voltages.

**Table 4-2. Limits for DC Volts Verification**

196 DCV Range	Applied DC Voltage	Allowable Readings (18° to 28°C)
300mV	300.000mV	299.974 to 300.026
3 V	3.00000 V	2.99987 to 3.00013
30 V	30.0000 V	29.9973 to 30.0027
300 V	300.000 V	299.970 to 300.030



**Figure 4-1. Connections for DC Volts Verification**

#### 4.5.2 TRMS AC Volts Verification

With the instrument set to 5½d resolution, perform the following procedure to verify the AC volts function:

**CAUTION**

Do not exceed 300V RMS 425V peak 10V•Hz between the input HI and LO terminals or instrument damage may occur.

1. Select the ACV function and autorange. Do not use zero to cancel the offset in this procedure. Turn zero off, if it is enabled.
2. Connect the AC calibrator to the Model 196 as shown in Figure 4-2.
3. Set the calibrator to output 290mV at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-3.
4. Repeat the 290mV measurement at the other frequencies specified in Table 4-3.
5. Repeat the procedure for the 3V, 30V and 300V ranges by applying the respective AC voltages listed in Table 4-3. Check to see that the reading for each range is within the limits listed in the table.

Table 4-3. Limits for TRMS AC Volts Verification

196 ACV Range	Applied AC Voltage	Allowable Readings (18°C to 28°C)					
		20Hz	50Hz	200Hz	10kHz	20kHz	100kHz
300mV	290.000mV	284.100 to 295.900	289.030 to 290.970	289.465 to 290.535	289.465 to 290.535	288.640 to 291.360	283.900 to 296.100
3 V	2.90000V	2.84100 to 2.95900	2.89030 to 2.90970	2.89465 to 2.90535	2.89465 to 2.90535	2.88930 to 2.91070	2.85350 to 2.94650
30 V	29.0000V	28.4100 to 29.5900	28.9030 to 29.0970	28.9465 to 29.0535	28.9465 to 29.0535	28.8640 to 29.1360	28.5350 to 29.4650
300 V	290.000V	284.100 to 295.900	289.030 to 290.970	289.465 to 290.535	289.465 to 290.535	288.640 to 291.360	*

\*Do not apply 290V at 100kHz to the input. This exceeds the V•Hz limit of the instrument. Maximum TRMS AC volt input at 100kHz is 100V. On the 300V range, allowable readings with 100V @ 100kHz applied to the input are 98.200 to 101.800. See paragraph 2.6.7 for clarification of the V•Hz specification.

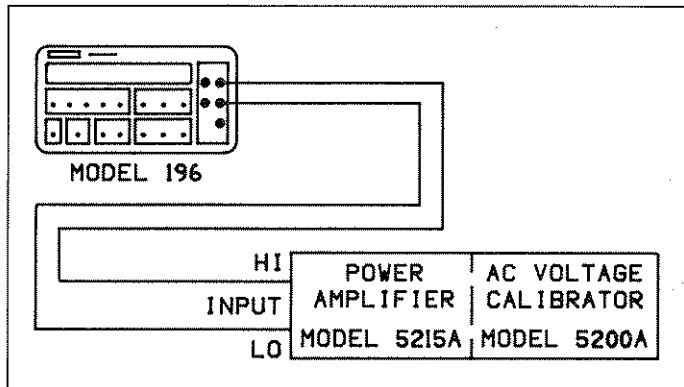


Figure 4-2. Connections for TRMS AC Volts Verification

### 4.5.3 Ohms Verification

With the Model 196 set to 5½d resolution, verify the ohms function as follows:

#### CAUTION

Do not exceed 425V peak or 300V RMS between the input HI and LO terminals or damage to the instrument may occur.

1. Select the ohms function and autorange.
2. Using Kelvin test leads (such as the Keithley Model 1641) connect the resistance calibrator to the Model 196 as shown in Figure 4-3.
3. Set the calibrator to the SHORT position and enable zero on the Model 196. Verify that the display reads 000.000.
4. Set the calibrator to output 190Ω and verify that the reading is within the limits listed in Table 4-4.
5. Disable zero and leave it disabled for the remainder of the ohms verification procedure.
6. Utilizing Figures 4-3 and 4-4, check the 3kΩ through 300MΩ ranges by applying the respective resistance levels listed in Table 4-4. Verify that the readings are within the limits listed in the table.

Table 4-4. Limits for Ohms Verification

196 Range	Set up	Applied Resistance	Allowable Readings (18°C to 28°C)
300 Ω	Figure 4-3	190.000 Ω	189.979 to 190.021
3 kΩ	Figure 4-3	1.90000 kΩ	1.89985 to 1.90015
30 kΩ	Figure 4-3	19.0000 kΩ	18.9985 to 19.0015
300 kΩ	Figure 4-4	190.000 kΩ	189.958 to 190.042
3MΩ	Figure 4-4	1.90000MΩ	1.89958 to 1.90042
30MΩ	Figure 4-4	19.0000MΩ	18.9808 to 19.0192
300MΩ	Figure 4-4	100.000MΩ	97.998 to 102.002

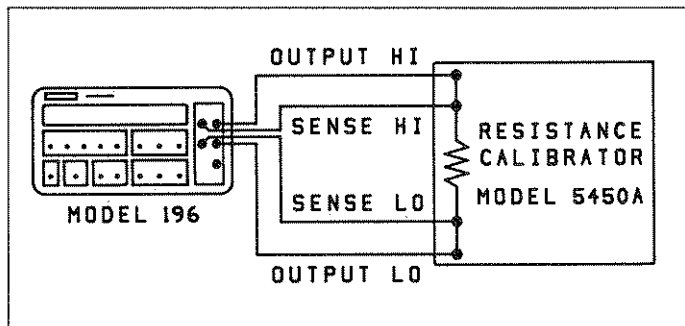


Figure 4-3. Connections for Ohms Verification (300Ω—30kΩ Range)

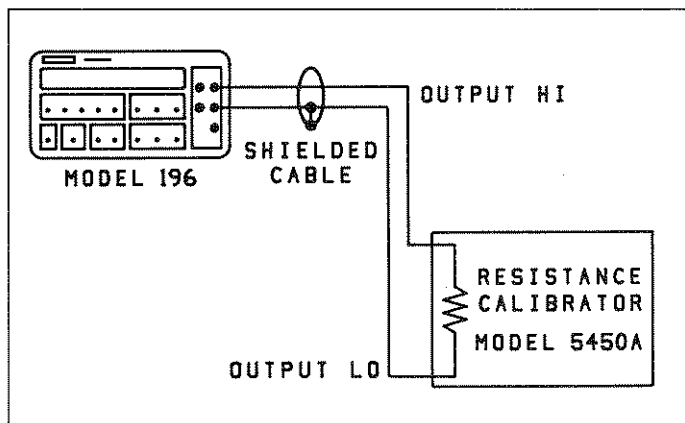


Figure 4-4. Connections for Ohms Verification (300kΩ—300MΩ Ranges)

### 4.5.4 DC Current Verification

With the instrument set to 5½d resolution, verify the DC current function as follows:

**CAUTION**

Do not exceed 3A to the AMPS and LO input terminals or the rear panel current fuse will blow.

1. Select the DCA function and autorange.
2. Connect the DC current calibration source to the Model 196 as shown in Figure 4-5.
3. Set the calibration source to output +300µA and verify that the reading is within the limits listed in Table 4-5.
4. Repeat the procedure for the 3mA, 30mA, 300mA and 3A ranges by applying the respective DC current levels listed in Table 4-5. Check to see that the reading for each range is within the limits listed in the table.
5. Repeat the procedure for each of the ranges with negative current levels.

Table 4-5. Limits for DC Current Verification

196 Range	Applied DC Current	Allowable Readings (18°C to 28°C)
300 µA	300.000 µA	299.710 to 300.290
3mA	3.00000mA	2.99840 to 3.00160
30mA	30.0000mA	29.9840 to 30.0160
300mA	300.000mA	299.840 to 300.160
3 A	3.00000 A	2.99720 to 3.00280

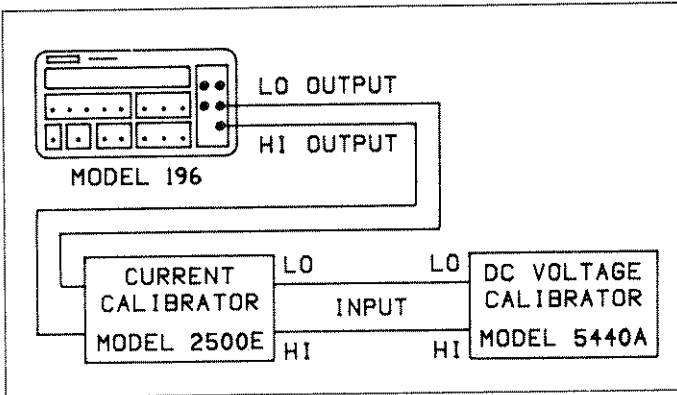


Figure 4-5. Connections for DC Current Verification

### 4.5.5 TRMS AC Current Verification

With the instrument set for 5½d resolution, verify the AC current function as follows:

**CAUTION**

Do not exceed 3A to the AMPS and LO input terminals or the rear panel current fuse will blow.

1. Select the ACA function and autorange. Do not use zero to cancel the offset in this procedure.

2. Connect the AC current calibration source to the Model 196 as shown in Figure 4-6.
3. Set the calibration source to output 300µA at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-6.
4. Repeat the 300µA measurement at the other frequencies specified in Table 4-6.
5. Repeat the procedure for the 3mA, 30mA, 300mA and 3A ranges by applying the respective AC current levels listed in Table 4-6. Check to see that the reading for each range is within the limits listed in the table.

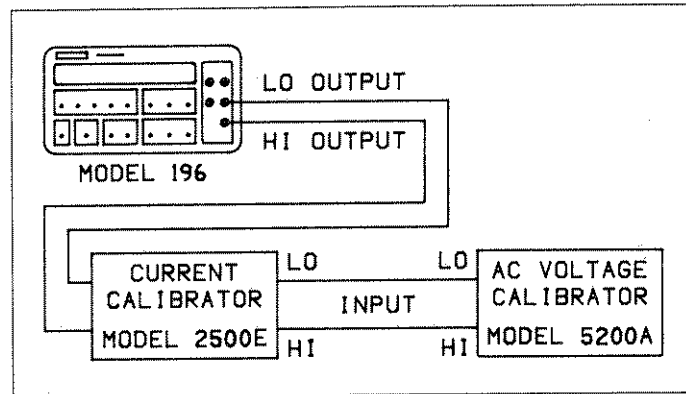


Figure 4-6. Connections for TRMS AC Current Verification

Table 4-6. Limits for AC Current Verification

196 Range	Applied AC Current	Allowable Readings (18°C to 28°C)		
		20Hz	45Hz	5kHz
300 µA	290.000 µA	284.100 to 295.900	287.290 to 292.710	287.290 to 292.710
3mA	2.90000mA	2.84100 to 2.95900	2.88160 to 2.91840	2.88160 to 2.91840
30mA	29.0000mA	28.4100 to 29.5900	28.8160 to 29.1840	28.8160 to 29.1840
300mA	290.000mA	284.100 to 295.900	288.160 to 291.840	288.160 to 291.840
3 A	2.90000 A	2.84100 to 2.95900	2.88160 to 2.91840	2.88160 to 2.91840

