Instruction Manual
Model 193
System DMM

SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 193.

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

Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazards exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace with test leads that have the same measure of safety as those supplied with the instrument.

For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors, before connecting or disconnecting the instrument. Always disconnect all unused test leads from the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.

Exercise extreme safety when testing high energy power circuits (AC line or mains, etc). Refer to the High Energy Circuit Safety Precautions found in paragraph 2.6 (Basic Measurements).

Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

SPECIFICATIONS

DC VOLTS

RANGE	MAXIMUM READING (5½ Digits)	RESOLUTION 6½	RESOLUTION 5½	INPUT RESISTANCE	ACCURACY (5½ Digits)** ±(%rdg+counts) 24 Hr., 23°±1°C	90 Days, 23°±5°C	1 Yr., 23°±5°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C	ANALOG SETTLING TIME***
200mV	219.999mV	100 nV	1 µV	>1GΩ	0.003+2*	0.005+2*	0.008+2*	0.0003+1	<2ms
2 V	2.19999 V	1 µV	10 µV	>1GΩ	0.002+1	0.005+2	0.007+2	0.0003+0.1	<1ms
20 V	21.9999 V	10 µV	100 µV	10MΩ	0.003+1	0.007+1	0.009+3	0.0007+0.1	<1ms
200 V	219.999 V	100 µV	1mV	10MΩ	0.003+1	0.007+1	0.009+3	0.0007+0.1	<1ms
1000 V	1000.00 V	1mV	10mV	10MΩ	0.004+1	0.007+1	0.009+5	0.0007+0.1	<1ms

*When properly zeroed.   **Multiply digit error by 10 for 6½-digit accuracy.   ***To 0.01% of step change.

NMRR: Greater than 60dB at 50 or 60Hz.

CMRR: Greater than 120dB at dc and 50 or 60Hz (with 1kΩ in either lead).

MAXIMUM ALLOWABLE INPUT: 1000V peak.

MAXIMUM MEASUREMENT RATES (into internal memory, filter and multiplex off):

3½ Digit	4½ Digit	5½ Digit	6½ Digit
1000 rdg/s	333 rdg/s	25 rdg/s	25 rdg/s

TRMS AC VOLTS (Option 1930)

RANGE	MAXIMUM READING (5½ Digits)	RESOLUTION 6½	RESOLUTION 5½	20Hz-50Hz*	ACCURACY (5½ Digits)*** ±(%rdg+counts) 1 Year, 18°-28°C 50Hz-10kHz*	10kHz-20kHz*	20kHz-100kHz**
2V	2.19999V	1 µV	10 µV	1+100	0.25+100	0.35+300	1+500
20V	21.9999V	10 µV	100 µV	1+100	0.25+100	0.35+300	1+500
200V	219.999V	100 µV	1mV	1+100	0.25+100	0.35+300	1+500
700V	700.00 V	1mV	10mV	1+100	0.35+100	0.5+300	1+500

*Above 2000 counts. **Above 20000 counts; 3%+500 typical below 20000. ***Multiply digit error by 10 for 6½-digit accuracy.

RESPONSE: True root mean square, ac or ac+dc.

CREST FACTOR: Rated accuracy to 3. Specified for pulse widths >10µs, peak voltage ≤1.36 × full scale.

AC+DC: Add 60 counts to specified accuracy.

MAXIMUM INPUT: 1000V peak ac+dc, 2×10⁷V•Hz.

SETTLING TIME: 0.5s to within 0.1% of change in reading.

INPUT IMPEDANCE: 1MΩ shunted by less than 120pF.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): Less than ±(0.1×applicable accuracy specification)/°C below 50kHz; (0.2×) for 50kHz to 100kHz.

3dB BANDWIDTH: 500kHz typical.

CMRR: Greater than 60dB at 50 and 60Hz (1kΩ unbalance).

dBV (Ref. = 1V):

INPUT	ACCURACY ±dBV 1 Year, 18°-28°C 20Hz-20kHz	20kHz-100kHz	RESOLUTION
−14 to +57dBV (200mV to 700V rms)	0.2	0.4	0.01dBV
−34 to −14dBV (20mV to 200mV)	1.5	3*	0.01dBV

*Typical

LOW FREQUENCY AC VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year) (3½ Digits) ±(%rdg+counts) 18°-28°C
200mV	100 µV	2+3
2 V	1mV	2+3
20 V	10mV	2+3
200 V	100mV	2+3
700 V	1 V	2+3

RESPONSE: True root mean square, ac+dc.

BANDWIDTH: 0.1 to 10Hz.

OHMS

RANGE	MAXIMUM READING (5½ Digits)	RESOLUTION 6½	RESOLUTION 5½	CURRENT THROUGH UNKNOWN	ACCURACY (5½ Digits)*** ± (%rdg + counts) 24 Hr., 23°±1°C	ACCURACY (5½ Digits)*** ± (%rdg + counts) 90 Days, 23°±5°C	ACCURACY (5½ Digits)*** ± (%rdg + counts) 1 Yr., 23°±5°C	TEMPERATURE COEFFICIENT ± (%rdg + counts)/°C 0°18°C & 28°-50°C
200 Ω	219.999 Ω	100 μΩ	1mΩ	1mA	0.0035 + 2*	0.007 + 2*	0.010 + 2*	0.001 + 0.7
2 kΩ	2.19999 kΩ	1mΩ	10mΩ	1mA	0.0035 + 2	0.007 + 2	0.010 + 2	0.001 + 0.1
20 kΩ	21.9999 kΩ	10mΩ	100mΩ	100 μA	0.0035 + 2	0.007 + 2	0.010 + 2	0.001 + 0.1
200 kΩ	219.999 kΩ	100mΩ	1 Ω	10 μA	0.0035 + 2	0.007 + 2	0.010 + 2	0.001 + 0.1
2MΩ	2.19999MΩ	1 Ω	10 Ω	1 μA	0.005 + 2	0.010 + 2	0.010 + 2	0.001 + 0.1
20MΩ	21.9999MΩ	10 Ω	100 Ω	100 nA	0.040 + 2	0.070 + 2	0.070 + 2	0.010 + 0.1
200MΩ	219.999MΩ	100 Ω	1 kΩ	100 nA**	3.2 + 2	3.2 + 2	3.2 + 2	0.230 + 0.1

*When properly zeroed.   **Nominal short circuit current.
***4-terminal accuracy 200Ω-20k range. Multiply digit error by 10 for 6½d accuracy.

CONFIGURATION: Automatic 2- or 4-terminal.

MAXIMUM ALLOWABLE INPUT: 350V peak or 250V rms.

MAXIMUM OPEN CIRCUIT VOLTAGE: −7V.

DC AMPS (Option 1931)

RANGE	RESOLUTION (5½ Digits)	ACCURACY (5½ Digits) (1 Year) ± (%rdg + counts) 18°-28°C	TEMPERATURE COEFFICIENT ± (%rdg + counts)/°C 0°-18°C & 28°-50°C
200 μA	1nA	0.09 + 10	0.01 + 0.5
2mA	10nA	0.09 + 10	0.01 + 0.5
20mA	100nA	0.09 + 10	0.01 + 0.5
200mA	1μA	0.09 + 10	0.01 + 0.5
2 A	10μA	0.09 + 10	0.01 + 0.5

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

MAXIMUM VOLTAGE BURDEN: 0.25V on 200μV through 20mA ranges; 0.28V on 200mA range; 1V on 2A range.

TRMS AC AMPS (Options 1930 and 1931)

RANGE	RESOLUTION (5½ Digits)	ACCURACY* 45Hz to 10kHz (5½ Digits) (1 Year) ± (%rdg + counts) 18°-28°C	TEMPERATURE COEFFICIENT ± (%rdg + counts)/°C 0°-18°C & 28°-50°C
200 μA	1nA	0.6 + 300	0.04 + 10
2mA	10nA	0.6 + 300	0.04 + 10
20mA	100nA	0.6 + 300	0.04 + 10
200mA	1μA	0.6 + 300	0.04 + 10
2 A	10μA	0.6 + 300	0.04 + 10

*Above 2000 counts.

RESPONSE: True root mean square, ac or ac + dc.

CREST FACTOR: Rated accuracy to 3. Specified for pulse width > 1ms, peak current ≤ 1.36 × full scale.

MAXIMUM VOLTAGE BURDEN: 0.25V on 200μV through 20mA ranges; 0.28V on 200mA range; 1V on 2A range.

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

SETTLING TIME: 0.5s to within 0.1% of change in reading.

dB (Ref. = 1mA):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 45Hz-10kHz	RESOLUTION
−34 to +66dB 20μA to 2A	0.3	0.01dB
−54 to −34dB 2μA to 20μA	2	0.01dB

TEMPERATURE (Thermocouple) (Over IEEE Bus Only)

THERMO-COUPLE TYPE	RANGE	RESOLUTION	ACCURACY* (1 Year) 18°-28°C
J	−100 to + 760°C	0.1°C	±0.5°C
K	−100 to +1372°C	0.1°C	±0.5°C
T	−100 to + 400°C	0.1°C	±0.5°C
E	−100 to +1000°C	0.1°C	±0.6°C
R	0 to +1768°C	1 °C	±3 °C
S	0 to +1768°C	1 °C	±3 °C
B	+350 to +1821°C	1 °C	±5 °C

*Relative to external 0°C reference junction; exclusive of thermocouple errors. Junction temperature may be external.

TEMPERATURE (RTD)

RANGE	RESO-LUTION	4-WIRE ACCURACY* 1 Yr., 18°-28°C	TEMPERATURE COEFFICIENT
−100° to +630°C	0.01°C	±0.18°C	±(0.0013% + 0.005°C)/°C
−148° to +1100°F	0.01°F	±0.36°F	±(0.0013% + 0.01 °F)/°C

*Excluding probe errors.

RTD TYPE: 100Ω platinum; DIN 43 760 or IPTS-68, alpha 0.00385 or 0.00392, 4-wire.

MAXIMUM LEAD RESISTANCE (each lead): 4-wire, 10Ω.

SENSOR CURRENT: 1mA

COMMON MODE REJECTION: Less than 0.005°C/V at dc, 50Hz and 60Hz (100Ω unbalance, LO driven).

MAXIMUM ALLOWABLE INPUT: 350V peak, 250V rms.

IEEE-488 BUS IMPLEMENTATION

Multiline Commands: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

Uniline Commands: IFC, REN, EOI, SRQ, ATN.

Interface Functions: SH1, AH1, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

Programmable Parameters: Range, Function, Zero, Integration Period, Filter, dB Reference, EOI, Trigger, Terminator, Delay, 500-rdg. Storage, Scaling, Calibration, Display, Multiplex Off, Status, Service Request, Self Test, Output Format.

GENERAL

DISPLAY: 14, 0.5-in. alphanumeric LED digits with decimal point and polarity. Function and IEEE bus status also displayed.

RANGING: Manual or fast autoranging.

ISOLATION: Input LO to IEEE LO or power line ground: 500V max., 5×10^5V•Hz; greater than 10^9Ω paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable 1ms to 999.999sec or triggered.

BENCH READING RATE: 5 readings/sec, except 20MΩ; 200MΩ range 2 readings/sec.

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

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

WARMUP: 1 hour to rated accuracy.

OPERATING ENVIRONMENT: 0 -50 C, 0% to 80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°C to 50°C (except 200MΩ range: 0% to 60% RH up to 28°C).

STORAGE ENVIRONMENT: −25° to +65°C.

POWER: 105-125V or 210-250V (internal switch selected), 50Hz or 60Hz, 40VA maximum. 90-110V & 180-220V versions available upon request.

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

DIMENSIONS, WEIGHT: 89mm high × 438mm wide × 441mm deep (3½ in. × 17¼ in. × 17⅜ in.). Net weight 33kg (15 lbs.).

ACCESSORIES AVAILABLE:
Model 1600A: High Voltage Probe
Model 1641: Kelvin Test Lead Set
Model 1651: 50-Ampere Shunt
Model 1681: Clip-On Test Lead Set
Model 1682A: RF Probe
Model 1685: Clamp-On Current Probe
Model 1751: General Purpose Test Leads
Model 1754: Universal Test Lead Kit
Model 1930: True RMS ACV Option
Model 1931: Current Option
Model 1938: Fixed Rack Mounting Kit
Model 1939: Slide Rack Mounting Kit
Model 7007-1: Shielded IEEE-488 Cable, 1m
Model 7007-2: Shielded IEEE-488 Cable, 2m
Model 7008-3: IEEE-488 Cable, 3 ft. (0.9m)
Model 7008-6: IEEE-488 Cable, 6 ft. (1.8m)

Specifications subject to change without notice.

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Keithley Model 193 System DMM, with the TRMS AC Volt and Current options installed, is a six function autoranging digital multimeter. At 6½ digit resolution, the LED display can display ±2,200,000 counts. The range of this analog-to-digital (A/D) converter is greater than the normal ±1,999,999 count A/D converter used in many 6½ digit DMMs. The built-in IEEE-488 interface makes the instrument fully programmable over the IEEE-488 bus. With the TRMS ACV option and the Current option installed, the Model 193 can make the following basic measurements:

1. DC voltage measurements from 100nV to 1000V.
2. Resistance measurements from 100μΩ to 200MΩ.
3. RTD temperature measurements from -100°C to 630°C.
4. TRMS AC voltage measurements from 1μV to 700V.
5. DC current measurements from 1nA to 2A.
6. TRMS AC current measurements from 1nA to 2A.

In addition to the above mentioned measurement capabilities, the Model 193 can make dB and TRMS AC + DC measurements.

1.2 FEATURES

Some important Model 193 features include:

- 14 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 for 1 to 99 readings from the front panel or over the bus.
- Data Store—An internal buffer that can store up to 500 readings is accessible from either the front panel or 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 can be used to replace standard command strings over the IEEE-488 bus.
- Thermocouple (TC) temperature measurements can be made over the IEEE-488 bus.

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 this 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 193.

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 1000V 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 193 specifications may be found preceding the Table of Contents of this manual.

1.7 INSPECTION

The Model 193 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 193 order:

Model 193 System DMM
Model 193 Instruction Manual
Safety Shrouded Test Leads
Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 193-901-00). The manual package includes an instruction manual and any applicable addenda.

1.8 USING THE MODEL 193 MANUAL

This manual contains information necessary for operating and servicing the Model 193 System DMM, TRMS ACV option and the Current option. The information is divided into the following sections:

- Section 1 contains general information about the Model 193 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 193 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 193 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 193 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 to the 1000VDC range.

Making Measurements

1. Connect the supplied safety shrouded test leads to the front panel VOLTS HI and LO input terminals. Make sure the INPUT switch is in the out (FRONT) position.
2. To make a voltage measurement, simply connect the input leads to a DC voltage surge (up to 1000V) 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 Data Store

Storing Data:
1. Press the DATA STORE button. The DATA STORE indicator will turn on and a storage rate (in seconds) will be displayed.
2. Select an interval, other than 000.000, using the ◄ and ►, and data buttons.
3. Press the ENTER button. The buffer size will be displayed. Size 000 indicates that data will overwrite after 500 readings have been stored.
4. If a different buffer size is desired, enter the value using the number buttons (0 through 9).
5. Press the ENTER button to start the storage process.

The data store mode can be exited at any time before the start of the storage process by pressing the RESET button. Once storage has commenced, the storage process can be stopped by pressing any function button. See paragraph 2.7.1 for complete information on storing data.

Recalling Data:

1. Press the RECALL button. The buffer location of last stored reading will be displayed.
2. To read the data at a different memory location, enter the value using the number buttons (0-9).
3. Press the ENTER button. The reading and the memory location will be displayed.
4. The ▲ and ▼ buttons can be used to read the data in all filled memory locations.
5. To read the highest, lowest and average reading stored in the buffer, press the number 1, 2 and 3 buttons respectively. Note that the memory location of the highest and lowest reading is also displayed. The average reading is displayed along with the number of readings averaged.

The recall mode can be exited by pressing the RESET button. See paragraph 2.7.2 for complete information on data recall.

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 91 (IEEE status), press the PRGM button and then 9 and 1 buttons. Table 2-2 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 ±) and the cursor control buttons (manual range buttons).
3. Programs that contain alternate conditions can be displayed by pressing one of the manual 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 mode.
5. A program can be exited at any time and thus not executed, by pressing the RESET button.

Paragraph 2.8 provides the detailed information for using the front panel programs.

1.10 ACCESSORIES

The following accessories are available to enhance the Model 193s, capabilities.

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

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

Model 1641 Kelvin Test Lead Set—The Model 1641 has special clip leads that allow 4-terminal measurements to be made while making only two connections.

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

Model 1681 Clip-On Test Lead Set—The Model 1681 contains two leads, 1.2m (48') long terminated with banana plugs and spring action clip probes.

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

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

Model 1751 Safety Test Leads—This test lead set is supplied with every Model 193. 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 1930 TRMS AC Volt Option—The Model 1930 is a True Root Mean Square (TRMS) AC plug-in option for the Model 193. This option allows the instrument to measure the TRMS value of an AC signal. When the Model 1930

is installed, AC + DC voltage measurements can be made. Field installation or removal/replacement of the Model 1930 will require recalibration of the Model 193 and the Model 1930.

Model 1931 Current Option—The Model 1931 is a plug-in current option for the Model 193. This option allows the instrument to measure DC current up to 2A. When both Models 1930 and 1931 are installed, the instrument can make TRMS AC current measurements and TRMS AC + DC current measurements. Field installation requires recalibration of the Model 193.

Model 1938 Fixed Rack Mount—The Model 1938 is a stationary mount kit that allows the Model 193 to be mounted in a standard 19 inch rack.

Model 1939 Slide Rack Mount—The Model 1939 is a sliding mount kit that allows the Model 193 to be rack mounted with the added feature of sliding the instrument forward for easy access to the rear panel and top cover.

Model 7007 IEEE-488 Shielded Cables—The Model 7007 connects the Model 193 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 193 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 8573 IEEE-488 Interface—The Model 8573 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 8573 join together to give the IBM advanced capabilities over IEEE-488 interfaceable instrumentation.

SECTION 2
BASIC DMM OPERATION

2.1 INTRODUCTION

Operation of the Model 193 may 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 193 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 near the AC power receptacle. 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 92 (see paragraph 2.8.11) 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 193 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 NVRAM). If RAM or ROM fails, the instrument will lock up. If E²PROM FAILS, the message "UNCALIBRATED" will be displayed. See paragraph 6.9.2 for a complete description of the power-up self test and recommendations to resolve failures.

2.2.3 Factory Default Conditions

At the factory, the Model 193 is set up so that the front panel controls and features are initially configured to certain conditions on power-up and when program RESET is run. These are known as the factory default conditions and are listed in Table 2-1.

Table 2-1. Factory Default Conditions

Control/Feature	Default Condition
Function	DCV
Range	1000V
Resolution	6½ Digits
Line Frequency	*
IEEE Address	*
RTD Alpha Value and scale	0.00392°C
Zero	Disabled
Zero Value	+0000000
dB	Disabled
dB Reference Value	1V, 1mA
AC + DC	Disabled
Data Store	Disabled
Recall	Disabled
Filter	Disabled
Filter Value	10

*Program 90 (save) can be used to establish the factory default condition. However, an "UNCALIBRATED" error will set factory default to an IEEE address of 10 and a frequency setting of 60Hz.

2.2.4 User Programmed Conditions

A unique feature of the Model 193 is that each function "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.

Certain configurations can be saved by utilizing front panel Program 90. On power-up, these user saved default conditions will prevail over the factory default conditions. Also, a DCL or SDC asserted over the IEEE-488 bus will set the instrument to the user saved default conditions. For more information, see paragraph 2.8.9 (Program 90).

NOTE
Keep in mind that power-up default conditions can be either factory default conditions or user saved default conditions.

2.3 FRONT PANEL FAMILIARIZATION

The front panel layout of the Model 193 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 14 character, alphanumeric, LED display is used to display numeric conversion data, range and function mnemonics (i.e. mV) and messages.

Status Indicators—These three indicators apply to instrument operation over the IEEE-488 bus. The REMOTE indicator shows when the instrument is in the IEEE-488 remote state. The TALK and LISTEN 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 INPUT switches, are momentary contact switches. Indicators are located above certain feature buttons to show that they are enabled. Included are AUTO (autorange), ZERO, FILTER, RECALL and DATA STORE. Some buttons have secondary functions that are associated with front panel program operation. See paragraph 2-8 for detailed information on front panel programs.

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.

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 "out" position and the rear panel input terminals are selected when the switch is in the "in" position.

FUNCTION GROUP—The FUNCTION buttons are used to select the primary measurement functions of the instrument. These buttons also have secondary functions.

DCV—The DCV button places the instrument in the DC volts measurement mode. The secondary function of this button is to enter the number 0. See paragraph 2.6.4 for DCV measurements.

ACV—With the ACV option installed, the ACV button places the instrument in the AC volts measurement mode. The secondary function of this button is to enter the number 1. See paragraph 2.6.6 for ACV measurements.

OHMS—The OHMS button places the instrument in the ohms measurement mode. The secondary function of this button is to enter the number 2. See paragraph 2.6.7 for resistance measurements.

ACA—With the ACV option and current option installed, 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.

DCA—With the current option installed, the DCA button places the instrument in the DC amps measurement mode. The secondary function of this button is to enter the number 4. See paragraph 2.6.8 for DCA measurements.

TEMP—The TEMP button places the instrument in the RTD temperature measurement mode. The secondary functions of this button are to select the TEMP program (select alternate alpha value and thermometric scale) and to enter the number 5. See paragraph 2.6.9 for RTD temperature measurements.

RANGE GROUP—The ▲ and ▼ buttons are used for manual ranging and the AUTO button is used for autoranging. These buttons also have secondary functions.

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 previous selected. The secondary functions of these buttons are associated with front panel program operation.

AUTO—The AUTO button places the instrument in the autorange mode and turns on the AUTO indicator. 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 ± sign.

MODIFIER GROUP—The MODIFIER buttons activate features that are used to enhance the measurement capabilities of the Model 193. These features in effect modify the selected function. In addition to their primary tasks, these buttons have secondary functions.

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. Refer to paragraph 2.6.2 for detailed information on the zero feature.

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. See paragraph 2.6.10 for dB measurements.

FILTER—The FILTER button turns on the FILTER indicator and causes the instrument to start weighted averaging a number (1-99) of readings. The factory default value is 10, but may be changed using the FILTER program (see paragraph 2.8.6). 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 6.

AC + DC—With the appropriate options installed, the AC + DC button (with ACV selected) places the instrument in the AC + DC measurement mode. With the ACV option installed, VAC + DC measurements can be made. With both the ACV and current option installed, AAC + DC measurements can be made. See paragraph 2.6.12 for AC + DC measurements. The secondary functions of this button are to select the AC + DC program (low frequency TRMS measurements) and to enter the number 7.

CONTROL GROUP—The CONTROL buttons are features that allow for the control and manipulation of various aspects of instrument operation. All of these buttons, except PRGM, have a secondary function.

RESOLN—The RESOLN button allows for the selection of the number of digits of display resolution. Each press of the RESOLN button increases resolution by one digit. Pressing the RESOLN button after the maximum resolution is reached will revert the display back to the lowest resolution. Display resolution of 3½, 4½, 5½ or 6½ digits can be selected for DCV and ACV. Display resolution of 4½ or 5½ digits can be selected for DCA and ACA. On OHMS, 3½, 4½ 5½ and 6½ digit resolution is available on the 200Ω through 200kΩ ranges. On the 2MΩ and 20MΩ ranges, 5½ and 6½ digits can be selected. On the 200MΩ range, only 5½d resolution is available. The RESOLN button has no effect on low frequency AC + DC (Program AC + DC), TEMP or dB measurements. The secondary function of this button is to enter the decimal point (.).

TRIGGER/ENTER—The TRIGGER/ENTER button is used as a terminator for data entry when the instrument is in the front panel program mode and as a front panel trigger when the data store is active.

STATUS/RESET
STATUS—Instrument status can be displayed when the instrument is in the normal measurement mode or logging readings. When the STATUS button is first pressed, the following current instrument conditions can be displayed with the use of the ▲ and ▼ buttons:

Software revision level
IEEE address
Line frequency setting
Multiplexer status (on/off)
MX+B status (on/off)
MX+B values
dB reference value
Filter value (00=filter disabled)
Zero status (on/off)
Zero value

Pressing the STATUS button a second time takes the instrument out of the status mode.

RESET—The RESET button is used to reset the instrument back to the previously entered parameter. Keyed in parameters are only entered after the ENTER button is pressed. If RESET is pressed with the last parameter of a program displayed, the program will be exited and the instrument will return to the previous operating state. This button aborts back to normal operation when it is in one of the following modes:

1. The data store is prompting for parameters (interval or size).
2. The instrument is in the RECALL mode.
3. A front panel program has been selected (except Program AC+DC which is treated as a normal measurement function (see STATUS).

Program RESET—Program RESET returns the instrument to the factory default conditions. See paragraph 2.8.7 for information on using this program.

DATA STORE—The DATA STORE button selects the 500 point data store mode of operation. Paragraph 2.7 contains a complete description of data store operation. The secondary function of this button is to enter the number 9.

RECALL—The RECALL button recalls and displays readings stored in the data store. Paragraph 2.7.2 provides a detailed procedure for recalling data. The secondary function of this button is to enter the number 8.

PRGM—The PRGM button places the instrument in the front panel program mode. Table 2-2 lists the available programs. Paragraph 2.8 contains descriptions and detailed operating procedures for each front panel program.

LOCAL—When the instrument is in the IEEE-488 remote state (REMOTE 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.

Table 2-2. Front Panel Programs

Program	Description
TEMP	Set RTD value and scale.
AC+DC	Low Frequency TRMS AC + DC.
dB	Recall/modify dB reference value.
ZERO	Recall/modify zero value.
FILTER	Recall/modify number of readings averaged (filter value).
RESET	Reset internal conditions to factory default.
4	MX + B select.
90	Save current front panel setup.
91	Recall/modify IEEE address.
92	Recall/modify line frequency setting (50/60Hz).
93	Self-test
94	Set values for MX + B program.
95	Multiplexer on/off.
96	Digital calibration.

2.3.3 Input Terminals

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 on the rear panel and that the INPUT switch 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 and four-wire RTD temperature measurements.

2.3.4 Current Fuse

The current fuse protects the Model 1931 from input current overloads. The instrument can handle up to 2A continuously or 2.2A for less than one minute. Refer to paragraph 6.3.2 for the current fuse replacement procedures.

2.4 REAR PANEL FAMILIARIZATION

The rear panel of the Model 193 is shown in Figure 2-2.

2.4.1 Connectors and Terminals

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 connector.

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.

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

External Trigger Input—This BNC connector is used to apply pulses to trigger the Model 193 to take one or more readings, depending on the selected trigger mode.

Voltmeter Complete Output—This BNC output connector provides a pulse when the Model 193 has completed a reading. It is useful for triggering other instrumentation.

2.4.2 Calibration Switch

Calibration of the Model 193 can only be done if the calibration switch is in the unlock position.

2.4.3. 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.

2.5 ERROR AND WARNING DISPLAY MESSAGES

Table 2-3 lists and explains the various display messages associated with incorrect front panel operation of the Model 193. Also included is a warning message that indicates to the user that hazardous voltages (40V or more) are present on the input terminals.
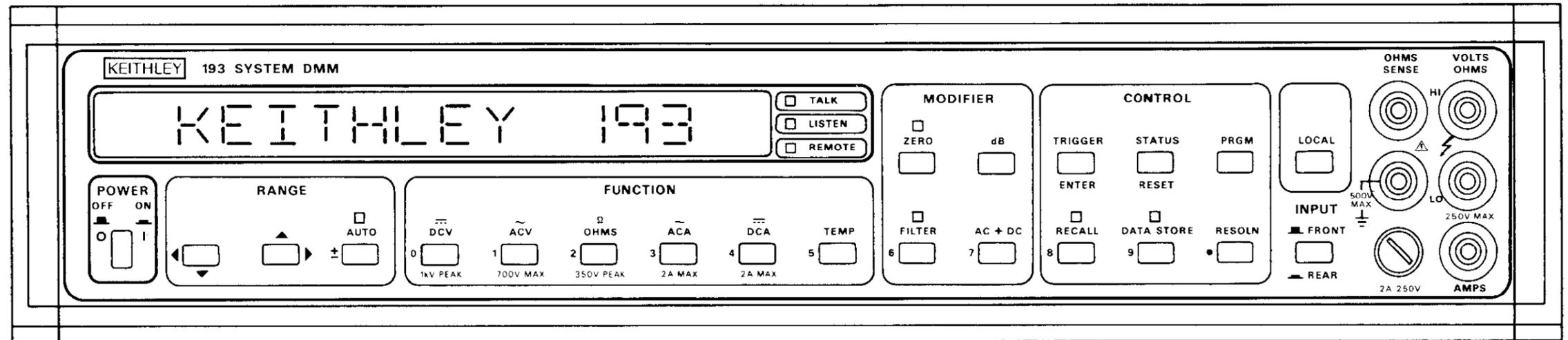
Figure 2-1. Model 193 Front Panel
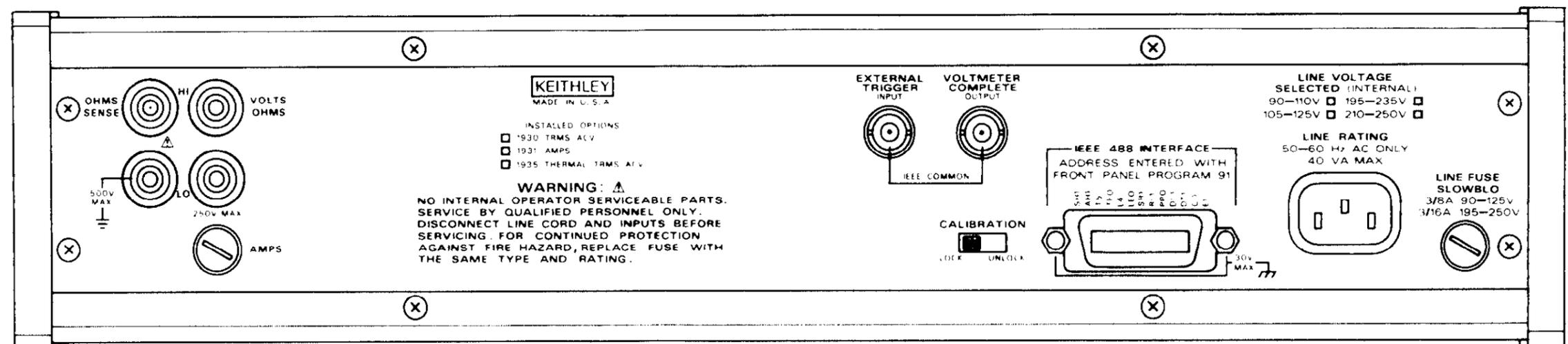
Figure 2-2. Model 193 Rear Panel

Table 2-3. Error and Warning Messages

Message	Explanation
NEED 1930 NEED 1931 NEED 1930-1931	Selected option not installed.
"H"	High Voltage: 40V or more on input.
NO PROGRAM	Invalid entry while trying to select program.
O.VERFLO KOHM	Overrange-Decimal point position and mnemonics define function and range (2kΩ range shown). The number of characters in the "OVERFLO" message defines the display resolution (6½d resolution shown).
TRIG-OVERRUN	Trigger received while still processing reading from last trigger.
CONFLICT	Trying to calibrate with instrument in an improper state.
NOT ACV or ACA	Selecting AC+DC or dB with instrument not presently in ACV or ACA.

2.6 BASIC MEASUREMENTS

The following paragraphs describe the basic procedures for making voltage, resistance, current, temperature, dB, and AC + DC measurements. An ACV option must be installed for ACV measurements, the current option must be installed for DCA measurements and both options must be installed for ACA and AAC + DC 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 result even when the meter is set to 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 193 is usable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least one hour 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 differences 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 10kΩ 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 193 is on. For example, if 1V is established as the baseline on the 2V range, then the baseline will also be 1V on the 20V through 1000V 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 5½ digit 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 193, at 6½ digit resolution, is 4400000 counts (excluding the 1000VDC and 700VAC ranges). With zero disabled, the displayed reading range of the instrument is ±2200000 counts. With zero enabled, the Model 193 has the capability to display ±4400000 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 (+2200000 counts and -2200000 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 2V range, the Model 193 will always overrange when more than ±2.2V is connected to the input.

Example 1—The instrument is set to the 2VDC range and a maximum -2.200000V is established as the zero value. When -2.200000V is connected to the input of the Model 193, the display will read 0.000000V. When +2.200000V is connected to the input, the display will read +4.400000V. Thus, the dynamic measurement range of the Model 193 is 0V to 4.4V, which is 4400000 counts.

Example 2—The instrument is still set to the 2VDC range, but a maximum +2.200000V is the zero level. When +2.200000V is connected to the input of the Model 193, the display will read 0.000000V. When -2.200000V is connected to the input, the display will read -4.400000V. Thus the dynamic measurement range of the instrument is -4.4V to 0V, which is still 4400000 counts.

Zero Correction—The Model 193 must be properly zeroed when using the 200mV DC or the 200Ω 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 200mV DC or the 200Ω range.
3. Connect the test leads to the input of the Model 193 and short them together. If four-wire resistance measurements are to be made, connect and short all four leads together.
   Note: At 5½ and 6½ digit resolution, low 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 200Ω 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 2.8.5 contains the complete procedure for using the ZERO program. To establish a baseline level by applying a level to the Model 193, 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 193 and note that level on the display.
4. 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
If ±40V or more is present on the input terminals, the Model 193 will display the mnemonic "H" to indicate the presence of hazardous voltage. For example, the display "00.0000HVDC" indicates than ±40V or more is present on the input.

5. 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:

1. 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 2.8.5 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.
2. 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.
3. Setting the range lower than the suppressed value will overrange the display; the instrument will display the overrange message under these conditions.
4. 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

When the filter is enabled, a number of measurements are averaged before being displayed. The factory default number is 10 , but it can be changed to a value from 1 to 99 with the use of 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 number of readings averaged, the longer the response time of the display. Perform the following procedure to use the filter:

1. If it is desired to check and/or change the filter value, utilize Program FILTER as explained in paragraph 2.8.6.
2. Press the FILTER button. The FILTER indicator will turn on.

Notes:

1. Pressing the FILTER button a second time will disable the filter.
2. 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 if 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.
3. 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—The Model 193 utilizes a digital filter to attenuate excess noise present on input signals. The filter is a weighted average type. The mathematical representation is:

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

Where,

$AVG(t)$ = displayed average
$AVG(t-1)$ = old displayed average
F = weighting factor (filter value)

As with any filter, the Model 193 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:
$F = 10$
$n = 5$

$$1 - \left(1 - \frac{1}{10}\right)^{6} = .468$$

Five readings after the step occurs, the display will be at ≈47% of the step change. After 10 readings (n = 10), the display will be at ≈68% and after 20 readings, the display will be at ≈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 193 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 193 filter is 10,000 counts for 6½d resolution, 1000 counts for 5½, 100 counts for 4½ and 10 counts for 3½.

2.6.4 DC Voltage Measurements

The Model 193 can be used to make DC voltage measurements in the range of ±100nV to ±1000V. 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 200mV 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.

2.6.5 Low-Level Measurement Considerations

Accuracy Considerations—For sensitive measurements, other external considerations besides the Model 193 will affect the accuracy. Effects not noticeable when working with higher voltages are significant in nanovolt and microvolt signals. The Model 193 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 193 is determined by the noise present. The displayed noise is inherent in the instrument and is present in all measurements. The noise voltage at the Model 193 input increases with source resistance..

For high impedance sources, the generated noise can become significant when using the most sensitive range (200mV, 6½d) of the Model 193. As an example of determining e_r (noise voltage generation due to Johnson noise of the source resistance), assume that the Model 193 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:

$$e_r = 6.35 \times 10^{-10}\sqrt{R \times f}$$
$$e_r = 6.35 \times 10^{-10}\sqrt{(1 \times 10^6)} \ (1)$$
$$e_r = 0.635\mu V$$

MODEL 193

CAUTION: MAXIMUM INPUT – 1000V PEAK
INPUT RESISTANCE = 200mV, 2V; >1GΩ
20V-1000V; 10MΩ

DC VOLTAGE SOURCE
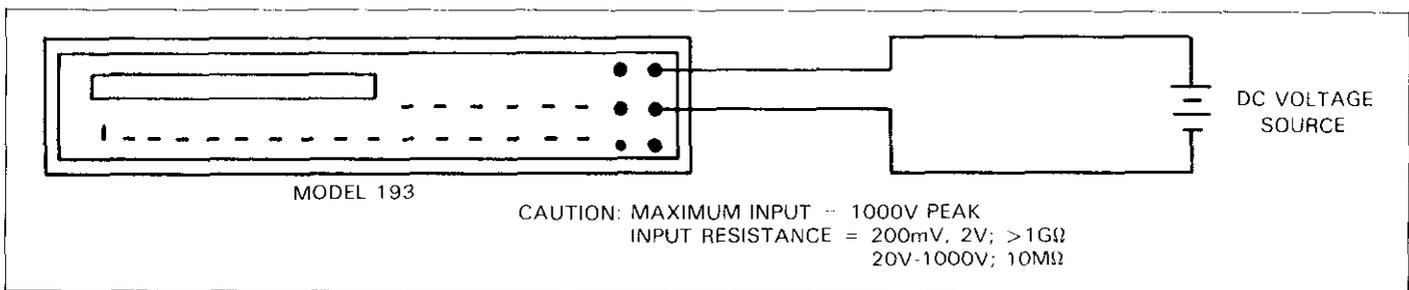
Figure 2-3. DC Voltage Measurements

Thus, an e_r of $0.635\mu V$ would be displayed at 6½d resolution as an additional 6 digits of noise on the Model 193. 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 193 input LO (particularly for low-level sources). Improper shielding can cause the Model 193 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 193 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 193 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 193. 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 TRMS AC Voltage Measurements

With the ACV option installed, the instrument can make TRMS AC voltage measurements from $1\mu V$ to 700V. 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 5½d) present when using the ACV function. Do not zero this level out. Paragraph 2.6.13 provides an explanation of AC voltage offset.

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

Clarifications of Model 1930 TRMS ACV Specifications:

Settling Time—0.5sec 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.

Crest Factor—Rated accuracy to 3 at full scale for pulse widths $>10\mu sec$ and peak voltage $<1.5 \times$ full scale. For crest factors >3 but <10, typical accuracy is degraded according to the following calculation:

$$AD = (CF-3) \times 0.36\%$$

Where: AD is accuracy degradation
    CF is the crest factor

Also, the peak signal must be less than $5 \times$ full scale, but not more than the maximum input specification.

Notes:
1. See paragraph 2.6.13 for TRMS measurement considerations.
2. For TRMS AC+DC measurements, see paragraph 2.6.12.
3. To make low frequency AC measurements in the range of 10Hz to 20Hz:
   A. The ACV option must be installed.
   B. The ACV function must be selected.

C. Digital filtering must be used to obtain a stable reading.

D. Allow enough settling time before taking the reading.

4. To make low frequency voltage measurements in the range of 0.1Hz to 10Hz, use Program AC+DC (see paragraph 2.8.3). The ACV option does not have to be installed for these measurements.

2.6.7 Resistance Measurements

The Model 193 can make resistance measurements from $100\mu\Omega$ to $200M\Omega$. The Model 193 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 2-4. For best results on the 200Ω, $2k\Omega$ and $20k\Omega$ 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 1641 Kelvin Test Lead Set is ideal for low resistance 4-terminal measurements. To make resistance measurements, proceed as follows:

1. Select the ohms function by pressing the OHMS 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.

NOTE
The 200Ω 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. For 2-terminal measurements connect the resistance to the instrument as shown in Figure 2-5. For 4-terminal measurements connect the resistance to the instrument as shown in Figure 2-6.

CAUTION
The maximum input voltage between the HI and LO input terminals is 350V peak or 250V RMS. Do not exceed these values or instrument damage may occur.

5. Take the reading from the display.

CAUTION: MAXIMUM INPUT = 1000V PEAK AC + DC, 2 × 10⁷V•Hz
INPUT IMPEDANCE = 1MΩ SHUNTED BY <120pF
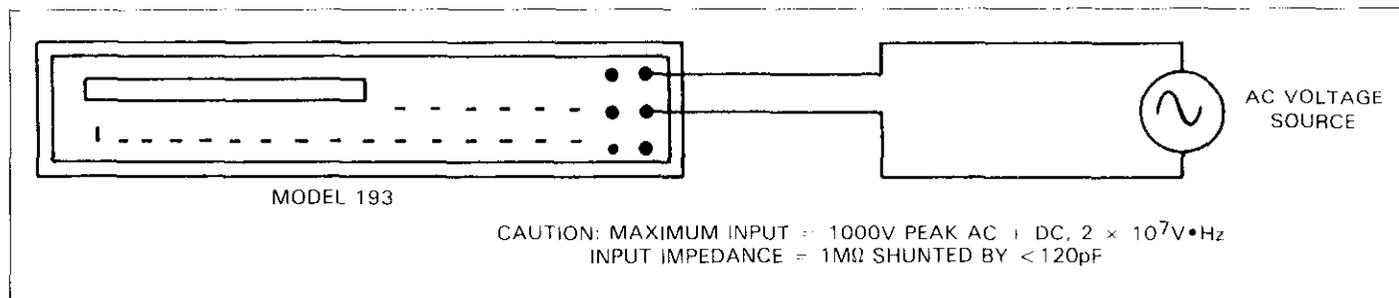
Figure 2-4. TRMS AC Voltage Measurements

Table 2-4. Resistance Ranges

Range	6½d Resolution	Current Through Unknown	Maximum Test Lead Resistance (Ω) for <1 Count Error (6½d)
200 Ω	0.1mΩ	1mA	1
2 kΩ	1mΩ	1mA	3.2
20 kΩ	10mΩ	100 μA	10
200 kΩ	100mΩ	10 μA	32
2MΩ	1 Ω	1 μA	100
20MΩ	10 Ω	100 nA	320
200MΩ	100 Ω	100 nA*	1k

*Short circuit current only.

Notes:
1. Incorrect readings will result if the resistance being measured is part of a live circuit.
2. Table 2-4 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 2kΩ range can be used to test diodes as follows:
   A. Select the 2kΩ range.
   B. Forward bias the diode by connecting the red terminal of the Model 193 to negative side of the diode. A good diode will typically measure between 500Ω to 1kΩ.
   C. Reverse bias the diode by reversing the connections on the diode. A good diode will overrange the display.

2.6.8 Current Measurements (DC or TRMS AC)

With the Model 1931 Current option installed, the Model 193 can make DC current measurements from 1nA (at 5½d resolution) to 2A. The same range of TRMS AC current measurements can be made if both the current and ACV options are installed in the instrument. Use the following procedure to make current measurements.

1. Select the DC current or AC current function by pressing the DCA or ACA button respectively.
2. Select a range consistent with the expected current or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-7.
5. Take the reading from the display.
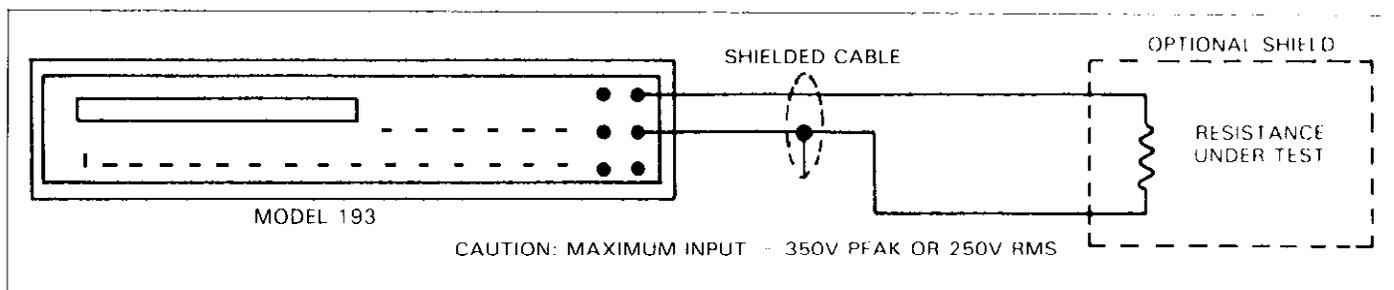
Figure 2-5. Two-Terminal Resistance Measurements
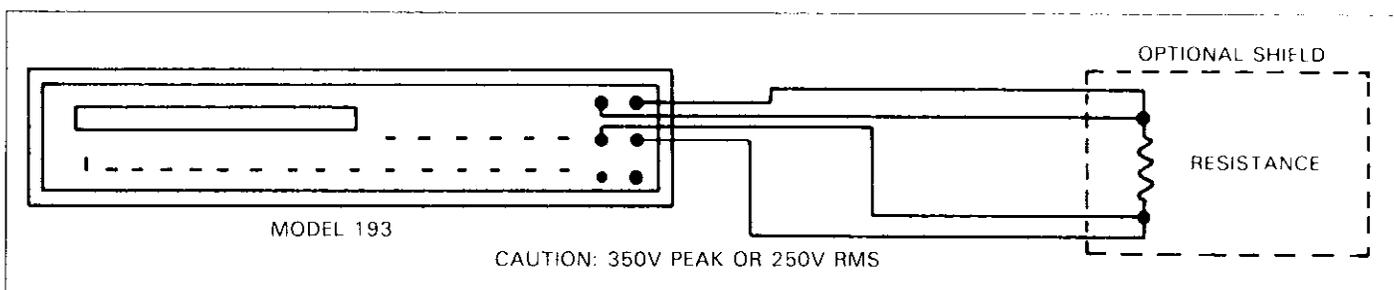
Figure 2-6. Four-Terminal Resistance Measurements
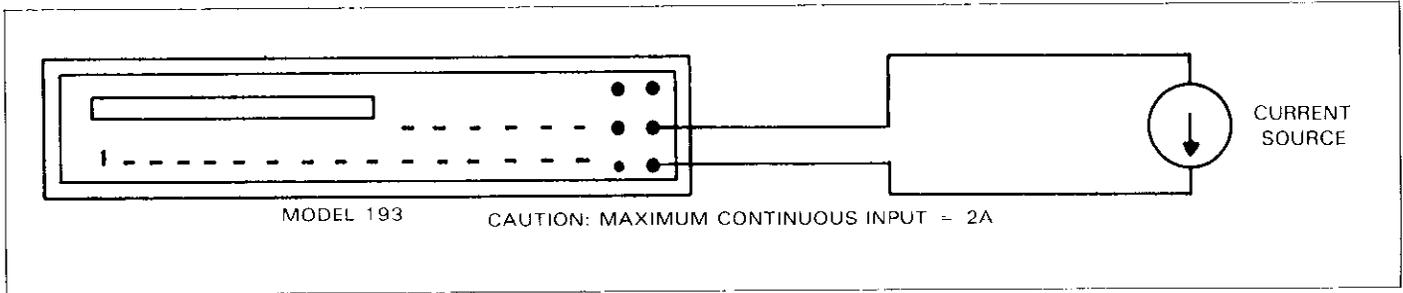
Figure 2-7. Current Measurements

2.6.9 RTD Temperature Measurements

The Model 193 can make temperature measurements from -100° to +630°C (-148° to +1100°F) using platinum RTD sensors. Resolution is 0.01 °C or °F. The front panel TEMP program allows the user to select the alternate alpha value (0.00385 or 0.00392) and the alternate thermometric scale (°C or °F). See paragraph 2.8.2 for detailed information for using the TEMP program. Use the following procedure to make RTD temperature measurements.

1. Select the RTD temperature function by pressing the TEMP button.
2. The instrument will now display one of the following readings:

    OVERFL °C PRTD or OVERFL °F PRTD

    The display is overranged at this time because an RTD sensor is not yet connected to the input. The °F or °C indicates the current thermometric scale and PRTD indicates the measurement mode (platinum resistance temperature device).
3. To check and/or change the alpha value or thermometric scale, utilize the TEMP program (see paragraph 2.8.2).
4. Select the front or rear panel input terminals with the INPUT switch and connect the platinum RTD sensor to the instrument as shown in Figure 2-8.
5. Take the reading from the display.

NOTE
With additional instrumentation, the Model 193 has the capability of making temperature measurements using thermocouple (TC) sensors. Selection of the various TC modes can only be accomplished over the IEEE-488 bus. See paragraph 3.10.22 for more information.
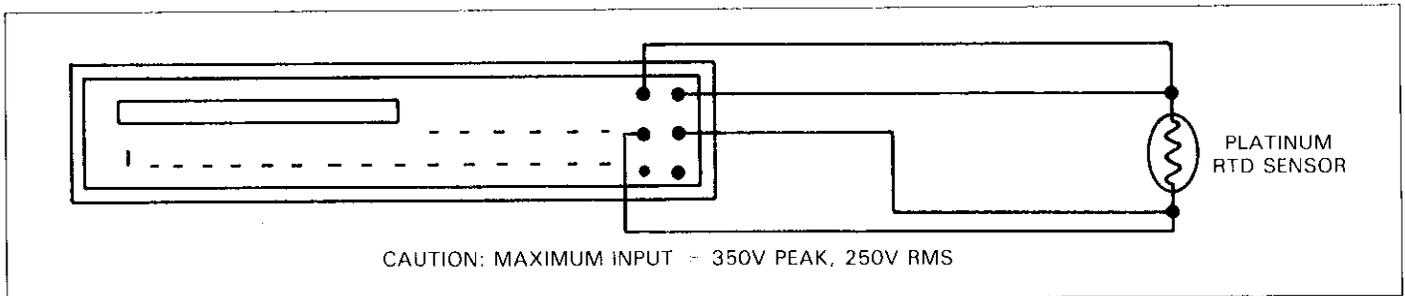
Figure 2-8. RTD Temperature Measurements

2.6.10 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:

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

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

At the factory the instrument is set up to be a dBV meter when ACV dB is selected. dBV is defined as decibels above or below a 1V reference. The instrument will read 0dB when 1V is applied to the input. The 1V reference is the factory default reference and is indicated on the display by the "V" mnemonic. Thus, whenever "dBV" is displayed, the operator will know that the reference is 1V. With ACA dB selected, the factory default reference is 1mA. The instrument will read 0dB when 1mA is applied to the input.

Reference levels other than 1V and 1mA can be established. There are two methods that can be used to establish a dB reference. One method is to use the zero feature. This simply consists of applying a signal to the instrument and pressing the ZERO button. That suppressed level is the dB reference (0dB point). The alternate method is to utilize the front panel dB program and enter the desired reference value. An advantage of using the dB program is that a source is not needed to establish a reference.

The following procedure explains how to use the zero feature to establish a reference:

1. Apply a voltage or current signal, that is to be used as the dB reference, to the input of the Model 193.
2. Press the ZERO button. The ZERO indicator will turn on and the display will zero. The reference is now whatever the applied signal is.
3. Disconnect the signal from the instrument.

Program dB allows the the user to check or change the dB reference of the instrument. The recommended programmable voltage reference range is from 10μV to 9.99999V. The recommended programmable current reference range is from 10nA to 9.99999mA. Paragraph 2.8.4 contains the information needed for using the dB program.

AC dB Measurements—Perform the following steps to make dB measurements:

1. Select the ACV or ACA function.
2. Select the front or rear panel input terminals with the INPUT switch.
3. Check and/or change the dB reference as previously explained.
4. Connect the signal to be measured to the input of the Model 193.
5. If AC + DC dB measurements are to be made, press the AC + DC button.

   Note: DC dB measurements can be made by selecting the AC + DC modifier as long as there is no AC component present on the input signal.
6. Enable the dB measurement mode by pressing the dB button.
7. Take the dB reading from the display.

WARNING
If 40V or more is present on the input terminals, the Model 193 will display the the mnemonic "H" to indicate the presence of hazardous voltage. For example, the display "60.00 dBV H" indicates that 40V or more is present on the input.

The following information explains the displayed mnemonics that are associated with dB measurements:

dBV = dB voltage measurement mode with the dB reference at 1V.

dB = dB voltage measurement mode.

dBA = dB current measurement mode. Unlike dBV, this message does not define the dB reference.

dBV A+D = AC+DC dB voltage measurement mode with 1V reference.

dB A+D = AC+DC dB voltage measurements.

dBA A+D = AC+DC dB current measurement mode.

H = High Voltage: 40V or more on input. This mnemonic could be displayed with any of the above messages.

dBm Measurements—dBm is defined as decibels above or below a 1mW reference. dB measurements can be made in terms of impedance rather than voltage or current. Because the instrument cannot directly establish impedance references, a voltage reference must be calculated and established for a particular impedance reference. Use the following equation to calculate the voltage reference needed for a particular impedance reference:

For 0dBm, $V_{ref} = \sqrt{1mW \cdot Z_{ref}}$

Example: Calculate the voltage reference needed to make dBm measurements referenced to 600Ω.

$$\text{For 0dBm, } V_{ref} = \sqrt{0.001W \cdot 600\Omega}$$
$$= \sqrt{.6}$$
$$= .77456V$$

Once the necessary voltage reference is known, it can be established in the Model 193 with the dB program. Subsequent dBm readings will be referenced to the corresponding impedance reference. Table 2-5 lists the voltage references needed for some commonly used impedance references.

dBW Measurements—dBW is defined as decibels above or below a 1W reference. dBW measurements are made in the same manner as dBm measurements; that is, calculate the voltage reference for a particular impedance and set the instrument to it with the dB program. The only difference between dBm and dBW is the reference point; 1mW vs 1W. The following equation can be used to calculate the voltage reference:

$$\text{For 0dBW, } V_{ref} = \sqrt{1W \cdot Z_{ref}}$$

Table 2-5. Corresponding Voltage Reference Levels for Impedance References

Reference Impedance (Ω)	Reference Voltage Level for:	
	0dBm	0dBW
8	0.0894	2.828
50	0.2236	
75	0.2739	
150	0.3873	
300	0.5477	
600	0.7746	
1000	1.0000	
$V_{ref.}$ for 0dBm $= \sqrt{10^{-3}W \cdot Z_{REF}}$		
$V_{ref.}$ for 0dBW $= \sqrt{Z_{REF}}$		

2.6.11 dB Measurement Considerations and Applications

Typically, the Model 193 will perform better than its published dB specification. The following example will illustrate this point:

1. Using the Model 193 in the dB mode (0.7746V reference), measure a 100mV RMS, 1kHz source. Typically, the Model 193 will read −17.79dBm.
2. The calculated dBm level for that source is -17.18dBm.
3. The 0.61dB error is considerably better than the 1.5dB specification. The specifications are intended to cover worst case measurement conditions.

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 193 in ACV, autorange and dB.
2. Connect the Model 193 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 193 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 193 to ACV and autorange.
3. Connect the Model 193 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 193. 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 193 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 193 is typically 500kHz. Do not use this application to check amplifiers that exceed the bandwidth of the Model 193.

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 = Center Frequency/Bandwidth

2.6.12 TRMS AC + DC Measurements

With an ACV option installed, the instrument can make voltage AC + DC (VAC + DC) measurements. With both the ACV option and current option installed, the instrument can make current AC + DC (AAC + DC) measurements. Also, the dB mode can be used when making AC + DC measurements. Perform the following procedure to make AC + DC measurements:

1. Select one of the following functions:
   A. ACV for VAC + DC measurements.
   B. ACA for AAC + DC measurements.
2. Select an appropriate range or autorange.
3. Press the AC + DC button.
4. Select the front or rear panel input terminals with the INPUT switch.
5. Connect the signal to be measured to the appropriate terminals.
   A. VOLTS HI and LO terminals for VAC + DC measurements.
   B. AMPS and LO terminals for AAC + DC measurements.
6. Take the AC + DC reading from the display.

Perform the following procedure to make dB AC + DC measurements.

1. Select one of the following functions:
   A. ACV for VAC + DC measurements.
   B. ACA for AAC + DC measurements.
2. Select autoranging for optimum resolution.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Press the AC + DC button.
5. Check and/or change the dB reference of the instrument as explained in paragraph 2.6.10.
6. Connect the signal to be measured to the instrument.
7. Press the dB button and take the reading from the display.

The following information explains the displayed mnemonics that are associated with measurements:
VA+D = AC+DC voltage measurement mode.
AA+D = AC+DC current measurement mode.
dBV A+D = AC+DC dB voltage measurement mode with 1V reference.
dB A+D – AC+DC dB voltage measurement mode.
dBA A+D = AC+DC dB current measurement mode.
LO VA+D = Low frequency AC+DC voltage measurement mode (Program AC+DC).

H = High Voltage: 40V or more on input. This mnemonic could be displayed with any of the dB measurements.

Notes:
1. To make low frequency AC + DC measurements in the range of 10Hz to 20Hz:
   A. An ACV option must be installed.
   B. The ACV function must be installed.
   C. Digital Filtering must be applied.
   D. Allow enough settling time before taking the reading.
2. To make low frequency AC + DC voltage measurements in the range of 0.1Hz to 10Hz, use Program AC + DC (see paragraph 2.8.3). An ACV option does not have to be installed for these measurements.

2.6.13 TRMS Considerations

Most DMMs actually measure the average value of an input waveform but are calibrated to read its RMS equivalent. This poses no problems as long as the waveform being measured is a pure, low-distortion sine wave. For complex, nonsinusodial waveforms, however, measurements made with an averaging type meter can be grossly inaccurate. Because of its TRMS measuring capabilities, the Model 193 (with an ACV option installed) provides accurate AC measurements for a wide variety of AC input waveforms.

TRMS Measurement Comparison—The RMS value of a pure sine wave is equal to 0.707 times its peak value. The average value of such a waveform is 0.637 times the peak value. Thus, for an average-responding meter, a correction factor must be designed in. This correction factor, K can be found by dividing the RMS value by the average value as follows:

$$K = 0.707/0.637$$
$$= 1.11$$

By applying this correction factor to an averaged reading, a typical meter can be designed to give the RMS equivalent. This works fine as long as the waveform is a pure sine wave, but the ratios between the RMS and average values of different waveforms is far from constant, and can vary considerably.

Table 2-6 shows a comparison of common types of waveforms. For reference, the first waveform is an ordinary sine wave with a peak amplitude of 10V. The average value of the voltage is 6.37V, while its RMS value is 7.07V. If we apply the 1.11 correction factor to the average reading, it can be seen that both meters will give the same reading, resulting in no error in the average-type meter reading.

Table 2-6. 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 Sine	10V	3.86V	3.90V	3.86V	1%
Full-Wave Sine	10V	3.08V	2.98V	3.08V	3.2%
Square	10V	10.00V	11.10V	10.00V	11%
Rectified Square Wave	10V	5.00V	5.55V	5.00V	11%
Rectangular Pulse	10V	$10 \bullet \sqrt{K}$	22.2K	$10 \bullet \sqrt{K}$	$\left[\dfrac{2.22K^{3/2} - K}{K} \right] \times 100$
Triangular Sawtooth	10V	5.77V	5.55V	5.77V	4%
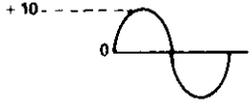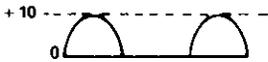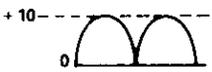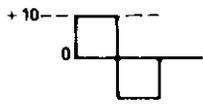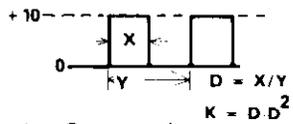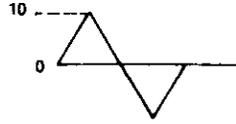
The situation changes with the half-wave rectified sine wave. As before, the peak value of the waveform is 10V, but the average value drops to 3.18V. The RMS value of this waveform is 3.86V, but the average responding meter will give a reading of 3.53V (3.18 x 1.11), creating an error of 11%.

A similar situation exists for the rectified square wave, which has an average value of 5V and an RMS value of 5.0V. The average responding meter gives a TRMS reading of 5.55V (5 × 1.11), while the Model 193 gives a TRMS reading of 5V. Other waveform comparisons can be found in Table 2-6.

AC Voltage Offset—The Model 193, at 5½d resolution, will typically display 150 counts of offset on AC volts with the input shorted. This offset is caused by amplifier noise and offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the zero feature. The following equation expresses how this offset (V_{offset}) is added to the signal input (V_{in}):

Displayed reading $= \sqrt{(V_{in})^2 + (V_{offset})^2}$

Example: Range $= 2VAC$
Offset $= 150$ counts (1.5mV)
Input $= 200mV$ RMS

Display reading $= \sqrt{(200mV)^2 + (1.5mV)^2}$

$= \sqrt{0.04V + (2.25 \times 10^{-6}V)}$

$= .200005V$

The offset is seen as the last digit which is not displayed at 5½ digit resolution. Therefore, the offset is negligible. If the zero feature was used to zero the display, the 150 counts of offset would be subtracted from V_{in} resulting in an error of 150 counts in the displayed reading.

Crest Factor—The crest factor of a waveform is the ratio of its peak value to its RMS value. Thus, the crest factor specifies the dynamic range of a TRMS instrument. For sinusoidal waveforms, the crest is 1.414. For a symmetrical square wave, the crest factor is unity.

The crest factor of other waveforms will, of course, depend on the waveform in question because the ratio of peak to RMS value will vary. For example, the crest factor of a rectangular pulse is related to its duty cycle; as the duty cycle decreases, the crest factor increases. The Model 193 has a maximum crest factor of 3, which means the instrument will give accurate TRMS measurements of rectangular waveforms with duty cycles as low as 10%.

2.7 DATA STORE

Data Store can store up to 500 readings, plus the minimum, maximum and average reading. Data can be stored at a user selectable rate.The rates span from 1msec to 16.67 minutes (999.999sec). Manual triggering is available (one-shot mode). In this mode, one reading is stored every time the TRIGGER button is pressed. Also, while in the one shot-mode, an external trigger source can be used to control the fill rate of the data store.

High Speed Data Store—The data store must be utilized to take advantage of the high speed measurement capabilities of the Model 193. With the data store set at its fastest storage rate (1000 readings per second), up to a half second burst of data (500 readings) can be stored. The stored readings can be retrieved from the front panel or sent over the IEEE-488 bus.

The data store is considered to be in the high speed mode, whenever one of the four fastest intervals (1msec, 2msec, 3msec and 4msec) is selected. In the high speed mode, the data store will only operate if the instrument is in a valid state. Table 2-7 lists the operating states that the instrument must be in to achieve high speed data storage. If the conditions in the table are not met when attempting to start the storage process, the instrument will exit the data store mode and return to the previous operating state.

NOTE: At 5½d and 6½d resolution, the fastest valid storage interval is 40msec. An interval less than 40msec will result in a short period error when the storage process is started. Readings will be stored as fast as the instrument can run.

2.7.1 Storing Data

Perform the following procedure to store data:

1. Press the DATA STORE button. The current storage interval (in seconds) will be displayed. An interval of 000.000 indicates that the one-shot mode is selected.
2. If a storage interval other than the one displayed is desired, enter the desired interval as follows: Cursor location is indicated by the bright flashing digit. Number entry is accomplished by placing the cursor on the character to be modified and pressing the appropriate data button (buttons numbered 0 through 9). Cursor control is provided by the ◄ and ► buttons which move the cursor left and right respectively. If the cursor is moved past the least significant digit, it will move back to the most significant digit.
3. With the desired storage interval displayed, press the ENTER button. A message that defines the size of the data store (up to 500 memory locations) will then be displayed. The size number determines how many readings will be stored before the storage cycle stops. However, the size number 000 indicates that the storage cycle will continue even after 500 readings have been stored. After the 500th reading is stored, readings will be stored beginning at the first memory location overwriting the previously stored data. Example: The following message will be displayed if the current size of the data store is 100:

$$END = 100$$

Table 2-7. High Speed Data Store

Data Store Interval	Valid Data Store Size*	Valid Functions	Valid Ranges	Valid Reading Rates
000.001, 000.002	001-500	DCV, ACV, DCA, ACA, AC+DC (except low frequency AC+DC)	All, except Autorange	3½d
000.003, 000.004				3½d 4½d

*Data store size 000 (continuous) cannot be used in the high speed data store mode.

4. If it is desired to change the size of the data store, enter the size value. The procedure to enter data is explained in step 2. If an attempt is made to enter a data store size greater than 500, the size will default to 500.

NOTE: Up to this point, pressing the RESET button will disable the data store and return to the previous state of operation.

5. With a data store size displayed, start the storage process as follows:

A. If a storage interval other than 000.000 is selected, press the ENTER button. The following message will be displayed briefly:

ENTERED

Readings will then start storing at the selected interval. The storage process is indicated by the flashing DATA STORE indicator light. The light stops flashing (remains on) when the data store is full.

NOTE: If a high speed interval is selected (1ms, 2ms, 3ms or 4ms), the display will blank for a short period of time while the readings are being stored. If the instrument is in an invalid operating state for high speed data storage (see Table 2-7), the instrument will exit the data store mode.

B. If storage is to be done manually (one-shot mode 000.000 interval selected), press the ENTER button. The following message will be displayed briefly:

ENTERED

The prompt for a trigger will then be displayed. The following example display shows the instrument on the 2VDC range:

$$\overline{-}.\overline{-}\,\overline{-}\,\overline{-}\,\overline{-}\,\overline{-} \quad \text{VDC}$$

Each press of the TRIGGER button will display and store one reading in the data store. The DATA STORE indicator light will continue to flash until the defined buffer size is filled. After the buffer fills, the light will remain on.

C. If the storage rate is to be controlled by an external trigger source (one-shot mode 000.000 interval selected), connect the trigger source to the EXTERNAL TRIGGER INPUT connector on the rear panel of the instrument (see paragraph 2.10.1 for trigger pulse specifications), and press the ENTER button. The following message will be displayed briefly:

ENTERED

The prompt for a trigger will then be displayed. The following example shows the instrument on the 20VDC range.

$$\overline{-}\,\overline{-}.\overline{-}\,\overline{-}\,\overline{-}\,\overline{-} \quad \text{VDC}$$

Each subsequent trigger pulse will cause a reading to be stored.

Notes:
1. Whenever numeric data entry is prompted for (storage interval and buffer size), the decimal point button (".") will clear the display to all zeroes. This is especially useful when selecting the data store one-shot mode (000.000).
2. When storing readings with AUTO range enabled, the display will autorange as usual, but recalled readings will reflect the range that the instrument was on when the data store was enabled.
3. Once data storage has started, the data store can be disabled by pressng any function button. That function will then be selected. However, if RECALL is also enabled, the data store can only be disabled by pressing the RESET button first and then a function button.
4. The front panel message "SHORT-PERIOD" indicates that the instrument, as currently configured, cannot run fast enough to store readings at the selected interval. For example, the instrument cannot store readings at a selected interval of 10msec if the unit is in the S3 rate mode (16.7msec integration period). In this case, the instrument will only store as fast as it can run.
5. Enabling the data store does not clear the buffer of previously stored readings. Instead, new readings will overwrite old readings starting at buffer location 001.

2.7.2 Recalling Data

Stored data may be recalled any time during or after the storage process as follows:

1. Press the RECALL button. The RECALL indicator will turn on and the memory location of the last stored reading will be displayed. For example, if the last stored reading was in memory location 20, then the following message will be displayed:

LOC=020

2. If it is desired to read the data in the dislayed memory location, then proceed to step 3. If it is desired to read the data at a different memory location, then the displayed memory location number must be changed as follows: Cursor location is indicated by the bright, flashing digit. Number entry is accomplished by placing the cursor on the character to be modified and pressing the appropriate data button (buttons numbered 0 through 9). Cursor control is provided by the ◄ and ► buttons which move the cursor left and right respectively. If the cursor is moved pass the least significant digit, it will move back to the most significant digit.

3. With the desired memory location number displayed, press the ENTER button. The following message will be displayed briefly:

<p style="text-align:center">ENTERED</p>

Entering a number that is greater than the defined data store size, will default the display to the highest memory location defined by the data store size.

4. The stored data will then be displayed along with the memory location. For example, if 193.0000V is stored at memory location 20, then the following message will be displayed:

<p style="text-align:center">193.0000   020</p>

5. To read the stored data from all filled memory locations, utilize the manual range buttons. The ▲ button increments the memory location number and displays the data stored there. After the highest filled memory location is read, the ▲ button continues the reading process at memory location 001. Conversely, the ▼ button decrements the memory location number and displays the data stored there. After memory location 001 is read, the ▼ button continues the reading process at the highest filled memory location.

6. To read the highest, lowest and average reading stored in the data store, proceed as follows:

A. To display the highest reading, enter the number 1 by pressing the "1" button. The following message will be displayed briefly:

<p style="text-align:center">HI=</p>

The highest stored reading along with the memory location of that reading will be displayed.

B. To display the lowest reading stored, enter the number 2 by pressing the "2" button. The following message will be displayed briefly:
<p style="text-align:center">LO=</p>
The lowest stored reading along with the memory location of that reading will be displayed.

C. To display the average reading, enter the number 3 by pressing the "3" button. The following message will be displayed briefly:
<p style="text-align:center">AVE=</p>
The average reading along with the number of memory locations used to calculate the average will be displayed. Memory locations that have an over-range reading will not be included in the average.

NOTE
With a HI, LO or AVE reading displayed, pressing the AUTO button will return the display to the last normal recalled reading. The ▲ button performs the same function as the AUTO button, except that it increments the display to the next memory location. Conversely, the ▼ button decrements the memory location.

7. In the recall mode, the status of the Modle 193, while it was storing readings, can be checked by pressing the "0" button. The function that the instrument was in will be displayed. For example, if storage was performed in the DC volts mode, the following message will be displayed when the "0" button is pressed:
<p style="text-align:center">VDC</p>
Use the ▲ and ▼ buttons to display the rest of the status messages which include:
IEEE address
Frequency setting
Multiplexer status (on/off)
MX+B status (on/off)
M value
B value
dB reference value
Filter value
Zero status (on/off)
Zero value

8. To exit the status mode, press the STATUS button.

9. To exit the recall mode, press the RESET button.

Notes:

1. If the data store is enabled and full while in the recall mode, DATA STORE indicator light will be on, but not flashing.

2. Low, high and average readings will continue to be updated as long as readings are still being stored in the data store.

3. After the instrument is turned off, readings in the data store will be retained for typically up to five days.

4. Enabling the data store does not clear the buffer of previously stored readings. Instead, new readings will overwrite old readings starting at buffer location 001.

2.8 FRONT PANEL PROGRAMS

There are fourteen programs available from the front panel of the Model 193. These programs are listed in Table 2-2. The following paragraphs describe and explain the operation of each program.

2.8.1 Cursor and Data Entry

Many of the Model 193 programs need data to be applied from the front panel. After these programs are selected, cursor location is indicated by a bright, flashing display digit with the rest of the modifiable characters at normal brightness.

Data entry is accomplished by placing the cursor on the appropriate character to be modified and pressing the selected data button (0 through 9, or decimal point). Cursor control is provided by the RANGE ◄ and ► buttons which move the cursor left and right respectively. If the cursor is moved pass the least significant digit, it will move back to the most significant digit. Polarity (± button) can be changed with the cursor on any character. Plus (+) is implied and thus, not displayed. When entering data, the decimal point button (".") can be used to clear the display to read all zeroes.

2.8.2 Program TEMP

Program TEMP allows the user to select the alternate RTD alpha value (0.00385 or 0.00392) and change the thermometric scale (°C or °F). Paragraph 2.6.9 provides information necessary for making RTD temperature measurements. Perform the following steps to use this program:

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

    PROGRAM   ?

2. Press the TEMP button. The current alpha value will then be displayed. If the instrument is currently set to the factory default alpha value, the following message will be displayed:

    RTD ∝ = 0.00392

3. Pressing one of the range buttons will toggle the display to the alternate alpha value as shown:

    RTD ∝ = 0.00385

4. To enter the displayed alpha value, press the ENTER button. The following message will be displayed briefly:

    ENTERED

5. The current thermometric scale will then be displayed. If the instrument is currently on °C, the following message will be displayed.

    SCALE = °C

6. Pressing one of the range buttons will toggle the display to the alternate scale as shown:

    SCALE = °F

7. To enter the displayed scale, press the ENTER button. The following message will be displayed briefly and the instrument will return to the previous operating state.

    ENTERED

Note: Alpha value 0.00392 and °C are the factory default power-up conditions. If it is desired to have the alternate alpha value and/or °F on power-up, select the alternate condition(s) using Program TEMP followed by Program 90 to save it (see paragraph 2.8.9).

2.8.3 Program AC + DC (Low Frequency AC)

Program AC + DC configures the Model 193 to make low frequency (0.1 to 10Hz) TRMS AC + DC voltage measurements at 3½d resolution. Keep in mind that the ACV option does not have to be installed for these measurements. Perform the following steps to use this program:

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

    PROGRAM?

2. Press the AC+DC button. The displayed reading will be accompanied by the mnemonic "LO VA+D".
3. Select a range that is appropriate for the anticipated measurement. It is recommended that AUTO range not be used.
4. Connect the signal to be measured to the input of the Model 193.
5. The instrument will then start displaying readings that will ramp to the final TRMS value.

NOTES:
1. The final reading will be achieved in approximately 3 to 4 minutes. This long time constant is due to the low frequency cutoff of 0.1Hz.
2. It does not matter what function the instrument is in when this program is selected.
3. To exit the program, press any function button.

2.8.4 Program dB

Program dB allows the user to check and/or modify the dB reference. The programmable voltage reference can be up to 9.99999V and the programmable current reference can be up to 9.99999mA. Detailed information on dB measurements is provided in paragraphs 2.6.10 and 2.6.11. 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:

    REF = 1.00000

3. Modify, if desired, the dB reference level as explained in paragraph 2.8.1 Cursor and Data Entry, and press the ENTER button. The recommended reference range is 10μV to 9.99999V and 10nA to 9.99999mA. The following message will be displayed briefly and then the instrument will return to the previously defined state.

    ENTERED

    Note: The factory default power-up voltage reference is 1.00000V with the instrument in ACV and 1.00000mA with ACA selected. If it is desired to have a different voltage reference on power-up, modify the voltage reference using Program dB followed by Program 90 to save it (see paragraph 2.8.9).

2.8.5 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. For example: If 1V DC is set as the zero value on the 2V DC range, the zero value in the program will be displayed as 1.000000. On the 20V 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 20V DC range and the current zero value is +3V DC, the following message will be displayed:

    Z = 03.00000

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, do so as explained in paragraph 2.8.1, Cursor and Data Entry, 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 90 to save it (see paragraph 2.8.9).

2.8.6 Program FILTER

Program FILTER allows the user to modify the weighting of the exponential 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:

    FILTER = 05

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 as explained in paragraph 2.8.1 Cursor and Data Entry.

5. With the desired filter value displayed, press the ENTER button. The following message will be displayed briefly and the instrument will return to the previously defined state with the filter enabled.

    ENTERED

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 90 to save it (see paragraph 2.8.9).

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.

2.8.7 Program RESET

Program RESET resets all instrument setup parameters back to factory default conditions. The factory default conditions are listed in Table 2-1. Perform the following steps to run this program:

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

PROGRAM   ?

2. Press the RESET button. The following message will be displayed briefly:

PROGRAM RESET

3. The following prompt will then be displayed:

PRESS 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 RESET can be aborted by pressing any front panel momentary button, except the ENTER button, when the prompt "PRESS 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 90 must be run if it is desired to have the factory default conditions on subsequent power-ups.

2.8.8 Program 4

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 94 (see paragraph 2.8.13). Perform the following steps to enable the MX + B feature:

1. Set the Model 193 to the desired function and range.
2. Connect the signal to be measured (X) to the input of the Model 193.

3. If the values of M and B need to be checked or changed, do so using Program 94.
4. Press the PRGM button. The following prompt will be displayed:

PROGRAM   ?

5. 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

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

MX + B ON

7. With the message "MX + B ON" displayed, press the ENTER button to enable MX + B. The following message will be displayed briefly and the instrument will return to the function initially set.

ENTERED

8. All subsequent readings (Y) will be the result of the equation: $Y = MX + B$.

Notes:
1. 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.
2. Once MX + B has been enabled, the Model 193 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.
3. 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

193 Range and Function	Normal Reading (X)	MX + B* Reading (Y)
20VDC	8.00000VDC	17.00000VDC
20VDC	– 5.00000VDC	– 2.50000VDC
20VAC	6.30000VAC	14.45000VAC
20kΩ	4.00000kΩ	11.00000kΩ

*Where M = + 1.5 and B = + 5.

2.8.9 Program 90 (Save)

Program 90 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.

One function (including dB, AC+DC or low frequency AC+DC) may be saved along with the following parameters:

Range
Resolution
Zero status (on/off) and value
Filter status (on/off) and value

On the other functions, filter and zero values are the only parameters that are be saved.

Other instrument parameters, that are saved include:

RTD alpha value
Temperature scale (°C/°F)
dB reference
MX+B status (on/off)
MX+B values
IEEE primary address
Line frequency setting
Multiplexer status (on/off)

Perform the following procedure to use the save program:

1. Set up the instrument as desired or run Program RESET (see paragraph 2.8.7) to return the instrument to the factory default conditions.
2. Press the PRGM button. The following prompt will be displayed:
<div align="center">PROGRAM   ?</div>
3. Enter the number 90 by pressing the "9" and "0" buttons. The following message will be displayed briefly:
<div align="center">PROGRAM SAVE</div>
4. The following message will then be displayed:
<div align="center">PRESS ENTER</div>
5. To save the instrument setup conditions, press the ENTER button. The following message will be displayed briefly:
<div align="center">ENTERED</div>

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 Reset (see paragraph 2.8.7) and save the conditions using Program 90.
4. When using this program, make sure that the rest of the instrument is in the desired operating state.

2.8.10 Program 91 (IEEE Address)

Program 91 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 dislayed:
<div align="center">PROGRAM   ?</div>
2. Enter the number 91 by pressing the "9" and "1" buttons. The IEEE address value will be displayed. Example: If the current primary address of the instrument is 10, the following message will be displayed:
<div align="center">IEEE=10</div>
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) as explained in paragraph 2.8.1.
4. With a valid status value displayed, press the ENTER button, the following message will be displayed briefly and the instrument will return to the previously defined state.
<div align="center">ENTERED</div>

Notes:
1. If an invlaid number is entered, the instrument will exit from the program with the IEEE primary address being set to 30.
2. To change the factory power-up default address of the instrument, select the desired IEEE address using this program and then Program 90 to save it.

2.8.11 Program 92 (Freq)

The Model 193 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 193:

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

PROGRAM ?

2. Enter the number 92 by pressing the "9" 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

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

FREQ = 50Hz

4. With the correct frequency setting displayed, press the ENTER button. The following message will be displayed briefly and the instrument will return to the previous operating state.

ENTERED

Note: To change the factory power-up frequency setting of the instrument, select the alternate frequency setting using this program and then run Program 90 to save it.

2.8.12 Program 93 (Diagnostics)

Program 93 is a diagnostic program designed to switch on various switching FET's, relays and logic levels to allow signal tracing through the instrument. Refer to paragraph 6.9.3 in the maintenance section to use this program to troubleshoot the instrument.

2.8.13 Program 94 (MX+B Status)

This program allows the operator to check/change the M and B values for the MX + B feature (Program 4) of the Model 193. The factory power-up default value of M is 1.000000 and the value of B is 0000000. See paragraph 2.8.8 for complete information on the MX + B feature. To check/change the values of M and B, proceed as follows:

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

PROGRAM ?

2. Enter the number 94 by pressing the "9" 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:

M = 1.000000

3. 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 as explained in paragraph 2.8.1 Cursor and Data Entry. Note that valid M values are in the range of -9.999999 to +9.999999.

4. With a M value displayed, press the ENTER button. The following message will be displayed briefly:

ENTERED

5. The current B value will now be displayed. If the factory default value is the current B value, the following message will be displayed:

B = 0000.000

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 B value, proceed to step 7. If it is desired to modify the value of M, do so as explained in paragraph 2.8.1 Cursor and Data Entry. Note that the B value range is from 0.0001×10^{-1} to ± 9999.999.

7. With a valid B value displayed, press the ENTER button. The following message will be displayed briefly and the instrument will return to the previously defined state of operation.

ENTERED

Notes:
1. User selected values of M and B will be stored within the Model 193 until the power is turned off (unless saved by Program 90). 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 20V range and 190.0000V with the instrument on the 200.0000V range.
2. The user can set the values for M and B as the power-up default values by running Program 90 (see paragraph 2.8.9).

2.8.14 Program 95 (Multiplexer)

The multiplexer auto zero/cal routines may be defeated by running Program 95. Using the Model 193 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 95 by pressing the "9" and "5" buttons. 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 following message will be displayed briefly and the instrument will return to the previous operating state.

    ENTERED

2.8.15 Program 96 (Cal)

The user can easily perform front panel digital calibration by applying accurate calibration signals and using Program 96. The calibration signals can be either prompted default values or numbers entered from the front panel. Para-

graph 6.6.5 describes the basic steps for using this program, while paragraphs 6.6.7 through 6.6.12 provide the complete front panel calibration procedure.

2.9 FRONT PANEL TRIGGERING

On power-up, the instrument is in the continuous trigger mode with the conversion rate determined by the internal time base. The instrument can be placed in the one-shot trigger mode, which allows one reading to be triggered each time the TRIGGER button is pressed. The one-shot trigger mode is accessed through the data store. The basic procedure to place the instrument in the one-shot mode is to turn on the data store, enter the one-shot mode and select an appropriate buffer size. Each triggered reading is then stored in the data store. Paragraph 2-7 provides a detailed procedure for using the data store and recalling the triggered reading.

2.10 EXTERNAL TRIGGERING

The Model 193 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.

2.10.1 External Trigger

The Model 193 may be triggered on a continous 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 2-9. 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.
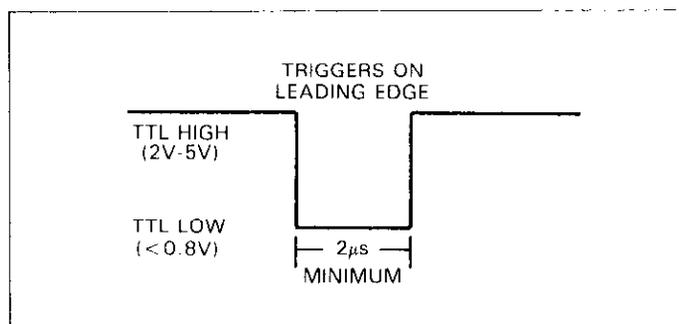
Figure 2-9. External Pulse Specifications

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 mode as explained in paragraph 2.9.
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. Note that the instrument may also be triggered by pressing the TRIGGER button.
4. To return the instrument to the continuous mode, disable data store.

Notes:
1. 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. The Model 193 must be in the appropriate trigger mode to respond to external triggering. See paragraph 3.10.7 for information on how to place the instrument in the proper trigger mode (T7) over the IEEE-488 bus.

2.10.2 Voltmeter Complete

The Model 193 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible negative-going pulse (see Figure 2-10) 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 193 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 193.

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 193 has completed a conversion.
4. In a one-shot trigger mode, the Model 193 will output a pulse once each time it is triggered.
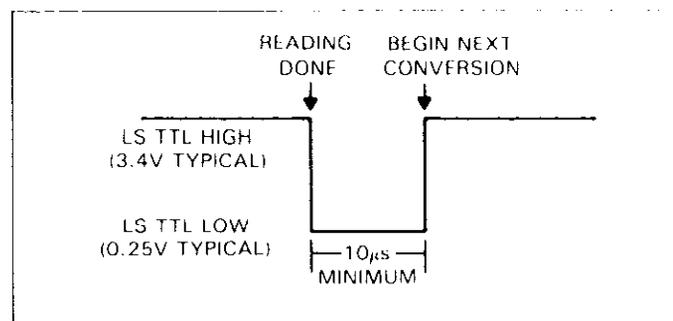
Figure 2-10. Voltmeter Complete Pulse Specifications

2.10.3 Triggering Example

As an example of using both the external trigger input and the meter complete output, assume that the Model 193 is to be used in conjunction with a Keithley Model 705 Scanner to allow the Model 193 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 193 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 mode of the Model 193.

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 705 to scan to the next channel. The process repeats until all channels have been scanned.

To use the Model 193 with the Model 705, proceed as follows:

1. Connect the Model 193 to the Model 705 as shown in Figure 2-11. Use shielded cables with BNC connectors. The Model 193 VOLTMETER COMPLETE OUTPUT jack should be connected to the Model 705 EXTERNAL TRIGGER INPUT jack. The Model 193 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 cards, as well as for the signal lines between the scanner and the Model 193.

2. Place the Model 193 in the one-shot trigger mode as explained in paragraph 2.9.

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 193 to take a reading. When the Model 193 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.
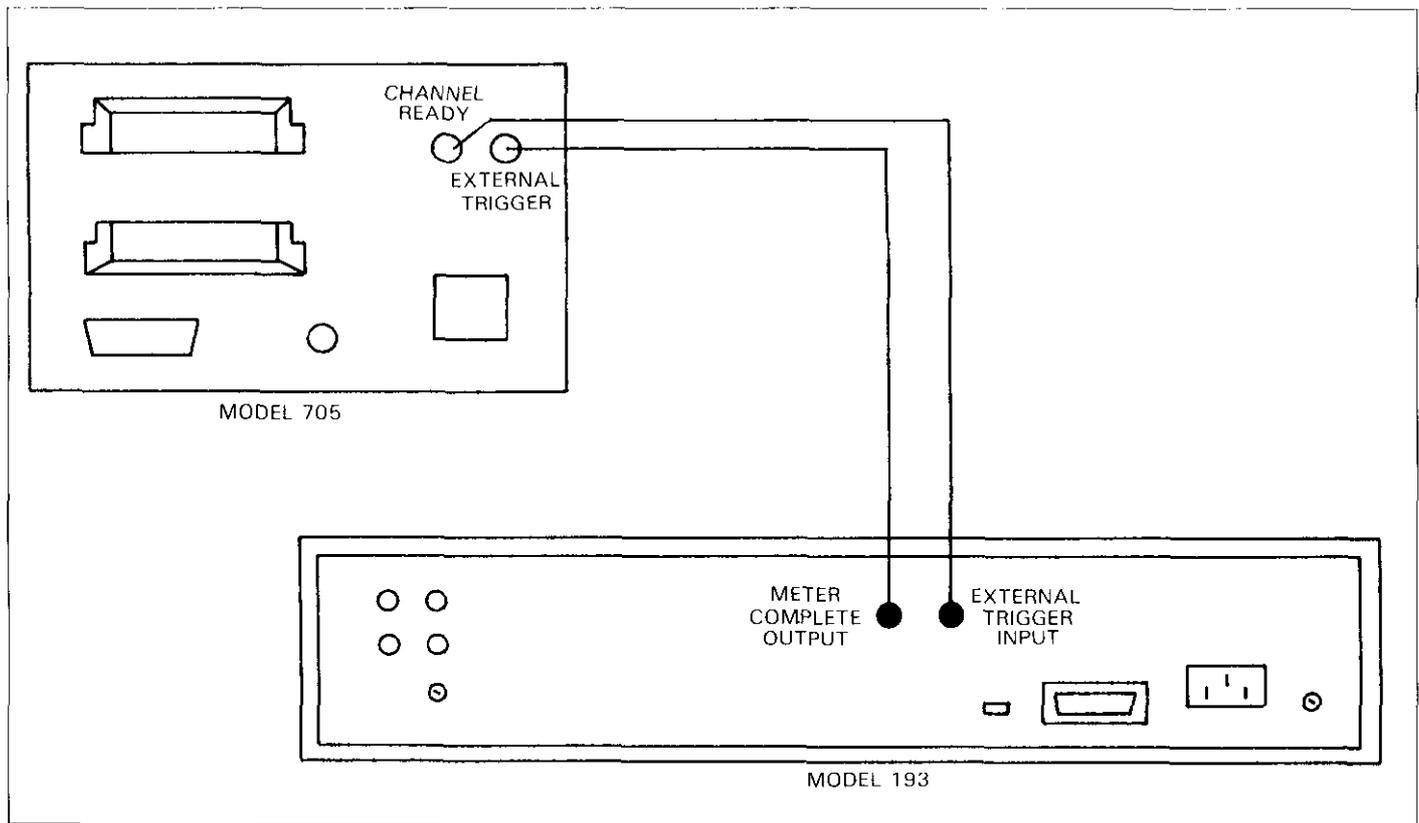
Figure 2-11. External Triggering Example

SECTION 3
IEEE-488 PROGRAMMING

3.1 INTRODUCTION

The IEEE-488 bus is an instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975 and given the IEEE-488 designation. In 1978, standards were upgraded into the IEEE-488-1978 standards. The Model 193 conforms to these standards.

This section contains general bus information as well as the necessary programming information and is divided into the following sections:

1. Introductory information pertaining to the IEEE-488 bus in general is located in paragraphs 3.2 through 3.6.
2. Information necessary to connect the Model 193 to the IEEE-488 bus is contained in paragraphs 3.7 and 3.8.
3. General bus command programming is covered in paragraph 3.9.
4. Device-dependent command programming is described in paragraph 3.10. These are the most important commands associated with the Model 193, as they control most of the instrument functions.
5. Additional information necessary to use the Model 193 over the IEEE-488 bus is located in the remaining paragraphs.

3.2 BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical set up for controlled operation is shown in Figure 3-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker and listener. The controller does what its name implies; it controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only or both a talker and a listener.

There are two categories of controllers: system controller, and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is 10 ($0A), the actual listen address is $2A ($2A = $0A + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of 10 decimal would be $4A ($4A = $0A + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however that many devices do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example: if the Model 193 is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information and the appropriate software can be used to direct the information to the desired location.

3.3 IEEE-488 BUS LINES

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the purpose of these lines, which are shown in Figure 3-1.
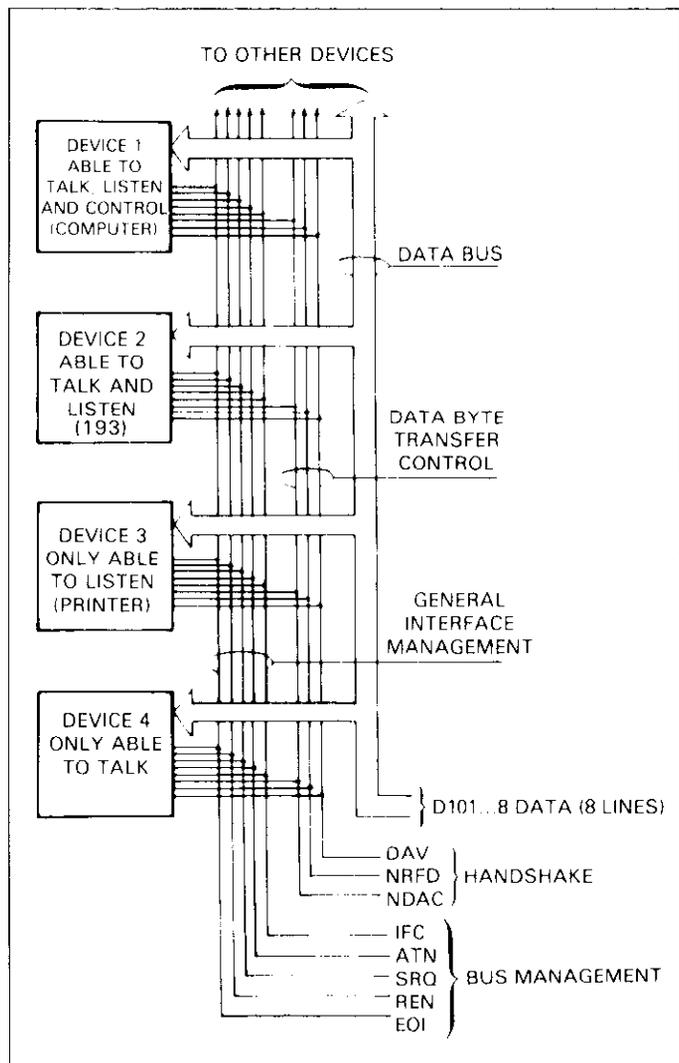
Figure 3-1. IEEE-488 Bus Configuration

3.3.1 Data Lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bidirectional. The data lines operate with low true logic.

3.3.2 Bus Management Lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands that are described in paragraph 3.4.1.

ATN (Attention)—The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear)—As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable)—The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify)—The EOI line is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request)—This line is used by devices when they require service from the controller.

3.3.3 Handshake Lines

The bus uses handshake lines that operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by the accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (Data Valid)—The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data)—The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device.

The complete handshake sequence for one data byte is shown in Figure 3-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The sequence just described is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses or commands as described in the following paragraph.
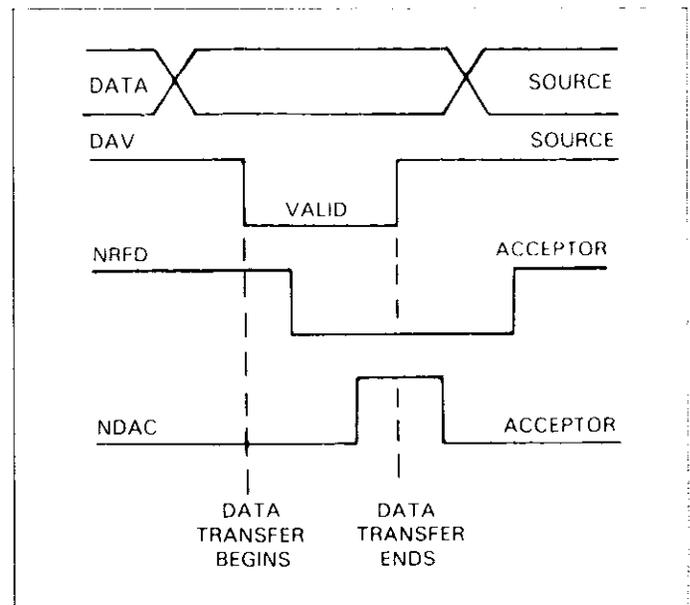
Figure 3-2. IEEE-488 Handshake Sequence

3.4 BUS COMMANDS

The Model 193 may be given a number of special bus commands through the IEEE-488 interface. This section briefly describes the purpose of the bus commands which are grouped into the following three categories:

Uniline Commands—Sent by setting the associated bus lines true (low).

Multiline Commands—General bus commands which are sent over the data lines with the ATN line true (low).

Device-Dependent Commands—Special commands whose meanings depend on device configurations; sent with ATN high (false).

These bus commands and their general purposes are summerized in Table 3-1.

3.4.1 Uniline Commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable)—REN is sent to set up instruments on the bus for remote operation. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End Or Identify)—EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear)—IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request)—SRQ is asserted by a device when it requires service from a controller.

3.4.2 Universal Commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the command is transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to the instrument to lock out its front panel controls.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device has requested service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Table 3-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Set up for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears Interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out front panel controls.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Poll Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Sends go to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent**		High	Programs Model 193 for various modes.

*Don't Care.
**See paragraph 3.10 for complete description.

3.4.3 Addressed Commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands:

SDC (Selective Device Clear)—The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local)—The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger)—The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

3.4.4 Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by the UNT command.

3.4.5 Device-Dependent Commands

The meaning of the device-dependent commands will depend on the configuration of the instrument. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function. For example, the command sequence F0X is used to place the Model 193 in the DC volts mode. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

3.5 COMMAND CODES

Each multiline command is given a unique code that is transmitted over the bus as 7 bit ASCII data. This section briefly explains the code groups, which are summarized in Figure 3-3.

Addressed Command Group (ACG)—Addressed commands and corresponding ASCII codes are listed in columns 0(A) and 0(B).

Universal Command Group (UCG)—Universal commands and values are listed in columns 1(A) and 1(B).

Listen Address Group (LAG)—Columns 2(A) through 3(B) list codes for commands in this address group. For example, if the primary address of the instrument is 10, the LAG byte will be an ASCII asterisk.

Talk Address Group (TAG)—TAG primary address values and corresponding ASCII characters are listed in columns 4(A) through 5(B).

The preceding address groups are combined together to form the Primary Command Group (PCG). The bus also has another group of commands, called the Secondary Command Group (SCG). These are listed in Figure 3-3 for informational purposes only; the Model 193 does not have secondary addressing capabilities.

Note that these commands are normally transmitted with the 7 bit code listed in Figure 3-3. For many devices, the condition of DIO8 is unimportant. However, many devices may require that DIO8 has a value of logic 0 (high) to properly send commands.

Hexadecimal and decimal values for each of the commands or command groups are listed in Table 3-2. Each value assumes that DIO8 has a value of 0.

Table 3-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
UNL	3F	63
UNT	5F	95

Figure 3-3. Command Groups

3.6 COMMAND SEQUENCES

The proper command sequence must be sent to the instrument before it will respond as intended. Universal commands, such as LLO and DCL, require only that ATN be set low when sending the command. Other commands require that the instrument be properly addressed to listen first. This section briefly describes the bus sequence for several types of commands.

3.6.1 Addressed Command Sequence

Before a device will respond to one of these commands, it must receive a LAG command derived from its primary address. Table 3-3 shows a typical sequence for the SDC command; the example assumes that a primary address of 10 is being used.

Note that an UNL command is generally sent before the LAG, SDC sequence. This is usually done to remove all other listeners from the bus so that the desired device responds to the command.

Table 3-3. Typical Addressed Command Sequence

| Step | Command | ATN State | Data Bus | | |
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	*	2A	42
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 10.

3.6.2 Universal Command Sequence

Universal commands are sent by setting ATN low and then placing the command byte on the data bus. ATN would then remain low during the period the command is transmitted. For example, if the LLO command were to be sent, both ATN and LLO would be asserted simultaneously.

3.6.3 Device-Dependent Command Sequence

Device-dependent commands are transmitted with ATN false. However, a device must be addressed to listen before these commands are transmitted. Table 3-4 shows the byte sequence for a typical Model 193 command (F0X), which sets the instrument for the DC volts mode of operation.

Table 3-4. Typical Device-Dependent Command Sequence

| Step | Command | ATN State | Data Bus | | |
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	*	2A	42
3	Data	Set High	F	46	70
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 10.

3.7 HARDWARE CONSIDERATIONS

Before the Model 193 can be operated over the IEEE-488 bus, it must be connected to the bus with a suitable cable. Also, the primary address must be programmed the correct value, as described in the following paragraphs.

3.7.1 Typical Controlled Systems

System configurations are many and varied and will depend on the application. To obtain as much versatility as possible, the IEEE-488 bus was designed so that additional instrumentation could be easily added. Because of this versatility, system complexity can range from the very simple to extremely complex.

Figure 3-4 shows two possible system configurations. Figure 3-4(A) shows the simplest possible controlled system. The controller is used to send commands to the instrument, which sends data back to the controller.

The system in Figure 3-4(B) is somewhat more complex in that additional instruments are used. Depending on programming, all data may be routed through the controller, or it may be sent directly from one instrument to another.

In very complex applications, a larger computer could be used. Tape drives or disks could be used to store any data generated by the instruments.

(A) SIMPLE SYSTEM

(B) ADDITIONAL INSTRUMENTATION
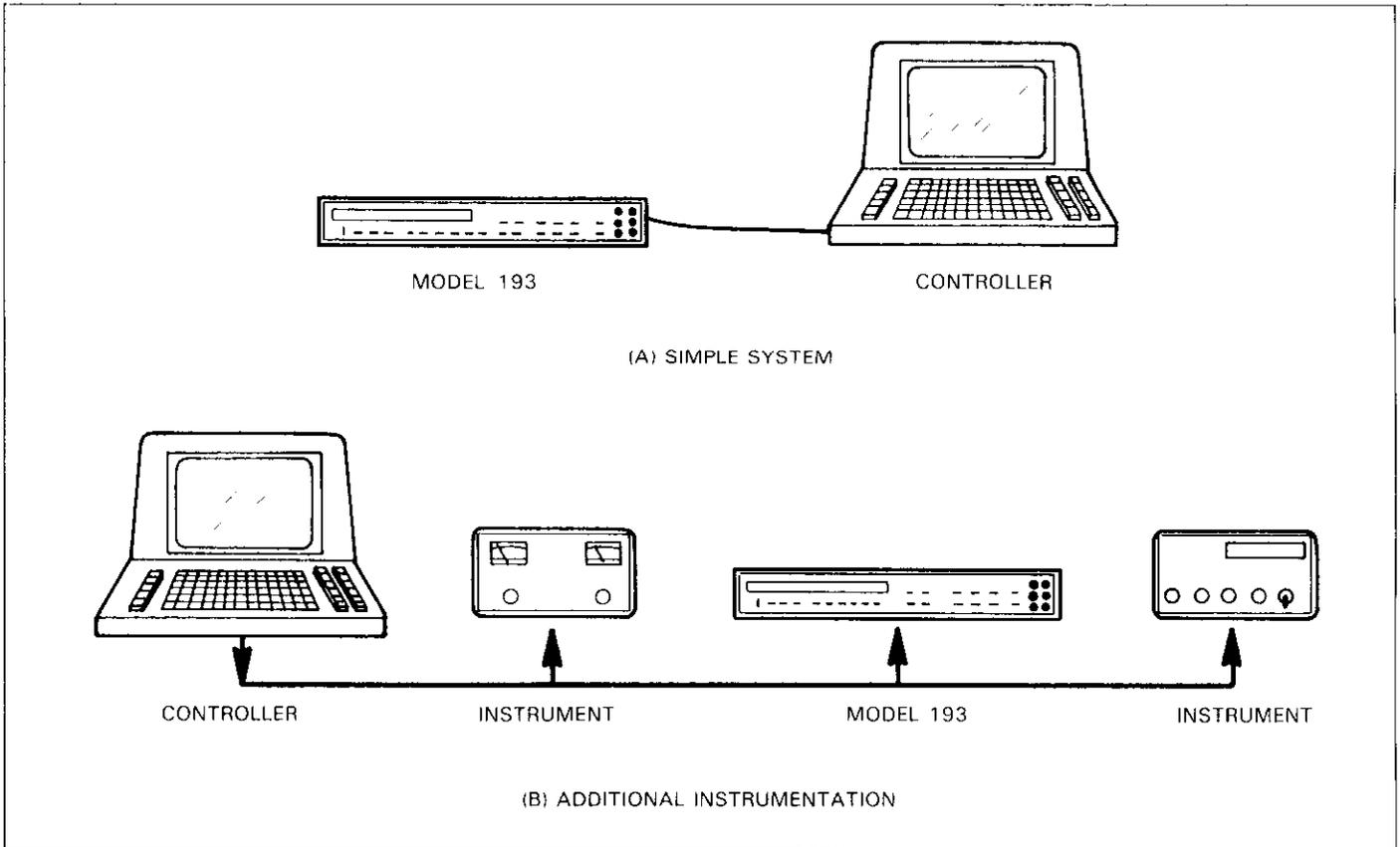
Figure 3-4. System Types

3.7.2 Bus Connections

The Model 193 is connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example is shown in Figure 3-5. The connector is design- ed to be stacked to allow a number of parallel connections. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, as identified by dark colored screws. Earlier versions had different screws, which are silver colored. Do not attempt to use these type of connectors with the Model 193, which is designed for metric threads.

A typical connecting scheme for the bus is shown in Figure 3-6. Each cable normally has the standard connector on each end. These connectors are designed to be stacked to allow a number of parallel connections on one instrument.

NOTE
To avoid possible damage, it is recommended that you stack no more than three connectors on any one instrument.
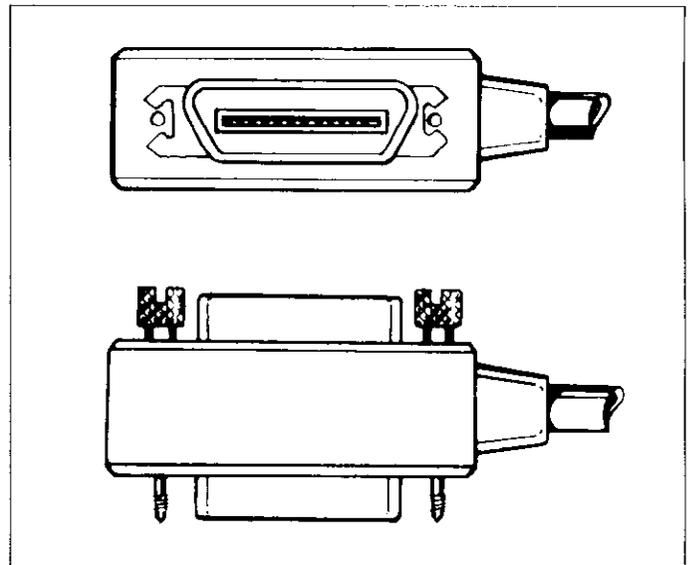
Figure 3-5. Typical Bus Connections
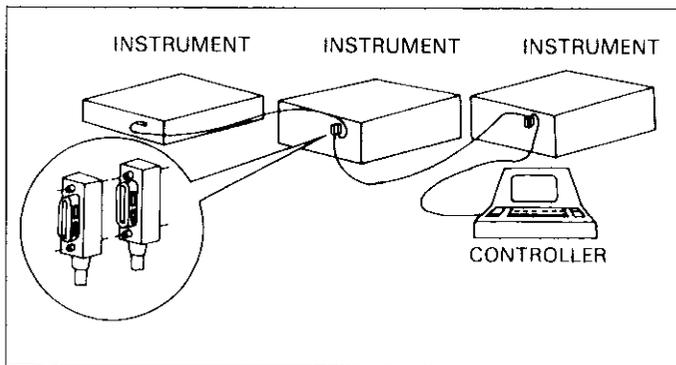
Figure 3-6. IEEE-488 Connections

Connect the Model 193 to the cable as follows:

1. Line up the connector on the cable with the connector on the rear panel of the instrument. See Figure 3-7 for connector location.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make sure the other end of the cable is properly connected to the controller. Some controllers have an IEEE-488 type connector, while others do not. Consult the instruction manual for your controller for the proper connecting method.
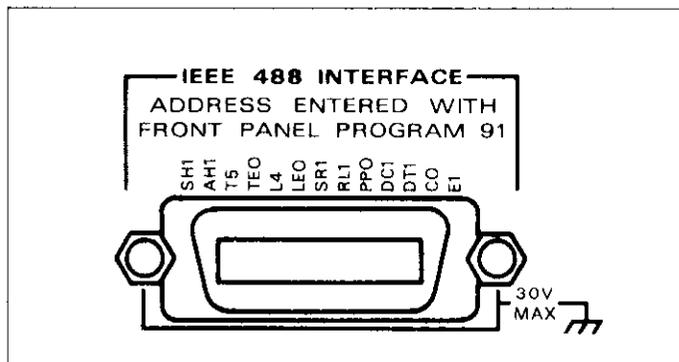
Figure 3-7. Model 193 IEEE-488 Connector

NOTE
The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is limited to 20 meters, or 2

meters times the number of devices, which ever is less. Failure to heed these limits may result in erratic bus operation.

Custom cables may be constructed by using the information in Table 3-5 and Figure 3-8. Table 3-5 lists the contact assignments for the various bus lines, while Figure 3-8 shows contact assignments.

CAUTION
The voltage between IEEE-488 common and chassis ground must not exceed 30V or instrument damage may occur.

Table 3-5. 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

*Number in parenthesis refer to signal ground return of reference contact number. EOI and REN signal lines return on contact 24.
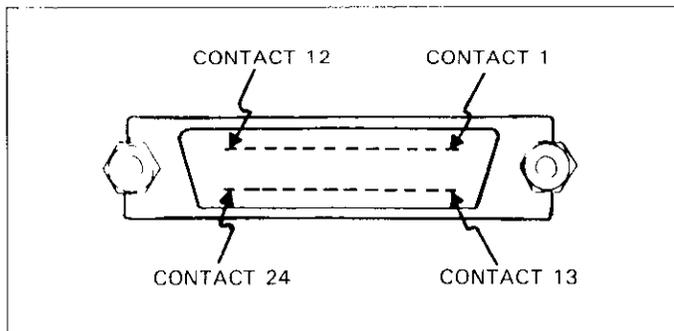
Figure 3-8. Contact Assignments

3.7.3 Primary Address Programming

The Model 193 must receive a listen command before it will respond to addressed commands. Similarly, the unit must receive a talk command before it will transmit its data. The Model 193 is shipped from the factory with a programmed primary address of 10. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples included in this manual assume that address.

The primary address may be set to any value between 0 and 30 as long as address conflicts with other instruments are avoided. Note that controllers are also given a primary address, so you must be careful not to use that address either. Most frequently, controller addresses are set to 0 or 21, but you should consult the controller's instruction manual for details. Whatever primary address you choose, you must make certain that it corresponds with the value specified as part of the controller's programming language.

To check the present primary address or to change to a new one, utilize front panel Program 91. See paragraph 2.8.10 for information on using this program.

NOTE
Each device on the bus must have a unique primary address. Failure to observe this precaution will probably result in erratic bus operation.

3.8 SOFTWARE CONSIDERATIONS

There are a number of IEEE-488 controllers available, each of which has its own programming language. Also, different instruments have differing capabilities. In this section, we will discuss programming languages for two typical controllers: the HP-85, and the IBM-PC interfaced

to the bus through a Keithley Model 8573 IEEE-488 interface. In addition, interface function codes that define Model 193 capabilities will be discussed.

3.8.1 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, the software is located in ROM, and no software initialization is required on the part of the user. With other controllers, software must be loaded from disk or tape and be properly initialized. With the HP-85, for example, an additional I/O ROM that handles interface functions must be installed. With the Keithley Model 8573 interface for the IBM-PC, software must be installed and configured from a diskette.

Other small computers that can be used as IEEE-488 controllers may have limited capabilities. With some, interface programming functions may depend on the interface being used. Often little software "tricks" are required 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.

3.8.2 Interface BASIC Programming Statements

Many of the programming instructions covered in this section use examples written with Hewlett Packard Model 85 BASIC and Model 8573 Interface statements. These computers and interfaces were chosen for these examples because of their versatility in controlling the IEEE-488 bus. This section covers those HP-85 and Model 8573 statements that are essential to Model 193 operation.

A partial of HP-85 and Model 8573 statements is shown in Table 3-6. 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.

Those statements with a 3-digit argument listed in the table show a primary address of 10 (the factory default primary address of the Model 193). For a different address, you would, of course, change the last two digits to the required value. For example, to send a GTL command to a device using a primary address of 22, the following statement would be used: LOCAL 722.

Some of the statements have two forms; the exact configuration depends on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command, while CLEAR 710 sends the SDC command to a device with a primary address of 10.

The Model 8573 statements, which are also listed in Table 3-6, take on a somewhat different form. Each of these statements uses the IBM BASIC CALL statement, with various variables passed as shown in the table. The command words, such as IBCLR (Interface Bus Clear) and IBSRE (Interface Bus Send Remote Enable), are, in fact, BASIC variables themselves, which must be initialized at the start of each BASIC program. In addition, you must remember not to use these keywords for any other purpose in your BASIC program.

Before using the Model 8573 examples throughout this section, you must configure the software by using the procedure below. Note that the binary handler file called GPIB.COM and the system configuration file called CONFIG.SYS must be present on the DOS boot disk, as described in the Model 8573 Instruction Manual.

1. Boot up your system in the usual manner and enter BASICA.
2. Place the Model 8573 software disk into the default drive and load the program called "DECL.BAS". Modify the program by changing the XXXXX values in lines 1 and 2 to 16000.
3. Add the following lines to the declaration file:
   ```
   7 NA$="GPIB0":CALL IBFIND
     (NA$,BRD0%)
   8 NA$="DEV0":CALL IBFIND
     (NA$,M193%)
   9 V%=10:CALL IBPAD
     (M193%,V%)
   ```

4. Now save the modified declaraion file for future use. Remember that you must load and run this short program before using the Model 8573 programming examples throughout this section. Also, do not use the BASIC CLEAR or NEW commands after running this program.

3.8.3 Interface Function Codes

The interface function codes, which are part of the IEEE-488-1978 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 193 are listed in Table 3.7. These codes are also listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 193 capabilities as follows:

SH (Source Handshake Function)—SH1 defines the ability of the Model 193 to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function)—AH1 defines the ability of the Model 193 to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function)—The ability of the Model 193 to send data over the bus to other devices is provided by the T function. Model 193 talker capabilities exist only after the instrument has been addressed to talk, or when it has been placed in the talk-only mode.

L (Listener Function)—The ability for the Model 193 to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities of the Model 193 exist only after the instrument has been addressed to listen.

Table 3-6. BASIC Statements Necessary to Send Bus Commands

Action	HP-85 Statement	Model 8573 Statement
Transmit string to device 10.	OUTPUT 710;A$	CALL IBWRT (M193%, CMD$)
Obtain string from device 10.	ENTER 710; A$	CALL IBRD (M193%, RD$)
Send GTL to device 10.	LOCAL 710	CALL IBLOC (M193%)
Send SDC to device 10.	CLEAR 710	CALL IBCLR (M193%)
Send DCL to all devices.	CLEAR 7	CMD$=CHR$ (&H14): CALL IBCMD (BRD0%, CMD$)
Send remote enable.	REMOTE 7	V%=1: CALL IBSRE(BRD0%, V%)
Cancel remote enable.	LOCAL 7	V%=0: CALL IBSRE(BRD0%, V%)
Serial poll device 10.	SPOLL (710)	CMD$=CHR$ (&H11): CALL IBCMD(BRD0%, CMD$)
Send Local Lockout.	LOCAL LOCKOUT	CALL IBRSP(M193%, SB%)
Send GET to device.	TRIGGER 710	CALL IBTRG (M193%)
Send IFC.	ABORTIO 7	CALL IBSIC(BRD0%)

SR (Service Request Function)—The SR function defines the ability of the Model 193 to request service from the controller.

RL (Remote-Local Function)—The RL function defines the ability of the Model 193 to be placed in the remote or local modes.

PP (Parallel Poll Function)—The Model 193 does not have parallel polling capabilities.

DC (Device Clear Function)—The DC function defines the ability of the Model 193 to be cleared (initialized).

DT (Device Trigger Function)—The ability for the Model 193 to have its readings triggered is provided by the DT function.

C (Controller Function)—The Model 193 does not have controller capabilities.

TE (Extended Talker Function)—The Model 193 does not have extended talker capabilities.

LE (Extended Listener Function)—The Model 193 does not have extended listener capabilities.

E (Bus Driver Type)—The Model 193 has open-collector bus drivers.

Table 3-7. Model 193 Interface Function Codes

Code	Interface Function
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T5	Talker (Basic Talker, Serial Poll, Talk Only Mode, Unaddressed To Talk On LAG)
L4	Listener (Basic Listener, Unaddressed To Listen On TAG)
SR1	Service Request Capability
RL1	Remote/Local Capability
PPO	No Parallel Poll Capability
DC1	Device Clear Capability
DT1	Device Trigger Capability
CO	No Controller Capability
E1	Open Collector Bus Drivers
TEO	No Extended Talker Capabilities
LEO	No Extended Listener Capabilities

3.8.4 IEEE Command Groups

Command groups supported by the Model 193 are listed in Table 3-8. Device-dependent commands, which are covered in paragraph 3.10, are not included in this list.

3.9 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general meaning regardless of the instrument type. Commands supported by the Model 193 are listed in Table 3-9, which also lists both HP-85 and Model 8573 statements necessary to send each command. Note that commands requiring that a primary address be specified assume that the Model 193 primary address is set to 10 (its default address). If you are using Model 8573 programming examples, remember that the modified declaration file must be loaded and run first, as described in paragraph 3.8.2.

Table 3-8. IEEE Command Groups

HANDSHAKE COMMAND GROUP
     DAC = DATA ACCEPTED
     RFD = READY FOR DATA
     DAV = DATA VALID
UNIVERSAL COMMAND GROUP
     ATN = ATTENTION
     DCL = DEVICE CLEAR
     IFC = INTERFACE CLEAR
     LLO = LOCAL LOCKOUT
     REN = REMOTE ENABLE
     SPD = SERIAL POLL DISABLE
     SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP
  LISTEN: LAG = LISTEN ADDRESS GROUP
         MLA = MY LISTEN ADDRESS
         UNL = UNLISTEN
  TALK: TAG = TALK ADDRESS GROUP
        MTA = MY TALK ADDRESS
        UNT = UNTALK
        OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP
     ACG = ADDRESSED COMMAND GROUP
     GET = GROUP EXECUTE TRIGGER
     GTL = GO TO LOCAL
     SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP
     RQS = REQUEST SERVICE
     SRQ = SERIAL POLL REQUEST
     STB = STATUS BYTE
     EOI = END

Table 3-9. General Bus Commands and Associated BASIC Statements

Command	HP-85 Statement	Model 8573 Statement	Affect On Model 193
REN	REMOTE 7	U%=1 : CALL IBSRE (BRD0%, U%)	Goes into remote when next addressed.
IFC	ABORTIO 7	CALL IBSIC(BRD0%)	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	CMD$=CHR$ (&H11) : CALL IBCMD (M193%, CMD$)	Front panel controls locked out.
GTL	LOCAL 710	CALL IBLOC(M193%)	Cancel remote.
DCL	CLEAR 7	CMD$=CHR$(&H14) : CALL IBCMD (M193%, CMD$)	Returns to default conditions.
SDC	CLEAR 710	CALL IBCLR(M193%)	Returns to default conditions.
GET	TRIGGER 710	CALL IBTRG (M193%)	Triggers reading in T2 an T3 modes.
	LOCAL 7	U%=0 : CALL IBSRE(BRD0%, U%)	Cancel LLO

3.9.1 REN (Remote Enable)

The remote enable command is sent to the Model 193 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true will not actually place the instrument in the remote mode. Instead the instrument must be addressed after setting REN true before it will go into remote.

To place the Model 193 in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 193 to listen.

HP-85 Programming Example—This sequence is automatically performed by the HP-85 when the following is typed into the keyboard.
        REMOTE 710 (END LINE)

After the END LINE key is pressed, the Model 193 will be in the remote mode, as indicated by the REMOTE light. If not, check to see that the instrument is set to the proper primary address (10), and check to see that the bus connections are properly made.

Model 8573 Programming Example—To place the Model 193 into the remote mode, type the following lines into the computer.
    U%=1 : CALL IBSRE(BRD0%, U%) (RETURN)
    CMD$=''X'' : CALL IBWRT(M193%, CMD$)
              (RETURN)

The instrument will go into the remote mode when the return key is pressed the second time.

3.9.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 193 in the local, 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 100μsec.

HP-85 Programming Example—Before demonstrating the IFC command, turn on the TALK indicator with the following statements:
        REMOTE 710 (END LINE)
        ENTER 710; A$ (END LINE)

At this point, the REMOTE and TALK lights should be on. The IFC command can be sent by typing in the following statement into the HP-85:
        ABORTIO 7 (END LINE)

After the END LINE key is pressed, the REMOTE and TALK lights will turn off, indicating that the instrument has gone into the talker idle state.

Model 8573 Programming Example—Place the instrument in the remote and talker active states with the following statements:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=CHR$(&H4A):CALLIBCMD
    (BRD0%,CMD$) (RETURN)
```

After the return key is pressed the second time, the instrument should be in the remote and talker active states, as indicated by the respective indicators.

To send IFC, enter the following statement into the IBM-PC:

```
CALL IBSIC(BRD0%) (RETURN)
```

After the return key is pressed, the instrument will return to the local and talker idle states.

3.9.3 LLO (Local Lockout)

The LLO command is used to remove the instrument from the local operating mode. After the unit receives LLO, all its front panel controls except POWER will be inoperative. REN must be true for the instrument to respond to LLO. REN must be set false to cancel LLO.

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

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

HP-85 Programming Example—The LLO command is sent by using the following HP-85 statement:

```
REMOTE 7 (END LINE)
LOCAL LOCKOUT 7 (END LINE)
```

After the second statement is entered, the instrument's front panel controls will be locked out.

Model 8573 Programming Example—To send the LLO command from the IBM-PC, type in the following statements:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=CHR$(&H11): CALL IBCMD$
    (BRD0%,CMD$) (RETURN)
```

After the return key is pressed, the Model 193 front panel controls will be locked out.

3.9.4 GTL (Go To Local) and Local

The GTL command is used to take the instrument out of the remote mode. With some instruments, GTL may also cancel LLO. With the Model 193, however, REN must first be placed false before LLO will be cancelled.

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

1. Set ATN true.
2. Address the Model 193 to listen.
3. Place the GTL command on the bus.

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

```
REMOTE 710 (END LINE)
```

Now send GTL with the following statement:

```
LOCAL 710 (END LINE)
```

When the END LINE key is pressed, the front panel REMOTE indicator goes off, and the instrument goes into the local mode. To cancel LLO, send the following:

```
LOCAL 7 (END LINE)
```

Model 8573 Programming Example—Place the instrument in the remote mode with the following statements:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''X'':CALL IBURT(M193%,CMD$)
        (RETURN)
```

Now send GTL with the following statement:

```
CALL IBLOC(M193%) (RETURN)
```

After return is pressed, the REMOTE indicator turns off, and the instrument goes into the local mode. To cancel LLO, send the following:

```
U%=0:CALL IBSRE(M193%,U%) (RETURN)
```

3.9.5 DCL (Device Clear)

The DCL command may be used to clear the Model 193 and return it to its power-up 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 193 receives a DCL command, it will return to either the factory default conditions listed in Table 3-10 or to the user programmed default conditions.

Table 3-10. Factory Default Conditions

Mode	Default Value	Status
Function	F0	DC Volts
Range	R5	1000V
Data Format	G0	Send prefix with data
Reading Mode	B0	A/D Converter
Self-test	J0	Clear
EOI	K0	Enable EOI and Bus Hold-off on X
Digital Filter	P0	Disabled
Exponential Filter	N1	On
Zero	Z0	Disabled
Delay	W00.000	no delay
SRQ	M0	Disabled
Rate	S3	100msec, 6½d
Trigger	T6	Continuous on external trigger
Multiplex	A1	Enabled
Terminator	=:	(CR)(LF)
Data Store Rate	Q0	One-shot mode
Data Store Size	I0	Continuous

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.

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

    CLEAR 7 (END LINE)

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

Model 8573 Programming Example—Place the unit in an operating mode that is not a power-up default condition. Now enter the following statement into the IBM computer:

    CMD$=CHR$(&H14):CALL IBCMD
    (BRD0%,CMD$) (RETURN)

When the return key is pressed, the instrument returns to the power-up default conditions.

3.9.6 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 193 receives the SDC command, it will return to either the factory default conditions listed in Table 3-10 or to the user programmed default conditions.

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

1. Set ATN true.
2. Address the Model 193 to listen.
3. Place the SDC command on the data bus.

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

    CLEAR 710 (END LINE)

After END LINE is pressed, the instrument returns to the power-up default conditions.

Model 8573 Programming Example—Place the unit in an operating mode that is not a power-up default condition. Now enter the following statement into the IBM computer:

    CALL IBCLR(M193%) (RETURN)

After the return key is pressed, the instrument returns to the power-up default conditions.

3.9.7 GET (Group Execute Trigger)

GET may be used to trigger the Model 193 to take readings if the instrument is placed in the appropriate trigger mode (more information on trigger modes may be found in paragraph 3.10.7).

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

1. Set ATN true.
2. Address the Model 193 to listen.
3. Place the GET command byte on the data bus.

HP-85 Programming Example—Type in the following statements into the HP-85 keyboard to place the instrument in remote and enable the correct trigger mode for this demonstration:

```
REMOTE 710 (END LINE)
OUTPUT 710;""T3X"" (END LINE)
```

Now send the GET command with the following statement:

```
TRIGGER 710 (END LINE)
```

When the END LINE key is pressed, the instrument will process a single reading.

Model 8573 Programming Example—Type in the following statements to make sure the instrument is in the remote and correct trigger modes for purposes of this demonstration:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=""T3X"":CALL IBWRT(M193%,CMD$)
                          (RETURN)
```

Now send GET to the instrument with the following statement:

```
CALL IBTRG(M193%) (RETURN)
```

When the return key is pressed, the instrument will process a single reading.

3.9.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 193 status byte. The status byte contains important information about internal functions, as described in paragraph 3.10.13. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 193.

The serial polling sequence is 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 mode and waiting to be addressed.
3. The Model 193 is then addressed to talk.
4. The controller sets ATN false.
5. The instrument then places its status byte on the data bus, at which point it is 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. ATN must be true when the address is transmitted and false when the status byte is read.

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

```
REMOTE 710 (END LINE)
S=SPOLL (710) (END LINE)
DISP S (END LINE)
```

When the END LINE key is pressed the second time, the computer conducts the serial polling sequence. The decimal value of the status byte is then displayed on the computer CRT when the END LINE key is pressed the third time. More information on the status byte may be found in paragraph 3.10.13.

Model 8573 Programming Example—Use the following sequence to serial poll the instrument and display the decimal value of the status byte on the computer CRT:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CALL IBRSP(M193%,SB%) (RETURN)
PRINT SB% (RETURN)
```

When the return key is pressed the second time, the serial polling sequence is conducted. The status byte value is displayed when the return key is pressed the third time.

3.10 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 193 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 193 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 193 are listed in Table 3-11. These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands with both the HP-85 and the IBM-PC/8573.

NOTE
Programming examples assume that the Model 193 is at its factory default value of 10.

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

1. Set ATN true.
2. Address the Model 193 to listen.
3. Set ATN false.
4. Send the command string over the bus one byte at a time.

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.

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

```
OUTPUT 710;A$
```

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

General Model 8573 Programming Example—Use the following general syntax to send device-dependent commands from the IBM-PC:

```
CALL IBWRT(M193%,CMD$)
```

Again, CMD$ contains the command letters to program the instrument. Remember that the modified declaration file must be loaded and run before using any of the programming examples.

Table 3-11. Device-Dependent Command Summary

Mode	Command	Description							Paragraph
Execute	X	Execute other device-dependent commands.							3.10.1
Function	F0	DC Volts							3.10.2
	F1	AC Volts							
	F2	Ohms							
	F3	DC Current							
	F4	AC Current							
	F5	Temperature in °F mode							
	F6	Temperature in °C mode							
	F7	ACV + DC							
	F8	ACA + DC							
	F9	Low Frequency ACV + DC							
	F10	ACV dB							
	F11	ACA dB							
	F12	ACV + DC dB							
	F13	ACA + DC dB							
Range		DCV	ACV	DCA	ACA	Ohms	Temp		3.10.3
	R0	Auto	Auto	Auto	Auto	Auto	Pt. 385		
	R1	200mV	2V	200μA	200μA	200Ω	Pt. 392		
	R2	2V	20V	2mA	2mA	2kΩ	Type K		
	R3	20V	200V	20mA	20mA	20kΩ	Type J		
	R4	200V	700V	200mA	200mA	200kΩ	Type T		
	R5	1000V	700V	2A	2A	2MΩ	Type E		
	R6	1000V	700V	2A	2A	20MΩ	Type R		
	R7	1000V	700V	2A	2A	200MΩ	Type S		
	R8	1000V	700V	2A	2A	200MΩ	Type B		
Zero	Z0	Zero disabled							3.10.4
	Z1	Zero enabled							
	Z2	Zero enabled using a zero value (V)							
Filter	P0	Filter disabled							3.10.5
	Pn	Filter on with a value of n (n=1 to 99)							
Rate	S0	318μsec integration at 3½d resolution							3.10.6
	S1	2.59msec integration at 4½d resolution							
	S2	Line cycle integration at 5½d resolution							
	S3	Line cycle integration at 6½d resolution							
Trigger Mode	T0	Continuous on Talk							3.10.7
	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							
Reading Mode	B0	Readings from A/D converter							3.10.8
	B1	Readings from data store							

Table 3-11. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Data Store Size	I0 In	Continuous data store mode Data store size of n (n=1 to 500)	3.10.9
Data Store Interval	Q0 Qn	One-shot into buffer n=interval in milliseconds (1msec to 999999msec)	3.10.9
Value	V±nn.nnnn or V±n.nnnnnnE+n	Calibration value, zero value and reference junction temperature value.	3.10.10
Calibration	C0 C1	Calibrate first point using value (V) Calibrate second point using value (V)	3.10.10
Default Conditions	L0 L1	Restore factory default conditions. Store present machine states as default conditions.	3.10.11
Data Format	G0 G1 G2 G3 G4 G5	Reading with prefixes. Reading without prefixes. Buffer readings with prefixes and buffer locations. Buffer readings without prefixes and with buffer locations. Buffer readings with prefix and without buffer locations. Buffer readings without prefixes and without buffer locations.	3.10.12
SRQ	M0 M1 M2 M4 M8 M16 M32	Disable Reading Overflow Data Store Full Data Store half full Reading Done Ready Error	3.10.13
EOI and Bus Hold-off	K0 K1 K2 K3	Enable EOI and bus hold-off on X. Disable EOI, enable bus hold-off on X. Enable EOI, disable bus hold-off on X. Disable both EOI and bus hold-off on X.	3.10.14
Terminator	YmX YmnX YX	One terminator character Two terminator characters No terminator	3.10.15
Status	U0 U1 U2 U3 U4 U5 U6 U7	Send machine status word. Send error conditions. Send translator words. Send buffer size. Send average reading in buffer. Send lowest reading in buffer. Send highest reading in buffer. Send current value.	3.10.16

Table 3-11. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Multiplex	A0	Multiplexer disabled	3.10.17
	A1	Multiplexer enabled	
Delay	Wn	n=delay period (.000sec to 60sec.)	3.10.18
Self-test	J0	Test ROM, RAM, NVRAM.	3.10.19
Hit Button	Hn	Hit front panel button number n. (see Figure 3-13).	3.10.20
Display	Da	Display up to 14 character message. a=character.	3.10.21
	D	Cancel display mode.	
Reference Junction	O0	Measure reference junction.	3.10.22
	O1	Here is reference junction temperature using value.	
Exponential Filter	N0	Internal exponential filter off.	3.10.23
	N1	Internal exponential filter on.	

3.10.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 193 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 710 (END LINE)
OUTPUT 710;""X"" (END LINE)
```

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

Model 8573 Programming Example—Enter the following statements into the IBM computer:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=""X"":CALL IBWRT(M193%,CMD$)
        (RETURN)
```

When the return key is pressed the second time, the X character is transmitted to the instrument, although no mode changes occur because no other commands are transmitted. Note that the instrument remains in the listener idle state after the command is transmitted because IBWRT automatically sends UNT (Untalk) and UNL (Unlisten) at the end of the transmission sequence.

3.10.2 Function (F)

The function command allows the user to select the type of measurement made by the Model 193. 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 = Temp in ±F mode
F6 = Temp in ±C mode
F7 = ACV + DC
F8 = ACA + DC
F9 = Low Frequency ACV + DC
F10 = ACV dB
F11 = ACA dB
F12 = ACV + DC dB
F13 = ACA + DC dB

Upon power-up, or after the instrument receives a DCL or SDC command, the Model 193 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 710 (END LINE)
OUTPUT 710;''F0X'' (END LINE)
```

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

Model 8573 Programming Example—Place the instrument in the ohms function by pressing the OHMS button and enter the following statements into the computer keyboard:
```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$='' F0X'' : CALL IBWRT(M193%,CMD$)
                        (RETURN)
```

When the return key is pressed the second time, the instrument changes to the DC volts function.

3.10.3 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 3-12. 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 193 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 710 (END LINE)
OUTPUT 710;''R3X'' (END LINE)
```

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

Model 8573 Programming Example—Make sure the instrument is in the autorange mode. Now enter the following statements into the IBM-PC keyboard:
```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$='' R3X'' : CALL IBWRT(M193%,CMD$)
                        (RETURN)
```

When the return key is pressed the second time, the instrument cancels the autorange mode and switches to the R3 range.

Table 3-12. Range Command Summary

| Command | Range | | | | | |
	DCV	ACV	DCA	ACA	OHMS	TEMP
R0	Auto	Auto	Auto	Auto	Auto	Pt. 385
R1	200mV	2V	200 μA	200 μA	200 Ω	Pt. 392
R2	2 V	20V	2mA	2mA	2 kΩ	Type K
R3	20 V	200V	20mA	20mA	20 kΩ	Type J
R4	200 V	700V	200mA	200mA	200 kΩ	Type T
R5	1000 V	700V	2 A	2 A	2MΩ	Type E
R6	1000 V	700V	2 A	2 A	20MΩ	Type R
R7	1000 V	700V	2 A	2 A	200MΩ	Type S
R8	1000 V	700V	2 A	2 A	200MΩ	Type B

3.10.4 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 2.8.5 (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 affect 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 V2X Z2X 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 3.10.10 for more information on using the V command.

Upon power-up or after the instrument receives a DCL or SDC command, the Model 193 will return to the default condition. The value of V will reset to zero.

HP-85 Programming Example—Set the instrument to the 2VDC range. With the front panel ZERO button, disable the zero mode, if enabled, and enter the following statements into the HP-85 keyboard:

```
REMOTE 710 (END LINE)
OUTPUT 710;''U1X''(END LINE)
OUTPUT 710;''Z2X'' (END LINE)
```

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

Model 8573 Programming Example—Set the instrument to the 2VDC range. With the front panel ZERO button, disable the zero mode, if enabled, and enter the following statements into the computer keyboard:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''U1X'':CALL IBWRT(M193%,CMD$)
                  (RETURN)
CMD$=''Z2X'':CALL IBWRT(M193%,CMD$)
                  (RETURN)
```

When the return key is pressed the third time, the ZERO indicator will turn on with a zero baseline level of 1VDC. The zero value will also be stored in the zero program.

3.10.5 Filter (P)

The filter command controls the amount of filtering applied to the input signal. The Model 193 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 193 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 710 (END LINE)
OUTPUT 710;''P20X'' (END LINE)
```

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

Model 8573 Programming Example—With the front panel FILTER indicator off, enter the following statements into the computer:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''P20X'':CALL IBWRT(M193%,CMD$)
                  (RETURN)
```

When the return key is pressed the second time, the filter will enable and have a filter value of 20.

3.10.6 Rate (S)

The rate command controls the integration period and the usable resolution of the Model 193. The rate commands are as follows:

S0 = 318μmsec integration at 3½d resolution
S1 = 2.59msec integration at 4½d resolution
S2 – Line cycle integration* at 5½d resolution
S3 = Line cycle integration* at 6½d resolution
* 20msec for 50Hz and 16.6msec for 60Hz

Upon power-up or after the instrument receives a DCL or SDC command, the Model 193 will return to the default condition.

HP-85 Programming Example—Using the front panel RESOLN button, set the display of the Model 193 for 6½d resolution. Now enter the following statements into the HP-85:

```
REMOTE 710 (END LINE)
OUTPUT 710;''S1X'' (END LINE)
```

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

Model 8573 Programming Example—Using the front panel RESOLN button, set the display of the Model 193 to 5½d resolution and enter the following statements into the computer:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''S1X'':CALL IBWRT(M193%,CMD$)
                                 (RETURN)
```

When the return key is pressed the second time, the S1 rate will be selected.

3.10.7 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 193 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 193 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 193 will return to the default condition.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''T1X'' (END LINE)
```

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

```
ENTER 710;A$ (END LINE)
DISP A$ (END LINE)
```

In this example, the ENTER statement addresses the Model 193 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.

Model 8573 Programming Example—Place the instrument in the T1 mode with the following statements:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''T1X'':CALL IBWRT(M193%,CMD$)
                                 (RETURN)
```

The instrument can now be addressed to talk to trigger a conversion, and the resulting data displayed with the following statements:

```
RD$=SPACE$(20):CALL IBRD(M193%,RD$)
                                 (RETURN)
PRINT RD$ (RETURN)
```

Each time the IBRD function is called, the instrument is addressed to talk, at which time it is triggered. When the conversion is complete, the reading is sent out over the bus to the computer, which then displays the resulting data.

3.10.8 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 193 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—From the front panel, store some readings in the data store. Enter the following statements into the computer to read the stored reading in the first memory location of the buffer. The reading will be displayed on the computer CRT.

```
REMOTE 710 (END LINE)
OUTPUT 710;""B1X"" (END LINE)
ENTER 710; A$ (END LINE)
DISP A$ (END LINE)
```

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

Model 8573 Programming Example—From the front panel, store some readings in the data store. Enter the following statements into the computer to read the stored reading in the first memory location of the buffer. The reading will be displayed on the computer CRT.

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=""B1X"":CALL IBWRT(M193%,CMD$)
                (RETURN)
```

```
RD$=SPACE$(25):CALL IBRD(M193%,RD$)
                (RETURN)
PRINT RD$ (RETURN)
```

The second statement above programs the reading mode to access the buffer reading. The third statement addresses the instrument to talk and reads the data string from the instrument, while the fourth statement prints the data string on the computer CRT.

3.10.9 Data Store Interval (Q) and Size (I)

The data store is controlled by the interval command (Q) and the size command (I). It is important to be aware at this time that either command will start the storage process. Thus, if both the interval and the size are to be modified, they must be sent together in the same command string.

With the Q command, the user can select the interval that the instrument will store readings or select the one-shot mode. In the one-shot mode, 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 millisec (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.

To store readings at a selected interval (Qn), the instrument can be in any trigger mode. When the selected trigger occurs, the storage process will commence.

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 torage 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. The storage process will start when either the Q or I command is sent over the bus.
2. The data store is disable by sending an F command that places the instrument in a different function.
3. The instrument must be in a valid operating state in order to use the high speed data store capabilities. The high speed intervals are 1ms, 2ms, 3ms and 4ms. Valid commands are listed in Table 3-13.
4. With S2 or S3 asserted, the fastest valid storage interval (I) is 40msec. An interval less than 40msec will result in a short period error when the storage process is started. Readings will be stored as fast as the instrument can run.
5. Either during or after the storage process, readings may be recalled by using the B1 command as described in the last paragraph. Also, the highest, lowest and average reading is a full buffer can be recalled by suing the appropriate U commands. See paragraph 3.10.18 for information on using the U commands.

Upon power-up or after the instrument receives a DCL or SDC command, the Model 193 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 710	Send remote enable.
25 OUTPUT 710; ''M2X''	SRQ on buffer full.
30 OUTPUT 710; ''Q100I100X''	Set store size to 100 and data store to 0.1sec rate.
40 S=SPOLL(710)	Serial poll the 193.
50 IF NOT BIT(S,1) THEN 40	If not full, wait.
60 OUTPUT 710; ''B1G0X''	Set read mode to data store.
70 FOR I=1 TO 100	Loop 100 times.
80 ENTER 710;A$	Get a reading.
90 DISP A$	Display it.
100 NEXT I	Loop back and get next reading
110 END	

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 30), wait for memory to fill (lines 40 and 50), turn on the data store output (line 60), and then request and display all 100 readings (lines 70-100).

Model 8573 Programming Example—To demonstrate data store operation, load the modified DECL.BAS file and enter the program lines below:

Table 3-13. High Speed Data Store

Data Store Interval	Valid Data Store Size*	Valid Functions	Valid Ranges	Valid Reading Rates
Q1, Q2		F0, F1, F3	All, except	S0
Q3, Q4	I1 - I500	F4, F7, F8	R0	S0, S1

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

PROGRAM	COMMENTS
10 NA$=''GPIB0'' : CALL IBFIND(NA$, BRD0%)	Find the board descriptor.
20 NA$=''DEV0'' : CALL IBFIND(NA$, M193%)	Find the instrument descriptor.
30 U%=10 : CALL IBPAD (M193%,U%)	Set primary address to 10.
40 U%=1 : CALL IBSRE (BRD0%,U%)	Send remote enable.
45 CMD$=''M2X'' : CALL IBWRT(M193%,CMD$)	SRQ on buffer full.
50 CMD$=''Q100I100X'' : CALL IBWRT (M193%,CMD$)	Set store size to 100 and data store to 0.1sec rate.
60 CALL IBSRP (M193%,SB%)	Get status byte.
70 IF(SB% AND 2)=0 THEN 60	If not full, wait.
80 CMD$=''B1G2X'' : CALL IBWRT (M193%,CMD$)	Set read mode to data store.
90 FOR I=1 TO 100	Loop 100 times.
100 RD$=SPACE$(25) : CALL IBRD (M193%,RD$)	Get a reading.
110 PRINT RD$	Display the reading.
120 NEXT I	Go back and get another.
130 U%=0 : CALL IBONL (BRD0%,U%)	Close the board file.
140 CALL IBONL (M193%,U%)	Close the instrument file.

Press the IBM F2 key to run the program. The store size is defined (line 50), the store is enabled (line 50), the program waits for memory to fill (lines 60 and 70), the output is turned on (line 80), and 100 readings are then requested and displayed (lines 90-120).

3.10.10 Value (V) and Calibration (C)

One advanced feature of the Model 193 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.

The V command is also used to program a zero value (see paragraph 3.10.4) and to set the reference junction temperature needed to make thermocouple (TC) measurements (see paragraph 3.10.22).

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

Vnn.nnnnn

Vn.nnnnnnE+n

Thus, the following two commands would be equivalent:

V20

V2.0E+1

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 20.00000 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)

The following example first sends a calibration value of 2 and then a calibration of 0.

V2XC0X

V0XC1X

If the calibration value is greater than 2200000 counts (at 6½d resolution) an IDDCO error message will be displayed on the Model 193 (see paragraph 3.11.1).

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.

NOTE
The calibration switch must be in the UNLOCK position before calibration can be accomplished.

HP-85 Programming Example—The following statements can be used to calibrate the instrument on the 200VDC range:

```
REMOTE 710 (END LINE)
OUTPUT 710;''U200XC0X'' (END LINE)
OUTPUT 710;''U0XC1X'' (END LINE)
```

When the second statement is executed, calibration of the high end of the 200VDC range is performed, assuming that the correct calibration value is applied to the instrument. When the third statement is executed, calibration of the low end of the 200VDC range is performed and permanent storage of the two calibration points take place.

Model 8573 Programming Example—Use the following statements to calibrate the 200VDC range:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''U200XC0X'' : CALLIBWRT
      (M193%,CMD$) (RETURN)
CMD$=''U0XC1X'' : CALLIBWRT
      (M193%,CMD$) (RETURN)
```

When the A second statement is executed, calibration of the high end of the 200VDC range is performed, assuming that the correct calibration value is applied to the instrument. When the third statement is executed, calibration of the low end of the 200VDC range is performed and permanent storage of the two calibration points takes place.

3.10.11 Default Conditions (L)

The L0 command allows the user to return the instrument to the factory default conditions. Factory default conditions are set at the factory and are listed in Table 3-10. The instrument will then power up to these default conditions. The current IEEE address and line frequency setting of the instrument are not affected by the L0 command.

The L1 command is used to save the current instrument conditions. The instrument will then power up to these default conditions.

The L command options are as follows:

L0=Restore instrument to factory power-up default conditions.

L1=Store present machine states as the power-up default conditions.

HP-85 Programming Example—Set the Model 193 to the ohms function, and enable zero and filter. Now, enter the following statements into the computer:

```
REMOTE 710 (END LINE)
OUTPUT 710;''L1X'' (END LINE)
```

After pressing END LINE the second time, cycle power on the Model 193 and note that the instrument returns to the conditions initially set in this example.

Model 8573 Programming Example—Set the Model 193 to the ohms function, and enable zero and filter. Now, enter the following statements into the computer:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''L1X'' : CALL IBWRT(M193%,CMD$)
              (RETURN)
```

After pressing END LINE the second time, cycle power on the Model 193 and note that the instrument returns to the conditions initially set in this example.

3.10.12 Data Format (G)

The G command controls the format of the data that the instrument sends over the bus. Readings may be sent with or without prefixes. Prefixes are the mnemonics preceding the reading and the buffer memory location. Figure 3-9 further clarifies the general data format. The G commands are as follows:

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 193 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 710 (END LINE)
OUTPUT 710;''B0XG1X'' (END LINE)
ENTER 710;A$ (END LINE)
DISP A$ (END LINE)
```

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.

Model 8573 Programming Example—Type in the following statements to place the instrument in the G1 mode:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''B0XG1X'' : CALL IBWRT
   (M193%,CMD$) (RETURN)
RD$=SPACE$(20) : CALL IBRD(M193%,CMD$)
   (RETURN)
PRINT RD$ (RETURN)
```

When the second statement is executed, the instrument will be placed in the G1 mode. The last two lines obtain the data string from the instrument and display it on the CRT. Note that the prefix and suffix are absent from the data string.

3.10.13 SRQ Mask (M) and Status Byte Format

The SRQ command controls which of a number of conditions within the Model 193 will cause the instrument to request service from the conroller by asserting SRQ. Once an SRQ is generated, that status byte can be checked to determine if the Model 193 was the instrument that asserted SRQ, and if so, what conditions can be checked by using the U1 command, as described in paragraph 3.10.16.

The Model 193 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 an IDDC, IDDCO, No Remote error occurs, or Self-Test fails.
3. When the data store is full.
4. When the data store is ½ full.
5. If a trigger overrun error occurs.
6. When the bus is ready.

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

SRQ Mask—The Model 193 uses an internal mask to determine which conditions will cause an SRQ to be generated. Figure 3-10 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 3-14. 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 M5X. To disable SRQ, send M0X. This command will clear all bits in the SRQ mask.
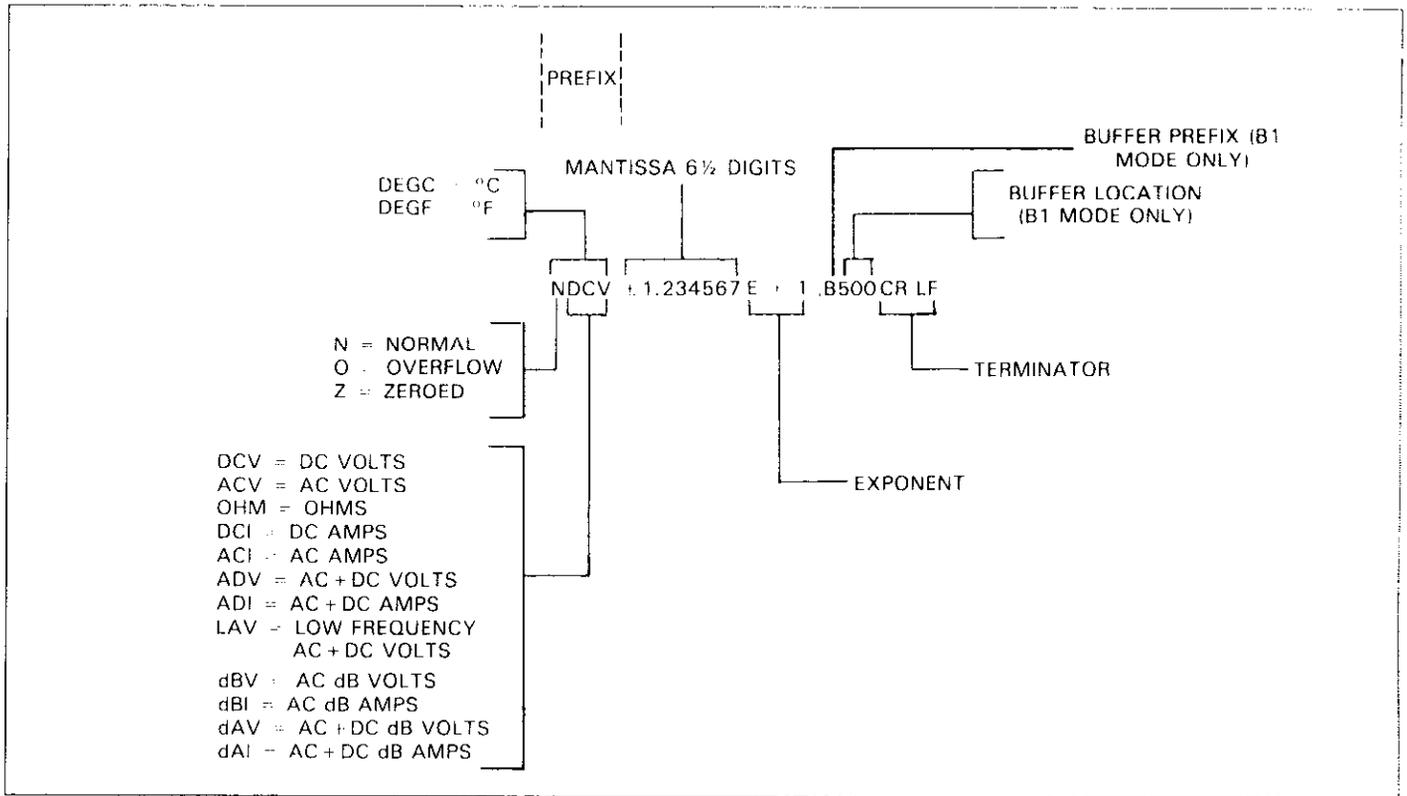
Figure 3-9. General Data Format
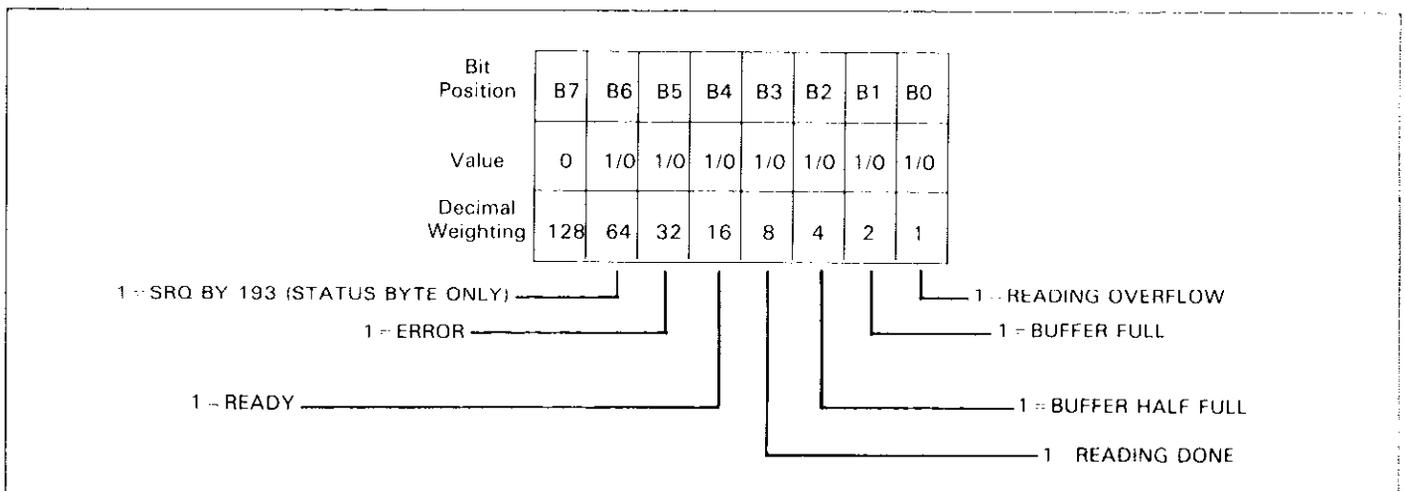
Figure 3-10. SRQ Mask and Status Byte Format

Table 3-14. SRQ Command Parameters

Command	Condition to Generate SRQ
M0	Disable
M1	Reading Overflow
M2	Data Store Full
M4	Data Store ½ Full
M8	Reading Done
M16	Ready
M32	Error

Status Byte Format—The status byte contains information relating to data and error conditions within the instrument. The general format of the status byte (which is obtained by using the serial polling sequence, as described in paragraph 3.9.8) is shown in Figure 3-10.

The bits in the status (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 ½ 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 Overrun
2. Short Period
3. Uncalibrated
4. Needs Model 1930
5. Needs Model 1931
6. Needs Model 1930 and 1931
7. Cal locked
8. Conflict
9. Translator
10. No Remote
11. IDDC
12. IDDCO
13. String Overflow

The nature of the error can be determined with the U1 command as explained in paragraph 3.10.16. An explanation of each error can also be found in paragraph 3.10.16.

Bit 6 (SRQ)—Provides a means to determine if SRQ was asserted by the Model 193. 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 710 @ CLEAR 7	Set up for remote operation, clear instrument.
20 OUTPUT 710; ''M32X''	Program for SRQ on IDDCO.
30 OUTPUT 710; ''K5X''	Attempt to program illegal option.
40 S=SPOLL(710)	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 enetered 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.

Model 8573 Programming Example—Load the modified DECL.BAS file into the IBM computer (see the Model 8573 Instruction Manual) and add the lines below:

PROGRAM	COMMENTS
10 NA$=''GPIB0'' : CALL IBFIND (NA$,BRD0%)	Find the board descriptor.
20 NA$=''DEV0'' : CALL IBFIND(NA$,M193%)	Find the instrument descriptor.
30 U%=10 : CALL IBPAD (M193%,U%)	Set primary address to 10.
40 U%=1 : CALL IBSRE (BRD0%,U%) : CALL IBCLR(M193%)	Send remote enable, clear instrument.
50 CMD$=''M32X'' : CALL IBWRT (M193%,CMD$)	Program for SRQ on IDDCO.
60 CMD$=''K5X'' : CALL IBWRT(M193%,CMD$)	Attempt to program illegal option.
70 PRINT''B7 B6 B5 B4 B3 B2 B1 B0''	Identify the bits.
80 MASK%=128	Define bit mask.
90 CALL IBRSP (M193%,SB%)	Serial poll the instrument.
95 IF SB% AND 32)=0 THEN 90	Wait for SRQ error.
100 FOR I=1 TO 8	Loop eight times.
110 IF (SB% AND MASK%) =0 THEN PRINT ''0'' ; ELSE PRINT ''1 '' ;	Mask off the bits and display them.
120 MASK%=MASK%/2	
130 NEXT I	
140 PRINT	
150 U%=0 : CALL IBONL (BRD0%,U%)	Close the board file.
160 CALL IBONL (M193%,U%)	Close the instrument file.

To run the program press the F2 function key. After placing the instrument in remote (line 40), the program then sets the SRQ mode (line 50). An attempt is made to program an illegal command option (line 60), at which point the instrument generates an SRQ and sets the error and SRQ bits in its status byte. Other bits may also be set depending on instrument status. Lines 70-90 display the bit positions, set the mask value to the most significant bit, and serial poll the instrument. Since the status byte is in decimal form, lines 100-130 are used to generate the binary equivalent of the status byte value.

3.10.14 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 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 193. 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 3-15 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.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''K2X'' (END LINE)
```

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.

Model 8573 Programming Example—To place the instrument in the K2 mode, enter the following statements into the IBM computer:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''K2X'' : CALL IBWRT(M193%,CMD$)
               (RETURN)
```

The Model 193 will be placed in the K2 mode when the second statement is executed. The EOI mode will be enabled, but the bus hold off will be disabled.

Table 3-15. Bus Hold-off Times

Commands	Bus Held Off On X for:
Function (F)	160mS typical (ACV and ACA functions 660mS typical)
Calibrate (C)	Depends on range and function as the calibration is actually performed during the hold off time. ex: 1000VDC = 9sec. 200MΩ = 19sec
Other	117mS to 200mS typical depending on the command sent.

3.10.15 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 ASCII character. The default terminator sequence is the commonly used carriage return, line feed (CR LF) sequence (CR=ASCII 13; LF=ASCII 10). The terminator will assume this default value upon power up, or after the instrument receives a DCL or SDC command.

The terminator sequence may be changed by sending the desired one or two characters after the Y command. Any ASCII character, except one of the following may be used:

1. All capital letters
2. All numbers
3. Blank
4. + - / , . and e

Special command sequences will program the instrument as follows:

1. YmX = One terminator character.
2. YmnX = Two terminator characters.
3. YX = No terminator.

NOTE
Most controllers use the CR or LF character to terminate their input sequences. Using a nonstandard terminator may cause the controller to hang up unless special programming is used.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''Y'';CHR$(10);CHR$(13);
         ''X'' (END LINE)
```

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 (LF CR) sequence.

Model 8573 Programming Example—Use the following statements to reverse the default terminator sequence:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''Y''+CHR$(10)+CHR$(13)+''X'' :
     CALL IBWRT(M193%,CMD$) (RETURN)
```

The terminator sequence will be reversed when the second statement is executed.

3.10.16 Status (U)

The status command allows access to information concerning various operating modes and conditions of the Model 193. 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 current value (V).

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 3-11. 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 3-11.

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 returned terminator characters are derived by ORing the actual terminator byte values with $30. For example, a CR character has a decimal value of 13, which equals $0D in hexadecimal notation. ORing this value with $30 yields $3D, or 61_{10}, which prints out as an ASCII equal sign (=). This terminator conversion step is necessary to convert the standard terminators into displayable form, as they will not normally print out on a computer CRT.

The U1 command allows access to Model 193 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 3-12 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 status (serial poll) byte, and the instrument can be programmed to generate an SRQ when an error condition occurs. See

paragraph 3.10.15. Note that all bits in the error condition word and the status 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:

Trigger Overrun—Set when the instrument receives a trigger while it is still processing a reading from a previous trigger.

Short Period—Set when the instrument cannot run as fast as the selected data store interval.

String Overflow—Set if more than a 14 character message is sent using the display (D) command.

Uncalibrated—Set when E²PROM memory fails the self test.

Needs Model 1930—Set when the ACV function is selected with the ACV option not installed.

Needs Model 1931—Set when the DCA function is selected with the current option not installed.

Needs Model 1930 and 1931—Set when the ACA function is selected with both the ACV and current options not installed.

Cal Locked—Set when trying to calibrate the instrument with the calibration switch in the locked position.

Conflict—Set when trying to calibrate the instrument while it is in an improper state.

Translator—Set when trying to define a translator word that already exists or when the translator buffer is full.

No Remote—Set when a progamming command is received when REN is false.

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

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.

FACTORY DEFAULT																			
1	0	00	0	0	0	00 1	00	000000	5	3	6	00000	0	0/1 I	0/1 ACV	0/1 CAL	0/1 F/R	=:	
193	A	B	FF	G	J	K	MM N	PP	QQQQQQ	R	S	T	WWWWW	Z	OP	OP	SW	SW	YY

MODEL NUMBER PREFIX (193)

MULTIPLEX (A)
0 = DISABLED
1 = ENABLED

READING MODE (B)
0 = A/D CONVERTER
1 = DATA STORE (BUFFER)

FUNCTION (F)
0 = DC VOLTS
1 = AC VOLTS
2 = OHMS
3 = DC CURRENT
4 = AC CURRENT
5 = TEMP. IN °F
6 = TEMP. IN °C
7 = ACV + DC
8 = ACA + DC
9 = LOW FREQ. ACV + DC
10 = ACV dB
11 = ACA dB
12 = ACV + DC dB
13 = ACA + DC dB

DATA FORMAT (G)
0 = RDG WITH PREFIXES
1 = RDG WITHOUT PREFIXES
2 = BUFFER RDGS WITH PREFIXES AND BUFFER LOCATIONS
3 = BUFFER RDGS WITHOUT PREFIXES AND WITH BUFFER LOCATIONS
4 = BUFFER RDGS WITH PREFIXES AND WITHOUT BUFFER LOCATIONS
5 = BUFFER RDGS WITHOUT PREFIXES AND BUFFER LOCATIONS

SELF-TEST (J)
0 = INACTIVE
1 = ROM, RAM and E²PROM PASSED
2 = E²PROM FAILED

EOI; BUS HOLD-OFF (K)
0 = EOI AND HOLD-OFF
1 = NO EOI AND HOLD-OFF
2 = EOI AND NO HOLD-OFF
3 = NO EOI AND NO HOLD-OFF

SRQ (M)
M00 = DISABLED
M01 = READING OVERFLOW
M02 = DATA STORE FULL
M04 = DATA STORE HALF FULL
M08 = READING DONE
M16 = READY
M32 = ERROR

EXPONENTIAL FILTER (N)
0 = DISABLED
1 = ENABLED

FILTER (P)
00 = FILTER DIABLED
nn = FILTER ENABLED WITH FILTER VALUE OF nn (D1 to 99)

DATA STORE RATE (Q)
000000 = ONE-SHOT MODE
nnnnnn = Interval (000001msec to 999999sec)

RANGE (R)

	DCV	ACV	DCA	ACA	OHMS	TEMP.
0 =	AUTO	AUTO	AUTO	AUTO	AUTO	PT.385
1 =	200mV	2V	200 μA	200 μA	200 Ω	PT.392
2 =	2 V	20V	2mA	2mA	2 kΩ	TypeK
3 =	20 V	200V	20mA	20mA	20 kΩ	TypeJ
4 =	200 V	700V	200mA	200mA	200 kΩ	TypeT
5 =	1000 V	700V	2 A	2 A	2MΩ	TypeE
6 =	1000 V	700V	2 A	2 A	20MΩ	TypeR
7 =	1000 V	700V	2 A	2 A	200MΩ	TypeS
8 =	1000 V	700V	2 A	2 A	200MΩ	TypeB

RATE (S)
0 = 1msec INTEGRATION, 3½d
1 = 4msec INTEGRATION, 4½d
2 = LINE CYCLE INTEGRATION, 5½d
3 = 100msec INTEGRATION, 6½d

TRIGGER (T)
0 = CONTINUOUS ON TALK
1 = ONE-SHOT ON TALK
2 = CONTINUOUS ON GET
3 = ONE-SHOT ON GET
4 = CONTINUOUS ON X
5 = ONE-SHOT ON X
6 = CONTINUOUS ON EXTERNAL TRIGGER
7 = ONE-SHOT ON EXTERNAL TRIGGER

DELAY (W)
nnnnn = 00.000 TO 60.000SEC

ZERO (Z)
0 = DISABLED
1 = ENABLED
2 = ENABLED USING ZERO VALUE

CURRENT OPTION
0 = NOT INSTALLED
1 = INSTALLED

ACV OPTION
0 = NOT INSTALLED
1 = INSTALLED

CALIBRATION SWITCH
0 = LOCKED POSITION
1 = UNLOCKED POSITION

FRONT/REAR SWITCH
0 = FRONT INPUT TERMINALS SELECTED
1 = REAR INPUT TERMINALS SELECTED

TERMINATOR (Y)
YmX = ONE CHARACTER
YmnX = TWO CHARACTERS
YX = NO TERMINATOR
: = CR LF

Figure 3-11. U0 Status Word and Default Values

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 current value. The value can be a calibration value, zero value or temperature compensation value.
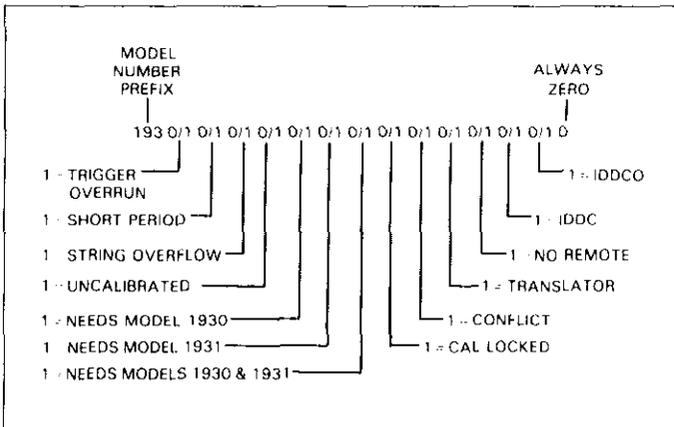
Figure 3-12. U1 Error Status Word

HP-85 Progamming Example—Enter the following statements into the computer to obtain and display all the status conditions (U0 through U7) of the Model 193.

PROGRAM	COMMENTS
10 REMOTE 710	Send remote enable.
20 DIM A$[40]	
30 OUTPUT 710; ''U0X''	Send U0 command.
40 DISP''MDL ABFFGJKM MNPPQQQQQQRSTUUUU UZ*****YY''	Display U0 word values.
50 ENTER 710; A$	Obtain U0 status from instrument.
60 DISP A$	Display U0 status word.
70 OUTPUT 710; ''U1X''	Send U1 command.
80 ENTER 710; A$	Get error condition word.
90 DISP A$	Display error condition word.
100 OUTPUT 710; ''U2X''	Send U2 command.
110 ENTER 710; A$	Get data condition.
120 DISP A$	Display data condition.
130 OUTPUT 710; ''U3X''	Send U3 command.
140 ENTER 710; A$	Get data condition.
150 DISP A$	Display data condition.
160 OUTPUT 710; ''U4X''	Send U4 command.
170 ENTER 710; A$	Get data condition.
180 DISP A$	Display data condition.
190 OUTPUT 710; ''U5X''	Send U5 command.
200 ENTER 710; A$	Get data condition.
210 DISP A$	Display data condition.
220 OUTPUT 710; ''U6X''	Send U6 command.
230 ENTER 710; A$	Get data condition.
240 DISP A$	Display data condition.
250 OUTPUT 710; ''U7X''	Send U7 command.
260 ENTER 710; A$	Get data condition.
270 DISP A$	Display data condition.
280 ENTER 710; A$	Get normal reading.
290 DISP A$	Display normal reading
300 END	

After entering the program, run it by pressing the HP-85 RUN key. All of the status conditions of the Model 193 will be listed on the CRT display. To show that status is transmitted only once, a normal reading is requested and displayed last.

Model 8573 Programming Example—Obtain and display all the status conditions (U0 through U7) of the Model 193 as follows: Load the modified DECL.BAS file from disk (see the Model 8573 Instruction Manual) and add the lines from the program below:

PROGRAM	COMMENTS
10 NA$=''GPIB0'':CALL IBFIND(NA$,BRD0%)	Find the board descriptor.
20 NA$=''DEV0'':CALL IBFIND(NA$,M193%)	Find the instrument descriptor.
30 U%=10:CALL IBPAD (M193%,U%)	Set primary address to 10.
40 U%=1:CALL IBSRE (BRD0%,U%)	Send remote enable.
50 CMD$=''U0X'':CALL IBWRT(M193%,CMD$)	Send U0 command.
60 PRINT ''ᴍᴅʟ ABFFGJK MMNPPQQQQQRSTWWWW WZ****YY''	Identify word bytes.
70 RD$=SPACE$(40): CALL IBRD (M193%,RD$)	Get status word from instrument.
80 PRINT RD$	Display status word.
90 CMD$=''U1X'':CALL IBWRT(M193%,CMD$)	Send U1 command.
100 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get error condition word.
110 PRINT RD$	Display error condition word.
120 CMD$=''U2X'':CALL IBWRT(M193%,CMD$)	Send U2 command.
130 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
140 PRINT RD$	Display data condition.
150 CMD$=''U3X'':CALL IBWRT(M193%,CMD$)	Send U3 command.
160 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
170 PRINT RD$	Display data condition.
180 CMD$=''U4X'':CALL IBWRT(M193%,CMD$)	Send U4 command.
190 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
200 PRINT RD$	Display data condition.
210 CMD$=''U5X'':CALL IBWRT(M193%,CMD$)	Send U5 command.
220 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
230 PRINT RD$	Display data condition.
240 CMD$=''U6X'':CALL IBWRT(M193%,CMD$)	Send U6 command.
250 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
260 PRINT RD$	Display data condition.
270 CMD$=''U7X'':CALL IBWRT(M193%,CMD$)	Send U7 command.
280 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get data condition.
290 PRINT RD$	Display data condition.
300 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get normal reading.
310 PRINT RD$	Display normal reading.
320 U%=0:CALL IBONL (BRD0%,U%)	Close the board file.
330 CALL IBONL (M193%,U%)	Close the instrument file.

Press the computer F2 key to run the program. All of the status conditions of the Model 193 will be listed on the CRT display. To show that status is transmitted only once, a normal reading is requested and displayed last.

3.10.17 Multiplex (A)

The Model 193 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 95 (paragraph 2.8.14) 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 710 (END LINE)
OUTPUT 710;''A0X'' (END LINE)
```

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

Model 8573 Programming Example—Disable the multiplex by entering the following statements into the computer:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''A0X'':CALL IBWRT(M193%,CMD$)
(RETURN)
```

When the second statement is executed, the multiplexer routines will disable.

3.10.18 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 seconds. The range of programmable delay values is from 0.000sec to 60sec.

Examples: For a delay of 0.002sec send W.002X.
For a delay of 30.05sec send W30.05X.
For a delay of 60sec send W60X.

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 710 (END LINE)
OUTPUT 710;''W.250X'' (END LINE)
```

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

Model 8573 Programming Example—Enter the following statements into the computer to program the instrument for a 250msec delay period:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''W.250X'':CALL IBWRT
(M193%,CMD$) (RETURN)
```

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

3.10.19 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 193 performs the following tests:

1. ROM Test
2. RAM Test
3. E^2PROM 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^2PROM fails, the message "UNCALIBRATED" will be displayed and the J byte in the U1 status word will be set to 2. An E^2PROM failure is also flagged in the U1 status word. If ROM and RAM fails, the instrument will lock up.

See paragraph 6.9.2 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 193 self-test:

```
REMOTE 710 (END LINE)
OUTPUT 710;''J0X'' (END LINE)
```

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. This byte may be cleared by reading the U0 status word (see paragraph 3.10.16).

Model 8573 Programming Example—Enter the following statements into the computer to run the self-test:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''J0X'' : CALL IBWRT(M193%,CMD$)
                              (RETURN)
```

When the return 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. This byte may be cleared by reading the U0 status word (see paragraph 3.10.16).

3.10.20 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 3-13.

Examples:

H3X—Selects the ACA function.

H0X—Selects the DCV function.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''H2X'' (END LINE)
```

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

Model 8573 Programming Example—Enter the following statements into the computer to place the instrument in the ohms function.

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''H2X'' : CALL IBWRT(M193%,CMD$)
                              (RETURN)
```

When the second statement is executed, the instrument will be placed in the ohms function.
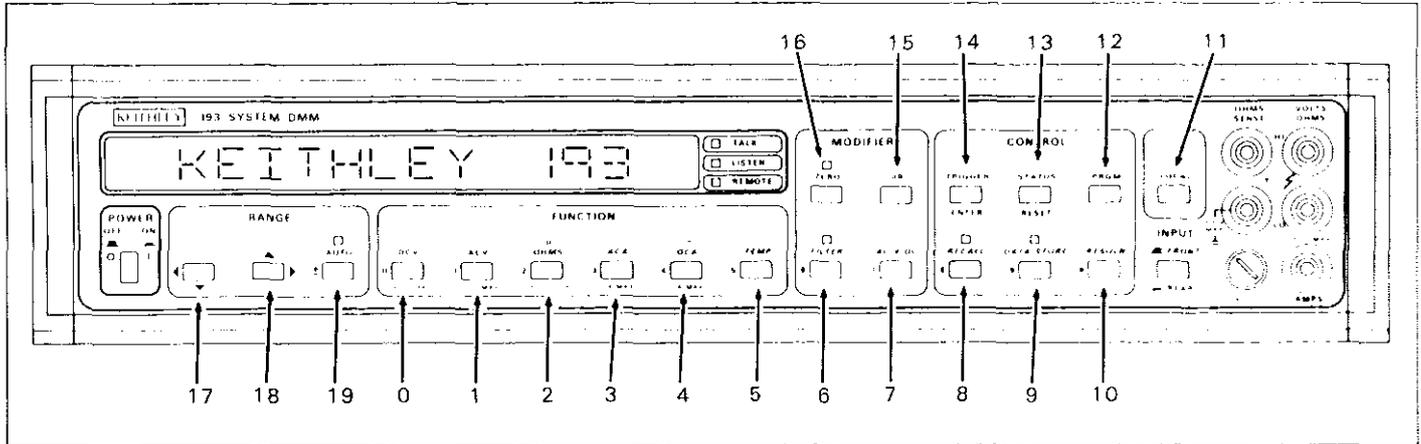
Figure 3-13. Hit Button Command Numbers

3.10.21 Display (D)

The display command controls the ASCII messages that can be placed onto the Moel 193 display. The Model 193 can only display messages in upper case. Messages entered in lower case will automatically be converted to upper case. Messages are controlled with the following commands:

Da = DIsplay character "a", where "a" represents a printable ASCII character. Up to 14 characters (including blanks may be sent.

D = Restores display back to normal.

Note: 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 send the message "I NEED IT BAD" starting at the second display character (one space), send the following command string:

'' D@I@NEED@IT@BAD%''

Spaces in the command string, as shown in the following examples, are ignored.

HP-85 Programming Example—Enter the following statements into the computer to display the message "KEITHLEY 193":

```
REMOTE 710 (END LINE
OUTPUT 710;''D KEITHLEY@193 %''
(END LINE)
```

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 710;''D%'' (END LINE)
```

Model 8573 Programming Example—Enter the following statements into the computer to display the message "KEITHLEY 193":

```
U%=1 CALL IBSRE(BRD0% ,U%) (RETURN)
CMD$=''D KEITHLEY@193 %'' CALL IBWRT
(M193%,CMD$) (RETURN)
```

When the second statement is executed, the instrument will diaplay its model number.

Display operation may be returned to normal operation with the following statement:

```
CMD$=''D%'' CALL IBWRT(M193%,CMD$)
(RETURN)
```

3.10.22 Reference Junction (O)

The Model 193 can make temperature measurements using Type K, J, T, E, R, S and B thermocouples (TC's). In order to make TC temperature measurements the Model 193 must know the temperature of the reference junction. When using the Keithley Model 705 or 706 Scanner with the Model 7057A TC Scanner Card installed, the Model 193 can measure the reference junction. However, if other TC setups are used, the Model 193 must be told the temperature of the reference junction. The following two commands are used to acquire the reference junction temperature:

O0 = Measure the reference junction.

O1 = Here is the reference junction temperature using Value (V).

The O0 command measures the reference junction temperature and automatically makes the calculation for the selected TC type. The O0 command can only be used with the Model 705 or 706 with the Model 7057A installed.

The O1 command is used for all other TC setups and is used in conjunction with the V command. The V command inputs the known reference junction temperature to the Model 193, and the O1 command enters the value and makes the required calculation for the selected TC type.

NOTE
Reference junction measurements should be made at <30sec intervals due to possible reference junction temperature drift caused by ambient temperature variations.

Perform the following procedure to make thermocouple measurements using the Model 705 Scanner with the Model 7057A Thermocouple Scanner Card installed:

1. Select the temperature measurement mode by sending F5X (for °F) or F6X (for °C) over the IEEE-488 bus.
2. Send one of the following commands over the bus to select the desired thermocouple type:
   R2X = Type K
   R3X = Type J
   R4X = Type T
   R5X = Type E
   R6X = Type R
   R7X = Type S
   R8X = Type B
3. Connect the OUTPUT of the thermocouple scanner card to the VOLTS HI and LO input terminals of the Model 193 using copper test leads.
4. Connect a thermocouple to the desired channel (2 through 10) of the thermocouple card.
5. Close channel 1 of the scanner, which is connected to the thermistor bridge of the scanner card.
6. Send the following command over the IEEE-488 bus to measure the reference junction temperature on the scanner card: O0X.
7. Set the Model 705 to the channel that has the thermocouple connected to it and close that channel.
8. Thermocouple temperature measurements can now be taken directly from the display of the Model 193.

HP-85 Programming Example—With the Models 705 and 7057A connected to the instrument, connect a Type K thermocouple to channel 2 of the scanner card. Make sure the IEEE address of the Model 705 is at 17. Enter the following program into the computer to make Type K thermocouple temperature measurements.

PROGRAM	COMMENTS
10 REMOTE 710,717	Send remote enable.
15 CLEAR 7	Clear all devices.
20 OUTPUT 710 ; ''F5R2X''	Set 193 to Type KTC and °F.
30 OUTPUT 717 ; ''B1C1X''	Close channel 1 of 705.
40 OUTPUT 710 ; ''O0X''	Measure reference junction.
50 OUTPUT 717 ; B2C2X''	Close channel 2 of scanner.
70 END	

Run the program by pressing the RUN key. The Model 193 will be configured for Type K thermocouples, read the reference junction temperature and then take one temperature measurement.

Model 8573 Programming Example—The following program will display one temperature measurement on the IBM CRT. With the Models 705 and 7057A connected to the Model 193, connect a type K thermocouple to channel 2 of the scanner card. Make sure the IEEE address of the Model 705 is at 17. Load the modified DECL.BAS file and enter the following lines:

PROGRAM	COMMENTS
10 NA$=''DEV1'' : CALL IBFIND(NA$,M705%)	Find 705 descriptor.
20 NA$=''DEV2'' : CALL IBFIND(NA$,M193%)	Find 193 descriptor.
30 U%=17 : CALL IBPAD (M705%,U%)	Set primary address to 17.
40 U%=10 : CALL IBPAD (M193%,U%)	Set primary address to 10.
50 U%=1 : CALL IBSRE (BRD0%,U%)	Send remote enable.
60 CALL IBCLR(705%)	Clear 705.
70 CALL IBCLR(193%)	Clear 193.
80 CMD$=''F6R2X'' : CALL IBWRT(M193%,CMD$)	Set 193 for Type K TCs.
90 CMD$=''B1C1X'' : CALL IBWRT(M705%,CMD$)	Close channel 1 of 705.
100 CMD$=''O0X'' : CALL IBWRT(M193%,CMD$)	Measure reference junction.
110 CMD$=''B2C2X'' : CALL IBWRT(M705%,CMD$)	Close channel 2 of 705.
120 U%=0 : CALL IBONL (BRD0%,U%)	Close the board file.
130 CALL IBONL(M193%,U%)	Close the 193 file.
140 CALL IBONL(M705%,U%)	Close the 705 file.

To run the program press the F2 function key. The Model 193 will be configured for type K thermocouples; read the reference junction temperature and then take one temperature measurement.

Use the following basic procedure to make TC temperature measurements using the O1 command:

1. Measure and note the temperature of the reference junction of the TC setup to be used.
2. Send the appropriate F and R commands over the bus to select the desired scale and TC type.
3. Connect the TC setup to the input of the Model 193.
4. Using the V command, send the noted reference junction temperature over the bus to the Model 193. Send the value in °C if F6 was asserted and send the value if °F if F5 was asserted. For example, if the instrument is in the °C temperature mode (F6) and the reference temperautre is 25.3°C, then send the following command over the bus: V25.3X.
5. Now send the following command to enter the temperature value and make the required calculation for the selected TC type: O1X.
6. TC temperature can now be taken directly from the display of the Model 193.

3.10.23 Exponential Filter (N)

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

N0 = Internal exponential filter off
N1 = Internal exponential filter on

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

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

```
REMOTE 710 (END LINE)
OUTPUT 710; ''N0X'' (END LINE)
```

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

Model 8573 Progamming Example—Enter the following statements into the computer to turn off the exponential filter:

```
U%=1:CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''N0X'':CALL IBWRT(M740%,CMD$)
                (RETURN)
```

When the return key is pressed the second time, the exponential filter will disable.

3.11 FRONT PANEL MESSAGES

The Model 193 has a number of front panel messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that occur when sending device-dependent commands to the instrument.

The following paragraphs describe the front panel error messages associated with IEEE-488 programming.

3.11.1 Bus Error

A bus error will occur if the instrument receives a device-dependent command when it is not in remote, or if an illegal device-dependent command (IDDC) or illegal device-dependent command option (IDDCO) is sent to the instrument. Under these conditions, the complete command string will be rejected and one of the following messages will be displayed:

<div align="center">

NO REMOTE

IDDC

IDDCO

</div>

NOTE
Selecting the ACV, ACA or DCA function over the bus with the appropriate options not installed, will result in an IDDCO message.

In addition, the error bit and pertinent bits in the U1 word will be set (paragraph 3.10.16) and the instrument can be programmed to generate an SRQ under these conditions (paragraph 3.10.13).

A no remote error can occur when a command is sent to the instrument when the REN line is false. Note that the state of REN is only tested when the X character is received. An IDDC error can occur when an invalid command such as E1X is transmitted (this command is invalid because the instrument has no command associated with that letter). Similarly, an IDDCO error occurs when an invalid option is sent with a valid command. For example, the command T9X has an invalid option because the instrument has no such trigger mode.

HP-85 Programming Example—To demonstrate a bus error, send an IDDC with the following statements:

```
REMOTE 710 (END LINE)
OUTPUT 710;''E1X'' (END LINE)
```

When the second statement is executed, the bus error message appears on the display for about one second.

Model 8573 Programming Example—Type in the following statements to demonstrate a bus error by sending an IDDC:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''E1X'' : CALL IBWRT(M193%,CMD$)
                              (RETURN)
```

The bus error message will be displayed for about one second when the second statement in executed.

3.11.2 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 effect 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:

<div align="center">TRIG-OVERRUN</div>

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''T3X'' (END LINE)
TRIGGER 710 @ TRIGGER 710 (END LINE)
```

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

Model 8573 Programming Example—Enter the following statements into the computer to demonstrate the trigger overrun message:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''T3X'' : CALL IBWRT(M193%,CMD$)
                              (RETURN)
CALL IBTRG(M193%) : CALL IBTRG(M193%)
                              (RETURN)
```

The trigger overrun error message will be displayed after the third line is executed.

3.12 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
S0T1X	3½d mode	12msec
S1T1X	4½d mode)	15msec
S2T1X	5½d mode	30msec
S3T1X	6½d mode	1.1sec

*Commands not listed are at factory default.

3.13 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 3-17.

3.13.1 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.

<div align="center">"ALIAS SETUP1 F1R0X ;"</div>

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 the error message "TRANSLATOR-ERR" to be displayed briefly. To clear the error, keep sending an "X" over the bus until the Translator error message no longer occurs.
2. A Translator error automatically takes the instrument out of the NEW mode and places it in the OLD mode. See paragraph 3.13.2 for an explanation on the NEW and OLD modes.
3. A Translator word cannot exceed 32 characters.
4. The Translator buffer can hold approximately 100 18-character Translator words. When the buffer is full, the message "TRANSLATOR-ERR" will be displayed.
5. The letter X cannot be used in Translator words.
6. The Model 193 will not recognize an undefined Translator word sent over the bus.
7. 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 3.13.2 for an explanation of NEW.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''ALIAS SETUP1 F1R0X;''
              (END LINE)
OUTPUT 710;''SETUP1'' (END LINE)
```

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).

Model 8573 Programming Example—Enter the following program statements into the computer to define a Translator word (SETUP 1) to emulate the command string F1R0X:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$='' ALIAS SETUP1 F1R0X ;'' : CALL
     IBWRT(M193%,CMD$) (RETURN)
CMD$=''SETUP1'' : CALL IBWRT
         (M193%,CMD$) (RETURN)
```

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

3.13.2 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 3.13.3.

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 710 (END LINE)
OUTPUT 710;''NEW'' (END LINE)
```

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

Model 8573 Programming Example—Enter the following program statements into the computer to place the instrument in the NEW mode:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''NEW'' : CALL IBWRT(M193%,CMD$)
              (RETURN)
```

When the return key is pressed the second time, the instrument will go into the NEW mode.

3.13.3 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.

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

```
REMOTE 710 (END LINE)
OUTPUT 710;''ALIAS SETUP1 F1X ;''
            (END LINE)
OUTPUT 710;''ALIAS SETUP2 R0X ;''
            (END LINE)
OUTPUT 710;''ALIAS SETUP3 NEW SETUP1 NEW
       SETUP2 ;'' (END LINE)
```

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).

Model 8573 Programming Example—The following program statements will create two Translator words and then combine them to form a third Translator word:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$='' ALIAS SETUP1 F1X ;'' : CALL IBWRT
      (M193%,CMD$) (RETURN)
CMD$='' ALIAS SETUP2 R0X ;'' : CALL IBWRT
      (M193%,CMD$) (RETURN)
   CMD$='' ALIAS SETUP3 NEW SETUP1 NEW
  SETUP2 ;'' : CALL IBWRT(M193%,CMD$)
            (RETURN)
```

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

3.13.4 Combining Translator Words With Keithley IEEE-488 Commands

One or more existing Translator 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 710 (END LINE)
OUTPUT 710;''ALIAS SETUP1 F1X ;''
            (END LINE)
OUTPUT 710;''ALIAS SETUP2 R0X ;''
            (END LINE)
OUTPUT 710;''ALIAS SETUP3 NEW SETUP1
   NEW SETUP2 P1Z1X ;'' (END LINE)
```

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

Model 8573 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:

```
U%=1 : CALL IBSRE(BRD0%,U%) (RETURN)
CMD$='' ALIAS SETUP1 F1X ;'' : CALL IBWRT
      (M193%,CMD$) (RETURN)
```

```
CMD$=''ALIAS SETUP2 R0X;'' CALL IBWRT
         (M193%,CMD$) (RETURN)
CMD$=''ALIAS SETUP3 NEW SETUP1 NEW
SETUP2 P1Z1X;'' CALL IBWRT(M193%,CMD$)
                (RETURN)
```

The second and third statements create two Translator words. When the return key is pressed the fourth time, the two words combine with the Keithley IEEE command string to form the word SETUP3.

3.13.5 Executing Translator Words and Keithley IEEE Commands

Translator words and Keithley IEEE commands can be executed in the same command string. The format for doing this is demonstrated in the following example:

"SETUP1 P1Z1X"

When the above command string is sent over the bus, the commands in SETUP1 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 710 (END LINE)
OUTPUT 710;''SETUP1 P1Z1X'' (END LINE)
```

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

Model 8573 Programming Example—The following program will assert the commands of an existing Translator word and the standard Keithley IEEE commands over the bus:

```
U%=CALL IBSRE(BRD0%,U%) (RETURN)
   CMD$=''SETUP1 P1Z1X'' CALL IBWRT
            (M193%,CMD$) (RETURN)
```

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

3.13.6 LIST

LIST is a reserved word that can be used to list the existing Translator words. 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 3.10.16).
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 he following program statements to list them:

```
REMOTE 710 (END LINE)
OUTPUT 710;''LIST'' (END LINE)
ENTER 710; A$ (END LINE)
DISP A$ (END LINE)
```

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.

```
U%=1 CALL IBSRE(URD0%,U%) (RETURN)
CMD$=''LIST'' CALL IBWRT(M193%,CMD$)
              (RETURN)
RD$=SPACE$(100) CALL IBRD(M193%,RD$)
              (RETURN)
PRINT RD$ (RETURN)
```

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

3.13.7 FORGET

FORGET is a reserved word that is used to purge all the Translator words from memory.

HP-85 Programming example—Enter the following program statements to purge memory of the Translator words:

```
REMOTE 710 (END LINE)
OUTPUT 710;''FORGET'' (END LINE)
```

When END LINE is pressed the second time, the Translator words will be purged from memory. The Translator word list can be requested, as explained in paragraph 3.13.6, to verify that the Translator words no longer exist.

HP-85 Model 8573 Programming Example—Enter the following program statements to purge memory of the Translator words:

```
U%=1 CALL IBSRE(BRD0%,U%) (RETURN)
CMD$=''FORGET'' CALL IBWRT(M193%,CMD$)
              (RETURN)
```

When the return key is pressed the second time, the Translator words will be purged from memory. The Translator word list can be requested, as explained in paragraph 3.13.6, to verify that Translator words no longer exist.

Table 3-17. 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).
NEW	Tells the Model 193 to recognize Translator words.
OLD	Tells the Model 193 to only recognize the Keithley device-dependent commands.
LIST	Used to list the Translator words.
FORGET	Used to purge Translator words from memory.

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 193 must be turned on and allowed to warm up for at least one hour before beginning the verfication 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.

4.5 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying the 1 year accuracy specifications of the instrument, at 5½ digit resolution, for each of the six measuring functions: DC volts, TRMS AC volts, ohms, TRMS AC amps, DC amps and RTD temperature. 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.

Table 4-1. Recommended Test Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	200mV, 2V, 20V, 200V, 1000V ranges ± 15 ppm.
Fluke	5200A	AC Voltage Calibrator	2V, 20V, 200V ranges; 20Hz ±0.1%; 50Hz-20kHz 0.02%; 100kHz ±0.33%.
Fluke	5215A	AC Power Amplifier	700V range: 20Hz ±0.12%; 50Hz-20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	200Ω-2MΩ ±15 ppm; 20MΩ ±32 ppm; 200MΩ ±225 ppm
Valhalla	2500E	Current Calibrator	200µ-2A ranges ±0.025%
Gen. Rad.	1433T	Decade Resistance	±0.01%

4.5.1 DC Volts Verification

With the Model 193 set to 5½ digit resolution, verify the DC volts function as follows:

CAUTION
Do not exceed 1000V 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 193 as shown in Figure 4-1.
3. Set the calibrator to 0V and enable zero on the Model 193. Verify that the display is reading 000.000mV ±2 counts.

NOTE
Low measurement techniques should be used when checking the 200mVDC range. Refer to paragraph 2.6.5 for low level measurement considerations.

4. Set the calibrator to output +200mV 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 2V, 20V, 200V and 1000V 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

193 DCV Range	Applied DC Voltage	Allowable Readings (18° to 28°C)
200mV	200.000mV	199.982 to 200.018
2 V	2.00000 V	1.99984 to 2.00016
20 V	20.0000 V	19.9979 to 20.0021
200 V	200.000 V	199.979 to 200.021
1000 V	1000.00 V	999.86 to 1000.14

4.5.2 TRMS AC Volts Verification

With the Model 1930 installed and the instrument set to 5½ digit resolution, perform the following procedure to verify the AC volts function:

CAUTION
Do not exceed 700V RMS 1000V peak 2×10^7V•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 193 as shown in Figure 4-2.
3. Set the calibrator to output 200mV at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-3.
4. Repeat the 200mVAC measurement at the other frequencies specified in Table 4-3.
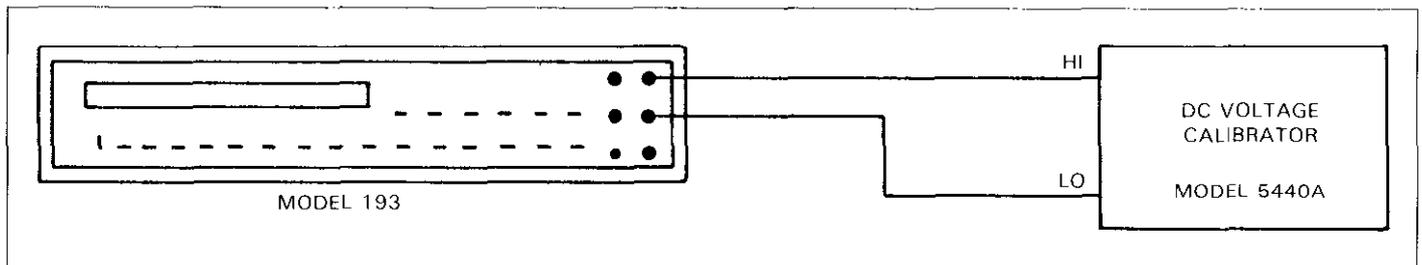
Figure 4-1. Connections for DC Volts Verification
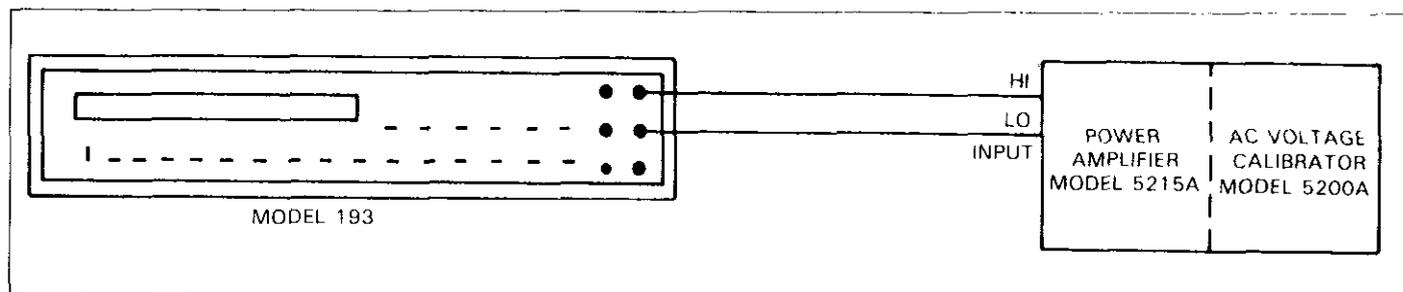
Figure 4-2. Connections for TRMS AC Volts Verification

Table 4-3. Limits for TRMS AC Volts Verification

193 ACV Range	Applied AC Voltage	Allowable Readings (18°C to 28°C)				
		20Hz	50Hz	10kHz	20kHz	100kHz
2V	2.00000V	1.97900 to 2.02100	1.99400 to 2.00600	1.99400 to 2.00600	1.99000 to 2.01000	1.97500 to 2.025.00
20V	20.0000V	19.7900 to 20.2100	19.9400 to 20.0600	19.9400 to 20.0600	19.9000 to 20.1000	19.7500 to 20.2500
200V	200.000V	197.900 to 202.100	199.400 to 200.600	199.400 to 200.600	199.000 to 201.000	197.500 to 202.500
700V	700.00 V	692.00 to 708.00	696.55 to 703.45	696.55 to 703.45	693.50 to 706.50	688.00 to 712.00

5. Repeat the procedure for the 2V, 20V, 200V and 700V 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.

4.5.3 Ohms Verification

With the Model 193 set to 5½ digit resolution, verify the ohms function as follows:

CAUTION
Do not exceed 350V peak or 250V 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 193 as shown in Figure 4-3.
3. Set the calibrator to the SHORT position and enable zero on the Model 193. Verify that the display reads 000.000.
4. Set the calibrator to output 200Ω 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 2kΩ through 200MΩ 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

193 Range	Set-up	Applied Resistance	Allowable Readings (18°C to 28°C)
200 Ω	Figure 4-3	190.000 Ω	189.979 to 190.021
2 kΩ	Figure 4-3	1.90000 kΩ	1.89979 to 1.90021
20 kΩ	Figure 4-3	19.0000 kΩ	18.9979 to 19.0021
200 kΩ	Figure 4-4	190.000 kΩ	189.979 to 190.021
2MΩ	Figure 4-4	1.90000MΩ	1.89979 to 1.90021
20MΩ	Figure 4-4	19.0000MΩ	18.9865 to 19.0135
200MΩ	Figure 4-4	100.000MΩ	96.798 to 103.202
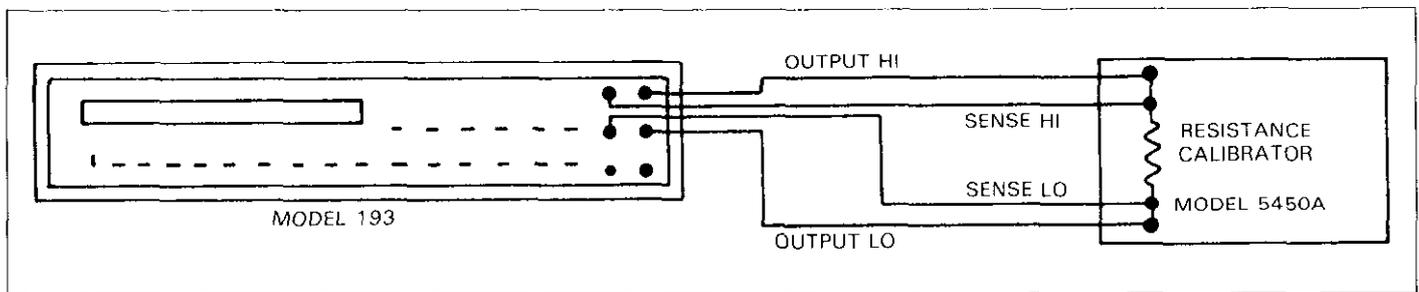
Figure 4-3. Connections for Ohms Verification (200Ω-20kΩ Range)
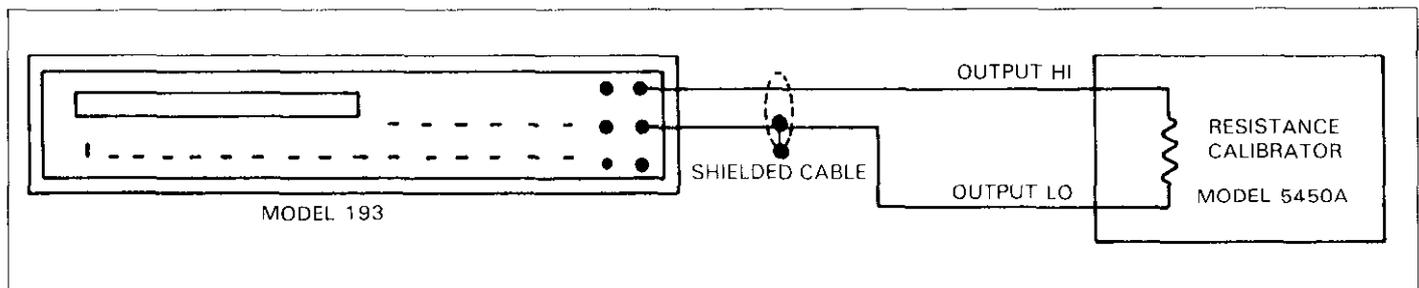
Figure 4-4. Connections for Ohms Verification (200kΩ-200MΩ Ranges)

4.5.4 DC Current Verification

With the Model 1931 installed and the instrument set to 5½ digit resolution, verify the DC current function as follows:

CAUTION
Do not exceed 2A (or 2.2A for more than 1 minute) to the AMPS and LO input terminals or the front panel current fuse will blow.

1. Select the DCA function and autorange.
2. Connect the DC current calibration source to the Model 193 as shown in Figure 4-5.
3. Set the calibration source to output +200μA and verify that the reading is within the limits listed in Table 4-5.
4. Repeat the procedure for the 2mA, 20mA, 200mA and 2A 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.
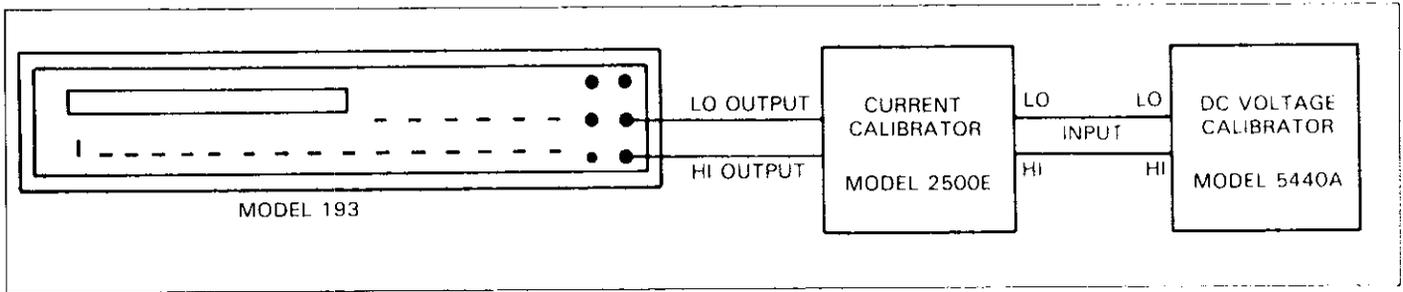
Figure 4-5. Connections for DC Current Verification

Table 4-5. Limits for DC Current Verification

193 Range	Applied DC Current	Allowable Readings (18°C to 28°C)
200 μA	200.000 μA	199.810 to 200.190
2mA	2.00000mA	1.99810 to 2.00190
20mA	20.0000mA	19.9810 to 20.0190
200mA	200.000mA	199.810 to 200.190
2 A	2.00000 A	1.99810 to 2.00190

4.5.5 TRMS AC Current Verification

With the Models 1930 and 1931 installed and the instrument set for 5½ digit resolution, verify the AC current function as follows:

CAUTION
Do not exceed 2A (or 2.2A for more than 1 minute) to the AMPS and LO input terminals or the front 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 193 as shown in Figure 4-6.
3. Set the calibration source to output 200μA at a frequency of 45Hz and verify that the reading is within the limits listed in Table 4-6.
4. Repeat the 200μA measurement at the other frequencies specified in Table 4-6.
5. Repeat the procedure for the 2mA, 20mA, 200mA and 2A 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

193 AC Range	Applied AC Current	Allowable Readings (18°C to 28°C)		
		45Hz	1kHz	10kHz
200 μV	200.000 μA	198.500 to 201.500	198.500 to 201.500	198.500 to 201.500
2mA	2.00000mA	1.98500 to 2.01500	1.98500 to 2.01500	1.98500 to 2.01500
20mA	20.0000mA	19.8500 to 20.1500	19.8500 to 20.1500	19.8500 to 20.1500
200mA	200.000mA	198.500 to 201.500	198.500 to 201.500	198.500 to 201.500
2 A	2.00000 A	1.98500 to 2.01500	1.98500 to 2.01500	1.98500 to 2.01500

4.5.6 RTD Temperature Verification

Model 193 RTD temperature verification is based on substituting precise, known resistance values for the temperature sensor and checking that the displayed reading falls within the required range.

1. Select the TEMP function.
2. Using front panel program TEMP, select alpha value 0.00392 and the °C temperature scale. See paragraph 2.8.3 for information on using the TEMP program.
3. Connect the precision decade resistance box to the Model 193 as shown in Figure 4-7. Four wire connections must be used as shown on the diagram.
4. Set the decade resistance box to 59.48Ω and verify that the reading is within the limits listed in Table 4-7.
5. Repeat step 4 using the other resistance values listed for the 0.00392 alpha value.
6. Using front panel Program TEMP, select the alternate alpha value of 0.00385.
7. Repeat the procedure by setting the decade resistance box to the respective resistance values listed for the 0.00385 alpha value in Table 4-7. Verify that the readings are within the limits listed in the table.

Table 4-7. Limits for RTD Temperature Verification

Nominal Temperature	α = 0.00385 Resistance Value	α = 0.00392 Resistance Value	Allowable Readings (18°C to 28°C)
−100°C	60.25Ω	59.48Ω	−100.18 to −99.82
0°C	100.00Ω	100.00Ω	−0.18 to 0.18
+100°C	138.50Ω	139.26Ω	99.82 to 100.18
+200°C	175.84Ω	177.34Ω	199.82 to 200.18
+400°C	247.04Ω	249.99Ω	399.82 to 400.18
+600°C	313.59Ω	317.93Ω	599.82 to 600.18
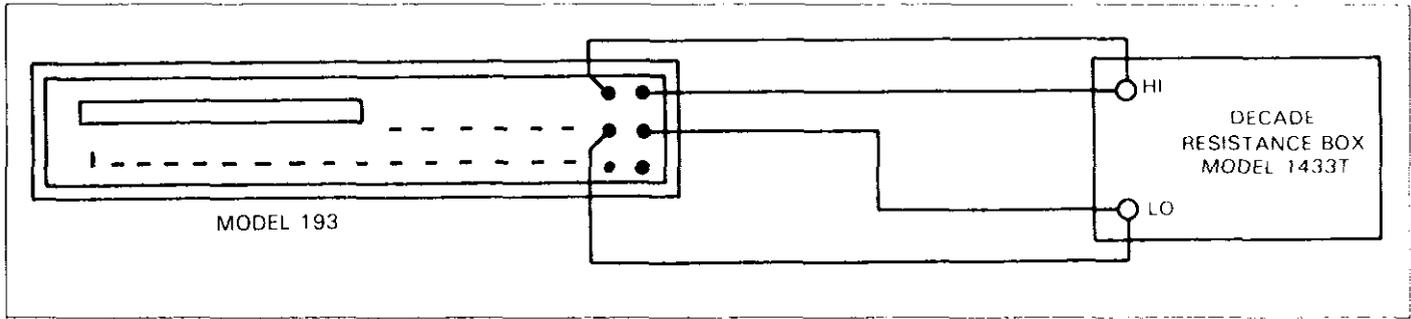
Figure 4-7. Connections for RTD Temperature Verification

SECTION 5
THEORY OF OPERATION

5.1 INTRODUCTION

This section contains an overall functional description of the Model 193. Also included, is information pertaining to the Model 1930 TRMS ACV option and the Model 1931 Current option. Detailed schematics and component location drawings are located at the end of this instruction manual.

5.2 OVERALL FUNCTIONAL DESCRIPTION

A simplified block diagram of the Model 193 is shown in Figure 5-1. The instrument may be divided into two sections: analog and digital circuitry. The analog and digital sections are electrically isolated from each other by using pulse transformers for control and communications. Separate power supplies for the analog and digital sections ensure proper isolation.

The analog section consists of the signal conditioning circuits, multiplexer, input amplifier, A/D converter and control circuitry. The heart of the digital section is the 68B09 microprocessor that supervises the entire operation of the instrument. Additional digital circuitry includes the display and IEEE-488 interface.

5.3 ANALOG CIRCUITRY

The detailed circuitry of the Model 193 analog section is located on schematic diagram number 193-126. Analog circuitry for the ACV and current options are found on their respective schematic diagrams.

5.3.1 Input Signal Conditioning

Signal conditioning circuitry modifies the input to a signal that is useable by the Model 193 and applies that signal to the multiplexer.

DCV

Signal conditioning for DC volts is performed by resistor divider network R181. The following attenuation of the input signal is provided:
Divided by 10 on the 20V range.
Divided by 100 on the 200V range.
Divided by 1000 on the 1000V range.

On the 200mV and 2V ranges K102 is energized, which removes the resistor divider network (R181) from the circuit and applies the input signal directly to the multiplexer through R180, R185 and range FET Q126. K102 is non-energized on the rest of the DCV ranges. On the 20V range, K103 closes and applies the divided input signal to the multiplexer. On the 200V range, the divided input signal is applied to the multiplexer through range FET Q125. On the 1000V range, FET Q124 turns on and applies the divided input signal to the multiplexer.

ACV

The Model 1930 is an AC(+DC) to TRMS converter with variable gain. The gain factor conditions the AC input voltage for application to the multiplexer circuitry.

The input signal is applied through C401 and R403 to Q408. For AC + DC operation, C401 is shorted by relay K401. The two stage amplifier is a variable gain inverting type with gain from −0.001 to −1 (see Table 5-1). The gain is selected accordingly by the double FET switches Q402-Q407. Two FETs are used for each range. They are configured in a T-type attenuator with the 10kΩ resistors R413, R414 and R416 to effectively attenuate high frequency (100kHz) signals.

The op amp is a two stage amplifier. The first stage is configured around dual FET Q408. Q408 allows the reduction of input bias current. The second stage is configured around U401. The output of U401 is applied to the TRMS converter U403. The output of U403 is a DC signal which is applied to the multiplexer.
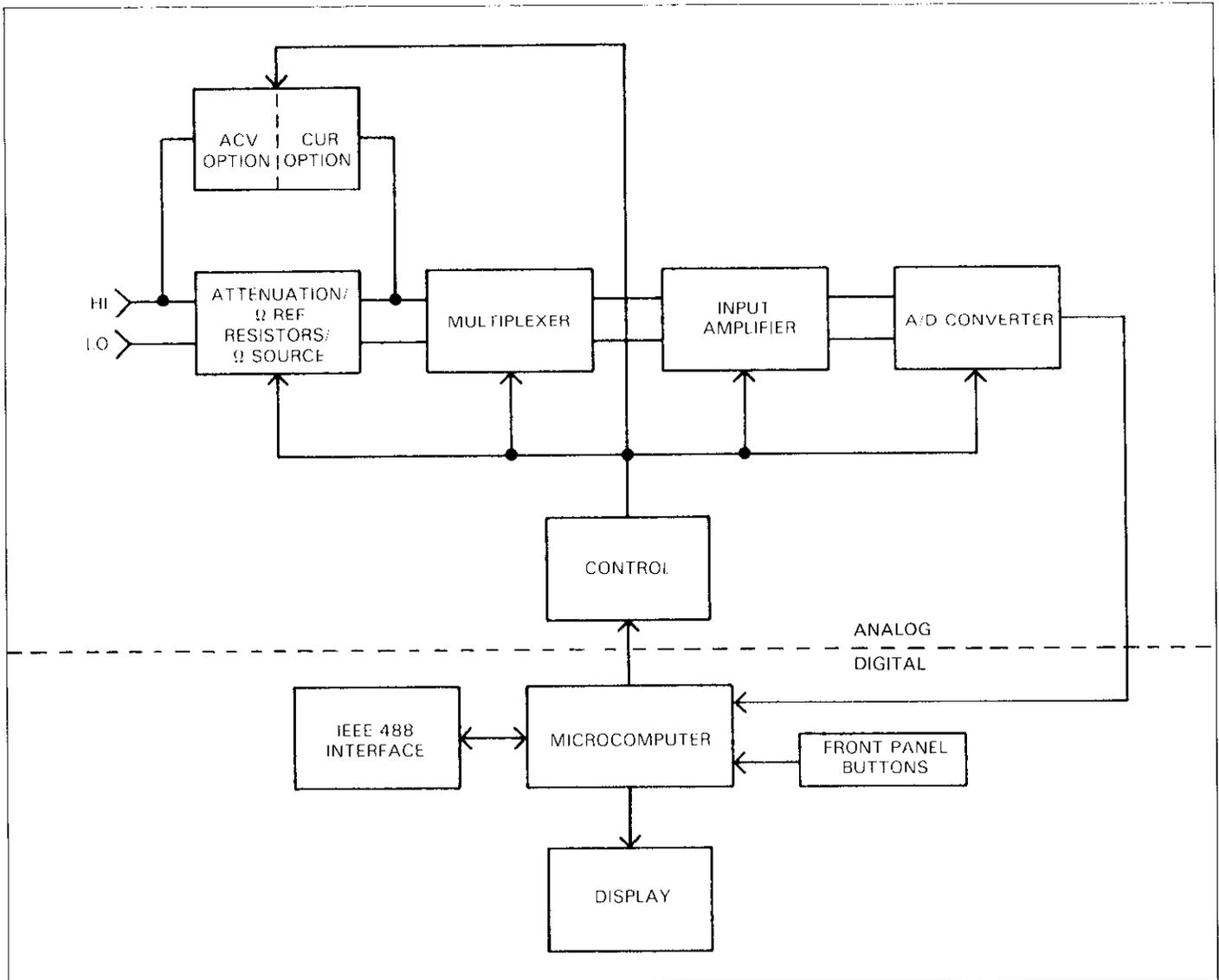
Figure 5-1. Overall Block Diagram

OHMS

Resistance measurements are made using the constant current technique (see Figure 5-2). When the resistance function is selected, a series circuit is formed between the ohms source, a reference resistor and the external unknown resistance. A simplified circuit of the ohms source is shown in Figure 5-3. Current flows through the reference resistor and the unknown resistance. Since this current is common to both resistances, the value of the unknown resistance can be calculated by measuring the voltage across the reference resistor and the voltage across the unknown resistance. The ohms source is a constant current source on the 200Ω through 20MΩ ranges. The current is the same regardless of the value of the unknown resistance. On the 200MΩ range, K102 is closed putting R181 resistor network in parallel with the unknown resistance. Thus, the source current is determined by the unknown resistance.
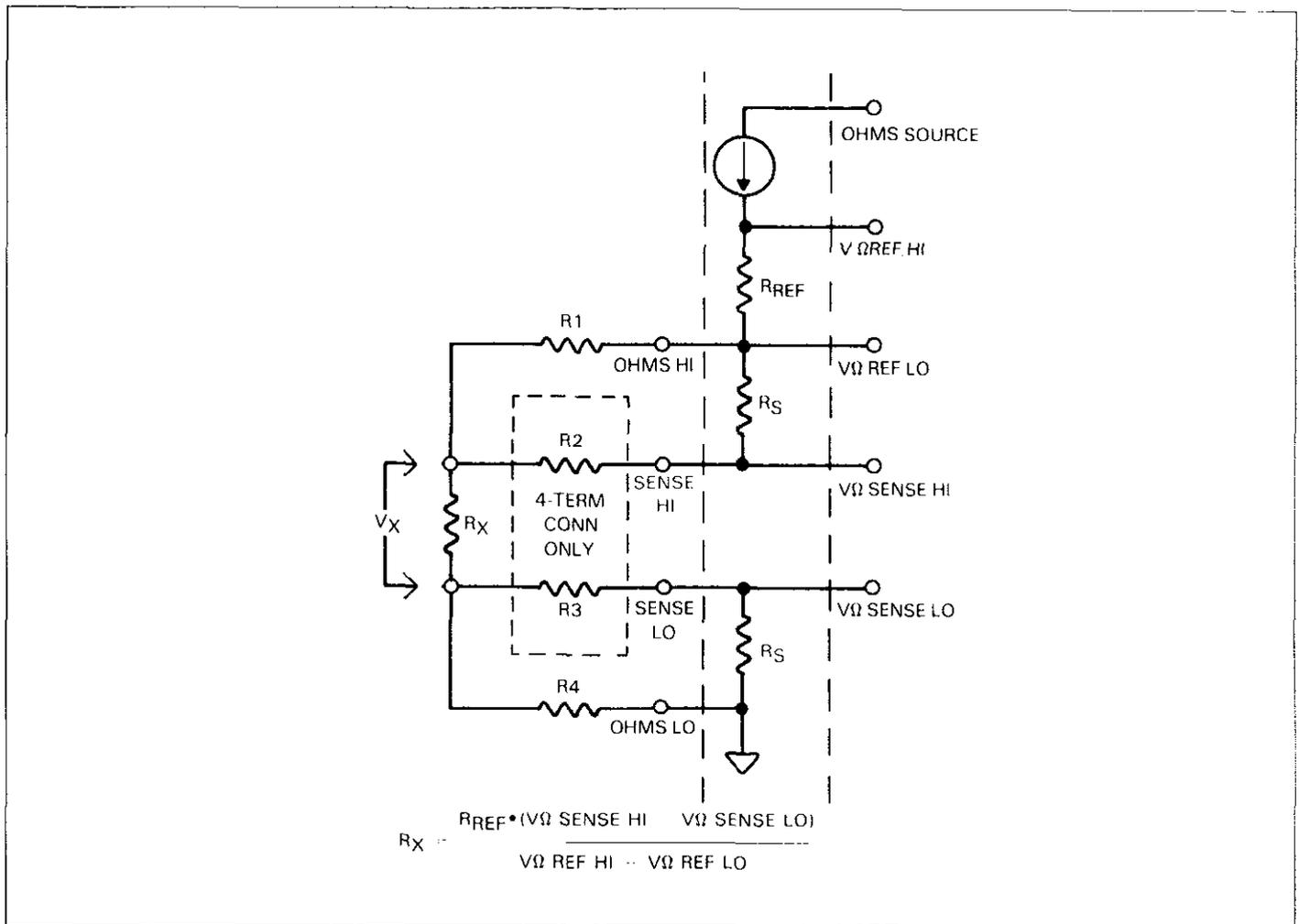
Figure 5-2. Input Configuration During 2 and 4-Terminal Resistance Mesurement

Table 5-1. Ranging Information

Range	Gain	Op Amp Feedback Resistance	Energized FETs
2V	1	2M	None
20V	1/10	(217k + R406)‖2M	Q406, Q407
200V	1/100	(19.6k + R405)‖2M	Q404, Q405
700V	1/1000	(2.12k + R404)‖	Q402, Q403
		(19.6k + R405)‖2M	Q404, Q405
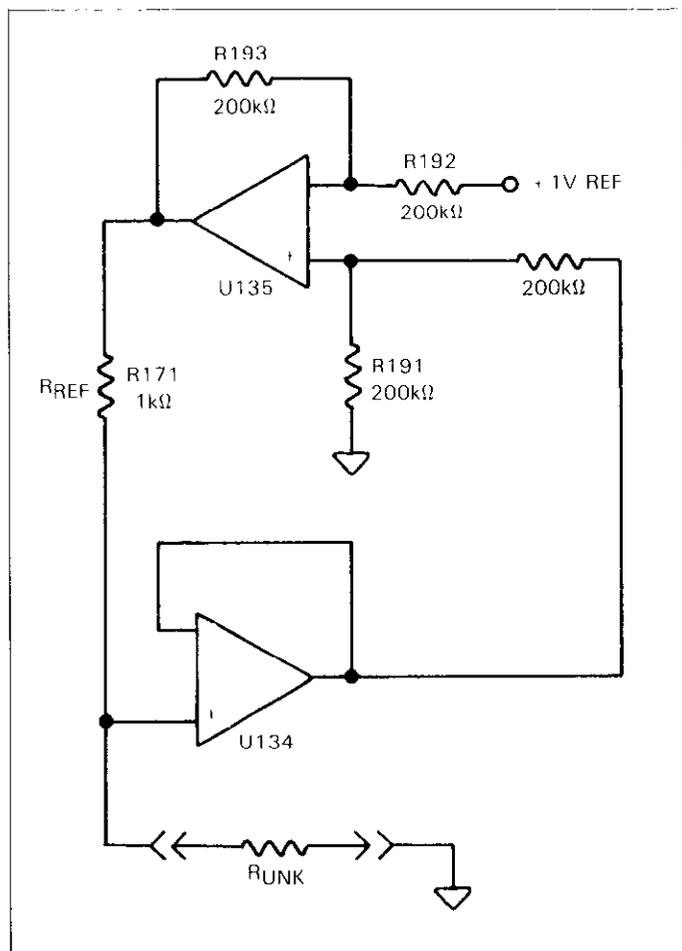
Figure 5-3. OHMS Source (2kΩ Range Shown)

For the 200Ω range, VΩ SENSE HI and VΩ SENSE LO are actually multiplied by a factor of 10 in the buffer circuit.

Figure 5-2 shows the equivalent circuit of the input circuit. R_X is the unknown measured resistance and R1, R2, R3 and R4 represent the test lead resistance. R2 and R3 are connected only during 4-terminal measurements. When using a 2-terminal configuration, all the current flows through the test leads R1 and R4. If R_X has a low value, the amount of voltage developed across the test leads can be significant. Since the voltage is sensed across the combined resistance of R1, R_X and R4, considerable error can be introduced into the reading. To use a 4-terminal connection, a second set of leads (R2 and R3) are connected to the unknown resistance. The amount of current through R2 and R3 is much smaller than the current through R1 and R4. Thus, the voltage seen by the instrument is much closer to the actual value across the measured resistance, minimizing the error.

DCA and ACA

Signal conditioning for DCA and ACA is performed by the Model 1931 Current option. Current shunts R101 through R105 are configured so that a full scale current input will result in a 200mV drop across the shunts on all current ranges. For DCA, this voltage drop is sensed (DC CURRENT SENSE OUT) and applied to the multiplexer of the Model 193. For ACA, the sensed voltage drop is first amplified by the X10 operational amplified (U102) before it is sent to the ACV option. This amplified ACV signal is then converted to DC and applied to the mutliplexer of the Model 193 (See ACV).

The following reference resistors are used for each range. A simplified circuit of resistance measurements is shown in Figure 5-4.

R171 (1kΩ) for the 200Ω and 2kΩ ranges
R170 (10kΩ) for the 20kΩ range
R169 (100.7kΩ) for the 200kΩ range
R168 ‖ R167 (1MΩ) for the 2MΩ range
R167 (9.99MΩ) for the 20MΩ and 200MΩ ranges

By measuring the four voltages in the series circuit, the unknown resistance can be computed by the microprocessor using the equation:

$$R_X = \frac{R_{REF} \times (V\Omega\ \text{SENSE HI} - V\Omega\ \text{SENSE LO})}{V\Omega\ \text{REF HI} - V\Omega\ \text{REF LO}}$$

TEMPERATURE

RTD temperature measurement readings are based on the 4-wire resistance measurements of a platinum RTD (resistance temperature detector). As the probe temperature rises, its resistance increases as well, although not in a precisely linear manner. Signal conditioning is provided by the 200Ω and 2kΩ resistance ranges and automatically autoranges (see OHMS).

Thermocouple (TC) measurements are based on the measurement of voltages generated by the thermocouple junction. Signal conditioning is provided by the 200mVDC range (see DCV).
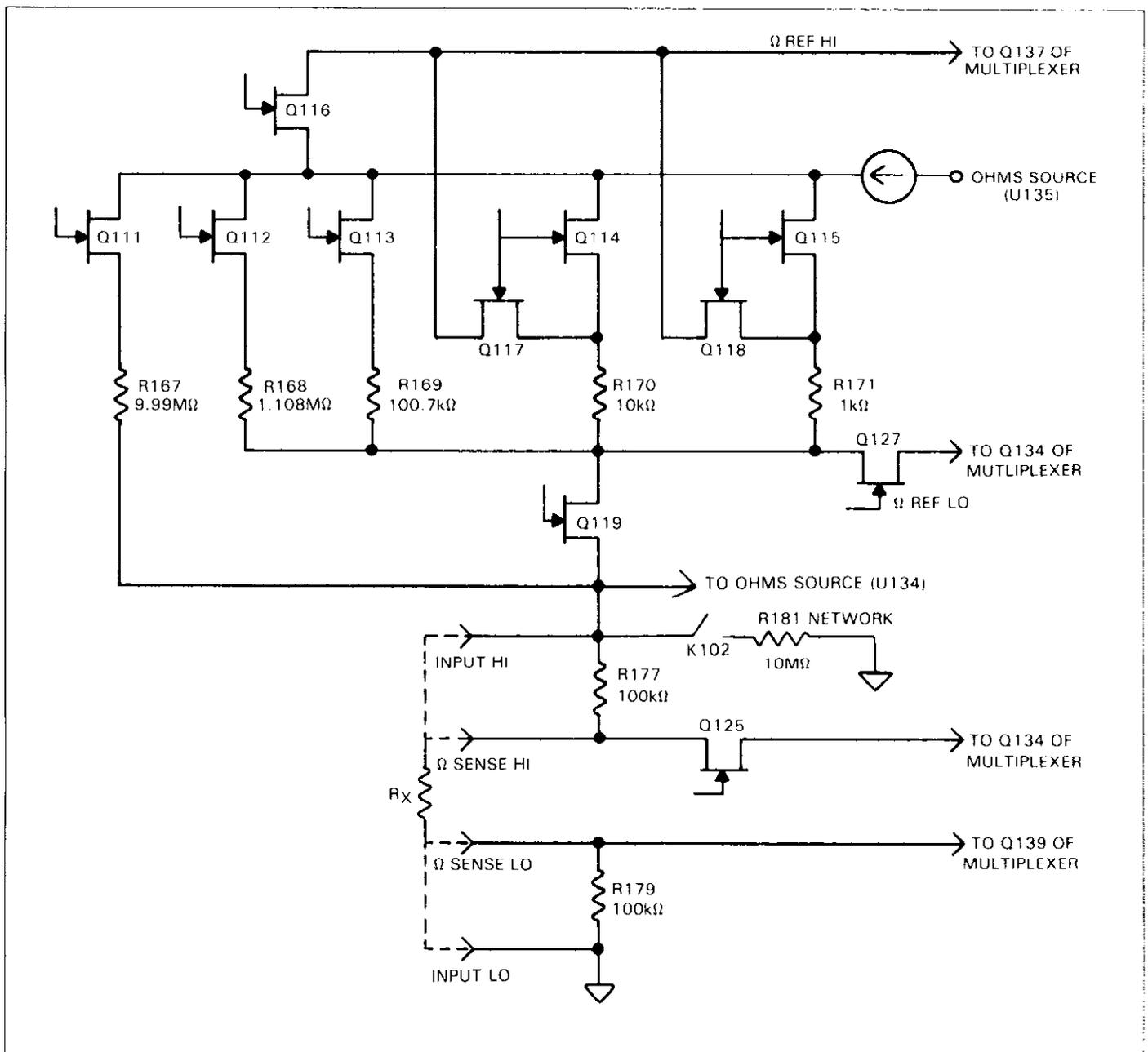
Figure 5-4. Resistance Measurement Simplified Circuitry

5.3.2 Multiplexer

The multiplexer circuitry selects among the various signals that are part of the Model 193 measurement cycle and connects them to the input buffer amplifier. Figure 5-5 shows a simplified schematic of the multiplexer circuitry. The Front/Rear INPUT switch detector FET (Q136) is not part of a measurement cycle.

Figure 5-6 shows the general switching phases for the various signals. During each phase, an integration is performed by the A/D converter, and the resultant data is used by the microprocessor to calculate the final reading.

Voltage and Current Measurements—During the reference phase, the +2.1V reference is selected through Q141. During the signal phase, signal high is selected through Q134, Q142 or Q143. During the zero phase, the multiplexer selects signal common through Q140 or Q138.

Resistance Measurements—During the ohms reference high phase, the reference signal high is selected through Q137. During the ohms reference low phase and the ohms sense high phase, the signals are selected through Q134. During the ohms sense low phase, the sense signal low is selected through Q139.

The precharge amplifier (U136A) is momentarily selected by Q136 just before signal FET Q134 is activated. The purpose of the precharge amplifier is to get the signal seen by the input buffer amplifier closer to the actual input at signal FET Q134. The precharge amplifier also provides the guard voltage for the input section and the drive to keep the FETs on until turned off by the control circuitry.
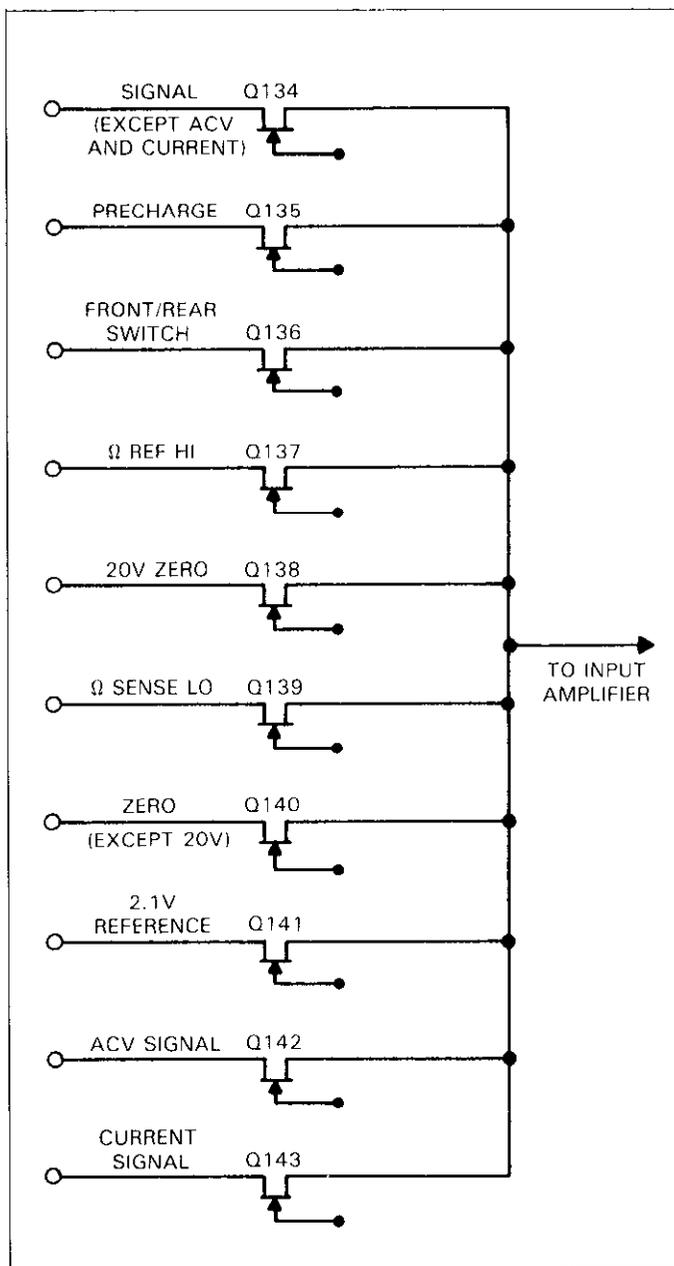
Figure 5-5. JFET Multiplexer
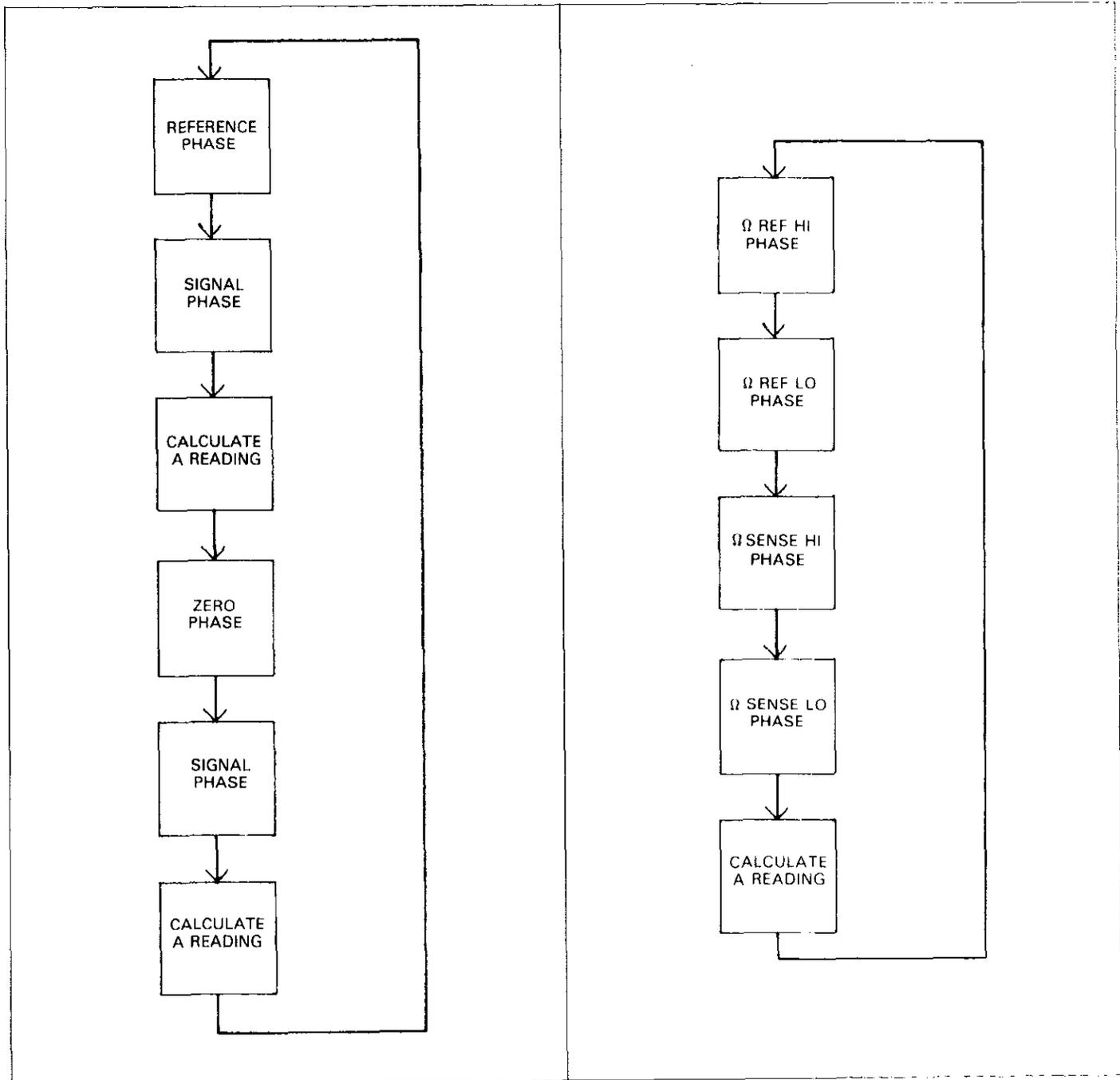
A. Typical Voltage and Current Measurements   B. Typical Resistance Measurement

Figure 5-6. Multiplexer Phases

5.3.3 +2.1V Reference Source

Voltage and current measurements are based on comparing the unknown signal with an internal +2.1V reference voltage source. During each measurement cycle, the unknown signal is sampled and then compared with signal common and the +2.1V reference values.

U105 provides a highly stable +6.95V reference, while U104 and R115 through R118 provide a constant current to minimize zener voltage variations. R113 and R114 divide down the +6.95V value to the final +2.1V reference voltage.

5.3.4 Input Buffer Amplifier

The input buffer amplifier provides isolation between the input signal and the A/D converter. Q101 provides the low noise, high impedance FET input to the noninverting amplifier U114. The amplifier can be configured for X1 or X10 gain with R126 and R127 acting as the divider network. When X1 gain is selected by the microprocessor, feedback is routed through pin 5 of the analog multiplex switch U131C. At X10 gain, feedback is routed through pin 3 of the multiplex switch.

5.4 A/D CONVERTER

The Model 193 uses a combination frequency, variable pulse width, analog-to-digital converter. A simplified schematic of the A/D used in the Model 193 is shown in Figure 5-7.

The charge balance phase begins when the input enable/disable line is set high. This occurs at the end of a software-generated delay period that allows the signal to settle after the appropriate multiplexer FET is turned on. Once the input is enabled, the signal from the buffer amplifier is added to the level shift current applied through R162 or R163. In this manner, the ±2.2V bipolar signal from the buffer amplifier is converted to a unipolar signal that can be integrated.

The integrator is made up of Q106, U129 and C124. When the input to the integrator is applied, the integrator output ramps up until its voltage is slightly higher than the voltage applied to the inverting input of the duty cycle comparator (U122B). The charge balance current, that is proportional to the input, is fed back to the integrator input through R156 and Q107. Since the charge balance current is much larger than the sum of the input and level shift currents, the integrator output now ramps in the negative direction until Q1 of U128 goes low. The VIA then counts the total number of pulses that occur during the charge balance phase.

At the end of the charge balance phase, the output of the integrator is resting at some positive voltage. Since the integrator output is connected to the non-inverting input of the final-slope comparator (U122A), the final-slope comparator output remains high until the integrator output ramps in the negative direction. During final-slope, Q107 is turned off and the feedback is fed through U127 back to the integrator input. The final-slope comparator output is then gated with the 3.84MHz clock and counted. Once the comparator output goes low, the VIA stops counting and the reading can be computed.
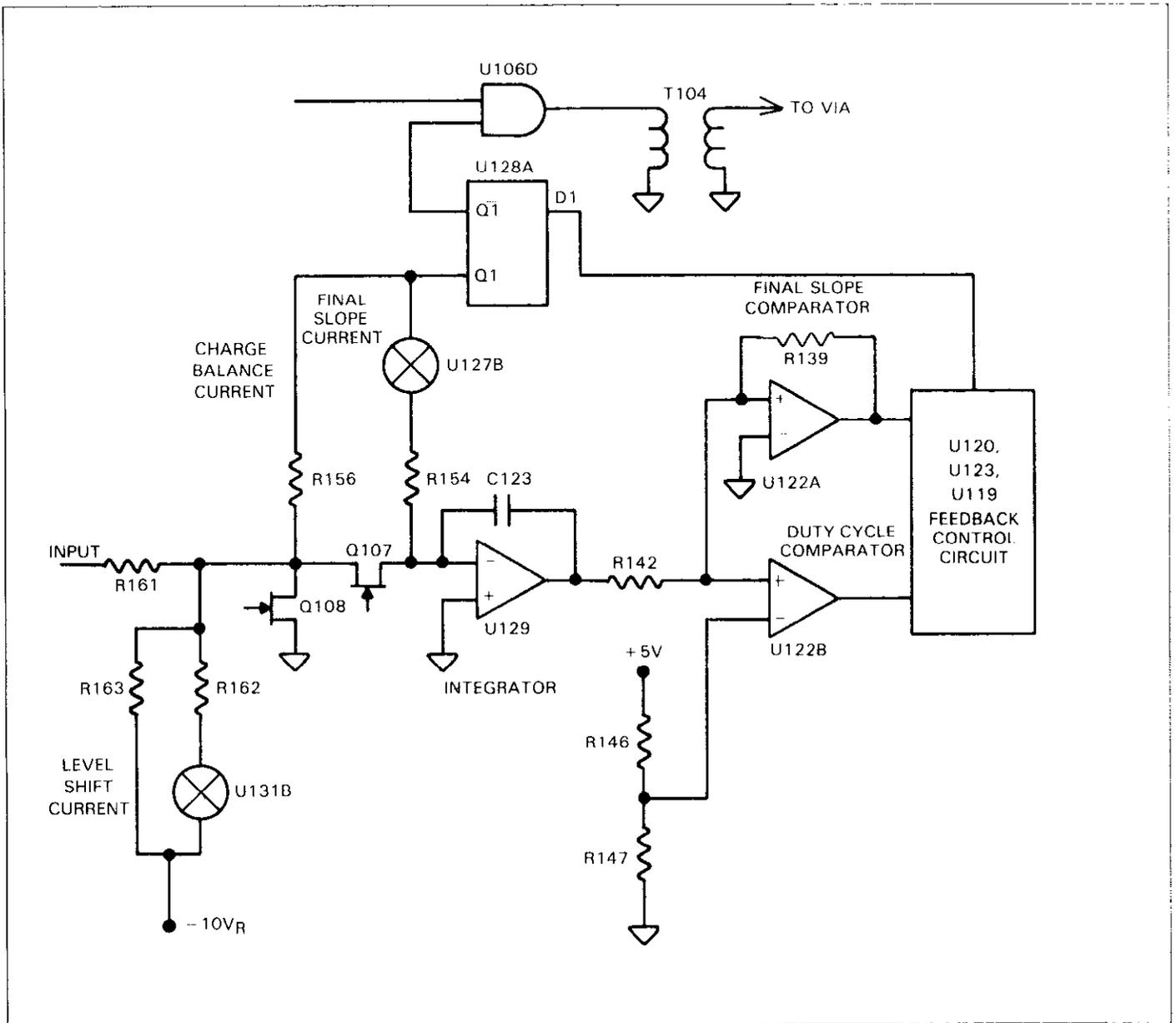
Figure 5-7. A/D Converter Simplified Schematic

5.5 CONTROL CIRCUITRY

The signals for the circuitry that provides control of the various FETs, relays and logic levels are supplied by the shift store registers U137, U138, U139, U140 and U103 (Model 1931). CLOCK, DATA and STROBE signals are sent from the VIA (U310) across the pulse transformers T302, T303 and T304. The pulse transformers provide 500V isolation between the analog and digital sections of the instrument. DATA is serially loaded into the shift store registers and a STROBE pulse causes the registers to simultaneously output the appropriate logic levels to the FET and relay drivers. During high speed measurements (500 readings to the buffer), registers U138, U139 and U140 are not used.

5.6 DIGITAL CIRCUITRY

The Model 193 is controlled by an internal microcomputer. This section briefly describes the operation of the microcomputer and associated digital circuitry. Refer to schematic diagram number 193-106 for circuit details.

5.6.1 Microcomputer

The microcomputer centers around the 8-bit 68B09 microprocessor. The MPU has direct control over the display, front panel switches, A/D converter, IEEE-488 bus, as well as the VOLTMETER COMPLETE Output and the EXTERNAL TRIGGER Input. Timing for the microprocessor is accomplished by the use of Y301; an 8MHz crystal. Internally, this frequency is divided down by four to obtain a bus operating frequency of 2MHz.

Instrument operation software is stored in EPROMs U314 and U315. The revision level of this software is displayed on power-up. Calibration constants and instrument set-up conditions are stored in E^{2}PROM (U312). U313 is the RAM and has battery back-up. Partial address decoding is used in this system. The function selected is determined by the state of A11, A12, A13, A14 and A15 address lines. These address lines determine which is selected by the decoders. The decoders are U303, U307 and U304. Only one device (ROM, RAM, VIA, etc) will have access to the data bus at any one time.

The battery (or capacitor) back-up circuitry turns on when power is turned off. The battery (or capacitor) is connected to the RAM circuitry. This retains the data in the buffer locations when the power is shut down. When power is lost, transistors Q301 and Q302 turn off and the battery (or capacitor) voltage is routed through R309 to the RAM circuitry.

The heart of the IEEE-488 circuitry is the GPIBA (U316). The GPIBA is capable of performing all IEEE talker-listener protocols. The bidirectional data lines D0 through D7 permit the transfer of data between the microprocessor and the GPIBA. The transceivers U308 and U317 are used to drive the output. Data is buffered by U308 and U317 and is transmitted to the bus via connector J1013.

5.6.2 Display Circuitry

The display information is sent through display latches U309 and U318. Upon each display update, new segment information is presented to the display latches and a clock pulse is sent on PA0. The clock pulse to U403 shifts a digit enable bit to the next digit to be enabled. Every 14 times the display is updated, a digit enable bit is generated at PA1 and goes to the data input of the shift register. U406 through U409 are the drivers for the LED segments of the display digits and the LED indicators.

5.7 POWER SUPPLIES

The main power supplies of the Model 193 are located on sheet 2 of 2 of schematic drawing number 193-106. Fuse F301 is the line fuse which is accessible from the rear panel. S301 is the POWER ON/OFF switch and S302 selects 115V or 230V operation by placing the transformer primary windings in parallel or series. The power transformers, T301, has three secondary windings; one for the +5V digital supply, one for the +5V analog supply and one for the ±15V analog supply. CR302, CR303 and CR304 provides fullwave rectification for the three supplies, while U301, VR301, VR302 and VR303 provides the regulation.

SECTION 6
MAINTENANCE

6.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 193. Fuse replacement and line voltage selection procedures are also included.

WARNING
The procedures included in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps in this section may expose you to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

6.2 LINE VOLTAGE SELECTION

The Model 193 may be operated from either 105-125V or 210-250V 50 or 60Hz power sources. The instrument was shipped from the factory set for an operating voltage marked on the rear panel. To change the line voltage, proceed as follows:

WARNING
Disconnect the line cord and all other equipment from the Model 193 before removing the top cover.

1. Remove the top cover as explained in paragraph 6.7 to gain access to the internally located switch.
2. Using a flat-blade screwdriver, place the line voltage switch in the desired position. The line voltage selection switch is located towards the front of the instrument near the power switch. See Table 6-1 for the correct position.
3. Install a power line fuse consistent with the line voltage. See paragraph 6.3.1 for the fuse replacement procedure.

CAUTION
The correct fuse type must be used to maintain proper instrument protection.

4. Mark the selected line voltage on the rear panel for future reference (to avoid confusion, erase the old mark).

5. Replace the top cover and connect the instrument to the line power.

Table 6-1. Line Voltage Selection

Line Voltage	Line Frequency	Switch Setting
105V–125V	50Hz–60Hz	115V
210V–250V	50Hz–60Hz	230V

6.3 FUSE REPLACEMENT

The Model 193 has two fuses for protection in case of overload. The line fuse protects the line power input of the instrument and the current fuse protects the Model 1931 Current option from excessive current. The fuses may be replaced by using the procedures found in the following paragraphs.

WARNING
Disconnect the instrument from the power line and from other equipment before replacing fuses.

6.3.1 Line Fuse

To replace the line fuse, proceed as follows:

1. Turn off the power and disconnect the line cord and all other test cables from the instrument.
2. Place the end of a flat-blade screwdriver into the slot in the line fuse holder on the rear panel. Push in and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder and its internal spring will push the fuse and the carrier out of the holder.
3. Remove the fuse and replace it with the proper type using Table 6-2 as a guide.

CAUTION
Do not use a fuse with a rating higher than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

4. Install the new fuse and the carrier into the holder by reversing the above procedure.

Table 6-2. Line Fuse Replacement

Line Voltage	Fuse Type	Keithley Part No.
105V – 125V	3/8A, 250V, Slo-Blo, 3AG	FU-18
210V – 250V	3/16A, 250V, Slo-Blo, 3AG	FU-29

6.3.2 Current Fuse

The current fuse protects the 200μA through 2A ranges of the Model 1931 Current option from an input current greater than 2A. To replace the current fuse, perform the following steps:

NOTE
The front panel current fuse is rated at 2A. With a 2,200,000 count display (at 6½ digit resolution) the 2A range can momentarily (approx. one minute) read 2.2A before the fuse will blow. This 10% overrange will not harm the instrument.

1. Turn off the power and disconnect the power line and test leads.
2. Place the end of a flat-blade screwdriver into the slot in the fuse holder on the front panel. Press in slightly and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure and remove the fuse carrier and the fuse.
3. Remove the defective fuse and replace it using Table 6-3 as a guide.

CAUTION
Use only the recommended fuse type. If a fuse with a higher current rating is installed, instrument damage may occur.

4. To replace the fuse carrier with the fuse, reverse the procedure in step 2.

Table 6-3. Current Fuse Replacement

Model 193	Fuse Type	Keithley Part No.
USA Models	2A, 250V, 3AG, Normal-Blo	FU-13
European Models	2A, 250V, 5 × 20mm, Normal-Blo	FU-48

6.4 MODEL 1930 TRMS ACV OPTION INSTALLATION

The Model 1930 expands the capabilities of the Model 193 allowing it to make TRMS AC voltage measurements. If purchased with the Model 193, the Model 1930 will be factory installed. However, the instrument may be upgraded in the field by installing the Model 1930 option as follows:

WARNING
Disconnect the line cord and test leads from the instrument before removing the top cover.

1. Remove the top cover of the instrument as explained in the disassembly instructions in paragraph 6.7
2. Plug the Model 1930 into its mating receptacle on the analog board as shown in Figure 6-1 and press the two fasteners into the PC board.
3. Connect the two wires of the Model 1930 as follows:
   A. If the Model 1930 is the only option installed, refer to Figure 6-1(A) to connect the wires to the analog board.
   B. If both the Models 1930 and 1931 are installed, refer to Figure 6-1(C) to connect the wires.
      Note: The blue wire must be securely clamped to the shield of the Model 1930 as shown in Figure 6-1.
4. Reinstall the top cover.
5. Perform the calibration procedure for TRMS AC volts found in paragraph 6.6. It is strongly recommended that the accuracy of the rest of the instrument be verified as explained in Section 3.

NOTE
If the option is removed from the instrument, a complete calibration on the Model 193 should be performed. Removal of the option may also change the IEEE address and line frequency setting of the instrument.

6.5 MODEL 1931 CURRENT OPTION INSTALLATION

The Model 1931 expands the capabilities of the Model 193 by allowing it to make DC current measurements. When both the Models 1930 and 1931 are installed, the instrument can make TRMS AC current measurements. If purchased with the Model 193, the Model 1931 will be factory installed. However, the instrument may be easily upgraded in the field by installing the Model 1931 as follows:

WARNING
Disconnect the line cord and test leads from the instrument before removing the top cover.

1. Remove the top cover of the instrument as explained in the disassembly instructions in paragraph 6.7.
2. Plug the Model 1931 into its mating receptacle on the analog board as shown in Figure 6-1 and press the two fasteners into the PC board.
3. Connect the wires of the Model 1931 as follows:
   A. If the Model 1931 is the only option installed, refer to Figure 6-1(B) to connect the wires.
   B. If both the Models 1930 and 1931 are installed, connect the wires as shown in Figure 6-1(C).
   Note: The red and blue wires must be securely clamped to the shield of the Model 1931 as shown in the illustrations.
4. Cut out Jumper W102. Jumper location is shown in Figure 6-1. Remember to replace the jumper if the instrument is to be operated with the Model 1931 removed.
5. Reinstall the top cover.
6. Recalibrate the entire instrument as explained in paragraph 6.6.

NOTE
If the option is removed from the instrument, a complete calibration on the Model 193 should be performed. Removal of the option may also change the IEEE address and line frequency setting of the instrument.

6.6 CALIBRATION

Calibration should be performed every 12 months, or if the performance verification procedures in Section 4 show that the Model 193 is out of specification. Calibration should also be performed if the ACV or current option is removed from the instrument. If any of the calibration procedures in this section cannot be performed properly, refer to the troubleshooting information in this section. If the problem persists, contact your Keithley representative or the factory for further information.

The entire calibration procedure may be performed without having to make any internal adjustments if AC input offset and high frequency (100kHz) have been verified, as explained in paragraph 6.6.10, steps 1 and 7. Calibration can be performed from the front panel (Program 96) or over the IEEE-488 bus.

NOTE
A "CONFLICT" error will be displayed, and the CONFLICT error bit in the U1 status word will be set when trying to calibrate the instrument while it is in an improper state. Also, if an "UN-CALIBRATED" error occurs, be sure to check the line frequency setting before performing calibration.

6.6.1 Recommended Calibration Equipment

Table 6-4 lists recommended calibration equipment. Alternate equipment may be used as long as equipment accuracy is at least as good as the specifications listed in the table.

6.6.2 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23°C ±1°C and a relative humidity of less than 70%.

6.6.3 Warm-Up Period

Turn on the instrument power and allow it to warm up for at least one hour before beginning the calibration procedure. If the instrument has been subjected to extremes of temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

6.6.4 Calibration Switch

A switch, located on the rear panel, allows the disabling or enabling of front panel and IEEE-488 bus calibration. When the switch is in the LOCK position, calibration cannot be performed. The following message will be briefly displayed when attempting to enter the calibration program while the switch is in the LOCK position:

CAL LOCKED

A. MODEL 1930 ONLY

B. MODEL 1931 ONLY

C. MODELS 1930 AND 1931
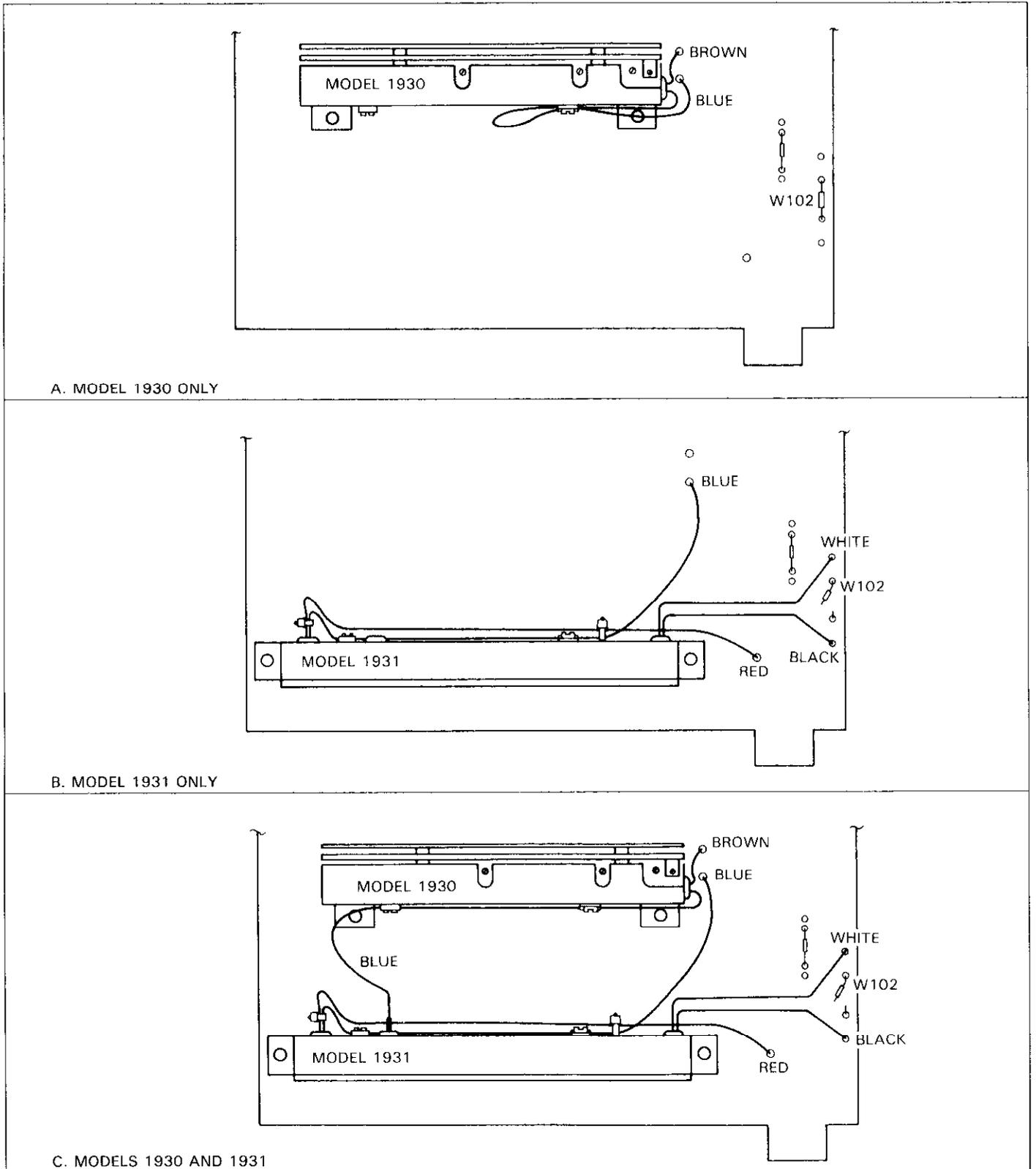
Figure 6-1. Models 1930 and 1931 Installation

Table 6-4. Recommended Calibration Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	200mV, 2V, 20V, 200V, 1000V ranges ± 15 ppm.
Fluke	5200A	AC Voltage Calibrator	2V, 20V, 200V ranges; 20Hz ±0.1%; 50Hz-20kHz 0.02%; 100kHz ±0.33%.
Fluke	5215A	AC Power Amplifier	700V range; 20Hz ±0.12%; 50Hz-20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	200Ω-2MΩ ±15 ppm; 20MΩ ±32 ppm; 200MΩ ±225 ppm
Valhalla	2500E	Current Calibrator	200μA-2A ranges ±0.025%

Calibration can only be accomplished with the calibration switch in the UNLOCK position.

6.6.5 Front Panel Calibration

The following information provides the basic procedure for calibrating the the instrument from the front panel. The detailed calibration procedure starts with paragraph 6.6.7.

1. Place the calibration switch to the UNLOCK position to enable calibration. The switch is located on the rear panel of the instrument.
2. Select the function and range to be calibrated (DCV, ACV, OHMS, DCA or ACA).
3. Select the front panel calibration program:
   A. Press the PRGM button. The following message will be displayed:

   PROGRAM?

   B. Enter Program 96 by pressing the 9 and 6 buttons. The following message will be displayed briefly:

   CAL=

   C. The default calibration point, which is the normal full-range reading for the selected range and function, will now be displayed. For example, if the 2VDC range was selected in step 2, the following calibration point will be displayed:

   2.000000 VDC

4. If a different calibration point is to be used, change the displayed value as follows: The flashing bright digit identifies the cursor position. At this time the cursor is at the most significant digit (MSD). The calibration point value is changed by placing the cursor on the character to be modified and pressing the appropriate data button (buttons numbered 0 through 9). The new number will replace the previous one and

the cursor will move one character to the right. Additional cursor control is provided by the two range buttons with the left and right arrows, which move the cursor right and left respectively. If the cursor is moved pass the least significant digit, it will move back to the MSD.

5. Connect the calibration signal to the instrument.
6. Press the ENTER button. The following message will be displayed for several seconds:

   CALIBRATING

7. The low end calibration point will now be displayed. For the 2VDC range, the following calibration point will be displayed:

   0.000000 VDC

Note: Calibration can be aborted with either the first or second calibration point prompt displayed by pressing the RESET button. The instrument will leave the calibration program without changing the previous calibration constants.

8. If a calibration point other than the one displayed is to be used, then change the display to the desired value as explained in step 4.
9. Set the level of the calibration signal to agree with the displayed calibration point.
10. Press the ENTER button. The following message will be displayed for several seconds:

   CALIBRATING

11. The two calibration points will be stored in E²PROM and the instrument will now exit the calibration program. Select the next range and function to be calibrated and repeat steps 3 through 10.

NOTE: If the calibration source has an offset, set the calibration points to agree with the actual output of the source. For example, if the source has a 1μVDC offset on the 200mVDC range, set the calibration points for 200.0010mV and 000.0010mV.

6.6.6 IEEE-488 Bus Calibration

IEEE-488 bus calibration is performed in a manner similar to front panel calibration, except that calibration constants are transmitted over the bus instead of being entered from the front panel. By combining appropriate IEEE-488 compatible calibration equipment with a suitable test program, calibration of the Model 193 could be performed on an automated basis. Refer to Section 3 for complete information on using the IEEE-488 bus. The following information provides the basic procedure for calibrating the instrument over the IEEE-488 bus. The detailed calibration procedure starts with paragraph 6.6.7.

Use the following basic procedure when calibrating the Model 193 over the IEEE-488 bus:

1. Place the calibration switch to the UNLOCK position. The switch is located on the rear panel of the Model 193.
2. Program the desired range and function over the bus. For example, to select the 200VDC range, send F0R4X.
3. The high end of the range is calibrated first. Apply a full range (or near full range) calibration signal to the input of the instrument. For example, for the 200VDC range, apply 200VDC to the instrument.
4. Send the required calibration value preceded by the V command letter and followed by the C0 calibration command. For example to calibrate the 200VDC range at the 200V calibration point, send V200XC0X.

NOTE: Calibration can be aborted at this time by sending an SDC or DCL command over the bus. The calibration constant sent in step 4 will not be stored in E²PROM.

5. The low end of the range is calibrated next. Apply a zero (or near zero) calibration signal to the input of the instrument. For example, for the 200VDC range apply 0V to the instrument.
6. Send the appropriate calibration commands for the second calibration point. For example, to calibrate the zero calibration point of the 200VDC range send V0XC1X. Note that C1 is used for the second calibration point.
7. Storage of the two calibration points into E²PROM automatically occurs when the second calibration command is sent.
8. Repeat steps 1-7 for the remaining ranges and functions.

HP-85 Programming Example—The following simple program demonstrates how to calibrate the Model 193 over the bus. The program assumes that the instrument's primary address is at 10.

PROGRAM	COMMENTS
10 REMOTE 710	Send remote enable.
20 FOR I=0 TO 1	Set program for one loop.
30 DISP ''APPLY CALI RATION SIGNAL''	Prompt for calibration signal.
40 DISP ''ENTER CALI BRATION COMMAND''	Prompt for command.
50 INPUT A$	Input command string from keyboard.
60 OUTPUT 710; A$	Send command string to 193.
70 ENTER 710; B$	Get a reading.
80 DISP B$	Display reading.
90 NEXT I	Loop back one time.
100 END	

To run the program, press the HP-85 RUN key. At the first set of prompts, apply a full range (or near full range) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer CRT will then display the calibration value. At the second set of prompts, apply a zero (or near zero) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer will display the calibration value and store both calibration constants into E²PROM.

Model 8573 Programming Example—Use the program below to send calibration commands to the Model 193 from an IBM computer equipped with a Keithley Model 8573 IEEE-488 interface. The lines below are to be added to the DECL.BAS program, as described in the Model 8573 Instruction Manual.

PROGRAM	COMMENTS
10 NA$='`GPIB0'`: CALL IBFIND (NA$,BRD0%)	Find board descriptor.
20 NA$='`DEV0'`: CALL IBFIND (NA$,M193%)	Find instrument descriptor.
30 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
40 V%=10:CALL IBPAD (M193%,V%)	Set primary address to 10.
50 FOR I=0 TO 1	Set program for one loop.
60 PRINT'`APPLY CALIBRATION SIGNAL'`	Prompt for calibration signal.
70 INPUT'`ENTER CALIBRATION SIGNAL'`;A$	Input command string.
80 CALL IBWRT (M193%,A$)	Send command string to instrument.
90 RD$=SPACE$(25): CALL IBRD (M193%,RD$)	Get a reading.
100 PRINT RD$	Display reading.
110 NEXT I	Loop back one time.
120 V%=0:CALL IBONL (BRD0%,V%)	Close the board file.
130 CALL IBONL (M193%,V%)	Close the instrument file.

After entering the program, run it by pressing the F2 function key on the computer. At the first set of prompts, apply a full range (or near full range) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer CRT will then display the calibration values. At the second set of prompts, apply a zero (or near zero) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer will display the calibration value and store both calibration constants into E²PROM.

6.6.7 Calibration Sequence

Calibrate the Model 193 in the order presented in the following paragraphs. The basic sequence is:

1. DC Volts calibration.
2. Ohms calibration.
3. AC Volts calibration (Model 1930 installed).
4. DC Current calibration (Model 1931 installed).
5. AC Current calibration (Models 1930 and 1931 installed).

6.6.8 DC Volts Calibration

To calibrate the DCV function, proceed as follows:

NOTE
For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DCV function and the 200mV range.
2. Connect the DC calibrator to the instrument as shown in Figure 6-2.

NOTE
Low measurement techniques should be used when calibrating the 200mVDC range. Refer to paragraph 2.6.5 for low level measurement considerations.

3. For front panel calibration, select Program 96 and proceed as follows:
   A. With the 200.0000mVDC calibration point displayed on the Model 193, set the DC calibrator to output +0.2000000V.
   B. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

   CALIBRATING

   C. With the 000.0000mVDC calibration point displayed, set the DC calibrator to output 0.0000000V.
   D. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

   CALIBRATING

   E. The instrument will exit the calibration program and return to the 200mVDC range.
   F. Repeat the procedures in step 3 for the remaining DCV ranges using Table 6-5 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the DC voltage calibrator to output +0.2000000V.
   B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V200E−3XC0X.
   C. Set the DC voltage calibrator to output 0.0000000V.
   D. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V0XC1X. Both calibration constants will be automatically stored in E²PROM.
   E. Repeat steps A through D for the remaining DCV ranges using Table 6-5 as a guide.

Table 6-5. DC Volts Calibration

193 DCV Range	Set-Up	193 Calibration Point (DCV)	DC Calibrator Setting	IEEE-488 Bus Command
200mV	Figure 6-2	200.0000mV	.2000000V	V200E-3XC0X
		000.0000mV	.0000000V	V0XC1X
2 V	Figure 6-2	2.000000 V	2.000000V	V2XC0X
		0.000000 V	0.000000V	V0XC1X
20 V	Figure 6-3	20.00000 V	20.00000V	V20XC0X
		00.00000 V	00.00000V	V0XC1X
200 V	Figure 6-3	200.0000 V	200.0000V	V200XC0X
		000.0000 V	000.0000V	V0XC1X
1000 V	Figure 6-3	1000.000 V	1000.000V	V1000XC0X
		0000.000 V	0000.000V	V0XC1X
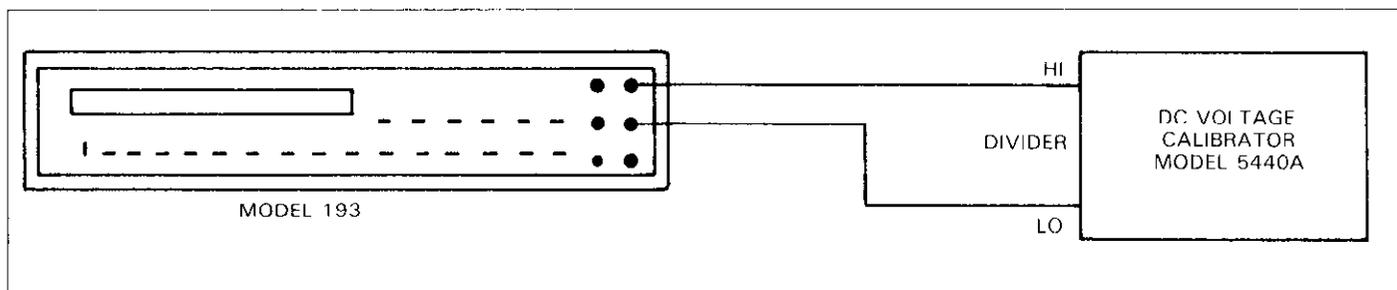
Figure 6-2. DC Volts Calibration Configuration (200mV and 2V Ranges)
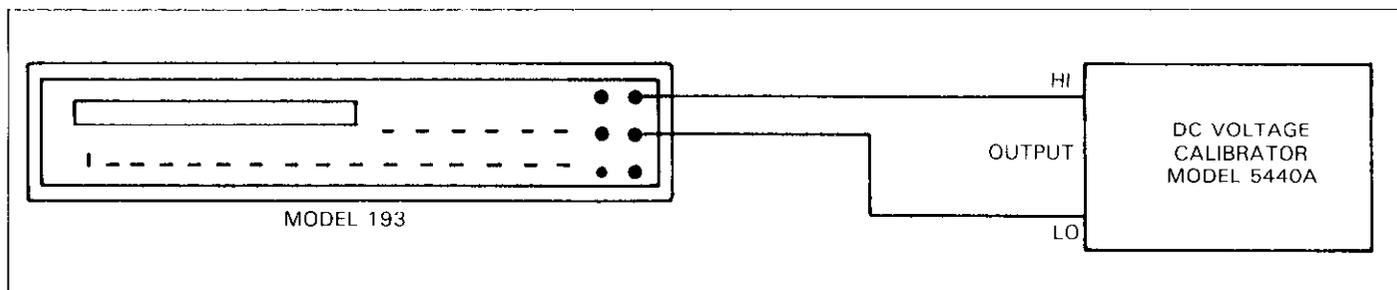
Figure 6-3. DC Volts Calibration Configuration (20V-1000V Ranges)

6.6.9 Resistance Calibration

To calibrate the ohms function, proceed as follows:

NOTE
For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ohms function and the 200Ω range.
2. Connect the resistance calibrator to the instrument as shown in Figure 6-4.
3. For front panel calibration, enter Program 96 as explained in paragraph 6.6.5, step 3 and proceed as follows:
   A. With the 190.0000Ω calibration point displayed on the Model 193, set the resistance calibrator to 190Ω.

B. After allowing sufficient time for the calibrator resistance to settle, press the ENTER button. The following message will be displayed for several seconds:

CALIBRATING

C. With the 000.0000Ω calibration point displayed, set the resistance calibrator to SHORT (0Ω).

D. After waiting sufficient time for the calibrator resistance to settle, press the ENTER button. The following message will be displayed for several seconds:

CALIBRATING

E. The instrument will exit the calibration program and return to the 200Ω range.

F. Repeat the procedures in step 3 for the remaining ohms ranges using Table 6-6 as a guide. Refer to Figure 6-5.

4. For IEEE-488 bus calibration, proceed as follows:

A. Set the resistance calibrator to 190Ω.

B. After allowing sufficient time for the resistance calibrator to settle, send the following commands over the bus: V190XC0X.

C. Set the resistance calibrator to SHORT (0Ω).

D. After allowing sufficient time for the resistance calibrator to settle, send the following command over the bus: V0XC1X. Both calibration constants will be automatically stored in E²PROM.

E. Repeat steps A through D for the remaining ohms ranges using Table 6-6 as a guide.
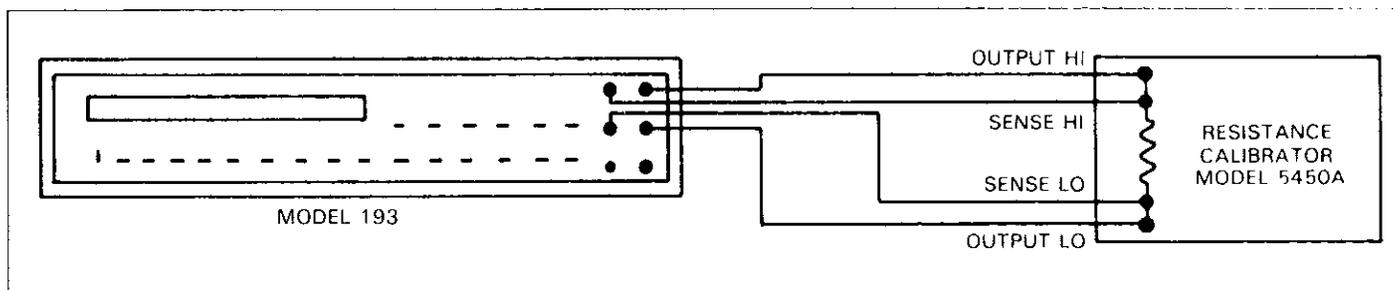
Figure 6-4. Four-Wire Resistance Calibration Configuration (200Ω-20kΩ Ranges)
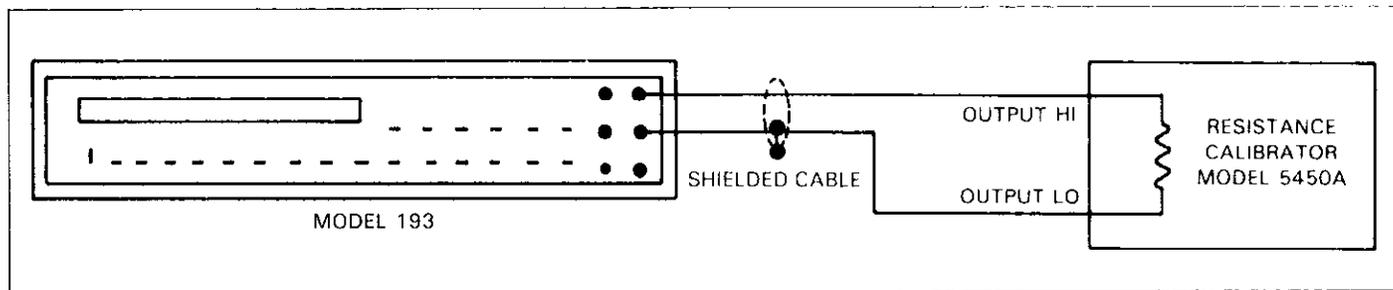
Figure 6-5. Two-Wire Resistance Calibration Configuration (200kΩ-200MΩ Ranges)

Table 6-6. Resistance Calibration

| 193 Range	Set-Up	193 Calibration Point	Resistance Calibrator Setting	IEEE-488 Bus Commands
200 Ω	Figure 6-4	190.0000 Ω 000.0000 Ω	190Ω Short (0Ω)	V190XC0X V0XC1X
2 kΩ	Figure 6-4	1.900000 kΩ 0.000000 kΩ	1.9kΩ Short (0Ω)	V1.9E3XC0X V0XC1X
20 kΩ	Figure 6-4	19.00000 kΩ 00.00000 kΩ	19kΩ Short (0Ω)	V19E3XC0X V0XC1X
200 kΩ	Figure 6-5	190.0000 kΩ 000.0000 kΩ	190kΩ Short (0Ω)	V190E3XC0X V0XC1X
2MΩ	Figure 6-5	1.900000MΩ 0.000000MΩ	1.9MΩ Short (0Ω)	V1.9E6XC0X V0XC1X
20MΩ	Figure 6-5	19.00000MΩ 00.00000MΩ	19MΩ Short (0Ω)	V19E6XC0X V0XC1X
200MΩ	Open Input	Open Input	Open	C0X

NOTE: The 20MΩ range must be calibrated before the 200MΩ range.

6.6.10 TRMS AC Volts Calibration

A full calibration of the ACV function includes four internal, manual adjustments. However, if input offset and high frequency are checked and found to be within the specifications, then the internal adjustments will not have to be done. The following procedure includes these checks. The flowchart in Figure 6-6 helps clarify the calibration procedure.

NOTE
For front panel calibration, omit step 6 of the following procedure. For IEEE-488 bus calibration, omit step 5.

1. Input Offset Check:
   A. Select the ACV function, AC + DC modifier, 5½d resolution and autorange.

NOTE
If the 2VDC range is way out of calibration, the message "NO OPTION" may be displayed when the ACV function is selected. To resolve the problem:

1. Calibrate the 2VDC range.
2. Cycle power on the instrument.
3. Repeat step A.

   B. Connect the DC calibrator to the instrument as shown in Figure 6-2.
   C. Set the DC calibrator to output + 1.000000V.
   D. Allow the measurement sufficient time to settle and note the reading on the display of the Model 193.
   E. Reverse the leads at the input of the instrument, allow the measurement to settle and note the reading on the display of the Model 193.
   F. If there is ≥ 10 count change between the readings, the input offset is within specification and need not be adjusted, therefore, omit step 2. If there is ≥ 10 count change, the input offset is too high and needs to be adjusted. Proceed to step 2.

2. Input Offset Adjustment:
   A. With the instrument off, disconnect the line cord and all other equipment from the Model 193.
   B. Remove the two screws securing the top cover to the chassis and slide the the cover back far enough to gain access to the Model 1930.
   C. Connect the line cord and power-up the Model 193.
   D. Select the ACV function, AC + DC modifier, 5½d resolution and autorange.
   E. Connect the DC calibrator to the instrument as shown in Figure 6-2.
   F. Set the DC calibrator to output + 1.000000V.
   G. After allowing the measurement sufficient time to settle, adjust the DC calibrator until the display of the Model 193 reads 1.00000V ± 10 counts.
   H. Reverse the leads at the input of the instrument, allow the measurement to settle and note the reading on the display.
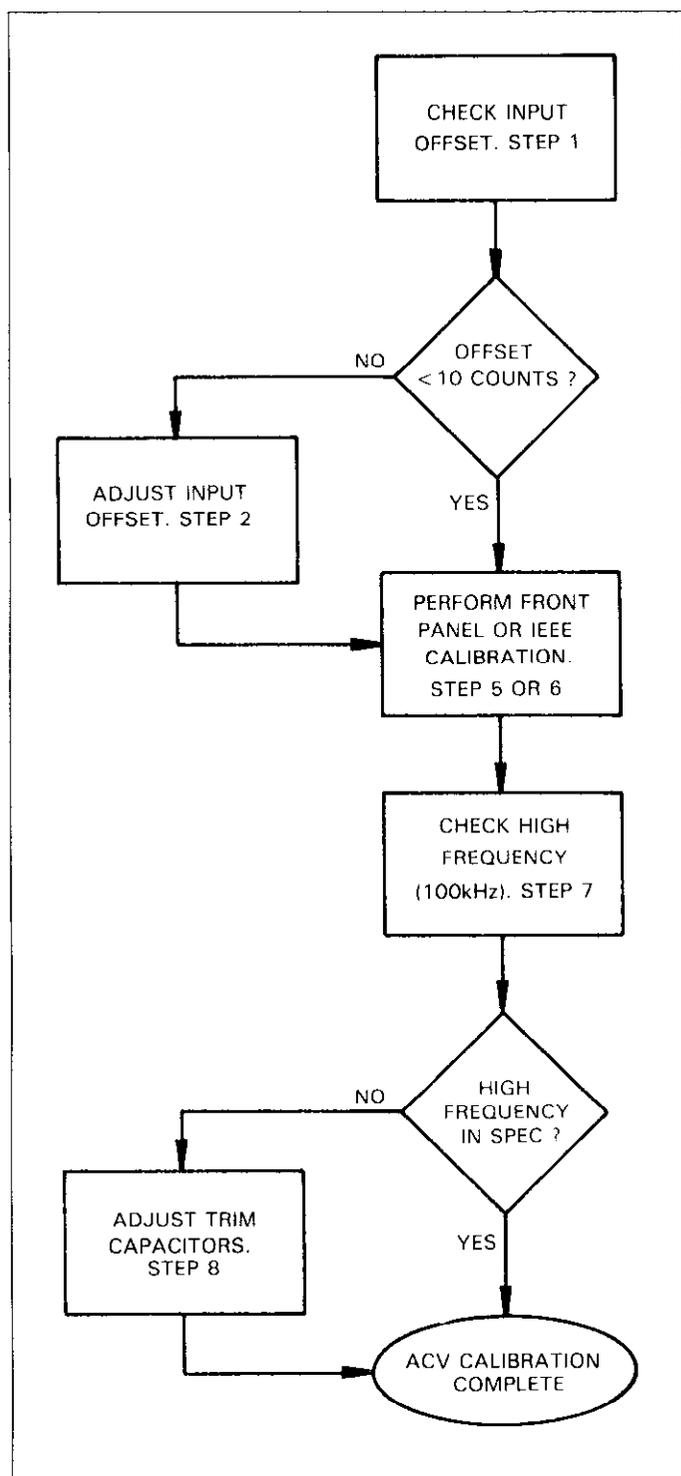
Figure 6-6. Flowchart of AC Volts Calibration Procedure

H. Reverse the leads at the input of the instrument, allow the measurement to settle and note the reading on the display.

I. Adjust R411 for a display reading that is the average of the two noted readings. For example, if the reading in step H is 1.00400V, then adjust R411 for a display reading of 1.00200V.

J. Repeat steps F through I until there is <10 counts change between the two readings.

K. Slide the top cover forward to help maintain internal temperatures, but do not replace the screws at this time.

3. Select the ACV function and the 2V range. Take the instrument out of AC + DC, if it is in that mode.

4. Connect the AC calibrator as shown in Figure 6-8.

5. For front panel calibration, select Program 96 as explained in paragraph 6.6.5, step 3 and proceed as follows:

A. With the 2.000000V AC calibration point displayed on the Model 193, set the AC calibrator to output 2.00000V at 500Hz.

B. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds.

CALIBRATING

C. With the 0.200000VAC calibration point displayed, set the AC calibrator to output .200000V at 500Hz.

D. After allowing the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

CALIBRATING

E. The instrument will exit the calibration program and return to the 2V AC range.

F. Repeat the procedures in step 5 for the remaining ACV ranges using Table 6-7 as a guide.

6. For IEEE-488 bus calibration, proceed as follows:

A. Set the AC voltage calibrator to output 2.00000V at 500Hz.

B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V2XC0X.

C. Set the AC calibrator to output .200000V at 500Hz.

D. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V20E-3XC1X. Both calibration constants will automatically be stored in E²PROM.

E. Repeat steps A through D for the remaining ACV ranges using Table 6-7 as a guide.

7. High Frequency Check (100kHz):

A. With the ACV function, autorange and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-8.

B. Set the AC calibrator to output 100.000V at a frequency of 100kHz and allow sufficient time for the measurement to settle.

C. If the reading is not 100.000V ±1500 counts, then omit steps D through G and proceed to step 8.

D. Set the AC calibrator to output 1.00000V at 100kHz and allow the measurement to settle.

E. If the reading is not 1.00000V ±1500 counts, then omit steps F and G and proceed to step 8.

F. Set the AC calibrator to output 10.0000V at 100kHz and allow the measurement to settle.

G. If the reading is not 10.0000V ±1500 counts, then high frequency will have to be adjusted as explained in the following procedure (step 8). If the high frequency readings were within the defined range, step 8 does not have to be performed and ACV calibration is completed.

8. High Frequency Adjustment:

A. Slide the top cover back to gain access to the Model 1930. If the top cover is fastened to the chassis, perform steps 2A, 2B and 2C.

B. With the ACV function and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-8.

C. Set the Model 193 to the 100V range and set the AC calibrator to output 100.000V at a frequency of 100kHz.

WARNING
Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. The shield on the analog board is at input low potential and may have up to 500V on it. Use an insulated alignment tool to make the following adjustments.

D. After allowing sufficient time for the measurement to settle, use an insulated alignment tool to adjust C413 (see Figure 6-7) for a display reading of 100.000V ±250 counts.

E. Set the AC calibrator to output 1.00000V at 100kHz and set the Model 193 to the 2V range.

F. After allowing the measurement to settle, adjust C402 for a display reading of 1.00000V ±50 counts.

G. Set the Model 193 to the 20V range and set the AC calibrator to output 10.0000V at 100kHz.

H. After allowing the measurement to settle, adjust C412 for a display reading of 10.0000V ±100 counts.

I. Repeat steps C through H until no other adjustments need to be made.

J. Turn the Model 193 off, disconnect the line cord and test cables and fasten the top cover to the chassis.

Table 6-7. TRMS AC Volts (Model 1930) Calibration

193 ACV Range	193 Calibration Point	AC Calibrator Voltage Setting @ 500Hz	IEEE-488 Bus Commands
2 V	2.000000 V	2.00000 V	V2XC0X
	0.200000 V	.200000 V	V200E-3XC1X
20 V	20.00000 V	20.0000 V	V20XC0X
	2.00000 V	2.00000 V	V2XC1X
200 V	200.0000 V	200.000 V	V200XC0X
	20.0000 V	20.0000 V	V20XC1X
1000 V	650.000 V	650.000 V	V650XC0X
	100.000 V	100.000 V	V100XC1X
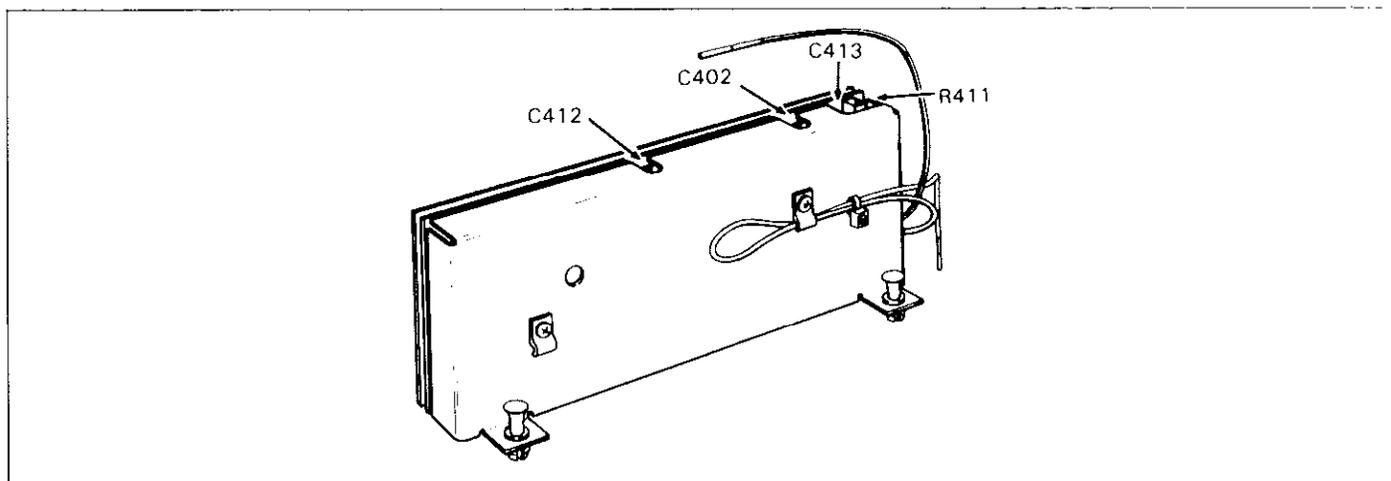
Figure 6-7. TRMS AC Volts Calibration Adjustments
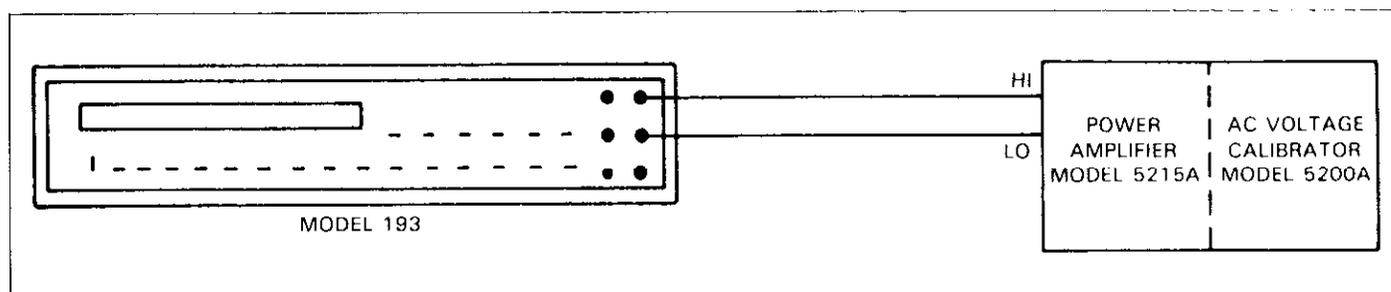
Figure 6-8. TRMS AC Volts Calibration Configuration

6.6.11 DC Current Calibration

With the Model 1931 installed, perform the following procedure to calibrate DCA:

NOTE
For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DCA function and the 200μA range.
2. Connect the DC current calibrator to the instrument as shown in Figure 6-9.
3. For front panel calibration, enter Program 96 as explained in paragraph 6.6.5, step 3 and proceed as follows:
   A. With the 200.0000μA DC calibration point displayed on the Model 193, set the current calibrator to output +200.000μA.
   B. After allowing sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:
      CALIBRATING

C. With the 000.0000μA DC calibration point displayed, set the current calibrator to output 000.000μA.
D. After allowing sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:
   CALIBRATING
E. The instrument will exit the calibration program and return to the 200μA range.
F. Repeat the procedures in step 3 for the remaining DCA ranges using Table 6-8 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the current calibrator to output 200.000μA.
   B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V200E-6XC0X.
   C. Set the current calibrator to output 000.000μA.
   D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V0XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining DCA ranges using Table 6-8 as a guide.

Table 6-8. DC Current Calibration

193 DCA Range	193 Calibration Point	DC Current Calibrator Output	IEEE-488 Bus Commands
200 μA	200.0000 μA	200.000 μA	V200E-6XC0X
	000.0000 μA	000.000 μA	V0XC1X
2mA	2.000000mA	2.00000mA	V2E-3XC0X
	0.000000mA	0.00000mA	V0XC1X
20mA	20.00000mA	20.0000mA	V20E-3XC0X
	00.00000mA	00.0000mA	V0XC1X
200mA	200.0000mA	200.000mA	V200E-3XC0X
	000.0000mA	000.000mA	V0XC1X
2 A	2.000000 A	2000.00mA	V2XC0X
	0.000000 A	0000.00mA	V0XC1X
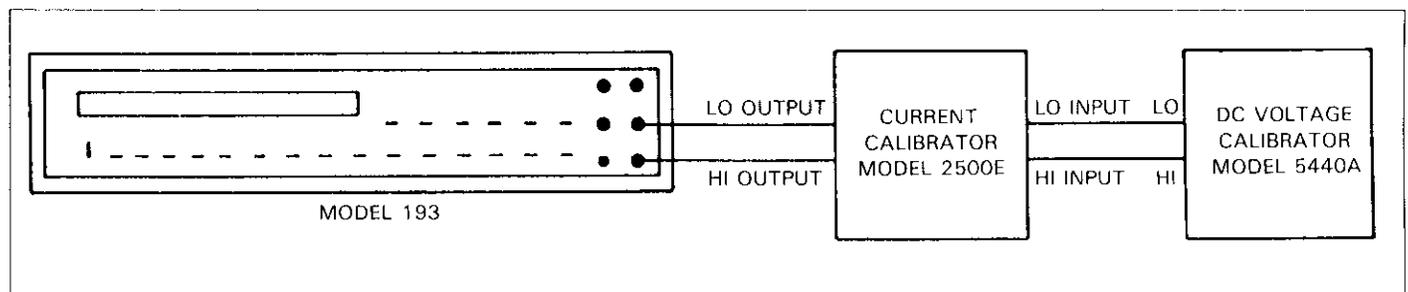
Figure 6-9. DC Current Calibration Configuration

6.6.12 TRMS AC Current Calibration

With both the Models 1930 and 1931 installed, perform the following procedure to calibrate the ACA function:

NOTE
For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ACA function and the 200μA range.
2. Connect the AC current calibrator to the instrument as shown in Figure 6-10.
3. For front panel calibration, enter Program 96 as explained in paragraph 6.6.5, step 3 and proceed as follows:
   A. With the 200.0000μA AC calibration point displayed on the Model 193, set the current calibrator to output 200.000μA at a frequency of 1kHz.
   B. After waiting sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:
      CALIBRATING
   C. With the 000.0000μA AC calibration point displayed,

set the current calibrator to output 000.000μA at 1kHz.
   D. After allowing the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:
      CALIBRATING
   E. The instrument will exit the calibration program and return to the 200μA range.
   F. Repeat the procedures in step 3 for the remaining ACA ranges using Table 6-9 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the current calibrator to output 200.000μA at 1kHz.
   B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V200E-6XC0X.
   C. Set the current calibrator to output 000.000μA at 1kHz.
   D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V0XC1X. Both calibration constants will automatically be stored in E^{2}PROM.
   E. Repeat steps A through D for the remaining ACA ranges using Table 6-9 as a guide.

Table 6-9. TRMS AC Current Calibration

193 ACA Range	193 Calibration Point	Current Calibrator Output @ 1kHz	IEEE-488 Bus Commands
200 μA	200.0000 μA	200.000 μA	V200E-6XC0X
	020.0000 μA	020.000 μA	V20E-6XC1X
2mA	2.000000mA	2.00000mA	V2E-3XC0X
	0.200000mA	0.20000mA	V200E-6XC1X
20mA	20.00000mA	20.0000mA	V20E-3XC0X
	02.00000mA	02.0000mA	V2E-3XC1X
200mA	200.0000mA	200.000mA	V200E-3XC0X
	020.0000mA	020.000mA	V20E-3XC1X
2 A	2.000000 A	2000.00mA	V2XC0X
	0.200000 A	0200.00mA	V200E-3XC1X
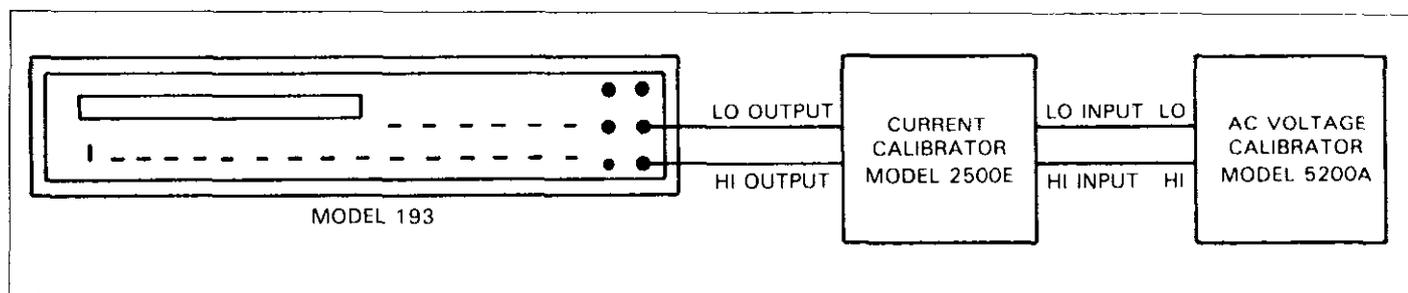
Figure 6-10. TRMS AC Current Calibration Configuration

6.7 DISASSEMBLY INSTRUCTIONS

If it is necessary to troubleshoot the instrument or to replace a component, use the following disassembly procedure. Refer to Figures 6-11 and 6-12.

WARNING
Disconnect the line cord and any test leads from the instrument before disassembly.

1. Remove the top cover as follows:
   A. The top cover is secured to the chassis of the Model 193 by two screws located at the rear of the instrument. Remove those two screws.
   B. Slide the top cover towards the rear of the instrument until it completely separates from the chassis.
2. Remove the bottom cover as follows:
   A. If installed, remove the four plastic feet located on the bottom cover. They are secured with four screws.
   B. The bottom cover is secured to the chassis of the Model 193 by two screws located at the rear of the instrument. Remove those two screws.
   C. Slide the bottom cover towards the rear until it completely separates from the chassis.

3. Remove the analog board as follows:
   A. The top shield is snugly secured to the analog board by four retaining clips. Remove the top shield by carefully lifting it up and off the analog board.

CAUTION
Take care not to contaminate components or the circuit board by touching , as this could adversely affect instrument performance.

   B. Disconnect the input wires from both the front and rear panel input terminals.
   C. Disconnect P/J 1016 which is a six pin connector (five pins used).
   D. Disconnect and remove the wires that feed through the four pulse transformers. When reinstalling, make sure that the wires are fed through the transformer cores in the correct direction as shown by the arrows etched on the PC-board and in Figure 6-11.
   E. From the bottom, remove the five screws that secure the analog board assembly to the mounting rails. Carefully remove the analog board from the instrument case taking care not to touch the PC board surfaces or any components.

F. The bottom shield is secured to the analog board by two screws accessible from the component side of the board. Again, be careful not to touch the PC board surfaces or any components when removing the shield.

4. Remove the digital board as follows:

A. Disconnect the display board ribbon cable (P/J 1017), located near the front of the instrument, from the digital board.

B. Disconnect the EXTERNAL TRIGGER Input and VOLTMETER COMPLETE wiring harness (P/J 1015).

C. Place the Model 193 on its side and remove the six screws securing the digital board to the mounting rails. The screws are accessible from the bottom.

D. Now place the instrument right-side up and remove the two screws securing the IEEE-488 connector to the rear panel.

E. Remove the four screws securing the rear panel to the chassis.

F. Remove the green, powerline ground wire from the rear panel. The ground wire is secured to the panel with a pem nut.

G. Place the rear panel in a location that is clear of the digital board.

H. Carefully lift the digital board out of the instrument.

5. Remove the display board as follows:

A. Remove each of the four decorative strips from the side panels as follows:

1. Place a thin blade screwdriver into one of the holes where the decorative strip is secured.

2. Carefully push outwards until the strip disengages from one of the fasteners.

3. Pull the strip away from the side panel.
   Note: To reinstall, align the strip in the recessed part of the side panel and then press the strip at the locations of the fasteners.

B. Remove the four screws that secure the front panel assembly to the side panels and disengage the front panel assembly from the chassis.

C. Loosen the four Allen set screws securing the bezel assemblies to the front panel. Remove the bezel assemblies from the front panel.

D. Lift the display board assembly from the front panel.

E. To separate the jumper board from the display board, disconnect the display ribbon cable at the display board and remove the two retaining screws that are accessible from the component side of the display board.

6. The instrument can be re-assembled by reversing the above procedure. Make sure that all parts are properly seated and secured and that all connections are properly made. To ensure proper operation, shields must be replaced and fastened securely.

WARNING
To ensure continued protection against safety hazards, power line ground (the green wire attached to the AC power receptacle) must be connected to the rear panel.

Figure 6-11. Connectors

MODEL 1931

TOP SHIELD

MODEL 1930

REAR PANEL

FRONT PANEL
ASSEMBLY

DIGITAL BOARD

ANALOG BOARD

DISPLAY BOARD ASSEMBLY
(DISPLAY BOARD &
JUMPER BOARD)

ALLEN SET SCREW (4)

MOUNTING RAIL (3)

BOTTOM SHIELD

SIDE PANEL ASSEMBLY (2)

DECORATIVE STRIP (4)

BEZEL ASSEMBLY (2)
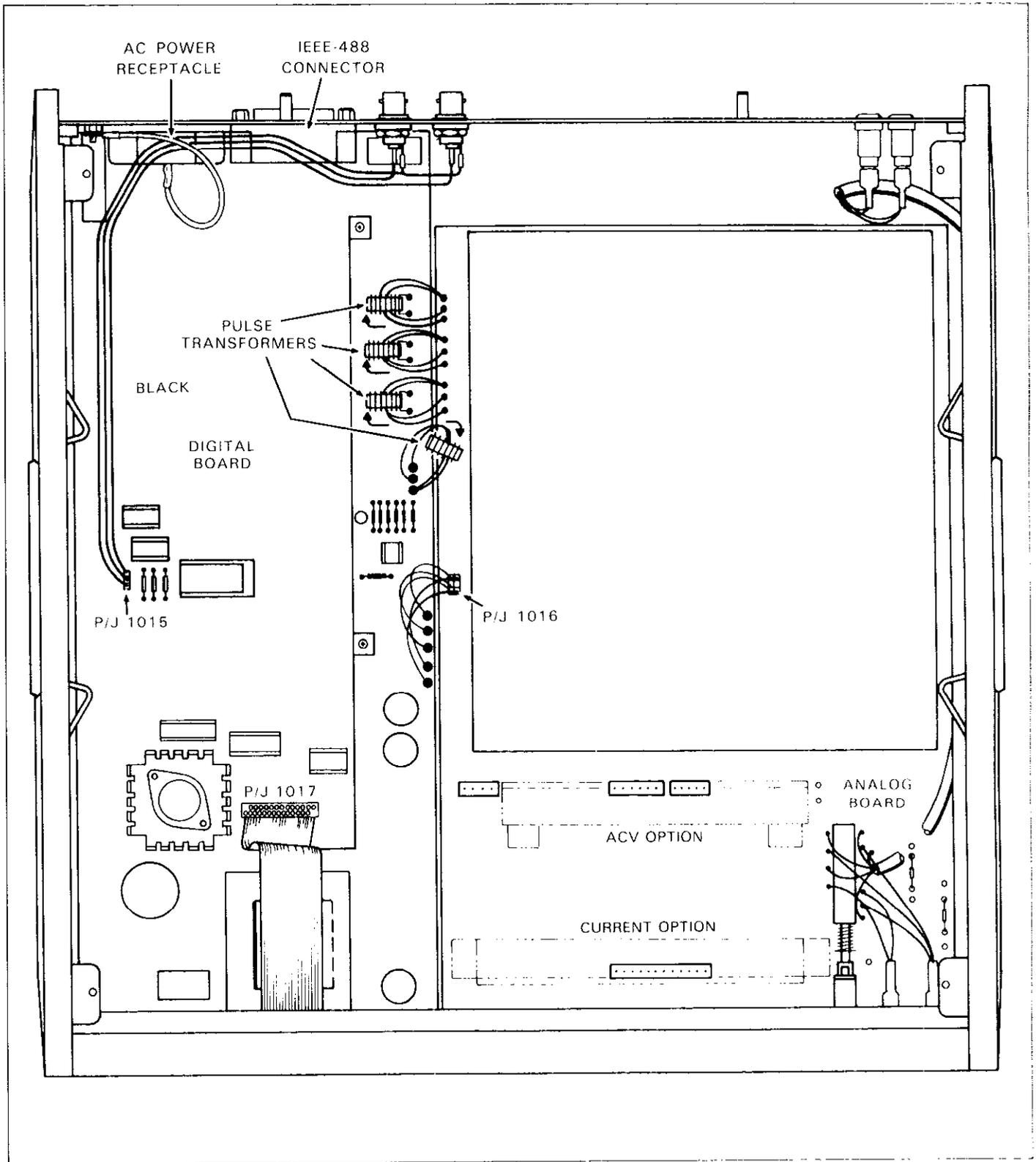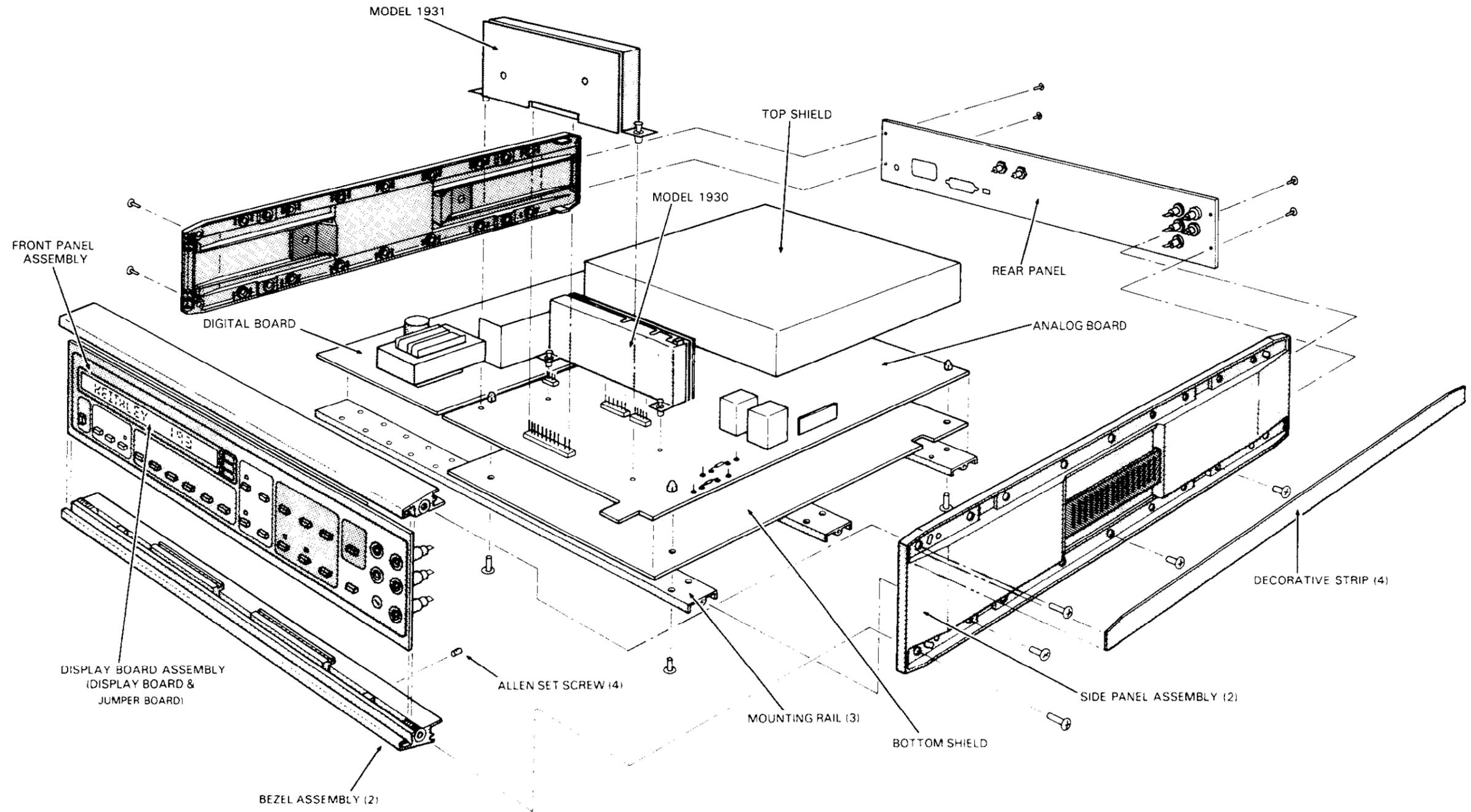
**Figure 6-12. Model 193 Exploded View**

6.8 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices operate at very high impedance levels for low power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices, if they are not handled properly. Table 6-10 lists static-sensitive devices used in the Model 193. When handling these devices, use the following precautions to avoid damaging them.

1. The devices listed in the table should be transported and handled only in containers specially designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder suckers.
6. Use only grounded tip solder irons.
7. Once the device is installed on the PC board, it is normally adequately protected and normal handling can resume.

6.9 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for use by qualified personnel having a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician. Note that schematic diagrams and component location drawings, which are an essential aid in troubleshooting, are located at the end of Section 7.

Table 6-10. Static-Sensitive Devices

Circuit Designation	Keithley Part No.
Model 193	
Q101	TG-175
Q106	TG-175
Q108	TG-128
Q111	TG-128
Q112	TG-139
Q113-Q115	TG-128
Q116-Q118	TG-139
Q119	TG-128
Q120-Q143	TG-139
U104	IC-413
U106	IC-412
U118	IC-135
U119	IC-283
U120, U121	IC-337
U122	IC-343
U123	IC-351
U124	IC-417
U125, U126	IC-416
U127	IC-31847-1
U128	IC-337
U129	IC-414
U301	IC-98
U302	IC-179
U303	IC-190
U304	IC-398
U305	IC-399
U306	IC-186
U307	IC-182
U309	IC-397
U312	LSI-67
U318	IC-397
U319	IC-213
U320	IC-351
U321	IC-177
U323	IC-173
U402	IC-141
Model 1930	
Q402	TG-84
Q404-Q408	TG-128
Model 1931	
U102	IC-206
U103	IC-251

6.9.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 193 depends not only on the skill of the technician, but relies on the use of accurate, reliable test equipment. Table 6-11 lists the equipment recommended for troubleshooting the Model 193. Other equipment such as logic analyzers and capacitance meters could also be helpful especially in difficult situations.

6.9.2 Power-Up Self Test

Upon power-up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E²PROM). Whenever one of the memory tests fails, the instrument will lock up and must be repaired. If all the tests pass, then the current IEEE address and software revision level of the instrument will be displayed. Immediately after turning on the Model 193, the following sequence will take place:

1. A digital check will be performed on the ROM circuitry. If the test fails, the instrument will lock up with the following message displayed:

OOOOOOOOOOOOOOO

Replacing U314 and U315 may resolve the problem.

2. If the ROM test passes, a digital self-test will then be performed on the RAM circuitry. If the RAM test fails, the instrument will lock up with the following error message displayed:

AAAAAAAAAAAAAA

Replacing U313 may resolve the problem.

3. Finally, the E²PROM circuitry where the calibration constants, IEEE address and line frequency settings are stored will be checked. If this test fails, the following message displayed:

UNCALIBRATED

Pressing any front panel momentary button will return the instrument to normal operation however, a complete calibration will have to be performed, and the IEEE address and line frequency setting should be checked. If the test still fails after calibration, try replacing U312 before recalibrating the instrument again.

4. The instrument will then go to the power-up default function.

Table 6-11. Recommended Troubleshooting Equipment

Equipment	Use
Five function DMM with 0.1% basic DCV accuracy, 10M input impedance.	Power supply and DC voltage checks; analog signal tracing continuity, logic levels.
Dual-trace, triggered sweep oscilloscope, DC to 50MHz.	Digital and analog waveform checks.
Digital Frequency Counter	Checking clock frequencies.

6.9.3 Program 93 - Self Diagnostic Program

This front panel program performs a display test and the same memory tests performed upon power-up. Also included is a troubleshooting test mode, that is designed to switch on various switching FETs and relays to allow signal tracing through the instrument. Perform the following procedure to utilize Program 93:

1. Press the PRGM button and then the 9 and 3 buttons. First is the display test. All segments of the display characters and front panel LEDs will be simultaneously displayed for a short period of time. This test allows the operator to note inoperative display segments of LEDs. Self test on the ROM, RAM, and E²PROM will then be performed. These are the same tests run on power-up and are explained in detail in paragraph 6.9.2.
2. The Model 193 will now go into the troubleshooting mode with the first N mode being displayed as follows:

N 01

The instrument is still on the same function and range as it was before Program 93 was run.
3. Using Table 6-12, reference the N mode to the current function and range to determine the proper working status of the listed circuit components.
4. To change the N mode, use the TRIGGER button.

5. To troubleshoot a different function and/or range, exit the program by pressing any front panel momentary button (except TRIGGER), select the desired function and/or range and again run Program 93.

6.9.4 Power Supplies

Table 6-13 shows the various checks that can be made to the power supplies of the Model 193. In addition to the normal voltage checks, it is a good idea to check the various supplies with an oscilloscope for signs of noise or oscillations.

6.9.5 Signal Conditioning Checks

These circuits can be checked by using the diagnostic program (Program 93) as explained in the paragraph 6.9.3.

6.9.6 Digital and Display Circuitry Checks

The digital and display circuitry can be checked out by using the troubleshooting data found in Tables 6-14 and 6-15.

Table 6-12. Model 193 Troubleshooting Mode

Range & Function	Measurement Phase	N Mode	Input Buffer Gain	Multiplex FET's On	Range FET's On	Relays On	1931 Relays On	1930 FET's On	1930 Relay K401 Energized (only if in AC + DC)
200mV DC	SIG	01	X10	Q134	Q126	K102			
	SIG ZERO	02	X10	Q140	Q126	K102			
	CAL	03	X1	Q141	Q126	K102			
	CAL ZERO	04	X1	Q140	Q126	K102			
2V DC	SIG	01	X1	Q134	Q126	K102			
	ZERO	02	X1	Q140	Q126	K102			
	CAL	03	X1	Q141	Q126	K102			
	No Test	04	—	—	—	—			
20V DC	SIG	01	X1	Q134		K103			
	SIG ZERO	02	X1	Q138		K103			
	CAL	03	X1	Q141		K103			
	CAL ZERO	04	X1	Q140		K103			
200V DC	SIG	01	X1	Q134	Q125				
	ZERO	02	X1	Q140	Q125				
	CAL	03	X1	Q141	Q125				
	No Test	04	—	—	—				
1kV DC	SIG	01	X1	Q134	Q124				
	ZERO	02	X1	Q140	Q124				
	CAL	03	X1	Q141	Q124				
	No Test	04	—	—	—				
2V AC	SIG	01	X1	Q142		K105	K107		X
	ZERO	02	X1	Q140		K105	K107		X
	CAL	03	X1	Q141		K105	K107		X
	No Test	04	—	—		—	—		—
20V AC	SIG	01	X1	Q142		K105	K107	Q406	X
	ZERO	02	X1	Q140		K105	K107	Q406	X
	CAL	03	X1	Q141		K105	K107	Q406	X
	No Test	04	—	—		—	—	—	—
200V AC	SIG	01	X1	Q142		K105	K107	Q404	X
	ZERO	02	X1	Q140		K105	K107	Q404	X
	CAL	03	X1	Q141		K105	K107	Q404	X
	No Test	04	—	—		—	—	—	—

Table 6-12. Model 193 Troubleshooting Mode (Cont.)

Range & Function	Measurement Phase	N Mode	Input Buffer Gain	Multiplex FET's On	Range FET's On	Relays On	1931 Relays On	1930 FET's On	1930 Relay K401 Energized (only if in AC + DC)
700V AC	SIG	01	X1	Q142		K105	K107	Q402	X
	ZERO	02	X1	Q140		K105	K107	Q402	X
	CAL	03	X1	Q141		K105	K107	Q402	X
	No Test	04	—	—		—	—	—	—
200Ω	REF HI	01	X1	Q125,Q137	Q115,Q118,Q119	K101,K102			
	REF LO	02	X1	Q127,Q134	Q115,Q118,Q119	K101,K102			
	SENSE HI	03	X10	Q125,Q134	Q115,Q118,Q119	K101,K102			
	SENSE LO	04	X10	Q125,Q139	Q115,Q118,Q119	K101,K102			
2kΩ	REF HI	01	X1	Q125,Q137	Q115,Q118,Q119	K101,K102			
	REF LO	02	X1	Q127,Q134	Q115,Q118,Q119	K101,K102			
	SENSE HI	03	X1	Q125,Q134	Q115,Q118,Q119	K101,K102			
	SENSE LO	04	X1	Q125,Q139	Q115,Q118,Q119	K101,K102			
20kΩ	REF HI	01	X1	Q125,Q137	Q114,Q117,Q119	K101,K102			
	REF LO	02	X1	Q127,Q134	Q114,Q117,Q119	K101,K102			
	SENSE HI	03	X1	Q125,Q134	Q114,Q117,Q119	K101,K102			
	SENSE LO	04	X1	Q125,Q139	Q114,Q117,Q119	K101,K102			
200kΩ	REF HI	01	X1	Q125,Q137	Q116,Q113,Q119	K101,K102			
	REF LO	02	X1	Q127,Q134	Q116,Q113,Q119	K101,K102			
	SENSE HI	03	X1	Q125,Q134	Q116,Q113,Q119	K101,K102			
	SENSE LO	04	X1	Q125,Q139	Q116,Q113,Q119	K101,K102			
2MΩ	REF HI	01	X1	Q125,Q137	Q116,Q112 Q119	K101,K102			
	SENSE HI	02	X1	Q125,Q134	Q116,Q112 Q119	K101,K102			
	SENSE LO	03	X1	Q125,Q139	Q116,Q112 Q119	K101,K102			
	No Test	04	—	—	—	—			
20MΩ	REF HI	01	X1	Q125,Q137	Q116,Q111	K101,K102			
	SENSE HI	02	X1	Q125,Q134	Q116,Q111	K101,K102			
	SENSE LO	03	X1	Q125,Q139	Q116,Q111	K101,K102			
	No Test	04	—	—	—	—			
200MΩ	REF HI	01	X1	Q125,Q137	Q116,Q111	K101			
	SENSE HI	02	X1	Q125,Q134	Q116,Q111	K101			
	SENSE LO	03	X1	Q125,Q139	Q116,Q111	K101			
	No Test	04	—	—	—	—			

Table 6-12. Model 193 Troubleshooting Mode (Cont.)

Range & Function	Measurement Phase	N Mode	Input Buffer Gain	Multiplex FET's On	Range FET's On	Relays On	1931 Relays On	1930 FET's On	1930 Relay K401 Energized (only if in AC + DC)
200µA AC	SIG	01	X1	Q142			K106, K101		X
	ZERO	02	X1	Q140			K106, K101		X
	CAL	03	X1	Q141			K106, K101		X
	No Test	04	—	—			—		—
2mA AC	SIG	01	X1	Q142			K106, K102		X
	ZERO	02	X1	Q140			K106, K102		X
	CAL	03	X1	Q141			K106, K102		X
	No Test	04	—	—			—		—
20mA AC	SIG	01	X1	Q142			K106, K103		X
	ZERO	02	X1	Q140			K106, K103		X
	CAL	03	X1	Q141			K106, K103		X
	No Test	04	—	—			—		—
200mA AC	SIG	01	X1	Q142			K106, K104		X
	ZERO	02	X1	Q140			K106, K104		X
	CAL	03	X1	Q141			K106, K104		X
	No Test	04	—	—			—		—
2A AC	SIG	01	X1	Q142			K106, K105		X
	ZERO	02	X1	Q140			K106, K105		
	CAL	03	X	Q141			K106, K105		
	No Test	04	—	—			—		
200µA DC	SIG	01	X10	Q143			K101		
	SIG ZERO	02	X10	Q140			K101		
	CAL	03	X1	Q141			K101		
	CAL ZERO	04	X1	Q140			K101		

Table 6-12. Model 193 Troubleshooting Mode (Cont.)

Range & Function	Measurement Phase	N Mode	Input Buffer Gain	Multiplex FET's On	Range FET's On	Relays On	1931 Relays On	1930 FET's On	1930 Relay K401 Energized (only if in AC + DC)
2mA DC	SIG	01	X10	Q143			K102		
	SIG ZERO	02	X10	Q140			K102		
	CAL	03	X1	Q141			K102		
	CAL ZERO	04	X1	Q140			K102		
20mA DC	SIG	01	X10	Q143			K103		
	SIG ZERO	02	X10	Q141			K103		
	CAL	03	X1	Q140			K103		
	CAL ZERO	04	X1	Q143			K103		
200mA DC	SIG	01	X10	Q143			K104		
	SIG ZERO	02	X10	Q140			K104		
	CAL	03	X1	Q141			K104		
	CAL ZERO	04	X1	Q140			K104		
2A DC	SIG	01	X10	Q143			K105		
	SIG ZERO	02	X10	Q140			K105		
	CAL	03	X1	Q141			K105		
	CAL ZERO	04	X1	Q140			K105		

Table 6-13. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S302 Line Switch	Set to 115 or 230V as required.	Line voltage selection.
2	F301 Line Fuse	Check for continuity.	Remove fuse to check.
3	Line Power	Plugged into live receptacle; power on.	
4	+5V Digital Supply U301, pin 2	+5V, ±5%	Referenced to digital common.
5	+5V Analog Supply VR301, pin 2	+5V, ±5%	Reference to analog common.
6	±15V Analog Supplies VR302, pin 2; VR303, pin 2	+15V, −15V, ±0.75V	Referenced to analog common.

Table 6-14. Digital Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U312, U313, U314, U315 (RAM or ROM)	Pass RAM, ROM and E^{2}PROM self-test on power up.	Display will lock if failure occurs.
2	U310, pin 2 (PA0)	TTL level pulses every 1msec.	VIA clock
3	U310, pin 3 (PA1)	TTL level pulses every 15msec.	Data
4	U310, pin 6 (PA4)	Switch data (+5V or 0V)	Data input to VIA
5	U310, pin 7 (PA5)	Switch data (+5V or 0V)	Data input to VIA
6	U310, pin 8 (PA6)	Switch data (+5V or 0V)	Data input to VIA
7	U310, pin 9 (PA7)	Switch data (+5V or 0V)	Data input to VIA
8	U310, pin 19	Variable pulse train (0V to +5V)	VIA Data Line
9	U320, pin 6	Variable pulse train (0V to +5V)	Data Output
10	U106, pin 13	Variable pulse train (0V to +5V)	Output of A/D Converter
11	U310, pins 12 through 16	Variable pulse train (0V to +5V)	Analog data to VIA
12	U311, pin 3	1kHz pulses	IRQ line
13	U311, pin 37	+5V, ±5%	Reset line
14	U316, pin 9	+5V signal pulsed 0V to +5V every 1msec.	INT line
15	U316, pin 19	+5V (Logic "1")	RESET line
16	U316, pin 18	2MHz square wave at 0V to +5V	lock
17	U316, pin 28	Should go false (+5V) when command is sent.	ATN line
18	U316, pins 28 (ATN), 24 (NDAC), 25 (NRFD), 26 (DAV), and the data lines.	Refer to Figure 3-2 for required conditions.	Handshake Sequence

Table 6-15. Display Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U403, pin 2	+5V, ±5%	+5V supply
2	U406, U407, U408, U409, pins 1, 7, 8 and 14	Variable pulses	Segment drivers
3	U401, U404, pins 10 through 16	Variable pulses	Digital drivers
4	U403, U405, pins 3, 4, 5, 6, 10, 11 and 12	1msec negative going pulse every 10msec.	
5	J1018, pin 24 (S1)	Depress S410, S412, S414, S416 or S418 button.	Pulse present when button pressed.
6	J1018, pin 22 (S2)	Depress S411, S413, S415, S417 or S419 button.	Pulse present when button pressed.
7	J1018, pin 21 (S3)	Depress S406, S407, S408, S409 or S420 button.	Pulse present when button pressed.
8	J1018, pin 20 (S4)	Depress S401, S402, S403, S404 or S405 button.	Pulse present when button pressed.

SECTION 7
REPLACEABLE PARTS

7.1 INTRODUCTION

This section contains replacement parts information, component location drawings and schematic diagrams for the Model 193.

7.2 PARTS LIST

Parts are listed alphanumerically in order of their circuit designations. Table 7-1 contains parts list information for the display board. Table 7-2 contains parts list information for the digital board. Table 7-3 contains parts list information for the analog board. A parts list for the Model 1930 option is contained in Table 7-4; while Table 7-5 contains a parts list for the Model 1931 option. Table 7-6 contains a mechanical parts list for the Model 193.

7.3 ORDERING INFORMATION

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

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

If an additional instruction manual is required, order the manual package (Keithley Part Number 193-901-00). The manual package contains an instruction manual and any applicable addenda.

7.4 FACTORY SERVICE

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

7.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

Schematic diagrams and component location drawings follow the appropriate replaceable parts list for that particular board.

Table 7-1. Display Board, Parts List

| Circuit Desig.	Description	Schematic Location	Keithley Part No.
C401	Capacitor, 10μF, 25V, Aluminum Electrolytic	D5	C-314-10
C402	Capacitor, 0.1μF, 50V, Ceramic Film	C5	C-237-.1
DS401-DS407	Display, Dual 14-Segment	Sev	DD-39
DS408-DS415	LED, Red	Sev	PL-71
J1018			CS-362-13
J1018			CS-363-13
R401	Resistor, Thick Film	Sev	TF-43
R402	Resistor, Thick Film	Sev	TF-43
R403	Resistor, Thick Film	Sev	TF-77
R404	Resistor, Thick Film	Sev	TF-77
S401-S420	Switch, Pushbutton	Sev	SW-435
U401	Darlington Transistor Array, ULN2003A	B3	IC-206
U402	Hex Inverter, Open Collector Output, CD4012AE	Sev	IC-141
U403	Integrated Circuit, SN74LS164	C5	IC-127
U404	Darlington Transistor Array, ULN2003A	D3	IC-206
U405	Integrated Circuit, SN74LS164	D5	IC-127
U406	Transistor Array, MPQ3906	H4	IC-396
U407	Transistor Array, MPQ3906	F4	IC-396
U408	Transistor Array, MPQ3906	F4	IC-396
U409	Transistor Array, MPQ3906	G4	IC-396
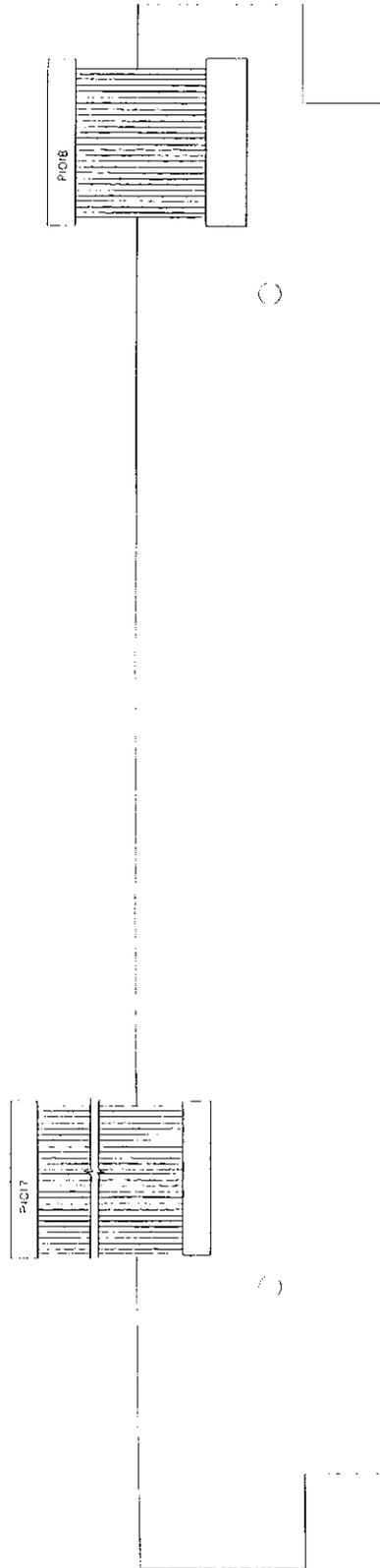
Figure 7-1. Jumper Board, Component Location Drawing. Dwg. No. 193-160
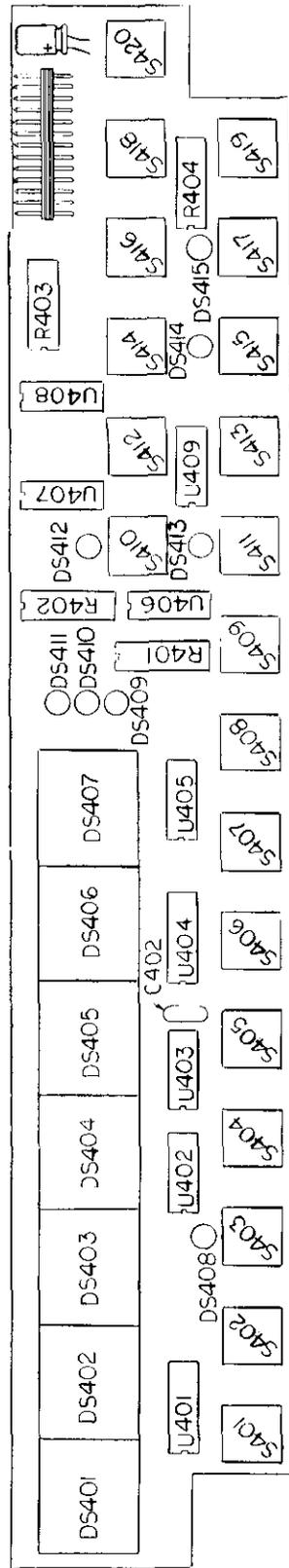
Figure 7-2. Display Board, Component Location Drawing. Dwg. No. 193-110
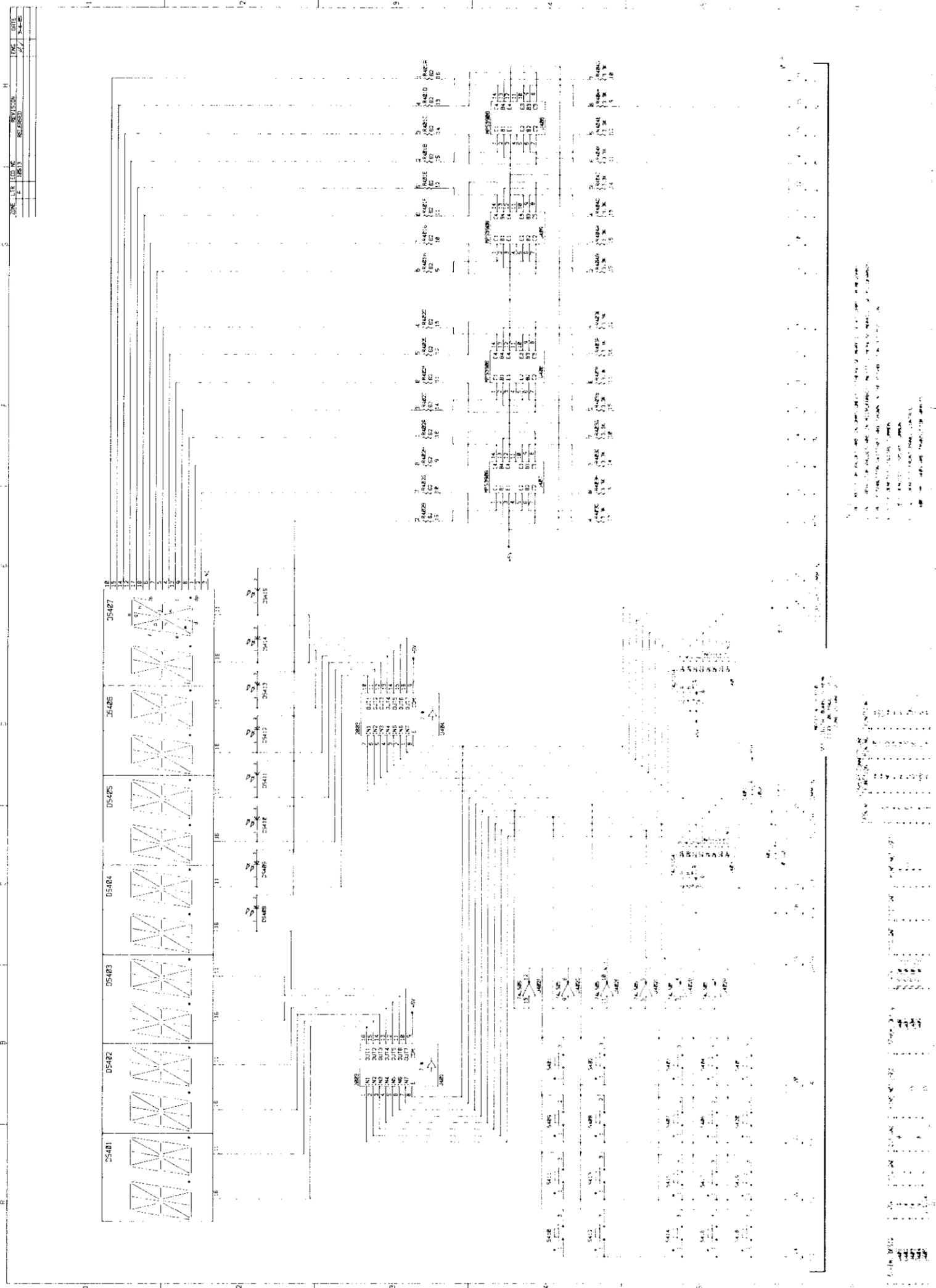
Figure 7-3. Display Board, Schematic Diagram, Dwg. No. 193-116

Table 7-2. Digital Board, Parts List

Circuit Desig.	Description	Schematic Location*	Keithley Part No.
BT301	Battery, NiCad, 3.6V	2/G2	BA-36
C301	Capacitor,	2/D2	C-342-10,000
C302	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/E2	C-314-10
C303	Capacitor, 0.33μ F, 50V, Ceramic Film	2/D2	C-237-.33
C304	Capacitor, 0.1μ F, 50V, Ceramic Film	1/A1	C-237-.1
C305	Capacitor, 0.1μ F, 50V, Ceramic Film	1/B1	C-237-.1
C306	Capacitor, 0.1μ F, 50V, Ceramic Film	1/C1	C-237-.1
C307	Capacitor, 0.1μ F, 50V, Ceramic Film	1/G1	C-237-.1
C308	Capacitor, 0.1μ F, 50V, Ceramic Film	1/F2	C-237-.1
C309	Capacitor, 0.1μ F, 50V, Ceramic Film	1/E1	C-237-.1
C310	Capacitor, 0.1μ F, 50V	1/H3	C-365-.1
C311	Capacitor, 0.01μ F, 500V, Ceramic Disc	1/H3	C-22-.01
C312	Capacitor, 0.1μ F, 50V	1/E4	C-365-.1
C313	Capacitor, 0.1μ F, 50V	1/F4	C-365-.1
C314	Capacitor, 0.1μ F, 50V, Ceramic Film	1/E4	C-237-.1
C315	Capacitor, 15pF, 1000V, Ceramic Disc	1/A5	C-64-15p
C316	Capacitor, 15pF, 1000V, Ceramic Disc	1/B5	C-64-15p
C317	Capacitor, 0.1μ F, 50V	1/A4	C-365-.1
C318	Capacitor, 0.1μ F, 50V	1/D4	C-365-.1
C319	Capacitor, 0.1μ F, 50V	1/C4	C-365-.1
C320	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/G2	C-314-10
C321	Capacitor, 0.1μ F, 50V, Ceramic Film	1/C4	C-237-.1
C322	Capacitor, 0.1μ F, 50V, Ceramic Film	1/B4	C-237-.1
C323	Capacitor, 10μ F, 25V, Aluminum Electrolytic	1/A6	C-314-10
C324	Capacitor, 0.1μ F, 50V	1/H2	C-365-.1
C325	Capacitor, 0.1μ F, 50V	1/A5	C-365-.1
C326	Capacitor, 0.1μ F, 50V	1/G4	C-365-.1
C327	Capacitor, 0.1μ F, 50V, Ceramic Disc	1/A6	C-22-.01
C328	Capacitor, 0.1μ F, 50V	1/G4	C-365-.1
C329	Capacitor, 0.1μ F, 50V	1/H2	C-365-.1
C330	Capacitor, 0.1μ F, 50V	1/D6	C-365-.1
C331	Capacitor, 0.1μ F, 50V		C-365-.1
C332	Not Used		
C333	Capacitor, 2200μ F, 25V, Aluminum Electrolytic	2/D3	C-314-2200
C334	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/E3	C-314-10
C335	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/E5	C-314-10
C336	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/E6	C-314-10
C337	Capacitor, 620μ F, 35V, Electrolytic	2/D5	C-309-620
C338	Capacitor, 620μ F, 35V, Electrolytic	2/D5	C-309-620
C339	Capacitor, 0.1μ F, 50V	1/D6	C-365-.1
C340	Capacitor, 0.1μ F, 50V	1/B5	C-365-.1
C341	Capacitor, 0.1μ F, 50V	1/B5	C-365-.1
C342	Capacitor, 0.1μ F, 50V	1/B6	C-365-.1
C343	Capacitor, 10μ F, 25V, Aluminum Electrolytic	1/B6	C-314-10
C344	Capacitor, 0.0047μ F, 500V, Ceramic Disc	1/B6	C-22-.0047
CR301	Bridge Rectifier, 1A, 100PIV	1/D5	RF-52
CR302	Bridge Rectifier, 5A, PE05	2/D2	RF-48
CR303	Bridge Rectifier, 5A, PE05	2/D3	RF-48
CR304	Diode, Silicon, 1.5A, 400V, W04M	2/D5	RF-46
CR305	Diode, Silicon, 1N4148	2/G2	RF-28
CR306	Diode, Silicon, 1N4148	1/A5	RF-28
CR307	Diode, Silicon, 1N4148	1/A6	RF-28
F301	Fuse, ⅜A, 250V, Slo-Blo, MDL	2/B4	FU-18
F301	Fuse, 7⁄16A, 250V, Slo-Blo, 3AG	2/G2	FU-29

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Table 7-2. Digital Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
J1013	Connector, IEEE	1/H2	CS-501
J1014	AC Receptacle	2/B5	CS-388
J1015	Connector, 3 pins	1/D5	CS-339-3
J1017	Connector, 26 pins	1/G6	CS-389-3
Q301	Translator, NPN, Silicon, 2N3904	2/G2	TG-47
Q302	Translator, PNP, Silicon, 2N3906	2/G2	TG-84
R301	Resistor, 100Ω, 5%, ¼W, Composition	1/C5	R-76-100
R302	Resistor, 100Ω, 5%, ¼W, Composition	1/D5	R-76-100
R303	Resistor, 3.3kΩ, 5%, ¼W, Composition	1/D5	R-76-3.3k
R304	Resistor, Thick Film	1/A3	TF-140
R305	Resistor, 1MΩ, 10%, ¼W, Composition		R-76-1M
R306	Resistor, 4.7kΩ, 5%, ¼W, Composition	2/F2	R-76-4.7k
R307	Resistor, 15kΩ, 5%, ¼W, Composition	2/F2	R-76-15k
R308	Resistor, 1kΩ, 5%, ¼W, Composition	2/G2	R-76-1k
R309	Resistor, 150Ω, 5%, ¼W, Composition	2/G2	R-76-150
R310	Resistor, 61.9kΩ, 1%, ⅛W, Composition	1/A5	R-88-61.9k
R311	Resistor, 20kΩ, 1%, ⅛W, Composition	1/A6	R-88-20k
R312	Resistor, 261kΩ, 1%, ⅛W, Composition	1/A6	R-88-261k
R313	Not Used		
R314	Not Used		
R315	Not Used		
R316	Not Used		
R317	Resistor, 470Ω, 5%, ¼W, Composition	1/C6	R-76-470
R318	Resistor, 470kΩ, 5%, ¼W, Composition	1/D6	R-76-470
R319	Resistor, 2.4kΩ, 5%, ¼W, Composition	1/C6	R-76-2.4k
R320	Resistor, 100Ω, 5%, ¼W, Composition	1/C6	R-76-100
R321	Resistor, 47Ω, 5%, ¼W, Composition	1/C6	R-76-47
R322	Resistor, 2.2kΩ, 5%, ¼W, Composition	1/D2	R-76-2.2k
R323	Resistor, 82Ω, 5%, ¼W, Composition	1/C5	R-76-82
R324	Resistor, 82Ω, 5%, ¼W, Composition	1/C5	R-76-82
R325	Resistor, 82Ω, 5%, ¼W, Composition	1/C6	R-76-82
S301	Switch	2/B4	SW-426
S302	Switch	2/B3	SW-397
S303	Switch	1/E6	SW-318
T301	Transformer, USA	2/C2	TR-210
T301	Transformer, Japan	2/C2	TR-233
T302	Pulse Transformer	1/B5	TR-211
T303	Pulse Transformer	1/B5	TR-211
T304	Pulse Transformer	1/B6	TR-211
U301	5V Regulator, LM309k	2/E2	IC-98
U302	Quad 2-Input Non Gate 74LS02	Sev	IC-179
U303	Dual 2 to 4 Line Decoder/Multiplexer, 74LS139	1/B1	IC-190
U304	3 to 8 Line Decoder, 74HCT138	1/C1	IC-398
U305	C-MOS Quad 2-Input NAND, 74HCT00	Sev	IC-399
U306	Hex Inverter, 74LS04	Sev	IC-186
U307	Decoders/Demultiplexers, 74LS138	1/E1	IC-182
U308	Octal GPIB Transceiver, 75161A	1/H4	IC-299
U309	C-MOS Tri-State Flip-Flop, MM74HCT374	1/F4	IC-397
U310	Versatile Interface Adapter (VIA), 6522A	1/E4	LSI-45
U311	8-Bit Microprocessing Unit, MC68B09	1/A4	LSI-65

Table 7-2. Digital Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U312	Programmable E² PROM, X28004A	1/D4	LSI-67
U313	8192 Word × 8 Bit Static CMOS RAM, HM6264LP-15	1/C4	LSI-66
U314	16k × 8 UV Erasable PROM, 27128	1/C4	193-800**
U315	8k × 8 UV Erasable PROM, 2764	1/B4	193-801**
U316	GPIB Adapter, 9914A	1/G4	LSI-49
U317	Octal GPIB Transceiver, 75160A	1/H3	IC-298
U318	C-MOS Tri-State Flip-Flop, MM74HCT374	1/F4	IC-397
U319	Dual 4 Bit Decade and Binary Counter, 74LS393	1/D6	IC-213
U320	Quad 2-Input NAND Gate	Sev	IC-351
U321	Microprocessor Bipolar Monolithic IC	1/A6	IC-177
U322	Not Used		
U323	Voltage Comparator, LM311N	1/C6	IC-173
VR301	+5V Voltage Regulator, 7805	2/E2	IC-93
VR302	Positive Voltage Regulator, 78M15CU	2/E3	IC-194
VR303	Negative Voltage Regulator, 79M15CU	2/E4	IC-195
VR304	Voltage Regulator Diode, Silicon, IN702A	1/C6	DZ-33
W301	Jumper	2/D3	J-3
Y301	Crystal, 8MHz	1/A5	CR-24-1

**Order same software as presently installed. For example, if the software revision level is C6 then order 193-800-C6 and 193-801-C6.

Figure 7-4. Digital Board, Component Location Drawing. Dwg. No. 193-100

Figure 7-5. Digital Board, Schematic Diagram, Dwg. No. 193-106

Figure 7-5. Digital Board, Schematic Diagram, Dwg. No. 193-106

Table 7-3. Analog Board, Parts List

Circuit Desig.	Description	Schematic Location*	Keithley Part No.
C101	Capacitor, 0.1μ F, 50V	2/B4	C-365-.1
C102	Capacitor, 1μ F, 50V, Ceramic Film	3/A6	C-237-1
C103	Capacitor, 1μ F, 50V, Ceramic Film	3/C6	C-237-1
C104	Capacitor, 1μ F, 50V, Ceramic Film	3/C6	C-237-1
C105	Capacitor, 1μ F, 50V, Ceramic Film	3/C6	C-237-1
C106	Capacitor, 0.015μ F, 200V, Polycarbonate	3/E2	C-221-.015
C107	Capacitor, 0.015μ F, 200V, Polycarbonate	3/E2	C-221-.015
C108	Capacitor, 100pF, 1000V, Ceramic Disc	3/F2	C-64-100p
C109	Not Used		
C110	Not Used		
C111	Not Used		
C112	Capacitor, 0.1μ F, 50V	3/F5	C-365-.1
C113	Capacitor, 0.1μ F, 50V	3/F6	C-365-.1
C114	Capacitor, 0.1μ F, 50V	4/A4	C-365-.1
C115	Capacitor, 68pF, 1000V, Ceramic Disc	4/A4	C-64-68p
C116	Capacitor, 47pF, 1000V, Ceramic Disc	4/A5	C-64-47p
C117	Capacitor, 0.1μ F, 50V	4/B2	C-365-.1
C118	Capacitor, 0.1μ F, 50V	4/B4	C-365-.1
C119	Capacitor, 0.1μ F, 50V	4/D1	C-365-.1
C120	Capacitor, .10μ F, 25V, Aluminum Electrolytic	4/C3	C-314-10
C121	Capacitor, 0.1μ F, 50V	4/D3	C-365-.1
C122	Capacitor, 0.1μ F, 50V	4/D2	C-365-.1
C123	Capacitor, 15pF, 1000V, Ceramic Disc	4/E1	C-64-15p
C124	Capacitor, 0.0047μ F, 100V, Metalized Polypropylene	4/E1	C-306-.0047
C125	Capacitor, 0.1μ F, 50V	4/E1	C-365-.1
C126	Capacitor, 0.1μ F, 50V	4/H3	C-365-.1
C127	Capacitor, 1μ F, 50V, Ceramic Film	4/F4	C-327-1
C128	Capacitor, 0.1μ F, 50V	4/F5	C-365-.1
C129	Capacitor, 1μ F, 50V, Ceramic Film	4/F5	C-237-1
C130	Capacitor, 0.1μ F, 50V	4/G4	C-365-.1
C131	Capacitor, 0.1μ F, 50V	4/G3	C-365-.1
C132	Capacitor, 0.1μ F, 50V	4/G4	C-365-.1
C133	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/C6	C-314-10
C134	Not Used		
C135	Capacitor, 220pF, 500V, Polystyrene	1/B4	C-138-220p
C136	Not Used		
C137	Capacitor, 150pF, 500V, Polystyrene	1/B4	C-138-150p
C138	Capacitor, 82pF, 1000V, Ceramic Disc	4/D2	C-64-82p
C139	Capacitor, 1000pF, 1000V, Ceramic Disc	4/B1	C-64-1000p
C140	Capacitor, 0.1μ F, 50V	3/F2	C-365-.1
C141	Capacitor, 0.1μ F, 50V	3/F2	C-365-.1
C142	Capacitor, 0.1μ F, 50V	3/E6	C-365-.1
C143	Not Used		
C144	Capacitor, 10μ F, 25V, Aluminum Electrolytic	2/G5	C-314-10
C145	Capacitor, 1μ F, 50V, Ceramic Film	4/G5	C-237-1
C146	Not Used		
C147	Capacitor, 1μ F, 50V, Ceramic Film	1/E2	C-237-1
C148	Capacitor, 1μ F, 50V, Ceramic Film	1/E2	C-237-1
C149	Capacitor, 330pF, 1000V, Ceramic Disc		C-64-330p
C150	Capacitor, 330pF, 1000V, Ceramic Disc		C-64-330p
CR101	Rectifier, 1N4006	1/G1	RF-38
CR102	Diode, Silicon, 1N4148	3/D5	RF-28
CR103	Diode, Silicon, 1N4148	3/D5	RF-28
CR104	Diode, Silicon, 1N4148		RF-28
F101	Fuse, 2A, 250V, 3AG, Normal-Blo	1/A5	FU-13
F101	Fuse, 2A, 250V, 5×20mm, Normal Blo	1/A5	FU-48

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Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
J1001	Input Terminal, Ω Sense HI, Front	1/A3	BJ-12-2
J1002	Input Terminal, Ω Sense LO, Front	1/A3	BJ-12-0
J1003	Input Terminal, Input HI, Front	1/A2	BJ-12-2
J1004	Input Terminal, Input LO, Front	1/A4	BJ-12-0
J1005	Input Terminal, Amps Input, Front	1/A5	BJ-12-9
J1006	Input Terminal, Ω Sense HI, Rear	1/A3	BJ-12-2
J1007	Input Terminal, Ω Sense LO, Rear	1/A3	BJ-12-0
J1008	Input Terminal, Input HI, Rear	1/A2	BJ-12-2
J1009	Input Terminal, Input LO, Rear	1/A4	BJ-12-0
J1010	Input Terminal, Amps Input, Rear	1/A5	BJ-12-9
J1016	Connector	3/H4	193-325
J1020	Connector, Male	—	CS-339-1
J1021	Connector, Male	—	CS-339-1
J1022	Connector, Male	—	CS-339-1
J1023	Connector	2/D6	29995
J1024	Contact Pin	1/A2	CS-463
J1025	Contact Pin	1/F6	CS-463
J1026	Connector	1,2/Sev	193-326
J1027	Contact Pin	1/B5	CS-463
J1028	Contact Pin	1/D5	CS-463
J1029	Contact Pin	1/E5	CS-463
J1030	Connector, Male	1/E5	CS-338-18
J1031	Contact Pin	1/A2	CS-463
J1032	Contact Pin	1/B2	CS-463
K101	Relay, 5V	1/B2, 2/F4	RL-72
K102	Relay, 5V	1/B2, 2/F5	RL-72
K103	Relay, High Voltage, 5V	1/B3, 2/F5	RL-82
K104	Not Used		
K105	Relay, High Voltage, 5V	1/A2, 2/F5	RL-82
L101	Choke, 100μH	4/B4	CH-14
L102	Choke		CH-29
L103	Choke		CH-29
P1020	Connector, MAXI-PV		CS-415
P1021	Connector, MAXI-PV		CS-415
P1022	Connector, MAXI-PV		CS-415
Q101	Transistor, MP-842	3/E2	TG-175
Q102	Transistor, NPN, Silicon, 2N3904	3/E3	TG-47
Q103	Not Used		
Q104	Not Used		
Q105	Transistor, N-Channel JFET	4/B5	TG-167
Q106	Transistor, MP-842	4/E2	TG-175
Q107	Transistor, N-Channel JFET, 2N5434	4/F2	TG-174
Q108	Transistor, N-Channel FET, 2N4392	4/F2	TG-128
Q109	Transistor, NPN, Silicon, 2N3904	4/G4	TG-47
Q110	Not Used		
Q111	Transistor, N-Channel FET, 2N4392	1/A1	TG-128
Q112	Transistor, N-Channel JFET, PF5301	1/B1	TG-139
Q113	Transistor, N-Channel FET, 2N4392	1/B1	TG-128
Q114	Transistor, N-Channel FET, 2N4392	1/B1	TG-128
Q115	Transistor, N-Channel FET, 2N4392	1/C1	TG-128
Q116	Transistor, N-Channel JFET, PF5301	1/D1	TG-139
Q117	Transistor, N-Channel JFET, PF5301	1/C1	TG-139
Q118	Transistor, N-Channel JFET, PF5301	1/C1	TG-139
Q119	Transistor, N-Channel JFET, 2N4392	1/B2	TG-128
Q120	Transistor, N-Channel JFET, PF5301	1/C2	TG-139

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
Q121	Transistor, N-Channel JFET, PF5301	1/C2	TG-139
Q122	Transistor, N-Channel JFET, PF5301	1/C3	TG-139
Q123	Transistor, N-Channel JFET, PF5301	1/C3	TG-139
Q124	Transistor, N-Channel JFET, PF5301	1/C4	TG-139
Q125	Transistor, N-Channel JFET, PF5301	1/C4	TG-139
Q126	Transistor, N-Channel JFET, PF5301	1/D2	TG-139
Q127	Transistor, N-Channel JFET, PF5301	1/D1	TG-139
Q128	Transistor, N-Channel JFET, PF5301	1/D2	TG-139
Q129	Transistor, N-Channel JFET, PF5301	1/D2	TG-139
Q130	Not Used		
Q131	Transistor, N-Channel JFET, PF5301	1/F3	TG-139
Q132	Transistor, NPN, Silicon, 2N3565	1/F1	TG-39
Q133	Transistor, High Voltage, NPN, TIP-49	1/F2	TG-137
Q134	Transistor, N-Channel JFET, PF5301	1/F2	TG-139
Q135	Transistor, N-Channel JFET, PF5301	1/F4	TG-139
Q136	Transistor, N-Channel JFET, PF5301	1/G1	TG-139
Q137	Transistor, N-Channel JFET, PF5301	1/G2	TG-139
Q138	Transistor, N-Channel JFET, PF5301	1/G3	TG-139
Q139	Transistor, N-Channel JFET, PF5301	1/G4	TG-139
Q140	Transistor, N-Channel JFET, PF5301	1/G4	TG-139
Q141	Transistor, N-Channel JFET, PF5301	1/F5	TG-139
Q142	Transistor, N-Channel JFET, PF5301	1/F6	TG-139
Q143	Transistor, N-Channel JFET, PF5301	1/G6	TG-139
Q144	Not Used		
Q145	Not Used		
Q146	Transistor, NPN, Silicon		TG-138
R101	Resistor, 47Ω, 5%, ¼W, Composition	2/A2	R-76-47
R102	Resistor, 100Ω, 5%, ¼W, Composition	2/A2	R-76-100
R103	Resistor, 2.4kΩ, 5%, ¼W, Composition	2/B2	R-76-2.4k
R104	Resistor, 1kΩ, 5%, ¼W, Composition	2/B1	R-76-1k
R105	Resistor, 47Ω, 5%, ¼W, Composition	2/A3	R-76-47
R106	Resistor, 100Ω, 5%, ¼W, Composition	2/A3	R-76-100
R107	Resistor, 2.4kΩ, 5%, ¼W, Composition	2/B3	R-76-2.4k
R108	Resistor, 1kΩ, 5%, ¼w, Composition	2/B3	R-76-1k
R109	Resistor, 47Ω, 5%, ¼W, Composition	2/A5	R-76-47
R110	Resistor, 100Ω, 5%, ¼W, Composition	2/A4	R-76-100
R111	Resistor, 2.4kΩ, 5%, ¼W, Composition	2/B4	R-76-2.4k
R112	Resistor, 1kΩ, 5%, ¼W, Composition	2/B4	R-76-1k
R113	Resistor Set (R113 and R114)	3/A5	R-293
R114	Resistor Set (R113 and R114)	3/A6	R-293
R115	Resistor, 6.49kΩ, 1%, ⅛W, Composition	3/B5	R-88-6.49k
R116	Resistor, 12.4kΩ, 1%, ⅛W, Composition	3/B6	R-88-12.4k
R117	Resistor, 2.1kΩ, 1%, ⅛W, Composition	3/B6	R-88-2.1k
R118	Resistor, 1.24kΩ, 1%, ⅛W, Composition	3/B5	R-88-1.24k
R119	Resistor, 15kΩ, 5%, ¼W, Composition	3/D2	R-76-15k
R120	Resistor, 12kΩ, 5%, ¼W, Composition	3/E3	R-76-12k
R121	Resistor, 13kΩ, 0.1%, ⅛W, Fixed	3/E2	R-176-13k
R122	Resistor, 15kΩ, 1%, ⅛W, Composition	3/E3	R-88-15k
R123	Resistor, 13kΩ, 0.1%, ⅛W, Fixed	3/E2	R-176-13k
R124	Not Used		
R125	Not Used		
R126	Resistor Set (R126 and R127)	3/F4	R-292
R127	Resistor Set (R126 and R127)	3/F4	R-292
R128	Resistor, 470Ω, 5%, ¼W, Composition	2/G4	R-76-470
R129	Not Used		
R130	Resistor, 3,4kΩ, 1%, ⅛W, Composition	3/E5	R-88-3.4k

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
R131	Resistor, 100kΩ, 1%, ⅛W, Composition	3/E5	R-88-100k
R132	Resistor, 100kΩ, 1%, ⅛W, Composition	3/E5	R-88-100k
R133	Resistor, 3.4kΩ, 1%, ⅛W, Composition	3/E6	R-88-3.4k
R134	Resistor, 17.4kΩ, 1%, ⅛W, Composition	3/F5	R-88-17.4k
R135	Resistor, 17.4kΩ, 1%, ⅛W, Composition	3/F6	R-88-17.4k
R136	Resistor, 10Ω, 5%, ¼W, Composition	3/F5	R-76-10
R137	Resistor, 10Ω, 5%, ¼W, Composition	3/F6	R-76-10
R138	Resistor, 10kΩ, 5%, ¼W, Composition	4/A1	R-76-10k
R139	Resistor, 220kΩ, 5%, ¼W, Composition	4/A1	R-76-220k
R140	Resistor, 22Ω, 5%, ¼W, Composition	4/A4	R-76-22
R141	Resistor, 10MΩ, 10%, ¼W, Composition	4/A5	R-76-10M
R142	Resistor, 3.9kΩ, 5%, ¼W, Composition	4/D1	R-76-3.9k
R143	Resistor, 10kΩ, 5%, ¼W, Composition	4/C2	R-76-10k
R144	Resistor, 4.7kΩ, 5%, ¼W, Composition	4/B4	R-76-4.7k
R145	Resistor, 4.7kΩ, 5%, ¼W, Composition	4/B5	R-76-4.7k
R146	Resistor, 3kΩ, 5%, ¼W, Composition	4/C2	R-76-3k
R147	Resistor, 3kΩ, 5%, ¼W, Composition	4/C2	R-76-3k
R148	Resistor, 7.87kΩ, 1%, ⅛W, Composition	4/C3	R-88-7.87k
R149	Resistor, 10kΩ, 5%, ¼W, Composition	4/D1	R-76-10k
R150	Resistor, 20kΩ, 1%, ⅛W, Composition	4/E1	R-88-20k
R151	Resistor, 20kΩ, 1%, ⅛W, Composition	4/E1	R-88-20k
R152	Resistor, 60.4kΩ, 1%, ⅛W, Composition	4/E2	R-88-60.4k
R153	Resistor, 142.8kΩ, 0.1%, ⅛W, Fixed	4/E3	R-176-142.8k
R154	Resistor, 1MΩ, 0.1%, ⅛W, Fixed	4/E3	R-176-1M
R155	Resistor, 10kΩ, 5%, ¼W, Composition	4/F2	R-76-10k
R156	Resistor, 7.78kΩ, 0.1%, ⅛W, Fixed	4/F3	R-176-7.78k
R157	Resistor, 10kΩ, 5%, ¼W, Composition	4/F2	R-76-10k
R158	Resistor, 2.8kΩ, 1%, ⅛W, Composition	4/F4	R-88-2.8k
R159	Resistor, 7.15kΩ, 1%, ⅛W, Composition	4/F4	R-88-7.15k
R160	Resistor, 10kΩ, 1%, ⅛W, Composition	4/F5	R-88-10k
R161	Resistor, 11.5kΩ, 1%, ⅛W, Composition	4/G1	R-88-11.5k
R162	Resistor, 48.7kΩ, 1%, ⅛W, Composition	4/G2	R-88-48.7k
R163	Resistor, 60.4kΩ, 1%, ⅛W, Composition	4/G2	R-88-60.4k
R164	Resistor, 14kΩ, 1%, ⅛W, Composition	4/G5	R-88-14k
R165	Resistor, 1kΩ, 5%, ¼W, Composition	4/G4	R-76-1k
R166	Resistor, Thick Film	1/Sev	TF-108
R167	Resistor, 9.99MΩ	1/A1	R-294-9.99M
R168	Resistor, 1.108MΩ, 0.1%, ¼W, Metal Film	1/B1	R-264-1.108M
R169	Resistor, 100.7kΩ, 0.1%, ⅒W, Metal Film	1/B1	R-263-100.7k
R170	Resistor, 10kΩ, 0.1%, ⅒W, Metal Film	1/B1	R-263-10k
R171	Resistor, 1kΩ, 0.1%, ⅒W, Metal Film	1/C1	R-263-1k
R172	Resistor, 333kΩ, 1%, ½W, Metal Film	1/D1	R-94-333k
R173	Resistor, 1MΩ, 10%, ½W, Composition	1/B2	R-1-1M
R174	Resistor, 1MΩ, 10%, ¼W, Composition	1/B2	R-76-1M
R175	Resistor, 1.5MΩ, 10%, 1W, Composition	1/A2	R-2-1.5M
R176	Resistor, 1MΩ, 10%, 1W, Composition	1/A2	R-2-1M
R177	Resistor, 100kΩ, 10%, 1W, Composition	1/A2	R-2-100k
R178	Resistor, 100kΩ, 1%, ½W, Metal Film	1/B3	R-94-100k
R179	Resistor, 100kΩ, 10%, 1W, Composition	1/A4	R-2-100k
R180	Resistor, 300kΩ, 1%, 8W	1/B2	R-247-300k

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
R181	Resistor, Thick Film	1/Sev	TF-202
R182	Resistor, Thick Film	1/Sev	TF-201
R183	Resistor, 324kΩ, 1%, ⅛W, Composition	1/C4	R-88-324k
R184	Resistor, 232kΩ, 1%, ½W, Composition	1/C4	R-94-232k
R185	Resistor, 33.2kΩ, 1%, ⅛W, Composition	1/C2	R-88-33.2k
R186	Resistor, 560Ω, 5%, ¼W, Composition	1/C3	R-76-560
R187	Resistor, Thick Film	1/Sev	TF-108
R188	Resistor, 200kΩ, 1%, ½W, Composition	1/D2	R-94-200k
R189	Not Used		
R190	Resistor, 200kΩ, 1%, ⅛W, Composition	1/F3	R-88-200k
R191	Resistor, 200kΩ, 1%, ⅛W, Composition	1/F2	R-88-200k
R192	Resistor, 200kΩ, 1%, ⅛W, Composition	1/F1	R-88-200k
R193	Resistor, 200kΩ, 1%, ½W, Metal Film	1/F1	R-94-200k
R194	Resistor, 1kΩ, 5%, ¼W, Composition	1/F1	R-76-1k
R195	Resistor, 2.4kΩ, 5%, ¼W, Composition	1/F2	R-76-2.4k
R196	Resistor, Thick Film	1/Sev	TF-108
R197	Not Used		
R198	Resistor, 333kΩ, 1%, ½W, Metal Film	1/G2	R-94-333k
R199	Resistor, Thick Film	1/Sev	TF-146
R200	Resistor, 953kΩ, 1%, ⅛W, Composition	1/G3	R-88-953k
R201	Resistor, 333kΩ, 1%, ½W, Metal Film	1/G4	R-94-333k
R202	Resistor, 316kΩ, 1%, ⅛W, Composition	1/F5	R-88-316k
R203	Resistor, 332kΩ, 1%, ⅛W, Composition	1/F5	R-88-332k
R204	Resistor, 10MΩ, 10%, ¼W, Composition	1/F5	R-76-10M
R205	Resistor, 332kΩ, 1%, ⅛W, Composition	1/G6	R-88-332k
R206	Resistor, 332kΩ, 1%, ⅛W, Composition	1/Sev	R-88-332k
R207	Resistor, 1MΩ, 1%, ⅛W, Composition	1/G6	R-88-1M
R208	Resistor, 100kΩ, 10%, 1W, Composition	1/E1	R-2-100k
R209	Resistor, 49.9kΩ, 1%, ⅛W, Composition	1/C3	R-88-49.9k
R210	Resistor, 82Ω, 5%, ¼W, Composition		R-76-82
R211	Resistor, 8.87kΩ, 1%, ⅛W, Composition	1/G3	R-88-8.87k
R212	Resistor, 10kΩ, 1%, ⅛W, Composition	1/F3	R-88-10k
R213	Resistor, 1MΩ, 10%, ¼W, Composition	1/F3	R-76-1M
R214	Not Used		
R215	Resistor, 360Ω, 5%, ¼W, Composition	1/F3	R-76-360
R216	Resistor, 360Ω, 5%, ¼W, Composition	1/F4	R-76-360
S101	Switch, Front/Rear	—	SW-459
S102	Switch, Front/Rear	1/A4	SW-458
T101	Transformer	4/G3	TR-211
TP1-TP6	Test Point Connector Pins	Sev	CS-339-1
U101	Voltage Comparator, LM311N	2/B2	IC-173
U102	Voltage Comparator, LM311N	2/B3	IC-173
U103	Voltage Comparator, LM311N	2/B4	IC-173
U104	Op Amp, MP5502DP	3/A5	IC-413
U105	Voltage Reference, Selected LM399	3/C5	193-600
U106	Integrated Circuit, 74HC02	3/Sev	IC-412
U107	Quad Comparator, LM339	2/E1	IC-219
U108	Quad Comparator, LM339	2/E2	IC-219
U109	Quad Comparator, LM339	2/E6	IC-219
U110	Quad Comparator, LM339	2/G1	IC-219
U111	Quad Comparator, LM339	2/G2	IC-219
U112	Quad Comparator, LM339	2/G3	IC-219
U113	Quad Comparator, LM339	2/G4	IC-219
U114	Linear Op Amp, 308A	3/E2	IC-203

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U115	Not Used		
U116	Wide Bandwidth JFET Input Op Amp, LF351N	3/E5	IC-176
U117	Dual JFET Input Op Amp, Selected LF353N	3/E5,6	30477
U118	BCD-to-Decimal Decoder	2/E3	IC-135
U119	Triple 2-Channel Analog Multiplexer, CD4053BC	2,3/Sev	IC-283
U120	Dual D Flip-Flop, 74HC74	4/Sev	IC-337
U121	Dual D Flip-Flop, 74HC74	4/Sev	IC-337
U122	Dual Voltage Comparator, LM393	4/Sev	IC-343
U123	Quad 2-Input NAND Gate, 74HC00	4/Sev	IC-351
U124	Synchronous Decade Up/Down Counter, 74HC192	4/C5	IC-417
U125	Synchronous Binary Up/Down Counter, 74HC193	4/D5	IC-416
U126	Synchronous Binary Up/Down Counter, 74HC193	4/E5	IC-416
U127	Multiplexer, selected CD4053DC	4/Sev	31847-1
U128	Dual D Flip-Flop, 74HC74	4/Sev	IC-337
U129	Inverting High Speed Op Amp, MP5501CP	4/D1	IC-414
U130	Not Used		
U131	Triple 2-Channel Analog Multiplexer, CD4053BC	3,4/Sev	IC-283
U132	Op Amp, MP5502DP	4/G4	IC-413
U133	Op Amp, MP5502DP	4/G5	IC-413
U134	Selected IC-218	1/E2	30167
U135	Op Amp, MP5502DP	1/F2	IC-413
U136	Op Amp, Selected	1/F3	193-602
U137	8-Stage Shift-Store Register, MC14094	2/D1	IC-251
U138	8-Stage Shift-Store Register, MC14094	2/D2	IC-251
U139	8-Stage Shift-Store Register, MC14049	2/D3	IC-251
U140	8-Stage Shift-Store Register, MC14049	2/D5	IC-251
U141	Darlington Transistor Array, ULN5003A	2/E4	IC-206
VR101	Diode, Zener, 6.3V	3/E5	DZ-58
VR102	Diode, Zener, 6.3V	3/E5	DZ-58
VR103	Diode, Zener, 4.3V	1/C3	DZ-63
VR104	Diode, Zener, 6.2V	1/F4	DZ-21
VR105	Diode, Zener, 8,2V	1/F3	DZ-61
VR106	Diode, Voltage Regulator	2/G5	DZ-33
W101	Jumper	1/B2	J-3
W102	Jumper	1/E5	J-3
Y101	Crystal, 3.84MHz	4/A4	CR-13
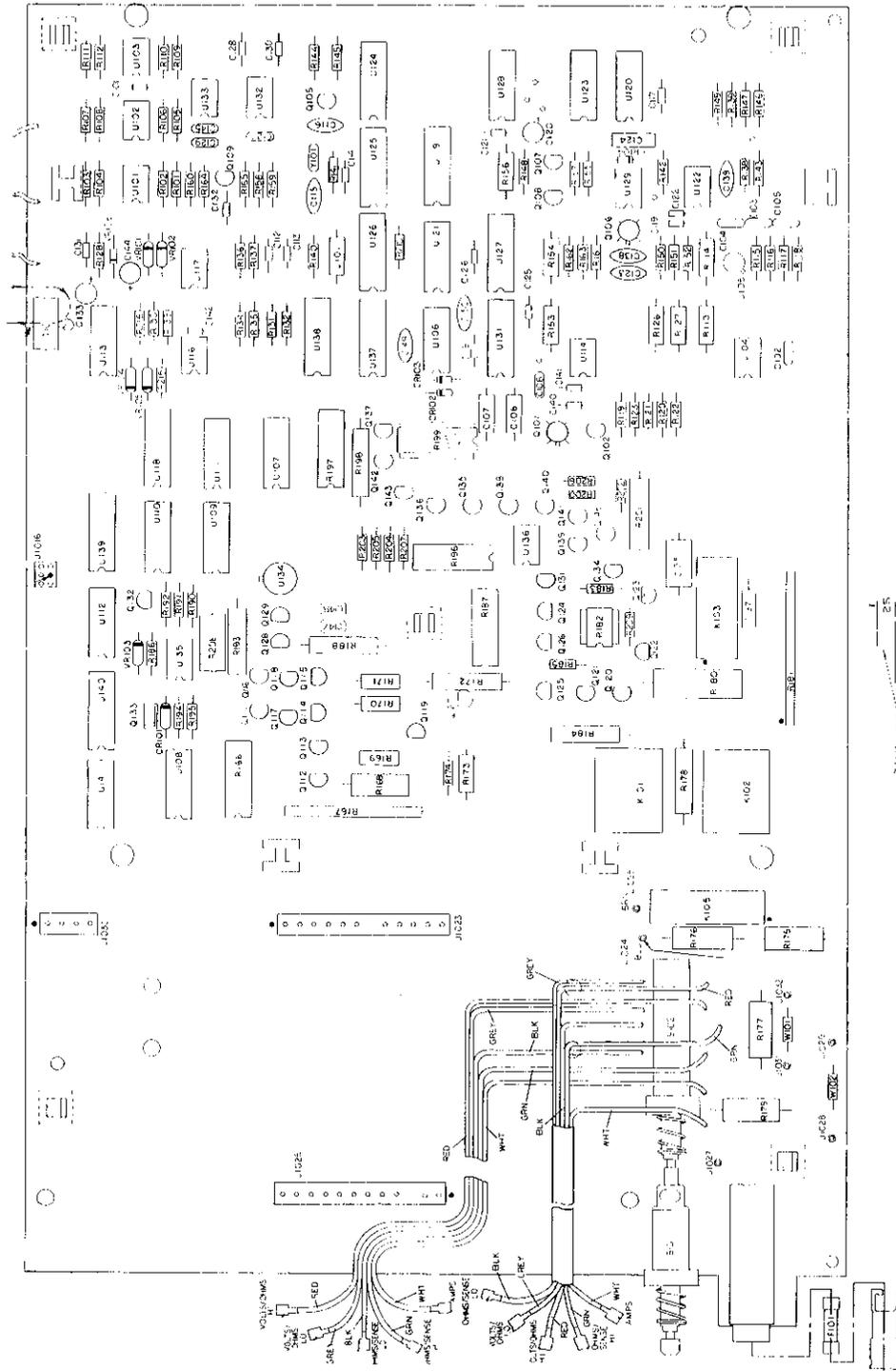
Figure 7-6. Analog Board, Component Location Drawing, Dwg. No. 193-120

Figure 7-7. Analog Board, Schematic Diagram, Dwg. No. 193-126 (sheet 1 of 4)

Figure 7-7. Analog Board, Schematic Diagram, Dwg. No. 193-126 (Sheet 2 of 4)

Figure 7-7. Analog Board, Schematic Diagram,
Dwg. No. 193-126 (Sheet 3 of 4)

Figure 7-7. Analog Board, Schematic Diagram, Dwg. No. 193-126 (Sheet 4 of 4)

Table 7-4. Model 1930, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C401	Capacitor, 0.05μF, 1000V, Metal Polystyrene	A4	C-285-.05
C402	Capacitor, 0.25pF-1.5pF, 2000V, Trimmer	C3	C-343
C403	Capacitor, 1.0μF, 50V, Aluminum Electrolytic	B3	C-325-1.0
C404	Capacitor, 1.0μF, 50V, Aluminum Electrolytic	B4	C-325-1.0
C405	Capacitor, 330pF, 500V, Polystyrene	C1	C-138-330p
C406	Capacitor, 30pF, 500V, Mica	C2	C-236-30p
C407	Capacitor, 0.25pF-1.5pF, 2000V, Trimmer	C3	C-216
C408	Capacitor, 1.2μF, 50V, Metalized Polycarbonate	F4	C-335-1.2
C409	Capacitor, 1.0μF, 50V, Metalized Polycarbonate	F5	C-335-1.0
C410	Capacitor, 1.0μF, 50V, Metalized Polycarbonate	F5	C-335-1.0
C411	Capacitor, 33pF, 500V, Mica	D4	C-236-33p
C412	Capacitor, 6.8pF, 50V, Tubular Ceramic	D4	C-282-6.8p
C413	Capacitor, 0.25pF-1.5pF, 2000V, Trimmer	B4	C-413
C414	Capacitor, 0.75pF, 50V, Tubular Ceramic	B4	C-282-.75p
CR401	Diode, Silicon	B2	RF-28
CR402	Diode, Silicon	B5	RF-28
CR403	Dode, Silicon	C5	RF-28
K401	Relay		RL-69
P1023	Connector, Female, 12 pin	A2,G2	CS-337-12
P1024	Connector, Female, Lug	A5	LU-90
P1025	Connector, Female, Lug	G5	LU-90
Q401	Transistor, PNP	B2	TG-84
Q402	Transistor, N-Channel, JFET, 2N4392	D2	TG-128
Q403	Transistor, N-Channel, JFET, 2N4392	E2	TG-77
Q404	Transistor, N-Channel, JFET, 2N4392	D2	TG-128
Q405	Transistor, N-Channel, JFET, Selected 2N4392	E2	TG-77
Q406	Transistor, N-Channel, JFET, 2N4392	D3	TG-128
Q407	Transistor, N-Channel, JFET, Selected 2N4392	E3	TG-77
Q408	Transsitor, Dual FET	C4	TG-118
R401	Resistor, 1kΩ, 1%, ¼W, Metal Film	B4	R-307-1k
R402	Resistor, 1kΩ, 1%, ¼W, Metal Film	B4	R-307-1k
R403	Resistor, 2MΩ, 0.5%, 1W, Metal Film	B4	R-303-2M
R404	Resistor, Pot, 100Ω, 10%, ¾W	C2	RP-89-100
R405	Resistor, Pot, 1kΩ, 10%, ¾W	C2	RP-89-1k
R406	Resistor, Pot, 10kΩ, 10%, ¾W	C3	RP-89-10k
R407	Resistor, Pot, 1kΩ, 10%, ¾W	F5	RP-89-1k
R408	Resistor, 2.12kΩ, 0.5%, ⅛W, Metal Film	C2	R-246-2.12k
R409	Resistor, 19.6kΩ, 0.5%, ⅛W, Metal Film	C2	R-246-19.6k
R410	Resistor, 217kΩ, 0.5%, ⅛W, Metal Film	C3	R-246-217k
R411	Resistor, Pot, 100kΩ, 10%, ¾W	D5	RP-89-100k
R412	Resistor, 1MΩ, 10%, ¼W, Composition	D2	R-76-1M
R413	Resistor, 10kΩ, 5%, ¼W, Composition	D2	R-76-10k
R414	Resistor, 10kΩ, 5%, ¼W, Composition	D3	R-76-10k
R415	Resistor, 1MΩ, 10%, ¼W, Composition	D3	R-76-1M
R416	Resistor, 10kΩ, 5%, ¼W, Composition	D3	R-76-10k
R417	Resistor, 1MΩ, 10%, ¼W, Composition	D3	R-76-1M
R418	Resistor, 2MΩ, 0.5%, ⅛W, Metal Film	C4	R-246-2.0M
R419	Resistor, 3.65kΩ, 1%, ⅛W, Composition	D4	R-88-3.65k
R420	Resistor, 24kΩ, 5%, ¼W, Composition	F5	R-76-24k

Table 7-4. Model 1930, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
R421	Resistor, 100kΩ, 1%, ⅛W, Composition	F2	R-88-100k
R422	Resistor, 22Ω, 5%, ¼W, Composition	G2	R-76-22
R423	Resistor, 2.2kΩ, 5%, ¼W, Composition	F4	R-76-2.2k
R424	Resistor, 3.3kΩ, 5%, ¼W, Composition	G4	R-76-3.3k
R425	Resistor, 2.2kΩ, 5%, ¼W, Composition	A2	R-76-2.2k
R426	Resistor, Pot, 100kΩ, 10%, ½W	F2	RP-111-100k
R427	Resistor, 2.2kΩ, 5%, ¼W, Composition	F5	R-76-2.2k
R428	Resistor, 499Ω, 1%, ⅛W, Composition	E5	R-88-499
R429	Resistor, 56.2kΩ, 0.5%, ⅛W, Metal Film	C4	R-246-56.2k
R430	Resistor, 56,2kΩ, 0.5%, ⅛W, Metal Film	C4	R-246-56.2k
R431	Resistor, 44.2kΩ, 1%, ⅛W, Composition	C5	R-88-44.2k
R432	Resistor, 100kΩ, 5%, ¼W, Composition	C5	R-76-100k
R433	Resistor, 169Ω, 1%, ⅛W, Composition	C5	R-88-169
R434	Resistor, 33kΩ, 5%, ¼W, Composition	D4	R-76-33k
R435	Resistor, 10Ω, 5%, ¼W, Composition	A3	R-76-10
R436	Resistor, 10Ω, 5%, ¼W, Composition	A3	R-76-10
U401	Monolithic JFET Input Op Amp	D4	IC-152
U402	Voltage Quad Comparator, LM339	F3	IC-219
U403	TRMS-to-DC Converter	F5	IC-305
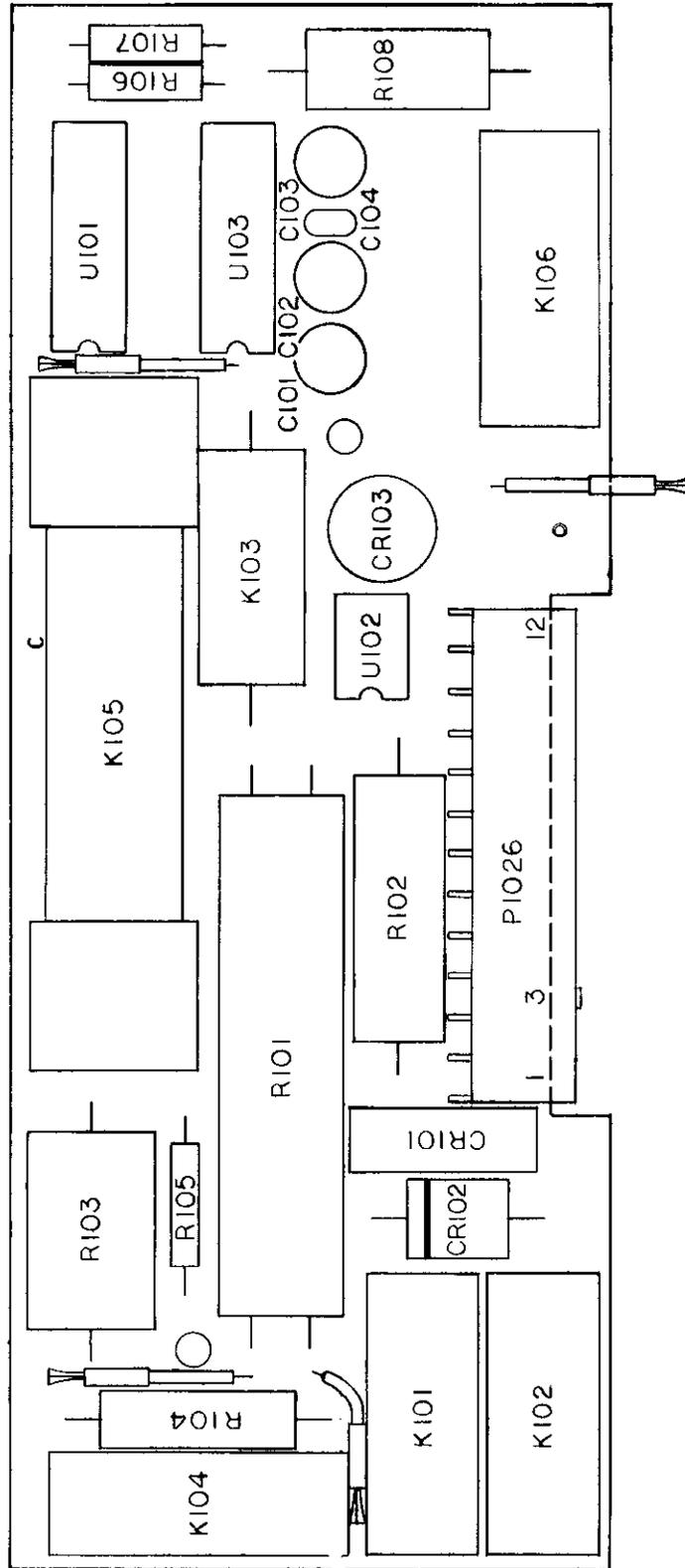
Figure 7-8. Model 1930, Component Location Drawing, Dwg. No. 1930-100
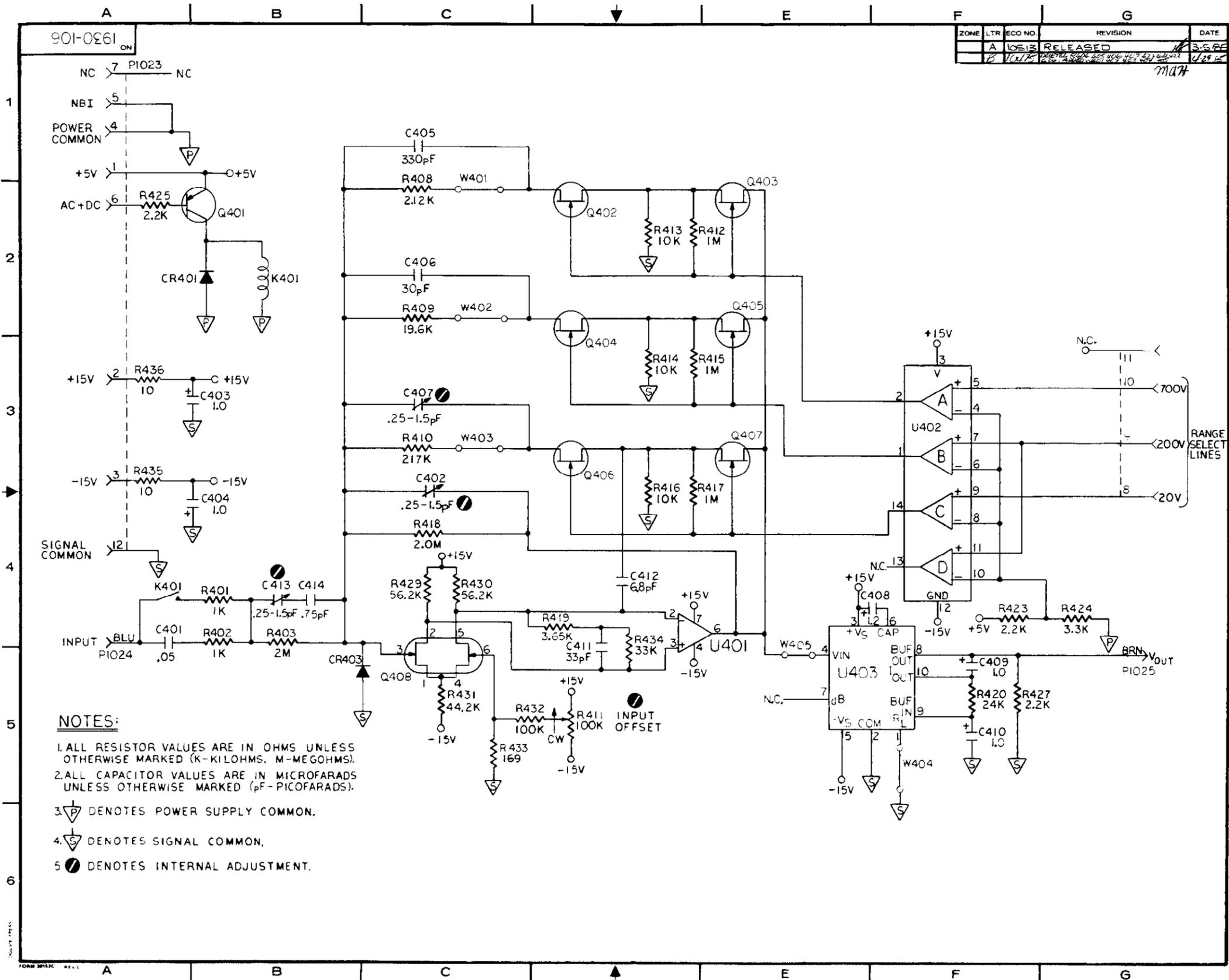
Figure 7-9. Model 1930, Schematic Diagram, Dwg. No. 1930-106

NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
3. ▽P DENOTES POWER SUPPLY COMMON.
4. ▽ DENOTES SIGNAL COMMON.
5. ◉ DENOTES INTERNAL ADJUSTMENT.

Table 7-5. Model 1931, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C101	Capacitor, 10μF, 25V, Aluminum Electrolytic	E2	C-314-10
C102	Capacitor, 10μF, 25V, Aluminum Electrolytic	E2	C-314-10
C103	Capacitor, 10μF, 25V, Aluminum Electrolytic	C1	C-314-10
C104	Capacitor, 0.1μF, 50V, Ceramic Film	B2	C-237-.1
CR101	Rectifier, PE05	B5	RF-48
CR102	Recitifer, Silicon, MR501	B6	RF-34
CR103	Rectifer, Silicon, PF40	G2	RF-46
J1024	Contact Pin	E1	CS-357
K101	Relay, 5V	D2	RL-73
K102	Relay, 5V	D3	RL-73
K103	Relay, 5V	D3	RL-59
K104	Relay, 5V	D4	RL-50
K105	Relay, 5V	D5	RL-49
K106	Relay, 5V	E1	RL-69
K107	Relay, 5V	E1	RL-69
P1025	Connector, Female, lug	E1	LU-90
P1026	Connector, Female, 12 pin	A2	CS-337-12
P1027	Connector, Female, lug	B5	LU-90
P1028	Connector, Female, lug	B6	LU-90
P1029	Connector, Female, lug	A6	LU-90
R101	Resistor, 0.1Ω, 0.1%, 7.5W, Wirewound	E5	R-262-0.1
R102	Resistor, 0.898Ω, 0.1%, 5W, Wirewound	E5	R-310-.898
R103	Resistor, 9Ω	E4	R-252-9
R104	Resistor, 90Ω, 0.1%, ½W, Metal Film	E3	R-169-90
R105	Resistor, 900Ω, 0.1%, ⅒W, Metal Film	E2	R-168-900
R106	Resistor, 1.005kΩ, 0.1%, ⅒W, Metal Film	F3	R-263-1.005k
R107	Resistor, 8.95kΩ, 0.1%, ⅒W, Metal Film	F3	R-263-8.95k
R108	Resistor, 10kΩ, 10%, 2W, Composition	F2	R-3-10k
U101	Darlington Transistor Array, ULN2003A	Sev	IC-206
U102	Operational Amp., JFET	E2	IC-342
U103	8 Stage Shift/Store Register, MC14094BCP	B3	IC-251
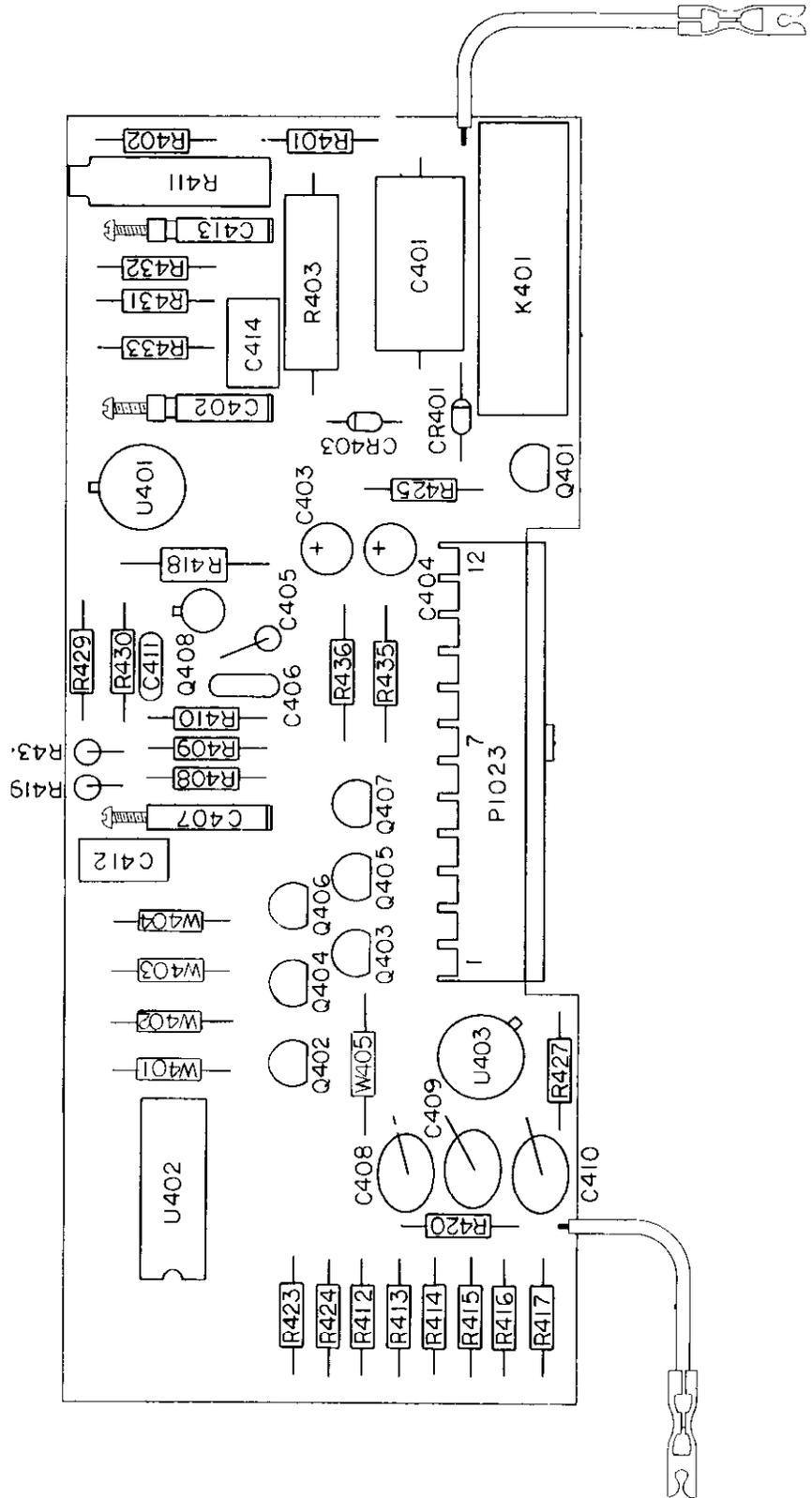
Figure 7-10. Model 1931, Component Location Drawing, Dwg. No. 1931-100

Figure 7-11. Model 1931, Schematic Diagram, Dwg. No. 1931-106

REPLACEABLE PARTS

Table 7-6. Model 193 Mechanical Parts List

Quantity	Description	Keithley Part No.
2	Side Panel Assembly	193-310
2	Front Bezel Assembly	228-303
1	Front Panel	193-302
1	Front Panel Overlay	193-303
1	Window	193-327
4	Banana Jacks (Black)	BJ-12-0
4	Banana Jacks (Red)	BJ-12-2
2	Banana Jacks (White)	BJ-12-9
8	LED Mounts (For Pilot Lights)	MK-22-1
3	Pushbuttons (Range)	228-317-4
6	Pushbuttons (Function)	228-317-5
4	Pushbuttons (Modifier)	228-317-6
7	Pushbuttons (Control and Local)	228-317-7
1	Pushbutton (Power)	29465-3
1	Pushbutton (Input)	29465-2
4	Supports (For Display Board)	228-318
1	Rear Panel Assembly	193-305
2	BNC Connectors	CS-249
3	Mounting Rails	228-319
2	Fuse Holders	FH-21
2	Fuse Carriers	FH-25
1	Fuse Carrier (European, Current)	FH-26
1	Heat Sink (for VR301)	HS-21
1	Heat Sink	HS-22
1	Shield (Mother Board)	193-312
6	Fasteners (Mother Board)	FA-167-3
6	Screws, Self Tapping (Mother Board)	FA-166-1
4	Hole Plugs (Analog Board)	HP-22
1	Shield (Analog Board, Top)	193-316
4	Fastener Clips (Secures Analog Board Shield)	FA-99
1	Shield Assembly (Analog Board, Bottom)	193-171
5	Fasteners (Analog Board)	FA-167-5
5	Screws, Self Tapping (Analog Board)	FA-166-1
1	Top Cover	228-312
1	Bottom Cover	228-313
2	Feet (Rear)	706-316
2	Feet (Front Assembly)	706-317
2	Decorative Strips (Top)	193-323
2	Decorative Strips (Bottom)	193-323
1	Line Cord	CO-7

*Some of these parts are shown in Figure 6-12.

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The number following each entry indicates the page number.