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Model 194A
High Speed Voltmeter
Instruction Manual

Contains Operating and Servicing Information

KEITHLEY

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WARRANTY

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

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

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

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

LIMITATION OF WARRANTY

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

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STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

KEITHLEY

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Instruction Manual
Model 194A
High Speed Voltmeter

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Instrument Division
Cleveland, Ohio, U.S.A.
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SPECIFICATIONS

DC CHARACTERISTICS

	16 BIT		8 BIT	
RANGE	RESOLUTION	ACCURACY* ±(%rdg + offset) (1 Yr., 18°-28°C)	RESOLUTION	ACCURACY* ±(%rdg + offset) (1 Yr., 18°-28°C)
320 mV	10 μV	0.030% + 200 μV	2.56 mV	0.42% + 2.56 mV
3.2 V	100 μV	0.025% + 2 mV	25.6 mV	0.42% + 25.6 mV
32 V	1 mV	0.035% + 20 mV	256 mV	0.42% + 256 mV
200 V	10 mV	0.035% + 200 mV	2.56 V	0.42% + 2.56 V

*After pushbutton or bus zeroing, and using average function (10,000 samples, 10μs sample rate).

INPUT IMPEDANCE: 1.1MΩ (1.0MΩ on 200V range) shunted by <47pF.

MAXIMUM ALLOWABLE INPUT: 250V peak, 2×10^7V•Hz.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, 42V peak, 5×10^5 V•Hz.

COMMON MODE REJECTION RATIO: >60dB at dc to 1kHz, 1kΩ unbalance.

DIFFERENTIAL NONLINEARITY: 16-Bit: ≤2 LSB. 8 Bit: ≤0.5 LSB.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): < ±(0.1 × applicable accuracy specification)/°C.

DYNAMIC CHARACTERISTICS

SAMPLE TRIGGER: Initiates each A/D conversion.

EXTERNAL SAMPLE TRIGGER INPUT: Rising edge, TTL compatible. DB-25 connector.

	INTERNAL SAMPLE TRIGGER 16 BIT	INTERNAL SAMPLE TRIGGER 8 BIT	EXTERNAL SAMPLE TRIGGER 16 BIT	EXTERNAL SAMPLE TRIGGER 8 BIT
SAMPLE RATE				
Maximum	100 kHz	1 MHz	100 kHz	1 MHz
SAMPLE INTERVAL				
Minimum	10 μs	1 μs	10μs	1 μs
Maximum	1 s	1 s	No limit	
Resolution	100 ns	100 ns	—	—
Jitter (typical)	±0.4 ns	±2 ns	±2 ns	±2 ns
TIMEBASE ACCURACY	±0.02%	±0.02%	±0.02%	±0.02%
NUMBER OF SAMPLES				
Minimum	1	1	1	1
Maximum	32k	64k	32k	64k

SIGNAL/NOISE RATIO (sinewave curve fit): 50dB for full range 100kHz sine input; 72dB typical at 10kHz.

SLEW RATE: 13V/μs minimum.

SETTLING TIME: 1 μs to 0.1% of final value.

CHANNEL CROSSTALK: <60dB at 500kHz.

INPUT COUPLING: Ac, dc, ground.

FREQUENCY RESPONSE (Filter Off):

0.2 dB	1 dB	3 dB
dc (15 Hz) - 20 kHz	dc (5 Hz) - 200 kHz	dc (2 Hz) - 750 kHz

( ) Indicates ac coupled performance.

LOW PASS FILTER: 50kHz, 500kHz, single pole.

MEASUREMENT TRIGGER

MEASUREMENT TRIGGER: Initiates acquisition of a set of samples.

DELAY:

Pre-Trigger: $-32k<n<-1$, 16-bit mode; $-64k<n<-1$, 8-bit mode. $|n|$ samples are stored prior to measurement trigger.

Post-Trigger: $1<n<1\times10^7$. Storage begins "n" samples after measurement trigger.

SOURCE:	Description
Input Signal	Slope: + or − Level: Selectable over input voltage range and resolution.
External:	Negative TTL edge, rear panel BNC.
Front Panel:	Manual pushbutton.
IEEE-488 Interface:	16 programmable trigger modes.
Other Channel:	Internally generated.

CHANNEL 2 (Option 1944A)

Permits synchronous or asynchronous sampling of data. Specifications are identical to those of Channel 1. All Channel 2 measurement parameters are independently selectable.

MATH FUNCTIONS

AVERAGE: $\dfrac{\sum_{i=0}^{n-1} V_i}{n} = V_{avg}$

PEAK TO PEAK: Difference between maximum and minimum values of samples.

PLUS PEAK: Maximum value of samples.

MINUS PEAK: Minimum value of samples.

STANDARD DEVIATION: $\sqrt{\dfrac{\sum_{i=0}^{n-1} (V_i - V_{avg})^2}{n}}$

TRUE ROOT MEAN SQUARE: $\sqrt{\dfrac{\sum_{i=0}^{n-1} (V_i)^2}{n}}$

INTEGRAL: $(\frac{1}{2}V_0 + \frac{1}{2}V_{n-1} + \sum_{i=1}^{n-2} V_i)\ t_s$.

DIFFERENCE: Channel 1 − Channel 2.

RATIO: Channel 1 / Channel 2.

NOTE: V_i: Voltage of sample i. **n:** Total number of samples. **i:** Location of individual sample. t_s: Sample interval.

REAL TIME (DMA) OUTPUT

FORMAT: Binary, 16-bit or 8-bit. **RATE:** Same as Sample Rate.

CONTROL LINES: End of Sample, Overrun, High Byte, Low Byte.

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ANALOG OUTPUT

MODES	OUTPUTS USED
CRT	x, y, z (blanking)
Oscilloscope	y, z (trigger)
Slow Plot	x, y, z (pen up/down)
Strip Chart	y

X OUTPUT: 0-10V full scale, 2.44mV resolution.

Y OUTPUT: 0-10V full scale, 2.44mV resolution.

Z OUTPUT: 0V, 5V or 15V.

ZOOM MAGNIFICATION: 0.1:1 to 1000:1.

PAN: Across entire memory.

FRONT PANEL PROGRAMS

0 IEEE ADDRESS: Set IEEE-488 address.

1 SELF TEST: Performs internal RAM and ROM check.

2 DIGITAL CALIBRATION: Executes calibration procedure.

3 CALIBRATION STORAGE: Stores calibration constants in NVRAM.

4 X OUTPUT FULL SCALE: Sets full scale X output voltage.

5 Y OUTPUT FULL SCALE: Sets full scale Y output voltage.

6 Z OUTPUT BLANKING LEVEL: Sets high or low blanking level.

IEEE-488 BUS IMPLEMENTATION

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

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

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

PROGRAMMABLE PARAMETERS: Range, Math Functions, Zero, Delay, Sample Rate, Number of Samples, Trigger, Calibration, Output Format, Self Test, Display, Status, Service Request, Storage, Filter, Terminator, Input Coupling, Buffer Size, Channel, Save and Recall Setups, Front Panel Programs 1-6, Key Sequence, Slope, Analog Outputs, EOI.

BINARY TRANSFER RATE: 90k bytes/second.

GENERAL

DISPLAY: 14-digit alphanumeric LED display; function, bus status also displayed.

RANGING: Manual or autoranging.

WARMUP: One hour to rated accuracy.

OPERATING ENVIRONMENT: 0° to 50°C, 0% to 80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: −25° to 65°C.

POWER: 105-125V or 210-250V (internal switch selectable), 50Hz or 60Hz, 120VA maximum. 90-110V and 180-220V version available.

CONNECTORS: All I/O connectors are BNC except Real Time Output (DB-25) and IEEE-488 connectors.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in. × 17⅛ in. × 17⅝ in.). Net weight 9.1kg (20 lbs.), Dual Channel.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

ACCESSORIES AVAILABLE:

Model 1938: Fixed Rack Mounting Kit
Model 1939: Slide Rack Mounting Kit
Model 1942: Sample Cable
Model 1944A: Channel 2
Model 7007-1: Shielded IEEE-488 Cable, 1m (3.2 ft.)
Model 7007-2: Shielded IEEE-488 Cable, 2m (6.5 ft.)
Model 7051-2: BNC Interconnect Cable, 2 ft.
Model 7051-5: BNC Interconnect Cable, 5 ft.
Model 7754-3: BNC to Alligator Cable, 3 ft.
Model 7755: 50Ω Feed-Through Termination
Model 8573A: IEEE-488 Interface for IBM PC, PC-AT

Specifications subject to change without notice.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

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

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that 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.

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The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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Contains an overview of the instrument including features, unpacking instructions, as well as available accessories.

SECTION 1
General Information

Includes an overview of front panel controls, rear panel configuration, and fundamental measurement procedures. Use this section to get your instrument up and running as quickly as possible.

SECTION 2
Getting Started

This section contains detailed operating information for the Model 194A, and the Model 1944A A/D Modules. Use this section as a reference on all front panel operating aspects of the instrument.

SECTION 3
Operation

Contains information on connecting the Model 194A to the IEEE-488 bus and programming the instrument from a computer.

SECTION 4
IEEE-488 Programming

Outlines procedures necessary to verify that the instrument is operating within stated specifications.

SECTION 5
Performance Verification

A complete description of operating principles for the instrument is located in this section. Analog, digital, microcomputer, and power supply circuits are described, as is the IEEE-488 interface.

SECTION 6
Principles of Operation

Details maintenance procedures including fuse replacement, option installation, line voltage selection, calibration, and troubleshooting.

SECTION 7
Maintenance

Includes replacement parts information, schematic diagrams, and component location drawings for the Models 194A and 1944A.

SECTION 8
Replaceable Parts

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

This section contains information on Model 194A features, warranty, manual addenda, safety terms and symbols, and specifications. Also included are procedures for unpacking and inspecting the instrument, as well as available accessories.

The information in Section 1 is divided into the following major paragraphs:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Preparation For Use
1.9 Repacking For Shipment
1.10 Accessories

1.2 FEATURES

The Model 194A High Speed Voltmeter is a high speed DC voltage sampling instrument suitable for a wide variety of applications, including the analysis of laboratory phenomenon, as well as the characterization of transient and periodic waveforms.

The Model 194A can sample at rates up to 1MHz with 2½ digit, 8-bit usable resolution, or up to 100kHz with 4½ digit, 16-bit resolution. Each A/D channel has 64K bytes of memory allowing up to 65,535 samples to be stored for later analysis with one of the many Model 194A mathematical functions.

Key Model 194A features include:

- Autoranging—Autoranging allows the instrument to measure a wide dynamic range of input signals.
- Zero—A zero feature allows a baseline signal level to be subtracted from subsequent readings. The baseline can either be taken from an applied signal, or keyed in from the front panel or programmed over the IEEE-488 bus.
- Filtering—Internal analog filtering with selectable poles of 50kHz or 500kHz is available to reduce the effects of noise.
- Math Functions—A number of mathematical functions including average, integral, standard deviation, true RMS, peak, and peak-to-peak are included with the instrument software.
- Dual-channel Operation—Two separate, isolated A/D channels are available with the optional Model 1944A A/D Module installed.
- IEEE-488 Interface—A standard feature of the Model 194A that allows the instrument to be controlled from a computer.
- Real Time Output—This port allows instrument data to be transmitted to a computer or similar device at the sampling rate via a user-supplied interface.
- Programmable Sampling Rates—The instrument can be programmed to sample data as fast as 1MHz, or as slow as 1Hz.
- Programmable Number of Samples—The number of samples per measurement sequence can be programmed to any value between 1 and 32,767 (16-bit resolution) or 1 and 65,535 (8-bit resolution).
- Programmable Triggering—The instrument can be triggered from the input signal, an external trigger signal, from the other channel (when the Model 1944A option is installed), or over the IEEE-488 bus. Programmable triggering parameters include single or continuous modes, delay, slope, and level.
- XY Mode—Allows the instrument to drive external display devices such as oscilloscopes and plotters. Internal software allows easy generation of graphs from sampled data.
- Translator Mode—Simplifies IEEE-488 programming by allowing the use of English-like syntax.
- External Sample Control—Allows sample collection to be synchronized to external events.

1.3 WARRANTY INFORMATION

Warranty information for your Model 194A may be found inside the front cover of this manual. Should it become necessary to use the warranty, contact your Keithley representative or the factory for information on obtaining warranty service. Keithley Instruments, Inc. maintains service facilities in the United States, West Germany, France, the Netherlands, Switzerland, and Australia. Information con-

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cerning the operation, application, or service of the Model 194A may be obtained by contacting an applications engineer at any of these locations.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after this manual is printed will be found on an addendum sheet included with the instrument. Please be sure that you read this information before attempting to operate or service your instrument.

1.5 SAFETY SYMBOLS AND TERMS

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

The ⚠ symbol on the instrument indicates that the user should refer to the operating instructions in this manual for further details.

The **WARNING** heading as used in this manual explains dangers that could result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.6 SPECIFICATIONS

Detailed Model 194A specifications are located at the front of this manual. Some terms used in the specifications are discussed in the following paragraphs.

1.6.1 Resolution

The resolution of an A/D converter is generally defined as the number of output states expressed in bits. The number of output states of a binary quantizing A/D converter is 2^n, where n represents the number of bits. The A/D converter in the Model 194A operates with either 8-bit or 16-bit resolution, depending on the sampling rate. Thus, the A/D converter has either 256 (2^8) or 65,536 (2^{16}) output states.

The resolution figures given in the specifications are derived by dividing the full scale displayable range by the number of steps for that particular converter resolution.

For example, in the 16-bit mode, the 320mV range is actually capable of displaying values in the range of -327.68 to + 327.67mV, for a total range of 655.35mV. Dividing this figure by the total number of quantized steps (65,535) yields the 10μV resolution figure given in the specifications.

1.6.2 Differential Non-Linearity

The differential non-linearity specification defines the maximum deviation of a quantized step width from the ideal quantization step width, FSR/(2^n−1), where FSR is the full scale range of the A/D converter (10V) and n is the number of bits (8 or 16) depending on the sampling rate.

1.6.3 Slew Rate

The slew rate specification applies to the sample and hold portion of the A/D converter and is usually defined as the maximum rate at which a capacitor can charge expressed in volts per microsecond. Generally, it is desirable to have as high a slew rate as possible in order to minimize response time.

1.6.4 Input Impedance and Coupling

The input impedance is simply the equivalent resistance appearing between input high and input low shunted by (in parallel with) the stated capacitance value. Figure 1-1 shows an equivalent circuit of the input impedance appearing at the VOLTAGE INPUT jack. Input impedance can become especially important when measuring voltage sources with high internal resistance: the resistive component can load the source, degrading measurement accuracy, and the capacitive element can increase response time to rapidly-changing signals.

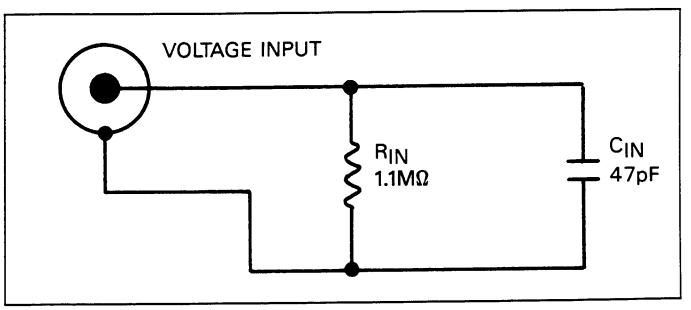


Figure 1-1. Equivalent Input Impedance

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Input coupling defines the method used to apply the signal voltage to the input amplifier. Figure 1-2 demonstrates the three forms of coupling used: AC, DC, and ground. With the DC coupling method in (a), a straight-through path is established. Figure 1-2(b) shows the AC coupling method, in which a capacitor is inserted in series with the high input signal path. In the case of ground coupling [Figure 1-2(c)], the input signal is effectively removed from the input terminals of the input amplifier by shorting the high and low terminals of the input amplifier together.

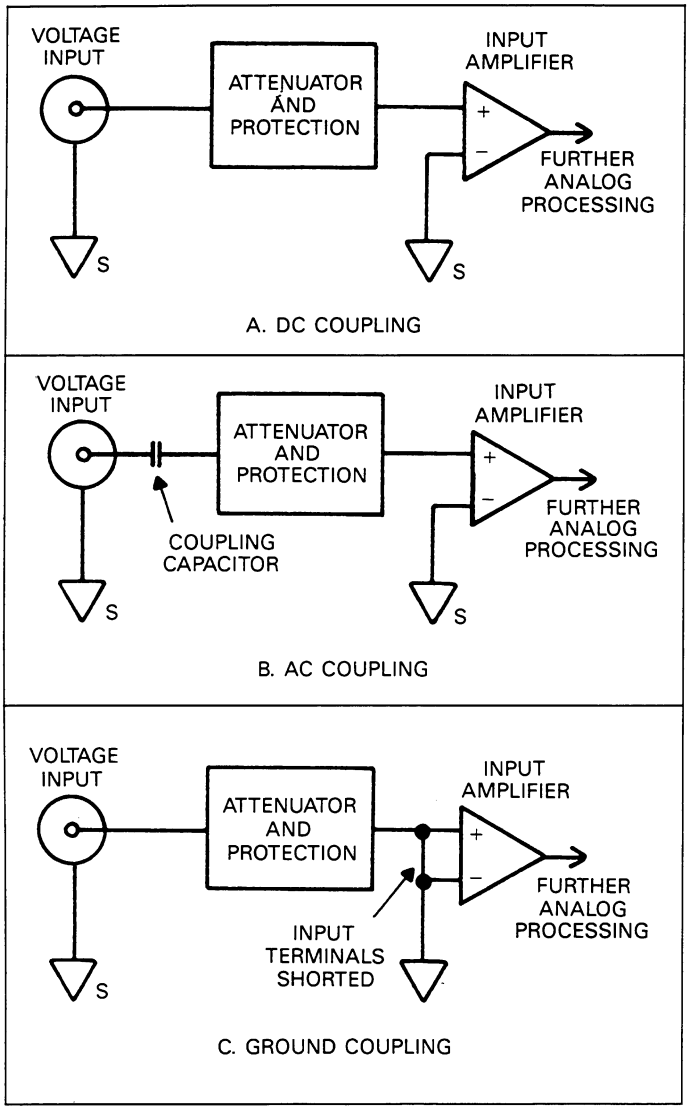


Figure 1-2. Methods of Input Coupling

1.6.5 Common-Mode Considerations

The low input terminal of the Model 194A can be floated up to 30V RMS, 42.4V peak above chassis ground. This voltage is known as the common mode voltage and is shown on the diagram in Figure 1-3. The advantage of floating the input is that you can measure many sources that are not referenced to power line ground. The 30V RMS limitation given in the specifications is defined by ANSI safety standards; since the shield of any cable connected to the instrument will also be at common mode potential, it is important that the 30V limitation be observed to avoid a possible shock hazard.

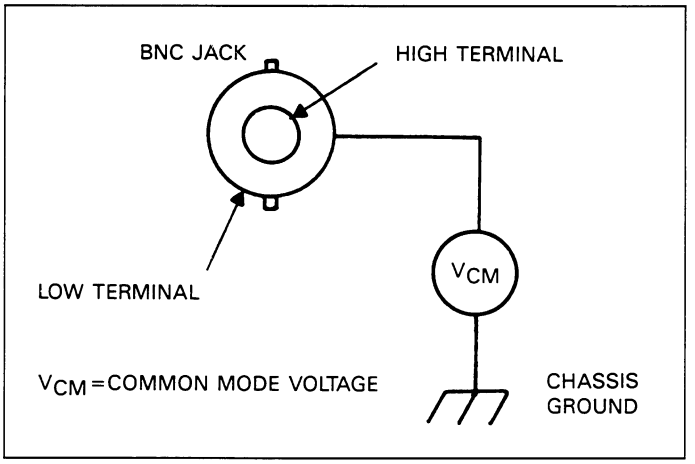


Figure 1-3. Common Mode Voltage

The common mode rejection ratio (CMRR) defines how much of a common mode signal in the specified frequency range will appear in the final reading, exclusive of other factors such as selected math function. Note that this specification is given is dB and can be converted to an equivalent noise voltage as follows:

$$V_N = \frac{V_{CM}}{10^{(CMRR/20)}}$$

where: V_N is the resulting noise voltage.
V_{CM} is the common mode voltage.
CMRR is the common mode rejection ratio in dB.

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As an example, assume that the common mode voltage is 30V, and that the CMRR is 60dB. The amount of the noise signal can be calculated as follows:

$$V_N = \frac{30V}{10^3}$$

$$V_N = 30mV$$

1.6.6 Crosstalk

The crosstalk specification defines how much of a signal applied to one A/D module will leak through to the other A/D module. This signal can be considered as an error or noise signal that could degrade measurement accuracy. Thus, crosstalk can be particularly important when measuring a low level signal on one channel with a high level signal on another channel.

Like the CMRR specification, crosstalk is given in dB, with the higher figure the better. The formula given above for CMRR can be used to determine how much noise voltage will appear in a given channel as the result of a signal applied to an alternate channel. For example, assume that 200V is applied to the channel 2 A/D converter. With a 60dB crosstalk figure, the noise voltage in channel 1 is:

$$V_N = \frac{200V}{10^3}$$

$$V_N = 200mV$$

1.6.7 DC Voltage Accuracy and Dynamic Characteristics

The accuracy figures given in the specifications are for DC voltages, and do not necessarily apply to AC signals. Certain dynamic characteristics may affect overall accuracy when measuring rapidly-changing signals. In particular, slew rate and settling time could degrade accuracy for signals with rapid rise and fall times. Slew rate and settling time are discussed elsewhere in this section.

Basic DC accuracy is specified as ±(percent of reading + an offset). Since the offset on a given range is constant, better accuracy will be achieved when measuring signals near full range than when measuring lower-level signals. Thus, for best accuracy, you should use the most sensitive range possible for the signal being measured.

Note that the accuracy figures given assume that the instrument has been properly zeroed. To zero the instrument, simply select ground coupling and press the ZERO button.

1.6.8 Settling Time

The settling time figure defines the length of time the instrument response takes to rise to and stay within certain limits. This specification includes the input amplifier and sample and hold circuitry, but excludes the A/D converter itself.

Figure 1-4 demonstrates how to interpret the settling time figure. Assume that the idealized step function shown in Figure 1-4(a) is applied to the instrument. A hypothetical response curve is shown in Figure 1-4(b). At point B, the instrument response rises to within stated limits, but, due to overshoot, continues to rise to point C. Because of ringing, the response drops slightly under the limit at point D, then rises to within the final limits and stays there at point E. Thus, the settling time would be interpreted to be the time period between the initial stimulus (point A) and the time the response reaches the stated limits (point E).

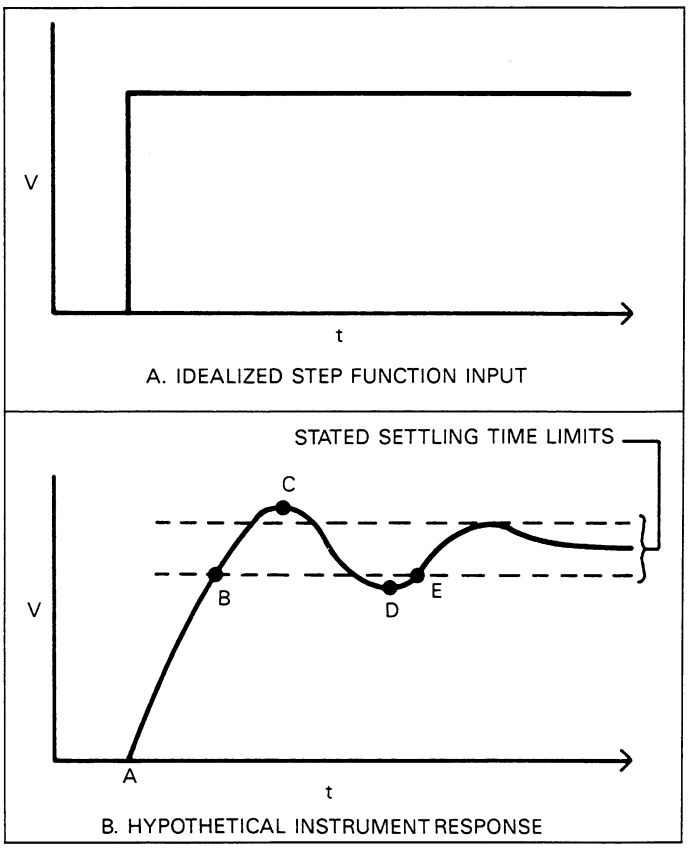


Figure 1-4. Settling Time

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1.7 UNPACKING AND INSPECTION

The Model 194A was carefully inspected and packed before shipment. Upon receiving the instrument, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage that might have occurred during shipment. Report any damage to the shipping agent at once. Retain the original packing material in case reshipment becomes necessary.

The following items are included with every Model 194A shipment:

Model 194A High Speed Voltmeter
Model 194A Instruction Manual
Additional accessories as ordered.

If the Model 1944A A/D Module was ordered with the instrument, it will be shipped already installed.

If an additional instruction manual is required, order the manual package, Keithley Part Number 194A-901-00. The manual package includes an instruction manual and all pertinent addenda.

1.8 PREPARATION FOR USE

Line Power—The Model 194A is designed to operate from 105-125V or 210-250V AC power sources. A special power transformer may be installed for 90-110V and 180-220V ranges. The factory set range is marked on a label near the rear panel of the instrument.

CAUTION
Do not attempt to operate the instrument on a line voltage outside the indicated range, or instrument damage may occur.

Line Voltage Selection—The operating voltage is internally selectable. Refer to Section 7 for the procedure to change or verify the line voltage setting.

Line Frequency—The Model 194A may be operated from either 50 or 60Hz power sources.

IEEE-488 Primary Address—If the Model 194A is to be controlled over the IEEE-488 bus, it must be set to the correct primary address. The primary address is set to 9 at the factory, but it can be programmed from the front panel, as described in Section 4.

1.9 REPACKING FOR SHIPMENT

Before shipment, the instrument should be repacked in its original shipping carton.

If the instrument is to be returned to Keithley Instruments for repair, include the following:

Write ATTENTION REPAIR DEPARTMENT on the shipping label.
Include the warranty status of the instrument.
Complete the service form at the back of this manual.

1.10 ACCESSORIES

The following accessories are available from Keithley Instruments, Inc to enhance Model 194A capabilities.

Model 1938 Rack Mount Kit—The Model 1938 allows the stationary mounting of the Model 194A in a standard 19-inch rack.

Model 1939 Rack Mount Kit—The Model 1939 is similar to the Model 1938 except that a sliding-mount configuration is used.

Model 1942 Sample Cable—The Model 1942 connects to the REAL TIME OUTPUT and allows synchronization of sample collection to external events.

Model 1944A A/D Module—The Model 1944A gives the Model 194A dual-channel A/D capability.

7007 Shielded IEEE-488 Cables—The Model 7007 cables include a shielded metric IEEE-488 connector on each end, the Model 7007-1 is 1m (3.3 ft.) long, while the Model 7007-2 is 2m (6.6 ft.) in length. These cables are shielded to minimize electrical interference.

7051 BNC Cables—The Models 7051-2 and 7051-5 are similar cables made up of RG-58C and are equipped with male BNC connectors on each end. The Model 7051-2 is two feet in length, while the Model 7051-5 is five feet long.

Model 7754 BNC-to-Alligator Cable—The Model 7754 has a male BNC connector on one end, and a pair of alligator clips on the other end.

Model 7755 50Ω Input Terminator—The Model 7755 is a feed-through BNC terminator that allows the proper termination of 50Ω cables.

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SECTION 2
GETTING STARTED

2.1 INTRODUCTION

This section contains introductory information on operating your instrument and is intended to help you get your Model 194A up and running as quickly as possible. It includes a brief description of operating controls, as well as fundamental measurement procedures. Once you are thoroughly familiar with the material presented here, refer to Section 3 for more detailed information.

Section 2 is organized as follows:

2.2 Front Panel Familiarization: Briefly describes each front panel control, outlines display operation, and lists where to find more detailed information in Section 3.

2.3 Rear Panel Familiarization: Describes each aspect of the Model 194A rear panel including connectors.

2.4 Power-Up Procedure: Describes how to connect the instrument to line power and the type of display messages to be expected during the power-up cycle.

2.5 Basic Measurement Techniques: Outlines input connections and gives the basic instrument configuration for making measurements.

2.6 Samples, Measurements, and Readings: Defines these terms as used in this manual.

2.2 FRONT PANEL FAMILIARIZATION

An overview of the Model 194A is given in the following paragraphs. The front panel of the instrument is shown in Figure 2-1. The panel consists of a 14-character alphanumeric display, 38 momentary-contact switches (many of which include display annunciators), and three LEDs that indicate IEEE-488 status.

2.2.1 Controls

All front panel controls except POWER are momentary contact switches. To augment the controls, many display annunciators are included. Many of the control buttons have secondary functions that are invoked with the SHIFT key. Primary (not shifted) functions are indicated above the corresponding keys, while secondary (shifted) functions are marked in yellow below the respective keys (except for the secondary modes associated with the MHz, kHz, and Hz keys, which are controlled by the FREQ/TIME button).

All controls are logically arranged and color coded into functional groups for ease of operation.

Table 2-1 summarizes these control functions and also lists the location in the manual where more detailed information concerning these functions may be found. In the following descriptions, shifted functions are placed in parentheses.

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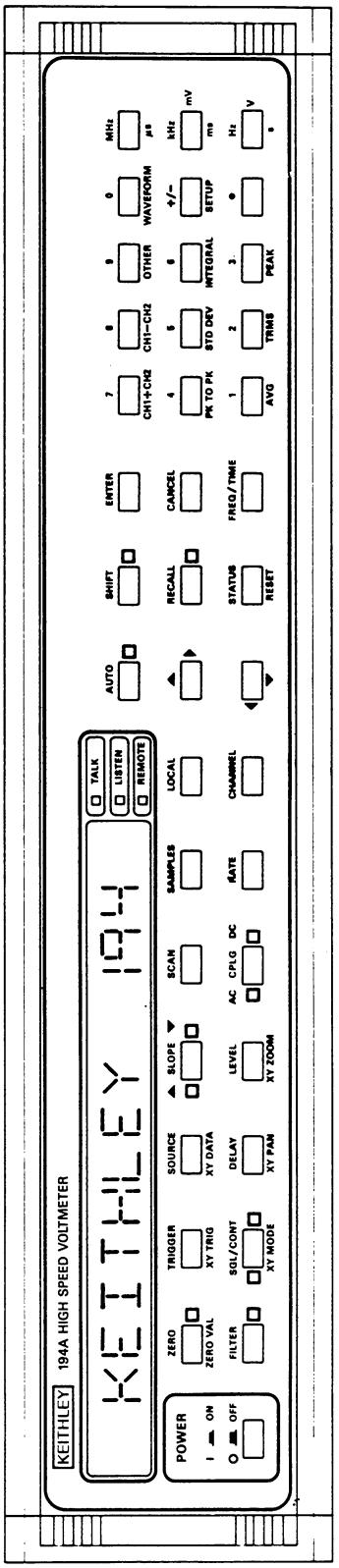


Figure 2-1. Model 194A Front Panel

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Table 2-1. Front Panel Control Summary

Control	Description	Paragraph
POWER	Control AC power to the instrument.	2.4
ZERO	Enable/disable zero mode (subtract baseline value from subsequent readings).	3.10
(ZERO VAL)	Key in zero value with data entry keys.	3.10
FILTER	Enable/disable 50kHz or 500kHz analog filter.	3.11
TRIGGER	Initiate measurement sequence when immediate triggering is enabled. Arm external, input signal, and other channel triggering.	3.6
(XY TRIG)	Start/stop XY analog output data.	3.12
SGL/CONT	Select single or continuous A/D arming.	3.6
(XY MODE)	Select XY mode to allow data plotting: CRT, oscilloscope, plotter, or strip chart.	3.12
SOURCE	Select external trigger pulse, immediate, input signal, or other channel as trigger source. (Use uprange or downrange to scroll through sources).	3.6
(XY DATA)	Select data source for XY analog output: measurement buffer, RAM, readings, or IEEE buffer.	3.12
DELAY	Program trigger delay (post or pre-trigger).	3.6
(XY PAN)	Program window for XY analog output.	3.12
SLOPE	Select positive or negative edge for triggering from input signal.	3.6
LEVEL	Program trigger threshold when triggering from input signal.	3.6
(XY ZOOM)	Program XY output horizontal scaling factor.	3.12
SCAN	Control future scanner module.	
CPLG	Set AC, DC or ground input signal coupling.	3.7
SAMPLES	Program number of samples or measurement duration.	3.5
RATE	Program sampling frequency or interval between samples.	3.5
LOCAL	Cancel IEEE-488 remote status, restore front panel operation, return display to normal.	4.7
CHANNEL	Select channels 1 or 2, dual channel display, or scanner channels.	3.9
AUTO	Enable/disable autoranging.	3.3
UPRANGE	Move uprange, move cursor right (data entry), increment sample number (RECALL), move viewed data right (XY PAN), increment scaling factor (XY ZOOM), select front panel program (OTHER), scroll through modes (FILTER, SOURCE, XY MODE, XY DATA).	3.3 3.3
DOWNRANGE	Move downrange, move cursor left (data entry), move viewed data left (XY PAN), decrement buffer location (RECALL), select front panel program (OTHER), scroll through modes (FILTER, SOURCE, XY MODE, XY DATA).	
SHIFT	Add second function to front panel keys (shifted modes marked in yellow).	
RECALL	Recall stored samples from measurement buffer.	3.8
STATUS	Obtain information on programmed operating modes.	3.15
(RESET)	Reset instrument to power-on conditions (same as SETUP 1).	3.18
ENTER	Enter data into memory during data entry process.	3.4
CANCEL	Cancel data entered into display during data entry.	3.4
FREQ/TIME	Enter data as reciprocal frequency or time.	3.4
Data Keys	Enter numeric data and time, frequency, or voltage units.	3.4
(CH1 ÷ CH2)	Divide channel 1 by channel 2 (dual A/D module units only).	3.14
(CH1 – CH2)	Subtract channel 2 from channel 1 (dual A/D module units only).	3.14
(OTHER)	Access IEEE address, self-test, NVRAM storage, digital calibration, X output full. scale value, Y output full scale value, Z output blanking level.	3.17
(WAVEFORM)	Display sample at trigger point.	3.13
(PK TO PK)	Display peak-to-peak value of measurement.	3.13
(STD DEV)	Display standard deviation of measurement.	3.13
(INTEGRAL)	Display integral of measurement in volt-seconds.	3.13
(SETUP)	Save, recall instrument configurations.	3.16

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Table 2-1. Front Panel Control Summary (Cont.)

Control	Description	Paragraph
(AVG)	Display average of measurement.	3.13
(TRMS)	Display true RMS value of measurement.	3.13
(PEAK)	Display peak value of measurement.	3.13

NOTE: Functions in parentheses ( ) are accessed by pressing SHIFT first. Math function keys need not use SHIFT unless data entry mode is in effect.

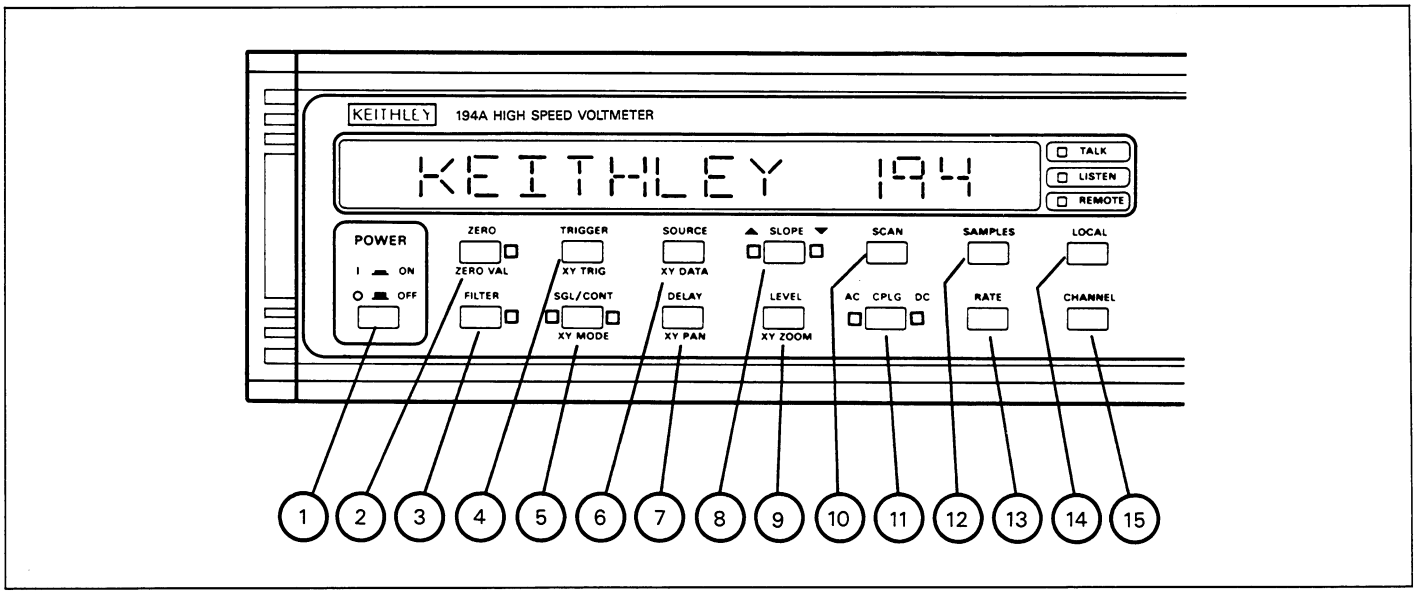


Figure 2-2. Front Panel Controls

The following controls are indicated in Figure 2-2.

① **POWER**—The POWER switch controls the AC power to the instrument. On and off positions are marked on the front panel. The instrument should be operated only on a line voltage in the range marked on the rear of the instrument.

② **ZERO**—The ZERO button enables and disables the zero mode, which allows a baseline reading to be subtracted from subsequent readings. The baseline value can either be obtained from an applied input signal, or it can be keyed in from the front panel. When the zero mode is enabled, the indicator to the right of the ZERO button will be on.

② **(ZERO VAL)**—This mode allows the baseline value used with the zero mode to be viewed or entered from the front panel by using the data entry keys.

③ **FILTER**—The FILTER button selects 50kHz or 500kHz single-pole analog filters. These filters can be used to reduced the effects of high frequency noise. Filter modes are then selected with uprange or downrange. The light next to the FILTER button will be on when either filter is enabled.

④ **TRIGGER**—This key initiates a continuous or single series of measurements, when immediate triggering has been selected with the SOURCE key. TRIGGER is also used to arm the A/D converter with other trigger sources.

④ **(XY TRIG)**—Used with the XY mode to start and stop data transmission through the analog output, which is used to graph data with external devices.

⑤ **SGL/CONT**—Selects single or continuous A/D arming modes. In the single mode, the A/D must be manually re-armed with TRIGGER. In the continuous mode, the A/D converter is automatically re-armed after each measurement. Annunciators adjacent to the SGL/CONT key indicate the selected mode.

⑤ **(XY MODE)**—This key is used to select the XY mode, which can be used to drive various display devices such as plotters and oscilloscopes via the analog output.

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⑥ **SOURCE**—Selects the trigger source. The trigger stimulus can come from an external trigger, the input signal, the other channel (for dual-channel instruments), or with the TRIGGER button. Sources are selected with uprange and downrange. The instrument may also be triggered with IEEE-488 commands, as discussed in Section 4.

⑥ **(XY DATA)**—Selects the data source for the analog output. Available sources include instrument displayed readings, the measurement buffers or 64k RAM for either channels 1 or 2 (channel 2 is available only with the Model 1944A option installed), or the IEEE reading buffer.

⑦ **DELAY**—The DELAY key is used to program the beginning point of a measurement sequence relative to the applied trigger stimulus. Both post- and pre-trigger modes are available. With post trigger, the instrument waits the programmed period before beginning sample storage; with pre-trigger, the instrument begins storing samples at the programmed interval before the trigger point. Both are available with all trigger sources.

⑦ **(XY PAN)**—This key allows you to select which group of samples located in the measurement buffer will be applied to the analog output. XY PAN effectively moves the analog output viewed data left or right.

⑧ **SLOPE**—The SLOPE button selects whether the instrument is triggered on the positive or negative edge of the input waveform. The two annunciators adjacent to the SLOPE button indicate the selected mode. Slope selection is applicable only when triggering from the input signal.

⑨ **LEVEL**—The LEVEL button permits you to program the signal voltage level at which the instrument is triggered only when triggering from the input signal. Trigger level values are keyed in with the data entry keys.

⑨ **(XY ZOOM)**—Applies a magnification or reduction factor to the horizontal axis on plots. XY ZOOM works in conjunction with XY PAN to sweep and expand areas of interest, or to get an overall view of collected data.

⑩ **SCAN**—The SCAN key is intended for use with a scanner module to become available in the near future.

⑪ **CPLG**—CPLG selects AC, DC, or ground coupling modes analogous to those found on an oscilloscope. AC and DC coupling are indicated by the respective indicators. Ground coupling is selected when both indicators are off.

⑫ **SAMPLES**—Allows selection of the amount of data taken by programming the number of samples to take during a measurement cycle, or the time duration of a measurement. The number of samples or the duration of the measurement cycle are keyed in with the data entry keys. Time duration or number of samples is selected with the FREQ/TIME key.

⑬ **RATE**—Allows the selection of the speed of data taken by programming sampling frequency or the time interval between individual samples. Time or frequency information (controlled by FREQ/TIME) is keyed in with the data entry keys.

⑭ **LOCAL**—The LOCAL key is used to remove the instrument from the remote mode when it is being used over the IEEE-488 bus. Note that all front panel controls except LOCAL and POWER will be inoperative when the instrument is in remote (REMOTE indicator on). LOCAL will also be inoperative if the IEEE-488 LLO (Local Lockout) command is in effect, as discussed in Section 4.

⑮ **CHANNEL**—When the instrument is equipped with the optional Model 1944A module, the CHANNEL button is used to select which channel is to be displayed. Three basic modes are available: channel 1, channel 2, and dual-channel display. For the two single-channel modes, the display mode also dictates which channel is affected by the other front panel buttons. Most of the other buttons are inoperative when the dual channel display mode is selected. CHANNEL is also used to return the display to the previous operating mode when using many Model 194A functions.

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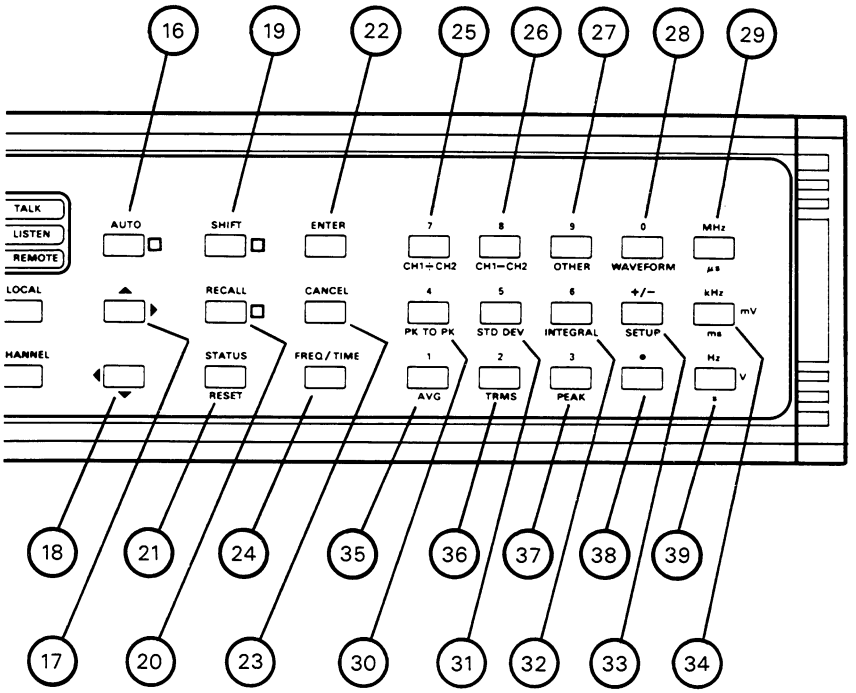


Figure 2-3. Front Panel Controls

The following controls are indicated in Figure 2-3.

(16) **AUTO**—The AUTO button enables or disables the autoranging mode. The annunciator to the right of the button will be on when the autoranging mode is enabled. While in this mode, the instrument will choose the best range to measure the applied signal. Note that a separate trigger may be required for each range change even if in auto. Autoranging may be cancelled by pressing AUTO a second time, or by pressing either the uprange or downrange keys.

(17) **Uprange (▲►)**—This key serves several functions. The most obvious is to move the instrument uprange once each time it is pressed until the highest range is reached. Once the maximum range is established, pressing uprange will have no further effect. In the data entry mode, this key moves the display cursor one place to the right each time it is pressed. In the XY pan mode, the uprange key moves the viewed data to the right. Uprange is used to increment the buffer location being accessed when the instrument is in the data recall mode. Finally, this key is used to scroll through front panel programs, trigger sources, and filter and XY modes.

(18) **Downrange (◄▼)**—Like the uprange key, downrange has a number of functions: to move the instrument down one range each time it is pressed, to move the display cursor to the left in the data entry mode, to decrement the scaling factor in the XY zoom mode, to move the viewed data to the left in the XY pan mode, to decrement the buffer location in the data recall mode, and to scroll through front panel programs, trigger sources, and filter and XY modes.

(19) **SHIFT**—The SHIFT key allows selection of secondary functions. Shifted modes are marked in yellow below the respective keys. When the shift mode is enabled, the yellow annunciator to the right of the key will be on. The shift mode can be cancelled by pressing the SHIFT key a second time. If a key with no shifted mode is pressed (for example, RECALL), a SHIFTLESS KEY error message will be displayed.

(20) **RECALL**—This key is used to recall data from the measurement buffer. Once in this mode, the buffer location to be accessed can be keyed in with the data entry keys, or decremented or incremented with the downrange or uprange keys. The RECALL annunciator will be on while the instrument is in the recall mode. To cancel this mode, press RECALL or CANCEL.

(21) **STATUS**—Returns information on present instrument configuration, including A/D and scanner module parameters, if installed. The instrument will scroll through various operating parameters.

(21) **(RESET)**—The RESET key returns the unit to power-on configuration determined by the setup 1 configuration.

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㉒ **ENTER**—The ENTER key performs the final step in the data entry process. Once the desired data appears on the display, pressing ENTER will store the data in memory for use by the mode in question. Modes requiring data entry are summarized in Table 2-2.

㉓ **CANCEL**—This key can be used during the data entry mode to cancel keyed in data without actually entering it into memory.

㉔ **FREQ/TIME**—FREQ/TIME is used to enter reciprocal frequency or time information while programming sample rate, scan rate, samples per measurement, or trigger delay.

㉕–㊴ **Data Entry Keys**—The data entry keys, which include 0 through 9, +/-, ., MHz (μs), kHz (ms,mV), and Hz (s,V), are used to enter data into the instrument for those modes that require data entry, such as samples, rate, level, delay, and so on. The type of units will depend on the entry mode. For example, time or frequency would be in effect when entering sampling rate, while voltage units (mV or V) would apply when entering a trigger level. The mode of the MHz (μs), kHz (ms), and Hz (s) keys is determined by the FREQ/TIME key-- not by the shift key. Table 2-2 lists modes, limits, and resolution values for the various modes programmed with the data entry keys. The MHz, kHz, and Hz keys implicitly perform an ENTER.

Table 2-2. Limits and Resolution for Programmable Parameters

Mode	Limits	Resolution
RATE	Time 1μsec-1sec	0.1μsec
	Frequency 1Hz-1MHz	Hz
SAMPLES	No: 1-65,535*	Samples
	Time: 0μsec-65,534sec*	0.1μsec
DELAY	No: Samples −65,536 to 10^7	Samples
	Time: −65,536 to $+10^7$sec	0.1μsec
LEVEL	±200V	μV
ZERO VAL	±200V	μV
X Output Full Scale**	1-10V nominal	μV
Y Output** Full Scale	1-10V nominal	μV

*32,768 in 16-bit mode.
**Accessed with OTHER key.

㉕ **(CH1÷CH2)**—This key programs the instrument to display the ratio of the channel 1 reading to the channel 2 reading. It is operational only if the Model 1944A option is installed in the CARD 2 location.

㉖ **(CH1-CH2)**—This button programs the Model 194A to display the algebraic difference between channels 1 and 2. It also is operational only if the Model 1944A option is installed in CARD 2.

㉗ **(OTHER)**—This key gives access to various front panel programs, including IEEE-488 address, self test, digital calibration, NVRAM programming, X output full scale value, Y output full scale value, and Z output blanking level.

㉘ **(WAVEFORM)**—Pressing this key displays the sample at the trigger point.

㉚ **(PK TO PK)**—Peak-to-peak values of the measurement can be displayed by pressing PK TO PK. Peak-to-peak values are calculated by subtracting the most negative sample from the most positive sample.

㉛ **(STD DEV)**—The standard deviation of the measurement samples can be displayed by pressing this button. The standard deviation gives a measure of the spread of sample data in comparison to the average of the measurement.

㉜ **(INTEGRAL)**—The integral of the measurement samples is obtained with the INTEGRAL button. The integral function returns the area under a curve (in volt-seconds), which is bounded by the amplitude of the samples and the measurement duration.

㉝ **(SETUP)**—Two different combinations of instrument operating modes may be stored and recalled through use of the SETUP key. Stored configurations are retained when power is removed. Setup can also be used to restore factory default configuration.

㉟ **(AVG)**—Displays the average of samples taken during a measurement sequence. The average value is simply the sum of the samples divided by the number of samples in the measurement.

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㊱ **(TRMS)**—Displays the calculated RMS value of the samples taken in a measurement sequence. The TRMS value of a waveform is equivalent to a DC voltage with the same heating value.

㊲ **(PEAK)**—Displays the most positive or most negative samples taken during a measurement. Positive and negative values may be obtained by repeatedly pressing PEAK.

NOTE

Keys 25-37 do not require pressing SHIFT if the Model 194A is in a state where data entry is meaningless. For example, if channel 1 is being displayed, you can press SHIFT AVG or just AVG to enter the average function.

2.2.2 Display

The Model 194A display consists of fourteen 14-segment LED display units. The display shows not only instrument readings, but, in many cases, messages to augment the various operating modes. The general display format is shown in Figure 2-4.

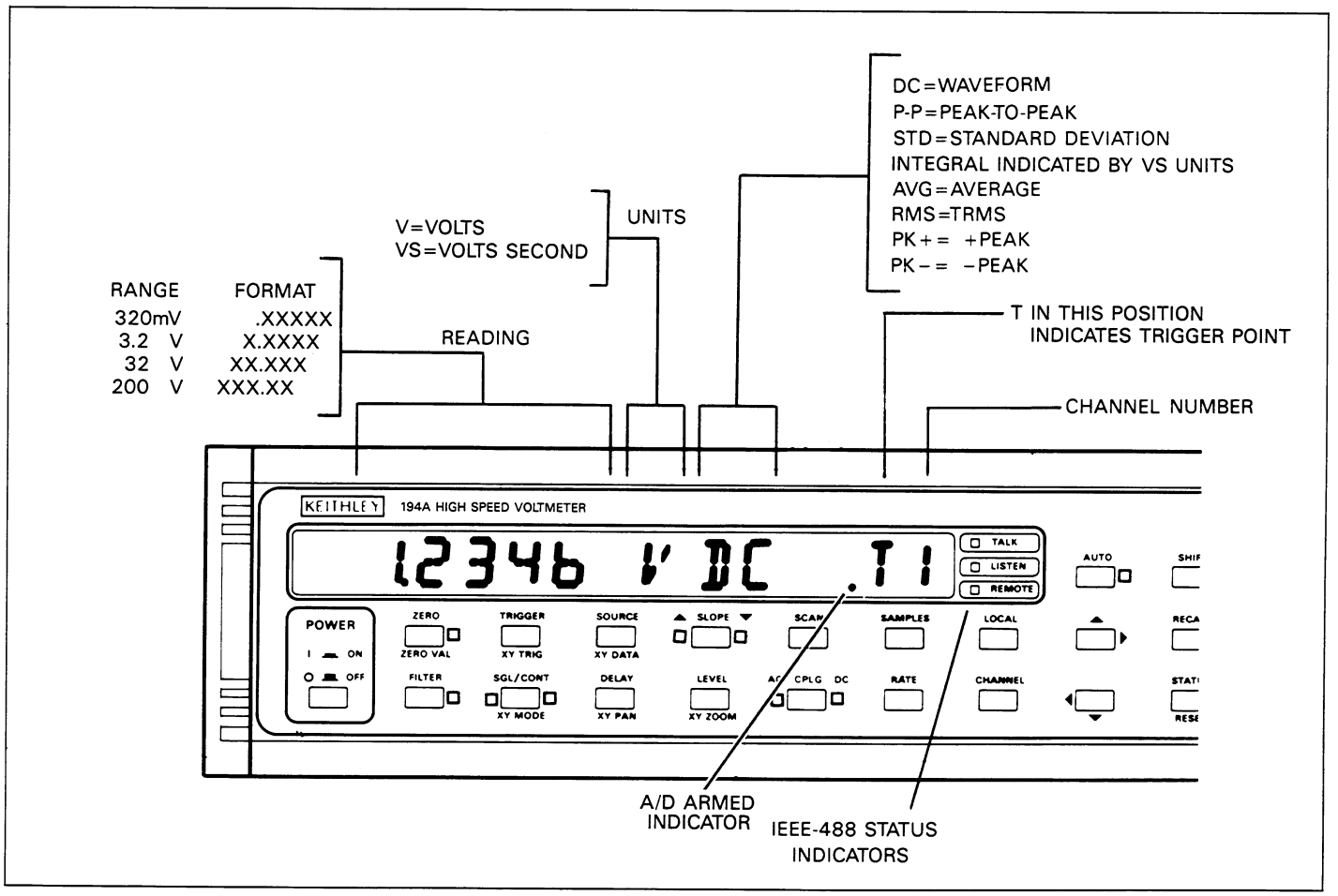


Figure 2-4. Display Format

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When reading normal instrument data, the display can take on one of three formats: channel 1 data, channel 2 data, and dual-channel display (the 1944A option must be installed for channel 2 or dual channel operation). For the single channel modes, the display mode also determines which channel is affected by most of the remaining control buttons. In the dual channel mode, many of the remaining front panel controls are locked out. The desired display mode is selected with the CHANNEL button.

The display normally shows 4½ digits regardless of whether the A/D converter is operating in the 8- or 16-bit mode. For sampling rates above 100kHz (or for more than 32,768 samples), the converter operates in the 8-bit mode. Thus, the usable display resolution is only 2½ digits under these conditions, even though 4½ digits are shown. For example, the usable resolution on the 320mV range at 16 bits is 10μV, but only 2.56mV in the 8-bit mode.

The display update rate is indicated by the flashing decimal point.

Channel 1 Example—The example below demonstrates the basic format for the display when reading channel 1. Note that units are specified, as is the channel number which appears at the extreme right.

-1.2345 V DC 1

Channel 2 Example—The example below shows the basic channel 2 display format. It is identical to the channel 1 format except for the channel number in the right digit.

2.5902 V DC 2

Dual-Channel Example—The example below demonstrates the basic dual channel display format. Note that channel numbers are not displayed in this mode.

−1.2345 2.5902

Note that channel 1 appears on the left in the dual channel mode.

NOTE

A decimal point between the second and third digits from the right will indicate when the A/D converter is armed and waiting for a trigger. See paragraph 3.6.

2.2.3 IEEE-488 Status Indicators

The TALK, LISTEN, and REMOTE LEDs (shown in Figure 2-4) indicate the instrument's status when it is being controlled over the IEEE-488 bus. Section 4 contains complete information on IEEE-488 operation. Note that all front panel controls except LOCAL and POWER will be inoperative when the REMOTE indicator is on.

2.2.4 Tilt Bail

A tilt bail is available on the bottom of the instrument to elevate the front panel to a convenient viewing height. To extend the bail, pull out each bail extension (on the bottom near each front corner) until it locks into place. To retract the bail, rotate each extension until it is flush with the bottom cover.

2.3 REAR PANEL FAMILIARIZATION

The rear panel of the Model 194A is shown in Figure 2-5. The rear panel includes all input and output signal connections, as well as a line fuse and AC receptacle. Each of these items is briefly described below and summarized in Table 2-3.

Table 2-3. Rear Panel Summary

Item	Description	Paragraph
VOLTAGE INPUT	Input signal applied	2.3
REAL TIME OUTPUT	Real time A/D data.	3.21
TRIGGER OUT	Trigger other instruments.	3.6
TRIGGER IN	Initiate measurement sequence.	3.6
ANALOG OUTPUT	Graph data on plotter or oscilloscope.	3.13
CLK	Synchronize several 194As.	3.20
IEEE-488 Interface	Connect 194A to IEEE-488 bus.	4.5
AC Receptacle	Apply power to instrument.	2.4
Line Fuse	Protect instrument from overload.	7.3

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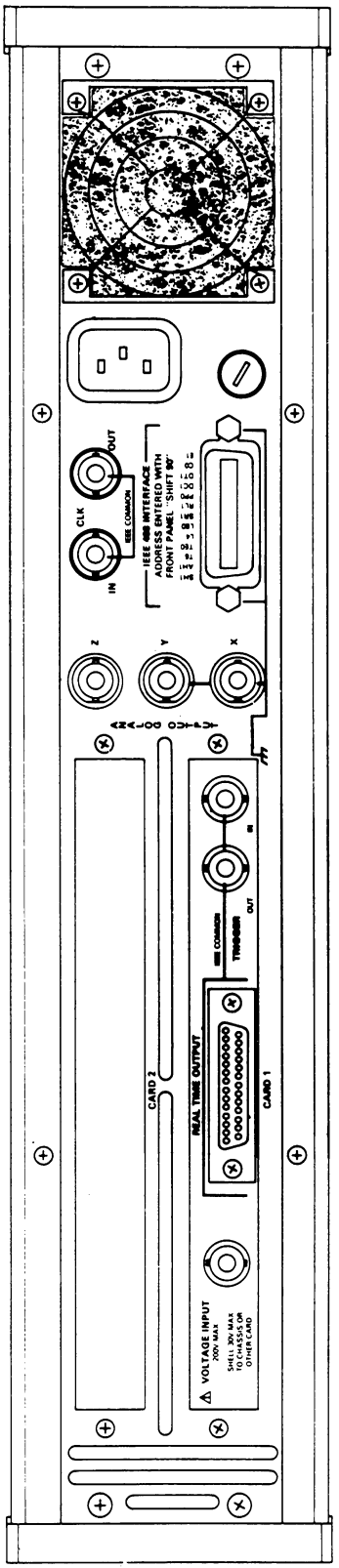


Figure 2-5. Model 194A Rear Panel

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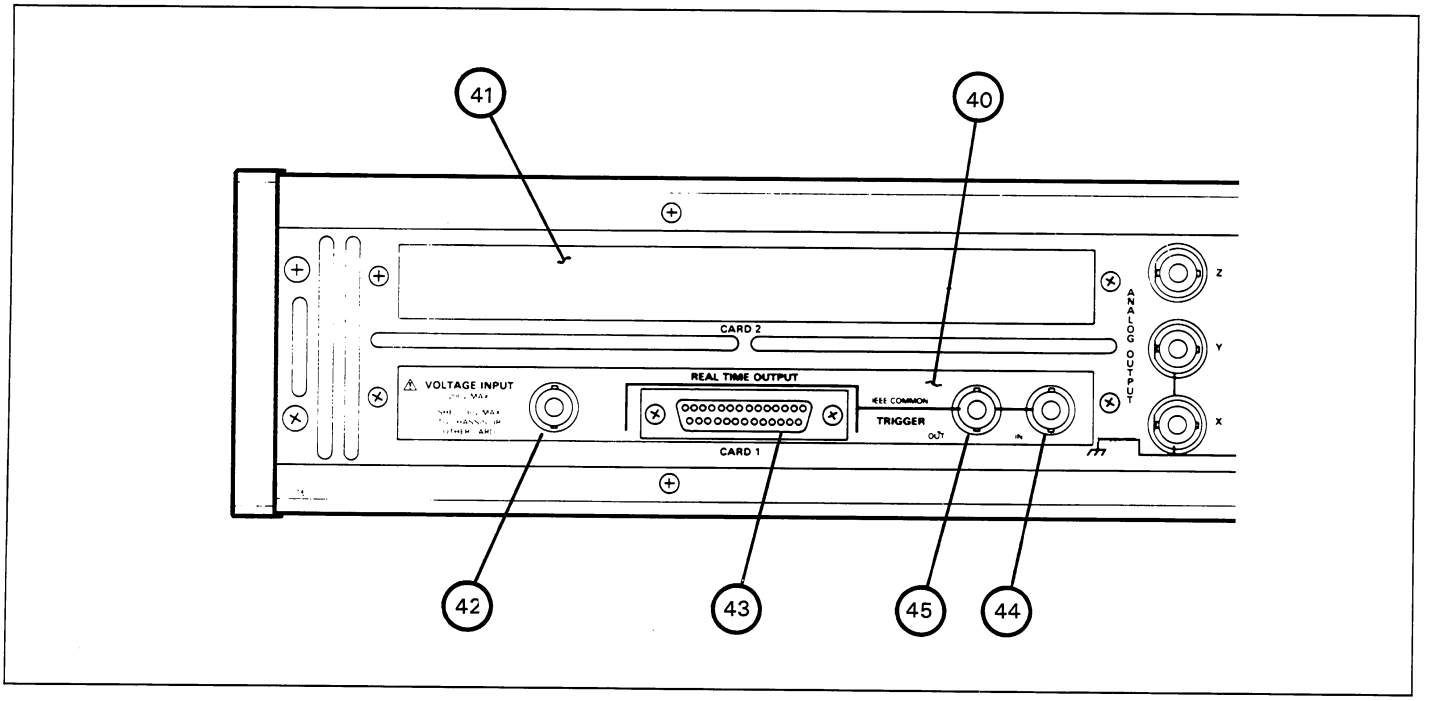


Figure 2-6. Rear Panel A/D Module Connectors

The following connectors are shown in Figure 2-6.

(40) **CARD 1**—CARD 1 is the standard input channel for the instrument. It includes a signal input, as well as triggering connections and a real time output.

(41) **CARD 2**—The Model 1944A option can be installed in the CARD 2 location. The Model 1944A is functionally equivalent to the module in CARD 1.

(42) **VOLTAGE INPUT**—The VOLTAGE INPUT jack is an isolated female BNC connector that is used to apply input signals to the instrument.

(43) **REAL TIME OUTPUT**—This DB-25 connector is used to transmit A/D data in byte or word parallel form to other equipment, such as a computer. Data can be transmitted at the programmed sample rate, up to the maximum conversion rate (1MHz) of the instrument. A user-supplied interface on the computer end is required to make the necessary connections. The REAL TIME OUTPUT also has signal lines for external sample control.

(44) **TRIGGER IN**—This BNC connector can be used to apply an external trigger pulse to initiate a measurement sequence. External triggering is available only when the instrument is properly programmed with the SOURCE key.

(45) **TRIGGER OUT**—This BNC connector provides a trigger output pulse when the Model 194A is itself triggered. It can be used to trigger other instrumentation.

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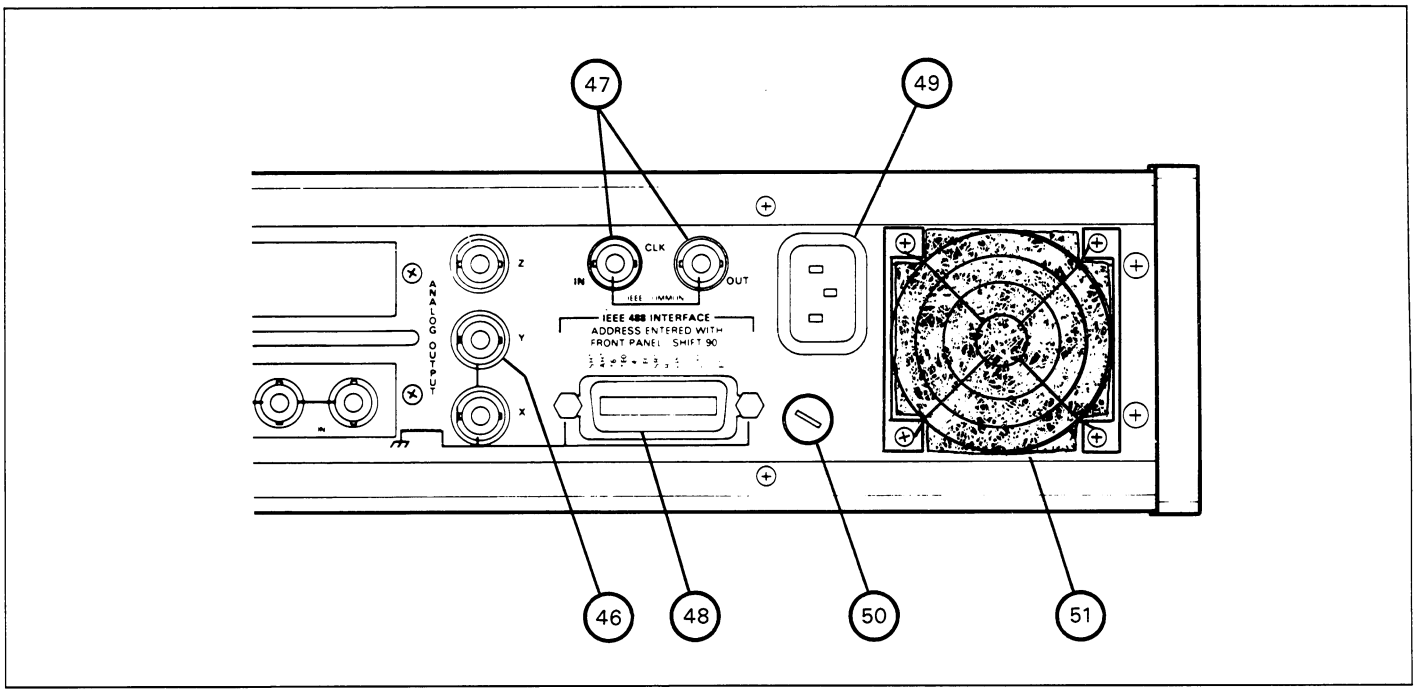


Figure 2-7. Rear Panel Connectors, Fuse and Fan

The following connectors are indicated in Figure 2-7

(46) **ANALOG OUTPUT**—The ANALOG OUTPUT jacks, which include the X, Y, and Z outputs, are used with the XY mode to plot data with external devices such as plotters, CRTs, or oscilloscopes. The X output provides time or interval information, while the Y output provides signal amplitude information. The Z output provides a blanking signal, trigger pulse, or pen lift signal, depending on the type of graphing device. The ANALOG OUTPUT jacks are standard BNC connectors.

(47) **CLK**—CLK IN and OUT can be used are to connect two or more Model 194As together for synchronous operation. CLK IN can also be used to operate the instrument from an external time base. Standard BNC connectors are used.

(48) **IEEE-488 Connector**—This connector is used to connect the Model 194A to the IEEE-488 bus. IEEE-488 function codes are marked above the connector.

(49) **AC Receptacle**—Power is applied through the supplied 3-wire power cord to the AC receptacle. The operating voltage is marked on a label adjacent to the rear panel. If necessary, the operating voltage can be changed, as described in Section 7.

(50) **Line Fuse**—The line fuse protects the power line input of the instrument from overloads. If the instrument repeatedly blows fuses, the problem must be rectified before continuing operation. Section 7 contains fuse replacement and troubleshooting procedures.

(51) **Fan**—The fan provides a continuous flow of cooling air over the various components within the instrument. To ensure proper cooling, the air flow path must be kept free of obstructions, including the exhaust vents on the opposite side of the rear panel. Also, the fan filter must be kept clean.

2.4 POWER UP PROCEDURE

Use the following procedure to connect the Model 194A to the power source and turn the instrument on.

2.4.1 Power Line Connections

Connect the instrument to line power as follows:

1. Connect the female end of the supplied line cord to the AC receptacle on the rear panel of the instrument. Connect the other end of the line cord to a grounded AC outlet.

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WARNING

The Model 194A 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 instrument is being operated on the correct line voltage. Failure to observe this precaution may result in instrument damage. If necessary, the operating voltage can be changed, as discussed in Section 7.

2. Turn on the power by pressing in the front panel POWER switch. The switch will be at the inner position when the instrument is on.
3. The instrument will then begin performing a self test as described in the following paragraph.

2.4.2 Power Up Self Test and Display Messages

When power is first applied to the instrument, it will perform a self test procedure to determine if any internal faults exist. The self test sequence consists of a ROM checksum test, a RAM test, and various hardware tests. During the self test period, all LEDs and display segments will be on, giving you an opportunity to check for proper display operation. Immediately preceding the self test, the following message will be displayed:

SELF TESTING

Assuming all tests are passed successfully, the instrument will display the following:

SELFTEST PASS

Followed by:

KEITHLEY 194

NOTE

If an NVRAM fault occurs in one of the modules, the instrument will not be able to recognize that module. If such an error occurs, the unit will display a CAN'T IDENTIFY error message for the appropriate channel. In this case, it will be necessary to program module recognition, as described in paragraph 7.4.2.

NOTE

If the power-up message stays on the display, press CHANNEL (or send C1X over the bus) to begin displaying readings.

Following this display, the instrument will display the programmed IEEE-488 address and software revision level, as in the example below.

REV. D2.2 IEEE=09

In this example, the IEEE-488 address is the factory default value (9), and the software revision level is D2.2. The software revision level of your instrument may be different and should be recorded for future reference should it ever become necessary to replace the internal ROM memory.

After this message, the instrument will enter the operational mode. Table 2-4 lists the factory default values for the instrument when it is first turned on. Note that you can press SHIFT RESET to return the instrument to these default conditions, if desired (assuming you haven't altered the SETUP 1 configuration).

If any errors are found during the self test sequence, the instrument will not begin normal operation, but will instead display appropriate error messages as an aid in determining the fault. These error messages are discussed in Section 7.

NOTE

If the instrument is still under warranty (less than one year from date of shipment), it should be returned to Keithley Instruments for repair. See paragraph 1.10 for details on returning the instrument.

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Table 2-4. Factory Default Power Up Conditions

Mode	Status
Range	Auto
Zero	Disabled
Zero Value	0V
Filter	Disabled
Trigger Mode	Continuous
Trigger Source	Immediate (TRIGGER button)
Trigger Delay	0
Trigger Slope	Off
Trigger Level	0V
Sample Rate	166.7μsec
Input Coupling	DC
Measurement Size	101 samples
Reading Function	Average
IEEE Address	09

NOTE: These modes will differ if the SETUP 1 configuration is changed.

2.5 BASIC MEASUREMENT TECHNIQUES

The following paragraphs describe the basic procedure to make basic measurements. More detailed information on various aspects of Model 194A operation is located in Section 3.

2.5.1 Warm Up Period

The Model 194A is usable immediately when it is first turned on. However, the instrument should be allowed to warm up for at least one hour to achieve rated accuracy.

2.5.2 Input Connections

The VOLTAGE INPUT jack is intended for all signal inputs to the instrument. This jack is an isolated BNC connector, with the outer shell connected to input low, and the center connector connected to input high.

WARNING

The maximum common-mode voltage (voltage between input low and chassis ground) is 30V RMS, 42.4V peak. Exceeding this value may create a shock hazard.

CAUTION

The maximum input voltage is 250V peak, 2×10^7V•Hz. Exceeding this value may cause damage to the instrument.

NOTE

Shielded cable should be used for all input and output connections to minimize the possibility of EMI radiation.

2.5.3 Fundamental Control Selection

Before making measurements with your Model 194A, you will probably want to select the following operating modes, as described below.

Step 1: Select the Channel

If your instrument is equipped with two A/D modules, select the channel you wish to use by pressing the CHANNEL button. The selected channel is displayed in the right most digit of the display. A dual channel display mode is also available with dual-channel units.

Step 2: Set the Range

Press uprange or downrange to select the measurement range (320mV, 3.2V, 32V, or 200V), or press AUTO and let the instrument choose the best range for the applied signal.

Step 3: Program the Sampling Rate

Press RATE followed by the desired data entry sequence. For example, to program a 10msec sampling interval, press the following in order: RATE, 1, 0, ms. Press FREQ/TIME immediately after RATE to change between time and frequency units.

Step 4: Program the Number of Samples

Press SAMPLES followed by the desired numeric keys. For example, to program 1000 samples, press the following in order: SAMPLES, 1, 0, 0, 0, ENTER. Press FREQ/TIME immediately after SAMPLES to toggle between measurement duration and number of samples.

Step 5: Select a Trigger Source

Press SOURCE and then uprange/downrange repeatedly to scroll through available trigger sources: IMMEDIATE, (TRIGGER button), INPUT SIGNAL, EXTERNAL, OTHER CHANNEL. Press CHANNEL to return to the normal display mode. (the trigger source is selected as soon as it appears on the display).

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Step 6: Choose the Single/Continuous Trigger Arming Mode

To arm the A/D converter (only once), press SGL/CONT until the SGL indicator is on. To automatically re-arm the A/D converter, press SGL/CONT until the CONT indicator is on. Once the desired mode is selected, apply the appropriate trigger, as selected by the SOURCE key, to begin the measurement sequence or sequences (TRIGGER must be pressed to arm the A/D converter for all modes except immediate).

Step 7: Select Input Coupling

Press the CPLG key to select the desired input coupling. Ground coupling is in effect when both AC and DC are off.

Step 8: Choose Your Math Function

Press the desired math key. For example, to select the average function, press AVG. (If you are already in a mode requiring data entry, you must press SHIFT first.)

2.5.4 Measurement Procedure

Use the following basic procedure to connect the instrument to a voltage source and display readings on the front panel.

1. Turn on the instrument power and allow a one-hour warm up period for rated accuracy. Verify that the instrument goes through its normal power up procedure, as described in paragraph 2.4.
2. Press SHIFT RESET to make certain that the factory default configuration is placed in effect, or program your own operating modes, as discussed in paragraph 2.5.3.
3. If your instrument is equipped for dual channel operation, select either channel 1 or channel 2 by pressing the CHANNEL button. The selected channel number will appear in the right most digit of the display for either of the single-channel modes.
4. Select a range that is consistent with the anticipated measurement by using the uprange or downrange buttons, or use autoranging and allow the instrument to select the best range.
5. Connect a suitable BNC cable to the VOLTAGE INPUT jack for the selected channel.
6. Connect the other end of the cable to the voltage source to be measured, as shown in Figure 2-8. Remember that the cable shield is connected to input common, and must not be floated more than 30V RMS above chassis ground.
7. Place the unit in the continuous trigger mode (CONT indicator on) and then press TRIGGER to ensure that the unit is processing readings.
8. At this point, the instrument should display the voltage level being measured. An OFLO error message will be displayed if the input signal is above the selected range, in which case the instrument should be moved uprange.

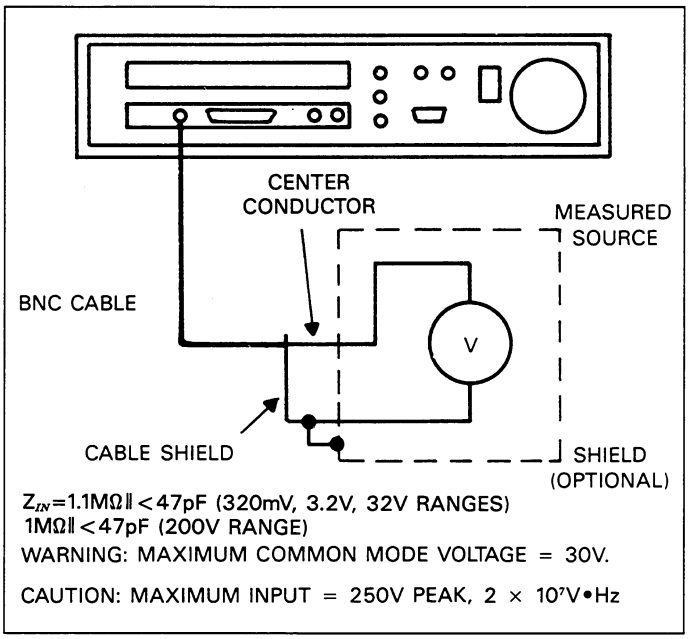


Figure 2-8. Basic Input Connections

2.6 SAMPLES, MEASUREMENTS AND READINGS

Throughout this manual you will encounter references to samples, measurements, and readings. The following paragraphs define and discuss these terms in order to clarify them.

2.6.1 Definitions

Sample—an individual A/D conversion resulting in a single unit of digitized binary data.

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Measurement—a series of samples stored in internal memory. You can control the number of samples and how fast they are taken with the SAMPLES and RATE keys.

Reading—a measurement that is mathematically processed in some way and then displayed on the front panel or transmitted over the IEEE-488 bus. Typical processes include waveform (display a single sample), average (average the samples in the measurement and display the result), and standard deviation (take the standard deviation of the measurement and display it).

2.6.2 Sampling Discussion

Using the procedure discussed in paragraph 2.5, the Model 194A appears to operate much like an ordinary DMM, in that a reading immediately appears on the display. Actually, the instrument is taking a number of samples, digitizing the analog value, and storing the result in its internal memory. The resulting sequence of samples is called a measurement. While in the continuous trigger mode (as in this example), the display is continuously updated with the sample stored in the memory location at the trigger point (assuming the waveform mode is in effect). Samples stored in the remaining locations can be accessed by using the RECALL button.

Figure 2-9 demonstrates the basic idea behind signal sampling. Here, a time-varying signal with the amplitude shown is being sampled at specific intervals. As each sample is taken, it is digitized into an 8-bit or 16-bit binary value (depending on the sampling rate and number of samples in the measurement) and stored in memory. The complete sampling sequence is a measurement, as defined above.

Once the measurement sequence is performed, a reading can be generated by processing the block of samples in some way. For example, to obtain the true RMS value of the measurement (remember a measurement is a series of samples), you would use the TRMS function. By using the instrument in a single trigger mode, you could apply a variety of different mathematical functions to a single measurement. Conversely, a single mathematical process could be applied to a variety of different signals by using the instrument in the continuous trigger mode. A single sample can be displayed by using the waveform mode (in which case the sample at the trigger point is displayed), or by using the RECALL button to display individual samples.

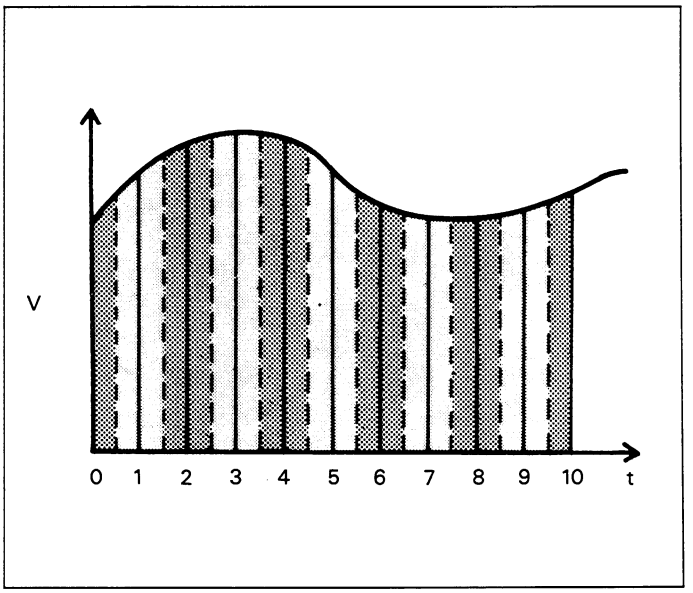


Figure 2-9. Basic Sampling

2.7 TYPICAL OPERATING MODES

The following information will help you to select the various operating modes for commonly encountered voltages and waveforms. Keep in mind that these are intended only as a starting point. Some experimentation may be required to determine the optimum instrument configuration for a particular measuring situation based on your particular waveform analysis requirements.

Table 2-5 summarizes recommended mode selection for four common voltages or waveforms: a DC voltage of 30V; a 60Hz, 2.82V RMS sine wave; a 2V, 1kHz symmetrical rectangular waveform; and a 50V peak, 15.734kHz sawtooth waveform.

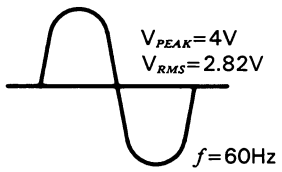
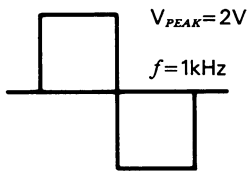
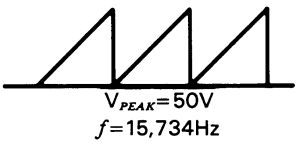
When selecting operating modes, the following points should be kept in mind:

1. The selected range should be high enough to handle the peak value of the waveform you are measuring. For example, the peak value of a 30V RMS sine wave is 42.4V. Thus, you would have to place the instrument on the 200V range to properly measure this waveform. Keep in mind that the instrument will normally display the OFLO (overrange) error message even if only one sample is overrange.

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2. When measuring sinusodial waveforms, the sampling frequency must be greater than twice the frequency you are measuring, or aliasing will occur. For example, with a 60Hz sine wave you might choose a sampling frequency of 150 or 200Hz. Since non-sinusodial waveforms are generally rich in harmonics, a good rule of thumb is to select a sampling frequency of at least 20 times the frequency of the periodic waveform. For example, with a 2kHz rectangular wave, a sampling frequency of at least 40kHz should be chosen.
3. The programmed number of samples will depend on the frequency of the signal you are measuring, the sampling rate, as well as how many cycles of the waveform you wish to capture. You can determine the required number of samples required to measure one complete cycle by dividing the period of the waveform by the sampling interval. For example, the period of a 1kHz signal is 1/1000=1msec. With a 50μsec sampling interval, the required number of samples is 1msec/50μsec=20 samples.
4. The type of coupling will depend on whether or not you wish to remove the DC component from a waveform. To measure a pure DC signal, you would obviously select DC coupling. For a symmetrical sine wave, AC coupling could be used to remove any small DC offset that might be present in the waveform.
5. The mathematical function you use will depend on your analysis requirements. For DC voltages the average function (along with the default 166.7μsec, 101 samples) is recommended to minimize 60Hz AC noise effects on the measurement. (If operating the unit on 50Hz power, the sampling interval should be 200μsec.).

Table 2-5. Recommended Operating Modes For Typical Waveforms

Waveform	Range	Sampling Interval	# Samples	Coupling	Math Function*
30VDC	32V	166.7μsec	101	DC	Average
 SINE WAVE	32V	1msec	100	AC	TRMS
 SYMMETRICAL RECTANGULAR WAVEFORM	3.2V	50μsec	20	DC	Peak-Peak
 SAWTOOTH WAVEFORM	200V	3μsec	25	DC	Peak

*Math function depends on required waveform analysis.

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SECTION 3
OPERATION

3.1 INTRODUCTION

This section contains complete and detailed information on most operating aspects of the Model 194A, including a complete description of each front panel operating mode, as well as pertinent information on rear panel functions such as triggering and real time output.

Section 3 is organized in the following manner:

3.2 General Display Messages: Gives a brief description of general front panel display messages associated with front panel operation.

3.3 Range Selection: Describes the operation of the ranging buttons, and how to determine the selected range from the display.

3.4 Data Entry: Outlines the data entry sequence used by many front panel operating modes.

3.5 Rate and Samples Programming: Contains information on programming the number of samples per measurement, as well as how fast those samples are taken.

3.6 Triggering: Gives complete information on all aspects of instrument triggering modes and functions, including how to select the trigger source, how to initiate a measurement sequence, and how to program trigger level and delay values.

3.7 Input Coupling: Covers instrument input signal coupling modes, and outlines how to select AC, DC, or ground coupling.

3.8 Recalling Data: Describes how to recall data stored in the measurement buffer during or after a measurement sequence.

3.9 Dual Channel Operation: Gives important operating information on using a Model 194A that is equipped with the optional Model 1944A Module in the channel 2 location.

3.10 Using Zero: Describes how to use the zero mode, including how to program baseline values from the front panel.

3.11 Filtering: Outlines operation of the 50kHz and 500kHz single pole analog filters.

3.12 Using the Analog Output: Describes how to use the analog output to drive graphing devices such as plotters, CRTs, and oscilloscopes.

3.13 Mathematical Functions: Describes the many available Model 194A math functions, including integral, average, peak to peak, and TRMS.

3.14 Ratio and Difference: Describes how to display the ratio and difference between the two channels.

3.15 Status: Tells how to recall instrument status and determine the configuration of various operating modes.

3.16 Setup Mode: Outlines how to store and recall two different instrument configurations in non-volatile memory.

3.17 Front Panel Programs: Summarizes access to such miscellaneous functions as IEEE-488 address programming and digital calibration through use of the OTHER key.

3.18 Reset: Tells how to quickly reset the instrument to its power up default conditions.

3.19 External Clock: Outlines methods for connecting two or more Model 194As together for synchronous operation.

3.20 Real Time Output: Describes how to use the real time output to transmit data to other equipment.

3.21 External Sample Control: Covers the external sample control feature of the Model 194A.

3.22 Measurement Considerations: Details some important considerations when using the Model 194A.

3.23 Typical Applications: Gives some typical uses for the unit.

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3.2 GENERAL DISPLAY MESSAGES

General display messages that may be encountered when using the Model 194A are summarized in Table 3-1. Many operating modes have additional display messages that are described in paragraphs pertaining to those modes.

Table 3-1. General Display Messages

Message	Description
OFLO	Overrange input applied, or stored in at least one buffer location.
— — — — —	No valid reading after A/D configuration was changed.
NMBR TOO LARGE	Parameter too large entered during data entry.
NMBR TOO SMALL	Parameter too small entered during data entry.
SHIFTLESS KEY	Key without shift mode pressed after pressing SHIFT.
NO A/D IN CH2	CH1÷CH2 or CH1−CH2 pressed with no channel 2 A/D module installed.
NO SCANNER	SCAN button pressed with no scanner module* installed.

*Future option of the Model 194A.

3.3 RANGE SELECTION

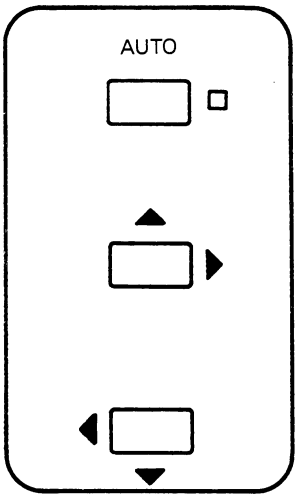
The Model 194A has four ranges, as summarized in Table 3-2. Note that the resolution of each range depends on the selected sampling rate and number of samples because of differences in A/D converter resolution. The operation of the various range modes is described in the following paragraphs.

Table 3-2. Range Summary

Range	Resolution		General
	16-Bit*	8-Bit**	Display Format
320 mV	10 μV	2.56mV	.XXXXX
3.2 V	100 μV	25.6 mV	X.XXXX
32 V	1mV	256 mV	XX.XXX
200 V	10mV	2.56 V	XXX.XX

*100kHz and lower sampling rate and #samples ≤32,768.
**Above 100kHz sampling rate or #samples >32,768.

RANGE BUTTONS



3.3.1 Autoranging

The AUTO button enables and disables the autoranging mode. The associated indicator will be on when the autoranging mode is enabled. While in this mode, the instrument will automatically select the best range to measure the applied signal. Autoranging may be cancelled either by pressing AUTO a second time, or by pressing the uprange or downrange keys. When autorange is cancelled, with the AUTO key, the unit will remain on the range that was previously selected.

NOTE
A separate trigger will still be required for each range change except in the continuous front panel mode.

Upranging occurs at 100% of range, while downranging takes place at 8% of range.

If the instrument is in the dual-channel mode, the AUTO button is locked out; however, if either channel was placed in autoranging before entering the dual-channel mode, it will remain in the autoranging mode, although the AUTO indicator will remain off under these conditions.

3.3.2 Uprange

The Uprange key is one of the two manual ranging buttons on the instrument. Each time this key is pressed, the instrument will move up one range. Once the instrument reaches the highest range, pressing this key will have no further effect. Pressing Uprange will also cancel the autorange mode, if enabled.

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The Uprange key is also used with many other front panel operations such as data entry and various XY modes. These aspects are covered in the respective paragraphs.

3.3.3 Downrange

The Downrange key operates much like the Uprange key, except, of course, for the fact that the instrument is moved downrange. Once the lowest range is reached, this key has no further effect. Pressing downrange, will also cancel autoranging, if that mode was previously selected.

Like the Uprange key, Downrange is used with other modes including data entry and various XY modes.

3.3.4 Range Selection Considerations

Generally, the lowest range that can be used without overranging the instrument is the best one for most situations (the instrument will display the "OFLO" error message if an overrange signal is applied). Doing so will generally result in the best overall accuracy. However, because the instrument operates a little differently than an ordinary DMM, there are some key points to keep in mind when selecting a range.

When the instrument is measuring a signal, it is actually taking a series of samples at pre-programmed intervals. As these samples are taken, the resulting data are stored in memory as a complete measurement. If the signal amplitude varies with time, it is possible that one or more of these samples is an overrange value. Under these conditions, the unit will still display the "OFLO" message even if most samples are on range. If this condition exists, it is still possible to go back and access the good samples by using the RECALL button.

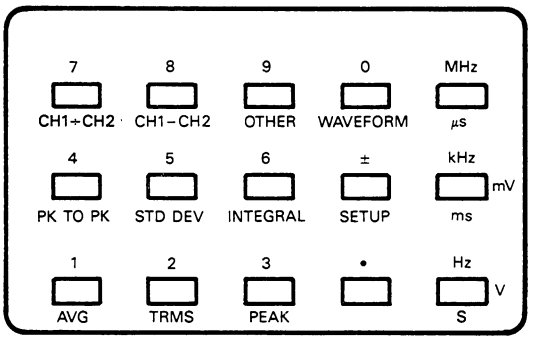
When the instrument is in the continuous trigger and autorange mode, it continuously samples the signal at the selected rate and attempts to choose the best range based on the maximum buffer sample amplitude. However, there could be some situations where an occasional overrange reading occurs because the instrument was unable to move uprange fast enough to keep up with the applied signal.

While autoranging, the instrument will take a complete measurement and, if necessary, change range; it will repeat measurements until a satisfactory range is found.

3.4 DATA ENTRY

Many front panel modes such as zero value, delay, trigger level, rate, and samples require that numeric data be entered from the front panel. Model 194A data is entered by using the ENTER, CANCEL, FREQ/TIME, 0 through 9, +/−, ., MHz, kHz, and Hz keys. The operation of these keys or key groups is discussed in the following paragraphs.

DATA ENTRY KEYS



3.4.1 Data Keys

The data keys, 0 through 9, +/−, ., MHz (μs), kHz (ms, mV), and Hz (s,V) are used to enter a numeric quantity into those modes requiring data entry. These keys are operational only when the instrument has been placed into the data entry mode by pressing another mode button requiring data entry. For example, pressing RATE will enter this mode and allow you to program a rate.

During the data entry process, a flashing digit or segment (the cursor) on the display will indicate which digit will be affected by a numeric key press. The 0 through 9, ., or +/− keys can be pressed at the appropriate times to enter the desired data. During the numeric entry process, the cursor can be moved to the right or left by pressing Uprange or Downrange respectively, and a single-digit change can be made at that point.

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If a numeric key is pressed instead of a cursor key immediately upon entering the data entry mode, the current value is blanked out and the new value must be keyed in completely.

The type of units that will be entered will depend on the selected mode-some modes require voltage units, while others require time/frequency information. For example, a trigger level is entered as a voltage, thus appropriate units (mV or V) are automatically selected by pressing one of those two keys. In a mode such as samples, frequency (MHz, kHz, or Hz) or time interval (μs, ms, or s) units are selected with the aid of the FREQ/TIME key, as discussed below.

NOTE

Pressing a units key automatically enters data. +/– may be pressed at any time during the numeric input sequence.

3.4.2 ENTER

The ENTER key performs the last step in the data entry process. Once you have keyed in the desired numeric data, pressing ENTER will store the parameter in question in memory for use by the instrument, unless an invalid parameter was entered. If data is not valid, the instrument will display one of the following error messages:

NMBR TOO LARGE

Or,

NMBR TOO SMALL

The instrument will then return to the data entry mode.

If the data is valid, pressing ENTER will cause the instrument to momentarily display the entered value, and then return to the previous operating mode. If a units key is pressed during the data entry process, ENTER need not be used.

ENTER is also used to store instrument configurations when using the setup mode, as discussed in paragraph 3.16.

3.4.3 CANCEL

The CANCEL key can be used during the data entry process to cancel data previously entered into the display with the data entry keys. When CANCEL is pressed, the display will return to the previous value. If no cursor or data entry keys were pressed, the unit will return to the previous mode.

Pressing CANCEL after pressing ENTER has no effect since the value is already stored in memory.

3.4.4 FREQ/TIME

FREQ/TIME is used in the data entry mode to toggle between reciprocal frequency time units when programming the following modes: sample rate, number of samples per measurement and delay.

When FREQ/TIME is used to program sample rate, it toggles the displayed value between samples (or scan sequence, for the scanner) per second in Hz, kHz, or MHz, and time interval between samples in sec, msec, or μsec.

When programming samples per measurement, FREQ/TIME toggles units between elapsed time for the entire measurement in sec, msec, or usec, and the number of samples per measurement.

When programming trigger delay, the FREQ/TIME key toggles data entry units between time in sec, msec, or μsec, and the total number of samples.

NOTE

Once the data entry keystroke sequence has begun, FREQ/TIME will have no effect.

3.4.5 Using the Cursor Keys

During the numeric entry process, the left (◄▼) and right (▲►) cursor keys can be used to move the cursor (flashing digit or segment) to the desired display digit location. Once the cursor is on the desired digit, a new value can be typed in; the change will affect only the location where the change is made. In this manner, a one or two digit change can be made easily without having to type in the new value completely.

If a numeric key is pressed first during the entry process without pressing a cursor key first, the current value is blanked out and the complete number must be keyed in.

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3.4.6 Data Entry Examples

The examples below will help demonstrate the basic procedure for entering instrument data. The various operating modes that are used here as a demonstration aid are covered in more detail in subsequent paragraphs of this section.

Example 1: Entering voltage units.

1. Press LEVEL to enter the trigger level entry mode. The instrument will then display the presently programmed trigger level. For example, the display might show:

   0.μV

2. To key in a trigger level of -1.675V, press: +/−, 1, ., 6, 7, 5. The display will show the numbers as they are keyed in.
3. Press V to store the new trigger level in memory. The instrument will briefy display the new value and then return to the previous operating mode.

Example 2: Entering frequency/time units.

1. Press the RATE key to enter the sampling rate entry mode. The instrument will then display the presently programmed value, for example:

   166.7μs

2. At this point, you can toggle between reciprocal time and frequency units by pressing the FREQ/TIME key.
3. Press FREQ/TIME until time units are entered (for example, ms)
4. To key in an interval of 23.4msec, press: 2, 3, ., 4, ms.
5. Press RATE to get back into the rate entry mode.
6. Press the FREQ/TIME key and note that you can toggle the display between frequency and time units. With a programmed interval of 23.4msec, the corresponding frequency is 42.73504Hz.

Example 3: Demonstrating a NMBR TOO SMALL error.

1. Press RATE to enter the sampling rate entry mode.
2. Press FREQ/TIME (if necessary) to display time interval units.
3. To attempt to program a 0ms (invalid) rate, press: 0, ms.
4. Note that the instrument displays the NMBR TOO SMALL error message, and then returns to the previously programmed value.

Example 4: Demonstrating the use of the CANCEL key.

1. Press RATE to enter the sample entry mode. Note that the instrument displays the presently programmed value.
2. Press: 3, 5.
3. Press CANCEL, and note that the display returns to the previous value.
4. Press: 5, 0, ms; note that the last value is entered into memory.

Example 5: Using the cursor keys.

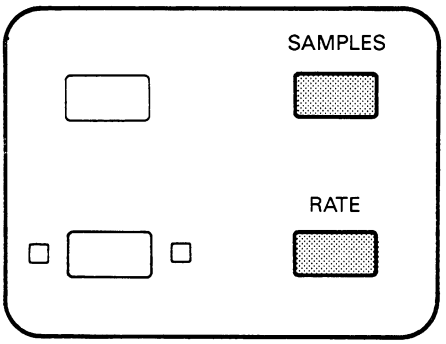
1. Press RATE to enter the sampling rate entry mode and note that the presently programmed value is displayed.
2. Use the right cursor (Uprange) key to move the flashing cursor to the right. You can stop on any digit and make a change, if desired. If you move off the display to the right, the cursor will wrap around to the first digit on the left.
3. Using the left cursor (Downrange key), move the flashing display cursor to the left. Again, you can stop on any digit and make a change, if necessary. Once the cursor reaches the extreme left, it will wrap around to the right most digit.
4. Once all changes have been made by using the cursor keys, press ENTER to store the new parameter in memory.

3.5 RATE AND SAMPLES PROGRAMMING

A measurement sequence is made up of a number of individual samples taken at predetermined intervals. Through the use of the RATE and SAMPLES keys, you have precise control over how many samples to take, and the time period between individual samples. Programming of each of these modes is performed by pressing the appropriate key (RATE or SAMPLES) and then using the data entry keys to enter the desired value. During the entry process, the display can be returned to the previous value by pressing the CANCEL key. If an incorrect parameter is entered, the instrument will display an error message (NMBR TOO SMALL or NMBR TOO LARGE, as the case may be).

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RATE AND SAMPLES BUTTONS



3.5.1 Programming Sampling Rate

The RATE key is used to program either the sampling frequency, or the time interval between individual samples. When programming frequency, values between 1Hz and 1MHz may be entered. When entering frequency, the unit will automatically adjust the frequency value to correspond to the resolution of the sampling interval (0.1μsec).

For rates above 100kHz, the usable display resolution is reduced to 2½ digits (although 4½ digits are displayed) because the A/D converter operates with 8-bit resolution above 100kHz, or when 32,768 or more samples are programmed.

When programming time intervals, values between 1μsec and 1sec may be entered. If a value below the allowable resolution (0.1μsec) is entered, the instrument will automatically adjust the entered parameter to the closest valid value.

The FREQ/TIME key can be used when entering rate parameters to toggle the instrument between the time and frequency entry modes. The display will show the type of units currently in effect. When new data is being entered, it will be entered in the same mode as the display currently shows unless FREQ/TIME has been pressed to change to reciprocal units.

Example 1: Program a 35μsec sampling interval.

1. Press RATE to allow entry of rate data. The display will show the currently programmed value. For example, the display might show:

   50.00000 kHz

2. Press the FREQ/TIME key several times and note that the display alternates between time and frequency. With a 50kHz rate, the display would alternate between 50kHz and 20μsec because one value is the reciprocal of the other (f = 1/T).
3. Press: 3, 5, μs to program the new value. The instrument will then return to the previous operating mode.

Example 2: Program a 100kHz rate.

1. Press RATE to enter the rate entry mode. The unit will then display the programmed value.
2. Press FREQ/TIME, if necessary, to display time interval information. If the instrument is still programmed with the 35μsec sampling rate from Example 1, the display will show:

   28.57142 kHz

3. Press: 1, 0, 0, kHz. The new rate will be programmed, and the instrument will return to the previous operating mode.

Example 3: Automatic recalculation of frequency units.

The resolution of the programmed sampling interval is 0.1μsec. When entering sampling rate as a frequency, however, it is quite possible for you to enter a frequency parameter that results in an interval below the 0.1μsec resolution limit. For example, with a 35kHz sampling rate, the resulting interval would be 28.571μsec. In this instance, the unit would adjust the frequency to result in the nearest whole interval-28.6μsec in this case. Thus, if a value of 35kHz were entered, the unit would actually program a value of 34.96503kHz.

1. Press the RATE key in order to enter the rate mode.
2. If necessary, press FREQ/TIME to place the instrument in the frequency entry mode.
3. Program a 35kHz rate with the following sequence: 3, 5, kHz.
4. Note that the unit adjusts the frequency value to 34.96503kHz.
5. Press RATE and then FREQ/TIME to display sampling interval. Note that a value of 28.6μsec is programmed.

3.5.2 Programming the Number of Samples

The number of samples to take in a given measurement sequence is programmed through use of the SAMPLES key, as you might expect. The input parameter for this mode may be entered either as the number of samples (1-65,535), or as a time duration for the measurement sequence (0-65,534s). As is the case when entering sampling rate, the FREQ/TIME key is used to toggle the instrument between these two modes. If you enter a time duration shorter than the programmed sampling rate, the unit will automatically round the input to the nearest valid value.

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NOTE

When the programmed number of samples is >32,768 the A/D converter operates in the 8-bit mode.

When entering time units, it is possible that you could key in a number that is not an integer multiple of the time interval between samples. In this case, the instrument will automatically convert your input to the closest valid value. For example, assume you have previously programmed a 12msec sampling rate and enter a sampling duration of 603msec. The instrument will automatically change this value to 600msec, which is the closest integer multiple of a 12msec sampling rate.

Note that the measurement duration is n−1 times the sampling interval. For example, with 100 samples programmed and a 1msec interval, the measurement duration is 99msec.

When programming the number of samples, the unit "remembers" whether you previously entered this parameter in number of samples or elapsed time, and it will automatically display the value in those units when the SAMPLES key is pressed. Also, if the number of samples is programmed in elapsed time, and you then change the sampling rate, the unit will automatically recalculate the number of samples to keep the total elapsed time the same. If this value is entered as a number of samples rather than as elapsed time, no such recalculation is performed. The end result is that the number you programmed remains the same.

The two display formats for the samples mode differ slightly depending on whether number of samples or elapsed time is entered. If time duration is specified, the display will include time units, as in the example below:

250.0μs

In this example, a time duration of 250μsec is specified.

The number of samples are specified, as in this example:

1200 SAMPLES

In this case, 1200 samples are to be taken during the measurement sequence.

Example 1: Program 750 samples.

1. Press the SAMPLES key. The unit will then display the presently programmed value. For example, the display might show:

   101 SAMPLES

   In this case, the factory default value is displayed.
2. Press FREQ/TIME and note that you can toggle the display between elapsed time and number of samples. For the purposes of this demonstration, leave the display in the number of samples mode.
3. Press: 7, 5, 0, ENTER. The unit is now programmed for a 750-sample measurement sequence.

Example 2: Program a 560msec sampling duration.

In the example below, it will be necessary to enter rate information as part of the demonstration sequence to make sure that the sampling duration is an even multiple of the sampling rate.

1. Press RATE to enter the rate entry mode.
2. Press: FREQ/TIME (if necessary to display rate in time interval rather than frequency units), 1, ms. A 1msec sampling interval has now been programmed.
3. Press SAMPLES to enter the sample entry mode. The unit will display the previously programmed value. If you entered the value from Example 1, the display should show:

   750 SAMPLES

4. Press FREQ/TIME to display the samples parameter in time units. Since a 1ms interval has been selected with the number of samples set to 750, the time duration will be 749msec.
5. Press : 5, 6, 0, ms to program the new sampling duration interval.
6. Press SAMPLES, FREQ/TIME and note that 561 samples are displayed -- a value that is one more than you might expect.

Example 3: Automatic rounding of sample duration.

As pointed out earlier, the instrument will automatically convert a programmed time duration to the nearest integer multiple of the sampling rate. The example below will demonstrate this process.

1. Press RATE, FREQ/TIME (if necessary to enter parameters as time interval information), 1, 2, ms. This keystroke sequence programs a 12msec sampling rate.

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2. Press: SAMPLES, FREQ/TIME (if necessary to enter data as time duration), 6, 0, 2, ms.
3. Note that the 602msec programmed value has changed to 600msec, which is the nearest integer multiple of the 12msec sampling interval.

Example 4: Setting the sampling duration smaller than the sampling interval.

The sampling duration cannot be smaller than the sampling interval, as discussed previously. The instrument will round off the value if you attempt to program the instrument in this manner, as in the example below.

1. Press RATE, FREQ/TIME (if necessary to place the display in the time interval mode), 1, 0, 0, ms, ENTER. This keystroke sequence programs a 100ms sampling interval.
2. Press SAMPLES, FREQ/TIME (if necessary to display and enter time units), 2, 0, ms.
3. Note that the measurement duration is changed to 0μsec (1 sample) because it is rounded down.

Example 5: Automatic recalculation of number of samples.

If the sampling rate is changed after programming measurement duration, the instrument will automatically recalculate the number of samples to keep the measurement duration the same, as in the example below.

1. Press RATE, FREQ/TIME (if necessary to enter time interval information), 1, ms. At this point a 1msec sampling interval has been programmed.
2. Press SAMPLES, FREQ/TIME (if necessary to enter duration as time information), 5, 0, 0, ms, ENTER. This sequence enters a 500msec sampling duration.
3. Press SAMPLES and FREQ/TIME to display the number of samples. The display should indicate that the programmed number of samples is 501 because the sampling duration is 500msec, and the sampling interval is 1msec.
4. Change the sampling interval to 5msec as follows. Press: RATE, 5, ms.
5. Press SAMPLES and FREQ/TIME to display the programmed number of samples. Note that the number of samples has been changed to 101 because of the change in sampling interval, although the sampling duration remains at 500msec, as previously programmed (you can verify these values by pressing the FREQ/TIME key while in the samples mode).

3.5.3 Samples and Rate Selection Considerations

Because the Model 194A can sample input signals at rates as high as 1MHz, it is ideal for many applications involving the analysis of many time-varying signals, both of the periodic and transient variety. To ensure optimum accuracy when measuring such signals, care must be taken when selecting both the sampling rate and the number of samples. In the following paragraphs, we will discuss some of these considerations that should be taken into account when choosing sampling rates and measurement durations.

Input signals to the Model 194A are in analog form. Internally, however, the Model 194A operates in the digital world. Thus, the analog signal must be converted into digital information by the A/D (Analog-to-Digital) converter of the instrument. This conversion process is not continuous, but rather is done at discrete intervals, determined by the entered rate parameter. If the sampling rate is too slow, considerable information about the original analog signal will be lost, and errors can creep into the resulting data.

For example, assume that a sinusoidal waveform is being sampled at regular intervals, and the result digitized and stored internally.

Once the data is sampled and stored, we can attempt to reconstruct the original waveform from the data. However, the result is no longer a smooth, continuous waveform, but is instead made up of discrete steps. Thus, as the result of this digitization process, we may have lost much important information about the original signal.

To make the steps in the reconstructed data smaller, we can increase the sampling rate. At the same time, we will have to increase the number of samples per measurement if we still wish to measure at least one cycle of the applied signal.

It is clear then, that we should make the sampling rate sufficiently high so as not to loose important information present in the original input signal. Information theory states that, for sinusoidal waveforms, the sampling frequency must be at least twice as high as the highest frequency component in the measured signal. Thus, if a 100kHz signal is to be sampled, the sampling frequency must be at least 200kHz.

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If the sampling frequency is not at least twice the frequency being sampled, a phenomenon known as aliasing results. When aliasing occurs, the sampled information will not contain data on the original waveform, but instead a new signal with a frequency equal to the difference between the sampling frequency and the original applied signal. For example, if a 100kHz signal is sampled at a 110kHz rate, a new signal of 10kHz will be the one actually seen in the resulting data. If the signal and sampling frequencies are exactly the same, a DC signal level will result, since the difference between the two signals is zero. Thus, it is imperative that the minimum 2:1 ratio of sampling frequency to measured frequency be maintained if accurate results are to be expected.

Once we have established our minimum sampling frequency based on the above criteria, we can then go ahead and choose the correct sample and rate parameters for a given situation. For example, assume that we are measuring a 20kHz sine wave. We would then press the RATE key and then key in the desired sampling frequency. Although a 40kHz frequency sampling frequency would be adequate, we might want to play it safe and choose a 50kHz sampling frequency for this measurement. Once the rate parameter is established, we can choose a sampling duration or number of samples to measure based on how many cycles, or how much of a single cycle we wish to sample. For example, if we wished to sample one complete cycle of the 20kHz waveform, the measurement duration would be 1/20kHz = 50μsec. Aside from which range to use, the only other consideration for a basic measurement would be the trigger method, as described in paragraph 3.6.

Thus far in our discussion, we have assumed that all signals are sinusoidal in nature. In the real world, of course, many complex waveforms exist. These complex waveforms can be broken down into a fundamental sinusoidal waveform and a number of harmonics in accordance with the Fourier series. While detailed Fourier analysis is beyond the scope of this discussion, you should be aware that such harmonics do exist.

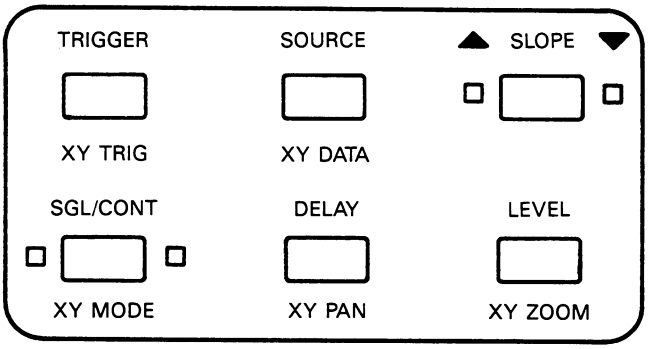
From this discussion, we can see that it may necessary to choose a sampling frequency substantially above the fundamental frequency of a non-sinusoidal waveform to ensure good results. For example, when sampling a 10kHz rectangular waveform it would be a good idea to choose a sampling frequency of 200kHz since a substantial portion of the ninth harmonic (90kHz) is present, and the sampling rate must be at least twice as high as the highest frequency.

Another consideration when selecting the sampling rate is the overall resolution and accuracy of the measurement. For sampling rates 100kHz and below, the A/D converter operates with 16-bit resolution (assuming the number of samples is $\leq$32,768), meaning that it digitizes the signal into 2^{16}, or 65,536 steps. Above 100kHz, the A/D converter has only 8-bit resolution, so it can resolve only 2^8, or 256 steps. The A/D resolution has a direct effect on display resolution as well as the ultimate accuracy of the measurement. At 100kHz and below, display resolution is 4¾ digits, while the usable resolution is reduced to 2¾ digits above 100kHz (the unit will still display 4¾ digits, however, above 100kHz). Consequently, instrument accuracy is not as good with sampling rates above 100kHz as it is below that value (refer to the specifications at the front of this manual for actual figures). Thus, if accuracy is of paramount importance, you should select a sampling rate of 100kHz or less and $\leq$32,768 samples, unless other factors such as measurement speed override this consideration.

3.6 TRIGGERING

A trigger stimulus is used to initiate a Model 194A measurement sequence. The duration of that sequence and the number of samples taken during the sequence will depend on previously selected rate and sample parameters.

TRIGGER BUTTONS



The unit can be triggered with the front panel TRIGGER button, the input signal, from a pulse applied to the external trigger input jack, or from the other channel (the instrument can also be triggered over the IEEE-488 bus, as discussed in Section 4). When triggering from the input signal, you can define slope and trigger level parameters. From the front panel, these modes are programmed with the various trigger buttons, as described in the following paragraphs.

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3.6.1 Trigger Source

The trigger source is selected by pressing the SOURCE key. The instrument will display one of the trigger sources, as summarized in Table 3-3. To select a different source, press uprange or downrange repeatedly until the desired trigger source is displayed. The new trigger source is saved once the source is displayed. To return to the previous mode, press SOURCE.

Note that the SOURCE key is inoperative when the instrument is in the dual-channel display mode.

NOTE

When you select external, input signal, or other channel triggering, you must first arm the A/D converter by pressing the TRIGGER button. The measurement sequence will then begin when the appropriate trigger stimulus occurs.

Table 3-3. Trigger Source Display Messages

Message	Selected Trigger Source
IMMEDIATE	TRIGGER button or IEEE trigger (X, GET, etc.)
EXTERNAL	Pulse applied to TRIGGER IN jack.
INPUT SIGNAL	Input signal, depending on selected slope and levels.
OTHER CHANNEL	Second channel when 1944A option installed.
TRIG ON TALK	IEEE talk command
TRIG ON X	IEEE X command
TRIG ON GET	IEEE GET command

3.6.2 Single/Continuous Arming Modes

A/D arming can be set up to operate in two different ways: in continuous or single modes. In a continuous mode, the unit will automatically re-arm the A/D converter after each measurement sequence. The unit will then perform another measurement sequence when it receives the appropriate trigger stimulus (as selected with the SOURCE key). In the single mode, however, the A/D converter must be manually re-armed after each measurement (the A/D converter can be re-armed from the front panel by pressing TRIGGER).

Single/continuous arming selection is performed by pressing the SGL/CONT button to select the desired mode; the appropriate indicator will then display the selected mode.

When the instrument is in the dual-channel display mode, the SGL/CONT button and associated indicators are inoperative.

NOTES:

1. If the instrument is in the immediate (TRIGGER button), continuous mode, it will process measurements continuously without requiring additional triggers.
2. If the selected trigger source is the input signal, external trigger, or other channel, the unit will require a separate trigger stimulus for each measurement regardless of whether the unit is in the single or continuous armed modes.
3. When going from the single, immediate mode to the continuous, immediate mode, it will be necessary for you to press the TRIGGER button to begin processing measurements.
4. The decimal point in the display (between second and third digits from the right) will turn on to indicate that the A/D converter is armed and waiting for a trigger.

Discussion

Basically, there are two steps needed for initiating a measurement sequence. First, the A/D converter must be armed, so that it is running and processing data. Secondly, the unit must be triggered by the appropriate trigger stimulus (determined by the selected source) before it will perform a measurement sequence. The only exception to this two-step process is when the immediate, front panel mode is selected. In this situation, pressing TRIGGER performs both steps simultaneously so that the A/D converter is armed and the measurement is initiated with a single action.

There are two fundamental reasons why the A/D converter must be running before a measurement sequence takes place. First, when input signal triggering is in effect, the A/D converter must supply input signal amplitude data to the digital comparator circuits so that they can trigger a measurement when the programmed trigger threshold is reached. Secondly, when using pre- or post-trigger, the unit must continuously store data so that it can later flag the beginning of the measurement relative to the programmed trigger point.

3.6.3 TRIGGER Button Operation

The Model 194A can be triggered by the front panel TRIGGER button, if the immediate mode has been selected as the trigger source (paragraph 3.6.1). Once activated, pressing TRIGGER will initiate a single or continuous sequence of measurements, depending which of those two modes was selected with the SGL/CONT button.

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The TRIGGER button is also used to arm the remaining trigger modes. For example, suppose you select input signal triggering with the SOURCE key. You must then press TRIGGER to start the A/D converter so it can process samples to determine when the input signal has crossed the programmed trigger threshold. Once the trigger occurs, the instrument will begin the measurement sequence in the usual manner.

NOTE

Pressing TRIGGER will alternately arm and disarm the A/D converter when in the continuous mode.

Note that TRIGGER is operational in the dual-channel display mode, as well as in the CH1-CH2 and CH1÷CH2 modes.

3.6.4 Trigger Delay

The DELAY key can be used to program the location of the beginning of a measurement relative to the trigger point. The delay value can be entered either in units of time, or in number of samples. The limits for the delay parameter are -65,536 to $+10^7$ seconds or -65,536 to $+10^7$ samples. The input data is alternated between time and sample units by pressing the FREQ/TIME key.

When negative values are entered, pre-triggering is in effect. Post-triggering is in effect when positive delay values are entered. Both post- and pre-triggering are available with all trigger sources.

NOTE

If pre-triggering is selected, and the A/D converter is armed, any previous stored measurements will be overwritten even if the next measurement sequence has yet to be triggered.

The basic keystroke sequence to enter a trigger delay is: DELAY, data, ENTER or time units. If an incorrect parameter is entered, an appropriate error message will be displayed. During the entry process, you can press CANCEL to restore the display to the previous value.

When entering the delay parameter in time units, it is possible that you might enter a value that is not an integer multiple of the sampling interval. Under these conditions, the instrument will automatically adjust the entered delay to the nearest valid value.

Whether delay is entered in time or sample units, the instrument will "remember" which units were previously in effect. Thus, pressing DELAY will give you a display of the delay parameter in previously programmed units. Also, if you enter the delay in time units, and then change the sampling rate, the instrument will maintain the same delay time by recalculating the number of samples to delay. However, no such recalculation is performed if you enter the delay parameter as a number of samples.

Example 1: Program a 50msec positive delay.

1. Program a 1ms sample interval as follows. Press RATE, FREQ/TIME (if necessary to display time units), 1, ms.
2. Press DELAY to enter the delay entry mode. The instrument will display the presently programmed value, for example: 0 DELAY.
3. If necessary, press FREQ/TIME to display the delay value in time units.
4. Press: 5, 0, +/− (only necessary if negative value is currently displayed), ms. The new trigger delay period is now programmed.

Example 2: Program a 25msec negative delay period.

1. Press DELAY to place the instrument in the delay entry mode. The unit will display the previously programmed value.
2. Press: +/−, 2, 5, ms. The new delay value is now programmed.

Example 3: Program an 80 sample positive delay.

1. Press DELAY to enter the delay entry mode.
2. Press FREQ/TIME to change the display to show number of samples.
3. Press 8, 0, +/−, ENTER. The new value is now programmed.

Example 4: Automatic recalculation of delay number of samples.

If the sampling interval is changed after programming the delay, the instrument will automatically recalculate the delay number of samples, as in the following example.

1. Press DELAY to enter the delay entry mode.
2. Press FREQ/TIME to display the delay in time units.
3. Program a 50msec positive delay as follows. Press 5, 0, +/− (only necessary if a negative value is displayed), ms.
4. Press DELAY then FREQ/TIME and note that the delay is programmed as 50 samples.

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5. Change the sampling interval to 5msec as follows. Press RATE, FREQ/TIME (if necessary to display time units), 5, ms. The sampling interval has now been changed to 5msec.
6. Press DELAY to program delay period. If necessary, use the FREQ/TIME key to display the number of samples. Note that the number samples to delay has been changed from 50 to 10 because of the change in sampling interval from 1msec to 5msec.

Discussion

The trigger delay parameter tells the instrument where to begin storing readings relative to the trigger point. If the parameter is zero, no delay occurs, and the trigger point is assumed to be the same as the first buffer sample. However, if the delay parameter is non-zero, the first sample location will be moved in accordance with the programmed delay parameter.

Figure 3-1 will help to demonstrate the basic concept behind delayed triggering. In Figure 3-1(A), the delay is zero, so the measurement begins at the trigger point. In (B), which shows a positive delay, the measurement sequence begins some time after the trigger occurs. That time period is, of course, determined by the programmed delay value.

In Figure 3-1(C), a negative delay is shown, with the first measurement occuring ahead of the trigger stimulus. The amount of delay is again determined by the programmed delay parameter.

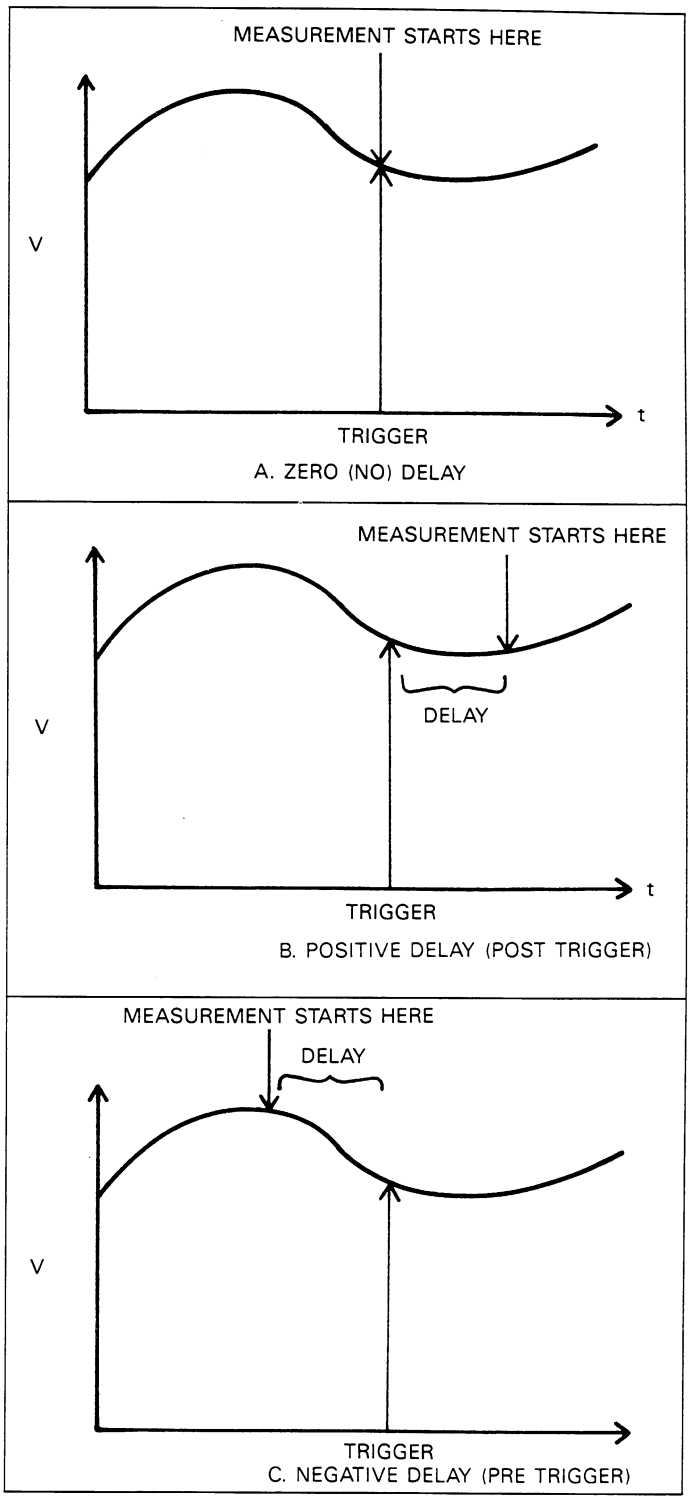


Figure 3-1. Trigger Delay

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3.6.5 Trigger Slope

The SLOPE key can be used to program the instrument to trigger either on the positive or negative-going edge of the input signal. The instrument can be toggled between these two modes by repeatedly pressing SLOPE. The active mode is indicated by the indicators adjacent to the SLOPE key.

If the instrument is in the dual-channel display mode, or if the selected trigger source is not the input signal, the SLOPE button and associated indicators are inoperative.

3.6.6 Trigger Level

The programmed trigger level can be entered into the unit by using the LEVEL key. This feature applies only when the selected trigger source is the input signal. When LEVEL is first pressed, the instrument will display the currently programmed trigger level. A new level can then be programmed with the data entry keys.

The allowable range for the trigger level is ±200V. Programming values above or below this range will result in an appropriate error message. If the programmed value is below the resolution of the A/D converter (10μV), the unit will round the value to the nearest allowed value.

Note that μV levels can be programmed with the μs key.

When the instrument is in the dual-channel display mode, the LEVEL button is inoperative.

Example 1: Program a +5V trigger level.

1. Press LEVEL to enter the level entry mode. The instrument will display the presently programmed trigger level. For example, the display might show:

   2.55V.

2. Press: 5, V. The unit will now briefly display the programmed value and return to the previous display mode with a 5V trigger level programmed.

Example 2: Program a -300μV trigger level.

1. Press LEVEL and note that the presently programmed trigger level is displayed.
2. Press: ., 3, +/−, mV. The new trigger level of -300μV is now programmed.

Discussion

The level and slope operating modes determine when the instrument is triggered from the applied input signal. If a positive slope is selected, triggering will take place when the input signal rises to the preset level that was programmed with the LEVEL key. If a negative slope is selected, triggering will occur when the signal level drops to that preset level.

Figure 3-2 will help to demonstrate slope and level triggering. In (A), the instrument is programmed for a positive slope with a level of +2.5V. When the input signal reaches the 2.5V threshold going in a positive direction, the instrument is triggered to begin the measurement sequence.

In (B), a similar situation exists, except that the unit is now programmed for a negative slope with a level of +1.5V. In this case, the unit is triggered once the input signal drops to the 1.5V level.

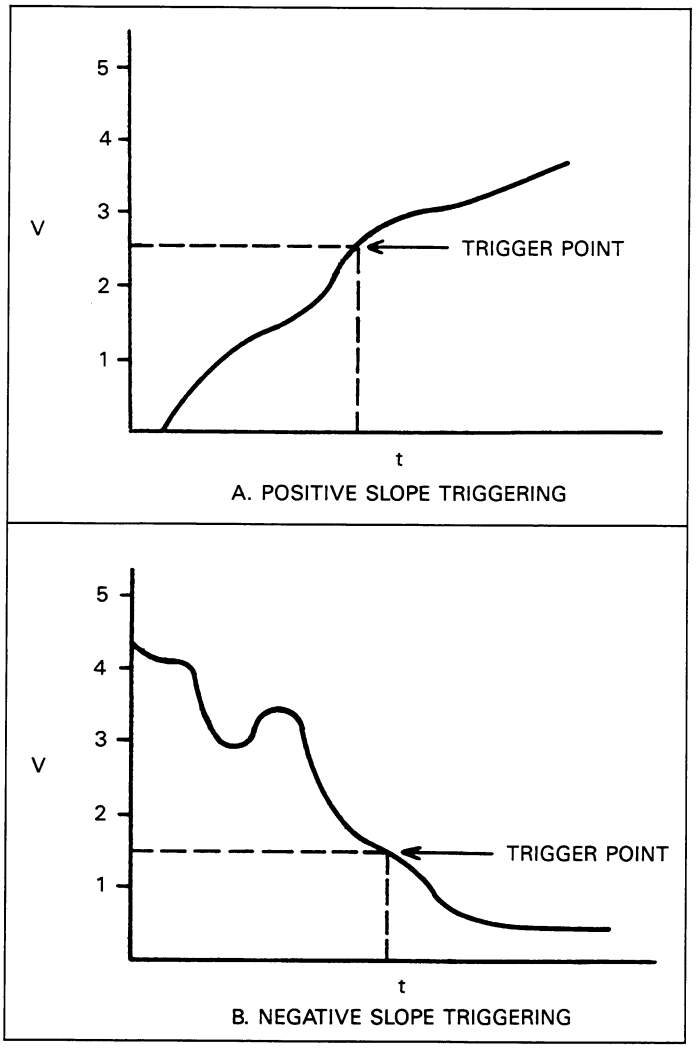


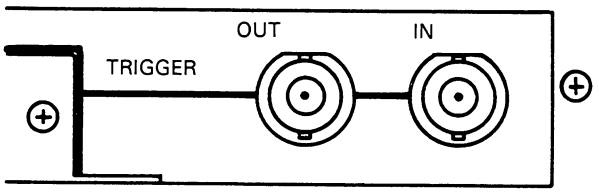
Figure 3-2. Level and Slope Triggering

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3.6.7 External Triggering

The TRIGGER IN jack can be used to apply a trigger pulse to the instrument to initiate a reading sequence. In a similar manner, the instrument will feed an output pulse out the TRIGGER OUT jack when it is triggered by some other stimulus.

TRIGGER JACKS



TRIGGER IN is a BNC connector that requires a negative going pulse to trigger the instrument. The specifications for the trigger pulse are shown in Figure 3-3. Before external triggering is active, the instrument trigger source must be programmed for that mode with the SOURCE key.

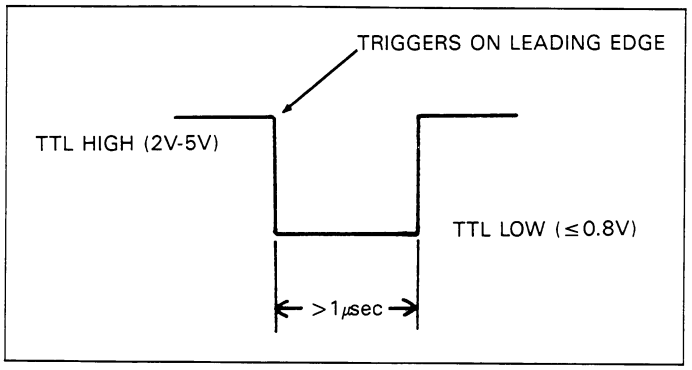


Figure 3-3. TRIGGER IN Pulse Specifications

CAUTION

The outer rings of both TRIGGER jacks are connected to chassis ground and cannot be floated.

NOTE

Shielded cable should be used for TRIGGER signal connections to minimize the possibility of EMI radiation.

Whenever the instrument is triggered, it will generate an output pulse via the TRIGGER OUT jack, with the specifications shown in Figure 3-4. The trigger pulse will be generated regardless of the selected trigger source, including input signal, external trigger input, other channel, or immediate modes (TRIGGER button or IEEE bus triggers).

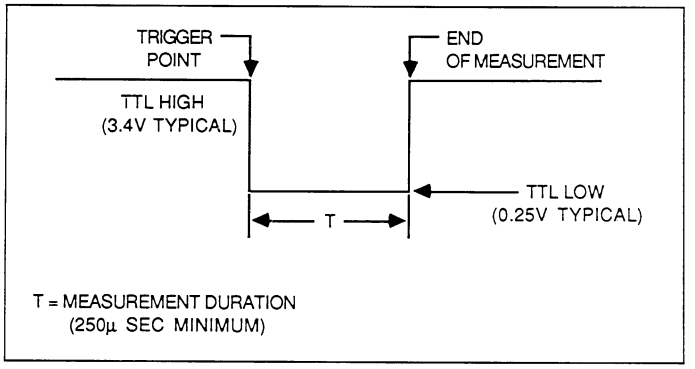
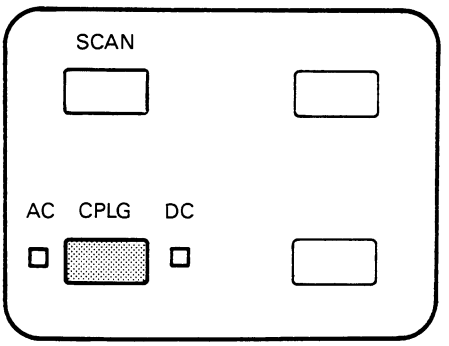


Figure 3-4. TRIGGER OUT Pulse Specifications

3.7 INPUT COUPLING

The CPLG key allows you to select AC, DC, or ground coupling modes that are analogous to those found on an oscilloscope. The LEDs associated with the CPLG key indicate AC and DC coupling modes, while ground coupling is indicated by both LEDs being off. You can toggle the instrument between these three modes by repeatedly pressing the CPLG key.

CPLG KEY



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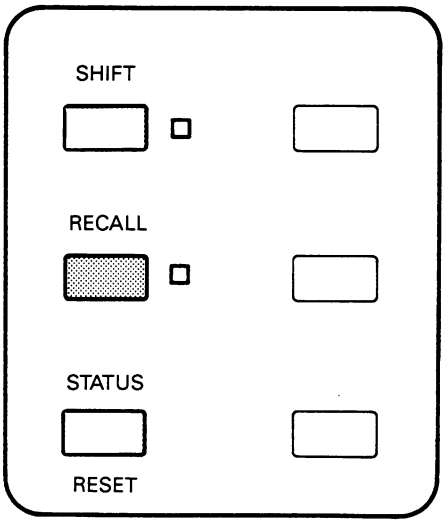
When DC coupling is selected, a straight-through DC signal path is established to the input section of the instrument. When AC coupling is in effect, the instrument low-frequency response rolls off (see specifications). Thus, DC coupling would be used when measuring DC signals or very low frequency AC signals, while AC coupling is useful for removing the DC component of the input signal.

When ground coupling is selected, the signal voltage is disconnected from the input amplifier, and the input amplifier terminals are shorted.

3.8 RECALLING DATA

The RECALL key allows you to recall any of the individual samples that are stored within the measurement buffer. Naturally, the number of buffer locations that contain valid data will depend on the programmed number of samples.

RECALL KEY



When the recall mode is enabled, the RECALL indicator will be on, and the display will show the data at the selected location, the buffer location and the channel, as in the example below.

25.000 0 1

In this example, a value of 25V is being read from the first (0) buffer location of channel 1.

While in the recall mode, you can random access data at any of the buffer locations by keying in the desired buffer location and then pressing the ENTER key. If an incorrect location is entered, an error message will be displayed.

For example, if you program a sample location higher than the programmed number, a NMBR TOO LARGE message will be displayed.

Alternately, you can increment or decrement buffer locations by using the Uprange or Downrange keys, respectively. If either of these buttons is held down for one second, the button will autorepeat.

Depending on whether the instrument is in the single or continuous mode, the samples in the various buffer locations may or may not be changing as you access them. In the single trigger mode, the samples will be updated only when the instrument is triggered. In the continuous trigger mode, however, buffer samples will be updated at a rate dependent on the selected sampling rate and interval.

When recalling data, the trigger point is indicated by the letter "T" in the display as in the example below:

25.000 478 T1

In this example, buffer location 478, which is the trigger point for the measurement sequence, is being displayed. For quicker access to the trigger point you can use the waveform mode, as discussed in paragraph 3.14.

To return the instrument to the normal display mode, simply press the RECALL button a second time. The unit will then return to the previous display mode.

Example: Random and sequential buffer access.

Use the example below to demonstrate buffer access. Before using this example, program the instrument for a 1ms sampling interval and 1000 samples with the RATE and SAMPLES keys. Set the instrument for the single trigger mode and apply a time-varying signal such as a 60Hz sine wave to the VOLTAGE INPUT jack on the rear panel. Select AC coupling with the CPLG key.

1. Press the RECALL button. The display will enter the recall mode and display the sample at the selected buffer location (0).

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2. Select a random buffer location by keying in a value with the data entry keys and then pressing ENTER. For example to view the 56th location, press: 5, 6, ENTER. The data at that location, along with the buffer location will then be displayed. For example, the display might show:

16.17 56 1

3. Use the Uprange and Downrange keys to sequentially increment and decrement buffer locations. Note that the buttons will autorepeat after being held down briefly.
4. Press the RECALL key to return to the normal operating mode.

3.9 DUAL CHANNEL OPERATION

When the optional Model 1944A A/D Converter Module is installed in the CARD 2 location, the Model 194A is equipped with two identical channels that operate virtually independently of one another. Aside from sharing the display and control buttons, each channel can be independently programmed for various operating modes. The following paragraphs describe dual-channel operation of the Model 194A.

3.9.1 Channel 2 Connections

As shown in Figure 3-5, the connections for the CARD 2 module are identical to those for CARD 1. The purpose of each connector is briefly described below. The paragraph where more detailed information may be found is also indicated.

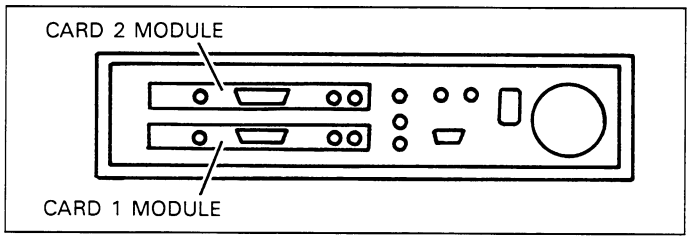


Figure 3-5. Rear Panel Showing Channel 2 Installed

VOLTAGE INPUT—All analog input signals are applied to this isolated BNC connector (paragraph 2.5).

CAUTION

The maximum input voltage is 250V peak, 2×10^7 V•Hz. The unit may be damaged if this value is exceeded.

WARNING

The maximum common-mode voltage is 30V. Exceeding this value may create a shock hazard.

REAL TIME OUTPUT—Provides binary data from the A/D converter at the sampling rate (paragraph 3.20).

TRIGGER OUT—Provides an output pulse to trigger other instrumentation when channel 2 is triggered for a measurement sequence (paragraph 3.6).

TRIGGER IN-—Allows channel 2 to be triggered from an external source. This mode is available only when properly programmed with the SOURCE key (paragraph 3.6).

CAUTION

Digital common is internally connected to chassis ground and cannot be floated.

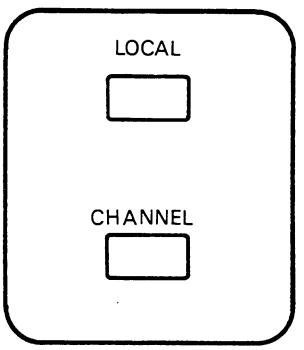
NOTE

Shielded cable should be used for all input and output connections to minimize the possibility of EMI radiation.

3.9.2 Channel Selection

The channel to be accessed is selected by using the CHANNEL button.

CHANNEL BUTTON



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Pressing CHANNEL does two things:

1. It toggles the display between channel 1, channel 2, and the dual-channel display mode. Table 3-4 shows typical displays for each of the three formats. For the two single-channel formats, the channel number appears in the right most digit. In the dual channel display mode, channel 1 is on the left, and channel 2 is on the right.
2. It allows you to access a particular channel for programming remaining parameters. To change channel operating modes, the display must be in the single channel mode of that particular channel. For example, to program the rate on channel 1, you must first use the CHANNEL button to display only that channel. Similarly, if you wish to change the range on channel 2, you must first display channel 2 by pressing CHANNEL and then use the appropriate range button to change the range.

Table 3-4. Display Format

Display	Mode
1.2345V DC 1	Channel 1 Display
−2.3156V DC 2	Channel 2 Display
0.2141 1.6789	Dual-Channel Display

3.9.3 Speed Considerations

Each channel has its own A/D converter, 64K bytes of memory, and clocking circuits. As a result, each channel can be independently programmed for the maximum (1MHz) sampling rate without affecting sampling rate of the other channel. However, the overall reading rate will be reduced if both channels are sampling simultaneously.

3.9.4 Cross Channel Triggering

Either channel can be triggered by the other channel to begin its measurement sequence. To do so, program each channel for the appropriate trigger mode, as required. Paragraph 3.6 covers triggering in detail.

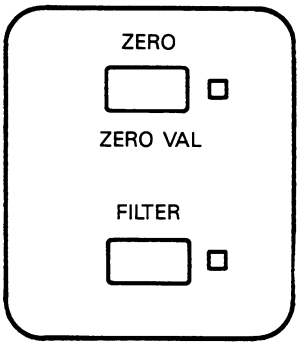
As an example, assume that channel 2 is to be triggered by channel 1, and that channel 1 is to be triggered by a positive-going input signal at a threshold of 4.6V.

1. Using the CHANNEL button, select the channel 2 display mode.
2. Press the SOURCE button and then uprange or downrange repeatedly until the following message is displayed: OTHER CHANNEL.
3. Press the CHANNEL button, as required, to select the channel 1 display mode.
4. Select input signal triggering with the SOURCE and uprange keys.
5. Using the SLOPE button, program channel 1 to trigger on the positive-going edge.
6. Press the LEVEL button and key in a trigger level of +4.6V. To do so, press: 4, . ,6 , V.
7. Arm both channels by pressing TRIGGER in the dual-channel display mode.
8. With this programming, channel 1 will be triggered when the input signal rises above 4.6V. Channel 2 will in turn be triggered by channel 1.

3.10 USING ZERO

The zero mode allows a stored offset value to be subtracted from subsequent readings. The stored offset can be obtained from an applied signal, or directly keyed in with the data entry keys. Once the baseline is stored, the zero mode can be enabled or disabled by pressing the ZERO button. When the zero mode is enabled, the ZERO indicator will be on.

ZERO KEYS



When the instrument is in the dual-channel display mode, the ZERO button and associated indicator are inoperative, although the instrument will remain in the selected zero mode if already so programmed when entering the dual-channel mode. The unit must be in a single-channel display mode to change or indicate the mode presently in effect.

The zeroed reading can be as small as the resolution of the instrument (10μV), or as large as full range. Some typical examples include:

Zeroed Reading	Applied Signal	Displayed Value
+10.500V	+18.600V	+8.100V
+2.566V	+1.8000V	-0.7560V
-12.600V	+4.5000V	+17.100V

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3.10.1 Zeroing From an Applied Signal

To store the zero offset value from an applied signal, perform the following procedure.

1. Select the desired channel.
2. Cancel the zero mode if presently enabled.
3. Select a range that is consistent with the anticipated measurement.
4. Connect the signal that is to be used as an offset value to the VOLTAGE INPUT jack of the selected channel.
5. Press the ZERO button to enable the zero mode. If there is no valid reading on the display, the zero mode cannot be enabled.
6. Disconnect the offset signal from the instrument and connect the signal to be measured in its place. Subsequent measurements will be the difference between the suppressed value and the applied signal.

WARNING

The voltage on the input terminals may be larger than the displayed value. For example, if a 175V zero offset is stored, an applied voltage of 200V will result in a displayed reading of only 25V.

7. To cancel the zero mode, simply press ZERO a second time. The stored value will be retained for use by the zero value mode discussed below.

3.10.2 Keying In the Zero Value

The zero feature may also be used by keying in the zero offset from the front panel. This mode is entered by pressing SHIFT ZERO VAL and then using the data entry keys to key in a new value. Once the value is entered, the zero mode will remain in effect until zero is disabled with the ZERO key. The ZERO indicator will be on when the zero mode is enabled.

The allowable range for the entered zero parameter is between -200 and +200V. Exceeding these values will result in the appropriate error message. Also, the instrument will display a NMBR TOO SMALL error if you attempt to program a zero value smaller than the resolution of the A/D converter (10μV).

As with the ZERO key, ZERO VAL is inoperative when the instrument is in the dual-channel display mode.

Program a zero value from the front panel as follows:

1. Press SHIFT ZERO VAL to enter the front panel zero mode. The instrument will prompt with the presently programmed value.
2. Using the data keys, key in the desired value. For example, program a zero value of 255mV as follows. Press : 2, 5, 5, mV.
3. The new zero value will be programmed, and the ZERO indicator will be on.
4. To cancel the programmed zero mode, simply press the ZERO key. The presently programmed zero value will be retained for use when ZERO VAL is pressed again.

3.10.3 Zero Mode Considerations

The display can show up to ±99999 counts in the zero mode, unlike a normal non zeroed reading, which is limited to −32,768, +32,767 counts. For example, if a zeroed value is −600mV, and the applied signal is +300.00mV, the display will show .90000V.

If the instrument is in the autorange mode, it will move up range if the ±99,999 count limit is exceeded. Once zero is enabled, setting the range lower than the zeroed value will create an overrange condition. The Model 194A will display the OFLO message in this case. Note that the instrument must be triggered to effect a range change.

When using zero with a mathematical function, the zeroed value is subtracted from the reading after the mathematical operation is performed.

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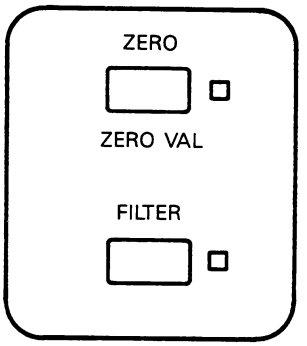
3.11 FILTERING

The Model 194A has two single-pole, low-pass analog filters with appropriate -3dB points of 50kHz and 500kHz. These filters are useful in situations requiring attentuation of high frequency noise or interference. The filters can be accessed by pressing the front panel FILTER button. Each time uprange or downrange is pressed, the display will indicate the selected filter mode, as summarized in Table 3-5. The filter mode is selected as soon as the appropriate message is displayed. If either the 50kHz or 500kHz filters are enabled, the FILTER indicator will be on. To return to the previous mode, press FILTER a second time.

Table 3-5. Filter Display Messages

Message	Description
FILTER OFF	Both filters disabled.
FILTER 500KHZ	Filter with −3dB point of 500kHz enabled.
FILTER 50KHZ	Filter with −3dB point of 50kHz enabled.

FILTER BUTTON



Typical curves for the two filters are shown in Figure 3-6.

Although filtering can be beneficial in the form of decreased noise, it does increase the response time to changes in input signal. Table 3-6 summarizes response times to within 10%, 1%, 0.1%, and 0.01% of final value for each of the two available filters.

Table 3-6. Filter Response Times

	Filter Response	
Response to Within:	50kHz	500kHz
10 %	7.33μsec	0.73μsec
1 %	14.66μsec	1.47μsec
0.1 %	21.99μsec	2.2 μsec
0.01%	29.32μsec	2.93μsec

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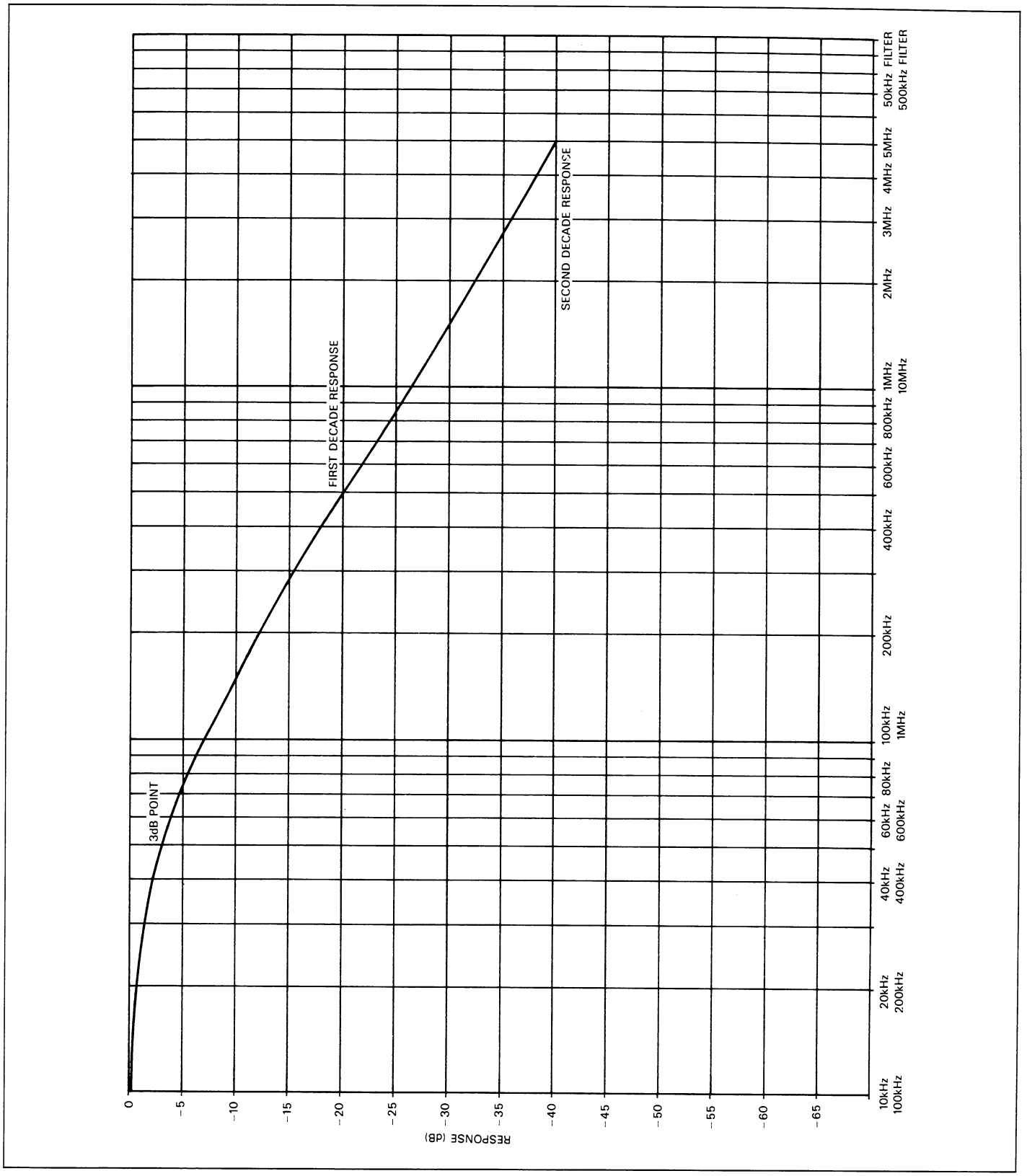


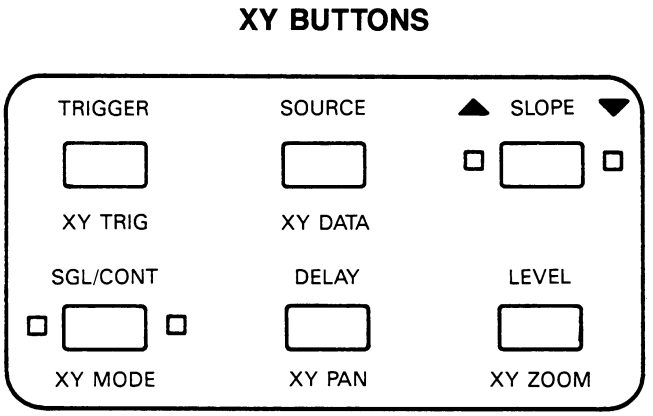
Figure 3-6. Typical Filter Response Curves

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3.12 USING THE ANALOG OUTPUT

The analog output of the instrument can be used to drive display devices such as oscilloscopes, CRTs, plotters and strip chart recorders. The Y output provides the amplitude information, while the X output provides horizontal position information for the graphing devices requiring such information. The Z output provides a blanking or pen lift signal, depending on the type of graphing device.

The following paragraphs describe the various operating modes of the analog output, including programming and output connections.



3.12.1 Analog Output Connections

The analog output has three jacks, which are shown in Figure 3-7. The X output provides position or time information in the CRT or plotter modes, the Y output provides amplitude information in all three modes, and the Z output provides a blanking signal in the CRT mode, a pen up signal in the plotter mode, and a trigger signal in the oscilloscope mode.

The Y output is unipolar, with the amplitude varying between 0 and the programmed full scale value (default, 10V). The minimum Y output (0V) corresponds to a minus full range input, while the maximum Y output is equal to a plus full range input. For example, on the 320mV range, a −327.68mV input voltage will yield a Y output value of approximately 0V, while a +327.68mV input will give the full scale value.

The X output is also unipolar with 0V corresponding to the position of the first sample, and the programmed full scale value corresponding to the position of the last sample.

The Z output is factory programmed so that low is 0V and high is 5V. The high level can be changed to +15V as discussed in paragraph 7.10.

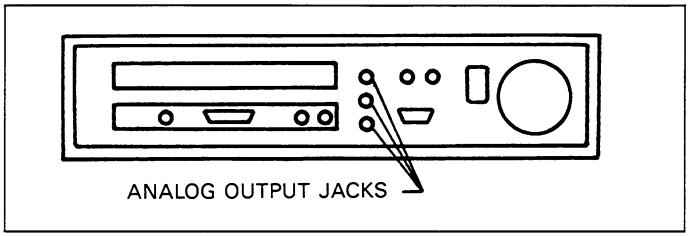


Figure 3-7. Rear Panel Showing ANALOG OUTPUT Jacks

Typical connections for using the analog output in the plotter mode are shown in Figure 3-8. In this instance, the instrument is driving a plotter. Note that the X output is connected to the X input of the plotter, the Y output is connected to the Y plotter input, while the Z output is connected to the pen up input of the plotter. Typical connections for using the analog output in the oscilloscope and CRT modes are shown in Figures 3-9 and 3-10.

CAUTION

Analog output common (outer ring) is connected to chassis ground and cannot be floated.

NOTE

Shielded cable should be used for analog output connections to minimize the possibility of EMI radiation.

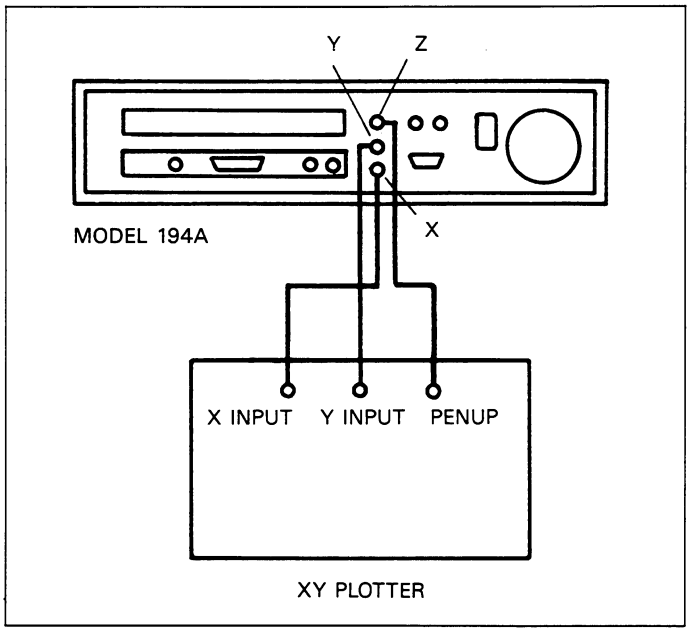


Figure 3-8. Typical Plotter Connections

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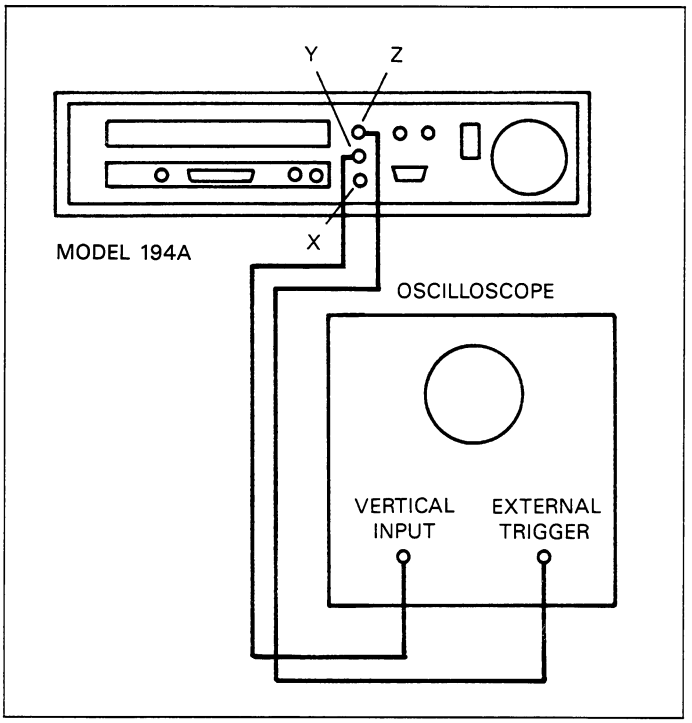


Figure 3-9. Typical Oscilloscope Connections

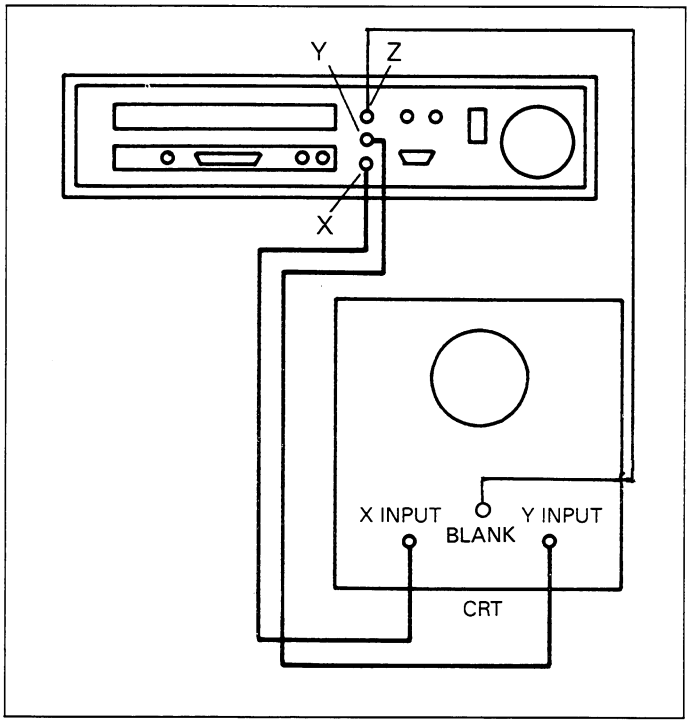


Figure 3-10. Typical CRT connections

3.12.2 Entering the XY Mode (XY MODE)

The XY MODE key is used to place the instrument in the XY mode (SHIFT must be pressed before pressing XY MODE). Repeated pressing of uprange or downrange causes the instrument to scroll through the various modes, as indicated by the display messages summarized in Table 3-7. When the associated message is displayed, the instrument immediately goes into that mode. Pressing XY MODE a second time will return the unit to the previous mode.

Table 3-7. XY Mode Display Messages

XY Function Key	Message	Description
XY MODE	XY OFF	XY Mode Disable
	XY CRT	CRT Mode Selected
	XY SCOPE	Oscilloscope Mode Selected
	XY SLOW PLOT	Plotter Mode Selected
	XY STRIP CHT	Strip Chart Mode Selected
XY DATA	MEASMNT BUFFER	Channel Measurement Buffer
	MEASMNT RAM	64K Measurement Buffer
	READINGS	Readings from Selected Channel
	IEEE-488 BUF	IEEE Output Buffer
XY ZOOM	XYZOOM = 1.0*	Scaling Factor
ZY PAN	XYPAN = 1*	Window Location

*Depends on programmed value.

Types of graphing devices include:

CRT: In the CRT mode, the X output drives the horizontal axis of the CRT while the Y output is used to drive the vertical axis. The Z output is used to provide a blanking

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signal during the CRT retrace period. In the CRT mode, only 100 points will be graphed. However, all samples in the measurement will be scaled. The output rate is 1msec per point.

Oscilloscope: The Y axis is used to drive the vertical input while the Z output is used to trigger the oscilloscope. Only 100 points are displayed in the oscilloscope mode; a measurement will be scaled in accordance with the scaling factor. Again, the output rate is 1msec per point.

Plotter: The Y and X output are used to drive the Y and X inputs of the plotter, while the Z output acts as a pen lift signal. A maximum of 4096 points are graphed in the plotter mode. If more than 4096 samples are in the measurement, the instrument will automatically scale it.

Strip Chart: Only the Y output is used in this mode. Each time a reading is completed, the value will appear at the Y output and remain at that level until a new reading is ready. The number of points that can be graphed is equal to the number of samples in the measurement. Thus, this mode will give you the best resolution.

NOTES:

1. The analog output should be left disabled (XY OFF) when not in use, in order to allow other functions ample microprocessor time to operate normally.
2. The Model 194A should be placed in the single trigger mode when using the analog output in order to speed up XY processing.
3. In the CRT and oscilloscope modes, analog output aliasing can occur if the measurement contains substantially more than 100 samples (the number of points plotted in these two modes). To avoid such aliasing, program the unit for no more than 100 samples per measurement.

3.12.3 Analog Output Data Source (XY DATA)

By using the XY DATA key, you can select the data source for the analog output. To select the source, you need only press XY DATA (remember to press SHIFT first) once and then press uprange or downrange until the appropriate message is displayed (Table 3-7). The displayed data source is placed into effect immediate. Press XY DATA again to return to the previous mode.

Available data sources include:

1. Measurement buffer for the currently selected channel.
2. Readings from the presently selected channel.
3. Entire 64K sampling buffer regardless of measurement size.
4. IEEE Reading Output Buffer.

Each of these sources is further described below.

Measurement Buffer: When this data source is selected, the measurement for the selected channel will be placed in the analog output buffer. If the programmed number of samples is larger than 100 (the size of the analog output buffer), and the unit is in the CRT or scope mode, the measurement will be automatically scaled so that a plot or screen display reflects all the samples in the measurement. If no measurement is available, no data will be transmitted.

Channel Readings: Selection of this mode empties the analog output buffer and allows new readings from the selected channel to be stored in the buffer as they become available. As readings become available, they will be transmitted via the analog output to your graphing device. In this manner, you could apply a variety of different math functions to a single measurement and then graph the results on a single plot.

64K Measurement RAM: This mode graphs the entire 64K RAM memory regardless of the programmed number of samples. Thus, all samples plotted by this mode may not be from the current meaurement. For example, eight 8K sample measurements could be displayed on a single plot. This data could be from previous single-channel measurements.

IEEE Reading Output Buffer: The 100 reading IEEE-488 output buffer that is controlled with the Q command is the source for the analog output in this mode. Each reading will reflect the entire associated measurement except for the waveform mode which only displays the trigger point.

NOTE

For dual A/D channel units, the selected A/D channel is the source for the analog output.

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3.12.4 Triggering the Analog Output (XY TRIG)

By using XY TRIG, you can start and stop the analog output. In this manner, you can stop the analog output, load the plotter with paper, and then initiate the plotting sequence. In addition, you can halt the plotting process at any time simply by pressing XY TRIG. When halting the plot in this manner, the pen will lift and return to the home position. XY TRIG is also used in other XY modes to update the analog output.

As with the remaining XY mode keys, you must press SHIFT first to initiate the mode.

3.12.5 Scaling the Analog Output (XY ZOOM)

In most cases, a measurement buffer will be larger than the analog output viewed data. In those cases, it may be necessary to apply a scaling factor in order to get a better resolution of the sampled measurement.

You can program a scaling factor to effectively increase the magnification of the plot with the XY ZOOM key If the scaling factor is 1, the complete measurement buffer will be reflected in the analog output. If the scaling factor is 2, only half the measurement will appear, and so on.

The minimum value for the scaling factor is 0.1, and the maximum value is 1000. The resolution of the scaling factor is 0.1, thus it is possible to program a scaling factor of 1.4. For example, the total number of samples reflected in the output would be $^{N}/_{1.4}$. With 900 samples, the number of samples reflected in the output would be 900/1.4 ≅ 642.

Program a scaling factor by using the following procedure:

1. Press SHIFT XY ZOOM. The instrument will then display the presently programmed scaling factor. For example, the display might show:

   XYZOOM = 1.0

2. You can change the scaling factor in one of two ways. Either press the desired numeric key and then ENTER, or use the Uprange or Downrange keys to increment or decrement the displayed value. In this case, it is not necessary to press ENTER, as the value is entered automatically. During the entry process, you can press the CANCEL key to return to the previous value.
3. If you enter an invalid parameter, the instrument will display an error message.

Discussion

Figure 3-11 demonstrates how using XY ZOOM can help zoom in on a portion of a plotted waveform. In (A), a scaling factor 4 is applied, with the result that only 100 of the 400 samples are reflected in the analog output sequence. In (B), a scaling factor of 1 is applied, so the entire measurement buffer is plotted. In this instance, only every fourth sample is reflected in the final signal. Thus, an appropriate scaling factor can be used to effectively increase resolution in cases where only a portion of a measurement requires graphing.

If the XY ZOOM parameter is less than 1, you will be effectively zooming out from your graph. In this case, other portions of the 64k RAM buffer not associated with the measurement will become visible in the plot.

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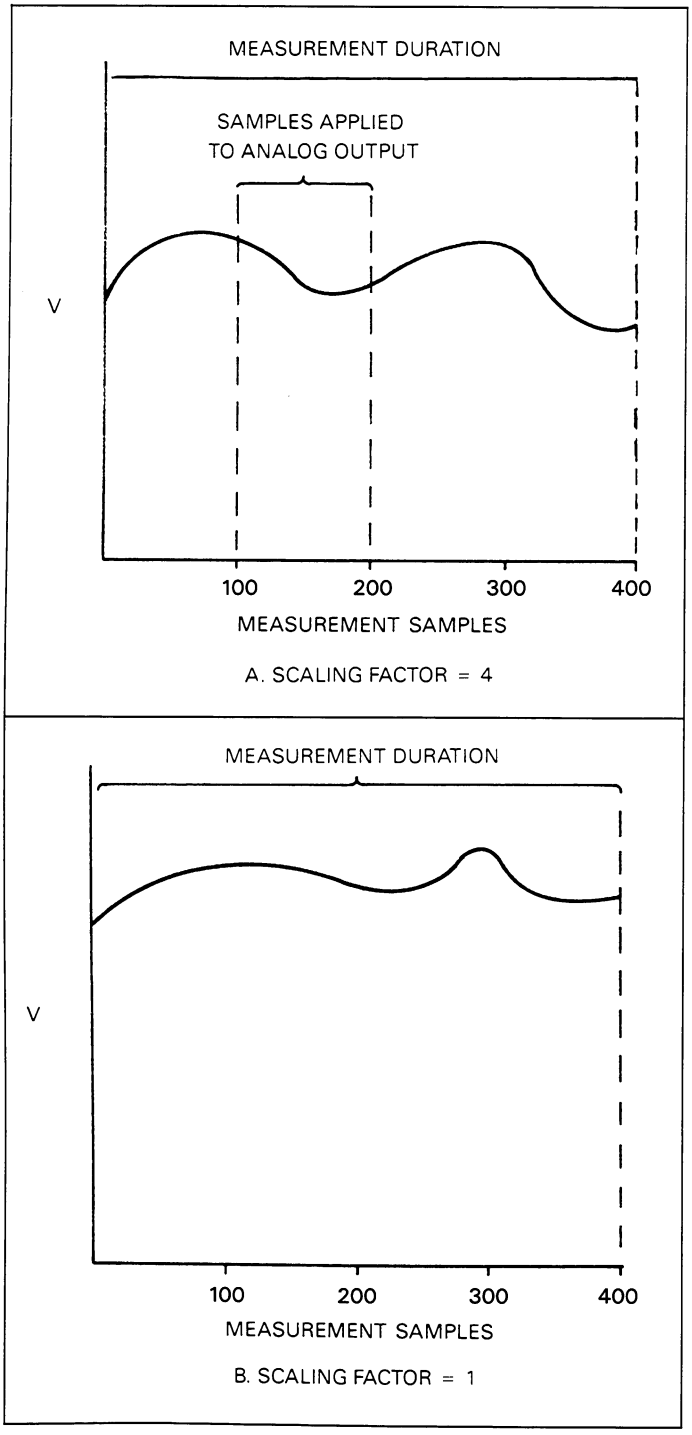


Figure 3-11. How Scaling Factor Affects Viewed Data

3.12.6 Controlling the Analog Output Viewed Data (XY PAN)

By using the XY PAN key, you can select the first measurement buffer sample to be placed in the analog output buffer, thus effectively moving the viewed data left or right. For example, if the measurement buffer contains 400 readings, 300 readings will not be seen, assuming the scaling factor set with XY ZOOM is 4. By using XY PAN, you can control which of those 100 samples you wish to see. This key is active only if the XY data source is a measurement buffer, and is inactive otherwise.

The smallest permissible value is −65,535, and the maximum value is: 65,535 (64k).

Program the analog output window as follows:

1. Press SHIFT XY PAN. The instrument will prompt with the presently programmed value of the first buffer location to appear at the analog output. For example, the display might show: XYPAN = 100. Under these conditions, samples 100-199 will be transmitted out the analog output, assuming a scaling factor of 1.
2. To change the value, key in the new digits with the numeric keys and press ENTER, or increment or decrement the displayed value with the Uprange or Downrange keys. If you use Uprange or Downrange, it is not necessary to press ENTER to enter the new value.
3. If an invalid value is entered, the instrument will display an error message.

Discussion

We can demonstrate how the XY PAN key can be used to move the analog output viewed data with the help of Figure 3-12. In all cases, the scaling factor is 4, and 400 samples are stored in the buffer. These samples are numbered 0-399.

In Figure 3-12(A), the XY PAN parameter is zero, with the result that samples 0-99 are included in the viewed data, while samples 100-399 are excluded from the viewed data and 100-399 do not appear at the analog output. In (B), the window begins at sample 100 and extends through sample 199. Figures 3-12(C) and 3-12(D) demonstrates viewed data placement for XY PAN parameters of 200 and 300, respectively.

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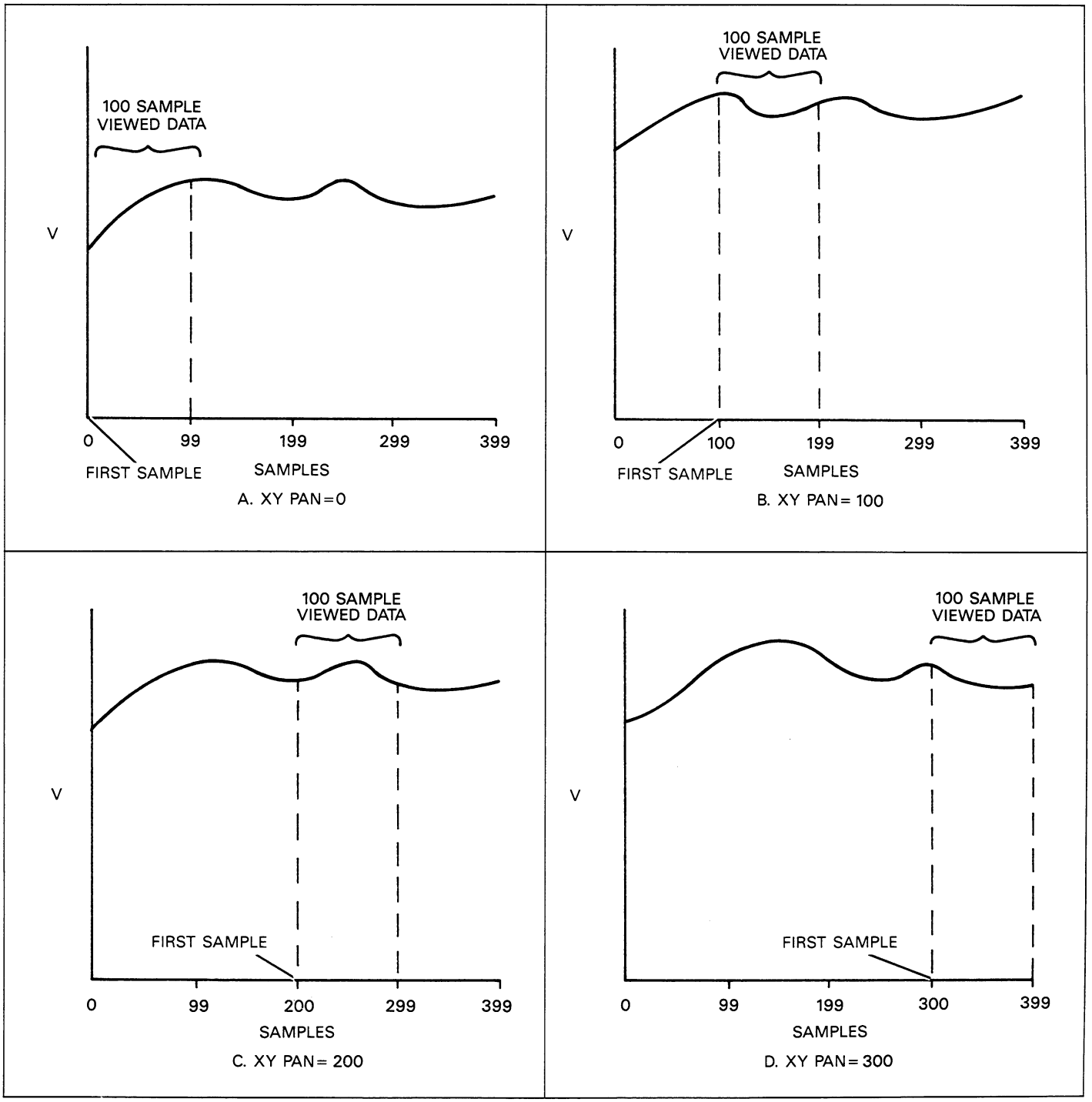


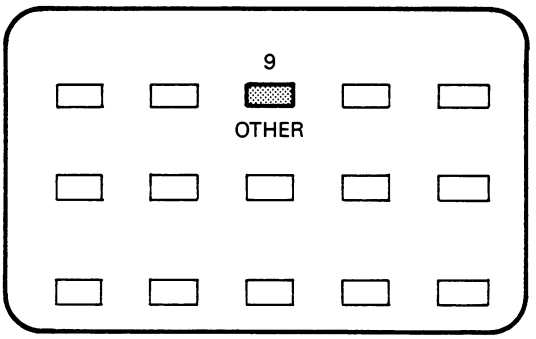
Figure 3-12. Moving Analog Output Viewed Data with XY PAN

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3.12.7 Setting Maximum Analog Output Levels

The maximum output levels of the X and Y outputs can be programmed to values between 1 and 10V, and the Z output blanking level can be set to high or low by using the OTHER key, as described in the following paragraphs. The full scale values can be changed at any time without affecting other operating modes. Table 3-8 summarizes keystroke sequences and display messages for each of these programming modes.

OTHER BUTTON



X Output Level Programming—The full scale X output can be programmed to values between 1 and 10V with 1μV resolution. To program the X output level, perform the following sequence.

1. Press: SHIFT, OTHER, 4, or SHIFT, OTHER, Δ, Δ, Δ, Δ, ENTER. The instrument will prompt with the presently programmed full scale value. For example, the display might show:

   X FS = 10.000000 V.

2. To change the value, use the numeric keys and press ENTER. For example, to program 1.25V, press: 1, ., 2, 5, ENTER. During the entry process, you can return to the previous value by pressing CANCEL.
3. If you attempt to program an incorrect level, an error message will be displayed.

Y Output Level Programming—Like the X output, the Y output full scale value can be set to values between 1 and 10V in 1μV increments. Program the Y output full scale value as follows:

1. Press: SHIFT, OTHER, 5, or SHIFT, OTHER, Δ, Δ, Δ, Δ, Δ, ENTER. The instrument will prompt with presently programmed Y output full scale value. For example, the display might show:

   Y FS = 10.000000V

2. Key in a new value if desired, and press ENTER. For example, to program a 5.1V value, press: 5, ., 1. , ENTER.
3. If you attempt to program an incorrect level, an error message will be displayed.

Table 3-8. XY Mode Level Programming

Mode	Range	Keystroke Entry	Display Message
X Output Full Scale Value	1V-10V	SHIFT, OTHER, 4	X FS = 10.000000V
Y Output Full Scale Value	1V-10V	SHIFT, OTHER, 5	Y FS = 10.000000V
Z Output Blanking Level	Low or High	SHIFT, OTHER, 6	Z BLANK = LOW

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Z Output Blanking Level—The Z output blanking level can be set to one of two levels: 0V (LOW) or 5V (HIGH) nominal (also, a provision is made on the I/O board for 15V nominal). The purpose of the blanking pulse will depend on whether the instrument is in the CRT, plotter, or oscilloscope modes.

If the instrument is programmed for the CRT mode, the blanking level is intended to blank the beam during the beam retrace period. If the instrument is being used in the plotter mode, the Z output blanking level can be used to tell the plotter to lift the pen and return to the home position. In the oscilloscope mode, the Z output blanking pulse can be used to trigger the oscilloscope to begin the horizontal sweep cycle.

Program the Z output blanking level as follows:

1. Press SHIFT, OTHER, 6. The unit will display the presently programmed blanking level (HIGH or LOW) as in this example:

   Z BLANK = LOW

2. Use the Uprange or Downrange key to toggle the display between LOW and HIGH levels.
3. The blanking level is placed into effect immediately.
4. Press CHANNEL to return to previous mode.

Discussion

Figure 3-13 demonstrates the operation of the blanking pulse. In (A) a HIGH level is assumed, while (B) shows a blanking pulse with a LOW level. Note that one pulse is essentially the inverted form of the other.

During the transmission of data through the XY outputs, the Z output is at the non-blanking level (0V when programmed for HIGH blanking, 5V when programmed for LOW blanking). After each transmission sequence, the Z output assumes the programmed blanking level. Note that the transmission sequence is recurrent in the CRT and oscilloscope modes, but it occurs only once with each XY trigger in the plotter mode.

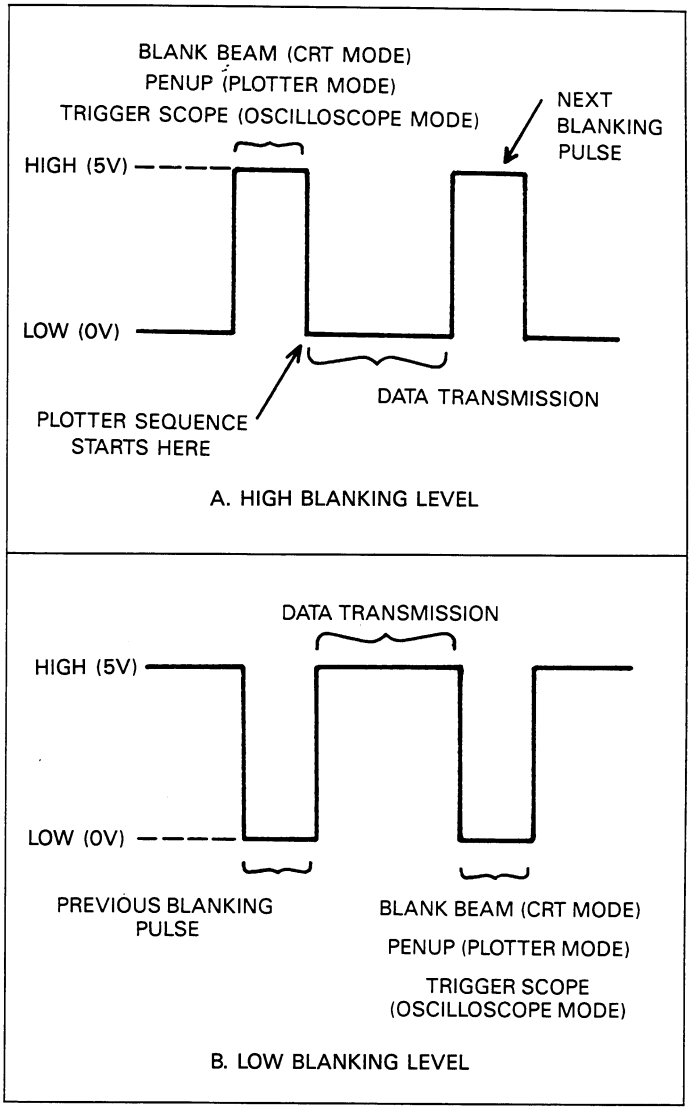


Figure 3-13. Output Blanking Levels

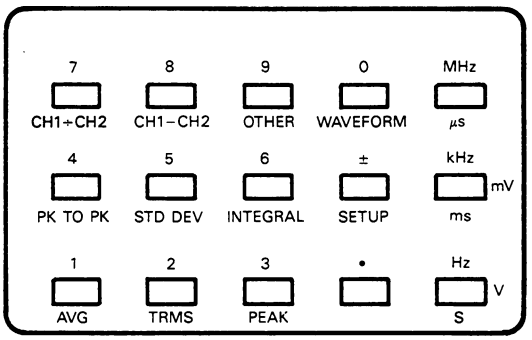
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3.13 MATHEMATICAL FUNCTIONS

The Model 194A has a number of built in mathematical functions that can be used to analyze a measurement. These functions include:

AVG (Average)
TRMS (True Root Mean Square)
PEAK (Positive and Negative Peak Values)
PK TO PK (Peak to Peak)
STD DEV (Standard Deviation)
INTEGRAL
WAVEFORM (Display sample at trigger point)

MATH BUTTONS



The keys associated with the mathematical functions are operational only when the instrument is in the single-channel display mode. However, either channel may be programmed for a particular function before placing the instrument in the dual-channel mode. To do so, use the CHANNEL button to display the desired channel and select the desired function. Once the function is selected, place the unit in the dual-channel display mode with the CHANNEL button.

These mathematical functions operate on the samples currently stored in the measurement buffer. Samples are numbered 0 through n-1, where n is the programmed number of samples in the measurement. If the instrument is in the single-trigger mode, selecting a function will cause that function to operate on the most recent measurement sequence. Thus, by taking a single measurement sequence, you can apply a variety of differerent math functions to a single measurement. Note, however, that only one function can be in operation at any given time; selecting a new mathematical function will cancel the previously selected function. It is not possible, for example, to take the integral of the standard deviation.

Once a function is selected, you can perform that particular function a number of times for different measurements simply by triggering the instrument. Each time the unit is triggered, the measurement buffer will be updated, the selected mathematical operation will be performed on the new measurement, and the result will be shown on the display.

If the zero mode is in effect for a particular channel, the zero baseline value will be subtracted from the reading after the function is performed. In every mode, the result will be overrange if one or more samples is overrange.

Display messages associated with the various math functions are summarized in Table 3-9. The indicated values are, of course, typical, and will depend on the measurement on which the particular function is being performed. If a valid measurement is not present in the buffer, the reading portion of the display will contain dashes.

NOTE

The display update rate may vary depending on the selected math function.

Table 3-9. Math Function Display Messages

Function	Display Message*	Description
AVG	−1.2345V AVG 1	Average of Readings
TRMS	1.2345V RMS 2	True RMS of Readings
PEAK	1.2345V PK+2	Display positive peak value.
PEAK	1.2345V PK−1	Display negative peak value.
PK TO PK	1.2345V P-P 1	Peak-to-Peak Value.
STD DEV	0.1012V STD 1	Standard Deviation
INT	4.0315E000 VS 2	Integral of Measurement
WAVEFORM	2.5931V DC T2	Display sample at trigger point.

*Displayed value depends on applied signal.

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3.13.1 Average

The average of the samples in the measurement buffer can be displayed by pressing SHIFT AVG (or simply AVG if not in the data entry mode). The instrument will then display the average of the samples in volts stored in the measurement buffer in accordance with the following formula:

$$V_{AVG} = \frac{\sum_{i=0}^{n-1} V_i}{n}$$

Where: V_i = voltage amplitude of individual sample
i = individual sample number (0 through n-1)
n = number of samples in the measurement

Thus, the average is determined simply by adding up all the samples and then dividing by the number of samples in the measurement.

Typically, the display might show:

1.2235 V AVG 1

In this case, the average of samples in channel 1 is being displayed.

The average function can be applied to measurements of any size, although taking the average of a single-sample measurement sequence makes no sense because the average is the same as the sample.

Example:

As an example, assume that the data listed in Table 3-10 has been taken during a measurement sequence. The average value is simply the sum of the samples divided by the number of samples (11). Thus, the average of this measurement would be:

$$V_{AVG} = 130.65/11$$
$$V_{AVG} = 11.877V$$

3.13.2 True RMS

The true RMS value of a voltage waveform is that value which would produce the same heating effect as an equal DC voltage. For a sine wave, the TRMS value equals 0.707 times the peak value.

To determine the true RMS value of the measurement, press SHIFT TRMS (or simply TRMS if not in the data entry mode). The instrument will respond by displaying the TRMS value in volts of the samples in the measurement buffer. Although TRMS can be applied to measurements of any number of samples, it is usable only for measurements of two or more samples.

A typical display in the TRMS mode is as follows:

2.9875 V RMS 2

In this instance, the TRMS value of the channel 2 measurement buffer is being displayed.

TRMS values are calculated as follows:

$$V_{TRMS} = \sqrt{\frac{\sum_{i=0}^{n-1} V_i^2}{n}}$$

Where: V_i = voltage amplitude of individual sample
i = individual sample number (0 through n-1)
n = number of samples in measurement

Example:

As an example, let us determine the TRMS value of the measurement with samples listed in Table 3-10. We can first determine the sum of the squares of all 11 samples as follows:

$$\sum_{i=0}^{i=n-1} = 1576.5825$$

The TRMS value can then be easily calculated by using the above value as follows:

$$V_{TRMS} = \sqrt{\frac{1576.5825}{11}}$$

$$V_{TRMS} = 11.97V$$

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Table 3-10. Data For Mathematical Function Examples

Sample Number	Amplitude
0	10.6 V
1	12.7 V
2	13.8 V
3	14.25V
4	13.9 V
5	12.4 V
6	11.1 V
7	10.5 V
8	10.8 V
9	10.6 V
10	10.0 V

3.13.3 Peak

The peak mode allows you to display positive and negative peak values in volts for the selected channel. Again, this function is only usable for readings with two or more samples.

Positive and negative peak values are defined as follows:

Positive Peak: the most positive sample stored in the measurement buffer.
Negative Peak: the most negative sample stored in the measurement buffer.

You can display positive and negative peak values as follows:

1. Press SHIFT PEAK (or PEAK if not in the data entry mode). The instrument will then display the positive peak value, as in this example:

   1.2345 V PK+1

2. You can toggle the unit between the + PEAK and -PEAK values by using the PEAK button. For example, the negative peak value might be as follows:

   -2.4451 V PK-1

3. To cancel the peak mode, select another mathematical function.

Example:

From our example measurement in Table 3-10, we can easily determine the positive and negative peak values. The most positive sample is number 3, which has an amplitude of 14.25V. The most negative (least positive) sample is number 10, with a signal level of 10V.

3.13.4 Peak-to-Peak

The peak-to-peak value of the selected channel can be displayed by pressing SHIFT PK TO PK (or PK TO PK if not in data entry mode). A typical display for this mode might be:

12.503 V P-P 2

In this case, the peak-to-peak value of the channel 2 measurement is being displayed.

Peak-to-peak values are calculated as follows:

$$V_{p\text{-}p} = |V_{+P} - V_{-P}|$$

Where: $V_{p\text{-}p}$ = peak-to-peak value in volts
V_{+P} = most positive sample in the measurement
V_{-P} = most negative sample in the measurement

This function is valid for measurements of any size, but when selected for a single-sample measurement, a reading of zero will be displayed.

Example:

As an example, assume the instrument is displaying the peak-to-peak value of the measurement shown in Table 3-10. The most positive sample is number 3, which has an amplitude of 14.25V. The most negative sample has an amplitude of 10.0V (number 10). Thus, the instrument would calculate and display the peak-to-peak value as follows:

$$V_{p\text{-}p} = 14.25 - 10.0$$
$$V_{p\text{-}p} = 4.25V$$

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3.13.5 Standard Deviation

Very often when dealing with a group of samples, it is necessary to know how much the data varies from the average of the measurement (group of samples). A common term used to describe this "spread" of data is the standard deviation. The Model 194A includes a standard deviation function to help you analyze data in this manner.

To obtain the standard deviation of the measurement, simply press SHIFT STD DEV (or simply STD DEV if not in the data entry mode). The instrument will then display the standard deviation of the measurement, as in the example below:

1.0001 V STD 1

This display would indicate that the standard deviation of samples in channel 1 is being displayed.

The Model 194A calculates the standard deviation as follows:

$$V_{STD} = \sqrt{\frac{\sum_{i=0}^{n-1} (V_i - V_{AVG})^2}{n}}$$

Where: V_{STD} = standard deviation of the measurement in volts

i = the number of an individual sample (0 through n-1)

n = the number of samples in the measurement

V_{AVG} = the average of the samples in the measurement

Example:

For example, assume we can calculated the standard deviation of our sample data from Table 3-10 as follows:

$$V_{STD} = \sqrt{\frac{24.8165}{11}}$$

$$V_{STD} = 1.502V$$

3.13.6 Integral

Pressing SHIFT INTEGRAL (or simply INTEGRAL if not in data entry mode) will display the integral of the measurement in volt-seconds. A typical display in the integral mode might be:

4.0315E001 VS 2

In this case the integral of the channel 2 measurement is displayed. Note that the VS indication in the display depicts that volt-second units are being shown. Note that the exponent of the integral is included in the display (E001 in this example).

The integral function may be applied to measurements of any sample size; however, usable readings are returned only for readings of two or more samples.

The Model 194A calculates the integral by summing areas associated with individual samples under a curve. Thus, the value returned by the integral function is an approximation of the area under the entire curve. The boundaries of this curve are defined by the measurement duration, as well as the amplitude of the signal being measured, as shown in Figure 3-14. Thus, the integral is calculated:

$$\int Vdt = [\ \tfrac{1}{2} V_0 + \tfrac{1}{2} V_{n-1} + \sum_{i=1}^{n-2} V_i]\ t_s$$

Where: $\int Vdt$ = the integral of the signal with respect to time

n = total number of samples in the measurement

Because each calculated curve area is only an approximation, the resulting integration process is only approximate. For maximum accuracy, choose the largest number of samples per measurement possible.

Example:

For example, using the formula above with the example data from Table 3-10, we have:

$$\int Vdt = [\ \tfrac{1}{2} V_0 + \tfrac{1}{2} V_{n-1} + \sum_{i=1}^{n-2} V_i\ ]\ t_s$$

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$$\int Vdt = [\ 5.3V + 5V + 110.05V\ ]\ 0.001$$

$$\int Vdt = 0.12035\ VOLT - SECONDS$$

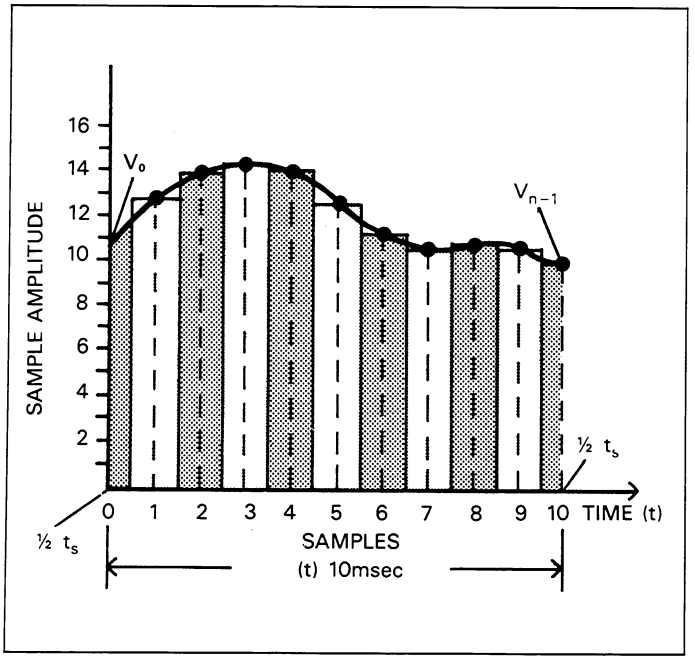


Figure 3-14. Integration by Approximate Area Summation

3.13.7 Waveform Mode

The waveform mode can be used to display the buffer sample that occurs at the trigger point. If it is not possible to display the trigger point location, the instrument will display the location as close as possible to the trigger point. The RECALL button can be used to view samples stored at other buffer locations.

A typical display in the waveform mode might be:

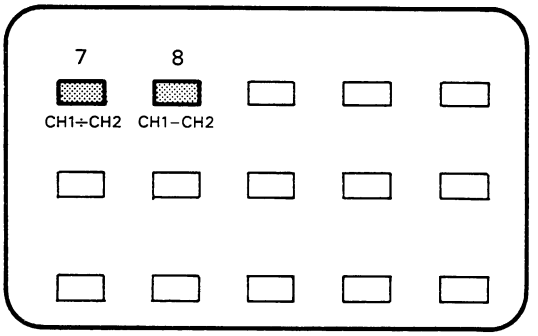
1.5467V DC T1

In this instance, the reading is 1.5467 and T indicates that the trigger point is being displayed.

3.14 RATIO AND DIFFERENCE

When the optional Model 1944A is installed, the Model 194A can be programmed to display the ratio or difference between channels 1 and 2, as discussed in the following paragraphs.

RATIO & DIFFERENCE BUTTONS



Display messages associated with these modes are summarized in Table 3-11. Note that the instrument displays the following message if one of these mode buttons is pressed with no channel 2 module present:

NO A/D IN CH2.

Most other front panel buttons are inoperative when in the ratio or difference modes.

Table 3-11. Ratio and Difference Display Messages

Message*	Description
1.2345EO1 XX 1-2	Display difference between channels 1 and 2 (see below for XX units).
1.2345E-3 XX 1/2	Display ratio of channel 1 to channel 2 (see below for XX units).
NO A/D IN CH2	1944A option not installed.
XX=	**Description**
blanks	Dimensionless
VS	Volt-seconds
V	Volts
S	Seconds
1/s	Reciprocal seconds
??	Invalid units

*Displayed values depend on calculated result.

3.14.1 Difference Mode

By pressing the CH1−CH2 key, you can display the difference between the channel 1 reading and the channel 2 reading. A typical display in this mode might be:

1.2567E-3 V 1-2

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This display indicates that the channel 2 reading is being subtracted from the channel 1 reading. Note that the displayed value has 4½ digit resolution and includes an exponent and appropriate units.

If one or both channels are programmed for mathematical functions, those functions are performed prior to the algebraic subtraction process. For example if channel 1 is programmed for the average function, and channel 2 is programmed for the TRMS function, the display will show the difference between the channel 1 average and the channel 2 RMS value.

Any combination of math functions for the two channels is valid, with the restriction that units must match. For example, you cannot subtract volts from volts seconds.

If either channel is in the waveform mode, the sample that is normally displayed will be applied to the CH1–CH2 mode. If either channel is in the overflow condition, the result of the subtraction will be overflowed.

3.14.2 Ratio Mode

The Model 194A can be programmed to display the ratio of channel 1 to channel 2 by pressing the CH1÷CH2 button. The instrument will then display the ratio of the two channels. A typical display might be:

2.3451EOI V 1/2.

Again, the displayed value has 4½ digit resolution and includes an exponent along with appropriate units.

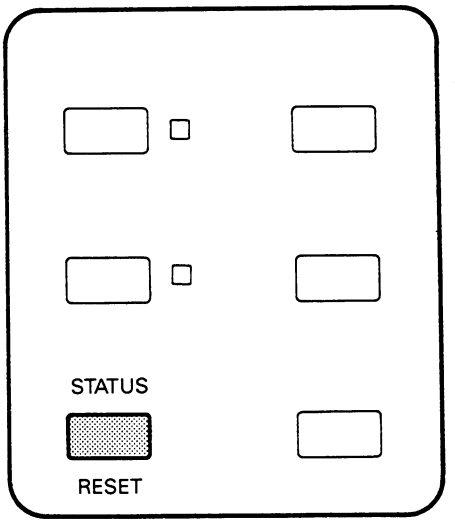
Any previously selected mathematical operations will be performed before the division process is completed. When in the waveform mode, the instrument will use the normally displayed waveform reading as input for the ratio calculation. Any combination of math functions for the two channels is valid.

If the channel 2 reading is zero, the OFLO message will be displayed.

3.15 STATUS

By pressing the STATUS key, you can obtain and display the status of the channel 1 A/D converter, as well as the A/D converter in channel 2. To check status of a particular channel, you must be in the single channel display mode for that channel.

STATUS BUTTON



When STATUS is pressed, the instrument displays the status of various operating parameters in the following order:

Zero value
Filter mode
Trigger source
Trigger mode
Delay (in time or number of samples)
Trigger level (if source is the input signal)
Sample rate
Measurement size (in elapsed time or number of samples)
Maximum sampling rate for 16-bit resolution
Maximum sampling rate for 8-bit resolution

Once the status mode is entered, the unit will scroll through and display the various status parameters at a rate of one per second. Table 3-12 shows typical display messages. To terminate the status mode, press any other front panel key. For example, you might wish to press CHANNEL, which will return the instrument to the previous mode.

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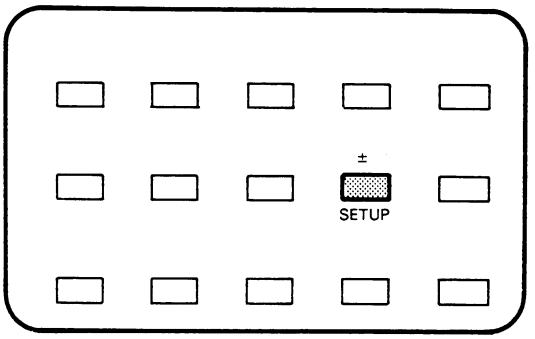
Table 3-12. Typical Status Mode Display Messages

Mode	Typical Display Message
Zero Value	0μV
Filter	FILTER OFF
Trigger Source	IMMEDIATE
Trigger Delay	0DELAY
Trigger Level	0μV
Sampling Rate	166.7μs
Number of Samples	100 SAMPLES
16-Bit Maximum Rate	16 BIT 100kHz
8-Bit Maximum Rate	8 BIT 1MHz

3.16 SETUP MODE

Through use of the setup mode, you can store two different instrument configurations in non-volatile RAM. These configurations will be retained for future recall even if the power has been turned off. Setup 0 also allows you to return to factory default configuration.

SETUP BUTTON



Stored parameters include the following:

Zero Mode (if enabled or disabled, and zero value)
Filter (Enabled or disabled)
Trigger Arming Mode (single/continuous)
Trigger Source
Trigger Delay (samples or time)
Trigger Slope
Trigger Level
Selected Range
Autorange (on or off)
Sample Rate (interval or frequency)
Measurement Size (number of samples or duration)
Input Coupling
Mathematical Function
IEEE-488 Primary Address

Display messages associated with the setup mode are summarized in Table 3-13. Note that the contents of the measurement buffer are not saved by the setup mode.

NOTE

If the unit is in the dual-channel display mode, pressing SETUP will result in a SETUP WHICH? message. At this point, you should use the CHANNEL key to select which channel to recall.

Table 3-13. Setup Mode Display Messages

Message	Description
RECALL SETUP n	Setup recall mode.
STORE SETUP n	Setup store mode.
WHICH CHANNEL?	Unit in dual-channel mode.
NMBR TOO SMALL	Setup parameter too small.
NMBR TOO LARGE	Setup parameter too large.
CAN'T STORE 0	Improper setup position.

3.16.1 Recalling Setups

Three setup positions (0-2) may be recalled by using the basic procedure below. Setup position 0 is permanently programmed at the factory for the configuration shown in Table 3-15, while the configurations stored in setup positions 1 and 2 can be programmed as discussed in paragraph 3.16.2. Note that the instrument assumes the SETUP1 configuration upon power up or when RESET is used.

1. For instruments equipped with two A/D modules, select the desired channel to be recalled with the CHANNEL button.
2. Press SETUP to enter the setup mode. The instrument will then display the selected configuration, for example:

   RECALL SETUP 0

3. To recall the presently displayed setup, simply press ENTER at this point.
4. To access a different setup than the one displayed, key in the new digit (0-2) and press the ENTER key.

3.16.2 Saving Setups

Two different instrument configurations may be stored in NVRAM by using the store aspect of the setup mode. Note that you cannot store a setup at position 0 as that position is permanently programmed with factory defaults.

1. If your unit has two A/D modules, use the CHANNEL button to select the channel to be configured.

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2. Select the various operating modes for the configuration to be saved using the appropriate front panel buttons.
3. Press SETUP twice in succession. The instrument will then display the following message:

STORE SETUP 1

4. To store presently selected setup, simply press ENTER.

NOTE
The SETUP 1 configuration is used for power on and RESET conditions.

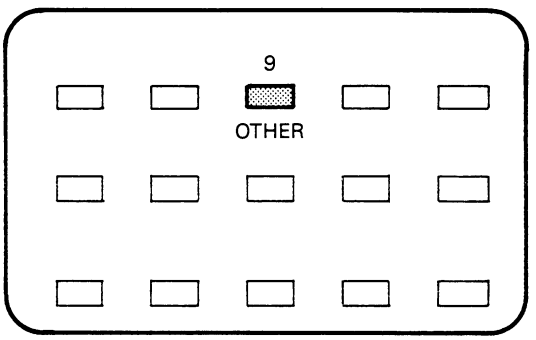
5. To store the configuration at a new position, key in the digit (1 or 2) and press ENTER. The unit will then store the new configuration. To return to the previous operating mode, press CHANNEL.
6. If you attempt to store a configuration at the SETUP 0 position, the unit will display the following message:

CAN'T STORE 0

3.17 FRONT PANEL PROGRAMS (OTHER KEY OPERATION)

Miscellaneous modes include programming the IEEE-488 address, self test, digital calibration, NVRAM storage of calibration constants, X output full scale value, Y output full scale value, and Z output blanking level. These modes, along with display messages are summarized in Table 3-14.

OTHER BUTTON



These various programs can be accessed by pressing OTHER (SHIFT will be necessary if in the data entry mode). The instrument will then respond with the message for the IEEE-488 address program:

0 IEEE- 488 ADR

At this point, you can key in a single digit number to select the desired program, (in which case ENTER is not necessary), or use the ▲ or ▼ key to scroll through available modes. Once the desired program is displayed, press the ENTER key to actually enter the selected program.

The various programs associated with the OTHER key are covered in detail in appropriate paragraphs of this manual as follows:

Program 0 (IEEE-488 address): paragraph 4.5.
Program 1 (self test): paragraph 7.8.
Programs 2 and 3 (digital calibration and NVRAM storage): paragraph 7.5.
Programs 4, 5, and 6 (Analog output levels): paragraph 3.12.7

Table 3-14. Front Panel Programs

Program	Description	Display Message
0	IEEE-488 Address	0 IEEE-488 ADR
1	Self Test	1 SELF TEST
2	Digital Calibration	2 DIGITAL CAL
3	NVRAM Storage of Calibration Constants	3 CAL TO NVRAM
4	X Output Full Scale	4 X OUTPUT FS
5	Y Output Full Scale	5 Y OUTPUT FS
6	Z Output Blanking Level	6 Z BLANK LEVL

3.18 RESET

Pressing SHIFT RESET returns the instrument to power-on default (SETUP 1) operating conditions. The factory default reset conditions are listed in Table 3-15. Note that these will be different if you modify the SETUP 1 configuration.

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Table 3-15. Factory Default RESET (SETUP 1) Conditions

Mode	Status
Range	Auto
Zero	Disabled
Filter	Disabled
Trigger Mode	Continuous
Trigger Source	Immediate (TRIGGER button)
Trigger Delay	0
Trigger Slope	off
Trigger Level	0V
Sample Rate	166.7μsec
Input Coupling	DC
Measurement Size	101 samples
Reading Function	Average

NOTE

These conditions are also restored by SETUP 0.

3.19 EXTERNAL CLOCK

The CLK IN and OUT jacks may be used to connect two or more Model 194As together for synchronous operation. To do so, connect the CLK OUT jack of the master unit to the CLK IN jack of the slave unit, as shown in Figure 3-15.

CAUTION

Digital common is internally connected to chassis ground and cannot be floated.

NOTE

Shielded cable should be used for the clock input and output connections to minimize the possibility of EMI radiation.

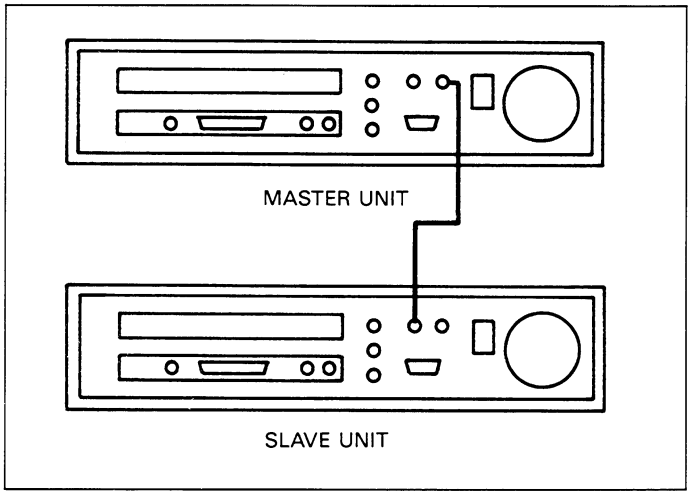


Figure 3-15. Synchronous Operation

Up to 16 units may be daisy chained together by using the same basic connecting scheme. Figure 3-16 shows five such units connected together: one master, and four slaves. External clock operation is automatic; the instrument will automatically switch to the external clock when the proper signal is detected.

CLK IN may also be used to apply an external time base at TTL levels (low, 0-0.8V, high 2.4-5V). The time base can be in the range of 1MHz to 10MHz; however, programmed sampling rates assume that a 10MHz signal is used. Thus, sampling rates must be adjusted accordingly if a non-standard clock is applied. For example, if the clock rate is 5MHz, the instrument will sample at exactly one-half the programmed rate.

NOTE

Both A/D modules (dual-channel units) use the same time base. Thus, any signal applied to CLK IN will affect both A/D modules.

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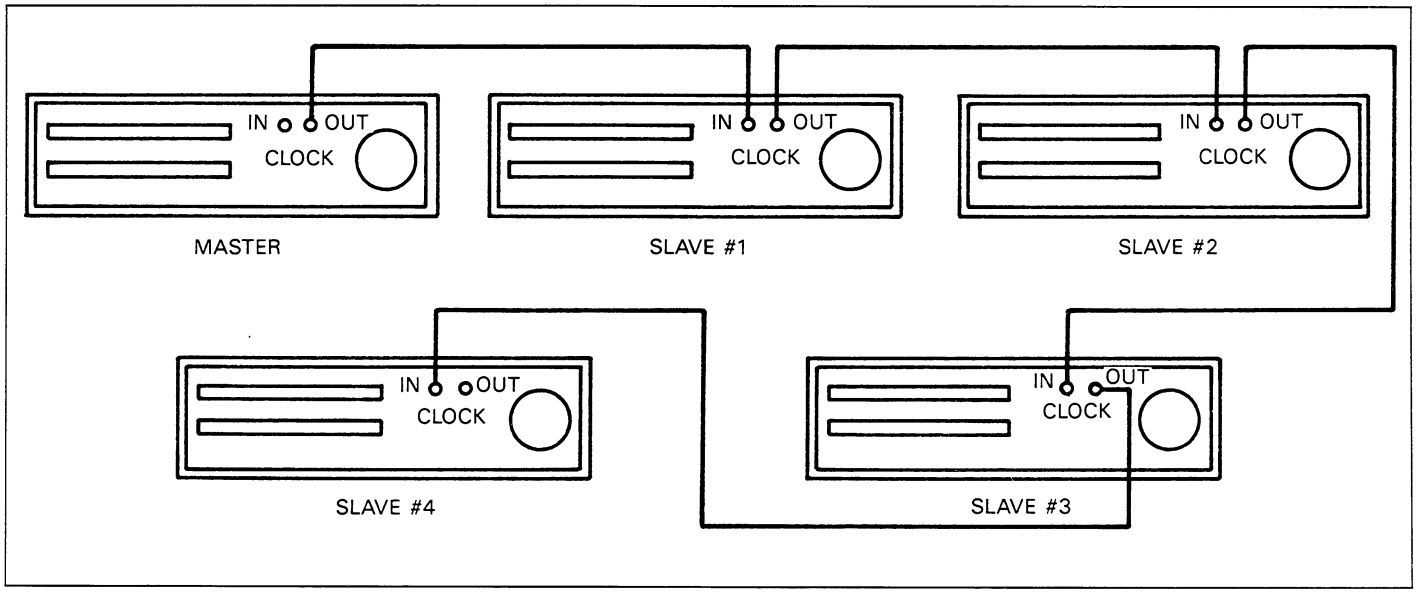


Figure 3-16. Synchronizing Five Units by Daisy Chaining

3.20 REAL TIME OUTPUT

Each A/D module has a real time output port that can transmit A/D data to an external device such as a computer on a real time basis.

Data can be taken a byte at a time (8 bits) or a word at a time (16 bits). The transmission rate will, of course, depend on the selected sampling rate. For example, if you program a 100kHz sampling rate, transmission will occur at that frequency.

3.20.1 Signal Lines

The pin out diagram for the real time connector is shown in Figure 3-17. Signal lines are listed in Table 3-16. Figure 3-18 shows a typical timing diagram for the real time output.

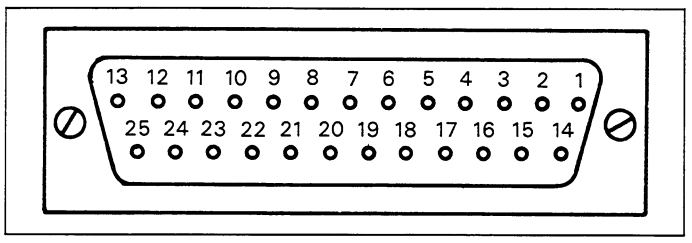


Figure 3-17. Real Time Output Connector

Table 3-16. Real Time Output Signals

Pin Number	Signal Line	1942 Cable Assignment*
1	Digital Common	Black, coaxial shield
2	MEASURING	
3	OVERRUN	
4	NEW CONVERSION	
5	HIGH BYTE	
6	D8	
7	D9	
8	D10	
9	D11	
10	D12	
11	D13	
12	D14	
13	D15	
14	ABORT*	White wire
15	SAMPLE TRIGGER*	Coaxial cable center conductor
16	Not Used	
17	LOW BYTE	
18	D0	
19	D1	
20	D2	
21	D3	
22	D4	
23	D5	
24	D6	
25	D7	

*Used with external sample control. See paragraph 3.21.

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CAUTION
Digital common is connected to chassis ground and cannot be floated.

NOTE
Shielded cable should be used with the real time output in order to minimize the possibility of EMI radiation.

Real time output signal lines include:

Data lines (D0-D15)—These lines have non-inverted A/D converter data. D0 is the least significant bit, and D15 is the most significant bit. Note that converter data has 16 bits at sampling rates of 100kHz and lower (and if the programmed number of samples is ≤32,768). Above 100kHz (or if the number of samples is >32,768), the converter operates in the 8-bit mode. In this case, relevant data is located only on D0 through D7.

NEW CONVERSION—This signal line will go high when converter data has been latched into the real time output data latches and is ready for transfer.

LOW BYTE—This line should be set low to enable the D0-D7 data lines. Note that the data lines D0-D7 will be in the high-impedance state when LOWBYTE is high.

HIGH BYTE—This line should be set low to turn on the D8-D15 data lines. D8-D15 will be in the high-impedance state when HIGHBYTE is high.

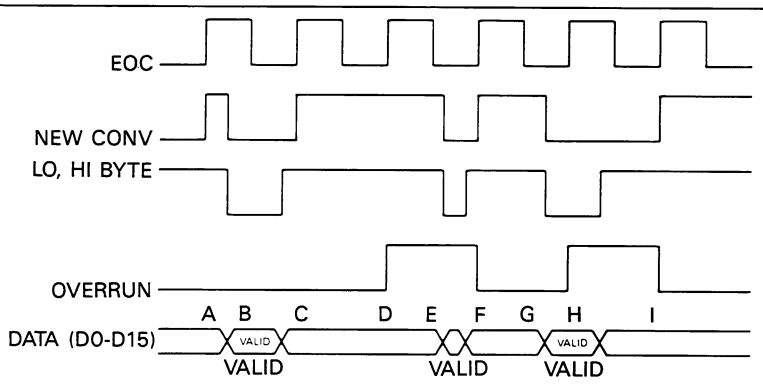
OVERRUN—This flag bit will be set high if data made available by a previous conversion was not taken. One or more data words will have been lost under these conditions.

MEASURING—This line will be high when the instrument is performing a measurement sequence; in other words, the triggering condition has been met.

3.20.2 Reading Real Time Data

The exact method used to transmit data will depend on the particular application; however, the procedure below gives the basic sequence for transfer of data. The sequence assumes the instrument is processing samples (MEASURING high). A flow chart of this sequence is shown in Figure 3-19.

1. Monitor the NEW CONVERSION line and observe when it goes high. When NEW CONVERSION goes high, the data byte or word has been latched into the output data latches.
2. Test the state of the OVERRUN flag. If it has been set high, you have missed one or more words of data. To correct an overrun condition, either increase the reading rate of the external equipment, or program a slower sampling rate.



A. EOC goes true, setting NEW CONVERSION
B. LOWBYTE and/or HIGHBYTE go true, clearing NEW CONVERSION
C. same as A
D. EOC goes true while NEW CONVERSION is still true, setting OVERRUN
E. same as B
F. EOC goes true with NEW CONVERSION false, setting NEW CONVERSION and clearing OVERRUN
G. same as B
H. EOC goes true while LOWBYTE and/or HIGHBYTE are still true, setting OVERRUN, NEW CONVERSION does not get set
I. EOC goes true after LOWBYTE and HIGHBYTE have gone false, clearing OVERRUN and setting NEW CONVERSION

Figure 3-18. Real Time Output Timing

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3. If data is to be transferred in low byte, high byte fashion, first pull LOW BYTE low and read the D0-D7 data lines. Next, pull HIGH BYTE low and read the D8-D15 data lines.
4. If all 16 bits are to be transferred at the same time, simply pull both LOW BYTE and HIGH BYTE low simultaneously and read D0 through D15 at the same time.
5. Test the state of the MEASURING line. If it is high, the instrument is still sampling, and steps 1-4 above can be repeated for the next sample. If MEASURING is low, the sequence has been terminated and no new data will be made available.

3.20.3 Computer Interfacing

The exact nature of the interface will, of course, depend on the computer being used. In this paragraph we will discuss computer interfacing in general terms.

Figure 3-20 shows a simplified block diagram of a typical computer interface. At the left side of the diagram, typical computer bus lines are shown, including the data bus (D0-D7), the address bus, as well as bus clock and reset lines. The interface itself is shown in the center part of the diagram, while Model 194A components of note are shown on the right.

The address decoding circuitry partitions the interface circuitry into three unique addresses as follows:

$\overline{\text{STATUS}}$: A read-only location that allows you to determine the conditions of the MEASURING, NEW CONVERSION and OVERRUN flags in the Model 194A.

$\overline{\text{LOW BYTE}}$: A read-only location that returns the low byte of instrument data.

$\overline{\text{HIGH BYTE}}$: A read-only location that returns the high byte of the real time data.

The tri-state buffer is the interface between a number of interface and Model 194A status lines, including SHIFT COMPLETE, OVERRUN, MEASURING, and NEW CONVERSION. Status of these lines can be checked by reading the STATUS location and then masking off the appropriate bit to determine the state of that particular line.

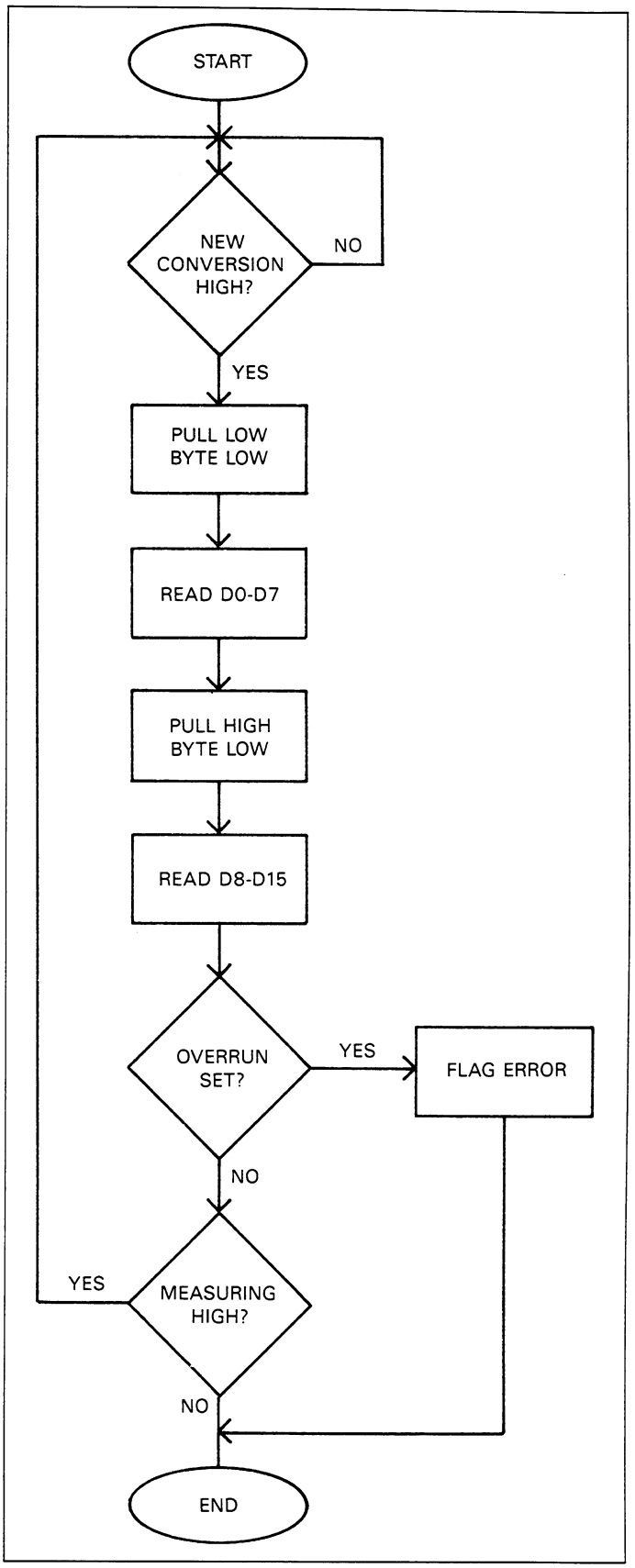


Figure 3-19. Flow Chart for Reading Real Time Data

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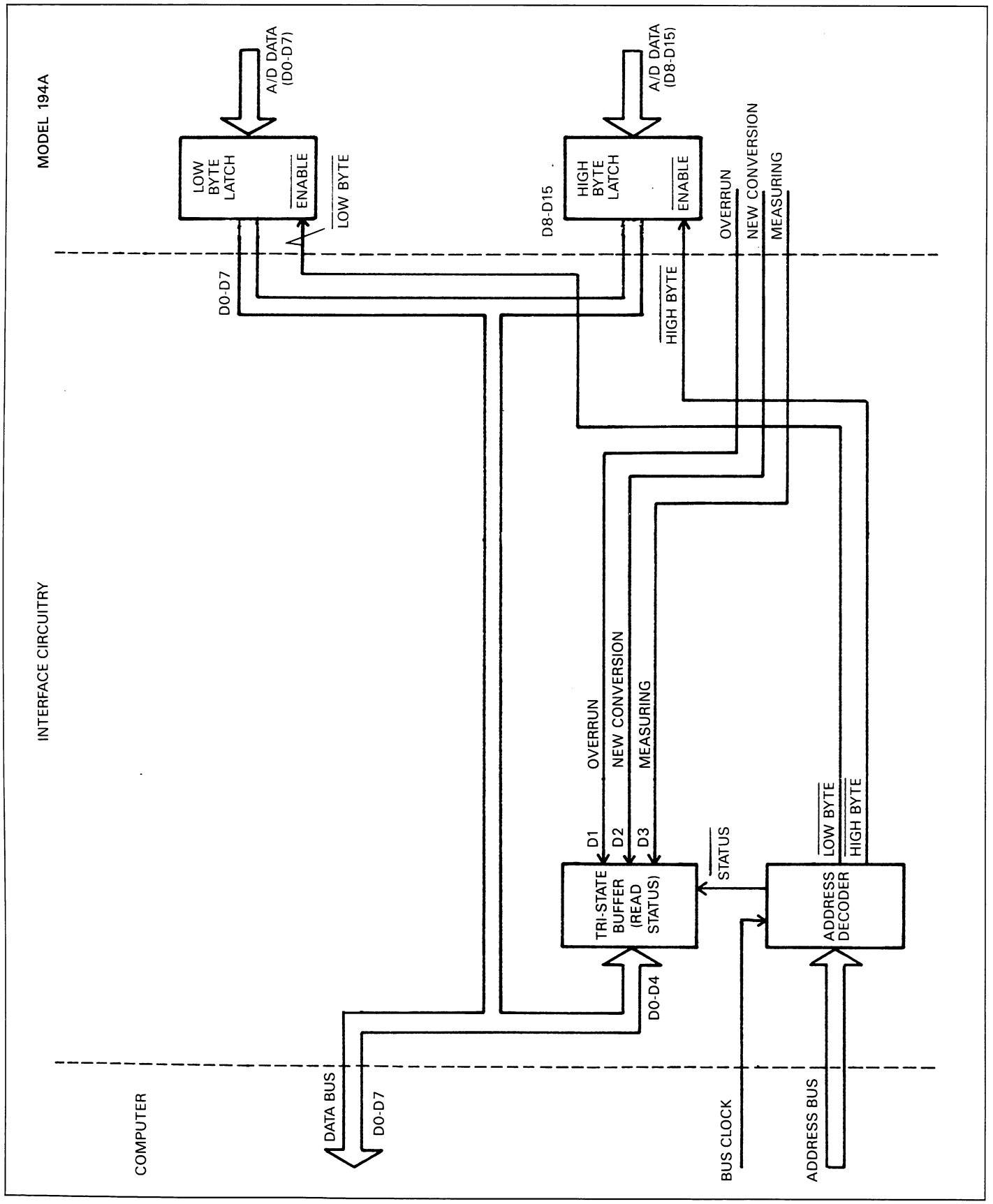


Figure 3-20. Simplified Block Diagram of Real Time Computer Interface

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Reading Real Time Data

Real time data can be read by performing a read operation to the low and high byte locations in sequence. The exact memory locations will, of course, depend on the address decoding scheme used. For example, assume that the interface is located at four memory locations beginning at address $DF00, with the three locations decoded as follows:

STATUS: $DF00
LOWBYTE: $DF02
HIGH BYTE: $DF03

Further assume that the three status signals are assigned the following data bus lines:

OVERRUN: D1
NEW CONVERSION: D2
MEASURING: D3

The following source code gives a simple example using 6502 assembly language on how to go about accessing real time data and storing it in computer memory. The program accesses 256 bytes (128 words) of instrument data and stores them in a memory buffer beginning at location $C000.

SOURCE CODE		COMMENTS
START	LDX #$00	Clear memory pointer.
LOOP	LDA $DF00	Load interface status into accumulator.
	AND #$04	Mask off NEW CONVERSION bit.
	BEQ LOOP	If no conversion, branch back and wait.
	LDA $DF02	Load low byte into accumulator.
	STA $C000,X	Put low byte in memory location with offset X.
	INX	Increment memory pointer.
	LDA $DF03	Load high byte into accumulator.
	STA $C000,X	Put high byte into memory location with offset X.
	LDA $DF00	Get interface status.
	AND #$08	Mask off MEASURING bit.
	BEQ PASS	If no longer measuring, end routine.
	INX	Increment memory location pointer.
	BNE LOOP	Branch back for next reading.
PASS	RTS	Return to calling routine.

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Speed Considerations

The interface discussed in this paragraph uses memory-mapped I/O. Thus, the limiting factor for the rate of data transfer lies in the speed of the processor involved. For a 6502 running at 1MHz, for example, we are looking at a byte transfer rate of 20-25μsec per byte--a speed that is much slower than the fastest (1MHz) sampling rate of the Model 194A. Even with a much faster 16-bit processor, it is doubtful whether the MPU could keep up with the available data at these extremely high rates.

Thus, for more rapid data transfer, the interface discussed here would have to be modified to incorporate a DMA (Direct Memory Access) controller IC. This arrangement would allow the interface to take data bytes as they come from the instrument and dump them directly to computer memory, bypassing the bottleneck of the MPU. Of course, this added speed would come at the expense of both software and hardware complexity.

3.21 EXTERNAL SAMPLE CONTROL

This paragraph contains information on connections, control signals, and basic operation of the Model 194A using the external sample trigger feature.

3.21.1 Connections

In order to use external sample triggering, the optional Model 1942 cable must be connected to the REAL TIME OUTPUT of the appropriate A/D module, as shown in Figure 3-21. The black and white wires are intended to apply the internal/external trigger select signal, while the coaxial cable is to be used to apply external SAMPLE TRIGGER pulses, as discussed below.

Table 3-16 summarizes the REAL TIME OUTPUT terminal assignments for those who wish to construct their own cables. Note that the white wire is connected to pin 15, while the black wire connects to digital common (pin 1). In a similar manner, the shield of the coaxial cable should also be connected to digital common, while the center conductor is to be connected to pin 14. Figure 3-22 shows these connections in detail.

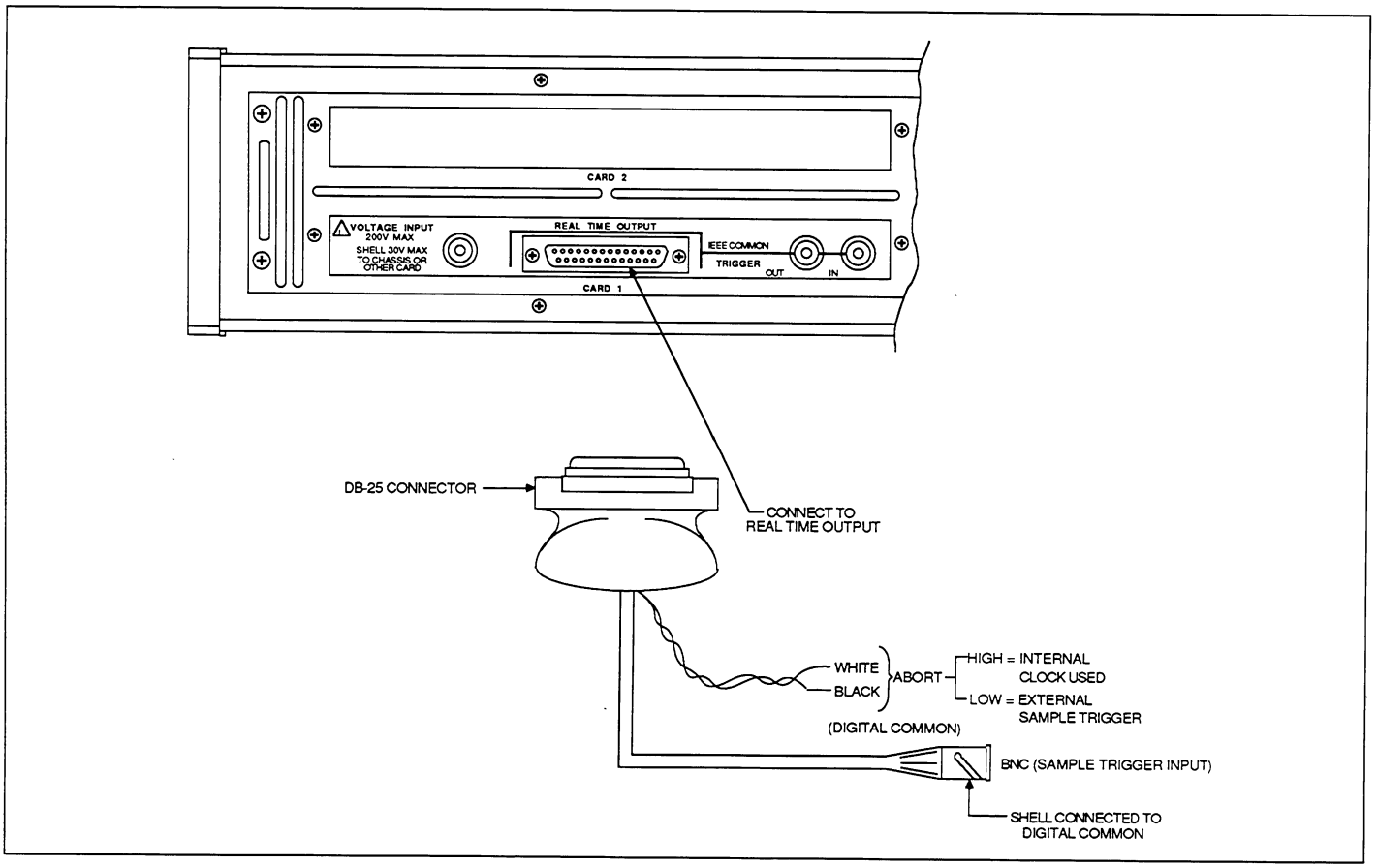


Figure 3-21. External Sample Triggering Connections

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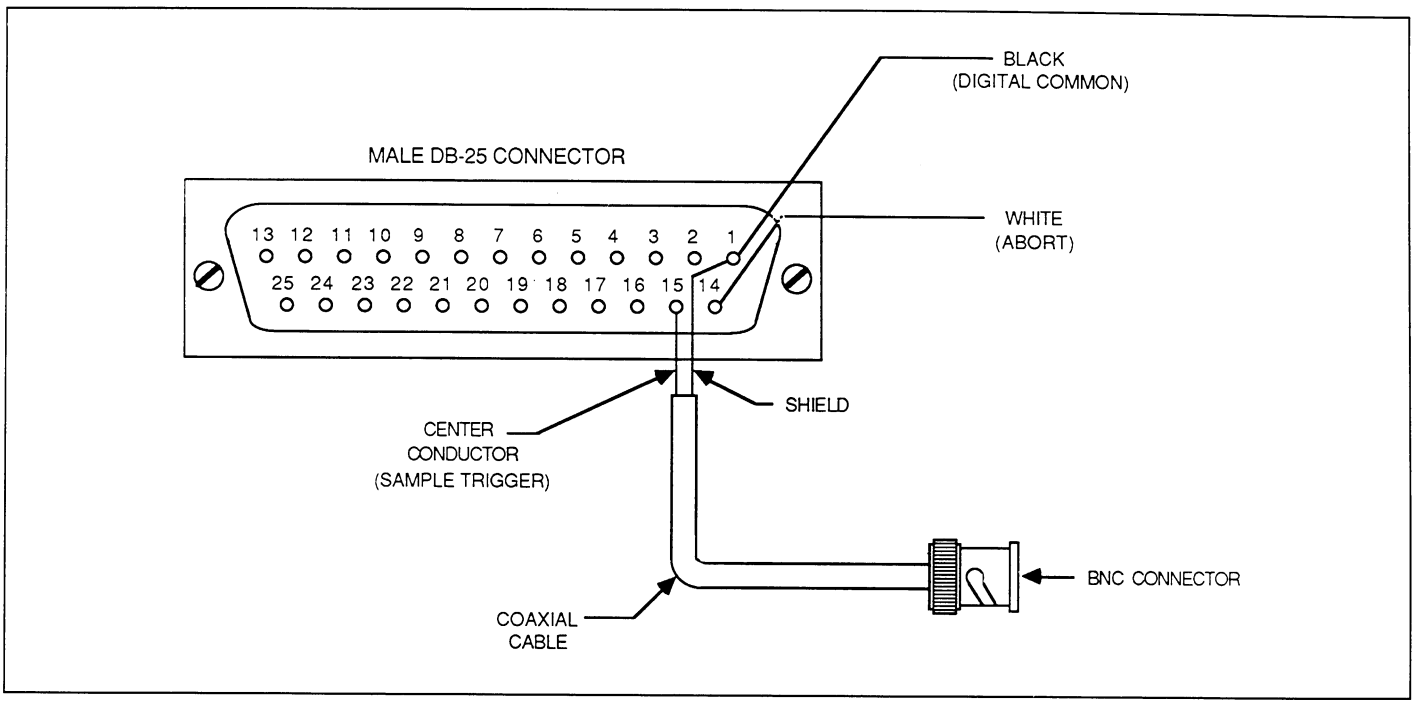


Figure 3-22. External Sample Cable

3.21.2 Control Signals

The two control signals that govern external sample triggering are the ABORT and SAMPLE TRIGGER lines. The ABORT signal is applied between the white and black wires, while the SAMPLE TRIGGER signal is applied to the BNC coaxial cable. The characteristics of these two signals are discussed below.

Internal/External Sample Triggering Selection (ABORT)

The logic level on the ABORT line selects between internal and external sample triggering signals, as shown in Figure 3-23. An open circuit or TTL high logic level on ABORT (white wire), referenced to digital ground (black wire), selects internal sample rate operation. Placing ABORT at TTL logic low, or shorting it to ground (black wire) selects external sample triggering, with samples taken at a rate determined by the signal applied to SAMPLE TRIGGER (see below). If ABORT is returned to TTL high during a measurement, data collection will continue using the internal sample trigger pulses at the programmed rate.

In most cases using external sample triggering, the black and white wires can be simply connected together. For convenience, a switch can be connected between the white and black wires allowing easy selection of internal or external sample triggering. When the switch is open, the instrument will process samples based on the internal clock; when the switch is closed, external sample triggering will be in effect.

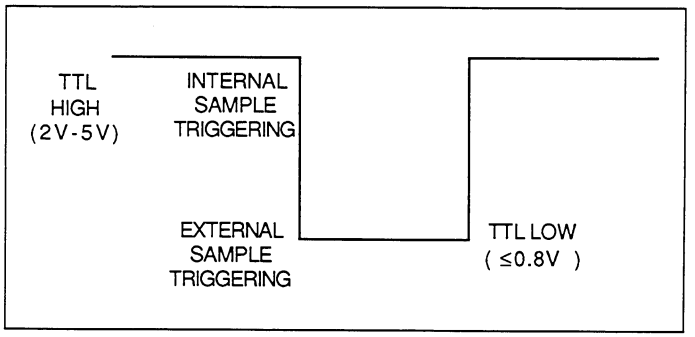


Figure 3-23. ABORT Input Specifications

External Sample Trigger Input (SAMPLE TRIGGER)

The SAMPLE TRIGGER input is a BNC terminated coaxial cable, which is compatible with TTL or open collector drive circuits, as shown in Figure 3-24. Pulses on this line must be at least 100nsec in duration for reliable operation. Note that each sample is triggered on the low-to-high transition of the SAMPLE TRIGGER line when ABORT is low.

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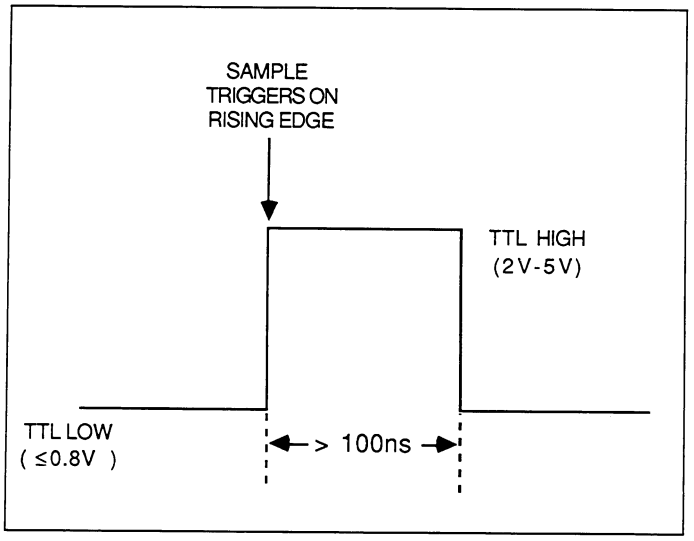


Figure 3-24. SAMPLE Input Pulse Specifications

The programmed rate (selected from the front panel with RATE or programmed with the S command over the IEEE-488 bus) controls the re-arm period between samples. Total re-arm time is typically the sampling interval determined by the programmed rate. For example, if the programmed rate results in a sampling interval of 1μsec, the re-arm time between samples will be approximately 1μsec.

In order to ensure that the instrument responds to each and every SAMPLE TRIGGER pulse, you must make certain that the interval between pulses is at least equal to the re-arm time discussed above. Pulses that occur during acquisition of an individual sample will be ignored, as the instrument will not trigger a new sample until re-armed.

3.21.3 External Sample Trigger Considerations

In most respects, the Model 194A operates the same whether using either internal or external sample triggering. Basically, you will still be required to program the number of samples, sampling rate, trigger mode, and so on. However, there are a couple of constraints that should be kept in mind, as discussed in the following paragraphs.

Minimum Sampling Duration

Regardless of the programmed sampling rate and number of samples, the Model 194A will always attempt to collect at least 200μsec worth of samples. For this reason, extra samples may be collected. As an example, assume that the unit is programmed to take one sample at the 1μsec rate. In this situation, 200 samples would be collected, and the last 199 samples would be discarded.

When using external sample triggering, you must make certain that sufficient samples are taken to satisfy the 200μsec minimum in order to complete the measurement. Two ways to do so are:

1. Supply sufficient trigger pulses through the SAMPLE TRIGGER input to complete the 200μsec minimum measurement duration.
2. Set the ABORT line high after valid samples are taken. Doing so will complete the measurement at the programmed rate using the internal rather than external sample triggering.

Negative Trigger Delay

Negative trigger delays should not be used with external sample triggering. For negative trigger delays, the instrument waits the programmed time before enabling the trigger. When using external sample triggering, there is no way to verify that the specified number of samples are taken before the trigger is enabled. For that reason, invalid data will be added to the beginning of the desired samples if negative delay settings are used.

Sample and Measurement Triggering

It is important to differentiate between sample triggering and measurement (waveform) triggering. Sample triggering is performed by the pulses applied to the SAMPLE TRIGGER input on the DB-25 connector (when external sample triggering is selected). In this situation, one sample per trigger pulse is taken (assuming sufficient re-arm time is allowed between triggers).

The measurement trigger initiates the acquisition of a set of samples, with the trigger stimulus depending on the programmed trigger source. (If external triggering is selected, the measurement trigger comes from the EXTERNAL TRIGGER INPUT). Since a measurement must always be triggered, you must still arm the A/D converter and apply the appropriate measurement trigger stimulus (as determined by the SOURCE key or IEEE-488 T command) before applying the sample triggers.

3.21.4 Instrument Programming

The following paragraphs discuss the fundamental procedures for taking data using external sample control and then reading that data.

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Taking Data

Processing data under external sample control is very similar to the process for internal control. The basic procedure is as follows:

1. Connect the Model 1942 Sample Cable to the REAL TIME OUTPUT jack of the appropriate A/D module. Connect the BNC cable to the external sample trigger source. Keep in mind that the SAMPLE TRIGGER input requires TTL-compatible signal levels (see Figure 3-24).
2. Select various operating modes such as range and filter, as required.
3. Select the SGL trigger mode and trigger source, as required. In many cases, you will probably use the immediate trigger mode, but other sources can be used, if desired.
4. Using the RATE and SAMPLES keys, program the desired sampling rate and number of samples in the measurement. Keep in mind that the rate should be the highest expected rate for the sample trigger pulse interval. The number of samples, of course, will depend on the required measurement size.
5. Set the ABORT line low to select external sample control (or simply short the black and white wires together).
6. Connect the signal to be measured to the INPUT jack of the appropriate A/D module.
7. Press the TRIGGER button to arm the A/D converter, then begin applying the sample trigger pulses (if a trigger mode other than immediate was selected, you must also first apply the appropriate measurement trigger). The unit will then process one sample per pulse. Be sure to apply sufficient pulses to complete the measurement (or set ABORT high after the desired samples are taken).
8. To begin a new measurement sequence, press TRIGGER to re-arm the A/D converter, then apply sample trigger pulses.

Evaluating Data

Once the measurement is complete, sample data can be evaluated with any of the usual methods. To view individual samples on the front panel, simply press the RECALL key and scroll through data, as required (over the bus, use the F0 and B commands to obtain sample data).

Other possible analysis methods include selecting a math function, or viewing/plotting data through the analog outputs. See paragraphs 3.12 and 3.13 for details.

3.22 MEASUREMENT CONSIDERATIONS

The following paragraphs describe a number of considerations to be taken into account when using the Model 194A.

3.22.1 Ground Loops

Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure 3-25 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires, or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the test leads can induce sufficient noise voltages to disturb sensitive measurements.

To prevent ground loops, instruments should be connected to ground only at a single point, as shown in Figure 3-26. Experimentation is the best way to determine an acceptable arrangement. For this purpose, measuring instruments should be placed on the lowest ranges. The configuration that results in the lowest noise signal is the one that should be used.

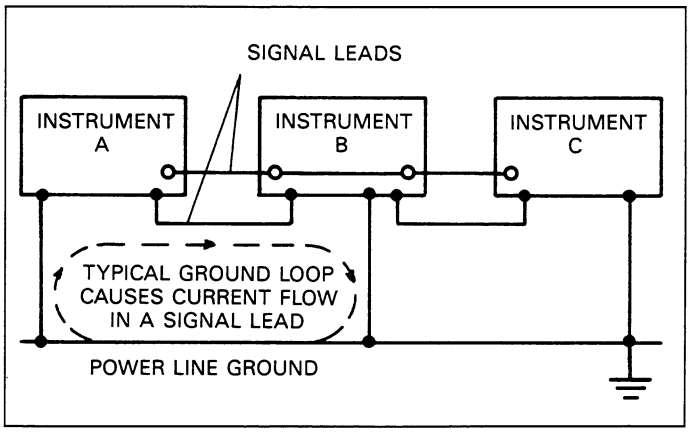


Figure 3-25. Multiple Ground Points Create a Ground Loop

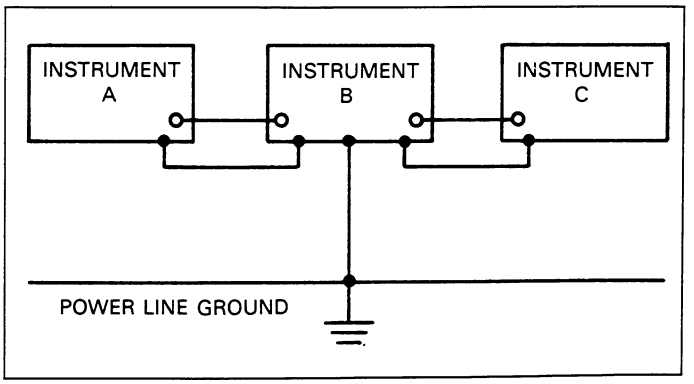


Figure 3-26. Eliminating Ground Loop

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3.22.2 RFI

Radio Frequency Interference (RFI) is a general term frequently used to describe electromagnetic interference over a wide range of frequencies across the spectrum. RFI can be especially troublesome at low signal levels, but it may also affect higher level measurements in extreme cases.

RFI can be caused by steady-state sources such as TV or radio broadcast signals, or it can result from impulse sources, as in the case of arcing in high voltage environments. In either case, the effect on instrument performance can be considerable if enough of the unwanted signal is present. The effects of RFI can be seen as an unusually large offset, or, in the case of impulse sources, sudden, erratic variations in the displayed reading.

RFI can be minimized by taking one or more of several precautions when operating the Model 194A in such noisy environments. The most obvious method is to keep the instrument and measured source as far from the RFI source as possible. Shielding the instrument, source, and test leads will often reduce RFI to an acceptable level. In extreme cases, a specially constructed screen room may be necessary to attenuate the troublesome signal.

In many cases, the internal 50kHz or 500kHz filters may provide sufficient attentuation of any RFI signals. In more difficult situations, it may be necessary to use external multiple-pole notch or band-stop filters, tuned to the offending frequency range. Keep in mind, however, that such filtering may have detrimental effects (such as increased response time) on the measurement.

3.22.3 Instrument Loading Effects

The input impedance of the Model 194A is 1.1MΩ (1MΩ, 200V range) in parallel with less than 47pF. The resistive component of the input impedance is sufficiently high so as to have a negligible loading effect on most sources. For sources with high internal resistance, however, the finite input resistance of the instrument can have a detrimental effect on measurement accuracy.

To see how instrument loading can affect the measurement, let us review the equivalent circuit in Figure 3-27. E_S and R_S are the source voltage and source resistance respectively, the instrument input resistance is R_I, and the voltage seen by the meter is V_M.

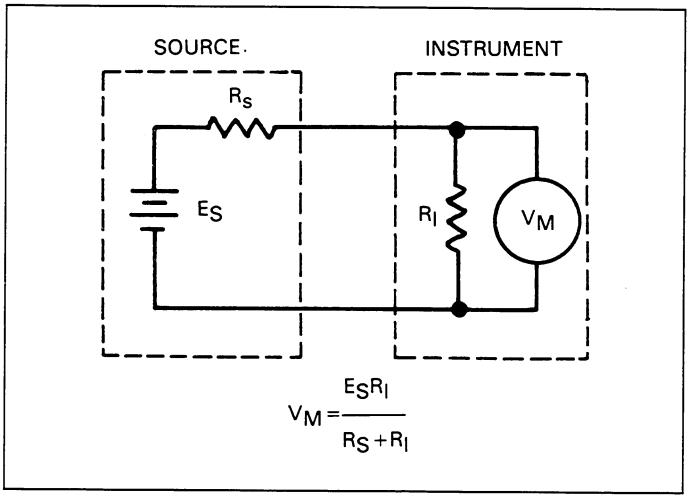


Figure 3-27. Loading Effects

R_S and R_I form a voltage divider that attenuates the input signal as follows:

$$V_M = \frac{E_S R_I}{R_S + R_I}$$

Thus, if R_S has a value of 100kΩ, and R_I is 1MΩ (the input resistance of the instrument), the actual voltage measured by the Model 194A with a 10V source will be:

$$V_M = \frac{10 \times 1M\Omega}{1M\Omega + 100k\Omega}$$

$$V_M = 9.09V$$

Thus, we see that the effects of instrument loading with high source resistances can be substantial, resulting in an error of almost 10% in this case.

For any given source resistance, we can calculate the percent error in the measurement from the following formula:

$$\%ERROR = \frac{R_S}{R_S + 1M\Omega} \times 100\%$$

For example, assume that R_S has a value of 1kΩ. The error due to instrument loading is:

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$$\%ERROR = \frac{1k\Omega}{1k\Omega + 1M\Omega} \times 100\%$$

$$\%ERROR = 0.0999\%$$

3.22.4 Input Capacitance Effects

Virtually any circuit has at least a small amount of distributed capacitance that can slow down measurement response time, especially if the Model 194A is being used at very high sampling rates. Even if the circuit itself has minimal capacitance, cable or instrument capacitance effects can be noticeable.

As an example, assume that the Model 194A is being used to measure the circuit shown in Figure 3-28. The source voltage and resistance are represented by E_S and R_S, the input capacitance is C_I, and the voltage is V_M. For the purposes of this discussion, we will ignore the effects of the input resistance.

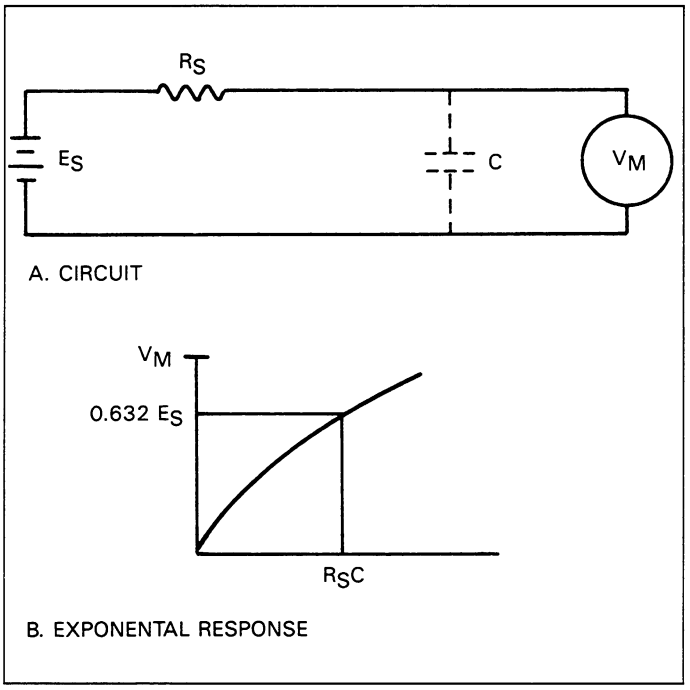


Figure 3-28. Input Capacitance Effects

When E_S is first applied, the voltage across the capacitance (and thus, at the input of the instrument) does not rise instantaneously to its final value. Instead, the capacitance charges exponentially as follows:

$$V_M = E_S (1 - e^{\frac{-t}{RC}})$$

Note that R_S is given in ohms, C is in farads, while t is in seconds.

Because of the charging action of C_I, the input voltage follows the exponential curve shown in Figure 3-28. At the end of one time constant (R_SC_I), the voltage will reach approximately 63% of its final value. At the end of two time constants ($2R_SC_I$), the voltage will reach 86% of its final value, and so on. Table 3-17 summarizes voltage and percent error values for ten different time constants.

The response time will, of course, depend on the relative values of R_S and C_I. For example, if R_S has a value of 1kΩ, and C_I has a value of 1000pF, a time constant of 1μsec results. Thus, to allow the reading to settle to within 0.1%, approximately 7μsec must be allowed.

While input capacitance does increase response time, it can help to filter out some of the higher frequency noise present in the signal by effectively limiting instrument bandwidth. If we assume that all input capacitance is lumped into a single element, the half-power (-3dB) point of the circuit in Figure 3-25 will be:

$$f\text{-}3db = \frac{1}{2\pi R_S C_I}$$

Thus, if R_S has a value of 1kΩ, and C_I has a value of 1000pF, the half-power point will be 159kHz.

Table 3-17. Voltage and Percent Error For Various Time Constants

Time*	V_M	%Error
τ	0.632 E_S	36 %
2τ	0.86 E_S	14 %
3τ	0.95 E_S	5 %
4τ	0.982 E_S	1.8 %
5τ	0.993 E_S	0.674%
6τ	0.9975 E_S	0.25 %
7τ	0.999 E_S	0.09 %
8τ	0.99966E_S	0.033%
9τ	0.9999 E_S	0.012%
10τ	0.99995E_S	0.005%

*$\tau = R_SC$

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3.22.5 AC Frequency Response Considerations

The strength of the Model 194A lies in its ability to analyze complex waveforms. The following paragraphs discuss a number of considerations to keep in mind when measuring AC signals, including low frequency response limits, as well as volt-hertz product considerations.

Low Frequency Response

When DC coupling is in effect, the instrument measures down to DC levels (0Hz). Thus, no consideration as to the reponse of the instrument at low frequencies need be given when using DC coupling.

If AC coupling is in effect, however, the instrument response rolls off at low frequencies. Thus AC coupling should not be used in cases where this attenuation factor might lead to significant errors in the measurement of low frequency signals, unless AC coupling is necessary to remove the DC component of an applied signal.

Volt-Hertz Considerations

With almost any measuring instrument, there exists a limit as to the maximum volt-hertz product that can be measured. Simply stated, the volt-hertz product defines the maximum peak voltage that can be measured at a given frequency.

For example, the maximum normal-mode input that can be safely applied to the Model 194A is 2×10^7 V•Hz. From this value, you can easily determine the maximum frequency at a given peak voltage by dividing the volt-hertz product by that voltage. For example, the maximum frequency at 20V peak would be:

$$f_{MAX} = \frac{2 \times 10^7 \text{V•Hz}}{20}$$

$$f_{MAX} = 1\text{MHz}$$

Note that other factors such as input amplifier frequency response and sampling rate affect measurement accuracy of higher frequencies.

3.23 TYPICAL APPLICATIONS

Applications for the Model 194A are many and varied and will depend largely on your particular needs. Basically, the Model 194A operates much like an ordinary DMM in that it measures DC voltages. However, special characteristics such as high sampling rates, a large measurement buffer, and built in math functions allow application of the instrument to measurements not possible with more ordinary units.

In the following paragraphs, we will discuss some typical applications for the Model 194A High Speed Voltmeter. Keep in mind that these examples are only representative of Model 194A capabilities, and by no means even begin to exhaust the possible uses for the unit.

3.23.1 Periodic Waveform Analysis

Probably one of the more obvious situations for the Model 194A is in cases calling for rapid sampling of the input signal, as is the case when analyzing periodic waveforms. The type of analysis, of course, will depend on the waveform as well as your particular requirements.

For example, assume that a 50kHz sine wave like the one shown in Figure 3-29 is to be analyzed. Our first task would be to set up the instrument to properly sample the waveform at hand. Operating modes such as range, sampling rate and interval, and trigger mode would be set up in accordance with our knowledge of the waveform being sampled.

Since the nominal peak-to-peak value of the waveform is ±10V, we could place the instrument on the 32V range. With a frequency of 50kHz, the waveform has a period of 1/50kHz = 20μsec. Thus, to capture at least one complete cycle of the waveform, we would have to choose a sampling interval of 20μsec. The maximum number of samples per cycle would then be 20 since the minimum sampling interval is 1μsec.

If the instrument is left in the continuous trigger mode, the measurement sequence will be repeated on a continuous basis. The various mathematical functions could then be used to provide important information such as the peak-to-peak, RMS, and average values.

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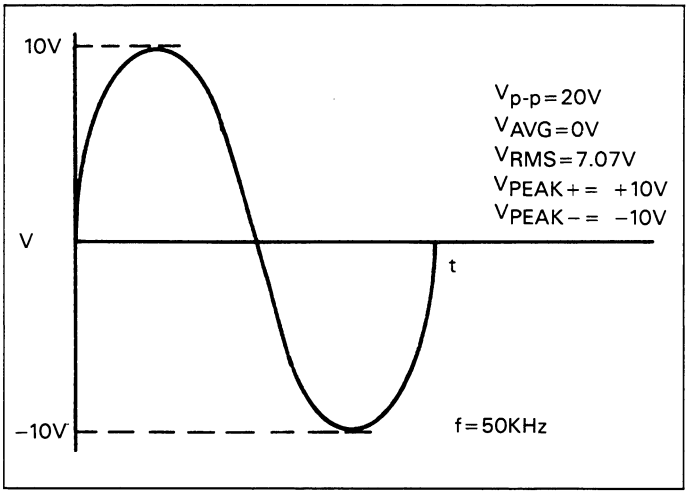


Figure 3-29. Periodic Waveform Analysis

3.23.2 Long Term Measurements

Although the Model 194A is primarily designed for high sampling rates, its large measurement buffer makes it suitable for any application requiring a large number of samples--even on a long term basis.

Long term drift analysis of power supplies is one area where such measurements may be required. The Model 194A could be programmed to sample the power supply voltage at specific intervals. Once the measurement cycle is completed, the peak-to-peak variations as well as the long-term average power supply voltage could then be easily obtained with the Model 194A mathematical functions.

For example, assume you desire to monitor the output voltage of a power supply at one second intervals. You would then program the instrument for this interval by entering information with the RATE key. The number of samples to be programmed would then depend on the duration of the test. With a one-second interval, a total of 7,200 samples would be required for a two-hour measurement period.

3.23.3 Digital Storage Oscilloscope

Oscilloscope analysis of recurrent or periodic waveforms is fairly routine since the scope can be triggered repeatedly to generate the required trace. Transient waveforms are another story, however, as it is generally difficult, if not impossible, to view such waveforms on an ordinary oscilloscope. The Model 194A, however, can give you digital storage oscilloscope capabilities when used with an external display device such as a plotter, CRT, or a basic oscilloscope.

Consider the transient waveform shown in Figure 3-30. When the Model 194A is performing a measurement sequence, it will measure all or part of the waveform, as determined by the sampling window. The relative size of this sampling window depends on the programmed rate and samples, as well as such trigger parameters as delay, slope, and level. Since the measured waveform is transient in nature, careful selection of these parameters is necessary to ensure proper triggering and measurement.

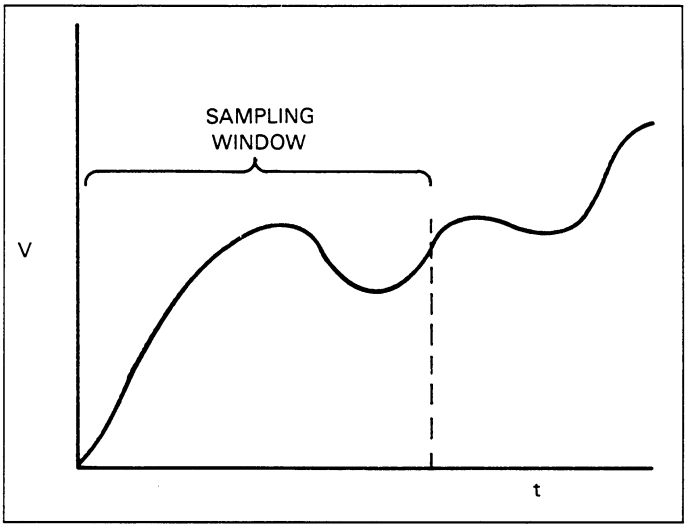


Figure 3-30. Transient Waveform

Once the waveform has been digitized and stored in the buffer, the XY mode can be used to graph the data. Three basic graphing modes are available: CRT, oscilloscope, and plotter.

The XY analog output is used to drive the graphing device regardless of the plot mode selected. Figure 3-31 shows typical connections for the oscilloscope and plotter modes. With the oscilloscope mode in (A), the Y output is used drive the vertical input of the scope, while the Z output is connected to the external trigger input. With the plotter in (B), the X and Y outputs drive the X and Y inputs of the plotter, while the Z output provides a pen up signal for the plotter.

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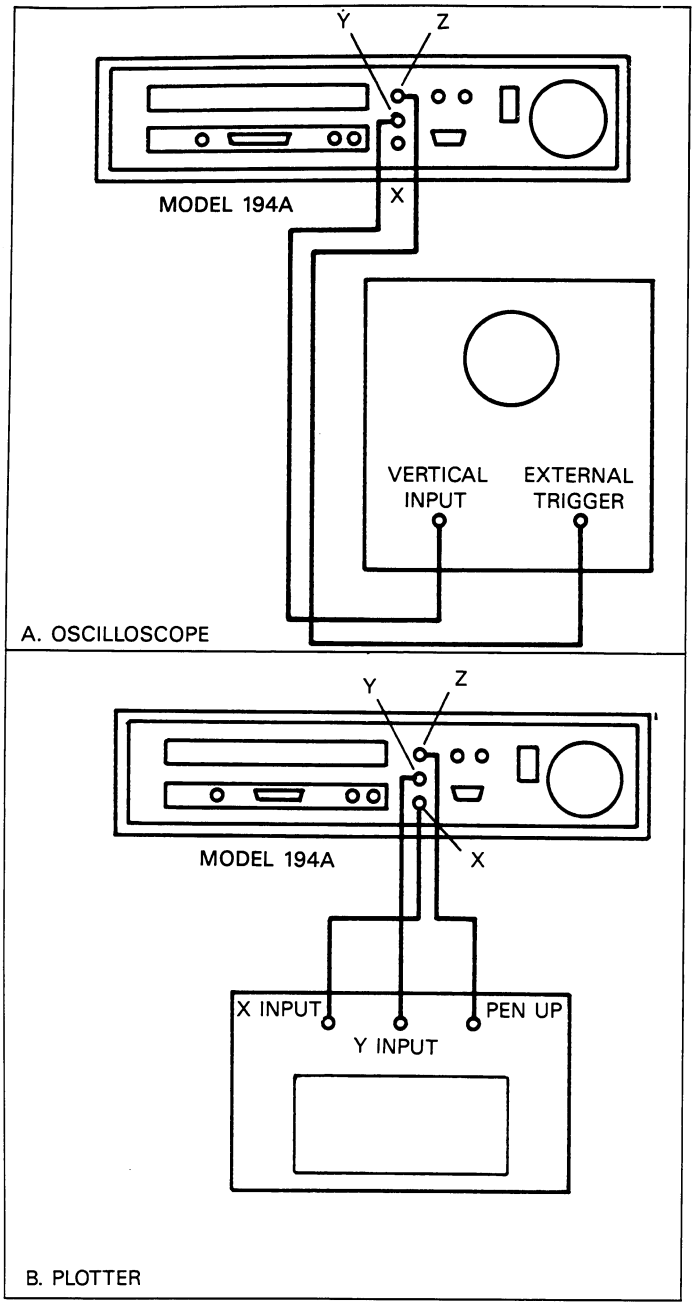


Figure 3-31. Typical Digital Oscilloscope Connections

3.23.4 Dual-Channel Voltmeter

The Model 194A can be equipped for dual-channel operation by adding an optional Model 1944A A/D Module. When the instrument is equipped in this manner, each channel operates independently from one another, with the exception of the display, front panel controls, and IEEE-488 bus. Since each channel can be independently programmed, the Model 194A can be set up to make two entirely different types of measurements at the same time.

For example, assume a periodic waveform is to be sampled and analyzed on channel 1, while a DC voltage is to be monitored for drift with channel 2. Figure 3-32 shows the basic configuration for this measurement. Each channel could be programmed for appropriate rate, samples, and trigger mode. With the periodic waveform, a rapid sampling rate would probably be required, while a much slower rate would be required for long-term drift analysis.

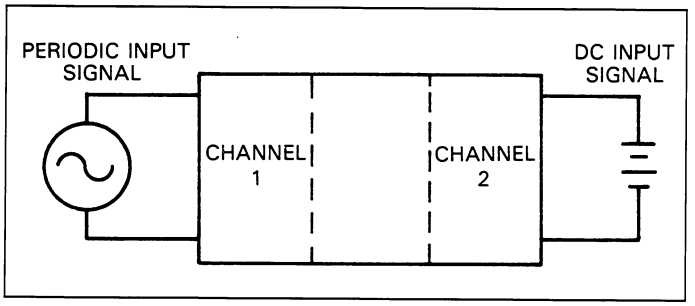


Figure 3-32. Dual Channel Operation

Once data is sampled and stored in the independent channel buffers, mathematical functions could be performed on each channel independently. For example, you may wish to obtain the RMS value of the waveform sampled on channel 1, and the average of the DC voltage measured on channel 2.

3.23.5 Catch a Falling Pulse

The Model 194A lends itself readily to pulse analysis due to its high sampling rates. Its buffer storage capabilities allows the instrument to catch rapid pulses and retain them for additional analysis.

Common pulse measurements include pulse duration, as well as rise and fall times. Generally, the rise time is defined as the period of time required for the pulse to rise

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from 10% of maximum value to 90% of full value. Conversely, the fall time is defined as the time period required to fall from 90% of maximum value to 10% of maximum value.

Assume we wish to analyze the fall time of a typical pulse like the one shown in Figure 3-33. This pulse has a peak amplitude of 10V, and a duration of approximately 30msec.

To properly analyze the fall time, we must choose correct operating parameters such as sampling interval and rate, as well as such triggering parameters as slope, level, and single/continuous mode. For example, if we know that fall time is approximately 10msec, we might choose a sampling duration of 15msec, allowing a certain amount of margin for error. With a 15msec duration, the maximum number of samples we can take is 15,000, since the instrument can sample at rates up to 1MHz. Above 100kHz, however, the A/D converter operates with 8-bit resolution instead of the 16-bit resolution in effect for sampling rates of 100kHz and less. Thus, if accuracy is a requirement, we may wish to settle for 1,500 samples, which would give us a 10μsec sampling interval.

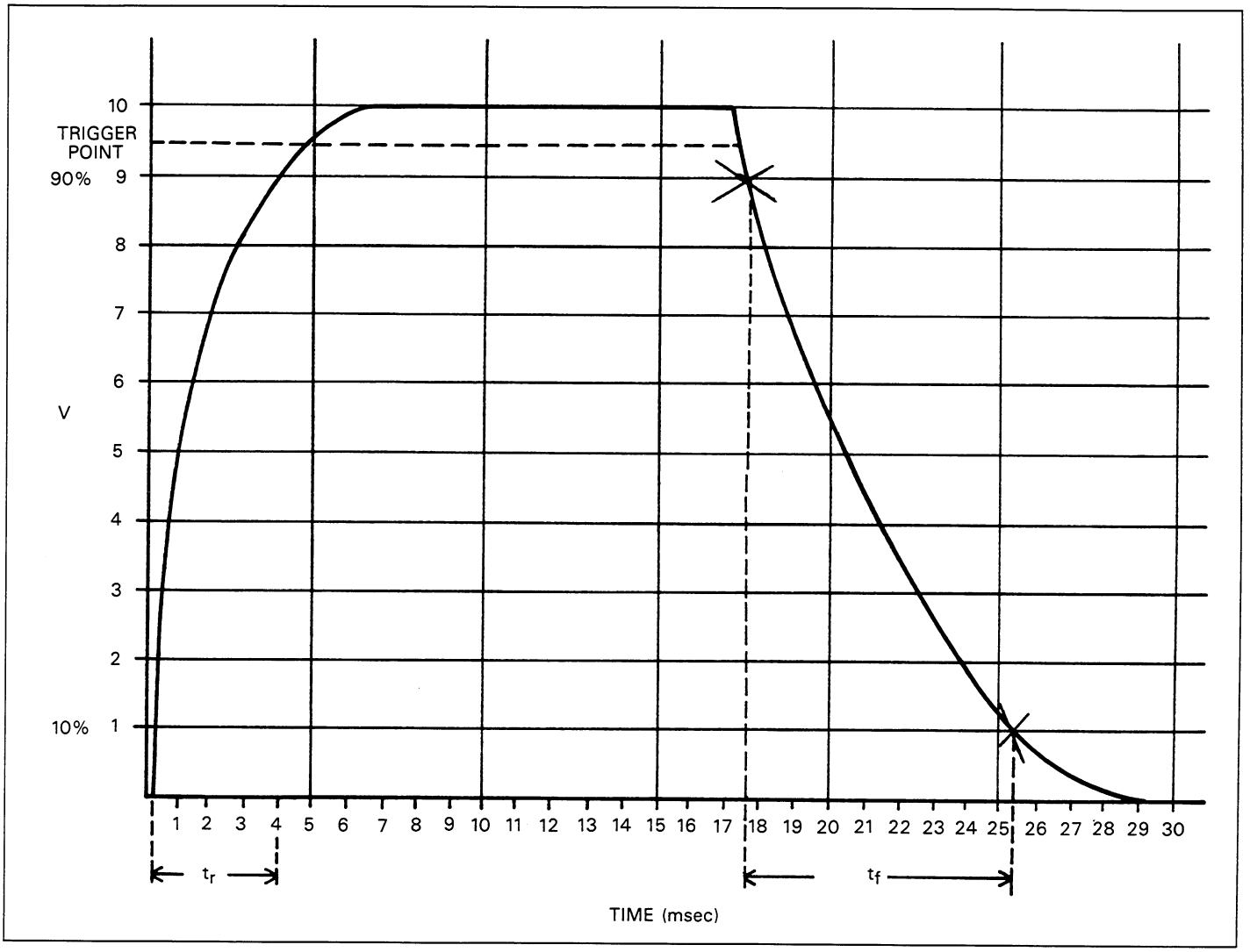


Figure 3-33. Pulse Rise and Fall Times

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Once the sampling rate and duration values are chosen, the next thing we must consider is the triggering parameters. Since we are in effect catching a single pulse, these parameters must be chosen carefully to place the sampling window on the appropriate segment of the pulse--in this case, on the falling edge.

The first aspect we must determine is whether to trigger on the negative or positive slope of the input waveform. Since we are attempting to measure the falling edge, we would obviously opt for negative slope triggering. The next aspect to consider would be the trigger level. In the example of Figure 3-33, we have chosen a trigger level of 9.5V. Thus, the instrument measurement sequence will be triggered when the pulse amplitude drops to 9.5V when going in the negative direction.

One final triggering aspect to be considered is whether to place the instrument in the single or continuous trigger mode. If a one-shot pulse is to be measured, naturally we would use the single trigger mode. However, the continuous trigger mode could be used if a train of identical pulses is to be measured.

Once the pulse has been captured, and the resulting data is stored in the measurement buffer, we can then use the recall mode to determine the 10% and 90% amplitude points. In the case of the pulse in Figure 3-33, these are simply 1V and 9V amplitude values. The fall time can then be determined from the relative buffer locations and the programmed sampling interval as follows:

$$t_f = (L_{10\%} - L_{90\%}) \times t_s$$

Where:

t_f = fall time
$L_{10\%}$ = buffer location number at 10% amplitude
$L_{90\%}$ = buffer location number at 90% amplitude
t_s = sampling interval.

For example assume that the 90% and 10% buffer location points are 150 and 900 respectively, and that the sampling interval is 10μsec (100kHz sampling frequency). The fall time under these conditions is:

$$t_f = (900\text{-}150) \times 10 \times 10^{-6}$$
$$t_f = 7.5\text{msec}$$

3.23.6 Reducing Noise in the Measured Signal

Very often 50 or 60Hz noise can creep into a DC input signal, resulting in erratic or erroneous readings. Such unwanted signals can be induced as normal mode noise (appearing between input high and input low), or common mode noise (appearing between input low and chassis ground). While the Model 194A has more than adequate noise rejection for most situations, additional noise reduction may be required in more difficult cases.

Figure 3-34 shows a sinusoidal noise signal riding on a DC level. If we assume that the noise signal waveform is symmetrical about the DC level, its average value will be zero; thus, such noise can be effectively cancelled by taking a number of samples and then taking the average of the samples.

For optimum noise rejection when using this method, the sampling sequence duration should be exactly equal to (or exact multiples of) the period of the noise waveform. The period of a 60Hz noise signal is 16.667msec. Thus, we might choose a sampling interval of 10μsec, and program the instrument for 1667 samples, resulting in a duration of 16.667msec per sampling sequence. The period of a 50Hz waveform is 50msec, so a total of 2000 samples would be programmed with a 10μsec interval to obtain the required 20msec sampling sequence duration.

Once the signal is connected for measurement, use the average function to display the average of the measurement. The degree of noise reduction will depend on the symmetry of the noise signal, as stated earlier. If the superimposed noise signal is not perfectly symmetrical, its DC or average value will not be zero, resulting in a DC level shift in the final reading. The amount of shift will depend on the noise amplitude and the degree of non-symmetry.

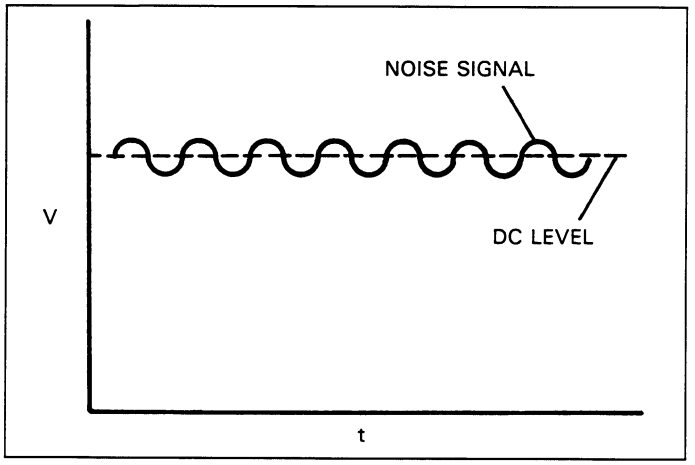


Figure 3-34. Noise Superimposed on DC Signal

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3.23.7 Noise Analysis

In some cases, it may be necessary to analyze noise, rather than attempt to eliminate it. Peak-to-peak or RMS noise values are the quantities most often required when analyzing noise. The Model 194A can be used to perform such noise analysis in a manner similar to that described in the last paragraph for noise reduction.

Once again, let us consider the AC noise signal riding on a DC level (Figure 3-34). The first thing we must do is separate the noise signal from the DC level for proper analysis. By using AC coupling on the input, the DC signal will be effectively eliminated.

Once the DC signal has been eliminated, the next considerations are the sampling duration and rate. The duration, of course, will depend on the length of the time span required for the analysis in question. The sampling rate depends on the expected noise spectrum. Again, a good yardstick is to choose a sampling frequency at least twice as high as the noise frequency, assuming that the noise signal is basically sinusoidal in nature.

Once a measurement sequence has been initiated, peak-to-peak or RMS values of the noise can be obtained by using the appropriate mathematical function. The instrument will then calculate and display the corresponding noise characteristic.

3.23.8 Mechanical Vibration Testing

Most equipment manufacturers perform some sort of vibration tests on their equipment in order to get some idea as to how well it will hold up in the real word. As with any test procedure, data is meaningful only if the test conditions are precisely controlled. The parameters of note with vibration testing are displacement, instantaneous velocity, and acceleration. The Model 194A can be used with external equipment to perform such tests with relative simplicity.

The basic instrument configuration for performing these tests is shown in Figure 3-35. Additional equipment required besides the Model 194A include the vibration table itself, an accelerometer, and the charge amplifier. The charge amplifier is necessary to convert the output of the piezoelectric accelerometer into a DC voltage that can be measured by the Model 194A.

When the equipment is being tested, the acceleration measured at the table will be converted into a voltage and measured by the Model 194A. The resulting data is then stored in the buffer of the instrument for further analysis. Data can be recalled as required to determine the acceleration at any instant of time.

The velocity can be found by integrating the acceleration as follows:

$$v = \int a\,dt$$

The integral function of the Model 194A could be used to perform the necessary conversion from acceleration to velocity. Specific transient waveforms could also be plotted using the analog output, if required.

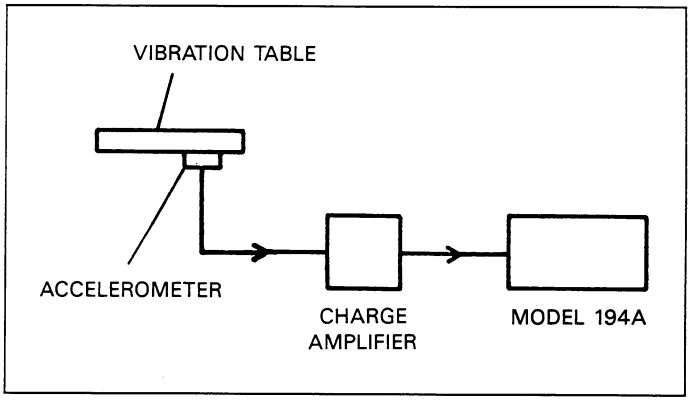


Figure 3-35. Vibration Testing

3.23.9 External Sample Triggering

Typical applications for external sample triggering are discussed below.

Potentiometer Linearity Testing

With minimal external equipment, the Model 194A can be used to test for linear change in resistance of potentiometers. Figure 3-36 shows the basic setup for such testing. In addition to the Model 194A, a current source, optical encoder, and motor, attached to the potentiometer shaft, will be necessary to perform the test. The current from the source flows through the potentiometer, developing a voltage, which is measured by the Model 194A. The optical encoder provides the SAMPLE TRIGGER pulses to take the individual samples.

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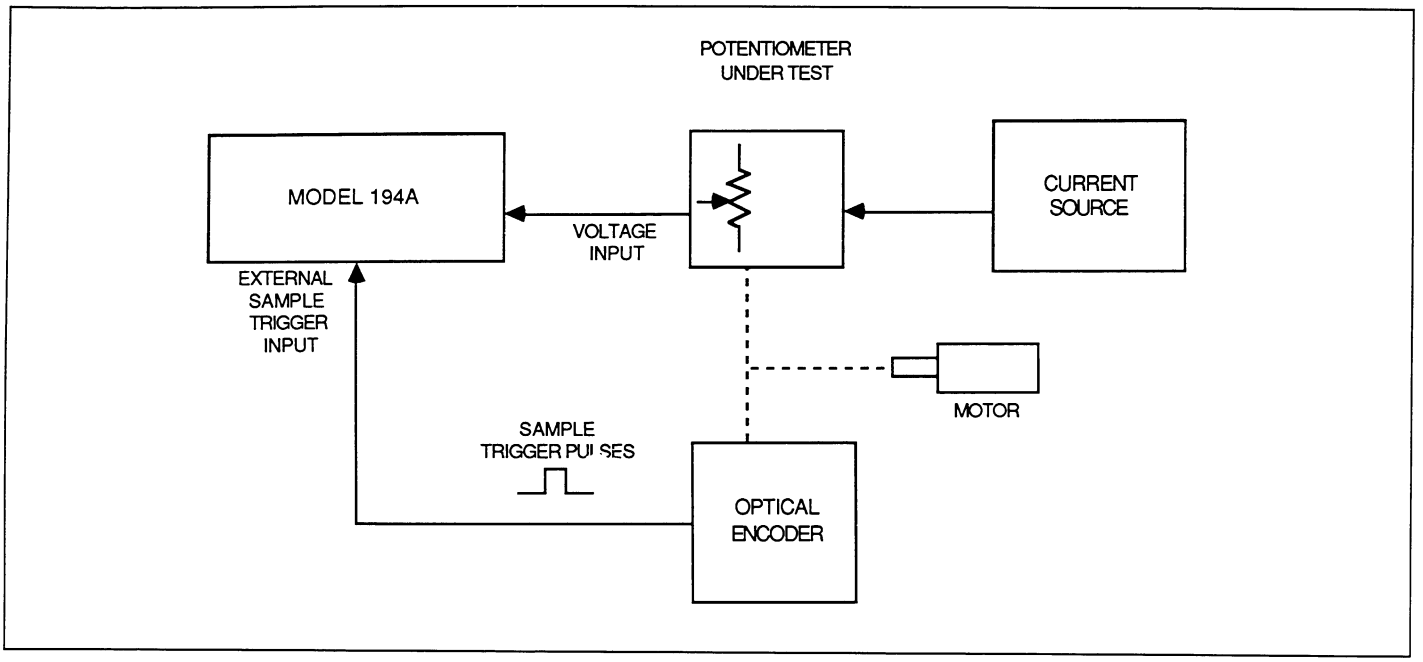


Figure 3-36. Potentiometer Testing

In order to run the test, the current source is set to the desired value, and the motor rotates the potentiometer shaft. As the shaft rotates, the optical encoder generates SAMPLE TRIGGER pulses at precise increments of rotation (typically 1 to 2 degrees). Once all samples are collected, it is a simple matter to determine the resistance from the voltage stored at each rotational position and the sourced current. Note that it is not necessary to rotate the shaft at a constant rate because the exact position of each voltage reading is accurately determined by triggering each Model 194A sample with the optical encoder.

Manual Sample Triggering

In some situations, it may be necessary to manually trigger individual samples. For example, an operator may be testing a number of individual components, in which case a separate sample would be required for each component.

For such manual testing, a suitable switch (such as a foot switch) can be connected to the sample trigger cable. In order to eliminate the effects of contact bounce, a suitably long sampling interval should be programmed; a 50msec interval should be sufficient in most cases. Note that it is not necessary to add a pull-up resistor as SAMPLE TRIGGER is internally pulled up to +5V.

Multiple Component Testing

The Model 194A can be used in conjunction with a scanner to test multiple components. For example, assume that the equipment shown in Figure 3-37 is to be used for batch testing of resistors. Again current is supplied by the source to develop a voltage across the resistor under test. The scanner, of course, is used to select the device under test, and it also provides the SAMPLE TRIGGER for the Model 194A through the CHANNEL READY output.

For complete automation, all the equipment is connected to a computer through the IEEE-488 bus. At the start of the test, the source is programmed for the desired current, and the scanner is then triggered to connect the first resistor for testing. At the end of the settling time, the scanner triggers the Model 194A measurement to take a sample, and then sequences to the next resistor. The process repeats, one sample per resistor, until the voltage across all resistors is measured and stored in the Model 194A measurement buffer.

At the end of the test, the individual samples could be read into the computer for further data processing. Alternately, a Model 194A math function such as standard deviation, average, or peak-to-peak could be applied to the data to determine resistor uniformity.

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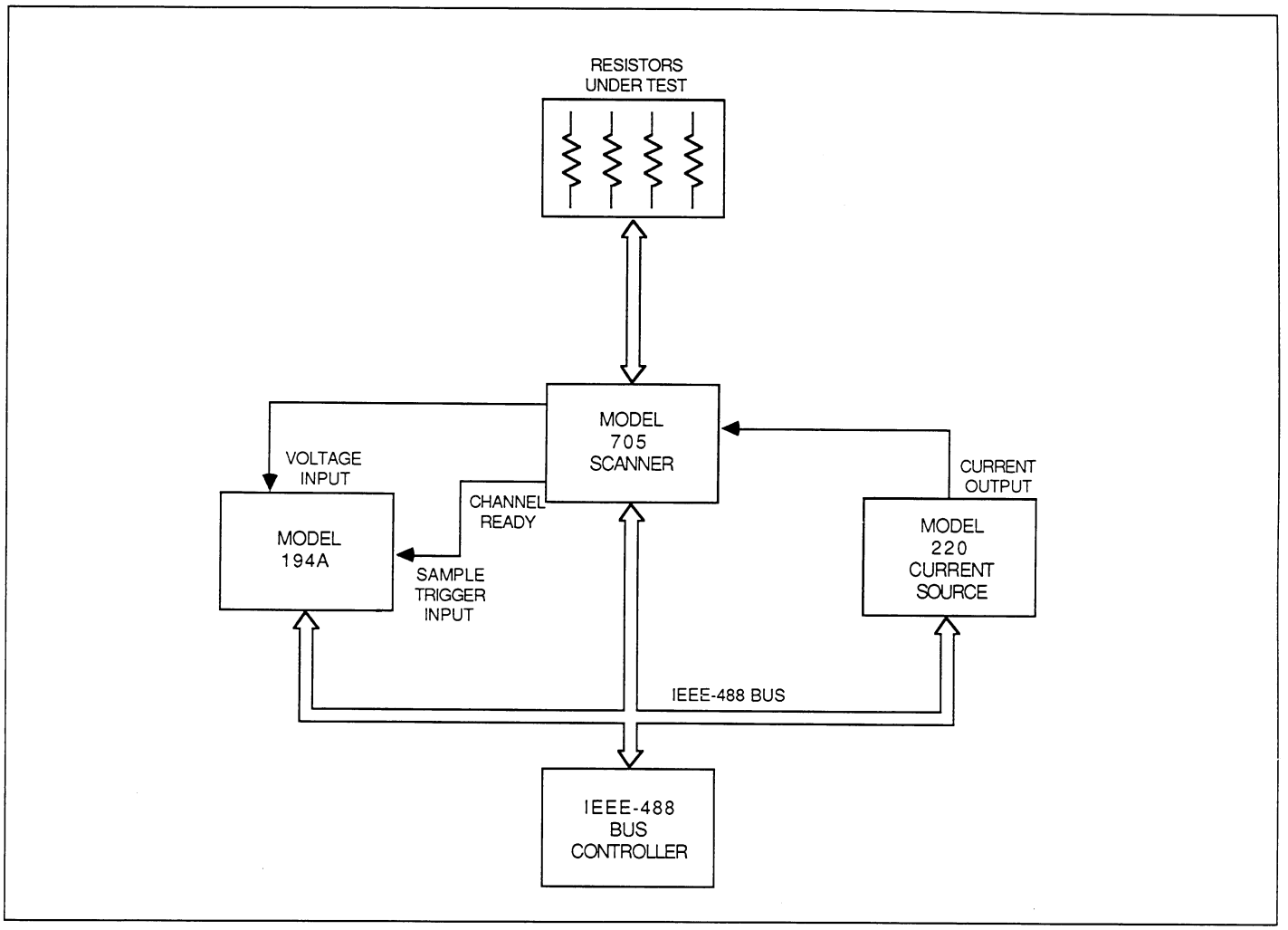


Figure 3-37. Automated Multiple Component Testing

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SECTION 4
IEEE-488 PROGRAMMING

4.1 INTRODUCTION

This section contains information on programming the Model 194A over the IEEE-488 bus. Detailed instructions for all programmable functions are included; however, information concerning operating modes presented elsewhere is not repeated here. Refer to Sections 2 and 3 for information not found in this section.

A detailed overview of the IEEE-488 bus is located in Appendix G. Device-dependent commands are summarized on pages 4-17 through 4-19 and in Appendix E.

Section 4 contains the following information:

4.2 A Short-cut to IEEE-488 Operation: Gives a simple step-by-step procedure for getting on the bus as quickly as possible.

4.3 Bus Connections: Shows typical methods for connecting the instrument to the bus.

4.4 Interface Function Codes: Defines IEEE standard codes that apply to the instrument.

4.5 Primary Address Selection: Tells how to program the instrument for the correct primary address.

4.6 Controller Programming: Demonstrates simple programming techniques for typical IEEE-488 controllers.

4.7 Front Panel Aspects of IEEE-488 Operation: Describes the operation of the LOCAL key and bus status indicators, and summarizes front panel messages that may occur during bus operation.

4.8 General Bus Command Programming: Outlines methods for sending general bus commands to the instrument.

4.9 Device-Dependent Commands: Contains descriptions of most of the programming commands used to control the instrument over the bus.

4.10 Using the Translator Mode: Describes an alternate programming method of using easily recognized user-defined words in place of device-dependent commands.

4.11 Bus Data Transmission Times: Lists typical times when accessing instrument data over the bus.

4.2 A SHORT-CUT TO IEEE-488 OPERATION

The paragraphs below will take you through a step-by-step procedure to get your Model 194A on the bus as quickly as possible and program basic operating modes. Refer to the remainder of Section 4 for detailed information on IEEE-488 operation and programming.

Step 1: Connect Your Model 194A to the Controller

With power off, connect the Model 194A to the IEEE-488 interface of the controller using a standard interface cable. Some controllers such as the HP-85 include an integral cable, while others require a separate cable. Paragraph 4.3 discusses bus connections in more detail.

Step 2: Select the Primary Address

Much like your home address, the primary address is a way for the controller to refer to each device on the bus individually. Consequently, the primary address of your Model 194A (and any other devices on the bus, for that matter), must be the same as the primary address specified in the controller's programming language, or you will not be able to program instrument operating modes and obtain data over the bus. Keep in mind that each device on the bus must have a different primary address.

The primary address of your Model 194A is set to 9 at the factory, but you can program other values between 0 and 30 by pressing SHIFT, OTHER, ENTER, and then using the data entry keys to change the primary address. Once the desired value is displayed, press ENTER to program the value.

More detailed information on primary address selection is located in paragraph 4.5.

Step 3: Write Your Program

Even the most basic operations will require that you write a simple program to send commands and read back data

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from the instrument. Figure 4-1 shows a basic flow chart that a typical simple program will follow. The two programming examples below follow this general sequence. These programs will allow you to type in command strings to program the instrument and display data on the computer CRT.

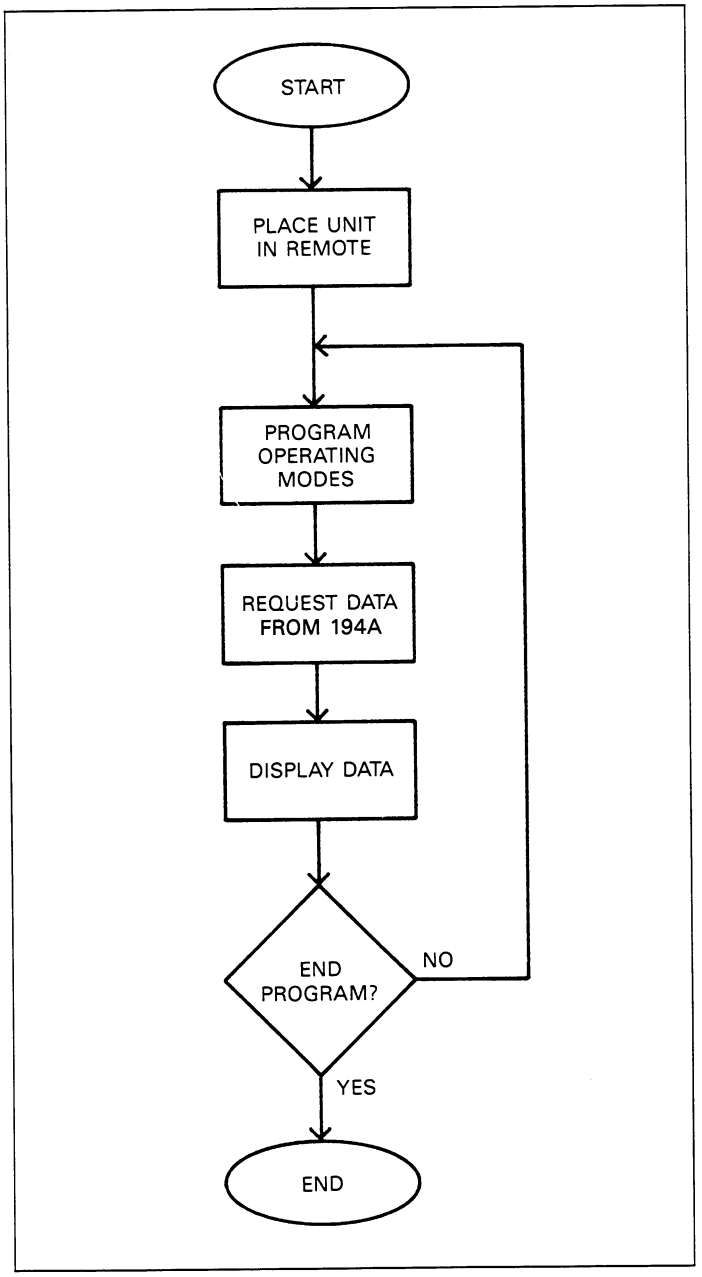


Figure 4-1. Typical Program Flow Chart

HP-85 Programming Example—Use the simple program below to send programming commands to the Model 194A and display the data string on the computer CRT.

PROGRAM	COMMENTS
`10 REMOTE 709`	Send remote enable.
`20 DISP ''COMMAND''; `	Prompt for command string.
`30 INPUT C$`	Input the command string.
`40 OUTPUT 709; C$`	Send command string to 194A
`50 ENTER 709; A$`	Get a reading from the instrument.
`60 DISP A$`	Display the reading.
`70 GOTO 20`	Repeat.
`80 END`	

Model 8573 Programming Example—Add the lines below to the modified declaration file (see Model 8573 Instruction Manual or paragraph 4.6.3 of this manual) to program instrument operating modes and display data on the computer CRT.

PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Send remote enable.
`20 INPUT''COMMAND'' ;CMD$`	Prompt for command string.
`30 IF CMD$=''EXIT'' THEN 90`	Type in EXIT to end program.
`40 CALL IBWRT (M194%,CMD$)`	Send command string to 194A.
`50 RD$=SPACE$(25)`	Define reading input buffer.
`60 CALL IBRD (M194%,RD$)`	Get reading string from 194A.
`70 PRINT RD$`	Print reading string.
`80 GOTO 20`	Repeat.
`90 V%=0:CALL IBONL (M194%,V%)`	Close the instrument file.
`100 CALL IBONL (BRD0%,V%)`	Close the board file.

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Step 4: Program Model 194A Operating Modes

You can program instrument operating modes by sending the appropriate command, which is made up of an ASCII letter representing the command, followed by one or two numeric parameters separated by commas for the command option. Table 4-1 summarizes the most often used Model 194A commands.

A number of commands can be grouped together in one string, if desired. Also, you must terminate the command or command string with the X character in order for the instrument to execute the commands in question.

If you are using the programming examples from Step 3 above, simply type in the command string when prompted to do so. Some example strings are given below.

C1X: select channel 1.
F0R0X: program waveform function, autoranging.
F1N0,1200X: program average function, 1200 samples per measurement.
I1R3F7X: program AC coupling, 32V range, integral function.

NOTE

Many controllers, including the HP-85 and IBM-PC, use commas to delimit their BASIC INPUT statements. When using the above programs, use different delimiter such as / or <space> in dual-parameter commands. For example, use N0/100X instead of N0,100X.

Step 5: Get Readings from the Model 194A

Usually, you will want to obtain one or more readings from the Model 194A. In the example programs above, a single reading is requested and displayed after each command. In other cases, you may wish to program the instrument configuration at the beginning of your program, and then obtain a whole series of measurements.

The basic reading string that the Model 194A sends over the bus is in ASCII characters of the form:

NDCV-1.2345E+0, CH1

where: N indicates a normal reading (O would indicate an overflow),
DCV shows the math function in effect (in this case, waveform),
-1.2345 is the mantissa of the reading data,
E+0 represents the exponent.
CH1 is the channel number (1 or 2)

Note that a variety of both ASCII and binary data formats are available, as discussed in paragraph 4.9.

4.3 BUS CONNECTIONS

The Model 194A is intended to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 4-2. The connector is designed to be stacked to allow a number of parallel connections at one instrument. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark colored screws. Earlier versions had different screws, which were silver colored. Do not attempt to use these type of connectors on the Model 194A, which is designed for metric threads.

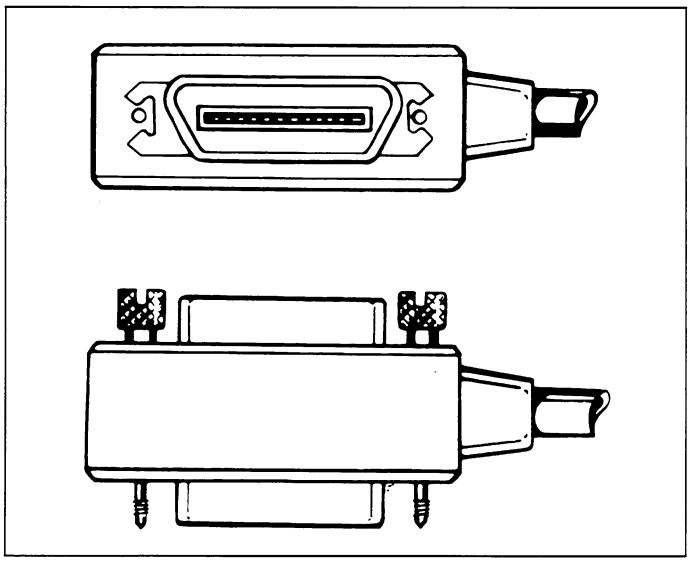


Figure 4-2. IEEE-488 Connector

A typical connecting scheme for a multiple-instrument test setup is shown in Figure 4-3. Although any number of connectors can be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.

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Table 4-1. Summary of Most Often Used IEEE-488 Commands

Mode	Command	Description
Execute	X	Execute other device dependent commands.
Function (Fn)	F0	Waveform (sample at trigger)
	F1	Average
	F2	TRMS
	F3	+Peak
	F4	−Peak
	F5	Peak to Peak
	F6	Standard deviation
	F7	Integral
	F20	CH1−CH2
	F21	CH1/CH2
Range (Rn)	R0	Auto
	R1	320mV
	R2	3.2V
	R3	32V
	R4	200V
	R12	Cancel auto, stay on range.
Rate (Sn,m)	S0,m	Take 1 sample every m sec.
	S1,m	Take samples at m Hz frequency.
Number of Samples (Nn,m)	N0,m	Take m samples per measurement.
	N1,m	Measurement duration=m sec.
Trigger (Tn,m)	T0	Continuous, talk
	T1	Single, talk
	T2	Continuous, GET
	T3	Single, GET
	T4	Continuous, X
	T5	Single, X
	T6	Continuous, external
	T7	Single, external
	T20,m	Continuous, +Slope using trigger level m volts
	T21,m	Single, +Slope using trigger level m volts
	T22,m	Continuous, −Slope using trigger level m volts
	T23,m	Single, −Slope using trigger level m volts
	T24	Continuous, other channel
	T25	Single, other channel
	T26	Continuous, TRIGGER button
	T27	Single, TRIGGER button
	T30	Start plotting
	T31	Stop plotting
Input Coupling (In)	I0	DC coupling
	I1	AC coupling
	I2	Ground coupling
Channel (Cn,m)	C1	Channel 1
	C2	Channel 2

NOTES:
1. The following characters may be substituted for the comma delimiter. ! @ # $ % & * ( ) = / \ < > ? <space>
2. A complete table of device-dependent commands is located on pages 4-17 through 4-19.

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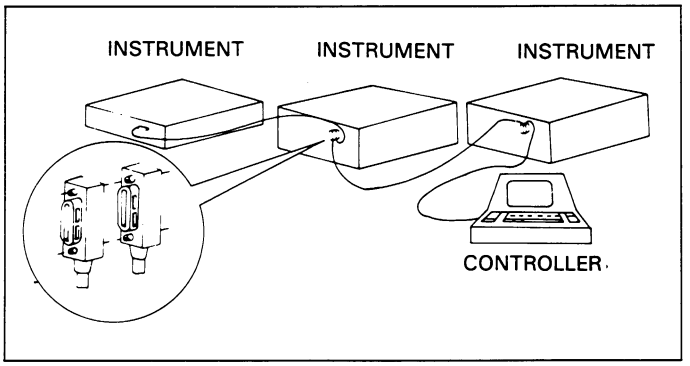


Figure 4-3. IEEE-488 Connections

Connect the Model 194A to the IEEE-488 bus as follows:

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

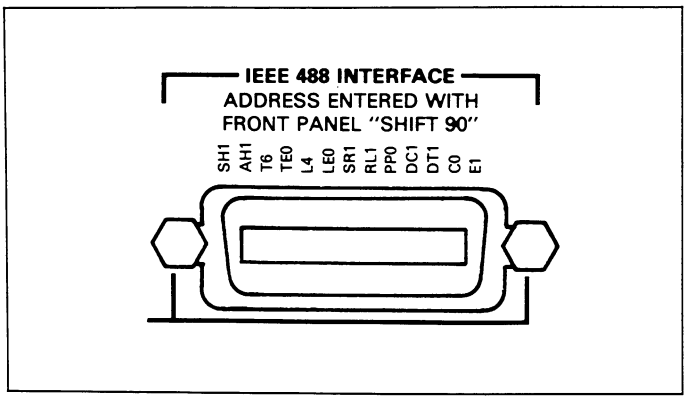


Figure 4-4. IEEE-488 Connector Location

NOTE

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

Custom cables may be constructed by using the information in Table 4-2 and Figure 4-5. Table 4-2 lists the contact assignments for the bus, and Figure 4-5 shows the contact configuration.

CAUTION

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

Table 4-2. IEEE Contact Designations

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

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

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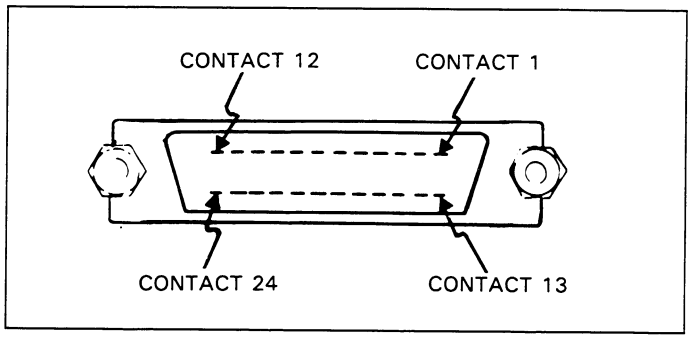


Figure 4-5. Contact Assignments

4.4 INTERFACE FUNCTION CODES

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions, and they should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 194A are listed in Table 4-3 and are listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 194A capabilities as follows:

SH (Source Handshake)—SH1 defines the ability of the Model 194A to properly handshake data or command bytes when the unit is acting as a source.

AH (Acceptor Handshake)—AH1 defines the ability of the Model 194A to properly handshake the bus when it is acting as an acceptor of data or commands.

T (Talker)—The ability of the Model 194A to send data over the bus to other devices is defined by the T function. Model 194A talker capabilities exist only after the instrument has been addressed to talk.

L (Listener)—The L function defines the ability of the Model 194A to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen.

SR (Service Request)—The SR function defines the ability of the Model 194A to request service from the controller.

RL (Remote-Local)—The RL function defines the capability of the Model 194A to be placed in the remote or local modes.

PP (Parallel Poll)—The Model 194A does not have parallel polling capabilities.

DC (Device Clear)—The DC function defines the ability of the Model 194A to be cleared (initialized).

DT (Device Trigger)—The ability for the Model 194A to have its readings triggered is defined by the DT function.

C (Controller)—The Model 194A does not have controller capabilities.

TE (Extended Talker)—The Model 194A does not have extended talker capabilities.

LE (Extended Listener)—The Model 194A does not have extended listener capabilities.

E (Bus Driver Type)—The Model 194A has open-collector bus drivers.

Table 4-3. Model 194A Interface Function Codes

Code	Interface Function
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T6	Talker (Basic Talker, Serial Poll, Unaddressed To Talk On MLA)
L4	Listener (Basic Listener, Unaddressed To Listen On MTA)
SR1	Service Request Capability
RL1	Remote/Local Capability
PP0	No Parallel Poll Capability
DC1	Device Clear Capability
DT1	Device Trigger Capability
C0	No Controller Capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker Capabilities
LE0	No Extended Listener Capabilities

4.5 PRIMARY ADDRESS SELECTION

The Model 194A must receive a listen command before it will respond to addressed commands over the bus. Similarly, the instrument must receive a talk command before it will transmit its data. These listen and talk commands are derived from the primary address of the instrument, which is set to 9 at the factory. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples in this manual assume the instrument is programmed for that address.

The primary address can be programmed for any value between 0 and 30. However, each device on the bus must have a unique primary address-- a factor that should be kept in mind when setting the primary address of the

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Model 194A. Most controllers also use a primary address; consult the controller instruction manual for details. Whatever address is used, it must be the same as the value specified as part of the controller's programming language.

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

1. Press SHIFT, OTHER, ENTER. The instrument will respond with the presently programmed primary address:

   IEEE ADDR = 09

2. In this example, the default value (9) is being displayed.
3. To exit without changing the address at this point, simply press the CHANNEL key.
4. To modify the address, key in a new value (0-30) with the numeric data keys.
5. Once the desired value is displayed, press the ENTER key. The new address will be programmed, and the instrument will return to the previous operating mode. If you key in an incorrect value, a NMBR TOO SMALL or NMBR TOO LARGE error will be displayed.
6. To permanently store the new address, press the following: SETUP, SETUP, 1, ENTER.

4.6 CONTROLLER PROGRAMMING

A number of IEEE-488 controllers are available, each of which has its own programming language. In this section, we will discuss programming languages for two typical controllers: The Hewlett-Packard HP-85, and the IBM PC equipped with a Keithley Model 8573 IEEE-488 interface.

4.6.1 Controller Handler Software

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

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

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

4.6.2 BASIC Interface Programming Statements

Most of the programming instructions covered in this section include examples written both in HP-85 BASIC, and IBM PC BASIC utilizing Model 8573 programming statements. These computers and interfaces were chosen for these examples because of their versatility in controlling the IEEE-488 bus. A partial list of statements for the HP-85 and the Model 8573 is shown in Table 4-4.

HP-85 statements have a one or three digit argument that must be specified as part of the statement. The first digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address. In the examples shown, the default Model 194A address (9) is shown. For a different address, you would of course change the corresponding digits in the programming statement.

Some of the statements have two forms, with the exact configuration depending on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command over the bus, while CLEAR 709 sends the SDC command to a device with a primary address of 9.

The Model 8573 statements listed in Table 4-4 take on a somewhat different form. These statements use the IBM BASIC CALL statement, with the 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.

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

Action	HP-85 Statement	Model 8573 Statement
Transmit string to device 9.	OUTPUT 709;A$	CALL IBWRT (M194%, CMD$)
Obtain string from device 9.	ENTER 709; A$	CALL IBRD (M194%, RD$)
Send GTL to device 9.	LOCAL 709	CALL IBLOC (M194%)
Send SDC to device 9.	CLEAR 709	CALL IBCLR (M194%)
Send DCL to all devices.	CLEAR 7	CMD$=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 9.	SPOLL (709)	CALL IBSRP (M194%, SB%)
Send local lockout.	LOCAL LOCKOUT 7	CMD$=CHR$(&H11):CALL IBCMD (BRD0%, CMD$)
Send GET to device.	TRIGGER 709	CALL IBTRG (M194%)
Send IFC.	ABORTIO 7	CALL IBSIC (BRD0%)

4.6.3 Model 8573 Software Configuration

Before using the Model 8573 examples throughout this section, you must configure the software with the procedure below. Note that the binary handler file GPIB.COM and the system configuration file 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. Load the Model 8573 software file 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$="DEV9":CALL IBFIND(NA$,M194%)
9 V%=9:CALL IBPAD(M194%,V%)
```

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

4.7 FRONT PANEL ASPECTS OF IEEE-488 OPERATION

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

4.7.1 Front Panel Error Messages

The Model 194A has a number of front panel error messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that may occur when sending device-dependent commands to the instrument, as summarized in Table 4-5.

Table 4-5. Front Panel IEEE-488 Messages

Message	Description
NOT IN REMOTE	Instrument programmed with REN false.
IDDC	Illegal Device-Dependent Command
IDDCO	Illegal Device-Dependent Command Option
NO A/D IN CH 2	F20 or F21 command sent with no channel 2.
NO SCANNER	Scanner command sent with no scanner.*

*Future 194A option.

The following paragraphs discuss each of these messages in detail. Note that the instrument may be programmed to generate an SRQ (paragraph 4.9.16), and the U1 error word can be checked for specific error conditions (paragraph 4.9.15) if any of these errors occur.

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Not In Remote Error

A not in remote error will occur if the instrument receives a device-dependent command and the REN (Remote Enable) line is false. In this instance, the following error message will be displayed on the front panel:

NOT IN REMOTE

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

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

```
LOCAL 7
OUTPUT 709; ''R1X''
```

Note that the NOT IN REMOTE error message is briefly displayed when the second statement above is executed.

Model 8573 Programming Example—Enter the statements below to demonstrate the NO REMOTE error message:

```
V%=0:CALL IBSRE(BRD0%,V%)
CMD$=''R1X'':CALL IBWRT(M194%,CMD$)
```

Note that the NOT IN REMOTE error message is displayed when the second statement above is executed

IDDC (Illegal Device-Dependent Command) Error

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

IDDC

To correct the error condition, send only valid commands. Refer to paragraph 4.9 for device-dependent command programming details.

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

```
REMOTE 709
OUTPUT 709; ''E1X''
```

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

Model 8573 Programming Example—Demonstrate an IDDC error with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''E1X'':CALL IBWRT(M194%,CMD$)
```

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

IDDCO (Illegal Device-Dependent Command Option Error)

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

IDDCO

For example, the command Y65X has an illegal option (65) that is not part of the instrument's programming language. Thus, although the command (K) itself is valid, the option (9) is not, and the IDDCO error will result.

To correct this error condition, use only valid command options, as discussed in paragraph 4.9.

NOTE

Programming channel 2 (C2X) with no channel 2 module will result in an IDDCO error.

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

```
REMOTE 709
OUTPUT 709; ''Y65X''
```

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

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Model 8573 Programming Example—Use the statements below to demonstrate an IDDCO error:

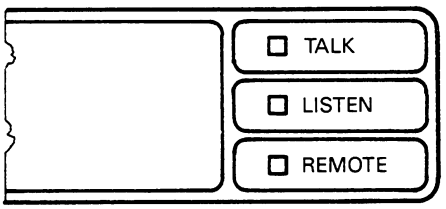
```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="Y65X":CALL IBWRT(M194%,CMD$)
```

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

4.7.2 IEEE-488 Status Indicators

The REMOTE, TALK, and LISTEN indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.

STATUS INDICATORS



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

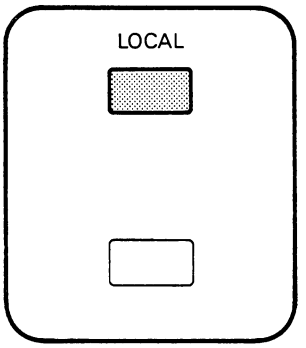
LISTEN—This indicator will be on when the Model 194A is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LISTEN will be off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

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

4.7.3 LOCAL Key

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

LOCAL KEY



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

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

4.8 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general purpose regardless of the instrument. Commands supported by the Model 194A are summarized in Table 4-6, which also lists HP-85 and Model 8573 statements necessary to send each command. Note that commands requiring a primary address assume that the Model 194A primary address is set to 9 (its factory default address). If you are using Model 8573 programming examples, be sure to use the declaration file, as described in paragraph 4.6.3.

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Table 4-6. General Bus Commands and Associated BASIC Statements

Command	HP-85 Statement	Model 8573 Statement	Effect On Model 194A
REN	REMOTE 7	V%=1:CALL IBSRE(BRD0%, V%)	Goes into effect 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 (M194%, CMD$)	LOCAL locked out.
GTL	LOCAL 709	CALL IBLOC(M194%)	Cancel remote, restore front panel operation.
DCL	CLEAR 7	CMD$=CHR$(&H14):CALL IBCMD (M194%, CMD$)	Returns to default conditions.
SDC	CLEAR 709	CALL IBCLR (M194%)	Returns to default conditions.
GET	TRIGGER 709	CALL IBTRG (M194%,)	Triggers measurement in T2 and T3 modes.

4.8.1 REN (Remote Enable)

REN is a uniline command that must be asserted by the controller to place the Model 194A in the remote mode. Simply setting REN true will not actually place the instrument in remote; instead, the unit must be addressed to listen after REN is set true.

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

To place the Model 194A in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 194A to listen.

HP-85 Programming Example—Place the Model 194A in remote with the following statement:

```
REMOTE 709
```

When the END LINE key is pressed, the Model 194A should be in the remote mode as indicated by the REMOTE annunciator light. If not, check to see that proper bus connections are made, and that the instrument is programmed for the correct primary address (9).

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

Model 8573 Programming Example—To place the Model 194A in the remote mode, type the following lines into the computer:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''X'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument goes into the remote mode when the return key is pressed the second time. Front panel controls (except LOCAL) will be inoperative. The instrument can be returned to the local mode by pressing the LOCAL key.

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4.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 194A in the talker and listener idle states. The unit will respond to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

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

```
REMOTE 709
ENTER 709;A$
```

At this point, the REMOTE and TALK indicators should be on.

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

```
ABORTIO 7
```

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

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

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=CHR$(&H49):CALL IBCMD(BRD0%,CMD$)
```

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

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

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

After the return key is pressed, the instrument will return to the talker idle state.

4.8.3 LLO (Local Lockout)

The LLO command is used to lock out operation of the LOCAL key, thereby completely locking out front panel operation of the instrument (recall that the remaining controls are locked out when the instrument is placed in remote). Operation of the LOCAL key can be restored by using the GTL command, as described in paragraph 4.8.4 below.

The instrument must be in remote to respond to LLO. However, if you send LLO with the unit in local and REN true, it will go into local lockout when next placed in remote. To permanently cancel LLO, REN must be set false.

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

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

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

```
REMOTE 709
LOCAL LOCKOUT 7
```

After the second statement is executed, the LOCAL key will be locked out.

Model 8573 Programming Example—Enter the following statements into the IBM PC to demonstrate the LLO command:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="X":CALL IBWRT(M194%, CMD$)
CMD$=CHR$(&H11):CALL IBCMD(BRD0%,CMD$)
```

After return is pressed the second time, the LOCAL key will be locked out.

4.8.4 GTL (Go To Local)

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

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

1. Set ATN true.
2. Address the Model 194A to listen.
3. Place the GTL command byte on the data lines.

HP-85 Programming Example—Place the instrument in the remote and LOCAL lockout modes with the following statements:

```
REMOTE 709
LOCAL LOCKOUT 7
```

Verify that the instrument is in remote and that LOCAL is locked out.

Send GTL as follows:

```
LOCAL 709
```

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

Model 8573 Programming Example—Place the instrument in the remote and LOCAL lockout modes with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="X":CALL IBWRT(M194%,CMD$)
CMD$=CHR$(&H11):CALL IBCMD(BRD0%,CMD$)
```

Verify that the instrument is now in remote, and that the LOCAL key is locked out.

Now send GTL with the following statement:

```
CALL IBLOC(M194%)
```

After the above statement is executed, the instrument will revert to the local mode, and operation of the front panel keys will be restored.

4.8.5 DCL (Device Clear)

The DCL command may be used to clear the Model 194A and return the unit to default conditions. Essentially, this command will perform the same function as the front panel RESET key, in that the instrument will return to the SETUP 1 configuration. Table 4-7 lists factory default conditions for the instrument after it receives a DCL.

NOTE

The primary address is not changed by DCL or SDC.

Table 4-7. Power On, DCL, or SDC Default Conditions

Mode	Command	Status
Function*	F1	Average
Range*	R0	Autorange
Rate*	S0,166.7	166.7μsec
Samples*	N0,101	101 samples
Trigger Mode	T26	Continuous, immediate
Delay*	W0,0	0 Samples
Data Format	G2	Single reading, prefix on, suffix on
Analog Output	O0	Disabled
Buffer Pointer	B0	Waveform cleared
Reading Buffer	Q0	Disabled
Filter*	P0	Filter off
Zero*	Z0	Disabled
Input Coupling*	I0	DC Coupling
SRQ	M0	Disabled
Channel	C1	Channel 1
EOI and Bus Hold Off	K0	Both Enabled
Terminator	Y<13 10>	CR LF
Primary Address†		9

*These modes are deteremined by the SETUP 1 (A1) configuration.
†Primary address is not affected by DCL/SDC.

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—Using several front panel buttons, alter instrument configuration from the factory default value and enter the following statement into the keyboard:

```
CLEAR 7
```

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

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Model 8573 Programming Example—Alter instrument configuration from the factory default value with several front panel controls and enter the following statement into the IBM PC keyboard:

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

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

4.8.6 SDC (Selective Device Clear)

SDC is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, SDC provides a method for clearing only a single, selected instrument instead of clearing all devices simultaneously, as is the case with DCL. When the Model 194A receives the SDC command, it will return to the default configuration. The factory default configuration is shown in Table 4-7, but many modes except for the primary address may be different if you change the SETUP 1 (A1) configuration.

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

1. Set ATN true.
2. Address the Model 194A to listen.
3. Place the SDC command byte on the data bus.

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

```
CLEAR 709
```

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

Model 8573 Programming Example—Alter instrument configuration with several front panel controls and enter the following statements into the IBM PC:

```
CALL IBCLR(M194%)
```

When the return key is pressed, the instrument returns to default configuration.

4.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 194A measurement sequence if the instrument is placed in the appropriate trigger mode (see paragraph 4.9). Once triggered, the instrument will perform the measurement sequence in accordance with previously selected rate and sample parameters.

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

1. Set ATN low.
2. Address the Model 194A to listen.
3. Place the GET command byte on the data bus.

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

```
REMOTE 709
OUTPUT 709;"T3X"
```

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

```
TRIGGER 709
```

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

Model 8573 Programming Example—Type in the following statements to place the instrument in the correct trigger mode for this demonstration:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="T3X":CALL IBWRT(M194%,CMD$)
```

Trigger the measurement sequence by sending GET with the following statement:

```
CALL IBTRG(M194%)
```

The measurement sequence will be triggered when the above statement is executed.

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4.8.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 194A status byte. The status byte contains important information about internal functions, as described in paragraph 4.9.16. The serial polling sequence can also be used by the controller to determine which instrument on the bus has asserted SRQ (Service Request).

The serial polling sequence is generally conducted as follows:

1. The controller sets ATN true.
2. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll enabled mode and waiting to be addressed.
3. The Model 194A is then addressed to talk.
4. The controller sets ATN false.
5. The instrument places its status byte on the data bus to be read by the controller.
6. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

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

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

```
REMOTE 709
S= SPOLL (709)
DISP S
```

When the above statements are executed, the Model 194A is serial polled, and the decimal value of the status byte is displayed on the computer CRT.

Model 8573 Programming Example—Serial poll the Model 194A from the IBM PC computer as follows:

```
V%=1:CALL IBSRE(BRD0%,V%)
CALL IBRSP(M194%,SB%)
PRINT SB%
```

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

4.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands concerned with the Model 194A are the most important commands associated with the instrument because they control most instrument operating modes. All front panel modes (such as rate and samples), as well as some modes not available from the front panel (like SRQ and terminator) can be programmed with these commands.

Command Syntax

Each command is made up of a single ASCII capital letter followed by one or more numbers representing an option or numeric parameter of that command. For example, the range can be set over the bus by sending the letter "R" followed by a number representing the range option.

Some commands have two parameters that must be separated by commas. For example, a typical sampling rate is programmed with the following command string: S0,100E-6X. The first parameter in this case (0) is a command option that instructs the instrument to program the sampling rate in seconds, while the second parameter (100) is the actual programming data. In this instance, a sampling rate of 100μsec is being programmed.

NOTE

The following characters may be used in place of a comma: ! @ # $ % ^ & ( ) = \ / < > ? : ; <space>.

Those commands which require numeric data can be programmed in either floating point or scientific notation. Thus, the following sets of commands are equivalent:

Programmed Mode	Floating Point	Scientific Notation
Buffer pointer	B1,100X	B1,1E2X
Delay	W0,10000X	W0,1E4X

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Multiple Commands

A number of commands can be grouped together in one command string, which is generally terminated by the "X" character. This character tells the instrument to execute the command or command string, as described in paragraph 4.9.1. Commands sent without the execute character will not be executed at that particular time, but they will be stored within an internal command buffer for later execution when the execute character is finally received. Note, however, that multiple commands using the same command letter and contained within one string must each be terminated with X as in this example: O4,6XO5,5X

NOTE

Command strings must be less than 60 charatcers long.

Invalid Commands

If an invalid command is sent as part of the command string, that command will not be executed (valid commands in the string will be executed, however). Under these conditions, the instrument may or may not display a front panel error message (IDDC or IDDCO), as covered in paragraph 4.7, and it can be programmed to generate an SRQ (Service Request), as discussed in paragraph 4.9.16.

NOTE

The instrument does not check the validity of commands until the X character is received.

Some typical examples of valid command strings include:

R0X Single command string.
R1I0P1X Multiple command string.
Q 1X Space is ignored
N0,100X Dual-parameter command string (parameters separated by comma)
S0/250E-6X dual-parameter command delimited by /.

Typical invalid command strings include:

E1X Invalid command, as E is not one of the instrument's valid commands.
Y65X Invalid command option because 65 is not an option of the Y command.
N0100E-6X Dual parameter command without the necessary separating comma or other legal delimiter.

The list below details which device-dependent commands will generate the IDDCO error message, and those commands which incorporate auto bounding. Auto bounding is when the unit automatically changes the option to within the valid range. For example, U20X will be changed to U12X, while U−1X will be changed to U0X.

Device-Dependent Command(s)	Action
J, F, B, T, L, M, D	No IDDCO, no autobound
Q, P, I, A	No IDDCO, autobound 0-2
G	No IDDCO, autobound 0-7
K	No IDDCO, autobound 0-3
H	No IDDCO, autobound 0-38
U	No IDDCO, autobound
C	No IDDCO, 2-8 gives NO SCANNER, 12 gives NO A/D IN CH2
F	No IDDCO, no autobound, 20, 21 give NO A/D in CH2, if appropriate. 9-19 are ignored.
R	No IDDCO, 12 disables autorange, other values autobounded 0-3.
S	No IDDCO, freq converted to time (if appropriate) then autobounded 1μsec-1sec.
N	No IDDCO, time converted to #samples (if appropriate), then autobounded 1-65,535.
W	No IDDCO, time converted to #samples (if appropriate), then autobounded 32,768−10^7 (16-bit), 65,536−10^7 (8-bit)
Z	No IDDCO, autobound first parameter 0-5 autobound second parameter −250V to +250V.
Y	IDDCO if not valid terminator, no autobound.
O	No IDDCO, first parameter 0, 1, 9 (no second) parameter. First parameter 2-8, (no autobound).

Device-Dependent Command Summary

Device-dependent commands that control the Model 194A are summarized in Table 4-8, which also lists the pertinent paragraph where each command is covered in detail. As listed, all command letters are in upper-case format; however, you can substitute corresponding lower-case letters, if desired. For example, you can use r1X in place of R1X.

NOTE

The X (execute) character must be in upper case.

Note that you can also use the translator mode to customize your programming language. The translator mode is discussed in detail in paragraph 4.10.

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Command Hierarchy

Device-dependent commands are not necessarily executed in the order received. Instead, the instrument processes them in a specific order once the X (execute) character is received. The 194A device-dependent command execution order is (first to last): C, J, G, K, Q, H, A, U, B, O, M, Y, D, F, R, P, I, S, N, T, W, Z, L.

Of course, you can dictate the desired order simply by placing the X character after each command or command grouping to force a particular sequence.

Table 4-8. Device-Dependent Command Summary

Mode	Command	Description	Paragraph
Execute	X	Execute other device dependent commands.	4.9.1
Function (Fn)	F0	Waveform (Individual samples)	4.9.2
	F1	Average	
	F2	TRMS	
	F3	+Peak	
	F4	−Peak	
	F5	Peak to Peak	
	F6	Standard Deviation	
	F7	Integral	
	F20	CH1-CH2	
	F21	CH1/CH2	
Range (Rn)	R0	Auto	4.9.3
	R1	320mV	
	R2	3.2V	
	R3	32V	
	R4	200V	
	R12	Cancel auto, stay on present range	
Rate (Sn,m)	S0,m	Take 1 sample every m seconds (1E-6 ≤ m ≤ 1).	4.9.4
	S1,m	Take samples at m Hz frequency (1 ≤ m ≤ 1E6).	
Number of Samples (Nn,m)	N0,m	Take m samples per measurement (1 ≤ m ≤ 65,535).	4.9.5
	N1,m	Measurement duration=m sec (0 ≤ m ≤ 65,534).	
Trigger (Tn,m)*	T0	Continuous, talk	4.9.6
	T1	Single, talk	
	T2	Continuous, GET	
	T3	Single, GET	
	T4	Continuous, X	
	T5	Single, X	
	T6	Continuous, external	
	T7	Single, external	
	T20,m	Continuous, +Slope using trigger level m (−200 ≤ m+200).	
	T21,m	Single, +Slope using trigger level m (−200 ≤ m+200).	
	T22,m	Continuous, −Slope using trigger level m (−200 ≤ m+200).	
	T23,m	Single, −Slope using trigger level m (−200 ≤ m+200).	
	T24	Continuous, other channel	
	T25	Single, other channel	
	T26	Continuous, immediate	
	T27	Single, immediate	
	T30	Start plotting	
	T31	Stop plotting	
Delay (Wn,m)	W0,m	Wait ±m samples relative to trigger (−65,536 ≤ m ≤ 1E7)	4.9.7
	W1,m	Wait ±m sec relative to trigger (−65,536 ≤ m ≤ 1E7)	

NOTE: Following characters may be used as delimiter in place of comma: ! @ # $ % ^ & ( ) = \ / < > ? : ; <space>
Descriptions of T0 through T27 show arming, trigger source.

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Table 4-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description				Paragraph
Data Format (Gn)		ASCII/Binary	#Readings to Terminator	Prefix	Suffix	4.9.8
	G0	ASCII	1	On	Off	
	G1	ASCII	1	Off	Off	
	G2	ASCII	1	On	On	
	G3	ASCII	n	On	Off	
	G4	ASCII	n	Off	Off	
	G5	ASCII	n	On	On	
	G6	Binary	n	Off	Off	
	G7	Binary	n(Byte count)	Off	Off	
Analog Output	O0	Abort Plotter				4.9.9
	O1	Test analog output (all outputs = full scale)				
	O2,0	XY Mode off				
	O2,1	CRT Mode				
	O2,2	Scope Mode				
	O2,3	Future Expansion				
	O2,4	Slow plot (XY analog plotter)				
	O2,5	Strip chart				
	O3,0	Measurement Buffer				
	O3,1	64K RAM Buffer				
	O3,2	Display Readings				
	O3,3	IEEE-488 Reading Buffer				
	O4,m	m=X Output Full Scale Voltage ($1 \leq m \leq 10$)				
	O5,m	m=Y Output Full Scale Voltage ($1 \leq m \leq 10$)				
	O6,m	m=Z Output Blanking Level (1=High, 0=Low)				
	O7,m	m=XY Zoom Value ($0.1 \leq m \leq 1000$)				
	O8,m	m=XY Pan Value ($0 \leq m \leq 65{,}536$				
	O9	Start Plotter				
Buffer Pointer (Bn,m)	B0	Clears waveform output, decrement reading buffer pointer.				4.9.10
	B1,m	Set measurement buffer start pointer to value m.				
	B2,m	Set measurement buffer end pointer to value m.				
	B3,m	Set reading buffer start pointer to value m.				
Buffer Control (Qn)	Q0	Buffer off				4.9.11
	Q1	Linear buffer				
	Q2	Circular buffer				
Filter (Pn)	P0	Analog filter off				4.9.12
	P1	500kHz on				
	P2	50kHz filter on				
Zero (Zn,m)	Z0	Disable zero				4.9.13
	Z1	Enable zero				
	Z2	Take next measurement and store as baseline.				
	Z3,m	Take value (m) and store as baseline ($-200 \leq m \leq +200$).				
	Z4	Take next measurement as baseline and enable zero.				
	Z5,m	Take value (m) as baseline and enable zero ($-200 \leq m \leq +200$).				
Input Coupling (In)	I0	DC coupling				4.9.14
	I1	AC coupling				
	I2	Ground coupling				

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Table 4-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Status (Un)	U0	Send machine status for current channel.	4.9.15
	U1	Send error status for instrument.	
	U2	Send data status for instrument.	
	U3	Send Z parameter (value).	
	U4	Send W parameter (delay).	
	U5	Send N parameter (number samples).	
	U6	Send S parameter (sampling rate).	
	U7	Not used	
	U8	Send trigger level value.	
	U9	Send measurement buffer start pointer.	
	U10	Send measurement buffer end pointer.	
	U11	Send reading buffer start pointer.	
	U12	Send list of Translator words (same as LIST).	
SRQ (Mn)*	M0	SRQ disabled	4.9.16
	M1	Overflow	
	M2	Data condition	
	M4	Button pressed	
	M8	Reading done	
	M16	Ready to accept commands	
	M32	Error	
Channel (Cn,m)	C1	Channel 1 A/D module	4.9.17
	C2	Channel 2	
	C12	Select composite channel (no parameter changes allowed).	
EOI and Hold Off (Kn)	K0	EOI and hold off on X enabled.	4.9.18
	K1	EOI disabled, hold off on X enabled.	
	K2	EOI enabled, hold off on X disabled.	
	K3	Both EOI and hold off on X disabled.	
Terminator (Yn,m)	Ym	Program m as single terminator (m=ASCII value of character).	4.9.19
	Yn,m	Program mn as two terminators (n, m=ASCII value of character).	
	YX	No terminator	
Save (Ln,m)	L1	Save setup 1.	4.9.20
	L2	Save setup 2.	
	L4,m	Calibrate using value m ($-200 \leq m \leq +200$).	
	L5	Store cal in NVRAM.	
Recall (An)	A0	Recall factory default setup.	4.9.21
	A1	Recall setup 1.	
	A2	Recall setup 2.	
Hit Button (Hn)	Hn	Act as if button n (1-38) has been pressed.	4.9.22
Display	Daaa	Display ASCII characters aaa (14 maximum).	4.9.23
	DX	Return display to normal.	
Self Test	J1	U0 self test bytes = 01; pass	4.9.24

*Multiple SRQ conditions can be programmed by adding command option numbers. For example, M6X programs unit to SRQ on data condition and button pressed.

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Programming Examples

Throughout the following paragraphs, numerous programming examples show how to send the various commands using two typical IEEE-488 controllers: the Hewlett-Packard Model 85 computer, and the IBM PC computer equipped with a Keithley Model 8573 IEEE-488 interface. Note that all these examples assume that the instrument's primary address is at its factory setting of 9. If you change the primary address of the instrument, you must modify the various programming examples accordingly.

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

1. Set ATN true.
2. Address the Model 194A to listen. The actual listen command byte is derived by ORing the primary address with $20.
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 commands and display a front panel error message.

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

```
OUTPUT 709; A$
```

A$ in this case contains the command letters representing the command string.

General Model 8573 Programming Example—Device-dependent commands can be sent from the HP-85 using the following statement:

```
CALL IBWRT(M194%,CMD$)
```

Again, CMD$ contains the letters of the command string.

NOTE

Instead of typing in complete programming examples in this section in the direct mode, you can use the example programs in paragraph 4.2.

4.9.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 194A to execute other device-dependent commands such as F (function) or R (range). Generally, the execute character will be the last character in the command string; however, there may be some cases where it is desirable to send a string of command characters at one time, and then send the execute character later on.

Commands or command strings sent without the X character will not be executed at that time, but they will be stored within the command buffer for later execution when the X character is finally received. Once the execute command is finally given, the stored commands will be executed, assuming that all commands are valid.

4.9.2 Function (F)

The function command allows you to select the type of mathematical function applied to the samples located in the measurement buffer. Options of the F command control such operating modes as waveform, TRMS and average, as summarized in Table 4-9. Once all samples are stored in the measurement buffer, the selected math function is performed to form a reading. This reading is then displayed and stored in the reading buffer at the present cursor location, if the reading buffer is enabled (Q command).

Upon power up, or after a DCL or SDC command, the instrument will be in a mode determined by the SETUP 1 configuration (factory default, F1 average).

NOTE

When in the F0 (waveform) mode, individual samples will be transmitted when data is requested over the bus. To cancel waveform output after changing functions, either request all samples in the measurement or send a B0 command.

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Table 4-9. Function Commands

Command	Description*
F0	Waveform (single samples)**
F1	Average of measurement.
F2	TRMS of measurement.
F3	+Peak of measurement.
F4	−Peak of measurement.
F5	Peak-to-peak value of measurement.
F6	Standard deviation of measurement.
F7	Integral of measurement.
F20	Channel 1 reading minus channel 2 reading.
F21	Channel measurement divided by channel 2 reading.

*Result of math function is placed in the next available reading buffer location when buffer is enabled.
**Each request for data accesses subsequent sample.

NOTES:

1. Only one mathematical function can be used at a time. It is not possible, for example, to take the standard deviation of the average reading.
2. Ratio and difference modes are available only if the Model 1944A option is installed in the channel 2 location.
3. If the reading buffer is disabled (Q0), the most recent reading from either channel (dual channel units) will be placed into the output buffer, and will be the channel reading sent as a result of the next data request.

HP-85 Programming Example—Type in the following lines to program the instrument to take the average of the measurement buffer:

```
REMOTE 709
OUTPUT 709; "F1X"
```

When the END LINE key is pressed the second time, the instrument displays the average of the samples located in the measurement buffer.

Model 8573 Programming Example—Type in the following statements to display the average of the samples in the measurement buffer:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="F1X":CALL IBWRT(M194%,CMD$)
```

Note that the instrument displays the average of the samples after the return key is pressed the second time.

4.9.3 Range (R)

The range command, and its options, give you control over the measurement sensitivity of the instrument. Essentially, this command performs the same functions as the front panel AUTO, Uprange, and Downrange buttons.

Range command options are listed in Table 4-10. Resolution values for the four ranges for both eight and 16-bit modes are also given. For sampling rates above 100kHz (interval less than 10μsec or if more than 32,768 samples are programmed), the A/D converter operates in the 8-bit mode, resulting in reduced resolution. Paragraph 3.3 covers instrument ranges in more detail.

Upon power up, or after a DCL or SDC command, the instrument will assume a range determined by the SETUP1 (A1) configuration. Factory default is R0 (auto).

Table 4-10. Range Commands

Command	Range	Resolution	
		8-Bit	16-Bit
R0	Auto		
R1	320 mV	2.56mV	10 μV
R2	3.2 V	25.6 mV	100 μV
R3	32 V	256 mV	1mV
R4	200 V	2.56 V	10mV
R12	Cancel auto*		

*Instrument stays on present range when autorange is cancelled.

HP-85 Programming Example—Using the front panel AUTO button, cancel autoranging, if enabled, and type in the following statements:

```
REMOTE 709
OUTPUT 709; "R0X"
```

Note that the instrument changes to the autorange mode when the second statement above is executed.

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Model 8573 Programming Example—Cancel autorange (if enabled) by using the AUTO button and type in the following statements:

```
U%=1:CALL IBSRE(BRD0%,U%)
CMD$=''R0X'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument goes into the autorange mode when the above statements are executed.

4.9.4 Rate (S)

The rate (S) command allows the sampling rate to be programmed over the bus. This command performs the same operation as the front panel RATE button except that information can only be entered in units of sec (interval) or Hz (frequency). Note that the A/D converter operates with 8-bit resolution for sampling rates less than 10μsec.

The rate command general format is shown in Table 4-11.

Sampling rate in seconds: S0,m, where m is in sec.
Sampling frequency: S1,m, where m is in MHz.

Upon power up, or after a DCL or SDC command, the rate parameter will assume a value determined by SETUP 1 (A1). Factory default is 166.7μsec.

Table 4-11. Rate Commands

Command	Mode	Allowable Range
S0,m	1 sample every m sec	1E−6sec to 1sec
S1,m	Sample at m Hz	1Hz to 1E6Hz

HP-85 Programming Example—Enter the statements below to program a 100μsec rate:

```
REMOTE 709
OUTPUT 709;''S0,100E-6X''
```

When the second statement above is executed, the instrument is programmed for a sampling interval of 100μsec.

Model 8573 Programming Example—Type in the following statements to program a sampling rate of 100μsec:

```
U%=1:CALL IBSRE(BRD0%,U%)
CMD$=''S0,100E-6X'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument assumes a sampling interval of 100μsec when the second statement above is executed.

4.9.5 Number of Samples (N)

The N command allows you to program the number of samples to be taken during a measurement sequence, or in measurement duration in a manner similar to that used with the SAMPLES key on the front panel. The general format for this command is shown in Table 4-12. Note that the maximum number of samples that can be programmed depends on whether the A/D converter is operating in the 8 or 16-bit mode. For sampling rates above 100kHz (less than 10μsec), or for more than 32,768 samples, the converter operates in the 8-bit mode.

When using the N1 command to program measurement duration, the resulting number of samples will be one more than you might expect. For example, programming a duration of 100msec with a sampling interval of 1msec will result in 101 samples.

Upon power up, or after a DCL or SDC command, the instrument will assume a value determined by the SETUP 1 (A1) parameter. Factory default is 101 samples.

Table 4-12. Number of Samples Commands

Command	Description	Allowable Range
N0,m	Take m samples per measurement	1-32,767 (16-Bit) 1-65,535 (8-Bit)
N1,m	Measurement duration=m sec.	0-65,534sec (8-bit) 0-32,766 (16-bit)

HP-85 Programming Example—Type in the following statements to program the instrument for 1000 samples:

```
REMOTE 709
OUTPUT 709;''N0,1000X''
```

When the second statement above is executed, the instrument will be programmed to take 1000 samples.

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Model 8573 Programming Example—Program the instrument to take 1000 samples per measurement sequence with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''N0,1000X'':CALL IBWRT(M194%,CMD$)
```

After the second statement is executed, the Model 194A will be programmed to take 1000 samples.

4.9.6 Trigger Mode (T)

The trigger mode command programs the type of trigger stimulus to be used to initiate a measurement sequence.

A number of different methods can be used to trigger the instrument, as summarized in Table 4-13. All but three of these modes (talk, GET, and X) are available from the front panel, as described in paragraph 3.6.

Upon power up, or after a DCL or SDC command, the instrument will be in the T26, continuous immediate mode.

Before the measurement sequence can take place, the A/D converter must be armed so that it is running and processing data. Basically, there are two ways to arm the A/D converter: single or continuous. In a single mode, the A/D converter must be armed before triggering each measurement sequence. Over the bus, the A/D converter is armed by sending the instrument the command for the trigger mode in question. In a continuous mode, however, the A/D converter is automatically re-armed after each measurement. Thus, in this situation, the trigger mode command would only be required once.

Regardless of whether the single or continuous mode is used, the instrument must still receive the appropriate trigger stimulus for each measurement (the only exception to this rule is when the continuous, immediate mode has been selected and triggered by pressing TRIGGER).

Table 4-13. Trigger Commands

Command	Single/Continuous**	Trigger Stimulus	Mode
T0	Continuous	Talk Command	A/D
T1	Single	Talk Command	A/D
T2	Continuous	GET Command	A/D
T3	Single	GET Command	A/D
T4	Continuous	X Command	A/D
T5	Single	X Command	A/D
T6	Continuous	External Trigger	A/D
T7	Single	External Trigger	A/D
T20,m*	Continuous	+Edge of input signal	A/D (−200≤m+≤200V)
T21,m*	Single	+Edge of input signal	A/D (−200≤m+≤200V)
T22,m*	Continuous	−Edge of input signal	A/D (−200≤m+≤200V)
T23,m*	Single	−Edge of input signal	A/D (−200≤m+≤200V)
T24	Continuous	Other Channel	A/D
T25	Single	Other Channel	A/D
T26	Continuous	Immediate	A/D
T27	Single	Immediate	A/D
T30		Trigger Command	Start plotter
T31		Trigger Command	Stop plotter

*m is trigger level at which unit is triggered.
**Refers to single or continuous arming of A/D converter. Unit must still receive one trigger per measurement regardless of selected mode (except T26, T27).

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As an example, let us compare the T2 (continuous, GET) and T3 (single, GET) modes. Sending T2X will arm the A/D converter, at which point the unit will be processing data, waiting for the GET trigger stimulus. When GET is received, the unit will process a single measurement, re-arm the A/D converter, and then wait for another GET command before taking another measurement. Note that it is not necessary to send T2X again before triggering another measurement. In contrast, you must send a T3X command before every GET when using that trigger mode. The same general rule applies when comparing the remainder of the trigger modes listed in Table 4-13.

A number of the trigger modes, including external, input signal, and other channels are also available from the front panel. When using these modes over the bus, it is not necessary to press TRIGGER to arm the A/D converter as arming takes place when the command in question is received.

A/D Trigger Modes

The trigger modes for the A/D modules are paired according to the type of trigger stimulus as follows:

Talk (T0 and T1): The measurement will be triggered when the unit is addressed to talk over the bus.

GET (T2 and T3): The IEEE-488 multiline GET command provides the trigger in these two modes.

X (T4 and T5): The X (execute) character triggers the instrument.

External (T6 and T7): An appropriate pulse, applied to the external trigger input jack, triggers the unit (see paragraph 3.6.7).

Positive Slope (T20,m and T21,m) The unit will be triggered when the input signal rises to a level programmed by the m parameter. Note that m is given in volts.

Negative Slope (T22 and T23): The instrument will be triggered when the input signal drops to a level programmed by the m parameter. Again, m is given in volts.

Other Channel (T24 and T25): Triggering takes place when the other channel is triggered. The method used to trigger the other channel depends on its programmed trigger mode. This mode is available only if the Model 1944A module is installed in the channel 2 location.

Immediate (T25 and T27): Sending these commands will provide the necessary stimulus in these two modes.

Plotter control: T30 and T31 provide methods to initiate and stop plotting via the analog output. The appropriate action will take place when the command is received.

NOTES:

1. Omitting the trigger level parameter, m, in the T20-T23 command strings will result in a trigger level of 0V.
2. The talk, X, and GET trigger modes can be verified from the front panel with the SOURCE key (press LOCAL first to cancel REMOTE). The instrument will then display one of the following messages, as appropriate:

   TRIG ON X
   TRIG ON TALK
   TRIG ON GET

   Note that these trigger sources are available only over the bus; if you continue to press uprange/downrange, you will change the trigger source.
3. Programming the A/D converter (for example, changing range) after it has been armed will disarm the converter. To re-arm the converter under these conditions, send the appropriate trigger command. For example, instead of T3XR0X, send R0XT3X. You can program non-A/D parameters such as SRQ without disarming the converter.

HP-85 Programming Example—Place the instrument in the single, GET trigger mode with the following statements:

```
REMOTE 709
OUTPUT 709; "T3X"
```

The instrument can now be triggered by sending GET with the following statement:

```
TRIGGER 709
```

When the above statement is executed, the instrument will perform a single measurement sequence.

Model 8573 Programming Example—Place the instrument in the single, GET trigger mode by using the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="T3X":CALL IBWRT(M194%,CMD$)
```


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Trigger a reading sequence by sending GET in the following manner:

```
CALL IBTRG(M194%)
```

The instrument will perform a single reading sequence when the above statement is executed.

4.9.7 Delay (W)

The W command programs a positive or negative delay value for the start of the measurement sequence relative to the trigger point. Thus, this command performs essentially the same function as the front panel DELAY key, which is covered in detail in paragraph 3.6.

The general format for the delay command is shown in Table 4-14. The two variations of the delay command are detailed below. Note that the range of the pre-trigger variation is much smaller than that of the post trigger mode.

W0,±m: The delay period is programmed in samples.

W1,±m: The delay period is programmed in sec.

Upon power up, or after a DCL or SDC command, the instrument will assume a delay progammed by SETUP 1 (A1). Factory default is 0 samples.

HP-85 Programming Example—Type in the following lines to program a post trigger delay of 250 samples:

```
REMOTE 709
OUTPUT 709; ''W0,250X''
```

The 250 sample post trigger delay period will be programmed when the second statement above is executed.

Model 8573 Programming Example—Use the following statements to program a post trigger delay period of 250 samples:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''W0,250X'':CALL IBWRT(M194%,CMD$)
```

The 250 sample post trigger delay period will be programmed when the second statement above is executed.

Table 4-14. Delay Commands

Command	Description	Allowable Range
W0,m	Wait ±m samples relative to trigger before storing first sample.	−32768 ≤ m ≤ 1E7 (16 Bit) −65536 ≤ m ≤ 1E7 (8-Bit)
W1,m	Wait ±m sec relative to trigger.	−32768 ≤ m ≤ 1E7 (16-Bit) −65536 ≤ m ≤ 1E7 (8-Bit)

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Table 4-15. Data Format Commands

Command	ASCII/Binary	Number* Readings	Prefix	Suffix	Reading Separator**
G0	ASCII	1	On	Off	<CR LF> and EOI
G1	ASCII	1	Off	Off	<CR LF> and EOI
G2	ASCII	1	On	On	<CR LF> and EOI
G3	ASCII	n	On	Off	<, >; <CR LF> and EOI (at end)
G4	ASCII	n	Off	Off	<, >; <CR LF> and EOI (at end)
G5	ASCII	n	On	On	<, >; <CR LF> and EOI (at end)
G6	Binary	n	Off	Off	<CR LF> and EOI (at end)
G7	Binary (Byte Count)†	n	Off	Off	EOI only (at end)

*number of readings between EOI and terminators.
**Default terminator (carriage return, line feed) shown.
†Byte count does not include four-byte status word.

4.9.8 Data Format (G)

The G command gives you control over the format of the data that is transmitted by the instrument over the IEEE-488 bus. Table 4-15 lists the data format command options and the parameters controlled by each command.

Upon power up, or after a DCL or SDC command, the instrument will be in a mode determined by SETUP1. Factory default is G2.

Basically, this command allows you to control the following aspects of the data format:

1. ASCII or binary data transmission: In the G0 through G5 modes, the ASCII format is used. Transmission is done in binary form in the G7 and G8 modes.
2. Number of readings. In G0, G1, and G2, only a single reading will be sent before the terminator or EOI. In the G3, G4 and G5 modes, a number of readings may be sent from a buffer (if enabled) before the terminator and EOI. The number that will be sent can be controlled with the buffer pointer (B) command, as discussed in the next paragraph.
3. Prefix control: The prefix indicates the type of measurement, as discussed below. Various modes omit the prefix as summarized in Table 4-15.
4. Suffix control: The suffix shows the channel number and buffer location being transmitted. Various G modes omit the suffix, as indicated in Table 4-15.
5. Reading separators: The terminator and EOI sequence marks the end of the transmission sequence regardless of whether single or multiple readings are transmitted. The default terminator sequence is the commonly-used CR LF (carriage return, line feed) sequence, but other terminators can be programmed with the Y command (paragraph 4.9.19). For multiple readings, the individual readings and channel and buffer numbers will be separated by commas, except for the binary modes.

NOTES:

1. EOI will be asserted (if enabled) after each reading in G0-G2. In G3-G7, EOI will be asserted only at the end of buffer transmission.
2. The byte count sent in the G7 mode excludes the four bytes in the binary status word, and the two count bytes. Thus, the total number of bytes transmitted will always be six more than the byte count.
3. When both A/D converters are running (dual channel units), readings for each channel will be made available to the IEEE-488 bus as thay are completed. To eliminate data output from a channel, place that channel in an unused single trigger mode (for example, T3).
4. If the unit is in the waveform (F0) mode, data will come from successive measurement buffer locations.
5. If the reading buffer is enabled (Q command) data will be sent from the reading buffer, as requested. The reading suffix shows the number of readings left in the buffer.
6. To dump the complete measurement buffer in the G3-G7 modes, place the unit in waveform (F0) mode.

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7. If a buffer is not enabled (Q0 or any function but F0), only one reading will be sent in G3-G7.
8. If accessing the reading buffer in the G7 mode, the byte count will show the number of readings left in the reading buffer.
9. The buffer suffix always indicates CH1 in ratio (CH1/CH2) and difference CH1−CH2).
10. The most negative value possible in the G6 and G7 binary data formats is −32,767 instead of −32,768.

ASCII Data Format

When the instrument is placed in the G0 through G5 modes, the data string is made up of ASCII characters with the general fromat shown in Figure 4-6. The various sections of the data string include:

1. Prefix (G0, G2, G3, and G5): Indicates the type of measurement function in effect (for example, TRMS). The prefix is omitted in the G1 and G4 modes.
2. Mantissa: A 4½ digit (±32,767 counts) signed value representing the instrument reading. Note that usable resolution is only 2½ digits (±128 counts) for sampling rates above 100kHz, or for more than 32,768 samples.
3. Exponent: Indicates a multiplier for the mantissa.
4. Suffix: Indicates the channel number and the remaining number of reading buffer locations remaining when the correct format mode is in effect. When in the waveform mode, the buffer location suffix indicates the individual sample number, 0-65,535. The buffer suffix will be omitted if the reading buffer is disabled (Q0) and if the unit is not in the waveform mode.

NOTE

When requesting waveform measurements in G6 or G7 data formats, raw binary data in offset binary will be sent. In any other function the data format will be in 16 bit two's-complement form.

Binary Data Format

When the instrument is operated in the G6 and G7 modes, it will transmit data in raw binary form with the general format shown in Figure 4-7. The main advantage to using the binary data format is that fewer bytes are involved, so data transmission is more rapid than when using the ASCII data format. Note that no terminator is sent in the G7 mode, and that the byte count excludes the four bytes in the status word.

The two binary modes include a 4-byte status word as shown in Figure 4-7(c). These bytes indicate the following:

Byte 1: Overflow, zero, 16/8-bit mode, invalid numeric value, waveform present in measurement buffer.

Byte 2: Range and channel.

Byte 3: Function

Byte 4: Exponent in 2s complement form.

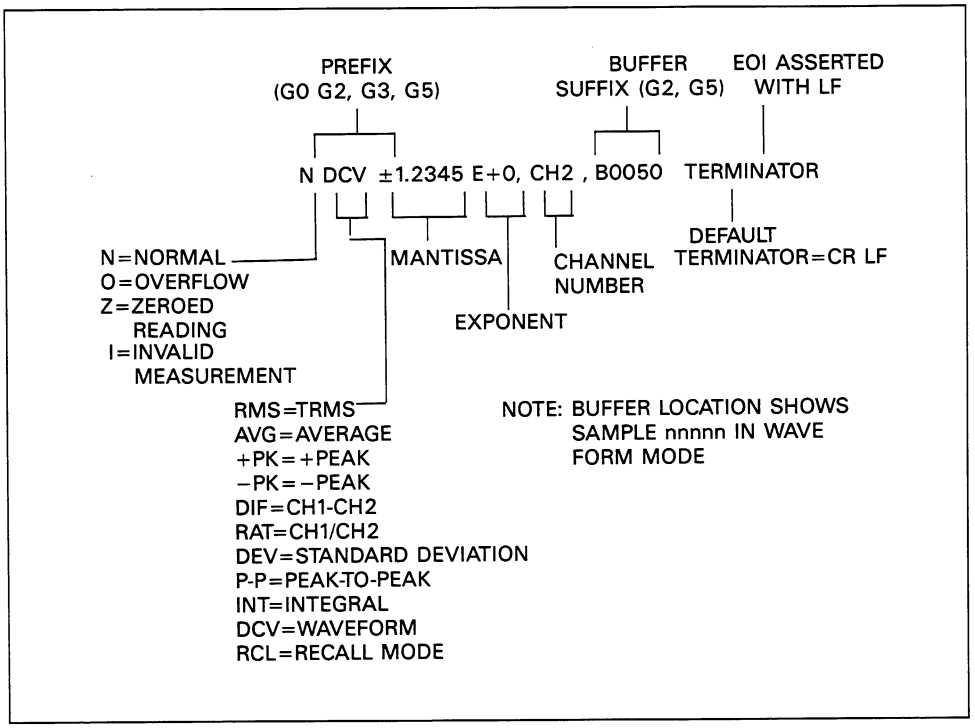
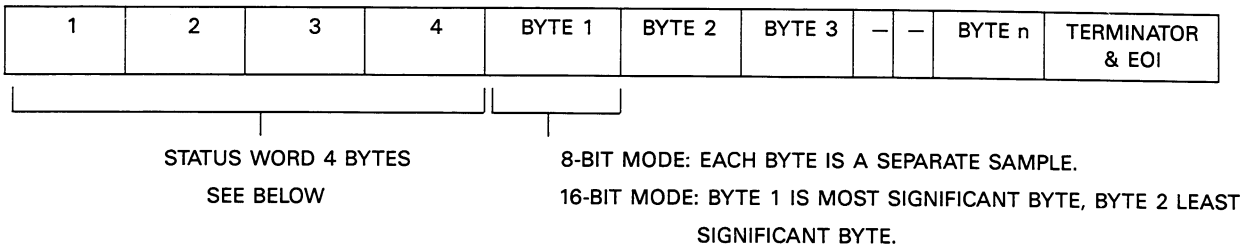


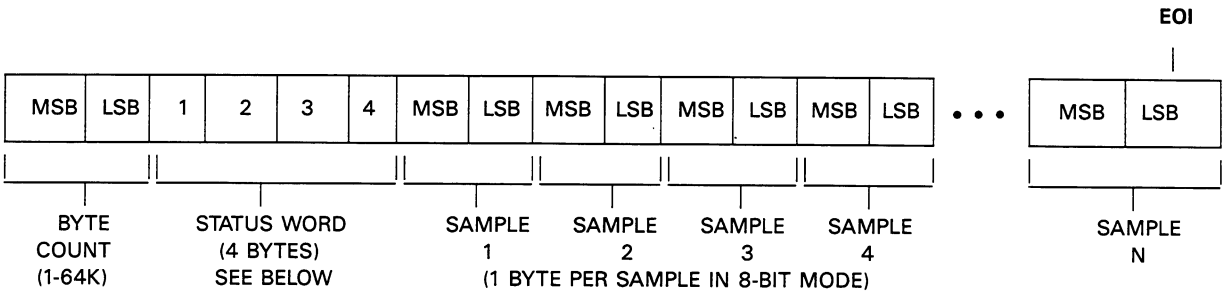
Figure 4-6. ASCII Data Format (G0 to G5)

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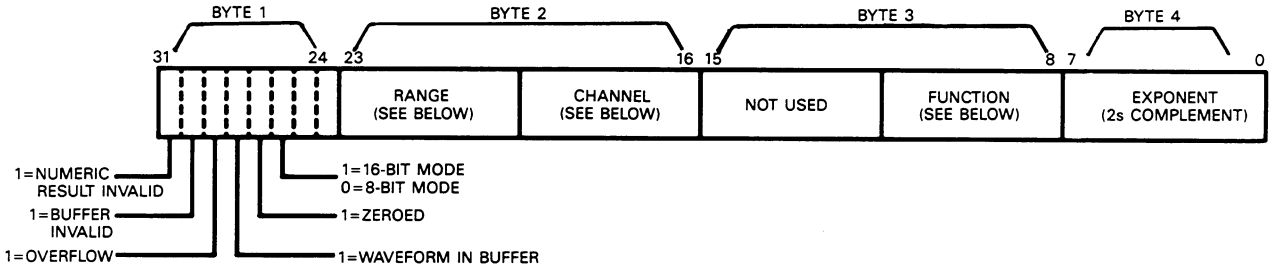
A. G6



B. G7



C.



RANGE

DECIMAL	BINARY	
0	0000	320mV
1	0001	3.2V
2	0010	32V
3	0011	200V

CHANNEL

0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8

FUNCTION

DECIMAL	BINARY	
0	0000	WAVEFORM
1	0001	AVERAGE
2	0010	TRMS
3	0011	+PEAK
4	0100	−PEAK
5	0101	PEAK-TO-PEAK
6	0110	STANDARD DEVIATION
7	0111	INTEGRAL
8	1000	RECALL

BYTE 1

INVALID NUMERIC: 1=READING IS INVALID
BUFFER INVALID: 1=MEASUREMENT BUFFER CONTAINS INVALID SAMPLE
OVERFLOW: 1=READING SAMPLE OVERFLOWED
WAVEFORM IN BUFFER: 1=MEASUREMENT BUFFER CONTAINS A WAVEFORM
8/16 BIT MODE: 1=16-BIT; 0=8-BIT
ZEROED: 1=ZERO IS ENABLED

Figure 4-7. Binary Data Formats

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Obtaining Data

Before the instrument will transmit its data string, it must be properly addressed to talk by the controller. The basic controller sequence for requesting data is as follows:

1. The controller sets the ATN line true.
2. The Model 194A is addressed to talk by placing the appropriate talk command byte on the data lines. For the default primary address (9), the correct talk command byte is $49.
3. The controller places the ATN line false.
4. The controller then begins its input sequence and inputs data bytes in succession until all are taken. Generally, the sequence will cease when the terminator is detected. Some controllers terminate on EOI.

Generally, data is placed into a string or numeric variable as the bytes are received. For example, a typical sequence for the HP-85 computer is:

```
ENTER 709; A$
```

In this instance, the complete reading string is placed in the A$ variable. In cases where numeric input is required, the instrument should be operated in a mode without a prefix and suffix (G1 or G4, for example). Under these conditions, readings can be placed directly into a numeric variable as in the example below:

```
ENTER 709; A
```

A is the variable into which the numeric value is placed. If the prefix and suffix are not eliminated with the correct G command, an incorrect value may be placed into the numeric variable.

In the G6 and G7 (binary modes), data bytes can be placed into a string variable in a similar manner. However, some form of algorithm must be used to convert data into displayable form. Consult your controller's instruction manual for details.

NOTE

This discussion assumes single channel operation. See paragraph 4.12 for more information on obtaining data with dual channel units.

HP-85 Programming Example—Use the following program to obtain and display an instrument data string.

PROGRAM	COMMENTS
`10 REMOTE 709`	Place instrument in remote.
`20 OUTPUT 709; ''G0F1T0X''`	Select data format, average mode.
`30 ENTER 709; A$`	Get reading from instrument.
`40 DISP A$`	Display the reading.
`50 END`	

In this program, the instrument is first placed in remote (line 10), and several operating modes are then programmed. The instrument is placed in the G0 data format, average, and correct reading modes (line 20), and data is then requested (line 30) and displayed (line 40). Note that data with prefix, without suffix is displayed because the instrument is in the G0 mode.

Model 8573 Programming Example—Add the following lines to the modified declaration file paragraph (4.6.3) and run the resulting program to obtain and display an instrument data string.

PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE(BRD0%,V%)`	Place 194A in remote.
`20 CMD$=''G0F1T0X'':CALL IBWRT (M194%,CMD$)`	Set data format, average mode.
`30 RD$=SPACE$(25)`	Define reading input buffer.
`40 CALL IBRD(M194%,RD$)`	Get reading string from instrument.
`50 PRINT RD$`	Display reading string.
`60 V%=0:CALL IBONL(M194%,V%)`	Close instrument file.
`70 CALL IBONL(BRD0%,V%)`	Close board file.

In the above program, the instrument is placed in remote (line 10) and then programmed for data format, waveform, and reading modes (line 20). A reading is then requested (line 40) and then displayed (line 50).

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4.9.9 Analog Output (O)

Options of the O command control plotting or graphing through the analog output. The majority of these commands perform the same function as the front panel XY mode buttons such as XY MODE, XY TRIG, and XY DATA. Full details on using the analog output may be found in paragraph 3.13.

The general format of the O command is:

On,m

where n and m are command options as indicated below:

Command	Description
O0	Abort plot if presently active.
O1	Test Analog Output (set outputs to full scale).
O2,0	XY Mode Off (Power on, DCL/SDC).
O2,1	CRT Mode
O2,2	Oscilloscope Mode.
O2,3	Future Expansion.
O2,4	Slow Plot (XY Analog Plotter).
O2,5	Strip Chart.
O3,0	Measurement Buffer.
O3,1	64K RAM Buffer.
O3,2	Display Readings.
O3,3	IEEE-488 Reading Buffer.
O4,m	Program m as X output full scale value ($1 \leq m \leq 10V$).
O5,m	Program m as Y output full scale value ($1 \leq m \leq 10V$).
O6,m	Set m as Z output blanking level (1=high; 0=low).
O7,m	Program m as XY Zoom value ($0.1 \leq m \leq 1.000$).
O8,m	Program m as XY Pan value ($0 \leq m \leq 64k$).
O9	Start Plotter.

Each of these command groups is further discussed below.

Start/Stop Plotting (O0 and O9)

These commands perform essentially the same functions as the XY TRIG button. By sending the appropriate command, you can start or stop the plot. Sending O9 with the plot mode enabled will also update the analog output buffer with current information. Note that these commands perform essentially the same functions as the T30 and T31 trigger commands.

Test Analog Output (O1)

This command sets the analog outputs to their programmed full scale values for testing purposes. The X, Y, and Z output levels are progammed with the O4, O5 and O6 commands respectively.

XY MODE (O2,m)

The O1,m command performs the same operation as the front panel XY MODE key in that it selects the type of graphing device to be used for plotting information: CRT, oscilloscope, XY analog plotter, or strip chart. In the CRT and scope modes, the horizontal resolution is 100 points, while that value increases to 4096 and programmed number of samples for the analog plotter and strip chart modes respectively.

XY DATA (O3,m)

As with the XY DATA key, this command selects the source of data for the plot: measurement buffer, 64K RAM buffer, front panel readings, or IEEE-488 reading buffer. The measurement buffer mode accesses the programmed number of samples, while the 64K RAM mode accesses the complete A/D RAM memory regardless of the programmed number of samples. Data in the front panel reading mode will be plotted as it becomes available for the front panel. The IEEE-488 reading buffer mode is controlled by the Q command.

X Output Full Scale (O4,m)

This command performs the same function as front panel Program 4. The allowable range for the X output full scale value m is 1 to 10V in 1μV increments. Note that m is in volts. Power up factory default is 10V.

Y Output Full Scale (O5,m)

O5,m programs the Y output full scale value in the same manner as front panel Program 5. The value m can be set to values in the range of 1 to 10V in 1μV increments. Again, m is in volts. Power up factory default is 10V.

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Z Output Blanking Level (O6,m)

The Z output blanking level can be set high or low with this command. If m=1, the level is high; if m=0, the level is low. Power up factory default is low.

XY ZOOM (O7,m)

The O7,m command programs a scaling factor to be applied to the plotted data. The minimum value for m is 0.1 and the maximum value is 1,000 with a resolution of 0.1. For example, if m is 2, half the measurement will appear in the final plot. Power up factory default is 1.0

XY PAN (O8,m)

The m parameter defines the first sample to appear in the final plot ($-65{,}535 \leq m \leq 65{,}536$). For example, if m is 100, the first sample to be plotted will be number 100. Power up factory default is 0.

HP-85 Programming Example—Enter the statements below to select the CRT mode:

```
REMOTE 709
OUTPUT 709; ''O2,1X''
```

The CRT mode will be selected when the second statement above is executed.

Model 8573 Programming Example—To enable the CRT mode, type the following statements into the IBM PC:

```
V%=1:CALL IBSRE(BRD0%, V%)
CMD$=''O2,1X'':CALL IBWRT(M194%, CMD$)
```

Note that the CRT mode is selected when the second statement above is executed.

4.9.10 Buffer Pointer Control (B)

The buffer pointer control commands selects the start and end pointers which define the beginning and ending points for data output for the measurement buffer when in the F0 waveform mode.

Once the pointers for the measurement buffer are set, data will be taken from that buffer beginning at the location defined by the start pointer on up to and including the last location defined by the end pointer. Once all samples defined by the start and end pointers have been taken, waveform data output will revert to normal until command is given.

Options of the B command are summarized in Table 4-16.

Table 4-16. Buffer Pointer Select Commands

Command	Description
B0	Clear waveform output; decrement reading buffer pointer.
B1,m	Use m as start pointer for measurement buffer access.
B2,m	Use m as end pointer for measurement buffer access.
B3,m	Use m as start pointer for reading buffer access.

The various options of the B command are further described as follows:

B0: Clear waveform output; decrement reading buffer pointer. If the unit is in the waveform mode (F0). B0 will return the measurement buffer start pointer to the first position and can allow data access from sample 0. B0 can also be used after changing from F0 to another function to clear waveform output and enable data output for the selected function. If the reading buffer is enabled (Q command), B0 will decrement the reading buffer pointer by one location.

B1,m: Here, m is a value that programs the start pointer for the measurement buffer. For example, with B1,10X, the first sample accessed is number 10.

B2,m: The end pointer for the measurement buffer is set to m. For example, if the command is B2,26X, the last sample accessed is 26.

B3,m: The start pointer for the reading buffer is programmed to a value of m. This value represents the first buffer location to be accessed by subsequent data requests. Note that the actual buffer location is one less than m.

NOTES:

1. The end pointer value cannot exceed the maximum size for either buffer.
2. The end pointer for the buffer cannot be set lower than the start pointer.

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3. Measurement buffer access is limited by the B1, B2 pointers only once each time one of these commands is given.
4. When programming B1,m, m can be negative to access the previous measurement as long as that measurement has not been overwritten by using pre-triggering.

Discussion

The Model 194A has two buffers associated with readings and samples: the measurement buffer and the reading buffer. The measurement buffer contains the individual samples, while the reading buffer, which is controlled with the Q command, contains up to 100 processed mathematical readings.

To access the samples located in the measurement buffer, you must first program the instrument for the F0 (waveform mode). Normally, data will be accessed in first sample-to-last sample order. That is, the first data will be sample 0, the next sample accessed will be sample 1, and so on, up to the last sample in the measurement. If you continue to request data after the last sample is taken, the unit will start again with sample 0.

By programming the start and end pointers, however, you can tell the instrument where to begin and end this transmission sequence. For example, if you program the instrument to begin at sample 10 and end at sample 20, it will start and end transmission at those points. Note however, that this pointer-limited sequence will occur only once each time a B1 or B2 command is given; the unit will then revert to normal waveform data transmission.

If you wish to cancel current waveform output and begin again at sample 0, simply send the B0 command. If the unit is still in the waveform mode, it will begin again at sample 0. If the function was re-programmed, waveform output will be cancelled, and subsequent data will reflect the programmed function.

The reading buffer operates a little differently, in that processed readings are placed in subsequent reading buffer locations as they become available. Normally, as you access reading buffer data, the number of locations left to be accessed in the buffer are transmitted as part of the data string (assuming the G2 data format is in effect). Thus, subsequent data requests will show that this number is decremented by one for each data string requested. The B3 command sets a pointer that effectively dictates the number of locations left to be accessed.

For example, assume that you turn on the buffer with the Q command and allow the buffer to fill (100 readings). With the first data access, the buffer location portion of the reading string will show 99 locations left (since you just requested a reading), the next request will show 98 readings, and so on. If you then send B3,50X, the subsequent reading string will indicate that 49 locations are then left in the buffer.

HP-85 Programming Example—Enter the statements below to program the start and end pointers for the measurement buffer to 10 and 25 respectively:

```
REMOTE 709
OUTPUT 709; ''B1,10XB2,25X''
```

The measurement buffer pointers will be set to 10 and 25 (start, end) when the second statement above is executed.

Model 8573 Programming Example—Enter the statements below to set the measurement start and end pointers to 10 and 25 respectively:

```
V%=1:CALL IBSRE(BRD0%,V%)
 CMD$=''B1,10XB2,25X'':
 CALL IBWRT(M194%,CMD$)
```

4.9.11 Reading Buffer Control (Q)

The reading buffer can store up to 100 processed mathematical readings. The Q command controls whether the buffer operates in a linear or circular manner. When either buffer mode is enabled, subsequent data requests will cause the instrument to transmit reading locations from the buffer. Both buffer types are essentially first-in, first-out buffers, but each acts a little differently once full, as described below.

Q command options are summarized in Table 4-17. The various options are further discussed below. Upon power up or after a DCL or SDC command, the reading buffer will be disabled (Q0).

When disabled, the reading buffer operates with a buffer size of one. This factor is significant only for dual-channel operation because all readings actually come from the reading buffer. Because the buffer in its disabled state contains only the most recently completed reading regardless of channel, IEEE data output may not be from the same channel as is currently being displayed on the front panel. In order to assure output from the desired channel, several steps can be taken, as discussed in paragraph 4.12.

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Table 4-17. Reading Buffer Control Commands

Command	Description
Q0	Reading buffer off.
Q1	Linear Reading buffer on.
Q2	Circular Buffer On.

Q1, Linear buffer: The instrument will store readings until all 100 readings have been stored and then stop storing when the buffer is full. Emptying the buffer re-opens it for more readings automatically.

Q2, Circular buffer: The instrument will store new readings in the buffer and then stop. Data is taken from the buffer in oldest to newest order. Figure 4-8 demonstrates the basic concept behind the circular buffer arrangement.

NOTES:

1. The buffer suffix on the reading string indicates the number of readings left in the buffer--not the buffer reading number.
2. Readings will be placed in the buffer as they become available. Readings will be placed in the buffer after each trigger stimulus.
3. For dual A/D-equipped units, channel readings will be placed in the next available buffer location as they are completed.
4. If the reading buffer is turned on with the unit in the waveform mode, only one reading buffer location is required for each waveform. Storing a new waveform in the reading buffer invalidates any previously stored waveforms.

HP-85 Programming Example—Enter the lines below in order to place the selected buffer in the circular mode:

```
REMOTE 709
OUTPUT 709; ''Q2X''
```

The selected buffer will be placed in the circular mode when the second statement above is executed.

Model 8573 Programming Example—Use the statements below in order to place the selected buffer in the circular mode:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''Q2X'':CALL IBWRT(M194%,CMD$)
```

The selected buffer will be placed in the circular mode when the second statement above is executed.

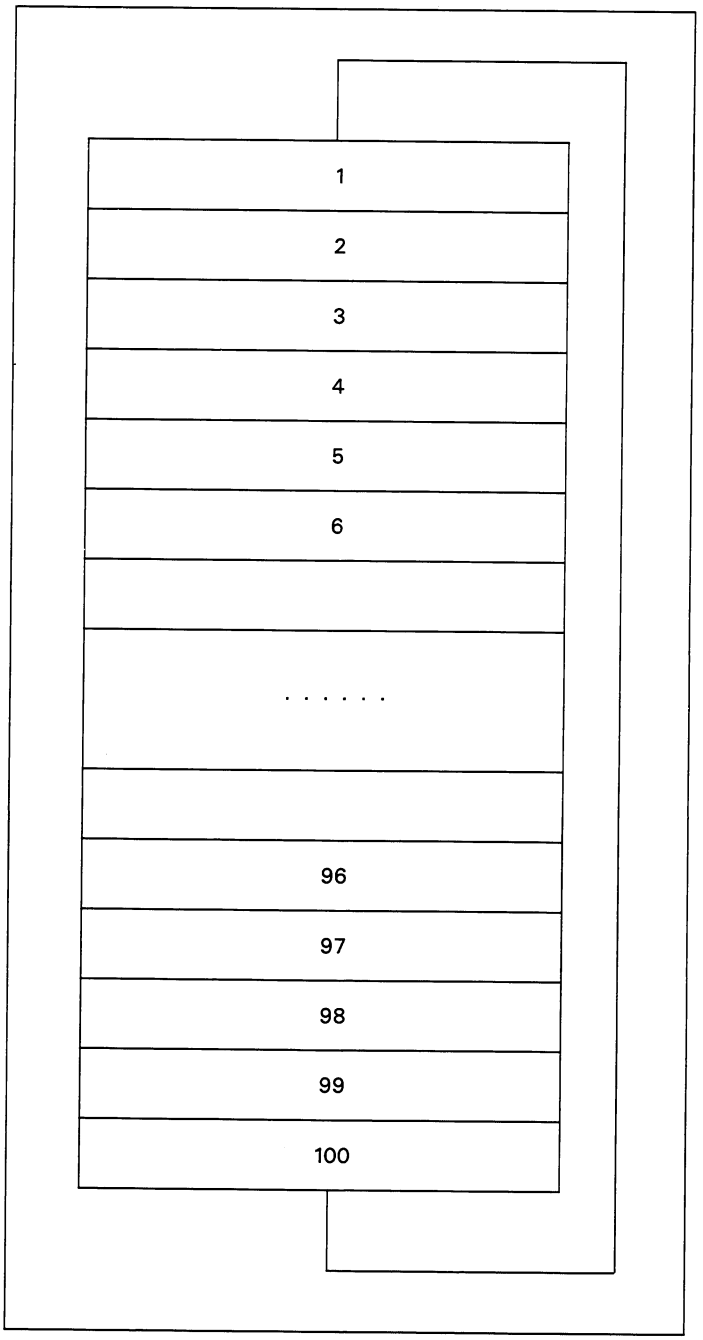


Figure 4-8. Circular Buffer

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4.9.12 Filter (P)

The filter commands and its options control the 50kHz and 500kHz analog filters. Thus, these commands control the same modes as the front panel FILTER button. Table 4-18 lists the filter command options and corresponding bandwidths. Paragraph 3.12 covers filtering in more detail.

Table 4-18. Filter Commands

Command	Description
P0	Analog filter off.
P1	500kHz bandwidth analog filter on.
P2	50kHz bandwidth analog filter on.

Upon power up, or after a DCL or SDC command, the filter will be programmed as determined by the SETUP 1 (A1) configuration. The factory default is filter off.

HP-85 Programming Example—Enter the statements below to turn on the 500kHz analog filter:

```
REMOTE 709
OUTPUT 709; "P1X"
```

When the END LINE key is pressed the second time, the 500kHz filter will be enabled.

Model 8573 Programming Example—Enable the 500kHz analog filter by typing the following statements into the IBM PC keyboard:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$="P1X":CALL IBWRT(M194%,CMD$)
```

Note that the 500kHz filter is enabled when the second statement above is executed.

4.9.13 Zero (Z)

The Z command allows a baseline value to be stored and substracted from subsequent measurements. The baseline can be obtained from an applied signal, or from a programmed value. Thus, this command and its options perform similar operations as the front panel ZERO and ZERO VAL buttons. The zero mode is covered in more detail in paragraph 3.11.

Upon power up, or after a DCL or SDC, the unit will assume a zero mode determined by the SETUP 1 (A1) configuration. Factory default is zero disabled (Z0).

Command options associated with the zero mode are summarized in Table 4-19. The basic options available with the command include:

Z0: This command disables the zero mode.

Z1: When this command is sent to the instrument, the zero mode will be enabled. The baseline value used is programmed by the Z2 or Z3 commands.

Z2: This command takes the current reading and stores it as a baseline value. Zero is not enabled by this command.

Z3,m: This command causes the instrument to take the value m and store it as the baseline value. Note that m is in volts.

Z4: This command combines the Z1 and Z2 commands. The current reading will be taken as a baseline, and the zero mode will be enabled.

Z5,m: The Z5 command combines Z1 and Z3, in that the value m will be stored as the baseline, and the zero mode will be enabled. Again, m is in volts.

Table 4-19. Zero Mode Commands

Command	Description
Z0	Disable Zero
Z1	Enable Zero
Z2	Take current reading and store it as a baseline.
Z3,m	Take value (m) and store it as a baseline ($-200 \leq m \leq 200V$).
Z4	Same as Z2 except also enable zero (Z1).
Z5,m	Same as Z3 except also enable zero (Z1) ($-200 \leq m \leq 200V$).

Upon power up, or after a DCL or SDC command, the zero mode will be set according to SETUP1 (A1) configuration. Factory default is disabled.

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NOTES:

1. If a mathematical function other than waveform is in effect, the zero baseline measurement will be subtracted from subsequent measurements after mathematical processing is performed.
2. Sending Z3 or Z5 without the m parameter will cause the instrument to use 0V.
3. The level parameter is in volt units.

HP-85 Programming Example—To enable the zero mode, type in the following statements:

```
REMOTE 709
OUTPUT 709; ''Z1X''
```

Note that the zero mode is enabled when the second statement above is executed.

Model 8573 Programming Example—Type in the following statements to demonstrate zero mode programming:

```
V%=1 :CALL IBSRE(BRD0%,V%)
CMD$=''Z1X'' :CALL IBWRT(M194%,CMD$)
```

Note that the zero mode is enabled when the second statement above is executed.

4.9.14 Input Coupling (I)

The input coupling commands, which are summarized in Table 4-20, select AC, DC, or ground coupling modes that are analogous to those found on an oscilloscope. In this manner, these command options operate in the same way as the front panel CPLG key. More detailed information on the coupling modes may be found in paragraph 3.7.

Table 4-20. Input Coupling Commands

Command	Description
I0	DC Coupling
I1	AC Coupling
I2	Ground Coupling

Upon power up, or after a DCL or SDC command, the instrument will be in a coupling mode determined by SETUP 1 (A1). Factory default is DC coupling.

HP-85 Programming Example—Use the following statements to place the instrument in the AC coupling mode

```
REMOTE 709
OUTPUT 709; ''I1X''
```

Note that AC coupling is selected when the second statement above is executed.

Model 8573 Programming Example—Type in the following lines in order to select AC input coupling:

```
V%=1 :CALL IBSRE(BRD0%,V%)
CMD$=''I1X'' :CALL IBWRT(M194%,CMD$)
```

Note that the AC coupling mode is selected when the second statement above is executed.

4.9.15 Status (U)

The status command allows access to information concerning instrument operating modes that are controlled by other device-dependent commands such as F (function) and R (range). Additional options of the status command allow access to data and error conditions, and the programmed values associated with the zero value, delay (W), number of samples, (N), rate (S), and trigger level (T).

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The status command has 12 options, as summarized in Table 4-21. These command options are discussed in the following paragraphs.

Table 4-21. Status Commands

Command	Description
U0	Machine status for current channel.
U1	Error status for entire instrument.
U2	Data status for entire instrument.
U3	Value programmed by zero (Z) command.
U4	Value programmed by delay (W) command.
U5	Value programmed by number of samples (N) command.
U6	Value programmed by rate (S) command.
U7	Not used
U8	Trigger level.
U9	Measurement buffer start pointer.
U10	Measurement buffer end pointer.
U11	Reading buffer start pointer (#readings in reading buffer).
U12	Translator word list (same as LIST)

Machine Status (U0)

When the command sequence U0X is transmitted to the Model 194A, the instrument will send its machine status word for the selected channel the next time it is addressed to talk instead of its normal data string. The status word will be transmitted only once each time the U0 command is given. To make sure that correct status is transmitted, this status word should be requested as soon as possible after the command is sent.

The format of the U0 machine status word is shown in Figure 4-9. The default values in the status word (upon power up or after a DCL or SDC command) are also shown in Figure 4-9.

Note that all returned values correspond to programmed numeric values. For example, if the instrument is in the R4 (200V) range, the corresponding byte in the status word will be an ASCII 4.

The number of the last button pressed is returned as the H parameter. Button numbers are summarized in Table 4-22.

Table 4-22. Values Returned in U0 Status for Last Button Pressed

Returned Value	Last Button Pressed	Returned Value	Button Pressed
0	None	21	ENTER
1	ZERO	22	CANCEL
2	FILTER	23	FREQ/TIME
3	TRIGGER	24	7
4	SGL/CONT	25	4
5	SOURCE	26	1
6	DELAY	27	8
7	SLOPE	28	5
8	LEVEL	29	2
9	SCAN	30	9
10	CPLG	31	6
11	SAMPLES	32	3
12	RATE	33	0
13	LOCAL	34	±
14	CHANNEL	35	.
15	AUTO	36	MHz
16	▲ ►	37	kHz
17	◄ ▼	38	Hz
18	SHIFT		
19	RECALL		
20	STATUS		

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194 Fnn Rnn Tnn Pn Zn Kn Hnn In An Ln Qn Gn Jnn Cnn Mnnn Ynnnnnn TERMINATOR

MODEL NUMBER (194)

FUNCTION (Fnn)
00=WAVEFORM
01=AVERAGE*
02=TRMS
03=+PEAK
04=−PEAK
05=PEAK TO PEAK
06=STANDARD DEVIATION
07=INTEGRAL
20=CH1-CH2
21=CH1/CH2

RANGE (Rnn)
0=AUTO*
1=320mV
2=3.2V
3=32V
4=200V

TRIGGER (Tnn)
00=CONTINUOUS, TALK
01=SINGLE, TALK
02=CONTINUOUS, GET
03=SINGLE, GET
04=CONTINUOUS, X
05=SINGLE, X
06=CONTINUOUS, EXTERNAL
07=SINGLE, EXTERNAL
20=CONTINUOUS, +SLOPE
21=SINGLE, +SLOPE
22=CONTINUOUS, −SLOPE
23=SINGLE, −SLOPE
24=CONTINUOUS, OTHER CHANNEL
25=SINGLE, OTHER CHANNEL
26=CONTINUOUS, IMMEDIATE
27=SINGLE, IMMEDIATE
30=START PLOTTING
31=STOP PLOTTING

FILTER (Pn)
0=OFF*
1=500kHz
2=50kHz

ZERO (Zn)
0=DISABLED*
1=ENABLED
2=SAVE MEAS
3=USE VAL.
4=Z1 + Z2
5=Z1 + Z3

EOI, BUS HOLD OFF (Kn)
0=EOI, HOLD OFF*
1=NO EOI, HOLD OFF
2=EOI, NO HOLD OFF
3=NO EOI, NO HOLD OFF

BUTTON PRESSED (Hnn)
00=NONE
01=ZERO
02=FILTER
03=TRIGGER
04=SGL/CONT
05=SOURCE
06=DELAY
07=SLOPE
08=LEVEL
09=SCAN
10=CPLG
11=SAMPLES
12=RATE
13=LOCAL
14=CHANNEL
15=AUTO
16=▲ ►
17=◄ ▼
18=SHIFT
19=RECALL
20=STATUS
21=ENTER
22=CANCEL
23=FREQ/TIME
24=7
25=4
26=1
27=8
28=5
29=2
30=9
31=6
32=3
33=0
34=±
35=•
36=MHz
37=kHz
38=Hz

INPUT COUPLING (In)
0=DC COUPLING*
1=AC COUPLING
2=GROUND COUPLING

RECALL SETUP (An)
0=FACTORY SETUP*
1=SETUP 1*
2=SETUP 2

SAVE (Ln)
1=SAVE SETUP 1*
2=SAVE SETUP 2
4=CALIBRATE USING VALUE
5=STORE CAL IN NVRAM

READING BUFFER (Qn)
0=DISABLED*
1=LINEAR BUFFER
2=CIRCULAR BUFFER, OVERWRITE

DATA FORMAT (Gn)
0=ASCII, PREFIX ON, SUFFIX OFF, 1RDG
1=ASCII, PREFIX OFF, SUFFIX OFF, 1RDG
2=ASCII, PREFIX ON, SUFFIX ON, 1RDG*
3=ASCII, PREFIX ON, SUFFIX OFF, n RDGS
4=ASCII, PREFIX OFF, SUFFIX OFF, n RDGS
5=ASCII, PREFIX ON, SUFFIX ON, n RDGS
6=BINARY, PREFIX OFF, SUFFIX OFF
7=BINARY, PREFIX OFF, SUFFIX OFF, BYTE COUNT

SELF TEST (Jnn)
CODE/MEANING
00=NO ERROR
01=SELFTEST COMPLETE, NO ERROR (GOES TO 00 ON U0 READ)
02=NOT USED
03=NOT USED
04=NOT USED
05=NOT USED
06=NOT USED
07=NOT USED
08=RAM ERROR ON MOTHERBOARD
09=ROM ERROR ON MOTHERBOARD
1X=A/D ERROR ON CH1 (SEE TABLE BELOW FOR X MEANING)
2X=A/D ERROR ON CH2 (SEE TABLE BELOW FOR X MEANING)

A/D ERROR CODES
0=NOISY A/D
1=NOT USED
2=INOPERATIVE CAL ADJUSTMENT
3=NOT USED
4=NOT USED
5=TIMEBASE ERROR
6=NOT USED
7=RAM ERROR

CHANNEL (Cnn)
01=CHANNEL 1*
02=CHANNEL 2
12=COMPOSITE CHANNEL

SRQ (Mnnn)
000=DISABLED*
001=OVERFLOW
002=DATA
004=HIT BUTTON
008=READING DONE
016=READY
032=ERROR

TERMINATOR (Ynnnnnn)
nnnnnn=Y(ASCII)
000000=NO TERMINATOR
013010=CR LF*

TERMINATOR
DEFAULT CR LF

*FACTORY DEFAULT

Figure 4-9. U0 Status Word

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Error Status (U1)

The U1 command allows access to Model 194A 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 4-10 the next time it is addressed to talk in the normal manner. The error condition word will be transmitted only once each time the U1 command is given. Note that the error word is actually a string of ASCII characters representing 1s and 0s.

NOTE

Bits in the U1 word will latch when corresponding conditions occur. Reading the U1 word will clear any latched bits.

An error condition is also flagged in the status (serial poll) byte, and the Model 194A can be programmed to generate an SRQ when one of these errors occurs. These aspects of Model 194A operation are covered in paragraph 4.9.16.

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

IDDC—Set when an illegal device-dependent command (IDDC) such as @1X is received (@ is illegal).

Samples Conflict—The user has programmed a valid measurement duration, then changed the sample rate to a value at which the 194A cannot take a sufficient number of samples to achieve the programmed measurement duration. The number of samples is not changed.

Delay Conflict—Same as Samples Conflict, only for trigger delay.

IDDCO—Set when an illegal device-dependent command option (IDDCO) such as K9X is received (9 is illegal).

Not In Remote—Set when a programming command is received when the REN line is false.

Trigger Overrun, Channel 1—Set when the channel 1 A/D converter is triggered when it is not armed.

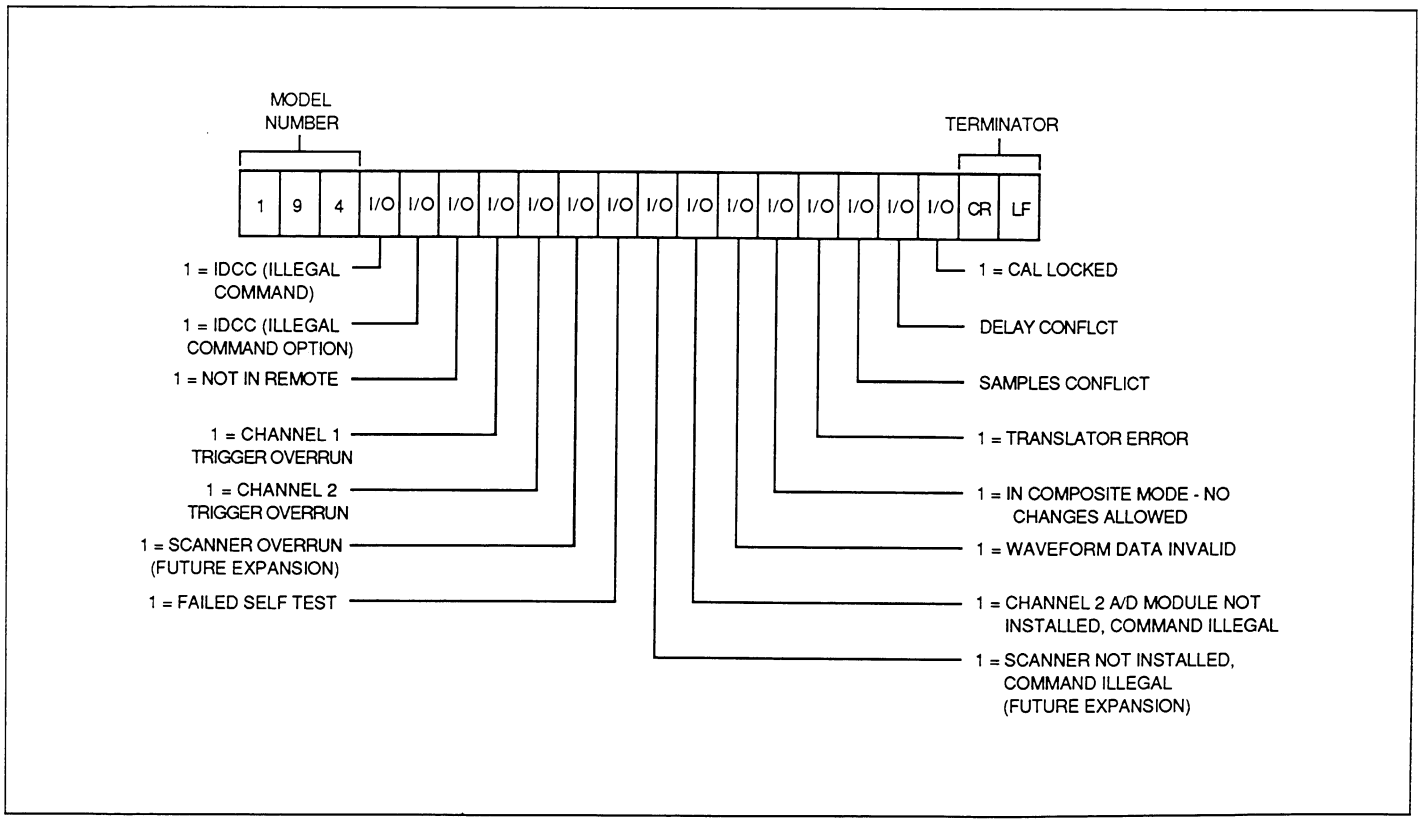


Figure 4-10. U1 Status Word Format

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Trigger Overrun, Channel 2—Set when the channel 2 A/D converter is triggered when it is not armed.

Failed Self Test—Set to 1 when a failure has occurred. The J bytes in the U0 word can then be checked to determine the nature of the error.

Scanner Overrun—Future Expansion.

Scanner Not Installed—Future Expansion.

Channel 2 A/D Module Not Installed—Set when a command associated with a module in the channel 2 location is received with that module not installed.

Waveform Invalid—Indicates that the waveform you are accessing over the bus may be invalid. Possible causes include triggering the unit without accessing all samples in current waveform and re-configuring the A/D converter (for example, changing the range).

Composite Mode—The unit is in the dual channel display mode. Mode changes are not allowed in the composite mode.

Data Status (U2)

In a similar manner, the U2 command allows access to instrument data conditions. When this command is transmitted, the instrument will transmit the data condition status word with the format shown in Figure 4-11 the next time it is addressed to talk. This information will be transmitted only once each time the command is received. Like the error word, the data word is made up of ASCII characters, most of which represent binary values. Unlike the error word, however, the data condition word will not be cleared when read. The various bits are 9 cleared by particular conditions described below.

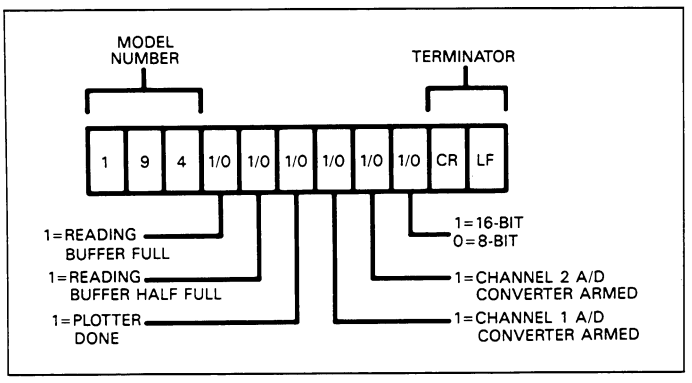


Figure 4-11. Data (U2) Status Word Format

The bits in the data condition word include:

Buffer Full—Set when all 100 readings have been stored in the reading buffer. Cleared when at least one buffer reading has been accessed.

Buffer One-half Full—Set when at least 50 readings have been stored in the reading buffer. Cleared when less than 50 readings are left to access.

Plotter Done—Set when the data plotted with the XY mode has been completed.

A/D Converter Armed—Set when the A/D converter is armed and ready to take a measurement. Cleared when the A/D converter is not armed.

8/16 Bit Mode—Indicates whether the A/D converter for the selected channel is in the 8- or 16-bit mode (0=8 bit; 1=16-bit)

NOTE

A buffer-full, one-half full, and plotter done, condition is also flagged by the data condition bit of the serial poll byte and the unit can be programmed to generate an SRQ. See paragraph 4.9.16.

Programmed Value Status (U3-U8)

These command options allow you to access the programmed parameters for the zero (Z), delay (W), number of samples (N), and sample rate (S). Figure 4-12 summarizes the formats of the returned values.

Buffer Pointer Values (U9-U11)

These status commands return the buffer pointers programmed with the B command as indicated below.

B1,m: Measurement buffer start pointer
B2,m: Measurement buffer end pointer
B3,m: Reading buffer start pointer

To access the desired parameter, simply send the desired command and address the instrument to talk in the normal manner. As with all the U command options, the corresponding status will be transmitted only once after each command is sent. The formats for the buffer pointer status values are shown in Figure 4-12.

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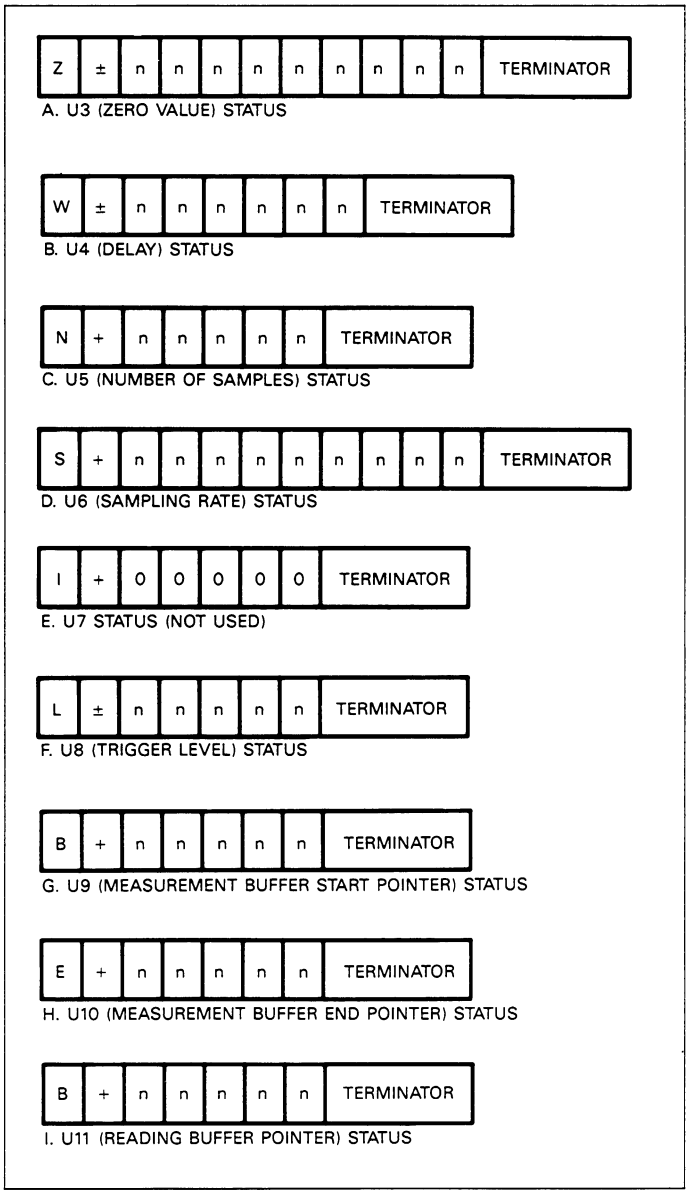


Figure 4-12. U3-U11 Status Word Format

NOTES:

1. The programmed terminator (default, CR LF) will be transmitted at the end of each status word.
2. EOI will be transmitted at the end of the status word unless disabled with the K command.
3. The U12 performs the same function as the LIST command; see paragraph 4.10

HP-85 Programming Example—Enter and run the program below to obtain and display the status words.

PROGRAM	COMMENTS
`10 DIM A$[50]`	Dimension string.
`20 REMOTE 709`	Place unit in remote.
`30 FOR I = 0 TO 11`	Loop 12 times.
`40 OUTPUT 709; "U"; I; "X"`	Program to obtain status word.
`50 ENTER 709; A$`	Get status from instrument.
`60 DISP A$`	Display status.
`70 NEXT I`	Go back and get next status word.
`80 END`	

In the example program, the instrument is placed in remote (line 20), and a loop is set up to request the 12 status words (line 30). The status word command is then sent to the instrument (line 40), and status is then requested and displayed (lines 50 and 60).

Model 8573 Programming Example—Add the following lines to the modified declaration file to obtain and display the status words.

PROGRAM	COMMENTS
`10 V%=1 :CALL IBSRE (BRD0%,V%)`	Send remote enable.
`20 FOR I = 0 TO 11`	Loop 12 times.
`30 CMD$="U"+STR$(I) +"X"`	Build status command string.
`40 CALL IBWRT (M194%,CMD$)`	Send status command.
`50 RD$=SPACE$(50)`	Define reading input buffer.
`60 CALL IBRD (M194%,RD$)`	Get status word.
`70 PRINT RD$`	Display status word.
`80 NEXT I`	Loop back for next status word.
`90 V%=0 :CALL IBONL (M194%,V%)`	Close instrument file.
`100 CALL IBONL (BRD0%,V%)`	Close board file.

In the above program, the instrument is first placed in remote (line 10), and a loop is set up to obtain the status words (line 20). The unit is then programmed for status (lines 30 and 40), and the corresponding status word is then obtained and displayed (lines 50-70).

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4.9.16 SRQ Mode (M) and Status Byte Format

The SRQ command controls which of a number of conditions within the Model 194A will cause the instrument to assert SRQ (Service Request). Once an SRQ has been generated, the status byte can be checked to determine if the Model 194A was the instrument that asserted SRQ, and, if so, what conditions caused it to do so. Note that additional data and error conditions can be checked by using the U1 and U2 status commands, as discussed in paragraph 4.9.15.

Upon power up, or after a DCL or SDC, the unit will be in the M0 (SRQ disabled) mode.

The Model 194A can be programmed to generate an SRQ under any of the following conditions:

1. If an overflowed reading has occurred.
2. If certain data conditions have occurred, including reading buffer full or half full, or plotter done in the XY mode (see paragraph 4.9.15).
3. If a front panel key has been pressed.
4. When a reading is completed.
5. When the instrument is ready to accept bus commands.
6. If an error has occurred. The nature of the error can be determined with the U1 command, as described in paragraph 4.9.15. Possible errors include: an illegal device-dependent command or command option received; the instrument was programmed while not in remote; a trigger overrun has occurred; the instrument failed the self test; a scanner command was received with no scanner installed (future option); the channel 2 A/D module is not installed; waveform data may be invalid; the unit is in the dual-channel display mode, or if a translator error occurs, or with a sample or delay conflict.

SRQ Mask

The Model 194A uses an internal mask to determine when to assert SRQ. Figure 4-13 shows the general format of the SRQ mask, which is made up of eight bits. The SRQ mask has the same general format as the status byte (discussed below) except for bit 6 which is not used in the SRQ mask.

SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit or bits in the mask. SRQ commands are summarized in Table 4-23. Note that you can program the unit for more than one set of conditions simultaneously. For example, the command sequence M9X would be sent to program SRQ under both overflow and reading done conditions.

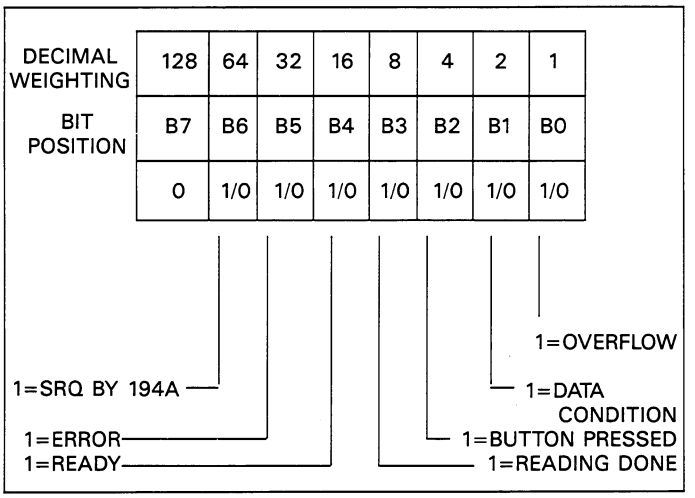


Figure 4-13. SRQ Mask and Status Byte Format

Table 4-23. SRQ Commands

Command*	Description
M0	SRQ Disabled
M1	Reading Overflow
M2	Data (Buffer full, ½ full, plotter done)
M4	Front panel button pressed.
M8	Reading Done
M16	Ready for new command.
M32	Error (IDDC, IDDCO, not in remote, trigger overrun, channel 2 not installed waveform invalid, composite mode, translator, samples or delay conflict.

*Program multiple SRQ conditions by adding individual command values. For example, send M12X for SRQ when a front panel button is pressed, and when reading is done.

Status Byte Format

The status byte contains information relating to data and error conditions within the instrument. The status byte is obtained from the instrument by using the following serial polling sequence.

1. The controller places the ATN line true.
2. The SPE (Serial Poll Enable) command byte is then placed on the bus by the controller.
3. The Model 194A is then addresssed to talk.
4. The controller sets ATN false.
5. The Model 194A places the status byte on the data lines to be read by the controller.

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6. The controller sets ATN true.
7. The SPD (Serial Poll Disable) command byte is then placed on the bus by the controller to end the serial polling sequence.

The general format of the status byte is shown in Figure 4-13. Note that most bits correspond to the bits in the SRQ mask, as described above. These bits flag the following conditions:

SRQ (bit 6)—This bit will be set if the service request was generated by the Model 194A. If bit 6 is cleared, other instruments on the bus should be checked to determine where the SRQ occurred.

Error (bit 5)—This bit will be set if one of the following errors has occurred:

1. An illegal device-dependent command (IDDC) or illegal device-dependent command option (IDDCO) was received.
2. The instrument was programmed with the REN line false.
3. A trigger overrun has occurred.
4. The unit failed the self test.
5. A channel 2 command was received with no channel 2 A/D module installed.
6. The waveform may be invalid.
7. A mode change was attempted with the unit in the dual-channel display mode.
8. A Translator error has occurred.
9. A sample or delay conflict has occurred.

Note that the exact nature of the error can be determined by using the U1 status command, as described in paragraph 4.9.15. Reading U1 will clear the error bits in the error status word and the error bit in the serial poll byte.

Ready (bit 4)—Set when the unit has processed all previous commands and is ready to accept additional commands over the bus. Cleared when the instrument is processing commands.

Reading Done (bit 3)—Set when a reading is ready to be sent over the bus. Cleared by requesting a reading over the bus.

Button Pressed (bit 2)—Set when a front panel button has been pressed (even if the unit is in remote). Cleared when the U0 status word is read.

Data Conditions (bit 1)—Set when any bit in the data status word is set. The exact nature of this condition can be determined by reading U2 status, as described in paragraph 4.9.15. Reading the U2 word clears this bit.

Reading Overflow (bit 0)—Set when an overrange input is applied to the instrument. Cleared when an on range reading requested from the instrument. Note that it may be necessary to re-program the range or re-trigger a measurement to get an on range reading.

NOTES

1. The status byte should be read once the instrument has generated an SRQ in order to clear the SRQ line.
2. All bits in the status byte will be latched when an SRQ is generated.
3. The status byte can be read to determine current instrument conditions even if SRQ is disabled.
4. If an error occurs, bit 5 (error) will remain latched until the U1 status word (paragraph 4.9.15) is requested.
5. If the corresponding data condition occurs, bit 1 will remain latched until the U2 status word is read.

HP-85 Programming Example—Enter and run the program below to demonstrate SRQ and status byte programming.

PROGRAM	COMMENTS
`10 DIM A$[50]`	Dimension string.
`20 REMOTE 709`	Place instrument in remote.
`30 OUTPUT 709;"M32X"`	Program for SRQ on error.
`40 OUTPUT 709;"E1X"`	Attempt to program illegal command.
`50 STATUS 7,2;S`	Get bus status.
`60 IF NOT BIT(S,5) THEN 50`	If no SRQ, go back and wait.
`70 S=SPOLL(709)`	Serial poll the 194A.
`80 DISP"B7 B6 B5 B4 B3 B2 B1 B0"`	Identify the bits.
`90 FOR I=7 TO 0 STEP -1`	Loop eight times.
`100 DISP BIT(S,I);`	Display the status byte bits.
`110 NEXT I`	
`120 DISP`	
`130 OUTPUT 709;"U1X"`	Program for U1 status.
`140 ENTER 709;A$`	Get U1 status to clear error.
`150 DISP A$`	Display U1 status.
`160 END`	

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In this example program, the computer first places the instrument in remote (line 20), and then programs the instrument to generate an SRQ on error. The statement at line 40 then attempts to program an illegal command (E1X). The program then waits for an SRQ to occur on the bus (lines 50 and 60), and then serial polls the instrument (line 70) and displays the status byte bits (lines 80-110). The error (U1) status word is then requested and displayed in order to clear the error bit in the status byte (lines 130-140).

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 4.6.3) to demonstrate SRQ and status byte programming.

PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Send remote enable.
`20 CMD$=''M32X''`	Build SRQ command string.
`30 CALL IBWRT (M194%,CMD$)`	Program for SRQ on error.
`40 CMD$=''E1X''`	Build illegal command string.
`50 CALL IBWRT (M194%,CMD$)`	Attempt to program illegal option.
`60 V%=&H1000:CALL IBWAIT(BRD0%,V%)`	Wait for SRQ.
`70 CALL IBRSP (M194%,SB%)`	Serial poll the 194A.
`80 MASK%=128`	Define bit mask.
`90 PRINT''B7 B6 B5 B4 B3 B2 B1 B0''`	Identify the bits.
`100 FOR I = 1 TO 8`	Loop eight times.
`110 IF (SB% AND MASK%) = 0 THEN PRINT ''0'';ELSE PRINT ''1'';`	Mask off bits and display them.
`120 MASK%=MASK%/2`	Modify mask for next bit,
`130 NEXT I`	
`140 CMD$=''U1X''`	Build command string U1 status.
`150 CALL IBWRT (M194%,CMD$)`	Program 194A for U1 status.
`160 RD$ = SPACE$(50)`	Define reading input buffer.
`170 CALL IBRD(M194%,RD$)`	Get error status.
`180 PRINT RD$`	Display error status.
`190 V%=0:CALL IBONL (M194%,V%)`	Close the instrument file.
`200 CALL IBONL(BRD0%,V%)`	Close the board file.

In the above program, the instrument is placed in remote (line 10) and then programmed to generate an SRQ under error conditions (lines 20 and 30). Next, an attempt is made to program an illegal command (lines 40 and 50), and the program then waits for the instrument to generate an SRQ (line 60). After the SRQ is generated, the instrument is serial polled (line 70), and the status bytes are then displayed (lines 90-130). Finally, the U1 error condition word is requested and displayed in order to clear the error bit in the status byte (lines 140-180).

4.9.17 Channel (C)

The C command allows selection of the channel 1 or channel 2 A/D modules (for those instruments equipped for dual-channel operation). Options of this command are summarized in Table 4-24.

NOTE

The C command affects only which channel is displayed and the channel affected by device-dependent commands. It does not, however, control the source of data sent over the IEEE-488 bus. Refer to paragraph 4.12 for more information on dual channel operation.

Table 4-24. Channel Control Commands

Command	Description
C1*	Select Channel 1
C2*	Select Channel 2
C12	Composite display channel; no mode changes allowed.

*NOTE: Selected channel determines which channel is affected by other device-dependent commands.

Upon power up, or after a DCL or SDC command, channel 1 will be selected.

C command options include:

A/D channel control (C1 and C2): Sending one of these commands will select the corresponding A/D module. The selected module determines the source of the reading displayed on the front panel. The selected channel is also the one that will be affected by most other device-dependent commands. In general, those commands which have front panel equivalents (for example, scan rate and range) can be programmed separately for each channel. Those commands which are exclusively associated with bus operation (for example, SRQ mode and terminator) affect both channels simultaneously regardless of the selected channel.

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Composite channel 1 and channel 2 (C12): This command places the unit in the dual channel display mode.

NOTES:

1. The Model 1944A option must be installed in order to use corresponding commands. The unit will display a NO A/D IN CH2 message. The instrument may be programmed to generate an SRQ if these commands are used without the appropriate option installed (paragraph 4.9.16).
2. Other modes cannot be programmed when the composite mode is in effect.

HP-85 Programing Example—Type in the following lines in order to select channel 1:

```
REMOTE 709
OUTPUT 709; ''C1X''
```

Note that channel 2 may be selected by using the correct channel number in the second statement above.

Model 8573 Programming Example—Use the following statements to select channel 1:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''C1X'':CALL IBWRT(M194%,CMD$)
```

To select channel 2, simply change the channel number in the second statement above.

4.9.18 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 (via the NRFD line) until all commands sent to the instrument are processed once the execute character is received. K command options are summarized in Table 4-25.

Table 4-25. EOI and Bus Hold-Off Commands

Command	Description
K0	Both EOI and bus hold-off on X enabled.
K1	EOI disabled, bus hold-off on X enabled.
K2	EOI enabled, bus hold-off on X disabled.
K3	Both EOI and bus hold-off on X disabled.

Upon power up, or after a DCL or SDC command, the K0 mode will be enabled.

EOI (End or Identify)

The EOI line on the IEEE-488 bus provides one method to positively identify the last byte in a multi-byte transfer sequence. Thus, EOI can be used to determine when the Model 194A is transmitting the last byte in its reading string. Note that when reading the entire buffer, EOI will be asserted only at the end of the entire buffer transmission sequence.

When enabled, EOI is asserted simultaneously with the last byte in the transmission. For example, with the default CR LF terminator, EOI will be asserted with the LF character. If the terminator is disabled, EOI will be asserted with the last byte of data.

Keep in mind that some controllers rely on EOI to mark the end of their input sequences. Thus, suppressing EOI may cause the controller input sequence to hang unless another termination method is used. Standard terminator characters are also transmitted at the end of the reading string, as discussed in paragraph 4.9.19.

Bus Hold-off

The bus hold-off mode allows the instrument to temporarily hold up bus operation when it receives the X character until all commands are processed. Keep in mind that all bus operation will be held up under these conditions--not just activity associated with the Model 194A. The advantage of using this mode is that no commands will be missed while previously received commands are being processed. Table 4-26 summarizes NRFD hold off times for various commands.

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Table 4-26. Typical NRFD Hold-off Times

Conditions	Hold-off (msec)
X TO X	15.7
F1 TO F5	132.8
F7 TO F0	132.8
R4 TO R0	163.2
S0,1 TO S0,1000	146.2
S1,1 TO S1,1000	210
N0,1 TO N0,1000	143.4
N1,.1 TO N1,.5	159.7
G1 TO G2	85.8
H1 TO H2	92.9
DNRFD TO D	77.8
P0 TO P2	212.7
T20,100 TO T23,−100	184.4
O2,0 TO O2,1	459.7
B0 TO B1,1B2,50	182.6
Q0 TO Q1	120.7
Z0 TO Z3,100	202.4
I0 TO I2	145.4
U0 TO U1	92.0
M0 TO M4	92.0
A0 TO A1	641.2
L1 TO L1	1760
C1 TO C2	135.6
K0 TO K1	128
J1 TO J1	13920

HP-85 Programming Example—Enter the following statements to program the instrument for the K2 mode:

```
REMOTE 709
OUTPUT 709; ''K2X''
```

The Model 194A will be placed in the K2 mode when the second statement above is executed. The EOI mode will be enabled, but the bus hold-off will be disabled.

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

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''K2X'':CALL IBWRT(M194%,CMD$)
```

After the above statements are executed, the instrument will be in the K2 mode. EOI will be enabled, but the bus hold-off mode will be disabled.

4.9.19 Terminator (Y)

The terminator that marks the end of the instrument's data string or status words can be programmed by sending the Y command followed by sending the ASCII value or values of the desired terminator or terminators (Table 4-27). ASCII values may be found in Appendix A. 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.

Table 4-27. Terminator Commands

Command	Description*
Yn	Use n as single terminator.
Yn,m	Use n and m as two-terminator sequence.
YX*	No terminator.

*n and m are ASCII values of desired characters.

The terminator sequence can be changed by sending the Y command followed by the ASCII values of desired one or two characters. However, the capital letters (A-Z) cannot be used since they are used as command letters.

Typical commonly-used sequences include:

1. Y10,13X=(LF CR)
2. Y13,10X=(CR LF)
3. Y13X=(CR)
4. Y10X=(LF)
5. YX=(no terminator)

NOTES:

1. Many controllers use the default terminator sequence to end their input sequences. Modifying the terminator may cause the input sequence to hang unless a different terminating method (such as EOI) is used.
2. The terminator sequence is sent only at the end of the complete transmission sequence regardless of the selected data format (G7 does not use the terminator, however).
3. The programmed terminator affects both channels simultaneously.
4. If EOI is enabled (paragraph 4.9.18), it will be asserted with the last terminator byte, or with the last byte of data if the terminator is disabled.

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5. A complete summary of ASCII character codes is located in Appendix A.
6. The instrument will not begin using a newly-programmed terminator until the second data string is sent out.

HP-85 Programming Example—Use the following statements to change the terminator to line feed only.

```
REMOTE 709
OUTPUT 709; ''Y10X''
```

Model 8573 Programming Example—Change the terminator to line feed with the following computer statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''Y10X'':CALL IBWRT
      (M194%,CMD$)
```

Note that the terminator sequence is changed to LF only when the second statement above is executed.

4.9.20 Save (L)

The save command allows two different instrument configurations to be stored in NVRAM for future recall. Additional options of the L command perform instrument calibration and store calibration parameters in NVRAM. Table 4-28 summarizes the options of the L command.

Table 4-28. Save Command Summary

Command	Description
L1	Store machine setup number 1 in NVRAM.
L2	Store machine setup number 2 in NVRAM.
L4,m	Calibrate using value m (−200 ≤ m ≤ 200V).
L5	Store calibration in NVRAM.

Save commands include:

Save machine setup (L1-L2): These commands perform essentially the same function as the front panel SETUP mode by allowing two different instrument configurations to be stored in NVRAM. Note that separate configurations for each A/D card may be saved by first selecting the desired channel, programming its various operating modes, and then using the desired save command option. Table 4-29 summarizes those instrument operating modes that can be saved in this manner. Once saved, these three instrument setups can be recalled by using the recall command described in paragraph 4.9.21.

NOTE

The unit returns to the L1 (SETUP 1) configuration upon power up or after a DCL/SDC command.

Table 4-29. Modes Stored By Save Command

Mode
Zero
Zero value
Filter
Range
Autorange (on/off)
Single/continuous Trigger Arming
Trigger Source
Trigger Delay (samples or time)
Trigger Slope
Trigger Level
Sampling Rate (interval or frequency)
Measurement Size (number samples or duration)
Math Function (average, TRMS, etc)
Input Coupling
IEEE-488 Primary Address
Data Format (G)

Calibrate (L4,m): This command calibrates the instrument using the value m. Each A/D channel of the instrument (for dual-channel models) requires separate calibration. Detailed calibration procedures are covered in Section 7.

NOTE

The calibration parameter is given in volts.

Store calibration (L5): The L5 command permanently stores calibration constants in NVRAM for the selected channel. Again, refer to Section 7 for complete details on calibrating the unit.

NOTE

In the following programming examples, do not substitute the L4 or L5 commands for those shown, or instrument calibration may be adversely affected.

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HP-85 Programming Example—Program the desired operating modes (see Table 4-29). and type in the following lines to store setup 1 for channel 1 in NVRAM:

```
REMOTE 709
OUTPUT 709; ''C1L1X''
```

When the second statement above is executed, the instrument configuration is saved in the setup 1 position.

Model 8573 Programming Example—Program the various operating modes (see Table 4-29), and type in the following lines to store the channel 1 instrument configuration in the setup 1 position:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''C1L1X'':CALL IBWRT(M194%,CMD$)
```

The present instrument configuration for the channel 1 module will be saved in the setup 1 position when the second statement above is executed.

4.9.21 Recall (A)

The recall command options allow the two setups stored with the save command to be recalled, as well as the factory default values. Recall commands are summarized in Table 4-30. To use this command, simply select the A/D channel to be recalled and then send the desired recall command. Modes that will be recalled are summarized in Table 4-29.

Upon power up, or after a DCL or SDC, the SETUP 1 (A1) configuration will be recalled.

NOTE

As shipped, all modes will be the same as A0.

Table 4-30. Recall Commands

Command	Description
A0	Factory Default
A1	Recall setup number 1.
A2	Recall setup number 2.

HP-85 Programming Example—Use the following statements to recall the setup 1 position for channel 1:

```
REMOTE 709
OUTPUT 709; ''C1XA1X''
```

Note that the instrument assumes the channel 1 operating modes stored in the setup 1 position when the second statement above is executed.

Model 8573 Programming Example—Recall the setup 1 position for channel 1 with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''C1XA1X'':CALL IBWRT(M194%,CMD$)
```

Note that channel 1 assumes the operating modes stored in the setup 1 position when the second statement above is executed.

4.9.22 Hit Button (H)

The H command and its options, allow you to emulate any front panel keystroke sequence. The H command options and corresponding front panel buttons are summarized in Table 4-31. Note that these numbers are the same as those returned by the U0 status command when the corresponding button is pressed (paragraph 4.9.15).

To emulate a particular front panel keystroke sequence, simply send the appropriate commands in order. For example, to enter the XY mode over the bus (SHIFT, XY MODE from the front panel), the following sequence would be sent: H18XH4X.

HP-85 Programming Example—Type in the following statements to emulate the SHIFT, XY MODE front panel sequence:

```
REMOTE 709
OUTPUT 709; ''H18XH4X''
```

Note that the instrument enters the XY mode when the second statement above is executed.

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Table 4-31. Hit Commands

Command	Button	Command	Button
H1	ZERO	H21	ENTER
H2	FILTER	H22	CANCEL
H3	TRIGGER	H23	FREQ/TIME
H4	SGL/CONT	H24	7
H5	SOURCE	H25	4
H6	DELAY	H26	1
H7	SLOPE	H27	8
H8	LEVEL	H28	5
H9	SCAN*	H29	2
H10	CPLG	H30	9
H11	SAMPLES	H31	6
H12	RATE	H32	3
H13	LOCAL	H33	0
H14	CHANNEL	H34	±
H15	AUTO	H35	•
H16	▲ ►	H36	MHz
H17	◄ ▼	H37	kHz
H18	SHIFT	H38	Hz
H19	RECALL		
H20	STATUS		

*SCAN is intended to control future scanner option.

Model 8573 Programming Example—Emulate the SHIFT, XY MODE front panel keystroke sequence with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%)
CMD$=''H18XH4X'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument changes to the XY mode when the second statement above is executed.

4.9.23 Display (D)

The display command allows you to send messages to the Model 194A to be displayed on the front panel. The general format of the display command is summarized in Table 4-32.

Table 4-32. Display Commands

Command	Description
DaaaaX	Display aaaa ASCII characters (14 maximum).
DX	Return display to normal mode*.

*LOCAL also returns display to normal mode.

To send a message to be displayed, simply follow the D command with the appropriate ASCII characters. Most ASCII characters that are normally displayed can be sent, including upper and lower case letters, and numbers. If a character cannot be displayed (for example, !), a dash will appear in the lower segment of the digit.

NOTE

Spaces are ignored. To display a space, use the "@" character.

As with all other commands, the string should be terminated with the execute character. For example, to display "PRESS KEY", the following command string would be used: DPRESS @ KEYX. The maximum number of characters that can be sent is 14. Any extra characters in the command string will be ignored.

To display an X character, send a lower case x, as upper case X is interpreted as an execute.

To return the instrument to the normal display mode, send DX, press the front panel LOCAL key, or issue the IEEE-488 GTL command.

HP-85 Programming Example—Use the program below to type in messages on the computer keyboard and program the instrument accordingly.

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PROGRAM	COMMENTS
10 REMOTE 709	Place 194A in remote.
20 CLEAR	Clear screen.
30 DISP''ENTER MESSAGE'';	Prompt for input.
40 INPUT A$	Input message string.
50 OUTPUT 709;''D''; A$;''X''	Program display message.
60 DISP''PRESS KEY TO CONTINUE''	Display pause message.
70 PAUSE	Pause program.
80 OUTPUT 709;''DX''	Return to normal display mode.
90 GOTO 30	Repeat.
100 END	

After typing in the above program, press the HP-85 RUN key. At the command prompt, type in your message and press the END LINE key. The message should then appear on the display of the Model 194A. Press the CONT key to repeat the sequence, and type in messages, as desired.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 4.6.3) to demonstrate operation of the display command.

PROGRAM	COMMENTS
10 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
20 CLS	Clear CRT.
30 INPUT''ENTER MESSAGE'' ;A$	Prompt for and enter message string.
40 IF A$=''EXIT'' THEN 110	Check if program is to end.
50 CMD$=''D''+A$+''X''	Build display command string.
60 CALL IBWRT(M194%,CMD$)	Display message.
70 PRINT''PRESS KEY TO CONTINUE''	Display continue message.
80 B$=INKEY$:IF B$ = '' '' THEN 80	Wait for computer key press.
90 CMD$=''DX'':CALL IBWRT (M194%,CMD$)	Return display to normal.
100 GOTO 30	Repeat the process.
110 V%=0:CALL IBONL (M194%,V%)	Close the instrument file.
120 CALL IBONL(BRD0%,V%)	Close the board file.

Run the above program, type in the desired string at the message prompt, and press return. To exit the program cleanly, type in "EXIT" at this point and press the return key. After typing in your message, note that it is displayed on the front panel of the Model 194A. To continue the program, press any computer key when prompted to do so.

4.9.24 Self Test (J)

The self test command, allows you to test much of the internal circuitry of the Model 194A, including front panel display segments, RAM, ROM, as well as many A/D converter circuits.

The self test is run by sending the following command over the bus:

J1X

The instrument will then run the test and set the self test bit in the U1 status word, if a failure occurs. A complete description of the U1 (error) status word may be found in paragraph 4.9.15. The values listed in the J byte portion of the U0 word will be returned, as summarized in Table 4-33.

Table 4-33. U0 Self Test Error Codes

Code	Meaning
00	No error
01	Self test complete, no error (goes to 00 on U0 read)
02	Not Used
03	Not Used
04	Not Used
05	Not Used
06	Not Used
07	Not Used
08	RAM error on mother board
09	ROM error on mother board
1X	A/D error on CH1 (see table below for X meaning)
2X	A/D error on CH2 (see Table below for X meaning)
	A/D ERROR CODES
0	Noisy A/D
1	Not Used
2	Inoperative cal adjustments
3	Not Used
4	Not Used
5	Timebase error
6	Not Used
7	RAM error

Refer to Section 7 for troubleshooting procedures if the self test should indicate a failure.

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HP-85 Programming Example—Use the program below to run the self test and obtain and display the U1 status word.

PROGRAM	COMMENTS
10 REMOTE 709	Place 194A in remote.
20 OUTPUT 709;	
''J1X''	Start self test.
30 WAIT 10000	Wait 10 seconds.
40 OUTPUT 709;''U1X''	Program for U1 error status.
50 ENTER 709; A$	Get error status.
60 DISP A$	Display error status.
70 END	

In this program, the instrument is placed in remote (line 10) and then programmed to perform the self test (line 20). The program waits 10 seconds for the instrument to perform the self test (line 30), and then obtains and displays the error status word (lines 40-70). B6 is the byte that flags the result of the self test; this bit will be set to 1 if a failure occurs.

Model 8573 Programming Example—Add the following lines to the modified declaration file (paragraph 4.6.3) to run the self test and display the resulting error word status.

PROGRAM	COMMENTS
10 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
20 CMD$=''J1X'':CALL IBWRT (M194%,CMD$)	Program for self test.
30 FOR I = 1 TO 10000:NEXT I	Wait for test to finish.
40 CMD$=''U1X'':CALL IBWRT (M194%,CMD$)	Program unit for U1 error word.
50 RD$=SPACE$(50)	Define reading input buffer.
60 CALL IBRD(M194%,RD$)	Get error word.
70 PRINT RD$	Display the status word.
80 V%=0:CALL IBONL (M194%,V%)	Close instrument file.
90 CALL IBONL(BRD0%,V%)	Close instrument file.

In the above program the instrument is placed in remote (line 10) and then programmed to perform the self test (line 20). The loop in line 30 creates a delay that allows the instrument to complete the test before going any further. The instrument is then programmed to obtain and display the status word (lines 40-80). Byte 6 (B6) will flag the result of the self test; this byte will be set to 1 if the self test fails.

4.10 TRANSLATOR MODE

The standard Translator software allows you to define your own programming words in place of standard Keithley device-dependent commands. One word can replace a single command or a string of commands. For example, the word SAMPLES could be used in place of N0,1000. In a more complex example, the word SETUP1 could be used in place of R0F1T3G4.

The Translator mode can also be used to emulate the command syntax of other manufacturers' products. For example, Hewlett-Packard uses the command RA to place their instruments in the autorange mode, while the Keithley equivalent is R0. By using the Translator mode, a kind of standard programmming language can be developed for a number of different instruments on the bus.

The Translator mode uses a number of reserved words and a special character, as summarized in Table 4-34. Note that these words and character are reserved and cannot be used as Translator words. In addition, the X (execute) character cannot be used in a Translator word.

Table 4-34. Translator Reserved Words and Character

Word/Character	Descriptor
ALIAS	Defines Translator words.
;	Terminates Translator string.
NEW	Enables Translator mode.
OLD	Disables Translator mode.
LIST	Allows access to Translator words.
FORGET	Purges Translator words.

The commands associated with the Translator mode are discussed in the following paragraphs.

4.10.1 Defining Translator Words (ALIAS)

Translator words are defined with the ALIAS command by including them in a programming string with the desired device-dependent commands. This process can be demonstrated by the example string below, which translates the device-dependent command string F1R0X into SETUP1:

```
''ALIAS SETUP1 F1R0X ;''
```


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where: ALIAS defines the next word as a Translator word.
SETUP1 is the Translator word.
F1R0X is the device-dependent command string.
; is a character necessary to terminate the Translator string.
(space). Spaces must be included as shown to delimit the various parts of the string.

Once the Translator word has been defined, the instrument will be programmed for the corresponding mode or modes the next time it receives the Translator word, assuming that the X character was included as the last character in the device-dependent string. In this example, sending SETUP1 will cause the instrument to go into the average function (F1) and into the autorange mode (R0).

NOTES:

1. Defining a Translator word that already exists will cause the following front panel error message to be displayed:

   TRANSLATOR-ERR.

   This error will also be displayed if you exceed available Translator memory (1024 bytes). A Translator error is also flagged in the U1 error word (paragraph 4.9.15). If a Translator error occurs, the NEW mode will be concelled.

2. A Translator word cannot exceed 31 characters.
3. A device-dependent command string associated with a Translator word cannot exceed 255 characters.
4. The number of Translator words that can be defined depends on the relative size of the various Translator words and device-dependent command string. A maximum of 1024 bytes are available for Translator memory. Each word definition requires a 17-byte overhead plus one byte per letter including the Translator word and the device-dependent command string.
5. The X (execute character) cannot be used in the Translator word itself, but it must be included as the last character in the associated device-dependent command string, if that particular Translator word is to be executed when sent.
6. Sending the ALIAS command automatically enables the Translator mode.
7. DCL or SDC will clear Translator words from memory and disable the Translator mode.

HP-85 Programming Example—The program below demonstrates basic techniques for programming Translator words. In this program, five different words are defined.

PROGRAM	COMMENTS
`10 DIM B$[50], C$[60]`	Dimension command string.
`20 REMOTE 709`	Place instrument in remote.
`30 FOR I = 1 TO 5`	Loop five times.
`40 READ A$ @ READ B$`	Read Translator strings.
`50 C$="ALIAS "&" "& A$ & " " & B$ & " ;"`	Build ALIAS string.
`60 OUTPUT 709; C$`	Program Translator word.
`70 NEXT I`	Loop back and program next word.
`80 DATA "SETUP1", "R0F0N0,10S0,100E-6X"`	Data statements containing commands to program range, program range, function, number of samples, and sampling interval.
`90 DATA "SETUP2", "R1F1N0,100S0,100E-6X"`	
`100 DATA "SETUP3", "R2F2N0,50S0,500E-6X"`	
`110 DATA "SETUP4", "R3F3N0,250S0,750E-6X"`	
`120 DATA "SETUP5", "R4F4N0,800S0,200E-6X"`	
`130 END`	

After entering the program, check it for accuracy and press the HP-85 RUN key. The five Translator words will then be sent to the instrument and programmed. The presence of the Translator words can be verified with the following statement:

```
OUTPUT 709; "SETUP1"
```

Note that the instrument assumes modes that are associated with the SETUP1 Translator word. This Translator word was assigned the following modes (line 80): Autorange (R0); waveform function (F0); 10 samples (N0,10); and 100μsec sampling interval (S0,100E-6).

The remaining four defined Translator words can be verified by substituting them in the above statement.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 4.6.3) to define five Translator words. The words and associated command strings are located in data statements at the end of the program.

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PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Send remote enable.
`20 FOR I = 1 TO 5`	Loop five times.
`30 READ A$: READ B$`	Read Translator strings.
`40 CMD$=''ALIAS ''+'' '' +A$'' ''+ B$ + '' ;''`	Build ALIAS command string.
`50 CALL IBWRT(M194%,CMD$)`	Program Translator string.
`60 NEXT I`	Loop back and program next string.
`70 DATA ''SETUP1'', ''R0F0N0,10S0,100E-6X''`	Data statements to define range, function, number of samples and sampling interval.
`80 DATA ''SETUP2'', ''R1F1N0,100S0,100E-6X''`	
`90 DATA ''SETUP3'', ''R2F2N0,50S0,500E-6X''`	
`100 DATA ''SETUP4'', ''R3F3N0,250S0,750E-6X''`	
`110 DATA ''SETUP5'', ''R4F4N0,800S0,200E-6X''`	

After entering the program, press the IBM F2 key to run it. The five Translator words defined in the data statements will then be programmed. The defined words can be verified by sending a Translator word to the instrument, as in the following example:

```
CMD$=''SETUP1'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument assumes modes programmed by the SETUP1 Translator word. Line 70 of the program defined these modes as follows: autorange (R0); waveform function (F0); 10 samples (N0,10); and 100μsec sampling interval (S0,100E-6).

You can verify the four other Translator words by substituting them in the statement above.

4.10.2 Enabling and Disabling the Translator Mode (NEW and OLD)

The NEW and OLD commands are reserved words that allow you to enable or disable the Translator mode respectively. These words are discussed in the following paragraphs.

NEW: This command enables the Translator mode and informs the instrument that the following command strings may contain Translator words. The instrument will then respond both to Translator words as well as the usual device-dependent commands. NEW can also be used to combine Translator words, as discussed in paragraph 4.10.3.

Note that using the ALIAS command automatically enables the Translator mode.

OLD: This command disables the Translator mode. After OLD is sent, the Model 194A will respond only to standard device-dependent command strings.

NOTE

Using NEW or OLD does not in any way change defined Translator words or the associated command strings.

HP-85 Programming Example—Run the program example from paragraph 4.10.1 to define the five Translator words. Now type in the following statement to disable the Translator mode:

```
OUTPUT 709;''OLD''
```

At this point, the Translator mode has been disabled. This fact can be verified by attempting to program one of the previously defined Translator words as follows:

```
OUTPUT 709; ''SETUP1''
```

Note that the instrument failed to respond to the Translator word.

Now re-enable the Translator mode and program a Translator sequence with the following statements:

```
OUTPUT 709; ''NEW''
OUTPUT 709; ''SETUP2''
```

Note that the instrument now assumes modes programmed by the SETUP2 Translator word because the Translator mode was enabled with the NEW command.

Model 8573 Programming Example—Run the program example from paragraph 4.10.1 to define the five Translator words. Now disable the Translator mode with the following statement:

```
CMD$=''OLD'':CALL IBWRT(M194%,CMD$)
```


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The Translator mode has now been disabled, a fact that can be verified by attempting to use one of the previously defined Translator words as in the following example:

```
CMD$=''SETUP2'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument no longer responds to Translator words; however, this mode can be re-enabled and verified with the following statements:

```
CMD$=''NEW'':CALL IBWRT(M194%,CMD$)
CMD$=''SETUP2'':CALL IBWRT(M194%,CMD$)
```

4.10.3 Combining Translator Words

Existing Translator words can be combined by using the NEW command, resulting in a Translator word that contains the commands of the original words. For example, existing words SETUP1 and SETUP2 could be combined in a new word called SETUP3. When SETUP3 is sent over the bus, the commands of both SETUP1 and SETUP2 will then be executed.

The basic format for combining Translator words is shown in the following example:

```
''ALIAS SETUP3 NEW SETUP1 NEW SETUP 2 ;''
```

where: ALIAS defines the Translator word.
SETUP3 is the new word to be defined.
SETUP1 and SETUP2 are existing words to be combined.
NEW is a reserved word that tells the instrument that SETUP1 and SETUP2 are Translator words and not device-dependent commands.
; is the terminator that marks the end of the ALIAS sequence.
(space). A space must be included between each word.

Note that the instrument will still recognize any original words even if combined. In this example, SETUP1 and SETUP2 will still be valid after SETUP3 is defined.

HP-85 Programming Example—Use the following statements to define two Translator words and then combine them in a third, called SETUP3:

```
REMOTE 709
CLEAR 7
OUTPUT 709; ''ALIAS SETUP1 F2X ;''
OUTPUT 709; ''ALIAS SETUP2 R0X ;''
OUTPUT 709; ''ALIAS SETUP3 NEW SETUP1 NEW
SETUP2 ;''
```

The second and third statements define the first two Translator words, while the fourth statement combines the commands associated with those two words into a new word called SETUP3.

The combined SETUP3 word can be verified with the following statement:

```
OUTPUT 709; ''SETUP3''
```

When the above statement above is executed, the instrument will assume modes defined by the SETUP3 word. In this example, the instrument will assume the TRMS function (F2) and autorange (R0) modes.

Model 8573 Programming Example—Use the statements below to first create two Translator words and then combine them into a third word called SETUP3:

```
V%=1:CALL IBSRE(BRD0%,V%)
CALL IBCLR (M194%)
CMD$=''ALIAS SETUP1 F2X ;'':CALL IBWRT
(M194%,CMD$)
CMD$=''ALIAS SETUP1 R0X ;'':CALL IBWRT
(M194%,CMD$)
CMD$=''ALIAS SETUP3 NEW SETUP1 NEW SETUP2 ;''
CALL IBWRT(M194%,CMD$)
```

The two original Translator words are defined when the second and third statements above are executed. These two original words are combined into SETUP3 by the fourth and fifth statements. The operation of the combined Translator word can be verified with the following statement:

```
CMD$=''SETUP3'':CALL IBWRT(M194%,CMD$)
```

Note that the instrument is placed into modes defined by the SETUP3 parameter: TRMS (F2) and autoranging (R0).

4.10.4 Reading Back Translator Words (LIST)

Programmed Translator words can be obtained from the instrument by the controller with the LIST command. After LIST is received by the instrument, the words can be obtained in the same manner used to access normal instrument data. The various words will be delimited by spaces, and the most recently programmed word will be transmitted first.

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NOTES:

1. If no Translator words exist in memory, nothing will be transmitted when the word list is requested.
2. Only the Translator words themselves will be sent following the LIST commands. The device-dependent commands will not be included in the list.
3. The programmed terminator and EOI will be transmitted at the end of the complete list sequence.

HP-85 Programming Example—Add the following lines to the HP-85 programming example from paragraph 4.10.1 to demonstrate the LIST command.

PROGRAM	COMMENTS
`15 DIM D$[50]`	Dimension string.
.....	
`71 OUTPUT 709;''LIST''`	Send LIST command to 194A.
`72 ENTER 709; D$`	Get Translator word list.
`73 DISP D$`	Display word list.

After adding the lines above to the previous program, press the HP-85 RUN key and note that the Translator words are listed on the CRT.

Model 8573 Programming Example—Add the lines below to the Model 8573 programming example from paragraph 4.10.1 to demonstrate the use of the LIST command.

PROGRAM	COMMENTS
`61 CMD$=''LIST'':CALL IBWRT (M194%,CMD$)`	Send LIST command to 194A.
`62 RD$=SPACE$(50)`	Define reading input buffer.
`63 CALL IBRD(M194%,RD$)`	Get Translator word list.
`64 PRINT RD$`	Display Translator words.

After adding the above lines, run the program and note that the Translator words are displayed on the computer CRT.

4.10.5 Purging Translator Words (FORGET)

Translator words can be purged (erased) from memory by using the reserved word FORGET. This command is sent to the instrument in the usual manner, as in the examples below.

NOTE

The DCL and SDC commands will also erase Translator words from memory.

HP-85 Programming Example—Run the HP-85 example program from paragraph 4.10.1 and then use the following statement to purge Translator words from memory:

```
OUTPUT 709;''FORGET''
```

When the statement is executed, the Translator words will be purged from memory. The Translator word list can be requested, as explained in paragraph 4.10.4, to verify that the words are no longer in memory.

Model 8573 Programming Example—Run the Model 8573 programming example from paragraph 4.10.1 and then type in the following statement to purge Translator words from memory:

```
CMD$=''FORGET'':CALL IBWRT(M194%,CMD$)
```

When this statement is executed, the Translator words will be purged from memory. The word list can be obtained, as described in paragraph 4.10.4, to verify that the words are no longer present.

4.11 BUS DATA TRANSMISSION TIMES

The length of time it takes to get a reading from the instrument over the bus once it is triggered depends on a variety of factors, including the programmed sampling rate and measurement size, the selected math function, as well as the trigger mode being used. Table 4-35 lists typical times for a variety of different conditions. Where applicable, default operating conditions are listed in the table.

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Table 4-35. Bus Data Transmission Times

Sampling Interval	Number of Samples	Math Function	Trigger to First Byte Out (msec)
166.7μsec	101	Average	47
166.7μsec	101	Peak-to-peak	40
166.7μsec	101	Integral	63
10μsec	1000	Average	122
10μsec	1	Average	22
1μsec	1000	Average	118
1μsec	1	Average	21
1μsec	1	Waveform	23
1μsec	1000	TRMS	208
1μsec	1000	+Peak	58
1μsec	1000	−Peak	58
1μsec	1000	Peak-to-peak	58
1μsec	1000	Standard Deviation	265
1μsec	1000	Integral	134

1. All measurements made in T1 (single, talk) mode.
2. All times are typical.

4.12 DUAL CHANNEL OPERATION

The following paragraphs contain additional information on programming and obtaining data from instruments equipped with two A/D modules.

4.12.1 Channel Selection

Selecting a channel to program is simply a matter of sending the C command with the correct option for the desired channel. For example, to select channel 1, send the command string "C1X". Similarly, the command string "C2X" would be sent to select channel 2. Once the appropriate command is sent, the selected channel will be displayed on the front panel, and all subsequent channel-dependent commands sent will affect only the programmed channel. Note, however, that the C command does not select which channel sends data over the IEEE-488 bus. Instead, additional steps must be taken to obtain data from the desired channel, as discussed below.

If you include the C command in a string with other commands in a string, you need not place the C command first in the string unless X appears before C. For example, assume the instrument is currently on channel 1 and you wish to program the range and function on channel 2. The following examples show correct and incorrect ways to do so:

C2R1F1X — Correct, as C is processed first, then range and function are changed.

R1F1XC2X — Incorrect because the first X character causes the range and function on channel 1 to be changed, after which the instrument switches to channel 2.

4.12.2 Dual Channel Architecture

In order to better understand the way the Model 194A operates in the dual channel mode, we will now briefly discuss fundamental instrument configuration. The basic architecture of the unit is shown in Figure 4-14.

Each module has its own A/D converter, which digitizes the analog input signal, and a 64K byte measurement buffer for sample storage. Because of this arrangement, each module can process raw data independently. Beyond this point, however, the two channels share the microcomputers, reading buffer, and IEEE-488 bus. Thus, although the display can handle two channels simultaneously, the reading buffer cannot as discussed in the following paragraph.

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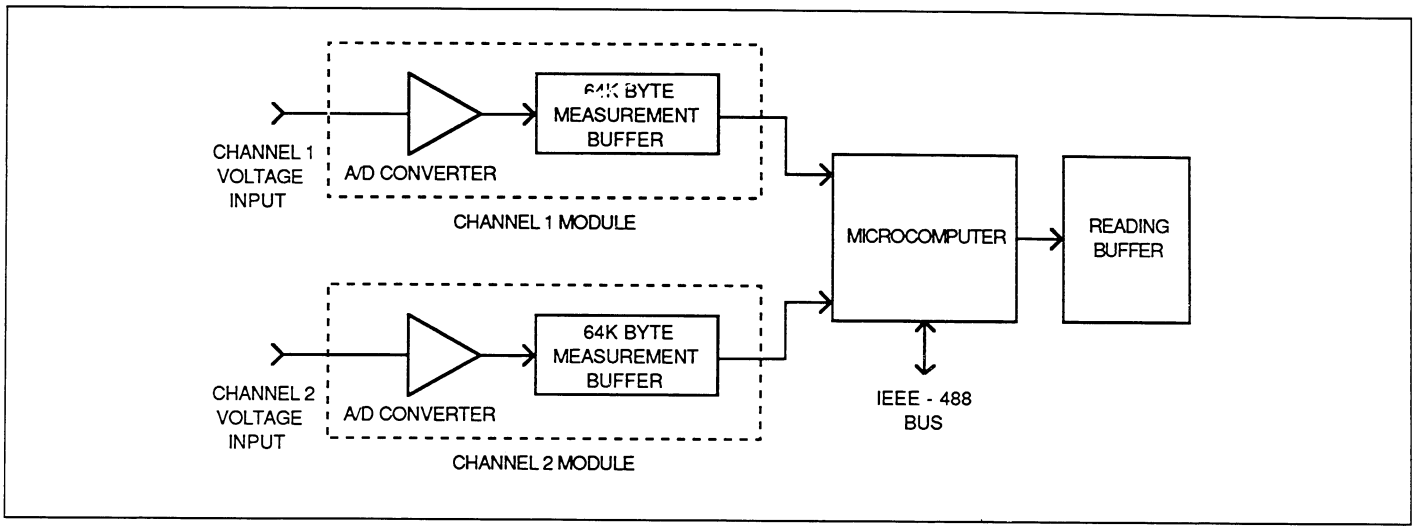


Figure 4-14. Dual Channel Mode

4.12.3 Reading Buffer Operation

IEEE-488 output always comes through the reading buffer whether or not that buffer has been enabled with the Q command. Thus, the specific data you get when requesting information depends on a variety of factors as follows:

1. Reading buffer disabled (Q0). In this case, the reading buffer has an effective size of one, with both channels sharing a single location. The location will be continuously updated with data from either channel as the measurement from that channel is completed, and the reading is processed. Any previous reading will be overwritten by the new one. Thus, you will always get only the most recent reading, whether from channel 1 or channel 2, when requesting data with the buffer disabled.
2. Reading buffer enabled (Q1 or Q2). When the reading buffer is enabled, a maximum of 100 readings can be stored. Channel readings are stored in successive buffer locations as the measurements are processed and the readings are made available. Again, since only a single buffer is available, the buffer will contain both channel 1 and channel 2 readings, in the order the readings become available.

4.12.4 Selecting Data Output

There are a number of ways to make certain that data sent over the bus comes only from the desired channel. Possible solutions include:

1. Turn off the unused channel. If you are using only one channel, turn the other one off by programming a single trigger mode for the channel to be turned off. For example, to turn off channel 1, you could send the string C1T3X. Since no data from an inactive channel is placed in the reading buffer, you will obtain data only from the desired channel.
2. Use non-immediate trigger modes for both channels. By discretionary use of the trigger modes, you can arrange to take only one measurement per channel and then control which reading is placed into the reading buffer by using the F command. The simple program sequence below (written in HP-85 BASIC) will demonstrate this process.

PROGRAM	COMMENTS
`100 OUTPUT 709; "C1T2X"`	! Program GET trigger.
`115 OUTPUT 709; "C2T2X"`	! Channel 2 trigger
`110 TRIGGER 709`	! Trigger both channels.
`120 OUTPUT 709; "C1F1X"`	! Compute channel 1 reading.
`130 ENTER 709; A$`	! Get channel 1 reading.
`140 DISP A$`	! Display channel 1 reading.
`150 OUTPUT 709; "C2F1X"`	! Compute channel 2 reading.
`160 ENTER 709; A$`	! Get channel 2 reading.
`170 DISP A$`	! Display channel 2 reading.
`180 END`	

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3. Use the F command to re-calculate a reading. Even if a reading has already been calculated, you can force another calculation for the desired channel to place the result in the reading buffer. For example, send C2F1X to compute the average of the channel 2 measurement and place the results in the reading buffer. Keep in mind that the other channel must not be running fast enough to overwrite this data between the time it is calculated and the time it is requested.
4. Enable the reading buffer. In some cases, it may be necessary to simply turn on the reading buffer and then go back to sort things out, so to speak. Use Q1 to enable a linear buffer, which will prevent the unit from overwriting your data once the buffer is full. When requesting data, you can use the channel number in the suffix to determine which channel is associated with each reading. Use the G2 (single reading) or G5 (multiple reading) data formats to enable the suffix. In some cases, it may be necessary to use a non-immediate trigger mode and then avoid triggering the other channel before data for the desired channel resides safely within the computer.

4.12.5 A Sample Dual-channel Program

The sample program below demonstrates some important concepts about dual-channel operation. The program will prompt you for commands to set up each channel, and then store data in the reading buffer. Data is then read into an array, with channel 1 data string going into V(n,1), and channel 2 data placed into V(n,2).

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PROGRAM	COMMENTS
10 DIM A$[100],B$[100]	! Dimension data string.
20 DIM V(100,2)	! Dimension reading array.
30 REMOTE 709	! Put 194A in remote.
40 CLEAR	! Clear CRT
50 CLEAR 7	! Send device clear.
60 DISP ''CHANNEL 1 SETUP''	! Prompt for channel 1 setup.
70 INPUT A$	! Input channel 1 setup.
80 DISP ''CHANNEL 2 SETUP''	! Prompt for channel 2 setup.
90 INPUT B$	! Input channel 2 setup.
100 OUTPUT 709; ''M2G2X''	! Program SRQ and data format.
110 OUTPUT 709; ''C1T26'';A$;''X''	! Program channel 1.
120 OUTPUT 709; ''C2T26'';B$;''X''	! Program channel 2.
130 OUTPUT 709; ''Q1X''	! Enable linear reading buffer.
140 DISP ''WAITING FOR BUFFER TO FILL''	
150 STATUS 7,2; S	! Get bus status.
160 IF NOT BIT(S,5) THEN 150	! Wait for SRQ.
170 OUTPUT 709; ''U2X''	! Request U2 status word.
180 ENTER 709; C$	! Get U2 status word.
190 IF C$[4,4] # ''1'' THEN 150	! If buffer not full, wait.
200 DISP ''BUFFER FULL, READING DATA''	
210 C1=0: C2=0	! Null channel reading counter.
220 FOR I = 1 TO 100	! Loop for all buffer readings.
230 ENTER 709; V,C,B	! Get voltage, channel, buffer #.
240 IF C=1 THEN C1=C1+1 @ V(C1,C) = V	! If channel 1, put reading in channel 1 array element.
250 IF C=2 THEN C2=C2+1 @ V(C2,C) = V	! If channel 2, put reading in channel 2 array element.
260 IF B=0 THEN DISP ''ALL BUFFER LOCATIONS TAKEN @ GOTO 280	! No more buffer readings if B=0.
270 NEXT I	! Loop for next buffer location.
280 DISP ''TOTAL CHANNEL 1 READINGS''; C1	! Display number of channel 1 readings.
290 DISP ''TOTAL CHANNEL 2 READINGS''; C2	! Display number of channel 2 readings.
300 DISP ''CHANNEL TO DISPLAY''	! Prompt for channel number.
310 INPUT C	! Input channel number.
320 IF C<1 OR C>2 THEN 300	! Check channel limits.
330 DISP ''READING NUMBER''	! Prompt for reading number.
340 INPUT N	! Input reading number.
350 IF C=1 AND N > C1 THEN 330	! Check reading number limits.
360 IF C=2 AND N > C2 THEN 330	! Check reading number limits.
370 DISP V(N,C)	! Display reading.
380 GOTO 300	
390 END	

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SECTION 5
PERFORMANCE VERIFICATION

5.1 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.

This section is organized as follows:

5.2 **Environmental Conditions:** Gives temperature and humidity limits.

5.3 **Initial Conditions:** Defines the warm up period for the instrument.

5.4 **Recommended Test Equipment:** Includes required equipment accuracy.

5.5 **Test Equipment Connections:** Shows how to connect a calibration source to the instrument.

5.6 **Verification Procedure:** Gives the procedure for verifying instrument accuracy, including verification limits.

5.7 **Computerized Verification:** Gives typical programming examples for verifying instrument accuracy over the IEEE-488 bus.

5.8 **AC Frequency Response:** Lists the procedure for checking the frequency response of the input amplifier.

5.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at an ambient temperature of 18-28°C (65-82°F) and at less than 70% relative humidity unless otherwise noted.

5.3 INITIAL CONDITIONS

The Model 194A must be turned on and allowed to warm up for at least one hour before beginning the verification procedures. If the instrument has been subjected to extremes of temperature (outside the range specified in paragraph 5.2), additional time should be allowed for internal temperatures to stabilize. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range. Make sure the fan is running before beginning the verification procdure.

5.4 RECOMMENDED TEST EQUIPMENT

Equipment necessary to verify instrument accuracy is listed in Table 5-1. Alternate equipment may be used as long as accuracy specifications are at least as good as those give above. In general, calibrator accuracy should be at least five times better than equivalent Model 194A specifications.

Table 5-1. Performance Verification Equipment

Description	Output Voltages	Accuracy	Manufacturer
DC Voltage Calibrator	±320mV, 3.2V, 32V, 200V	±0.005%	Fluke Model 343A
AC Voltage Calibrator	200mV, 2V, 6V, 18V, 50V @ 20kHz, 200kHz, 750kHz	±0.05%	Fluke Model 5200A

*RMS values shown.

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5.5 TEST EQUIPMENT CONNECTIONS

Figure 5-1 shows the basic scheme for connecting the DC calibrator to the Model 194A. While channel 1 connections are shown, connections for channel 2 on those units so equipped would be similar. When making the connection, use only good quality shielded cable. One end of this cable should be equipped with a BNC connector to mate with the VOLTAGE INPUT jack on the instrument, while the other end of the connector can be terminated with a dual banana jack. When making the calibrator connection, the cable shield should be connected to the low output terminal of the DC calibrator.

CAUTION
Maximum input is 250V peak, 2 × 10^7 V•Hz.

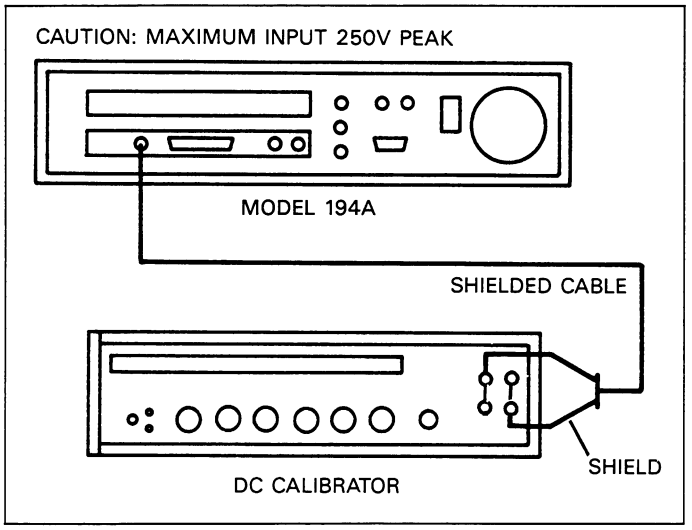


Figure 5-1. DC Verification Connections

5.6 VERIFICATION PROCEDURE

The steps below outline the procedure for verifying instrument accuracy. This procedure is intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications, refer to Section 7 for calibration procedures, unless the instrument is still under warranty. Figure 5-2 shows a flow chart of the verification procedure.

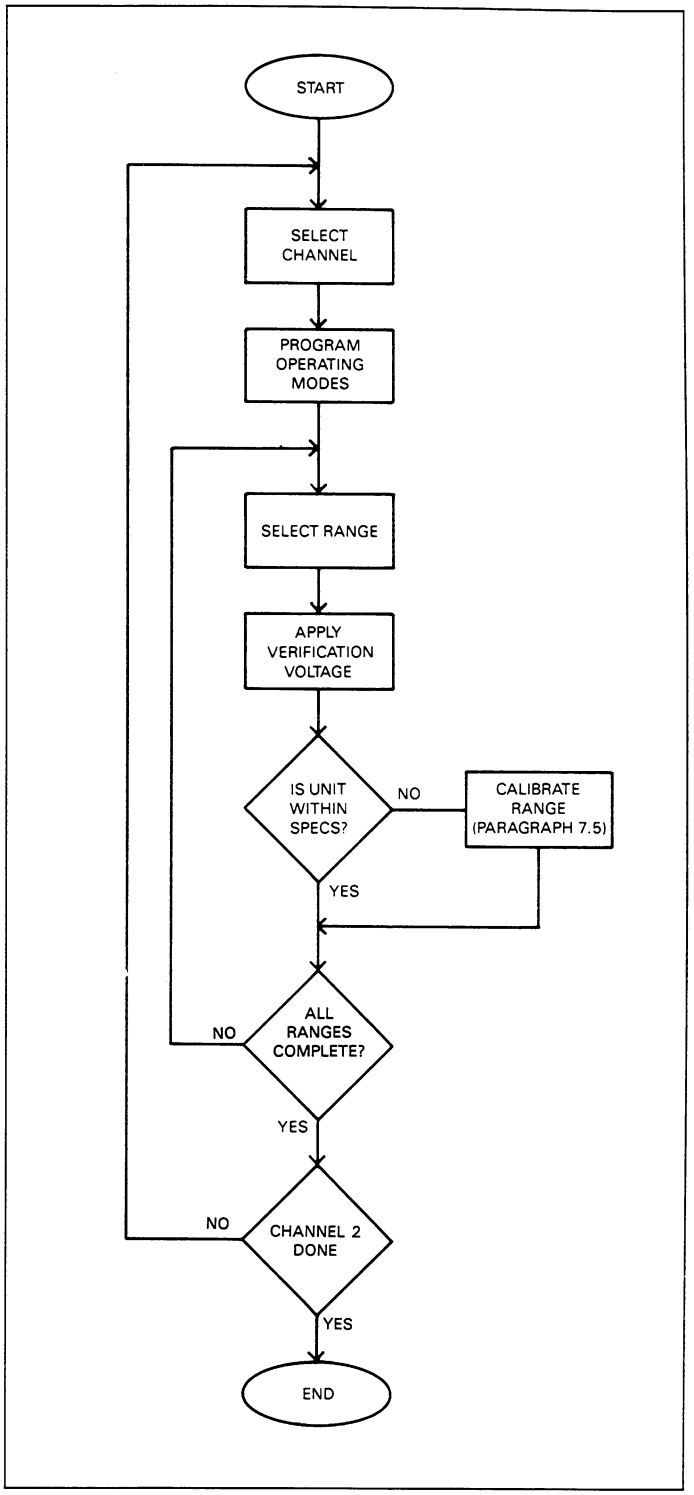


Figure 5-2. Flow Chart

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WARNING

The maximum common-mode input voltage (the voltage between input low and chassis ground is 30V. Exceeding this value may create a shock hazard. Some of the following procedures may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

CAUTION

The maximum voltage between the high and low input terminals is 250V peak. Instrument damage may occur if this value is exceeded.

1. Connect the channel being verified to the DC calibrator as discussed in paragraph 5.5.
2. For two-channel units, select channel NOT being verified and press SGL/CONT. Do not press TRIGGER.
3. Select the channel being verified with the CHANNEL button.
4. Program the following operating modes with the associated front panel buttons:
   A. Samples 10,000
   B. Rate 10μsec
   C. Coupling: DC
   D. Function: average
   E. Trigger: continuous
5. Select the 320mV range by using the Downrange button. Press TRIGGER.
6. Program the calibrator to output 0.0000V. Press the Model 194A ZERO button to enable the zero mode. Note: The 194A must be rezeroed for each range.
7. Select the range and verification voltage as specified in Table 5-2. Verify that the Model 194A reading is within the limits stated in Table 5-2 under the 16-bit mode heading.
8. Select the next range and verification voltage listed in Table 5-2 and verify that the reading is within stated limits.
9. Repeat this procedure for the remaining ranges listed in the table. Always use the lowest possible calibrator range for the selected calibrator voltage.
10. Repeat steps 4 through 8 for voltages with negative polarity.
11. Program a 9.9μsec sampling interval and 10,102 samples; repeat the above procedure. Use the limits stated in Table 5-2 for the 8-bit mode.
12. If the Model 1944A option is installed in the channel 2 location, repeat steps 1 through 10 for that channel. Naturally, you should use the channel 2 VOLTAGE INPUT jack for the calibrator voltage input.

5.7 COMPUTERIZED VERIFICATION

The following paragraphs contain example programs for performing the verification procedure on a semi-automated basis. All the necessary programming steps to control the Model 194A for both 8-bit and 16-bit mode verification are included in these programs. Steps necessary to control the DC calibrator are not included because of the variation in programming languages among such instruments. However, program modifications should be fairly simple in most cases, depending on the complexity of the calibrator. Consult the calibrator instruction manual for details.

In each of the following programs, the operator will be prompted to apply the correct calibration voltage at the appropriate point in the procedure and then press a key to continue. The program will obtain a reading from the Model 194A and then compare that reading to limits contained in program data statements. If the instrument is out of specifications at any point, the operator will be notified of that fact by an appropriate message on the computer CRT.

Table 5-2. Performance Verification Limits

Range	Verification Voltage	Allowable Reading (18-28°C)	
		16-Bit*	8-Bit**
320 mV	300.00 mV	299.71 to 300.29 mV	296.18 to 303.82 mV
3.2 V	3.0000V	2.9972 to 3.0028 V	2.9618 to 3.0382 V
32 V	30.000 V	29.969 to 30.031 V	29.618 to 30.382 V
200 V	200.00 V	199.73 to 200.27 V	196.6 to 203.4 V

*Sampling rates ≤100kHz and number of samples ≤32,768.

**Sampling rates >100kHz or number of samples >32,768.

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5.7.1 HP-85 Verification Program

Enter and run the program below to verify Model 194A accuracy with a Hewlett-Packard Model 85 computer.

```
10 REMOTE 709 !                    PUT 194A IN REMOTE
20 CLEAR !                         CLEAR DISPLAY
30 CLEAR 7 !                       SEND DEVICE CLEAR
40 DISP "CHANNEL (1 OR 2)";!       PROMPT FOR CHANNEL TO TEST
50 INPUT C
60 IF C<1 OR C>2 THEN 40
70 CLEAR !                         CLEAR DISPLAY
80 E=0 !                           SET ERROR COUNTER TO ZERO
90 OUTPUT 709 ;"C2W0,0XH4XH4X" !   STOP CHANNEL 2
100 OUTPUT 709 ;"C1W0,0XH4XH4X" ! STOP CHANNEL 1
110 OUTPUT 709 ;"C";C;"X" !        PROGRAM USER SELECTED CHANNEL
120 OUTPUT 709 ;"F1Q0G1X" !        AVERAGE,CLEAR BUFFER,NO PREFIX OR SUFFIX
130 FOR I=1 TO 4 !                 TEST EACH OF 4 RANGES
140 OUTPUT 709 ;"R";I;"X" !        SELECT RANGE
150 READ V$,L1,L2,L3,L4 !          READ PROMPT AND READING LIMITS
160 DISP
170 DISP "APPLY ";V$;" TO 194A" ! USER PROMPT FOR INPUT VOLTAGE
180 DISP "   AND PRESS 'CONT'"
190 DISP
200 PAUSE !                        WAIT FOR USER INPUT
210 OUTPUT 709 ;"N0,10001X" !      SELECT 10001 SAMPLES
220 OUTPUT 709 ;"S0,10.0E-6X" !    SELECT 10US RATE (16 BIT DATA)
230 OUTPUT 709 ;"I2Z0T27X" !       GROUND COUPLING, ZERO OFF,GET READING
240 ENTER 709 ; Z !                WAIT FOR READING DONE BY READING ZERO
250 OUTPUT 709 ;"I0Z4T27X" !       DC COUPLING,USE MEASURED ZERO
260 ENTER 709 ; R !                GET READING FROM 194A
270 IF R>L1 AND R<L2 THEN 340 !    CHECK WITH LIMITS FOR THIS RANGE
280 DISP V$;" RANGE OUTSIDE" !     LINE 270 FAILED LIMIT CHECK,
290 DISP " 16 BIT LIMITS " !       SO NOTIFY USER AND INCREMENT
300 DISP "LIMITS:";L1;"to";L2 !    ERROR COUNTER
310 DISP "MEASURED:";R
320 E=E+1
330 DISP
340 OUTPUT 709 ;"N0,10102X" !      SELECT 10102 SAMPLES
350 OUTPUT 709 ;"S0,9.9E-6X" !     SELECT 9.9US FOR 8 BIT OPERATION
360 OUTPUT 709 ;"I2Z0T27X" !       GROUND COUPLING,ZERO OFF,TAKE READING
370 ENTER 709 ; Z !                WAIT FOR READING DONE BY READING ZERO
380 OUTPUT 709 ;"I0Z4T27X" !       DC COUPLING,USE MEASURED ZERO,TAKE READING
390 ENTER 709 ; R !                GET READING FROM 194A
400 IF R>L3 AND R<L4 THEN 470 !    CHECK READING WITH ALLOWED LIMITS
410 DISP V$;" RANGE OUTSIDE" !     LINE 400 FAILED ALLOWED LIMITS,
420 DISP "  8 BIT LIMITS " !       SO NOTIFY USER AND INCREMENT
430 DISP "LIMITS:";L3;"to";L4 !    ERROR COUNTER
440 DISP "MEASURED:";R
450 E=E+1
460 DISP
470 IF E=0 THEN DISP "PASS" !      IF NO ERRORS, NOTIFY USER
480 NEXT I !                       LOOP BACK FOR NEXT RANGE
```


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```
490 DISP
500 DISP "PLEASE REDUCE VOLTAGE" ! END OF TEST, SO REMIND USER
510 DISP " TO SAFE LEVEL !!!" !    THAT 200V IS STILL PRESENT
520 DISP
530 IF E=0 THEN DISP "194A PASSED ALL TESTS" !  IF NO ERRORS,NOTIFY USER
540 IF E<>0 THEN DISP "194A FAILED";E;"TESTS" ! NOTIFY USER OF ANY FAILURES
550 END !                          END OF PROGRAM
560 REM LINES 590-620 CONTAIN PROMPTS AND LIMITS FOR EACH RANGE
570 REM (MESSAGE,16-BIT LOWER LIMIT,16-BIT UPPER LIMIT,
580 REM 8-BIT LOWER LIMIT,8-BIT UPPER LIMIT)
590 DATA "320.00mV",.3197,.3203,.3161,.3239
600 DATA "3.2000V",3.1972,3.2028,3.161,3.239
610 DATA "32.000V",31.969,32.031,31.61,32.39
620 DATA "200V",199.73,200.27,196.6,203.4
```

5.8 AC FREQUENCY RESPONSE

Use the following procedure to determine whether or not input amplifier frequency response adjustment is necessary. If the instrument fails the test procedure, the AC frequency response of the 32V and 200V ranges can be adjusted, as described in paragraph 7.5.

The test points for the procedure below are summarized in Table 5-3.

Table 5-3. AC Frequency Response Verification

Range	Applied Voltage	Allowable Reading
320mV	200mV @ 20kHz	.19536 to .20464V
	200mV @ 200kHz	.17600 to .22400V
	200mV @ 750kHz	.11800 to .28200V
3.2 V	2 V @ 20kHz	1.9536 to 2.0464 V
	2 V @ 200kHz	1.7600 to 2.2400 V
	2 V @ 750kHz	1.1800 to 2.8200 V
32 V	18 V @ 20kHz	17.536 to 18.464 V
	6 V @ 200kHz	5.280 to 6.720 V
200 V	50 V @ 20kHz	48.84 to 51.16 V

Notes:
1. Limits based on Frequency Response Specifications (Filter off).
2. Voltages are RMS.

1. Connect the AC calibrator (Table 5-1) to the VOLTAGE INPUT jack of the channel being tested. Use the basic connecting scheme shown in Figure 5-3.
2. Using the CHANNEL button, select the channel being tested.
3. Set the Model 194A for the following operating modes:
   A. Rate: 11μsec
   B. Samples: 1000
   C. Coupling: AC
   D. Trigger: Continuous, input signal, 0μV level.
   E. Math Function: TRMS
   F. Filter: off
   G. Zero: off
4. Select the 320mV range on the unit, and set the calibrator output to 200mV RMS at a frequency of 20kHz.
5. Press TRIGGER to initiate a measurement.
6. Verify the reading is between 0.19536 and 0.20464V as summarized in Table 5-3.
7. Repeat steps 4 through 6 for 200kHz and 750kHz (see Table 5-3).
8. Repeat steps 4 through 7 for the 3.2V through 200V range (see Table 5-3 for calibration voltages and frequencies).

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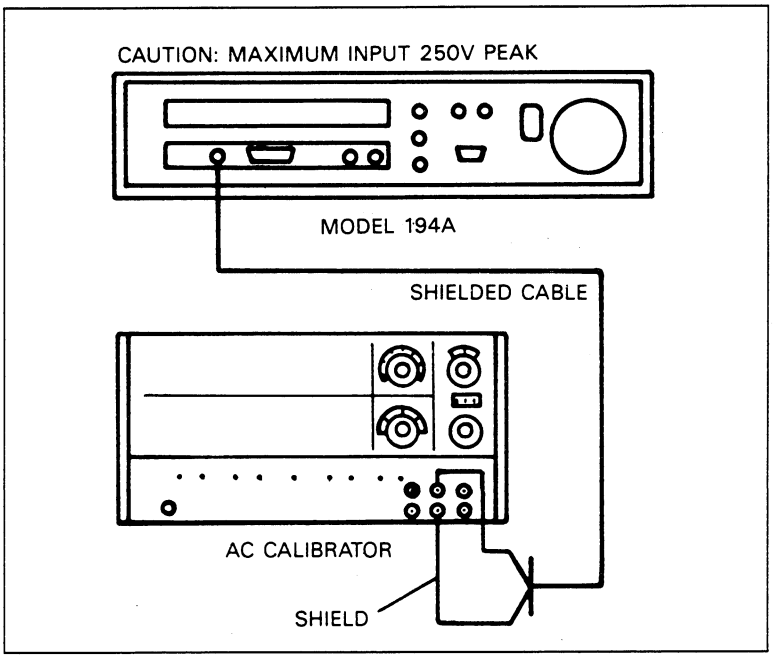


Figure 5-3. AC Verification Connections

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SECTION 6
PRINCIPLES OF OPERATION

6.1 INTRODUCTION

This section contains an overall functional description of the Model 194A in block diagram form, as well as details of operating principles for various circuits within the instrument. Many descriptions include simplified block diagrams. Detailed schematic diagrams and component layout drawings for the various circuit boards are located in Section 8.

Information in this section is arranged as follows:

6.2 Functional Description: Presents Model 194A circuitry in block diagram form and gives an overview of circuit operation.

6.3 Analog Circuitry: Describes operation of the analog input circuitry for the instrument including input attenuator and signal amplification circuits.

6.4 A/D Converter: Describes the basic operation of the 8/16 bit A/D converter and associated control circuitry.

6.5 Digital Control Circuitry: Outlines operation of the digital circuitry used for trigger control, reading counter, as well as the 64K dual-port memory.

6.6 Microcomputer: Presents a detailed description of the 68008-based microcomputer, including ROM memory, address decoding, front panel interface, and IEEE-488 bus circuits.

6.7 I/O Circuitry: Details operation of circuits used to drive the front panel display, read keyboard data, and control the X, Y, and Z analog outputs.

6.8 Power Supplies: Describes the operation of the various power supplies used to power instrument circuitry.

6.9 Display Board: Details operation of the front panel display and keyboard circuits.

6.2 FUNCTIONAL DESCRIPTION

A simplified block diagram of the Model 194A is shown in Figure 6-1. Fundamentally, the circuit consists of analog and A/D circuitry, the 68008 MPU and its support circuits and power supply circuitry. Channel 2 circuitry for those instruments outfitted with the optional Model 1944A A/D module is identical to that shown for channel 1.

Input signals are applied to the input amplifier through the rear panel VOLTAGE INPUT jack. The input amplifier attenuates or amplifies the input voltage, as required, essentially conditioning input signals into values optimized for use by the A/D converter. Selectable 50kHz and 500kHz analog filters are also part of the input amplifier circuitry.

Once the signal is conditioned by the input amplifier, it is applied to the sample and hold circuitry, which is actually contained within the A/D module. The purpose of the sample and hold is to freeze the signal voltage at some steady-state value during the A/D conversion process.

A/D conversion is performed by the 8/16 bit A/D converter section of the module. For sampling rates of 100kHz and below, the converter operates in the 16-bit mode, resulting in a usable display resolution of 4½ digits. Above 100kHz, the converter operates in the 8-bit mode, reducing usable display resolution to 2½ digits, although the 4½ digit format is maintained.

Once the signal has been digitized, the resulting data is fed over the isolators in serial form to the 64K dual-port memory, the trigger control circuitry, and the real time output. This isolated serial transmission scheme is used to maintain electrical isolation between the analog and digital sections of the instrument.

Because data is dumped directly to the 64K byte memory, data can be sampled at rates as high as 1MHz. Data is sampled in real time by the trigger control circuitry for use in determining when to trigger the A/D converter if triggering from the input signal. Data is also fed to the real time output of the instrument, which can be used to transmit data in real time to an external device such as a computer.

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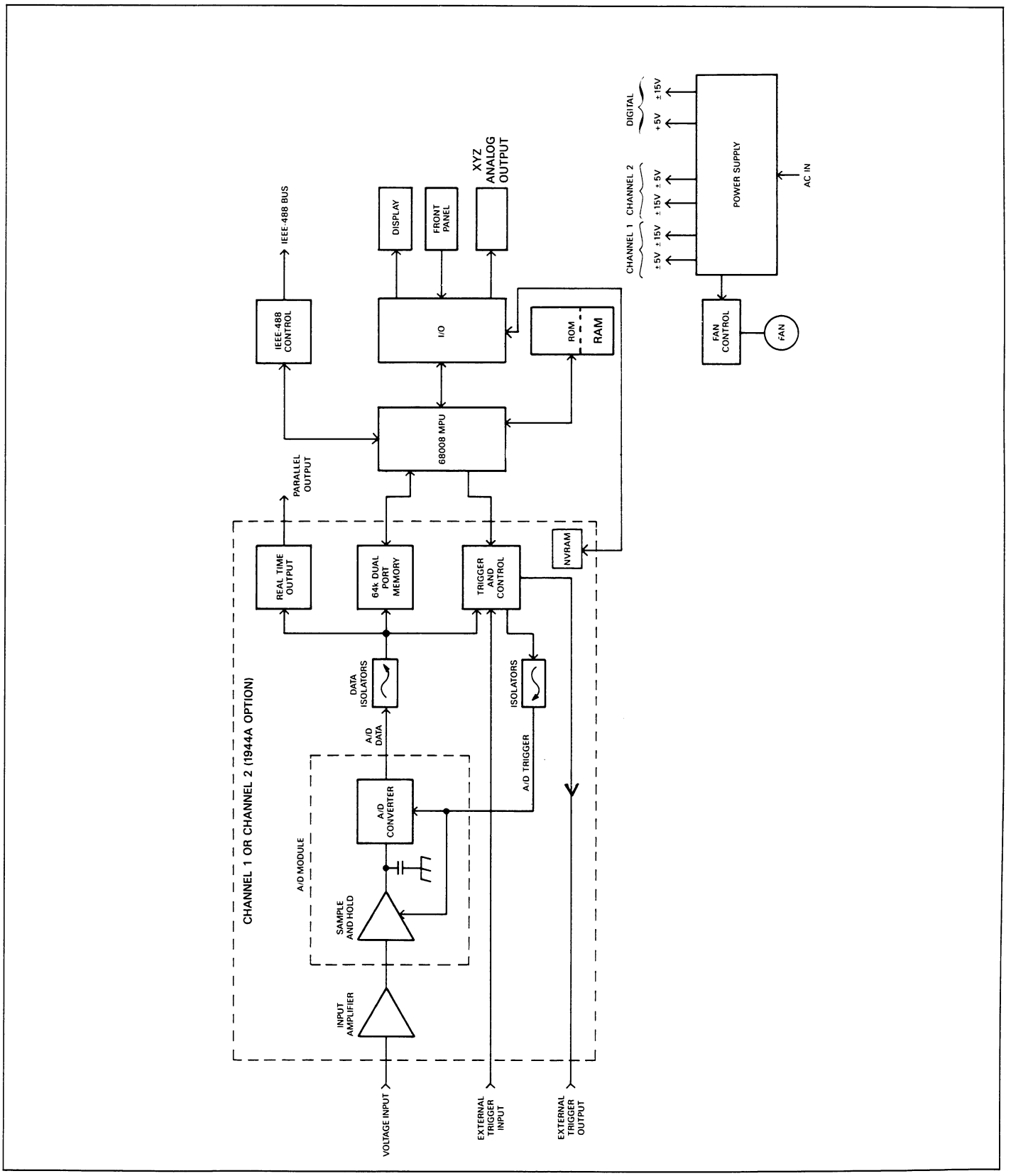


Figure 6-1. Simplified Block Diagram

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The microcomputer section consists of the 68008 MPU and associated components. Software for the instrument is contained in the ROM ICs. The MPU, with the help of the software, supervises all operating aspects of the instrument, including A/D converter operation, front panel controls and display, the IEEE-488 bus, the analog outputs, as well as the operation of the second A/D channel, if that module is installed.

The power supply converts the AC input power line voltage into various DC voltages used by the instrument. Each channel has its own ±5V and ±15V analog supplies to ensure proper isolation. Other supplies include the +5V digital and additional ±15V supplies for switcher circuits and analog outputs.

6.3 ANALOG CIRCUITRY

For a detailed schematic of the analog circuitry, refer to drawing number 194A-126, page 2 located at the end of Section 8.

6.3.1 Block Diagram

A simplified block diagram of the analog circuitry is shown in Figure 6-2. The analog input circuitry can be divided into six sections: input coupling, attenuation, protection, x1.526 gain stage, filter, and switchable gain amplifier. The coupling circuitry selects AC or DC coupling at the input stage, and the attenuator selects x1, x0.1, or 0.01 attenuation factors for the 32V and 200V ranges. The protection circuitry protects the circuit from overvoltage inputs. The x1.526 gain stage supplies a fixed gain. The filter circuitry applies either 50kHz or 500kHz single-pole filters. The switchable gain amplifier can be set to x1 or x10 gain values, depending on the selected range.

6.3.2 Circuit Description

Input signals are applied through J1011 to the input amplifier via R328 or C384 and R321, depending on the positions of K303 and K304. From the input coupling circuit, signals are applied the input attenuator made up of R312, R313, and R318. Frequency compensation is performed by C374, C375, C383, and C386. The actual attenuation factor is selected by K302 and Q301. Attenuation factors of x0.1 (32V range) or x0.01 (200V range) are applied by placing K302 in the correct position and switching Q301 on or off to take R312 in or out of the circuit. Table 6-1 summarizes attenuator values for the four ranges.

Input protection is necessary in cases where an over voltage input might be applied. Protection circuit components include CR302, CR302, VR301, VR302, Q302, and Q303.

The signal is next applied to a fixed gain stage made up of U387 and associated components. U387 is an operational amplifier being used in the non-inverting configuration. The gain of this stage is set to x1.526 by resistors R322 and R323. This gain factor is applied to convert a nominal +32,767, +32,768 count input into a ±5V full scale value to take full advantage of the A/D converter range.

The analog filtering is performed by R320, R327, and C387. Actually, only one RC combination can be in effect at any given time. Q304 switches in the 50kHz filter, while Q307 controls the 500kHz filter. When the filter is disabled, both FETs will be off.

The final stage in the input amplifier is the x1/x10 gain amplifier, which is made up of U386 and associated components. The stage is also a non-inverting operational amplifier. The gain of this stage is set to either x1 or x10, depending on the selected range (see Table 6-1). Gain is set by resistors R314 and R319, and FETs Q305 and Q306. For example, when x10 gain is selected, Q305 will be on, and Q306 will be off. Under these conditions, the amplifier gain is:

$$A = 1 + R314/R319$$
$$A = 1 + 1800/200$$
$$A = 10$$

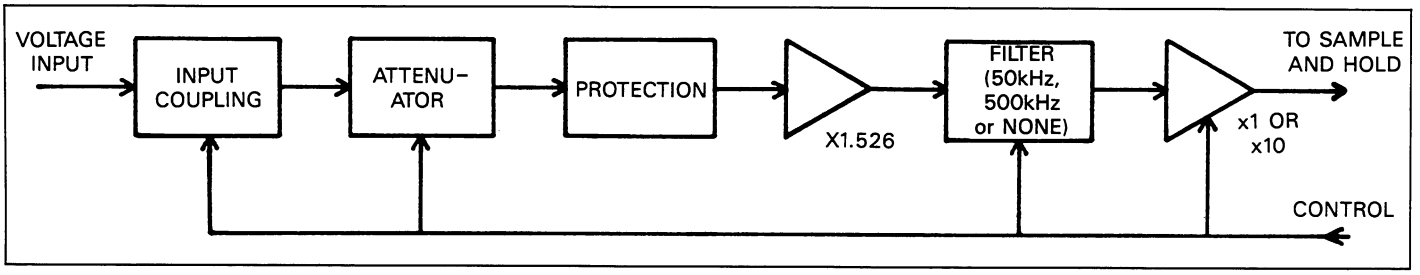


Figure 6-2. Simplified Block Diagram of Analog Circuitry

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Table 6-1. Attenuator and Gain Values

Range	Attenuator	X1/X10 Gain Amp	Overall Gain
320 mV	X1	X10	X15.26
3.2 V	X1	X1	X 1.526
32 V	X0.1	X1	X 0.1526
200 V	X0.01	X1	X 0.01526

6.4 A/D CONVERTER

Once the signal is processed and conditioned by the input amplifier, it is applied to the A/D converter circuitry. The purpose of this circuitry is to convert the analog input voltage into a digital or binary value that can be stored in memory and used by the microprocessor for data processing.

The following paragraphs discuss the operation of the A/D converter in detail. First, a simplified block diagram of the circuit is presented along with an introductory discussion. Next, a more detailed analysis of the various A/D circuits is given. When reading through the discussion of the A/D converter, it will be helpful to refer to schematic drawing number 194A-126, page 1 located at the end of Section 8.

6.4.1 Converter Block Diagram

A simplified block diagram of the A/D converter is shown in Figure 6-3. The circuit can be broken down into five major sections: the A/D converter itself, the data parallel-to-serial data conversion circuits, the opto-isolators, the control serial-to-parallel converters, and the data control circuits.

The analog input signal is applied to the sample and hold input of the A/D converter module. The output of the converter is in either 8-bit or 16-bit binary form, depending on the selected converter mode. The parallel data output is then converted to serial for transmission across the isolators to the digital control circuitry discussed later in this section. Transmission is actually done in dual-serial form with odd/even bit pairs transmitted simultaneously. The data control circuit generates a 5MHz clock and other control signals to synchronize data transmission.

A single trigger line is used to trigger the A/D converter to make a conversion. Trigger pulses are generated by the trigger control circuitry discussed later in this section.

Serial control data is used by the A/D and input amplifier control section. This data is shifted in with the help of the clock and strobe lines. A total of five 8-bit serial-to-parallel converters are used to control 8/16 bit A/D converter modes, set the offset and gain parameters for the A/D converter, and to control the input amplifier through relays and FETs.

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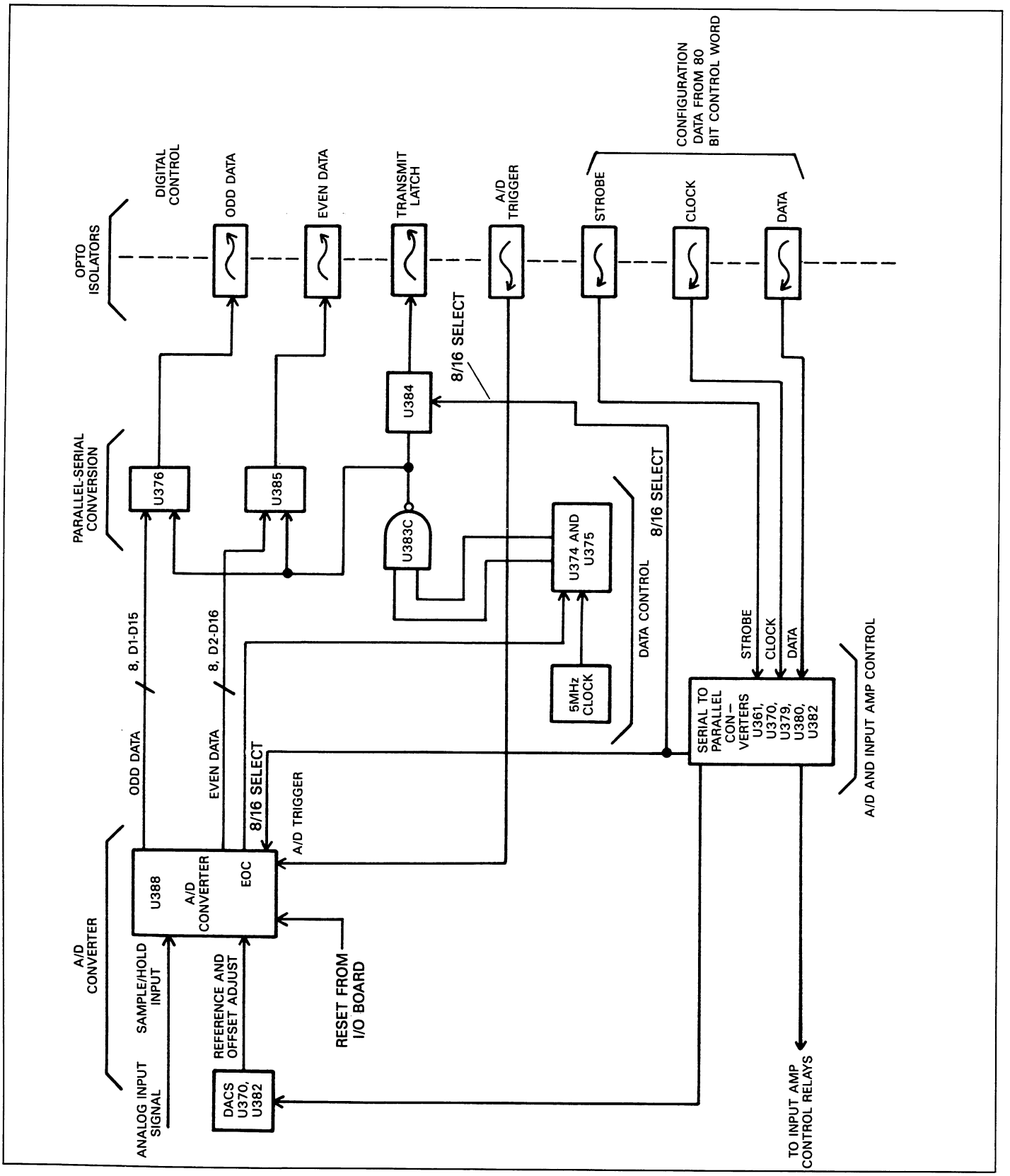


Figure 6-3. Block Diagram of A/D Converter

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6.4.2 Converter Module

U388 is the actual converter module, which performs both the sample/hold and A/D converter processes. The analog input signal is applied to the S/H ANALOG IN terminal (pin 23). Other terminals of note include the TRIGGER, EOC, 8/16 SEL, D1-D16, EXT. OFF ADJ., and EXT REF ADJ.

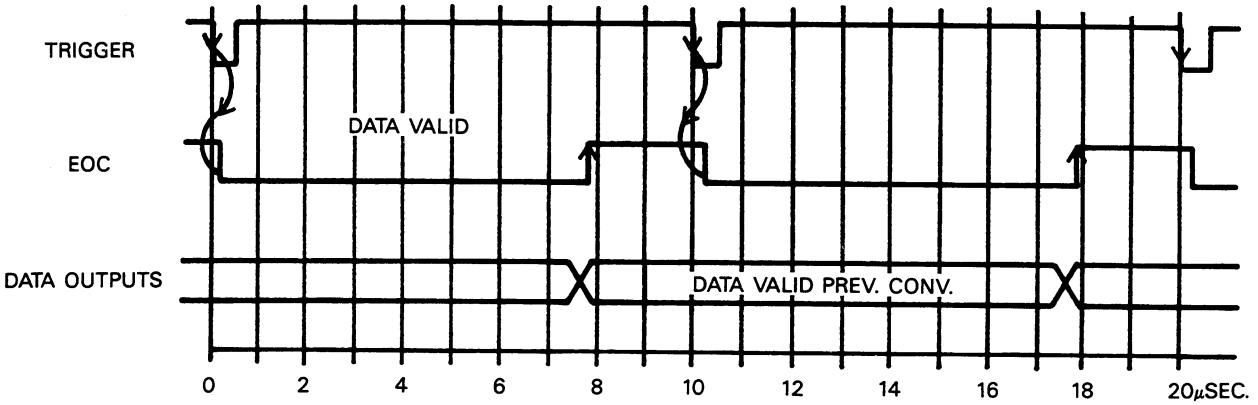
A negative pulse, applied to the TRIGGER terminal, starts the A/D conversion process. The duration of that process will depend on whether the converter is operated in the 8- or 16-bit mode. The logic level on the 8/16 SEL terminal determines the mode: if 8/16 SEL is high, the converter operates in the 8-bit mode; if 8/16 SEL is low, the converter operates in the 16-bit mode.

Once triggered, the converter will take a finite time to complete the conversion process. The amount of time necessary will depend on whether the converter is being operated in the 8- or 16-bit modes. Figure 6-4 shows a general timing diagram for the converter in both modes.

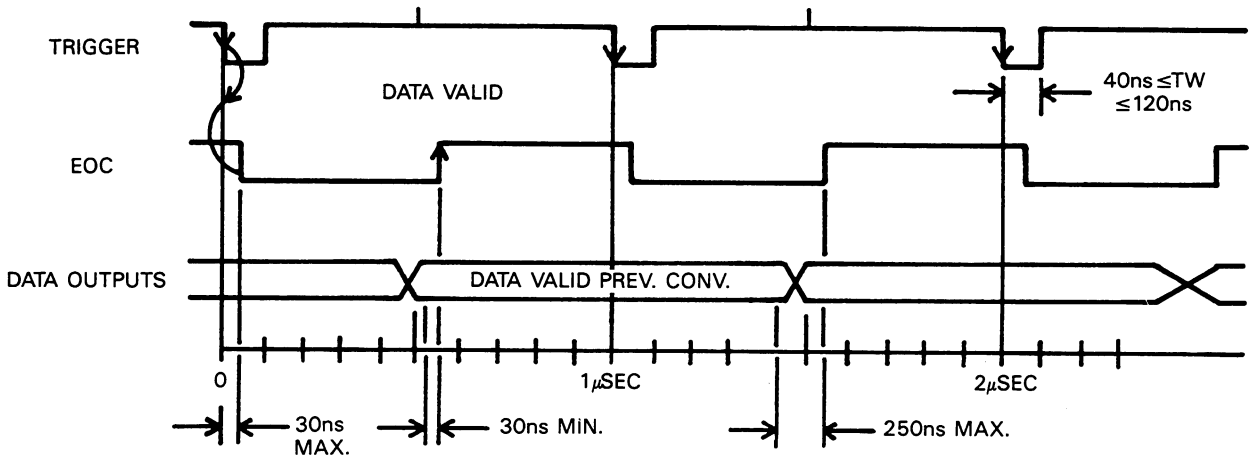
A completed conversion is indicated by a positive-going edge on the EOC line. Note that data present on the data terminals is from the previous conversion; that is, data always runs one conversion behind the trigger pulse. Once data is converted, it is available in parallel on the D1-D16 data lines (16-bit) or D1-D8 data lines (8-bit). D1 is the LSB (least signficant bit) and D16 or D8 is the MSB (most signficant bit), depending on whether the converter is in the 8- or 16-bit mode.

In order to maintain high accuracy, converter offset and reference levels are software controlled through the use of two 12-bit DACs (digital-to-analog converter), U362 and U363. U362 controls the reference, while U363 controls the offset of the converter. The digital information controlling these DACs is obtained from the serial control word (discussed later) part of which is shifted into U361, U370, and U382, which convert the serial information into parallel bytes used to control the DACs. Note that four bits of U370 control U362 while the remaining four bits control U363. Information that controls these DACs is obtained from calibration constants derived when the instrument is calibrated.

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A. 16 BIT OPERATION



B. 8 BIT OPERATION

NOTE: MIN/MAX TIMING VALUES QUOTED IN FIG. B ARE VALID FOR BOTH 8 BIT AND 16 BIT OPERATION

Figure 6-4. A/D Converter Timing

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6.4.3 Parallel-to-Serial Data Conversion

The parallel data output of the A/D converter must be converted into serial form before it can be transmitted over the opto-isolators to the digital control circuitry. This task is performed by U376 and U385, which are parallel-to-serial converter ICs (74LS165). As pointed out earlier, a dual-serial transmission scheme is used, with odd/even bit pairs transmitted simultaneously. Thus, U376 converts and transmits odd data bits (D1, D3 and so on), while U385 handles the even data bits (D2, D4, etc.).

At the end of a converter cycle, a signal derived from the A/D converter EOC signal is used to pull the PL terminals on U376 and U384 low. This action latches the A/D converter data into these two ICs. Data is then shifted out the Q1 terminals under control of a clock pulse applied to the CP1 terminals of the two ICs. The data bits are first buffered by sections of U371 (74LS244) before being applied to the LED sections of the data transmission opto-isolators. U367A transmits odd data bits, and U367B transmits even data bits. The receiving ends of these isolators convert the generated light pulses back into electrical impulses in the usual manner. The serial pulses are then converted back into parallel to be stored in memory, used by the trigger circuits, and transmitted out the real time output. These aspects are discussed later in this section.

6.4.4 Data Transmission Control

The data transmission process is controlled by a stable reference clock and several other components. These include Y101, U383A, U374, U375, U383C, U384, U371E and U371F, and U366B and U366B.

Y101 generates a stable 10MHz reference signal for the data transmission process. This signal is squared by U383A, one segment of a quad 2-input NAND gate IC (74LS00), and then applied to section 1 of a dual D-type flip-flop, U374 (74LS74). This flip-flop divides the signal by two to form the 5MHz clock that synchronizes data transmission. The second section of U374 and the first section of U375 (also a 74LS74), make up a shift register that effectively delays the A/D converter EOC signal by two cycles. Meanwhile, U383C is used to gate the EOC signal, while U384, a parallel-to-serial converter (74LS165), is used to select 8- or 16-bit data transmission modes.

As previously described, the A/D converter EOC line goes high when data is ready at the A/D converter data lines. This logic level is then latched into the 2Q output of U374 with the next 5MHz clock pulse and applied to the 1D input of U375. After two clock pulses, both inputs of U383C will be high, and its output will go low. This action causes A/D converter data to be latched into U376 and U384. At the same time, the logic levels on the P0-P7 terminals of U384 will be latched into its register. If the converter is being operated in the 8-bit mode, P1-P4 will be high; however, these four inputs will be low if the converter is operated in the 16-bit mode.

As each 5MHz clock pulse occurs, an odd/even pair of A/D data bits is shifted out U376 and U384. At the same time, bits previously latched into U384 by the delayed EOC signal will be shifted out. Thus, the bits latched into U384 will be shifted out through U371F and U366B to the digital control circuitry. After four clock cycles (8-bit mode) or eight clock cycles (16-bit mode), the serial output of U384 will go high, causing the transmitted data to be latched into registers located in the digital section, as discussed below. In this manner, U384 controls whether 8-bits or 16-bits are transmitted.

The 5MHz clock is used to synchronize the operation of the parallel-serial converters, U376, U384, and U385, as discussed previously. In addition, this clock is used to synchronize circuits in the digital section. Towards that end, the 5MHz clock is transmitted through U371E and opto-isolator U366A to the digital circuits discussed later in this section.

The A/D converter module must be triggered before it will perform a conversion. Trigger pulses orginate in the trigger control section of the digital circuitry discussed below. These trigger pulses are transmitted through U365 and buffered by U371C, after which they are applied to the A/D converter.

6.4.5 Serial Control

Various operating aspects of the A/D converter and input amplifier are controlled by bits in the serial control word. The serial control word is made up of 10 bytes (80 bits), five of which control the A/D converter or the input amplifier. These five bytes are shifted into serial shift register ICs, U379, U380, U361, U370, and U382 (4094). The remaining five bytes are shifted into similar ICs which are located in the digital section to be discussed later.

Serial control word data is generated in the digital section, shifted in through U364, and applied to the DATA input of U379. The clock necessary for the shifting process is applied through U364, buffered by U371A, and applied to the CLOCK input of U379. After eight bits have been shifted in, data overflows out the Q_s output of U379 to the DATA input of U361. In a similar manner, the Q_s outputs of the remaining shift register ICs (U370, U382, and U380)

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are connected serially, with the Q_8 output of the preceding IC being connected to the DATA input of the following IC.

Once all 80 bits (40 in the A/D section) are shifted in, the strobe pulse is applied to latch the various bits into the shift register outputs. In the A/D section, this strobe pulse is applied through U365, buffered by U371D, and applied to the STROBE terminals of the five shift register ICs. Since all STROBE terminals are connected together, all 80 bits are latched simultaneously.

The five shift registers ICs in the A/D converter section perform the following control functions:

1. The Q_8 output of U379 is used to select 8- or 16-bit operation of the A/D converter. If Q_8 is high, the A/D converter operates in the 8-bit mode; if Q_8 is low, the converter operates in the 16-bit mode. Q_1, Q_3, and Q_5 through Q_7 of U379 are used to control FETs in the input amplifier section. Elements of U377 and U378 are used to convert standard logic levels into ±15V levels to turn the FETs on or off.
2. The Q_6 through Q_8 outputs of U380 are used to control relays K301, K302, and K303 in the input amplifier. U381 supplies the drive capability to power the relay coils.
3. U361, U370, and U383 are used to store digital calibration information for the A/D converter. This information is converted to analog form by two 12-bit DACs (U362 and U363), as previously discussed. U361 and four bits of U370 are used for A/D reference adjustment, while the remaining four bits of U370 and all eight bits of U382 are used to store converter offset data.

6.5 DIGITAL CONTROL CIRCUITRY

The digital control circuitry within the Model 194A is used to store data and control its flow, control A/D triggering, and keep track of the number of samples taken with its sample counter. The following paragraphs describe the operation of the digital circuitry in detail. First an overview is presented in block diagram form. Next a detailed analysis for each of the major sections is given. These descriptions are keyed to various schematic diagrams located at the end of Section 8. The pertinent schematic or schematics are called out with each individual description.

6.5.1 Block Diagram of Digital Circuitry

A simplified block diagram is shown in Figure 6-5. Major circuitry includes that necessary to convert serial A/D converter data into parallel form, trigger comparator, trigger control logic, sample counter, the 64K byte dual-port memory, and the real time output. For clarity, some of the circuitry located in the A/D converter section is also shown on the diagram.

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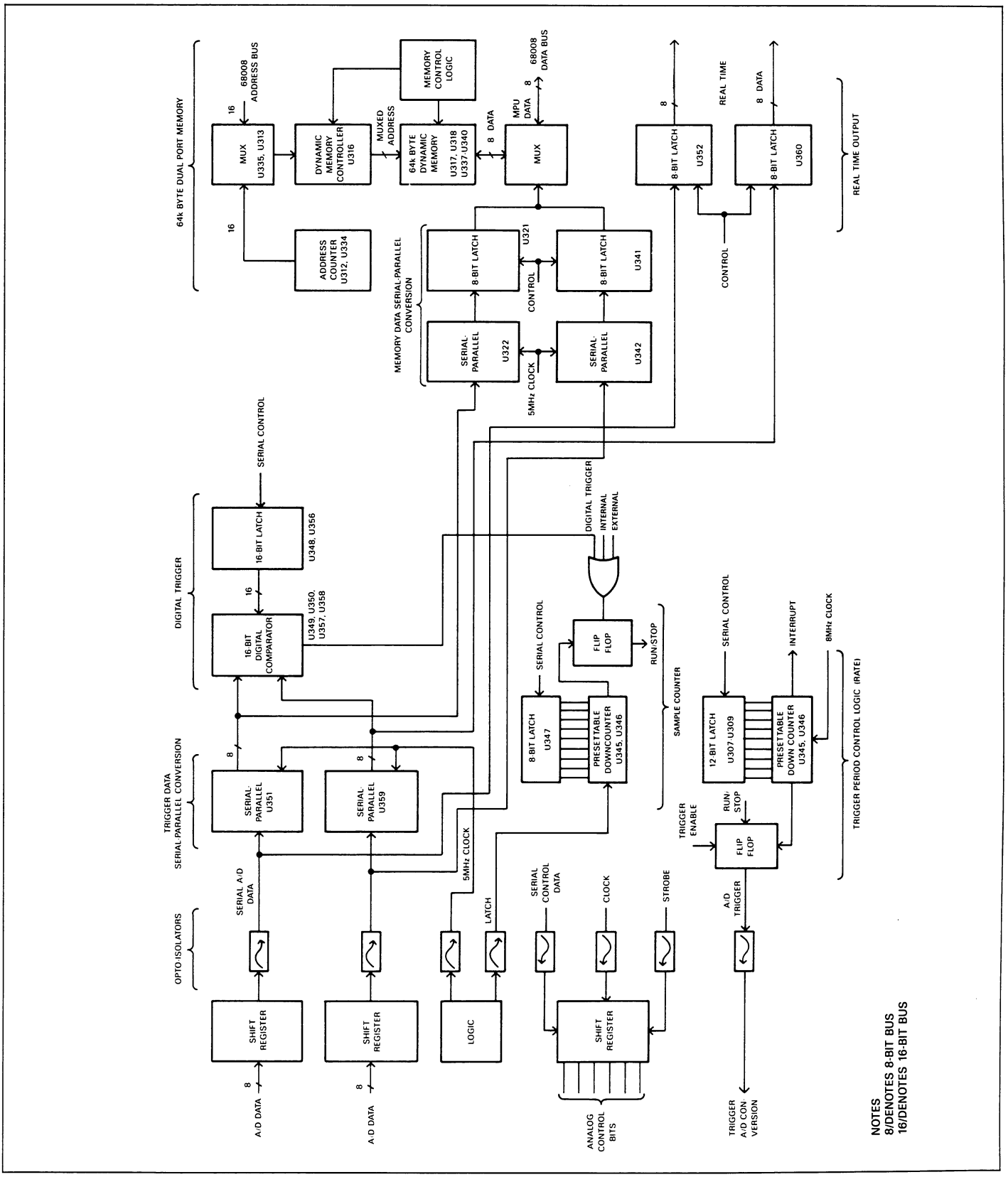


Figure 6-5. Digital Control Block Diagram

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Serial-to-Parallel Data Conversion

Parallel A/D converter data is converted into serial form by two shift registers and transmitted across two opto-isolators, as described previously. Data is then converted back to parallel by two sets of serial-to-parallel converters. One set supplies data to the trigger comparator and real time output circuits, while the other serial-to-parallel converters feed data to the 64K dual-port memory.

Digital Trigger

The digital trigger circuits consist of a 16-bit digital comparator and a 16-bit latch. The latch is loaded serially with two control bytes from the microprocessor. As discussed earlier, this control information is part of the 10-byte control word that is passed serially as part of the control sequence.

The digital comparator monitors both the preset trigger level data in the 16-bit latch, and data from the A/D converter. If the two binary numbers are the same, a trigger pulse appears at the output of the comparator. If the instrument is programmed to trigger from the input signal, the RUN/STOP flip-flop is triggered to start a series of A/D readings. The number of readings to be taken will depend on the reading counter.

Sample Counter

The sample counter is made up of an 8-bit latch and a presettable counter. The latch is serially preloaded with control information from the microprocessor via the 80-bit control word. Once the 8-bit latch contains the correct information, the downcounter is loaded with the count information. The counter then decrements by one count each time an A/D sample is taken. The count pulse is fed across the opto-isolator from circuitry located in the A/D section.

Trigger Period Control

A similar counter arrangement is used to control the trigger period. A 12-bit latch is loaded with data from the serial control word. The value loaded will depend on the programmed sampling interval. Once the latch is loaded, the counter is preset from the latch by a control pulse. The countdown period is controlled by the 10MHz clock of the microprocessor, or by an external clock pulse if one is applied.

Since the counter is only 12 bits wide, it counts only to 4096. With the 10MHz clock, the maximum count period is: 4096/10MHz = 0.4096msec. Thus, to extend the trigger period to the one second maximum, a separate software counter must be employed as well. Every time the hardware counter reaches zero, a microprocessor interrupt is generated, at which point it increments the software counter. Once the correct conditions for both the software and hardware counters are reached, an A/D trigger pulse is generated, and another reading sample is taken, assuming that the RUN/STOP and TRIGGER ENABLE signals are at the correct logic level.

64K Byte Dual-Port Memory

The 64K byte dynamic memory is shared by the A/D converter and the mircroprocessor--an arrangement that gives the memory block its dual-port name. To allow both circuits access to the memory, a number of memory control and multiplexer circuits are necessary. The dynamic memory controller refreshes the dynamic memory and also multiplexes the addresses. If the 68008 MPU is accessing memory, the address comes from its address bus. If A/D data is being stored, the address is supplied by the address counter.

In a similar manner, the microprocessor and A/D data busses are multiplexed into the memory data lines. When the A/D is storing data, it gains access to the data lines of the memory ICs, while the MPU gains access to the data lines when it requires data access.

Real Time Output

One final portion of the digital control circuitry is the real time output, which provides data output for other equipment at the conversion rate. Two 8-bit latches store essentially the same data bits that are stored in memory. Real time output data transmission is controlled by additional logic circuitry not shown on the block diagram.

6.5.2 Isolator Data Transmission

For the following discussion, please refer to drawing number 194A-126, page 2 located at the end of Section 8.

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The 5MHz shift clock and opto latch signals are applied through opto-isolators located in U366. As with the A/D converter data signals, these logic levels are buffered by sections of U369 before being applied to other circuits.

Several logic signals originating in the digital control section are passed through the isolators to control the A/D converter and input amplifier. These signals include the serial data, clock, and strobe signals for the analog control bits, and the A/D trigger pulse. These signals are transmitted to the A/D converter section by opto-isolators U364 and U365. As with the remaining signals, these levels are first buffered by elements of U369.

6.5.3 Serial-to-Parallel Data Conversion

Circuits for the following discussion will be found on schematic drawing number 194A-126, page 3 located at the end of Section 8.

Serial-to-parallel data conversion is performed by two sets of circuits. One set converts data for the digital trigger circuits, while the other performs the conversion for the memory and real time output circuits. Even-bit A/D converter data is applied to the A and B inputs of U342 and U359, while odd-bit converter data is applied to the A and B inputs of U322 and U351. U322 and U342 convert serial data to parallel for the memory, and U351 and U359 perform the same conversion process for the digital trigger and real time output circuits. Each of these four ICs is a serial-in, parallel-out shift register (74LS164). The data shift-in process is controlled by the 5MHz clock that originates in the A/D converter section.

The 16-bit parallel output of U351 and U359 is applied to the digital comparator and real time output circuits discussed below. The 16-bit parallel output of U322 is latched into U321 and U341, which are used to store the A/D converter data briefly before it is stored in memory. U321 and U341 are octal D-type flip-flops (74LS374), which are equipped with 3-state outputs. Once data is latched into these two ICs, the outputs are turned on by placing the CONT terminals low, thus feeding data to the data lines of the memory ICs.

6.5.4 Sample Counter

The sample counter circuits are located on drawing number 194A-126, page 3.

The sample counter itself is made up of U345 and U346, which are up/down binary counters (74LS193). Since each counter is capable of counting only four bits, two such ICs are necessary to extend the count to the necessary eight bits.

At the appropriate time, the counters are loaded through their parallel inputs with data from U347. This IC is a serial-in, parallel-out shift register, which stores control information from the 80-bit serial control word. Data originating in the microcomputer section is shifted into U347 under the control of microcomputer software. The actual count data will depend on the programmed number of samples.

Once the counter is loaded, it will count one unit with each sample. Once the count is complete, an output pulse at the BORROW terminal of U346 is generated. This pulse ultimately controls the RUN/STOP flip-flop, U368A.

6.5.5 Digital Trigger Comparator Circuits

The digital comparator circuits are located on drawing number 194A-126, pages 2 and 3.

ICs associated with the digital comparator circuits include U356, U357, and U358 (page 3), and U348, U349, U350, U327A, U353, and U354 (page 2). U349, U350, U357, and U358 are 4-bit magnitude comparator ICs (74LS85). These ICs compare the difference between the A/D binary data stored in U351 and U359, and binary trigger level information stored in U348 and U356. U348 and U356 are serial-in, parallel-out shift registers (74LS164) that store the binary trigger level information. That trigger level information is part of the 80-bit serial control word, and is shifted in serially. It is derived from the programmed trigger level keyed in by the operator, or programmed over the IEEE-488 bus.

The digital comparators work in conjunction with U353 and U354 to generate a compare pulse when the A/D data goes through a transition point below or above that set by trigger level data. These ICs are set up differently depending on whether positive or negative slope triggering is in effect. For example, if negative slope trigger is programmed, the compare pulse will be generated when the A/D data goes below the preset trigger level stored in U348 and U356. When the compare pulse is generated, the A/D reading sequence is started and will run in accordance with the programmed rate and number of samples.

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The digital comparator circuits operate only when the selected trigger source in the input signal. Thus, these circuit have no effect on A/D converter sampling for other trigger sources.

6.5.6 Trigger Period Control Logic

The trigger period control logic may be found on drawing number 194A-126, page 3. The purpose of this circuitry is to generate A/D converter trigger pulses at programmed intervals.

This control logic is made up of two 12-bit latches (U306 and half of U310), a 12-bit counter (U307, U308, and U309), and miscellaneous gates and flip-flops. U306 and U310 are serial-in, parallel-out shift registers (74LS164), while U307, U308, and U309 are synchronous presettable binary counters (74LS161).

Counter control data is first loaded serially into U306 and U310 from the 80-bit serial control word. This binary information will depend on the programmed sampling rate. Once all bits are in the 74LS164 shift registers, they are strobed into the counter ICs to begin the counting process. This loading operation is carried out by setting the LOAD terminals of U307, U308, and U309 low.

The trigger period counters are controlled by a clock pulse applied to the CLK inputs of the three ICs. Normally, the 10MHz MPU clock is used, but an external clock signal will be used instead if a suitable clocking signal is applied to the EXT CLOCK INPUT on the rear panel of the instrument.

During the count-up process, the MPU monitors the state of the O_D terminal of U309. When it goes high, a software counter is incremented, the counter is then reloaded with data from U306 and U310, and the process repeats. Once both the hardware and software counters have reached the required count values, the process is terminated, as the programmed number of samples have been taken.

6.5.7 64K Byte Dual-Port Memory

Elements of the 64K byte dual-port memory include the memory ICs, the dynamic memory controller, the address bus multiplexer, an address counter, and the data bus multiplexer. These components can be found on drawing number 194A-126, pages 3 and 4, located at the end of Section 8.

Memory Storage and Control

The memory ICs are U317-U320 and U337-U340. Each of these devices is a 64K X 1 bit dynamic RAM (6665A). Each IC stores one bit of the 64K bytes of available storage. An individual storage element within the IC is actually a very small capacitor. Since the stored charge periodically leaks off, the dynamic RAMs must be periodically refreshed.

Dynamic RAM refreshing is one task performed by the dynamic memory controller IC, U316 (4500). Refresh is accomplished by placing the RAS line low approximately every 8μsec. Since 128 rows are present in each IC, each row is refreshed approximately every 1msec. The dynamic memory controller also multiplexes addresses for the memory ICs since those devices have only eight address lines.

Each memory IC is organized into a 128 bit X 512 bit row-column matrix. Thus, to address a specific memory element or bit, both a row address and a column address must be provided. This sequence is automatically performed by U316. The row or column address is placed on the MA0-MA7 lines, and the appropriate strobe line, CAS (column address strobe) or RAS (row address strobe) is then set low. Once the addresses are strobed into the memory ICs, the data bits can be accessed through the D and Q lines. In order to write to the memory ICs, the W line must be placed low.

Address Counter and Multiplexers

U312 and U334 maintain the address count for the A/D converter. Each of these ICs is dual 4-bit binary ripple counter (74LS393). As each A/D data byte is stored, the counter is incremented so that the subsequent data byte is stored in the next higher memory location.

As pointed out earlier, the A/D converter and the microprocessor share the dual-port memory. In order to do so, the address and data lines are multiplexed, with the A/D converter circuits or the MPU gaining access to the memory ICs at the appropriate times. U313, U314, U335, and U336 perform the multiplexing function for the address lines. Each of these ICs is an octal buffer with 3-state outputs (74LS244). The multiplexing action is performed by turning on the outputs of the appropriate pair of ICs to address the desired memory location. When A/D data is being stored, the outputs of U313 and U335 will be on and the outputs of U314 and U336 will be off. Conversely, the outputs of U314 and U336 will be on and the U313 and U335 outputs will be off when the microprocessor is accessing the memory circuits.

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In a similar manner, U304, U321, and U341 operate together to multiplex the data bus. U304 is an octal bus transceiver with 3-state outputs (74LS645). U321 and U341 are octal D-type flip-flops with 3-state outputs (74LS374). When the MPU is accessing memory, the U304 outputs will be on and the outputs of U321 and U341 will be off. U321 and U341 also act to convert the 16-bit A/D data word into two bytes that can be stored in an 8-bit wide memory location. U341 controls the low byte, and U321 switches the high byte. Thus, only one of the three data bus multiplexing ICs will be turned on at any given time.

6.5.8 Digital Control-to-Microprocessor Interfacing Circuits

The microprocessor accesses numerous circuits in the digital control section through U315 and U323. U315 is a PIA (Peripheral Interface Adapter), 6821, while U323 is a VIA (Versatile Interface Adapter), 6522. Each of these ICs has two 8-bit programmable I/O ports. U315 allows the MPU to read the address counter, and it also performs other functions such as trigger selection. U323 provides numerous control functions including run/stop control, trigger slope control, address counter clear, as well as the data, clock, and strobe signals for the 80-bit serial control word.

6.5.9 Non-Volatile Memory Circuits (NVRAM)

Calibration constants and operating parameters stored with the setup mode are stored in the two NVRAM ICs, U301 and U302 (2443). These ICs also store identifying information as to the type of module installed in channel 2 location. Each device is organized into 16 words of 16 bits each. Data transfer to and from these devices is done serially through the PIAs located on the I/O board.

6.6 MICROCOMPUTER

All Model 194A operation is supervised by the microcomputer. The following paragraphs describe the fundamental operating principles behind this important section of the unit. First a block diagram is given, followed by a more detailed description of each part of the microcomputer. While reading though the various descriptions, it will be necessary to refer to drawing number 194-106, pages 2 and 3 located at the end of Section 8.

6.6.1 Microcomputer Block Diagram

A simplified block diagram of the microcomputer is shown in Figure 6-6. The 68008 microprocessor controls all aspects of instrument operation. Software for the MPU is contained in ROM ICs. The clock circuits generate a 10MHz clock for the processor and A/D converter circuits as well as a 5MHz clock for the IEEE-488 interface circuits. The decoder circuits segment the memory into 64K blocks. The control bus carries those signals necessary to interface the MPU to memory circuits and peripheral devices. The microcomputer has a single RAM IC that is used for working storage.

The data bus is eight bits wide, with the data lines carrying the D0-D7 designation. Although the MPU has 20 address lines (A0-A19), only 16 of those (A0-A15) are carried through to most circuits.

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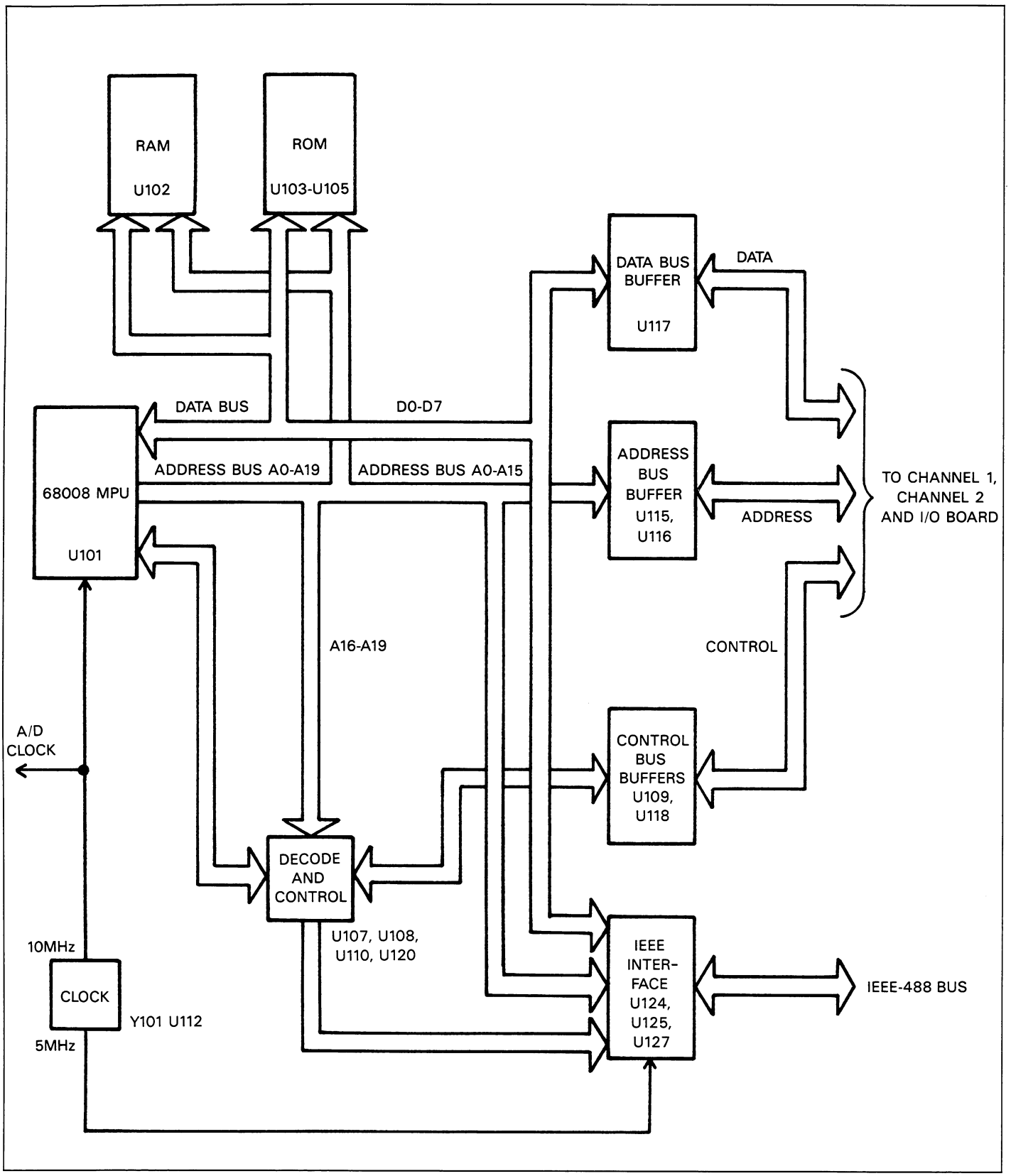


Figure 6-6. Microcomputer Block Diagram

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6.6.2 68008 Microprocessor

The 68008 microprocessor (U101) is almost identical in operation to its full 16-bit brother--the 68000. While the 68000 has a 16-bit data bus, the 68008 has a data bus that is only eight bits wide. One other difference lies in the memory addressing capabilities. The 68008 is capable of addressing 1 megabytes, while the 68000 can address 16 megabytes.

Internally, the 68008 has eight 32-bit data registers and seven 32-bit address registers. In addition two stack pointers--a user stack pointer and a supervisor, or machine stack pointer--are included to enhance operation. Because of the many internal 32-bit operations that can be performed, many Model 194A functions are handled faster and more efficiently than would be possible with a standard 8-bit processor.

As shown on the diagram (page 2 of drawing number 194-106), the 68008 has eight data lines (D0-D7) and 20 address lines (A0-A19). Numerous control lines supervise data transfer between the device and memory and peripheral ICs as follows:

$\overline{AS}$: set low when a valid address appears on the address lines.

$\overline{DS}$: set low when valid data is available on the data lines.

$\overline{R/W}$: Set high when reading data from memory or a peripheral device; set low when writing to memory or a peripheral device.

Interrupt Control ($\overline{IPL1}$/$\overline{IPL2}$): These interrupt control lines indicate the coded priority level of the device that may be requesting an interrupt.

Data Transfer Acknowledge ($\overline{DTACK}$): This input line indicates that a data transfer has been completed when it is set low.

Processor Status (FC0, FC1, FC2): These three lines indicate the status of the processor. In the Model 194A, these are decoded by U126B to acknowledge an interrupt.

Enable (E): This line provides an enable clock to peripheral ICs such as the PIAs and VIAs present in other sections of the instrument.

CLK: The 10MHz microprocessor clock is applied to this input.

Valid Peripheral Address (VPA): This input terminal provides synchronization of data transfer when communicating with peripheral ICs.

RESET and HALT: A low logic level is applied to these terminals during power up in order to reset the processor and peripheral ICs.

Bus Error ($\overline{BERR}$): A low logic level on this input terminal indicates to the processor that a bus error such as a nonresponding device has occurred.

V_{cc} and GND: The +5V digital supply provides power to the IC through these terminals.

6.6.3 Clock and Reset Circuits

The clock that drives the microprocessor originates in Y101 as a 20MHz stable reference signal. This clock signal is divided down to 10MHz by U112A, which is one-half of a dual JK flip-flop (74LS73). The 10MHz signal is then applied to the CLK input of the 68008 microprocessor. The clock signal is then divided in half once again by U112B, and the resulting 5MHz clock signal is then sent to the IEEE-488 GPIA (General Purpose Interface Adapter) IC, U127.

The 10MHz clock is also normally used to drive some A/D control circuits. However, a clock pulse, applied to the rear panel external clock input, can be used to synchronize a number of Model 194As together. U123, U111C, and U122A function together to detect and gate the external clock input. If a suitable signal is detected, the external signal is then routed to the digital control circuits instead of the usual 10MHz MPU clock.

Upon power up, the MPU is reset by briefly placing the RESET and HALT terminals at a low logic level. This reset action is performed by a timing circuit made up of U106 (8211) and associated components. The reset pulse is also applied to numerous peripheral ICs located on the A/D converter module(s), and the I/O board.

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6.6.4 Address Decoder

Several ICs are used to decode the memory map into segments and blocks. A general memory map for the instrument is shown in Figure 6-7. A more detailed summary of the map is listed in Table 6-2.

Table 6-2. Memory Mapping

Address*	Description	IC(s)
$0E000-$0FFFF	RAM	U102
$10020	Keyboard VIA	U410
$10082	Display PIA	U404
$10084	Display PIA	U407
$10100	IEEE-488 Interface	U127
$10200	Analog Output	U412-U415
$20000-$2FFFF	Channel 1 RAM	U317-U320, U337-U340
$30010	Channel 1 A/D VIA	U323
$30040	Channel 1 A/D PIA	U315
$40000-$4FFFF	Channel 2 RAM	U317-U320, U337-U340
$50010	Channel 2 A/D VIA	U323
$50040	Channel 2 A/D PIA	U315
$60000–$7E000	ROM	U103-U105

U108 is used to divide the MPU address range into 64K byte segments. This IC is a 1-of-8 decoder/demultiplexer (74LS138). The IC inputs (A,B,C, and G2A) monitor the A16-A19 address lines, and the outputs drive the select circuits for the various peripheral and memory segments. The corresponding output will go low when a particular 64K segment is selected. For example, Y0 will go low when selecting the ROM memory block, which lies in the range of $00000 to $0FFFF.

The ROM memory segment is divided into blocks. ROM decoding is performed by U107A, one half of a dual 1-of-4 decoder (74LS139). The other half of U107, is used to decode the IEEE-488 interface and I/O board circuits.

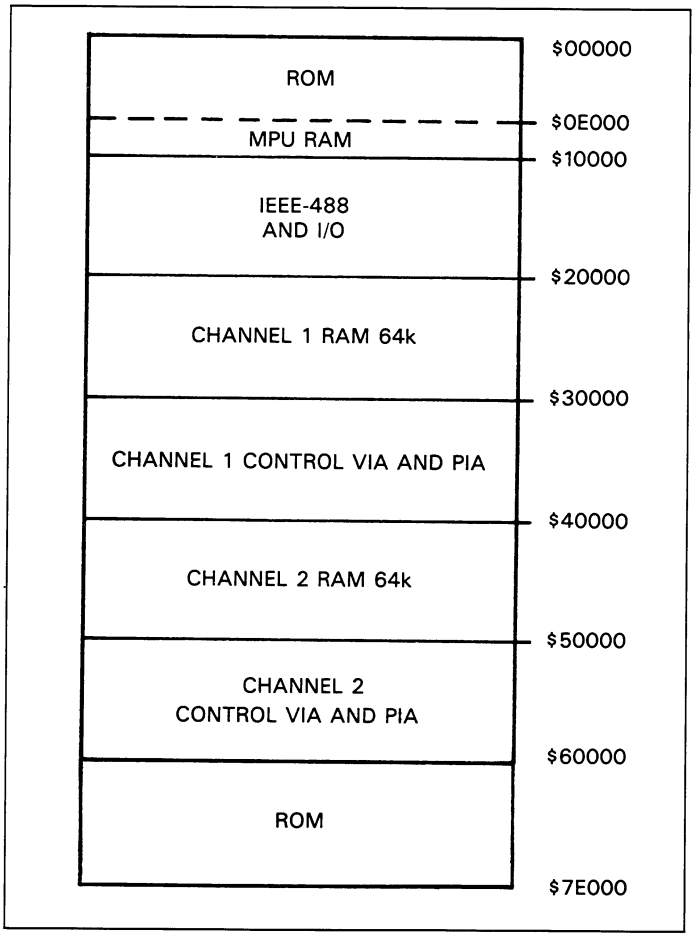


Figure 6-7. Memory Map

6.6.5 Control Circuits

Several miscellaneous circuits are used to generate control signals for the MPU bus. These include U110, U120, and a section made up of U113A, U114, and U126A.

U110 is an 8-bit serial-to-parallel converter (74LS165) that is used to generate the DTACK (Data Transfer Acknowledge) signal for the microprocessor. U120 is also a 74LS165 IC being used to generate the BERR (Bus Error) signal for the MPU. Each of these ICs functions has a delay line to provide a specific delay period for the correspond-

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ing signal. DTACK is used to tell the processor that data transfer has been successfully completed, while BERR informs the processor that there is a problem with the cycle currently being completed. Typically, such an error will occur when a device on the bus does not respond as intended.

The VMA and VPA signals are generated by U114 with the help of gating from U113A and U126A. U114 is a dual JK flip-flop (74LS73), while U113A and U126A are standard gates. The VMA signal is used to signal to peripheral devices that a valid address is present on the address lines. VPA is an input line that informs the processor that the address now in effect is a peripheral address, and the E line should be used for data transfer.

6.6.6 Memory Circuits

Software for the 68008 microprocessor is contained within ROM ICs. The ROM (Read Only Memory) ICs in the Model 194A include U103, U104, and U105. U102 provides working storage for the MPU.

6.6.7 Buffers

Throughout the Model 194A, numerous ICs in the microcomputer, A/D module(s), I/O section, and scanner (if present) are connected to the address, data, and control buses. Because of the large number of circuits involved, each bus must be given additional drive capability--a task performed by several buffer ICs.

Address bus buffering is done by U115 and U116, each of which is an octal buffer (74LS244). Since address bus information flows only in one direction (from the MPU to external circuits), these ICs are uni-directional.

In a similar manner, U109 and U118 are used to buffer various control lines. Some control signals flow from the microprocessor to external circuits, while others flow from external components to the MPU.

Since information on the data bus flows in both directions, a bidirectional buffer IC must be used. U117 is an octal transceiver IC (74LS645) that provides such capabilities. The direction is controlled by the logic level on the DIR line, which is connected to the R/$\overline{W}$ signal. When DIR is high, data flows from external circuits, through U117, to the MPU, as the microprocessor is performing a read operation under these circumstances. When DIR is low, data flows from the MPU to external ICs due to the write operation involved.

6.6.8 IEEE-488 Interfacing

The IEEE-488 interface is made up of U124, U125, and U127. U127 is a GPIA (General Purpose Interface Adapter), 9914, while U124 and U125 are 75160 and 75161 interface bus drivers.

The 9914 GPIA simplifies interfacing to the IEEE-488 bus because many control sequences take place automatically. For example, when a data write to the bus is performed, the handshake is automatically performed by the 9914.

On the MPU side, data transmission is performed much like any other data bus transaction. MPU data access is performed through the D0-D7 lines, while the RS0-RS2 lines serve to select among the 14 internal registers (seven read, seven write) of the IC. Chip selection is performed by the CS line.

The output of the 9914 IC is in standard IEEE-488 format: the eight data lines (DIO1-DIO8), the three handshake lines (DAV, NRFD, and NDAC), and the five management lines (ATN, REN, IFC, SRQ, and EOI) are all active low with approximately zero volts representing a logic one.

The two bus drivers (U124 and U125) are necessary to bring the drive capability of the interface up to the requirements of the IEEE-488 standard, which includes provisions for a maximum of 15 devices. The outputs of the bus drivers are connected to J1004, which is a standard IEEE-488 connector.

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6.7 I/O (Input/Output) Circuitry

The I/O circuitry interfaces the microcomputer to the display, keyboard, the analog outputs, real time output serial control, and the NV (non-volatile RAM). A schematic diagram of this circuitry may be found on drawing number 194-166 located at the end of Section 8.

6.7.1 I/O Block Diagram

Figure 6-8 shows a simplified block diagram of the input/output circuitry. Circuit operation centers around three peripheral ICs which perform many of the interfacing functions. Two PIAs (Peripheral Interface Adapter) provide the interface to the front panel display. These ICs also provide the interface to the NVRAMs located on the A/D. The primary function of the VIA (Versatile Interface Adapter) is to interface the MPU to the keyboard circuits. This IC also provides the serial control interface on the real time output.

The data latches store data to be used by the real time analog outputs. For the X and Y outputs, data is converted to analog form by 12-bit DACs (Digital-to-Analog Converters). No DAC is necessary for the Z output as that output assumes only one of two logic levels, high or low.

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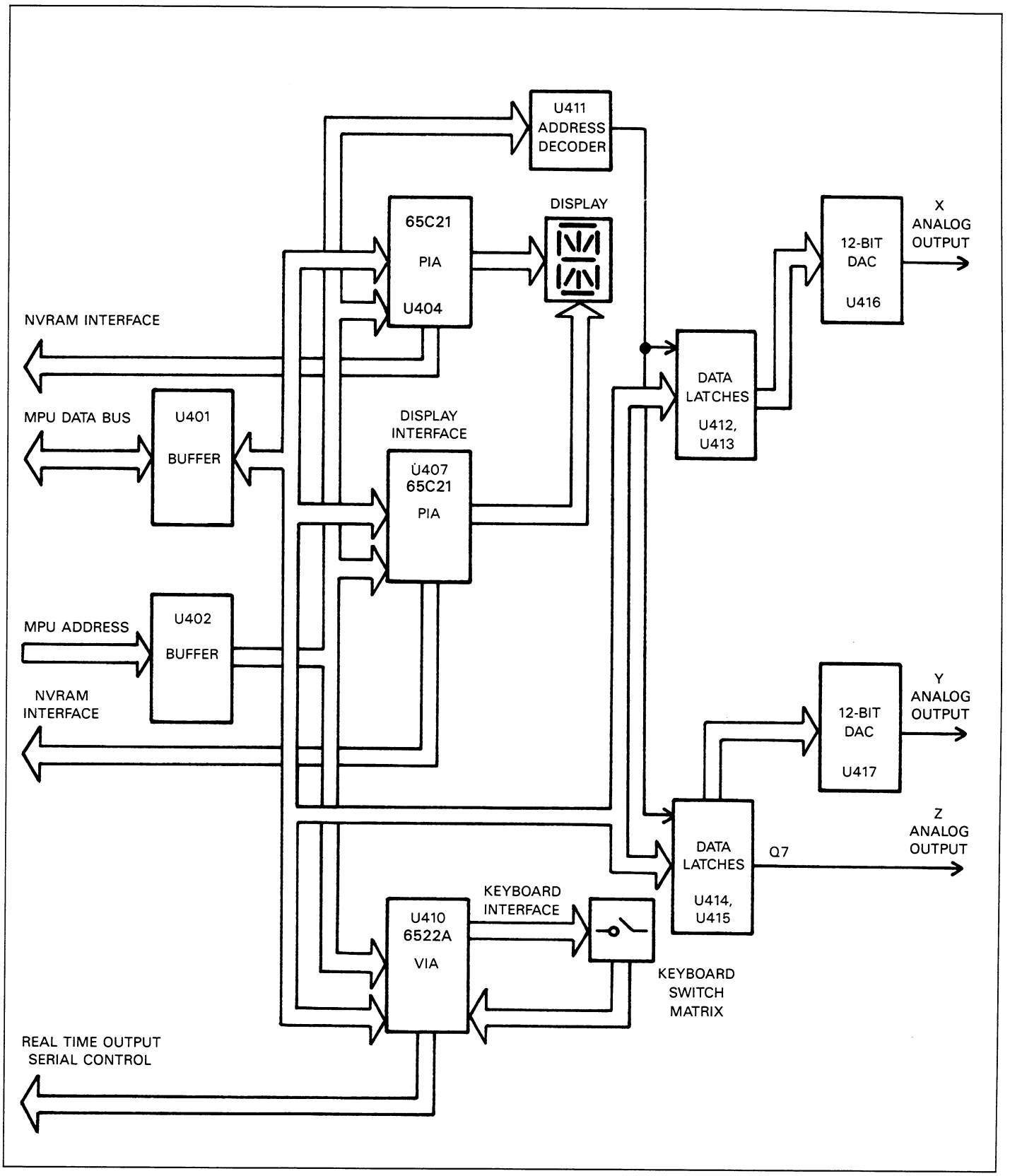


Figure 6-8. I/O Block Diagram

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6.7.2 Bus Buffering

The data and address buses are further buffered on the I/O board by U401 and U402. U401 buffers the data bus, and U401 buffers the address bus. U401 is an octal bus transceiver (74LS645), while U402 is an octal buffer (74LS244). The DECODE, VPA, and RESET lines are also buffered by elements of U403, which is a hex Schmitt trigger inverter IC (74LS14).

6.7.3 Display and Keyboard Interface

Display interfacing is provided by U404 and U407, which are 65C21 PIAs (Peripheral Interface Adapter). Each PIA has two 8-bit I/O ports and associated control lines. Since both PIAs are used to drive the displays, both ports are programmed as outputs.

U404 provides display segment information, while U407 gives display digit information. Additional drive capability is added by various ICs and resistor networks. Segment drive circuitry includes U405, U406, and R401-R406, while the digit drivers are U408 and U409 U405 and U406 are octal driver ICs (2595A), while U408 and U409 are high voltage, high current darlington arrays (2003A).

In a similar manner, U410 is used to interface to the front panel keyboard. U410 is a 6522A VIA (Versatile Interface Adapter), which has two bi-directional 8-bit ports. Additional advanced features of the 6522A include two 16-bit timers and a serial shift register.

One port of U410 is programmed as an output, while the other port is programmed as an input. The keyboard is scanned by setting each output bit in succession and then reading all the input bits. The switch that is closed is then determined by noting the resulting scanned data.

6.7.4 Serial and NVRAM Control

Each A/D and scanner module has two NVRAMs that store calibration constants and operating parameters. Control of the NVRAMs is performed through the CA2 and CB2 terminals of U404, and the CA2, CB2, PB6, and PB7 terminals of U407.

In a similar manner, data is passed to or from the serial control terminals on the real time output via the CA1, CB1, CB2, and PB6 terminals of U410 during power up, setup progamming, or calibration constant storage.

6.7.5 Analog Output Interfacing

Data for the analog outputs are latched at the appropriate times into U412-U415. Each of these ICs is an 8-bit register (74LS273). U412 and one-half of U413 hold data for the X analog output, while the other half of U413 and U414 store data for the Y analog output. A single bit (O_7) of U415 is all that is necessary to control the Z output.

Digital information for the X and Y outputs is converted into analog form by 12-bit DACs (DAC-80). U416 is the digital-to-analog converter for the X output, and U417 performs the conversion for the Y output. Output protection is afforded by CR401, CR402, and R407 (X output), and by CR403, CR404, and R408 (Y output).

The single bit necessary for the Z output is taken from the O_7 terminal of U415. Q401 buffers (and inverts) the output before it is applied to the Z output terminal. R409 and R410 give the user the option of selecting a +5V or 15V maximum output level, respectively. Output protection components include CR405, CR406, and R411.

6.8 POWER SUPPLIES

The Model 194A has a number of power supplies that are used to provide power to various circuits within the instrument. The schematic diagram of these supplies may be found on drawing number 194-106, page 1 located at the end of Section 8.

6.8.1 Power Supply Block Diagram

Figure 6-9 shows the block diagram of the power supply section. AC line voltage is applied through the power transformer to the various rectifier-regulator sections that supply the various voltages. The line voltage selection switch is used to select the operating voltage range of the instrument (105-125V or 210-250V).

Three groups of supplies are included in the power supply section. The digital section supplies power to all digital circuitry on the mother board, as well as to digital circuits located on the A/D module(s), and the fan. The +5V digital section employs a switching regulator to maximize efficiency and minimize heat generation.

Each channel in the Model 194A uses a separate group of regulated supply voltages. Separate +5V, -5V, +15V, and -15V supplies are used for each channel in order to ensure isolation between channels.

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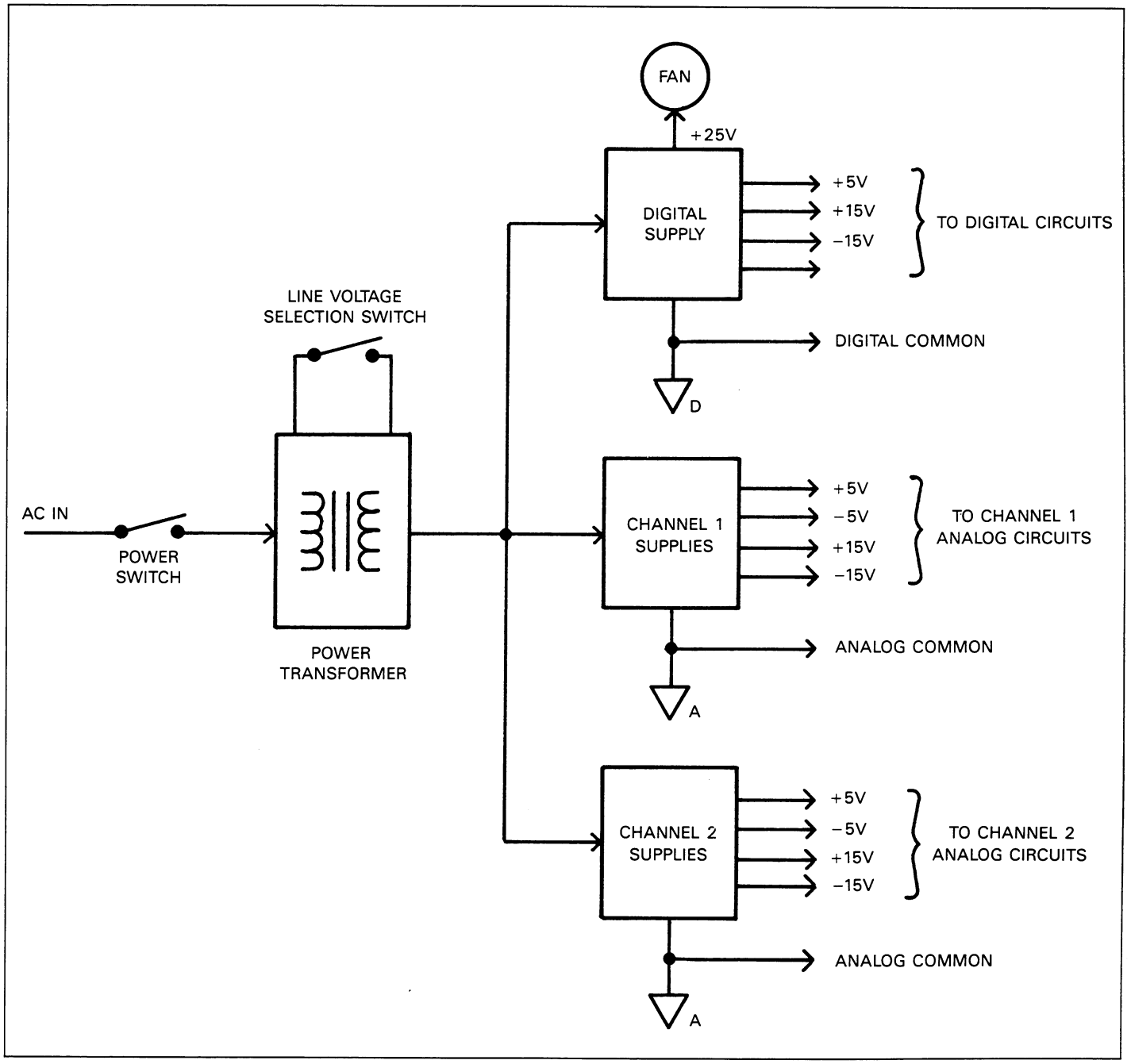


Figure 6-9. Power Supply Block Diagram

6.8.2 Power Line Input

AC power is applied through J1001, which is the AC receptacle located on the rear panel of the instrument. F101 is the line fuse, which protects the power line input, and S101 is the power switch. The line voltage selection switch, S102, places the power transformer (T101) primary windings in parallel or series depending on whether the instrument is to be operated from 105-125V or 210-250V power sources. From the primary, power is magnetically coupled to the transformer secondary winding, where it is available for use by various rectifier and regulator sections discussed in the following paragraphs.

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6.8.3 Digital Supplies

The digital supplies include a +5V supply that powers the bulk of the digital circuitry within the instrument, as well as separate +15V and -15V supplies that power miscellaneous circuits. The +5V supply uses a switching regulator to maximize efficiency, as well as to keep power supply transformer bulk to a minimum.

DC Rectification

AC power is supplied to the digital supply section by one secondary winding of T101. Coupled voltage is rectified by CR110, which is a bridge rectifier. Input filtering is done by C109. The nominal +25V developed across C109 is used by the +5V, +15V, and -15V supplies, as well as the cooling fan.

Switching Regulator

Key components associated with the switching regulator include Q101, CR101, T102, L101, U119, Q103, Q104, as well as numerous miscellaneous resistors and capacitors. Q101, a power MOSFET, is the switching transistor for the supply, while U119 is the pulse width modulator. Q104 drives the primary of T102 which couples switching pulses to the gate of Q101 to control that device. L101 provides current storage between input pulses, while CR101 provides a flyback path when Q101 is off.

U119 uses an internally generated 50kHz clock to govern the modulation process. This operating frequency is set by R121 and C145. Through use of internal comparators, U119 monitors the amplitude of the +5V supply output and changes the duty cycle of the pulses at the C1 and C2 outputs accordingly. The duty cycle of the pulses that switch Q101 is changed by a corresponding amount in order to regulate the supply output.

For example, assume that the supply voltage begins to rise slightly. Circuitry within U119 then acts to reduce the duty cycle of Q101, thus lowering the output voltage. Conversely, the duty cycle will increase if the supply output drops, maintaining voltage within regulator limits.

Since a switching supply operates in a pulsating fashion, more stringent filtering than normal is required. C139, L102, and C143 make up a pi filter to attenuate any switching noise or ripple at the supply output.

Supply Protection

Three forms of protection are included with the switching regulator to protect the supply and external circuits from over voltage or over current conditions: the fuse, a crowbar circuit, and a current limiting circuit.

F102 is a 6A fuse that protects the power supply from catastrophic failures. The fuse also works in conjunction with the crowbar circuit made up of VR111, R115, C141, and Q102. This circuit monitors the supply output voltage to determine if a safe level has been exceeded. If the voltage exceeds 6V, SCR Q102 fires, causing fuse F102 to blow.

The current limiting circuitry includes Q103 and associated components. If an overcurrent condition too fast for the fuse react is detected, Q103 shuts down U119, effectively turning off Q101. With Q101 shut down, the supply output is turned off.

+15V and -15V Supplies

The nominal +25V generated by CR110 and C109 is further filtered by C107 and regulated to +15V by VR101, a standard IC regulator (78M15). Additional filtering of this +15V supply is performed by C106.

The -15V supply originating in this section is generated somewhat differently. Pulses from the switching transistor are coupled through R108 to a voltage doubler made up of C122, CR104, and CR105. The doubled output is regulated to a stable -15V value by VR102, which is a negative 15V regulator (7915).

6.8.4 Analog Supplies

Separate, isolated analog supplies are available for each input channel in the Model 194A. Each supply group is fed from a separate transformer secondary winding and includes +5V, -5V, +15V, and -15V supplies. Since the two groups are identical, only one is covered in the following discussion.

Rectification for the +15V and -15V supplies is performed by CR111. Filtering for the +15V supply is performed by C123, while regulation is done by VR104, an IC regulator (78M15). In a similar manner, C125 filters the -15V supply, while VR105, a -15V regulator IC (7915), provides the regulation. Capacitors across the +15V and -15V outputs add additional filtering and provide stability.

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The +5V and -5V supplies operate in essentially identical fashion. CR113 rectifies the AC input, while C125 and C114 filter the +5V and -5V supplies respectively. VR106 regulates the +5V supply, and VR105 regulates the -5V supply. Both of these devices are standard IC regulators (7805 and 7905 for the positive and negative supplies respectively). The supply outputs are further filtered by C112 and C113.

6.9 DISPLAY BOARD

The following paragraphs describe the basic operating principles of the various circuits on the display board.

6.9.1 Block Diagram of Display Board

Figure 6-10 shows a simplified block diagram of the display board. The circuitry can be divided into three sections: 14-segment displays, LED annunciators, and switch matrix. Both the 14-segment displays and LED annunciators are multiplexed to minimize necessary drive circuitry. The PIAs and drivers that drive the display components are actually located on the I/O board.

The 38 switches on the display board are organized into a row-column matrix in order to simplify interfacing. The switch matrix connects directly to the VIA located on the I/O board.

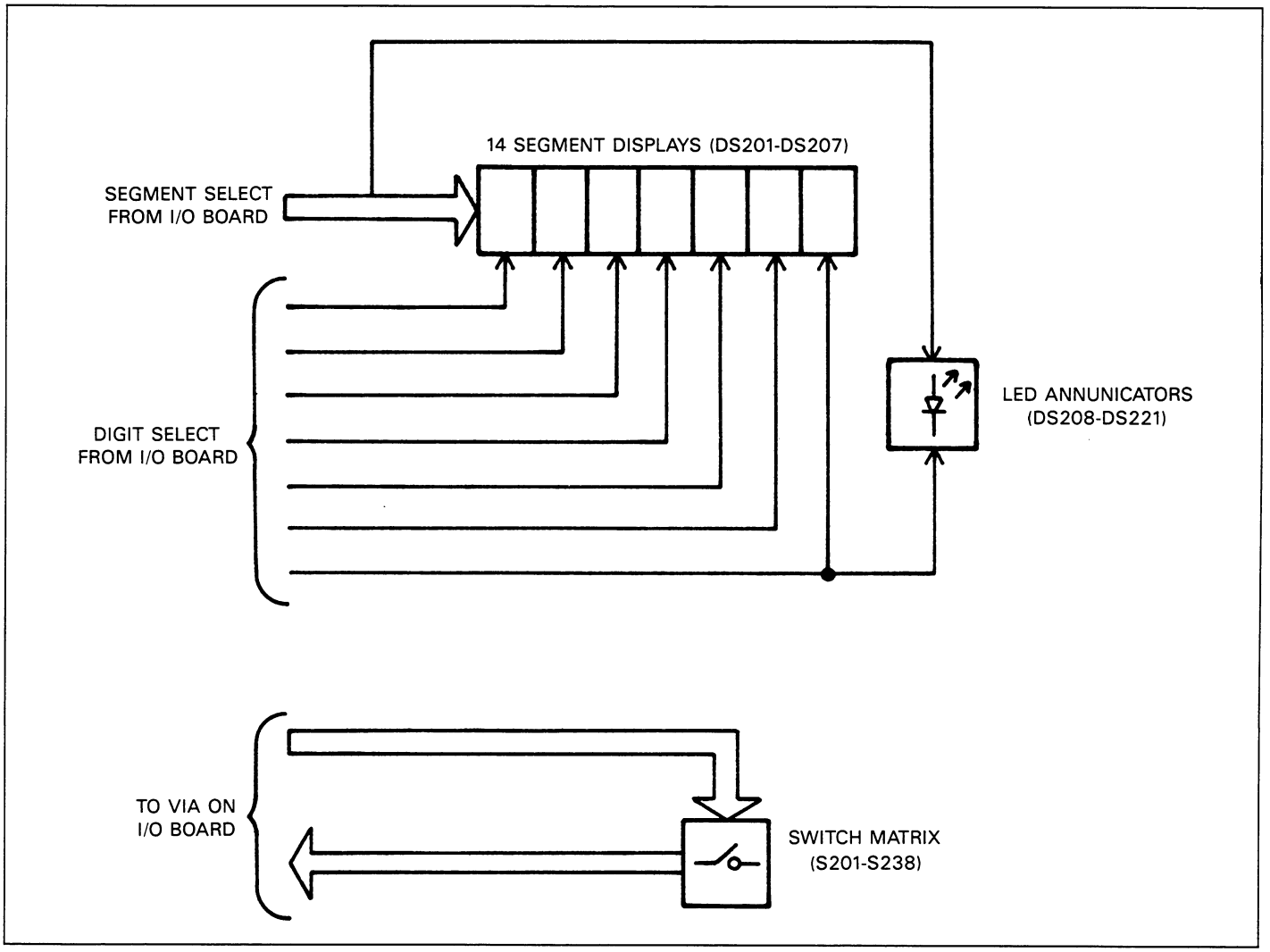


Figure 6-10. Display Board Block Diagram

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6.9.2 Circuit Description

For the following discussion, please refer to drawing number 194-116 located at the end of Section 8.

DS201 through DS207 are the 14-segment LED display units, while DS208 through DS221 are the LED annunciators. The switches in the switch matrix include S201 through S238.

The display and annunciators operate on a multiplexed basis, meaning that each LED unit is actually on for a brief period of time. In the Model 194A, the display is refreshed approximately 62 times per second. Thus, each digit will be on for about 1msec and off for the remainder of the 16msec period per refresh cycle.

To help clarify this operation, let us review the basic sequence necessary to turn the various digits. Segment data is first applied to the 14 segment lines. This data will depend on which segments in the display are to be turned on. Since the segment terminals are connected to the anodes, a high logic level must appear on the lines for those segments that are to be turned on.

Next, the digit select line for the first digit is brought low for 1msec, turning that digit on. At the same time, the remaining digit select lines must be kept high so that the other digits remain off. After the 1msec duration has passed, the digit select line is placed high, and the next digit is turned on in a similar manner. The process repeats until all 14 digits have been scanned and refreshed.

The operation of the LED annunciators is similar except that only one segment line is necessary to turn the device on. The anode of the LED must be high, and the cathode must be low for the device to turn on.

The switch matrix is read by placing one of the row lines high and then scanning the columns to determine which switch is closed. This action is performed by the two ports on the VIA located on the I/O board. Switch debounce is performed in software.

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SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 194A. Fuse replacement, line voltage selection, and option installation procedures are also included.

WARNING

The procedures in this section are intended for use only by qualified service personnel. Do not perform these procedures unless you are qualified to do so. Some of the procedures may expose you to potentially lethal voltages (>30V RMS) that could result in personal injury or death if normal safety precautions are not observed.

Information in this section is arranged as follows:

7.2 Line Voltage Selection: Describes the procedure for checking or setting the operating line voltage of the instrument.

7.3 Fuse Replacement: Outlines the procedures necessary to replace the line, and digital supply, fuses.

7.4 Option Installation: Gives the procedure for installing the Model 1944A A/D Module.

7.5 Calibration: Details the procedure for calibrating the Model 194A, including recommended calibration equipment.

7.6 Special Handling of Static-Sensitive Devices: Covers precautions to be taken when handling static-sensitive parts within the instrument.

7.7 Disassembly: Lists the procedure for disassembling and re-assembling the instrument.

7.8 Troubleshooting: Gives troubleshooting procedures for the various boards and modules within the Model 194A.

7.9 Fan Filter Cleaning/Replacement: Gives the procedure for cleaning the fan, or replacing it if necessary.

7.10 Z Output High Level Modification: Describes how to set the Z output high level to +5V or +15V.

7.11 Circuit Board Jumper Locations: Shows the factory positions for the jumpers located on the A/D and mother boards.

7.2 LINE VOLTAGE SELECTION

The Model 194A may be operated from 105-125V or 210-250V 50 or 60Hz power sources. A special transformer may be installed for 90-110V and 180-220V ranges. The instrument was shipped from the factory set for an operating voltage marked on a label next to the rear panel. To change or verify the line voltage setting, proceed as follows:

WARNING

Disconnect the line cord and all other instruments from the Model 194A before removing the top cover.

1. Remove the two screws that secure the top cover to the rear panel and slide the cover off the instrument from the rear.
2. Locate the line voltage selection switch adjacent to the power transformer on the mother board (see Figure 7-1).
3. Place the line voltage selection switch in the appropriate position, as outlined in Table 7-1.
4. If the line voltage setting has been changed, install a new fuse, as discussed in paragraph 7.3.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

5. Mark the selected line voltage on the label for future reference.
6. Replace the top cover, being careful not to snag wires, and secure it with the two screws that were removed earlier.

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Table 7-1. Line Voltage Selection

Line Voltage	Voltage Selection Switch Position
105-125V	115V
210-250V	230V
90-110V*	115V
180-220V*	230V

*Requires special power transformer.

7.3 FUSE REPLACEMENT

The paragraphs below give procedures for replacing the line, and digital supply fuses. The line fuse is accessible from the rear panel, but the top cover must be removed in order to gain access to the digital supply fuse.

WARNING
Disconnect the instrument from the power line and all other equipment before removing the top cover or replacing fuses.

7.3.1 Line Fuse Replacement

The rear panel line fuse protects the power line input of the instrument. This fuse can be replaced as follows:

1. With the power off, place the end of a flat-bladed screwdriver into the slot in the rear panel fuse holder. Press in gently and rotate the fuse carrier approximately one-quarter turn counterclockwise. Release pressure on the holder and allow the internal spring to push the carrier and fuse out of the holder.
2. Remove the fuse and replace it with the type recommended in Table 7-2.

CAUTION
Do not use a fuse with a higher rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before resuming operation of the unit.

3. Install the new fuse and fuse carrier by reversing the above procedure.

Table 7-2. Line Fuse Selection

Line Voltage	Fuse Type	Keithley Part Number
90-125V	1A, 250V, 3AG, Slo Blo	FU-10
180-250V	½A, 250V, 3AG, Slo Blo	FU-4

7.3.2 Digital Supply Fuse Replacement

An internal fuse protects the +5V digital supply from over current conditions. Replace this fuse as follows:

1. Remove the top cover to gain access to the fuse.
2. Remove the digital supply fuse from the fuse clips with a fuse puller or similar tool. Figure 7-1 shows fuse location.
3. Replace the fuse with the following type: 6A, 125V, Normal Blo, 8AG, Keithley Part Number FU-73.

CAUTION
Do not use a fuse with a higher rating than specified above, or instrument damage may occur.

4. After replacing the fuse, replace the top cover and secure it properly before resuming normal operation.

7.4 OPTION INSTALLATION

Installation of the optional Model 1944A A/D module is detailed in the following paragraphs.

7.4.1 Installation Procedures

Refer to Figure 7-2 and install the Model 1944A as follows.

WARNING
Disconnect the line cord and all other equipment from the Model 194A before removing the top cover.

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1. Remove the two screws that secure the top cover to the instrument and slide the cover off from the rear of the instrument.
2. Remove the screws securing the CARD 2 cover plate and remove the plate. Save the cover plate and hardware in case the module should be removed in the future.
3. Install the four plastic standoffs supplied with the module in the holes at the edges of the channel 1 A/D module, as shown in Figure 7-2.
4. Install the module with the jacks protruding through the rear panel. Secure the module to the rear panel with two screws. Press down lightly on the module board to secure the board on the standoffs that were installed in step 3.
5. Plug the +15V and -15V supply connector to J1021 or J1022 (which ever one is presently unused) on the mother board, as shown in Figure 7-2. Line up the plug in the connector with the missing pin on the mother board. Route the cable through the top hole in the I/O board.
6. Connect the +5 digital supply connector to J1023 or J1024 (unused connector) on the mother board. This connector is polarized and can be installed only in one direction. Route the cable through the top hole in the I/O board.
7. Connect the ribbon cable to J1020 on the mother board, taking care to line up the pins properly. The red line on the ribbon cable at the mother board end should be located closest to the front panel. Push down firmly to make certain the connector is properly installed.
8. Be sure to connect the two black ground cables to the locations on the mother board (see Figure 7-10).
9. Install the top cover and secure it with the two screws removed earlier.
10. Connect the unit to the power line and turn on the power.
11. Verify that the module is operational by pressing the CHANNEL button to access channel 2.
12. If, during power up, the instrument gives you a message that it cannot recognize the module installed in the channel 2 location, it will be necessary to program module recognition, as described in paragraph 7.4.2.

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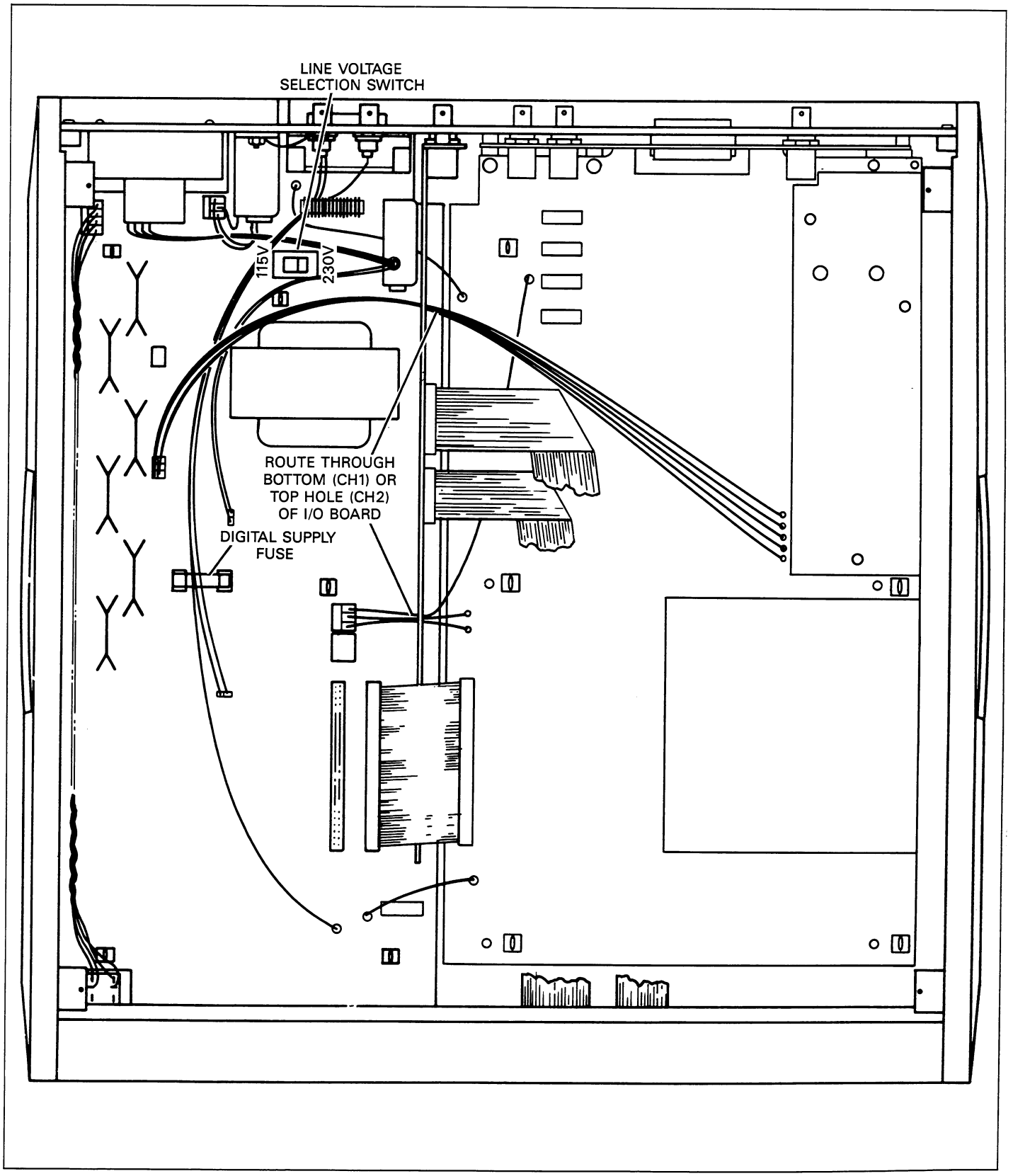


Figure 7-1. Line Voltage Switch and Digital Supply Fuse Locations

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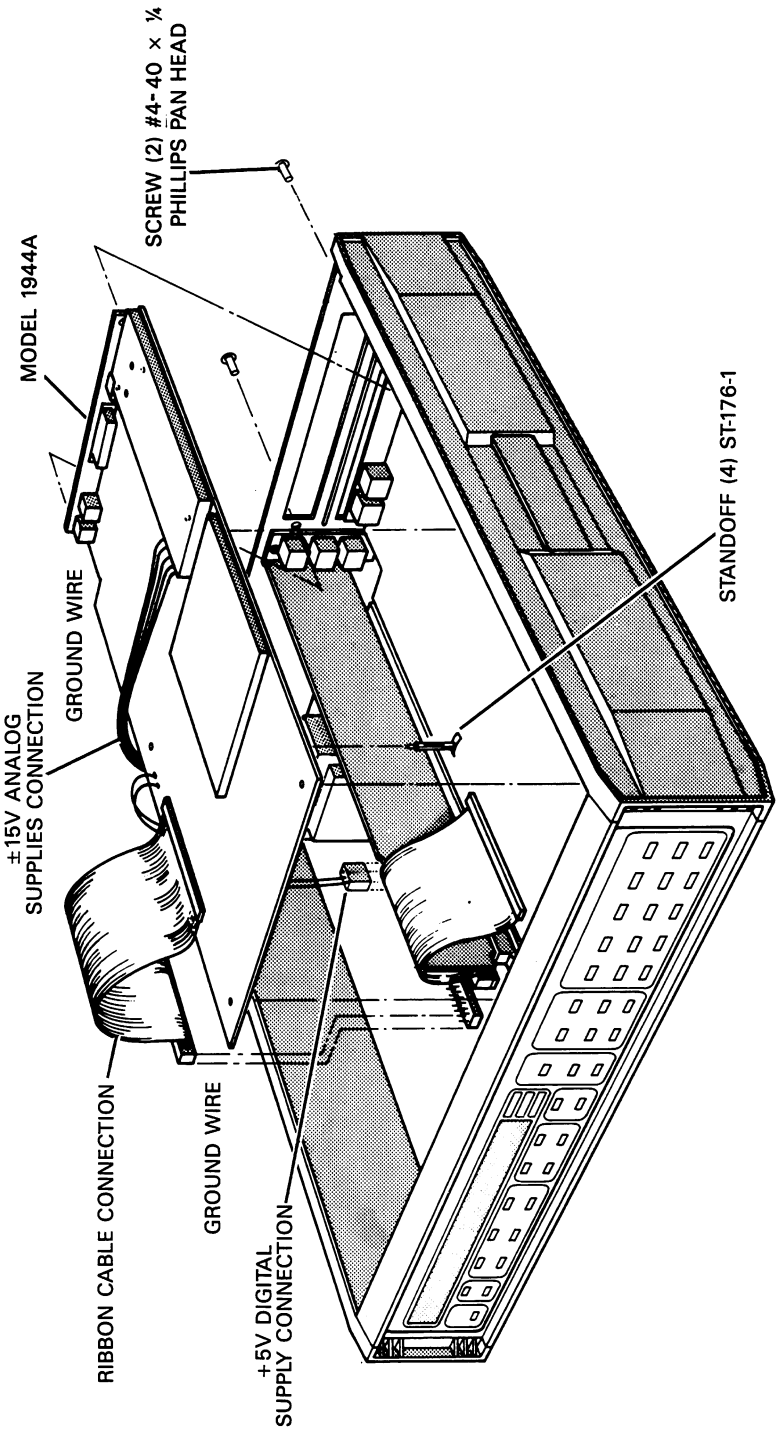


Figure 7-2. Model 1944A A/D Module Installation

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7.4.2 Module Recognition Programming

Normally, a module is factory programmed to be properly recognized by the unit when it is first turned on. In rare instances, however, a problem with one of the NVRAMs on the module may occur, with the result that the module will not be properly recognized. Use the following procedure to program the instrument for the module installed. The same procedure can be used to program the channel 1 A/D module should a similar NVRAM problem occur with that module in the future.

NOTE

If A/D module recognition programming is necessary, calibration accuracy of the instrument is suspect because calibration constants are also stored in NVRAM. The performance verification procedures in Section 5 should be performed to check instrument accuracy. Instrument configurations defined by the setup mode may also be altered if an NVRAM fault occurs.

1. Turn on the power to the instrument, and verify that the unit goes through its usual power up cycle. If a recognition fault occurs, the instrument will notify you of that fact with the following message:

   CAN'T IDENTIFY 1

   Note that the channel number that cannot be identified is displayed along with this message.
2. Use the Uprange or Downrange button to scroll through module types, as displayed on the front panel. For a Model 1944A installed in the channel 1 location, the display message is:

   1MHZ A/D IN 1

   With an A/D module installed as channel 2, the message is:

   1MHZ A/D IN 2

   The 1MHz frequency indicates the maximum conversion rate of the installed A/D module.
3. When the type of module installed in the corresponding location is shown on the display, press the ENTER key to complete programming.
4. Cycle power and verify that the instrument goes through its normal power up cycle without displaying a module recognition error. If the problem still exists, one of the NVRAMs on the corresponding module may be faulty. Refer to the troubleshooting procedures in paragraph 7.8 for further information.
5. If A/D module recognition was programmed, refer to Section 5 for procedures to verify module accuracy. If those procedures show that the NVRAM fault has degraded accuracy, the module should be calibrated by using the procedures in paragraph 7.5 of this section.

7.5 CALIBRATION

An advanced feature of the Model 194A is its digital calibration capabilities. Instead of the more conventional time-consuming method of adjusting numerous calibration potentiometers, the technician need only apply an appropriate calibration voltage and then digitally calibrate the instrument, either from the front panel, or over the IEEE-488 bus.

Calibration should be performed every 12 months, or if the performance verification procedures located in Section 5 show the instrument is operating outside its stated specifications (Model 194A specifications are located at the front of this manual). If the calibration procedure cannot be performed properly, refer to the troubleshooting information in this section.

WARNING

Certain steps in the calibration procedure require the use of hazardous voltage. Be careful not to contact these voltages to ensure personal safety.

7.5.1 Recommended Calibration Equipment

Recommended calibration equipment is listed in Table 7-3. Other equipment may be substituted as long as accuracy specifications are at least as good as those given in the table. In general, calibration equipment accuracy should be at least five times better than equivalent Model 194A specifications.

NOTE

Use a calibrator with low noise or the instrument may not calibrate properly.

7.5.2 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23 ±3°C and a relative humidity of less than 70%. If the instrument has be subjected to a temperature outside this range, or to higher humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

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Table 7-3. Recommended Calibration Equipment

Description	Output Voltages	Accuracy	Manufacturer and Model
DC Voltage Calibrator	320mV, 3.2V, 32V, 200V	±0.005%	Fluke 343A
AC Voltage Calibrator	10V, 30V @ 1kHz, 45kHz	±0.05%	Fluke 5200A

7.5.3 Warm-up Period

To ensure long-term accuracy, turn on the power to the Model 194A and allow it to warm up for at least one hour before beginning the calibration procedure.

7.5.4 Calibration Lock Jumper

A calibration lock jumper, located on the I/O board allows you to disable or enable NVRAM storage of calibration constants. The following paragraphs outline jumper location, changing the jumper position NVRAM storage, temporary calibration, and changes to the U1 error status word.

Jumper Location

Figure 8-8 shows the location of the CAL ENABLE jumper (W401) on the I/O board. If the jumper is in the enabled position, you can store new calibration constants using front panel Program 3 (OTHER 3), or by sending an L5X command over the IEEE-488 bus. If the jumper is in the disabled position (or not present at all), you will not be able to store calibration constants in NVRAM. An appropriate error message will be displayed and a bit in the U1 status word will be set, as discussed below.

NOTE

As shipped, the CAL ENABLE jumper will be in the enabled position.

Changing Jumper Position

Use the following procedure to place the calibration lock jumper in the desired position:

WARNING

Disconnect the line cord and all other equipment from the instrument before removing the top cover.

1. Remove the two screws that secure the top cover and slide the cover off the instrument to the rear.
2. Locate the CAL ENABLE jumper on the I/O board (see Figure 8-8). Place this jumper in the desired position.
3. Replace the top cover and secure it to the rear panel with the two screws that were removed earlier.

Calibration Lock Error Message

If you attempt store calibration constants with the jumper in the disabled position, the instrument will display the following message for one second:

CAL LOCKED

U1 Status Word Changes

A CAL LOCKED bit is located in the U1 status word, as shown in Figure 4-10. If NVRAM storage of calibration constants is attempted with the jumper in the disabled position, this bit will be set to 1.

You can also program the instrument to generate an SRQ when a CAL LOCKED condition is true by sending M32X. The U1 status word can then be read to determine which error condition caused the SRQ. Refer to paragraphs 4.9.15 and 4.9.16 for details.

Temporary Calibration

Even with calibration locked out, you can temporarily calibrate the instrument from the front panel or over the bus. The new calibration constants will remain in effect until power is turned off, the IEEE DCL or SDC command is received by the instrument or the front panel RESET key is pressed.

7.5.5 Front Panel Calibration

Front panel calibration of the instrument involves connecting a precise DC voltage calibration source to the instrument and then entering the front panel calibration program. A general flow chart of the procedure is shown in Figure 7-3. Note that those ranges not calibrated by this procedure will retain former calibration.

CAUTION

The maximum input voltage is 250V peak, 2×10^7V•Hz.

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1. Connect the DC calibrator to the VOLTAGE INPUT jack of the A/D module being calibrated, as shown in Figure 7-4.
2. Select the channel to be calibrated with the CHANNEL button.

NOTE

The necessary operating parameters are automatically selected by the instrument.

3. Place the Model 194A on the 320mV range.
4. Set the DC calibrator to the value in the first line of Table 7-4 (320.00mV).
5. Enter the front panel calibration program by pressing OTHER and using uprange until the DIGITAL CAL message is shown. Press ENTER. The presently selected calibration value will be displayed
6. Key in a value of 320.00mV with the data entry keys and press ENTER. The unit will then perform zero and gain calibration, a process that will take a number of seconds to complete. If gain or zero cannot be performed properly the appropriate message will be displayed.

CAN'T CAL GAIN
or
CAN'T CAL ZERO

If calibration of the presently selected range is successful, the following message will be displayed:

CALIBRATION OK

7. Repeat steps 3 through 6 above for the 3.2V, 32V, and 200V ranges. The correct calibration voltages and program parameters are listed in Table 7-4.
8. Repeat the above procedure for the channel 2 A/D module, if installed.
9. Press OTHER, uprange (three times) and press the ENTER key to enter the NVRAM storage program. Press the ENTER key to permanently store calibration. Note that this last step is necessary to permanently store calibration parameters in NVRAM.

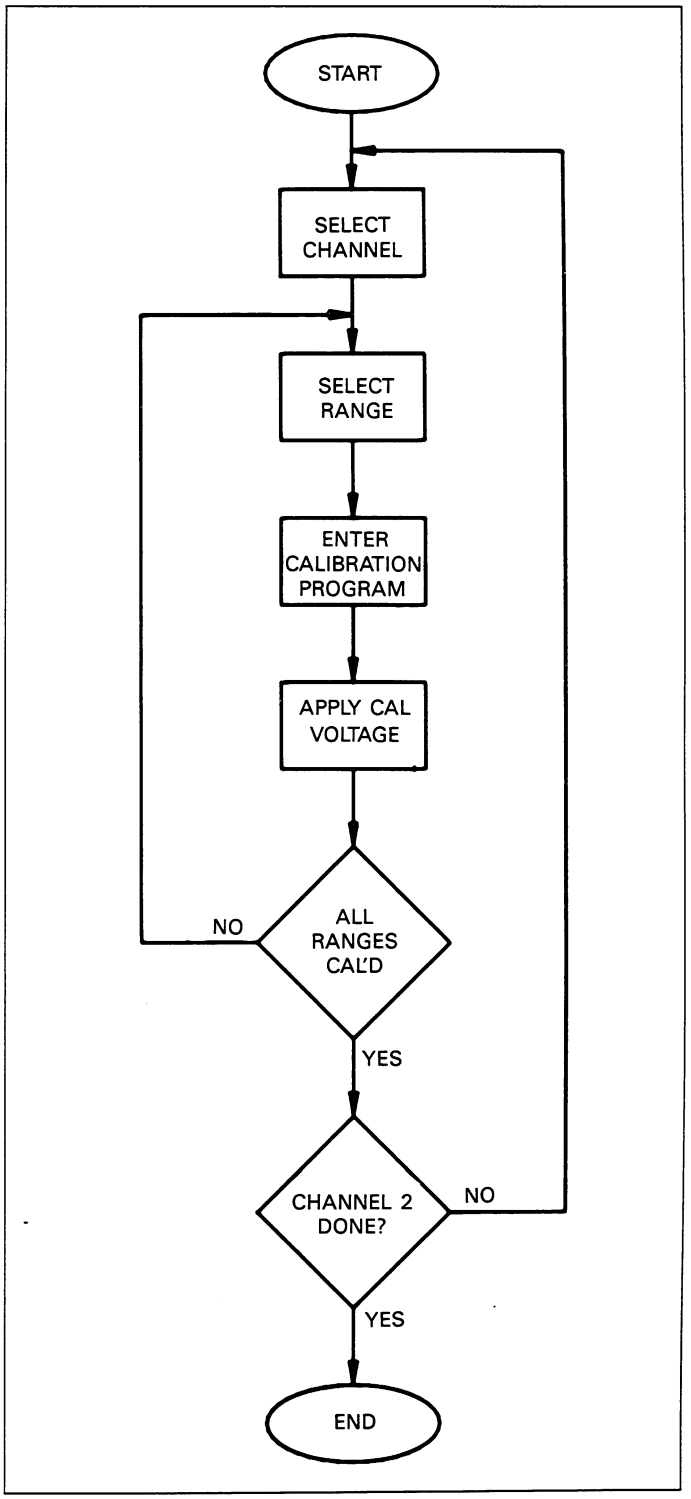


Figure 7-3. Calibration Procedure Flow Chart

Table 7-4. Calibration Summary

Step	Range	Calibration Voltage	Calibration Program Parameter
1	320 mV	320.00 mV	320.00 mV
2	3.2 V	3.2000 V	3.2000 V
3	32 V	32.000 V	32.000 V
4	200 V	200.00 V	200.00 V

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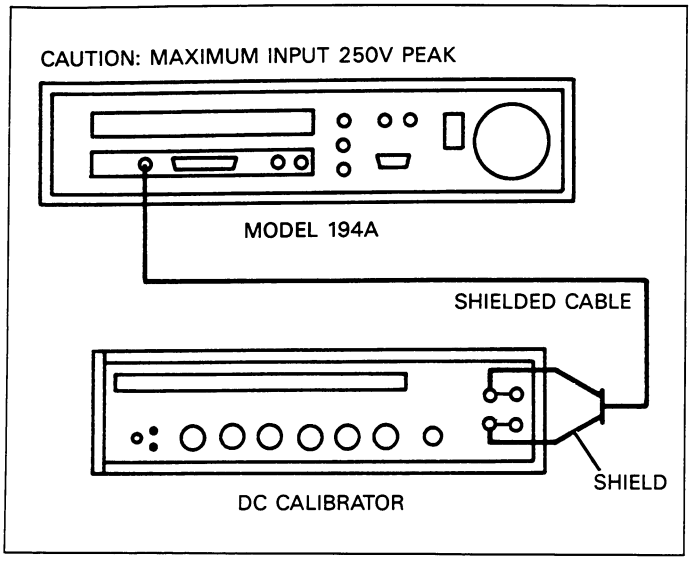


Figure 7-4. Calibration Connections

7.5.6 IEEE-488 Bus Calibration

Two programs are included below to calibrate the instrument over the IEEE-488 bus. These programs do not include the necessary programming to control the calibrator because various calibrators use different commands. However, if you are using an IEEE-488-interfaceable calibrator, you should be able to modify these programs quite easily to calibrate the instrument on a completely automated basis.

NOTE

The operator should observe the front panel and make certain that the "CALIBRATION OK" message is displayed for each range. There is no other method available to indicate possible calibration problems.

HP-85 Calibration Program—Use the program below with a Hewlett-Packard Model 85 computer to calibrate the instrument.

PROGRAM	COMMENTS
`10 REMOTE 709`	Place instrument in remote.
`20 CLEAR`	Clear CRT.
`30 CLEAR 7`	Send device clear.
`40 DISP''CHANNEL (1 OR 2)'';`	Prompt for channel.
`50 INPUT C`	
`60 IF C<1 OR C>2 THEN 40`	Check channel limits.
`70 OUTPUT 709;` `''C'';C;''X''`	Program channel to cal.
`90 FOR I = 1 TO 4`	Loop four times.
`100 OUTPUT 709;` `''R'';I;''X''`	Program 194A range.
`110 READ A$, A`	Read cal parameters.
`120 DISP''APPLY '';A$;'' TO` `UNIT, PRESS 'CONT' ''`	Prompt for cal value.
`130 PAUSE`	Wait to go on.
`140 OUTPUT 709;` `''L4,'';A;''X''`	Send cal command and value to 194A.
`145 WAIT 20000`	
`150 NEXT I`	Go back and cal next higher range.
`160 WAIT 10000`	Wait 10 seconds for signal to settle.
`170 OUTPUT 709;''L5X''`	Store cal in NVRAM.
`180 DISP''CALIBRATION` `COMPLETE''`	
`190 END`	
`200 DATA ''320.00MV'',0.32`	Data statements containing calibration values for display and to send to instrument.
`210 DATA ''3.2000V'',3.2`	
`220 DATA ''32.000V'',32`	
`230 DATA ''200.00V'',200`	

Model 8573 Calibration Program—Use the program below to calibration the Model 194A from an IBM PC or XT computer equipped with a Keithley Model 8573 IEEE-488 interface. The lines below are intended to be added to the modified declaration file, as described in paragraph 4.8.3.

PROGRAM	COMMENTS
`10 CLS`	Clear CRT.
`20 V%=1:CALL IBSRE` `(BRD0%,V%)`	Send remote enable.
`30 CALL IBCLR(M194%)`	Send selective device clear.
`40 INPUT''CHANNEL` `(1 OR 2)'';C`	Input channel to cal.
`50 IF C<1 OR C>2 THEN 40`	Check channel limits.
`60 CMD$=''C''+`	Build channel com-
`STR$(C)+''X''`	mand string.
`70 CALL IBWRT(M194%,CMD$)`	Send channel command to 194A.
`100 FOR I = 1 TO 4`	Loop four times.

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PROGRAM	COMMENTS
110 CMD$=''R'' +STR$(I)+''X''	Range command string.
120 CALL IBWRT(M194%,CMD$)	Program 194A range.
130 READ A$, A	Read cal parameters.
140 PRINT''APPLY '';A$; ''TO 194A, PRESS ANY KEY''	Prompt to apply cal voltage.
150 B$=INKEY$:IF B$='' '' THEN 150	Wait for a key to be pressed.
160 CMD$=''L4,''+STR$(A) +''X''	Build cal command string.
180 CALL IBWRT(M194%,CMD$)	Send cal command to 194A.
185 FOR J=1 TO 20000: NEXT	
190 NEXT I	Loop back and cal next higher range.
200 FOR I=1 TO 10000:NEXT	Delay loop.
210 CMD$=''L5X'':CALL IBWRT (M194%,CMD$)	Store cal constants in NVRAM.
220 V%=0:CALL IBONL (M194%,V%)	Close the instrument file.
240 CALL IBONL(BRD0%,V%)	Close the board file.
250 PRINT''CALIBRATION COMPLETE''	
260 END	
270 DATA 320.00MV,0.32	Data statements
280 DATA 3.2000V,3.2	containing calibration values for display and to send to the 194A.
290 DATA 32.000V,32	
300 DATA 200.00V,200	

7.5.7 Input Amplifier Frequency Compensation Adjustment

The input amplifier incorporates two trimmer capacitors in order to adjust the input amplifier for flat response. These two capacitors are accessible through the input amplifier shield, as indicated in Figure 7-5. Use only a non-metallic alignment tool when making these adjustments in order to avoid misadjustment that could be caused by tool capacitance.

Proceed as follows:

1. Connect the AC calibrator to the channel being tested using the connections shown in Figure 7-6.
2. Select the channel being tested and the following operating modes on the Model 194A:
   A. Sampling interval: 10μsec
   B. Samples: 1000
   C. Trigger: Continuous
   D. Coupling: AC
   E. Math function: TRMS
   F. Filter: Off
   G. Trigger Source: Input Signal
   H. Trigger Level: 0V
3. Select the 200V range on the instrument and disable zero. Press TRIGGER.
4. Set the calibrator output to 30.00V at a frequency of 1kHz.
5. Enable the zero mode on the Model 194A (press ZERO).
6. Change the calibrator frequency to 45kHz, but leave the output at 30.00V.
7. Adjust C386 on the input amplifier (Figure 7-5) for a reading of 000.00V ±0.2V on the display.

NOTE

When making adjustments, allow sufficient time for any changes to be reflected in the display.

8. Disable the zero mode.
9. Set the calibrator output to 10.000V at a frequency of 1kHz.
10. Change the Model 194A to the 32V range and enable zero.
11. Set the calibrator frequency to 45kHz, but leave the output voltage at 10.000V.
12. Adjust C374 on the input amplifier (Figure 7-5) for a reading of 00.000V ±0.02V on the display.
13. Repeat steps 3 through 12 above to minimize interaction between the two adjustments.

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Table 7-5. AC Response Adjustment Procedure

Step	Applied Voltage*	Model 194A Range	Model 194A Reading**	Comments
1	30V @ 1kHz	200V	—	Zero disabled
2	30V @ 45kHz	200V	000.00V±0.2V	Zero enabled
3	10V @ 1kHz	32V	—	Zero disabled
4	10V @ 45kHz	32V	00.000V±0.02V	Zero disabled

*RMS values.
**Appropriate trimmer to be adjusted for this reading.

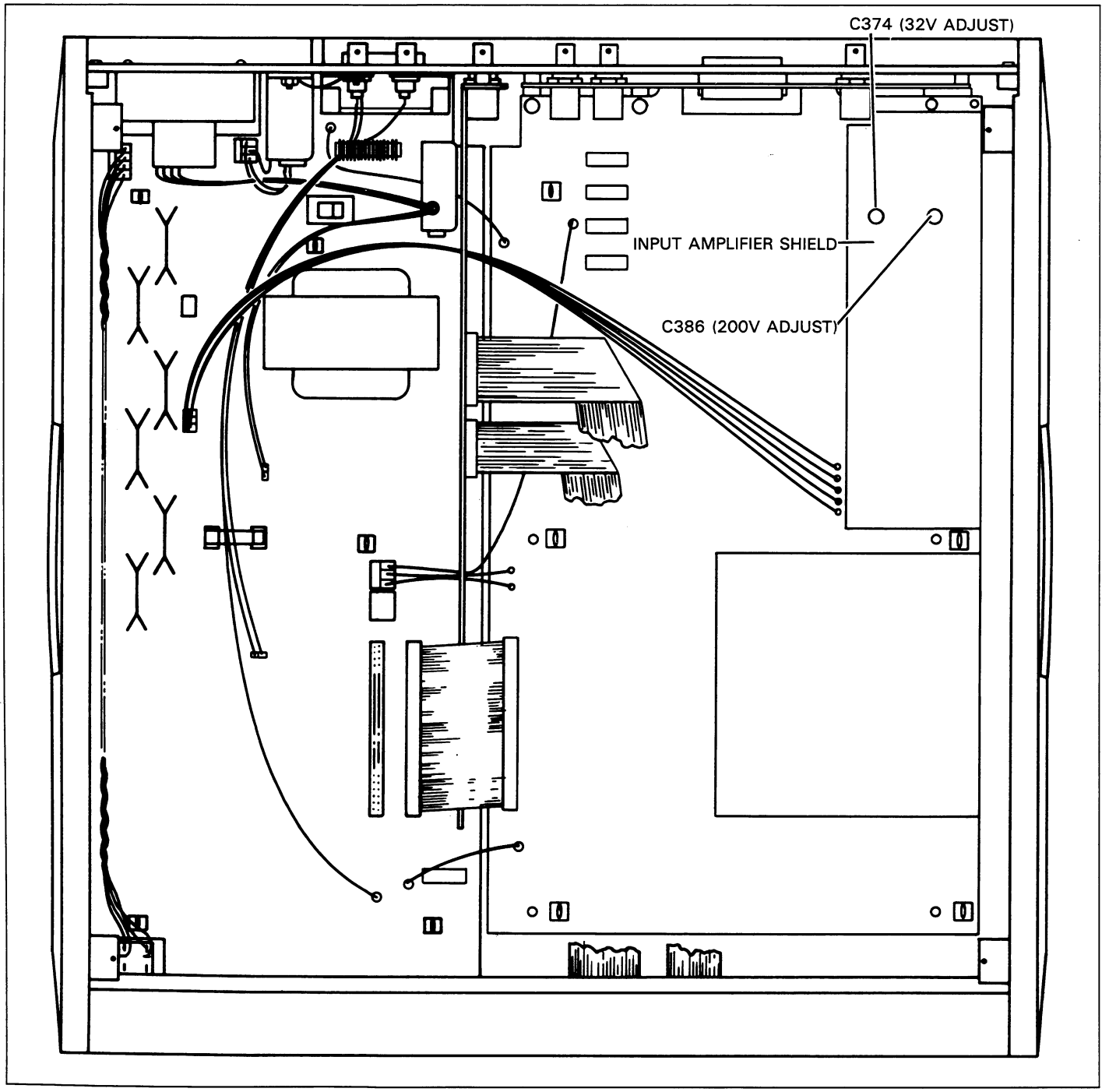


Figure 7-5. Frequency Compensation Adjustment Locations

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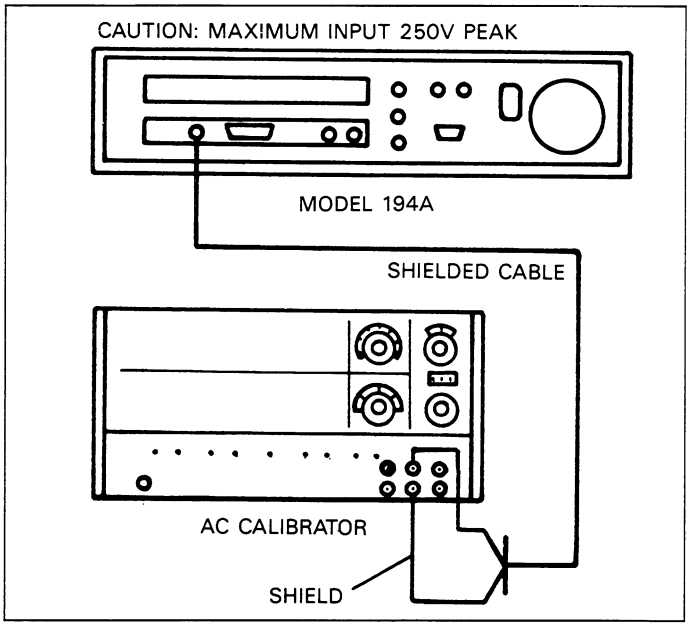


Figure 7-6. AC Frequency Response Calibration Connections

7.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices are designed to operate at high impedance levels for lower 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 carefully. Table 7-6 lists the static-sensitive devices used in the Models 194A and 1944A. When handling these devices, use the precautions below to avoid damaging them with static discharge.

1. The ICs listed in the table should be transported and handled only in containers 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 soldering irons.
7. Once the device is installed on the PC board, it is usually adequately protected and normal handling can resume.

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Table 7-6. Static Sensitive Devices

Circuit Designation	Description	Keithley Part No.
Q301	N-channel JFET, 2N5434	TG-174
Q304-Q306	N-channel JFET, 2N4392 (Selected)	TG-77
U101	Microprocessor, 68008L10	LSI-69
U102	RAM, 8832	LSI-76
U103	ROM	194-801**
U104	ROM	194-802**
U105	ROM	194-803**
U127	GPIA, 9914	LSI-49
U301, U302	NVRAM, 2443	IC-353
U315	PIA, 6821	LSI-8
U316	DMA controller, 4500	LSI-64
U317-U320	Dynamic RAM, 6665A	LSI-63
U323	VIA, 6522	LSI-28
U337-U340	Dynamic RAM, 6665A	LSI-63
U361	CMOS Shift Register, 4094	IC-251
U362, U363	12-bit DAC, DAC-80	IC-323
U364-U367	CMOS Decoder/Driver, HP-2630	IC-327
U388	A/D Converter Module	MO-4
U404, U407	PIA, 65C21	LSI-61
U410	VIA, 6522A	LSI-45
U416, U419	12-bit DAC, DAC-80	IC-323

**Last two digits depend on current software revision level.

7.7 DISASSEMBLY

The following paragraphs contain disassembly procedures for the Models 194A and 1944A. Generally, disassembly should be carried out in the order presented here unless otherwise noted.

WARNING
Disconnect the line cord and all other equipment from the instrument before beginning the disassembly procedure.

7.7.1 Top and Bottom Cover Removal

Refer to Figure 7-7 and remove the top or bottom cover using the corresponding procedure below.

Removing the Top Cover

1. Remove the two screws that secure the top cover to the rear panel.
2. Carefully slide the top cover to the rear of the instrument until it is free of the case sides then completely remove it.

Removing the Bottom Cover

1. Place the Model 194A upside down on a soft cloth to avoid scratching the case.
2. Remove the two screws that secure the cover to the rear panel.
3. Remove the four feet located on the bottom cover.
4. Slide the bottom cover to the rear of the instrument until it is free of the case and remove it completely.

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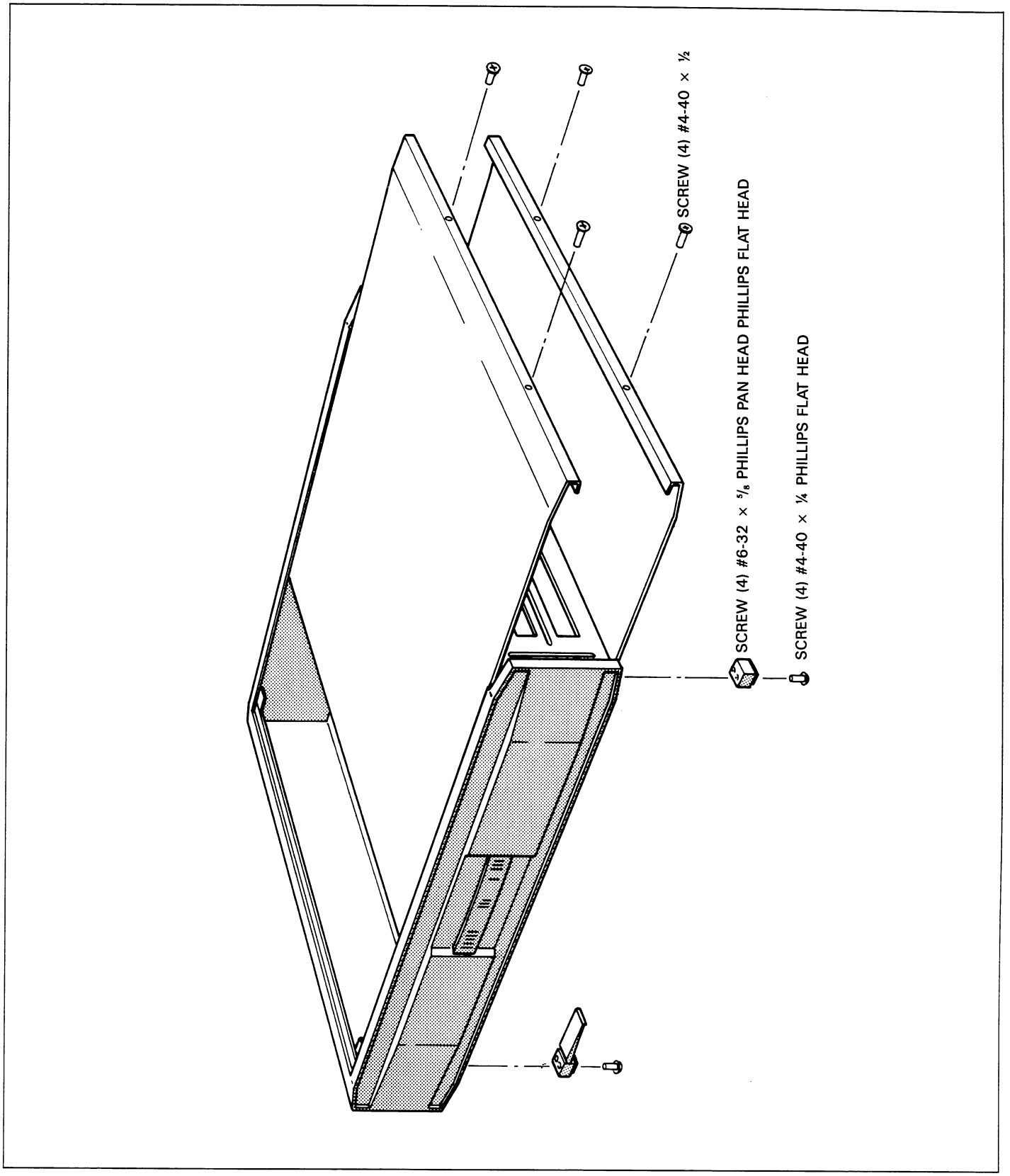


Figure 7-7. Top and Bottom Cover Removal

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7.7.2 Circuit Board Removal and Replacement

Removal and replacement of the various circuit boards is covered below. The circuit boards should be removed in the order shown, and replaced in reverse order. General circuit board configuration is shown in Figure 7-8, and cable connections are shown in Figure 7-9.

Removal

1. Remove the CARD 2 module (if installed), as follows:
   A. Disconnect the two power supply cables and ground cables.
   B. Disconnect the ribbon cable at the mother board end.
   C. Remove the two screws that secure the module to the rear panel.
   D. Pull the board free of each plastic standoff (2 for the 1941, 4 for the 1944A) by squeezing the standoff slightly with a pair of pliers.
   E. Slide the module back away from the rear panel and remove it once clear.
2. The I/O board can be removed as follows:
   A. Disconnect the channel 1 A/D module power supply and ribbon cables from the mother board.
   B. Remove the two screws that secure the I/O board to the rear panel.
   C. Pull the board partially free of the mother board, but do not attempt to remove it completely at this time.
   D. Disconnect the two ribbon cables going to the display board attached to the front panel.
   E. Remove the two screws that secure the fan control module to the I/O board and remove the control module. Carefully lay it aside on the mother board.
   F. The I/O board may now be completely removed from the instrument.
3. Remove the channel 1 A/D module with the procedure below.
   A. If you have not already done so, disconnect the power supply, ribbon cables, and ground cables from the mother board. Also, remove the I/O board.
   B. Turn the instrument upside down and remove the six screws that hold the A/D module to the three bottom rails (two screws in each rail).
   C. Place the instrument right side up, and remove the two screws that secure the A/D module to the rear panel.
   D. Slide the module toward the front of the instrument slightly until the connectors clear the slot in the rear panel, then remove the A/D module completely.
   E. If necessary, the input amplifier shield can be removed by removing the three screws that secure it to the A/D module and then lifting the shield free of the board.
4. The mother board may now be removed as follows:
   A. Disconnect the wires running to the power switch and AC receptacle on the rear panel.
   B. Disconnect the fan control module and the CLK BNC jacks from the mother board.
   C. Remove the two nuts that secure the IEEE-488 connector to the rear panel.
   D. Remove the four screws that hold the rear panel to the sides of the case.
   E. Carefully remove the rear panel; the fan control module is loose, so be sure not to strain the wires going from the module to the fan.
   F. Turn the instrument upside down and remove the five screws that hold the mother board to the case bottom rails. It will be necessary to hold the board in place while removing the screws. The two end rails have two screws each, while the middle rail has only one screw.
   G. Turn the instrument right side up and remove the mother board from the case.

Circuit Board Installation

In general, circuit boards can be installed by reversing the above procedure. However, the following points should be noted when installing boards:

1. Make sure that all screws are properly installed and that none of the boards is sagging, possibly causing a short.
2. Make sure that all connectors are properly replaced. Use the cable diagram in Figure 7-9 as a guide.
3. Pay particular attention to the installation of ribbon cables. It is possible to improperly position these cables so that the connector is one or more pins off.
4. Make certain the the A/D, scanner, and I/O boards are properly secured to the rear panel with the screws that were removed during disassembly.
5. Check to see that the fan control module is properly attached to the I/O board, and that the I/O board is properly seated in its connector socket.

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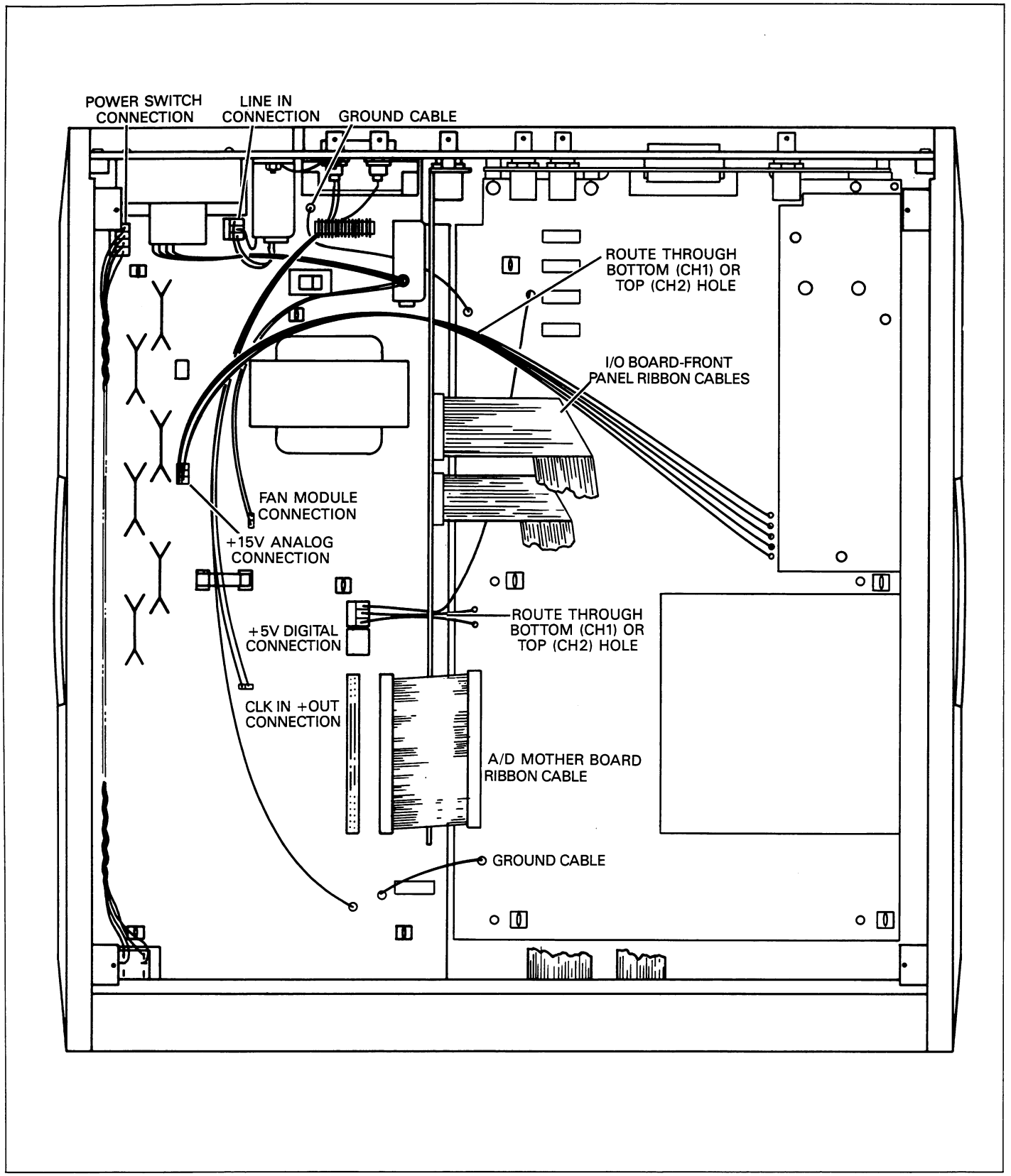


Figure 7-9. Cable Connections

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7.7.3 Case Disassembly

Refer to Figure 7-10 and disassemble the case as follows:

1. Using a small screwdriver, pop the trim strips out from the inside. Note that the trim strips are not interchangeable from top to bottom.
2. Remove the four screws that secure the front panel to the case ends and remove the front panel (the rear panel was removed as part of the procedure in paragraph 7.7.2).
3. Remove the two screws that attach each bottom rail to the case sides and remove the rails.
4. If desired, remove the two screws that attach each handle to the case sides. Compress the handle and guide it through the slots to remove it.
5. When reassembling the case, make sure that the rails are installed in the correct positions, or it will not be possible to properly secure the circuit boards that attach to the rails.

7.7.4 Rear Panel Disassembly

Refer to Figure 7-11 and remove parts from the rear panel as follows:

1. Remove the four screws and nuts that attach the fan and fan guard to the rear panel and remove them.
2. Remove the nut that holds the green ground wire to the rear panel and disconnect the wire.
3. Remove the two nuts that secure the line receptacle/filter and remove the receptacle.
4. To remove the two BNC connectors, unscrew the nuts and pull the jacks and attached wires of the mounting holes.
5. When installing these parts, make sure that all screws and nuts are tight, and that the ground wire is properly connected.

WARNING

The ground wire must be properly installed to ensure continued protection against possible shock hazards.

7.7.5 Front Panel Disassembly

An exploded view of the front panel assembly is shown in Figure 7-12. Use the following procedure to disassemble the front panel.

1. Remove the screws that attach the power switch to the front panel and remove the switch.
2. Using an allen wrench, loosen the two allen screws that secure each front panel rail, and remove each rail from the front panel.
3. Remove the display board from the front panel.
4. When reassembling the front panel, make sure that the rails are flush with the end of the panel, and that the display board is installed properly in the card guides in the rails. Note that some adjustments may be necessary if front panel buttons stick.

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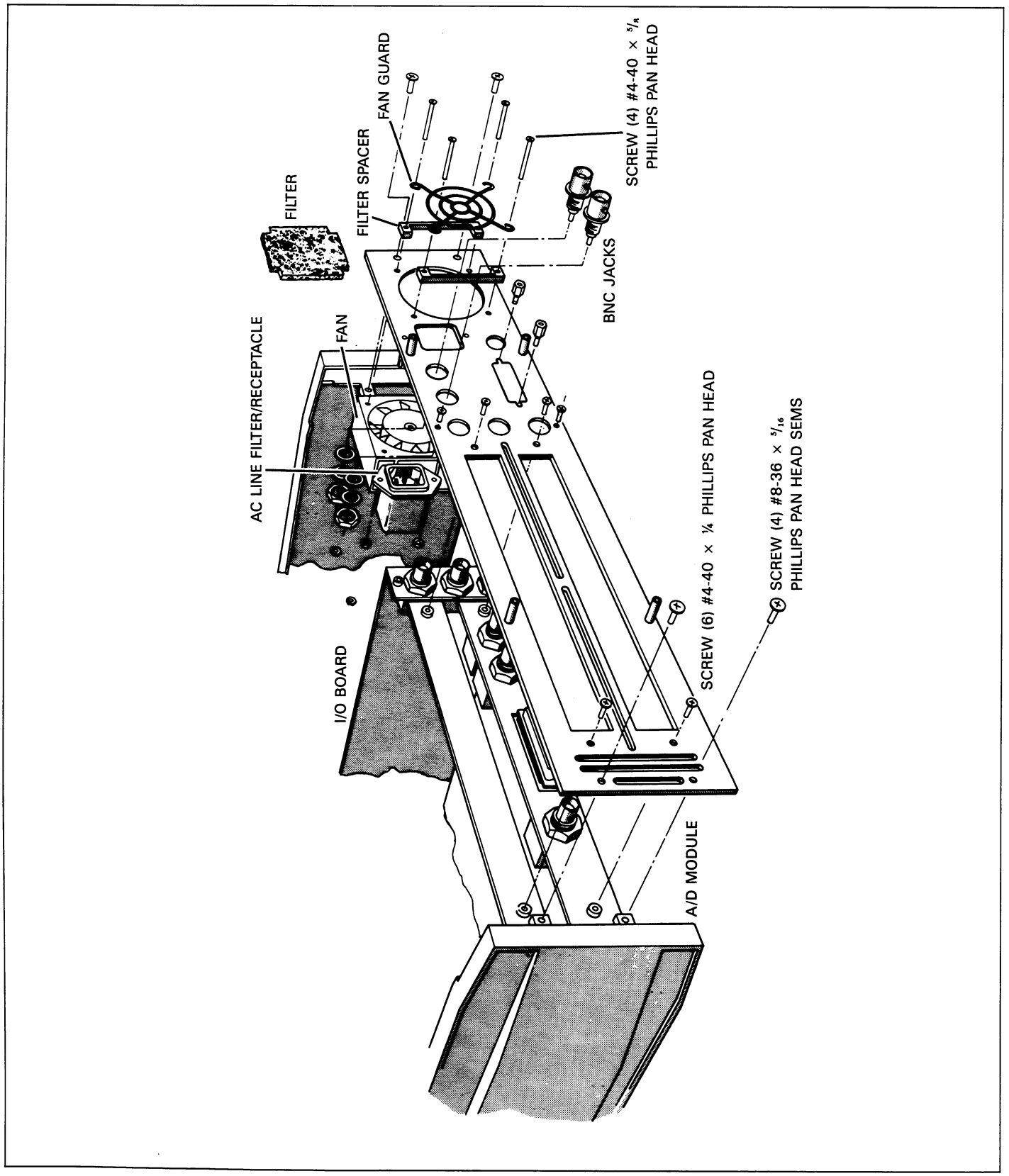


Figure 7-11. Rear Panel Disassembly

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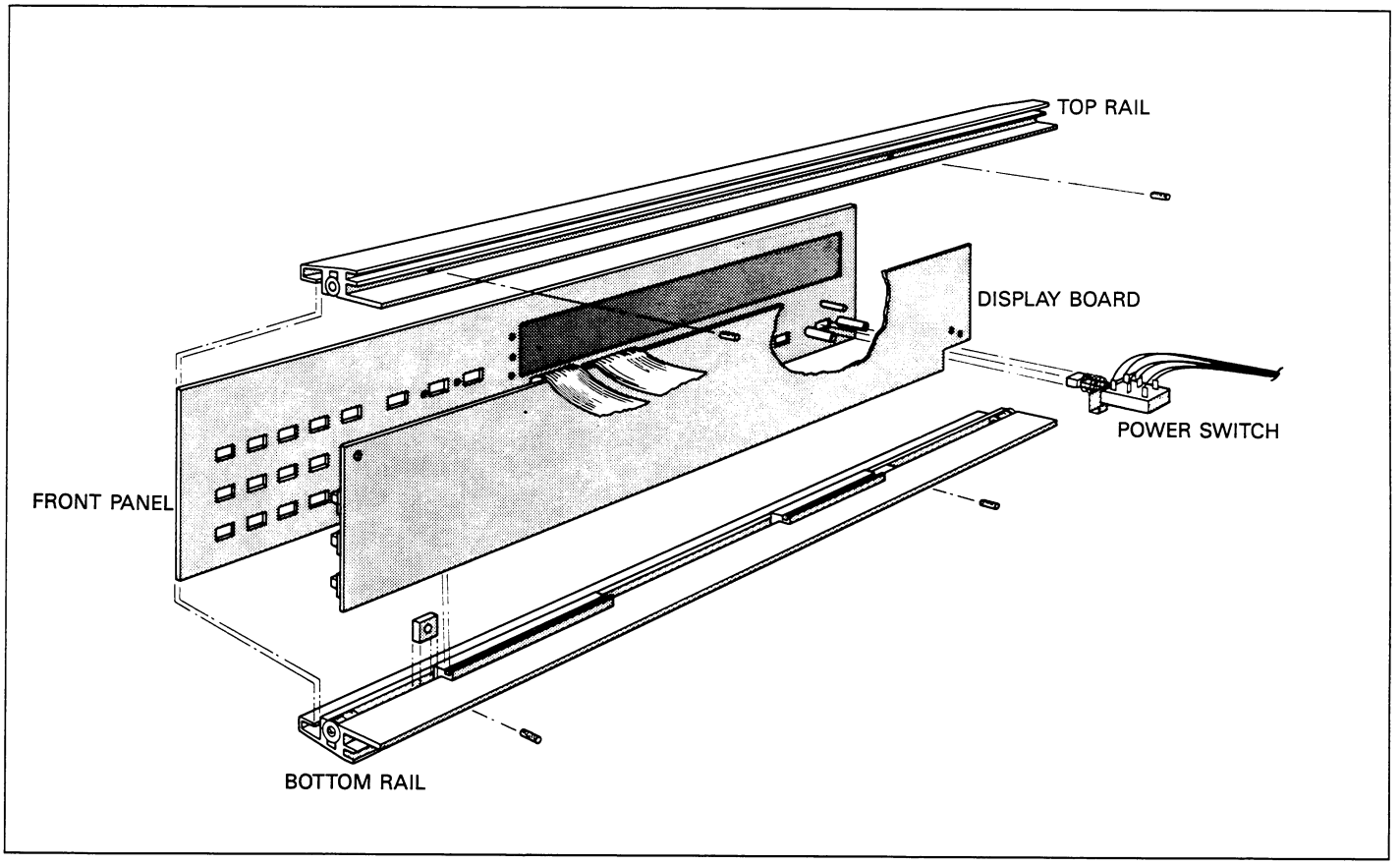


Figure 7-12. Front Panel Disassembly

7.8 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for 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 in this troubleshooting section has be written to assist in isolating a defective circuit or circuit section. Isolation of a specific component is left to the technician.

Schematic diagrams, component layout drawings, and parts lists for the various circuit boards within the instrument are located at the end of Section 8.

7.8.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 194A depends not only on the skill of the technician, but also relies on the use of accurate, reliable test equipment. Table 7-7 lists recommended equipment to be used when troubleshooting the Model 194A.

7.8.2 Self Test

During the power up cycle, the instrument will check many internal components including RAM and ROM memory to make certain everything is in working order. During the test procedure, all front panel annunciators and display segments will turn on to allow you to check that all are operating properly.

If a self test error occurs, the instrument will display an appropriate error message, as summarized in Table 7-8.

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Table 7-7. Recommended Troubleshooting Equipment

Description	Manufacturer and Model	Use
4½ digit DMM	Keithley; 175	DCV, ACV, resistance checks.
Dual-trace 100MHz Oscilloscope	Tektronix; 2235	Digital waveform checks, AC signal tracing.
DC Calibrator	Fluke; 343A	Accurate DC signal source.
AC Calibrator	Fluke; 5200A	Accurate AC signal source.

Table 7-8. Self Test Display Messages

Message	Description	Comments
SELF TESTING	Mother board test in progress.	All LEDs on during test.
ROM ERROR	ROM failure	Message appears for failure only.
RAM ERROR	RAM failure	Message appears for failure only.
SELF TESTING	A/D board test in progress	Testing A/D
A/D RAM ERR 1	RAM or indicated A/D defective	Failure only
A/D RATE ERR 1	Improper rate on A/D	Failure only
NOISY A/D 1	A/D is noisy	Failure only
SELF TEST PASS	Unit passed all tests	
ENTER 1 IF OK	Prompt for user input	Enter 1 if no error, 0 if error shown (unit locks up)

Front Panel Self Test

The self test can also be run by using front panel Program 1. To run the self test from the front panel, press the following buttons in sequence:

SHIFT, OTHER, UPRANGE, ENTER

The unit will then run the test and display any error messages as previously described.

The selft test procedure is as follows:

1. The display indicates SELFTESTING for one second.
2. ROM and RAM on the mother board are tested. During this test, the display blanks. The ROM test computes a 16-bit bytewise checksum on each of the three ROMs, and compares these against the checksums which were calculated and stored when the software was compiled. The RAM test checks each byte location by storing a test pattern and then reading it back to see if it reads what it wrote.
3. The display lights up with all segments, decimal points, and annunciators on.
4. Any A/D boards installed are tested. The A/D test is as follows:
   A. The A/D is programmed to take 20400 16-bit samples at 100μsec interval, with GND input coupling, on the 300mV range. The measurement is performed and timed, and the actual time it took is compared to what it should have taken. If the actual measurement time is not within 10% of the calculated time, it signifies a timebase error.
   B. The A/D memory pointer is examined to see if it wrapped around 7FFF hex. If it did, the jumper on the A/D board is set for 32K; otherwise it is set for 64K. This information is stored for use by the A/D operating software.
   C. Now that the extent of the A/D RAM is known, the RAM is tested using the same algorithm as that used for the mother board RAM.
   D. The standard deviation of the measurement is calculated. If the result is more than one millivolt, it indicates a noisy A/D error.

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5. The results of the self tests are examined-if no errors are detected, the display shows SELFTEST PASS for one second and then the 194A proceeds with whatever it is that it is supposed to do. Also, the value 01 is stored in the self test field of the U0 string for IEEE-488 output.
6. If any errors are detected, the highest numbered one is displayed for one second, and its number stored in the self test field of the U0 string.

IEEE-488 Bus Self Test

To perform the self test over the IEEE-488 bus, simply send the following command over the bus: J1X. The self test bit in the U1 status word can then be checked to determine whether the test passed or failed. Figure 7-13 shows the general format of the U1 status word and the values that flag self test pass or fail conditions. Note that the nature of the error can be deteremined by checking the values of the J bytes, as described in paragraph 4.9.15.

The following programming examples will demonstrate the basic procedure for running the self test over the bus.

HP-85 Programming Example—After entering the program below, run it to perform the self test.

PROGRAM	COMMENTS
`10 REMOTE 709`	Place 194A in remote.
`20 OUTPUT 709; ''J1X''`	Send self test command to 194A.
`30 WAIT 10000`	Wait 10 seconds for test to complete.
`40 OUTPUT 709;''U1X''`	Send error status command.
`50 ENTER 709; A$`	Get error word.
`60 B$=A$[10,10]`	Strip off self test byte.
`70 IF B$=''1'' THEN DISP ''SELF TEST FAILED''`	Display results of self test.
`90 END`	

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 4.8.3) and run the program to perform the self test.

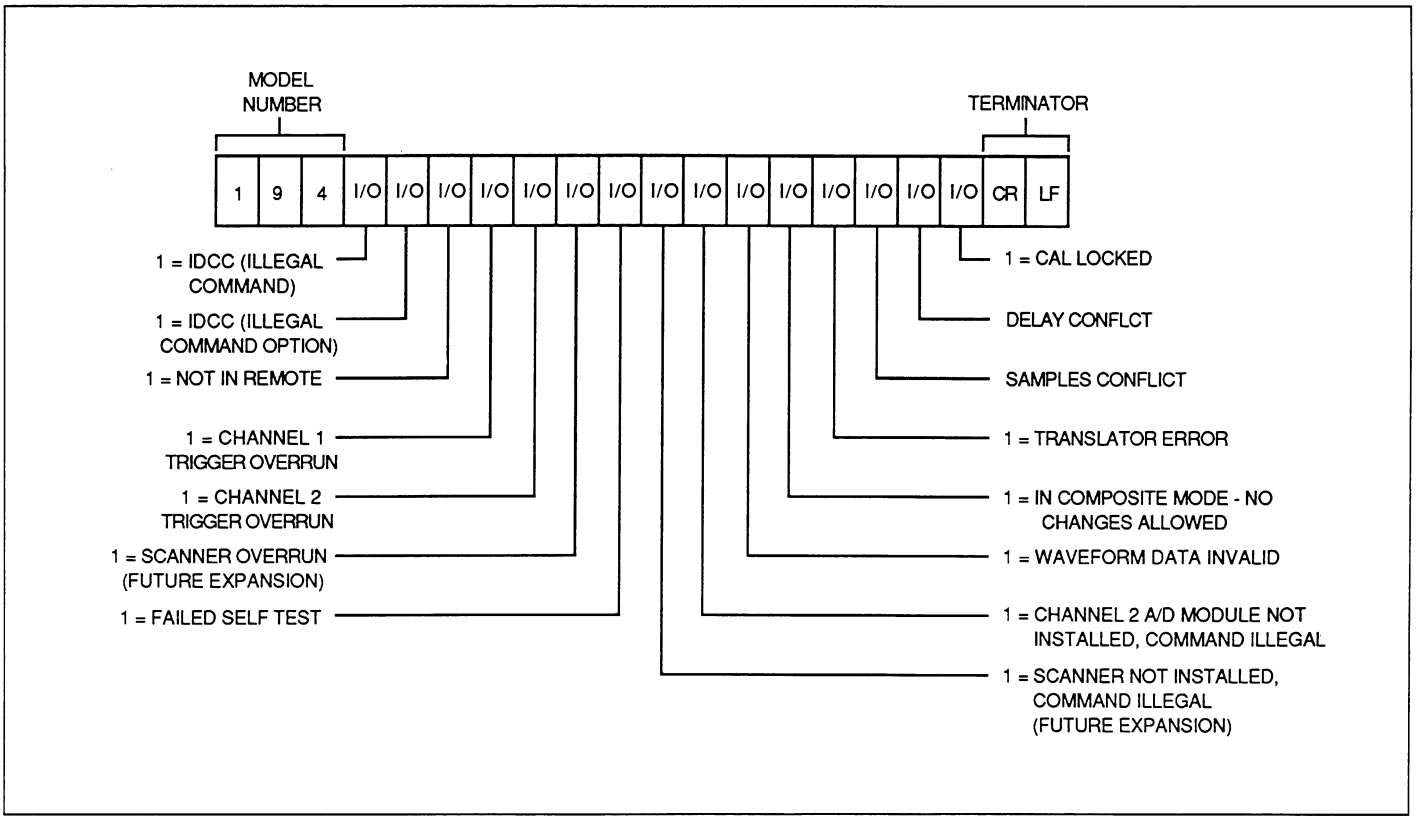


Figure 7-13. U1 Status Word Format

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PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Send remote enable.
`20 C$=''J1X'':CALL IBWRT (M194%,C$)`	Send self test command.
`30 FOR I = 1 TO 10000:NEXT`	Wait for test to be completed.
`40 C$=''U1X'':CALL IBWRT (M194%,C$)`	Send error status command.
`50 RD$=SPACE$(25)`	Define reading input buffer.
`60 CALL IBRD(M194%,RD$)`	Get error word from 194A.
`70 A$=MID$(RD$,10,1)`	Strip off self test byte.
`80 IF A$ = ''1'' THEN PRINT ''SELF TEST FAILED''`	Display self test results.
`100 V%=0:CALL IBONL (M194%,V%)`	Close instrument file.
`110 CALL IBONL(BRD0%,V%)`	Close board file.

7.8.3 Troubleshooting Sequence

The exact troubleshooting sequence will, of course, depend on the particular problem. However, you can use the general sequence shown in the flow chart of Figure 7-14 to troubleshoot the instrument. The simplified block diagram in Figure 7-15 indicates which table to consult for procedures to check out various sections within the instrument.

7.8.4 Power Supply Checks

The various power supplies within the instrument should be checked first to make sure that all are functioning properly. If the various operating voltages are not within the required limits, troubleshooting the remaining circuitry can be difficult, if not impossible.

Table 7-9 summarizes the various power supply voltages that should be checked. In addition to the usual voltage checks, it may be a good idea to check the various supplies with an oscilloscope to make sure that no noise, ripple, or ringing is present.

7.8.5 Microcomputer

The 68008-based microcomputer supervises virtually every operating aspect of the instrument. Thus, problems in this area could render the instrument partially or completely inoperative. Table 7-10 lists the basic procedure to be used when troubleshooting the microcomputer.

7.8.6 Display Board

Check out the display board by using the procedure in Table 7-11. If some signals shown are incorrect, the problem may be on the I/O board.

7.8.7 I/O Board

The I/O board controls the display, keyboard and analog output. Circuitry on the I/O board may be checked with the procedure in Table 7-12.

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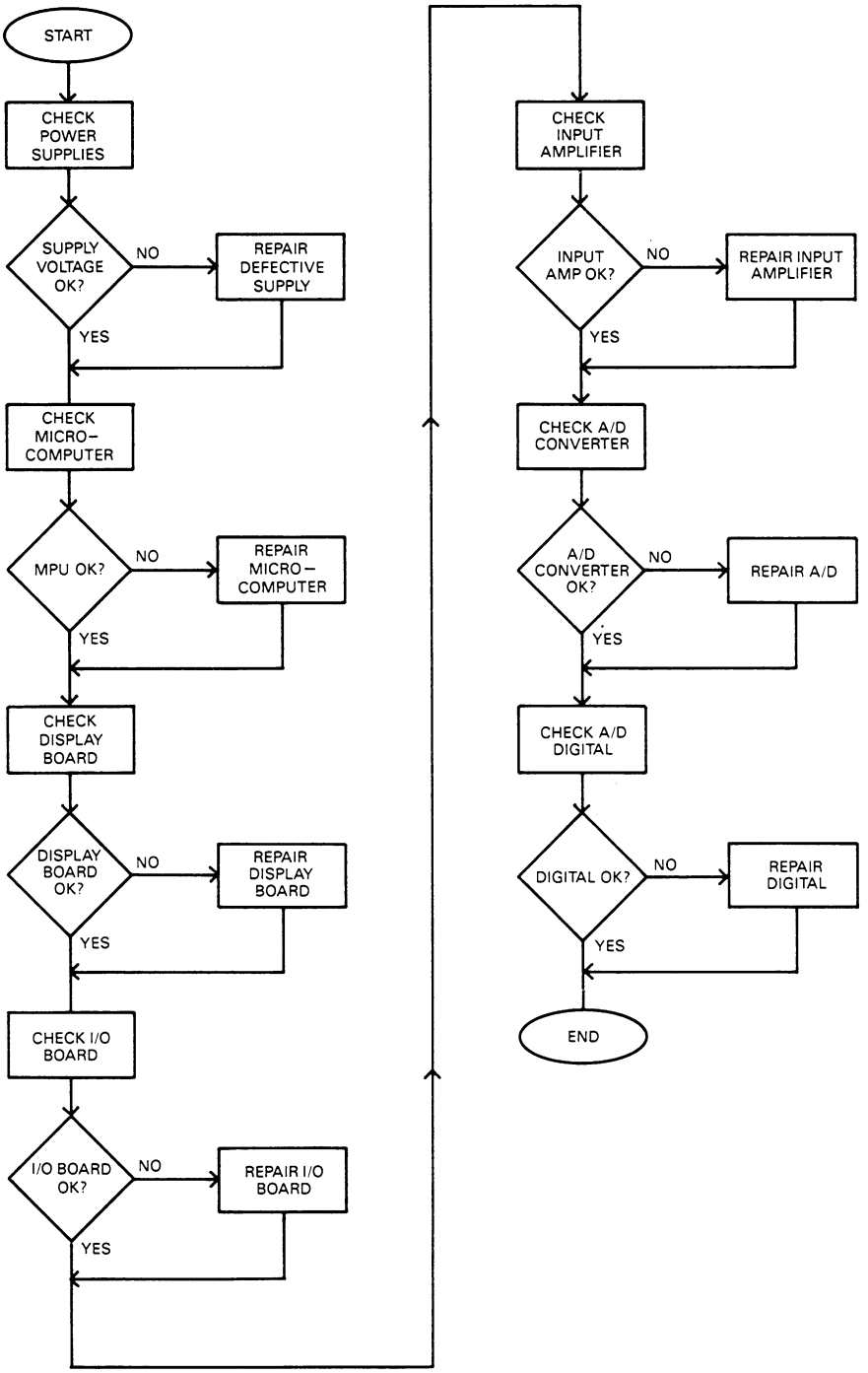


Figure 7-14. Troubleshooting Flow Chart

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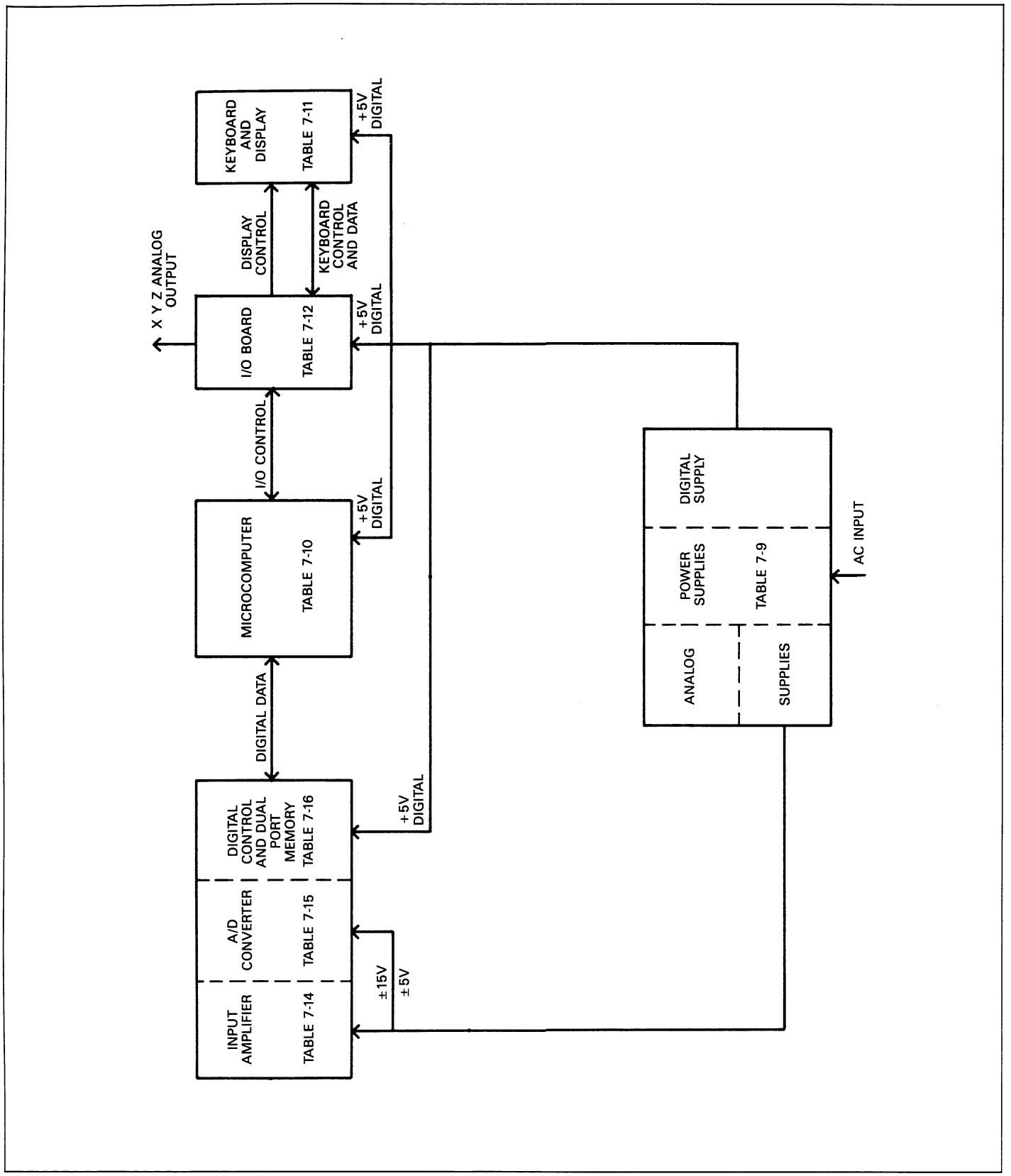
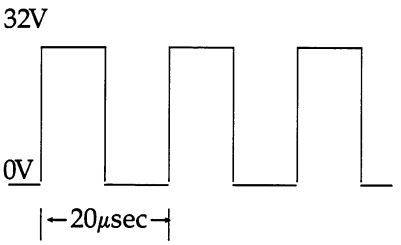
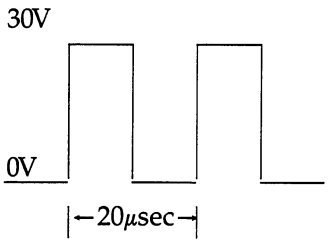


Figure 7-15. Troubleshooting Block Diagram

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Table 7-9. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S102 (Line voltage select)	Set to 115 or 230V as required	Operate on correct line voltage.
2	Line fuse (F101)	Continuity	Check with ohmmeter.
3	Digital supply fuse (F102)	Continuity	Check with ohmmeter.
4	AC power	Plugged into live receptacle, power on.	
5	VR104, pin 1	+25V, ±20%	Referenced to VR104, pin 3
6	VR104, pin 2	+15V, ±5%	Referenced to VR104, pin 3
7	VR103, pin 2	−25V, ±20%	Referenced to VR104, pin 3
8	VR103, pin 3	−15V, ±5%	Referenced to VR104, pin 3
9	VR106, pin 1	+12V, ±20%	Referenced to VR104, pin 3
10	VR106, pin 2	+5V, ±5%	Referenced to VR104, pin 3
11	VR105, pin 2	−12V, ±20%	Referenced to VR104, pin 3
12	VR105, pin 3	−5V, ±5%	Referenced to VR104, pin 3
13	VR108, pin 1	+25V, ±20%	Referenced to VR108, pin 3
14	VR108, pin 2	+15V, ±5%	Referenced to VR108, pin 3
15	VR107, pin 2	−25V, ±20%	Referenced to VR108, pin 3
16	VR107, pin 3	−15V, ±5%	Referenced to VR108, pin 3
17	VR110, pin 1	+12V, ±20%	Referenced to VR108, pin 3
18	VR110, pin 2	+5V, ±5%	Referenced to VR108, pin 3
19	VR109, pin 2	−12V, ±20%	Referenced to VR108, pin 3
20	VR101, pin 1	+25V, ±20%	Referenced to digital common (J1023/1024 pin 2 or 3)
21	J1023, pin 1	+5V, ±5%	Referenced to digital common
22	VR101, pin 2	+15V, ±5%	Referenced to digital common
23	VR102, pin 3	−15V, ±5%	Referenced to digital common
24	U119, pin 14	+5V, ±5%	Referenced to digital common
25	U119, pin 8 and 11		Duty cycle varies with load.
26	R108/T102 junction		Duty cycle varies with load.

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Table 7-10. Microcomputer Checks

Step	Item/Component	Required Condition	Remarks
1	Programming	Program 100 samples, 10μsec rate, continuous trigger.	All voltages referenced to digital common.
2	U112, pin 12	10MHz square wave.	10MHz clock
3	U112, pin 9	5MHz square wave.	5MHz clock
4	J1103	10MHz square wave.	Clock output
5	U114, pin 9	Negative going pulses.	VMA signal
6	U117, pins 2-9	Data bus pulses.	Check for stuck bit.
7	U115, pins 9-18	Address bus (A0-A7) pulses.	Check for stuck bit.
8	U116, pins 9-18	Address bus (A8-A15) pulses.	Check for stuck bit.
9	U118, pin 3	800kHz square wave.	E clock for peripheral ICs.
10	U118, pin 7	Varying positive going pulses.	Data strobe signal.
11	U118, pin 9	Varying positive going pulses.	Address strobe signal.
12	U118, pin 12	10MHz square wave.	CLK signal
13	U118, pin 14	10MHz square wave.	$\overline{\text{CLK}}$ signal
14	U118, pin 16	10MHz square wave.	RCLK signal
15	U101, pin 37	Stays low for 100msec on power up, then goes high.	RESET signal
16	U101, pin 34	10MHz square wave.	MPU clock
17	U101, pin 38	1MHz square wave.	Enable clock
18	U101, pin 4	High logic level.	$\overline{\text{BERR}}$ signal
19	U101, pin 31	Varying square wave, approximately 1.4MHz.	$\overline{\text{DTACK}}$ signal
20	U127, pin 18	5MHz square wave.	IEEE chip clock
21	U127, pins 10-17	Data bus pulses.	Check data bus at IEEE chip.
22	U102-U105, pins 11-19	Data bus pulses.	Check data bus at RAM and ROM ICs.

Table 7-11. Display Board Checks

Step	Item/Component	Required Condition	Remarks
1	Power on	All LEDs and segments light briefly upon power up.	All voltages referenced to power line ground. Display board problems could be caused by I/O board defects.
2	FILTER button	Display FILTER 500kHz message.	
3	DS201-DS207 pins 11 and 16	Sawtooth waveform.	Digit driver pulses.
4	DS201-DS207 pins 1, 2, 4-15, 17, 18	Variable pulses.	Segment driver pulses.
5	S201-S238	Check for continuity.	Continuity when button is pressed.
6	Switch matrix columns	1msec negative going pulse every 40msec.	Keyboard scan pulses (NOTE: duration and interval may vary with software revision).

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Table 7-12. I/O Board Checks

Step	Item/Component	Required Condition	Remarks
1		Power on	All voltages referenced to digital common.
2	U404, U407, U410, pin 25	1MHz square wave.	PIA and VIA E clock.
3	U404, U407, U410, pins 26-33	Data bus pulses.	Check for presence of data pulses.
4	U404, pins 2-17	Positive going pulses.	Display segment driver data.
5	U407, pins 2-15	Positive going pulses.	Display digit driver data.
6	U405, pins 11-18	Positive going pulses.	Display segment data.
7	U406, pins 11-18	Positive going pulses.	Display segment data.
8	U408, pins 10-16	Sawtooth waveform.	Display digit data.
9	U409, pins 10-16	Sawtooth waveform.	Display digit data.
10	U410, pins 10-15	Negative going pulses.	Keyboard scan data.
11	U410, pin 2	Pulses present when ZERO button is pressed.	Returned key board data.
12	U410, pin 3	Pulses present when TRIGGER button is pressed.	Returned keyboard data.
13	U410, pin 4	Pulses present when LEVEL key is pressed.	Returned keyboard data.
14	U410, pin 5	Pulses present when RATE key is pressed.	Returned keyboard data.
15	U410, pin 6	Pulses present when SHIFT key is pressed.	Returned keyboard data.
16	U410, pin 7	Pulses present when TRMS key is pressed.	Returned keyboard data.
17	U410, pin 8	Pulses present when RECALL key is pressed.	Returned keyboard data.
18	Front panel	Program 1000 samples, 10μsec rate, continuous trigger.	
19	VOLTAGE INPUT jack	Apply time varying signal.	Select appropriate range.
20	XY mode programming	Program X and Y 10V full scale, enter XY mode, trigger XY output with XY TRIG.	
21	U412-U414, pins 3-8, 13-18, U415, pins 3-8, 18	Data bus pulses.	Check for stuck bit on data (D0-D7).
22	U412-U415, pin 1	Negative going pulse while XY mode is running.	Analog output latch enable pulses.
23	U416, pins 1-12	Varying data pulses.	X output digital data.
24	U417, pins 1-2	Varying data pulses.	Y output digital data.
25	U415, pin 19	Pulse at XY mode transmission interval.	Z blanking pulse.
26	J1007	Positive-going ramp.	X analog output.
27	J1006	Analog signal (depends on measured signal).	Y analog output.
28	J1005	Pulse at XY mode transmission interval.	Z output pulse.

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7.8.8 Analog Circuitry Checks

The input amplifier circuitry processes input voltages, supplying the necessary gain or attenuation, depending on the selected range. Table 7-13 outlines the basic procedure for troubleshooting the analog circuitry. Gain values for the four ranges are summarized in Table 7-14.

7.8.9 A/D Converter Checks

The A/D converter transforms the analog input signal into binary numbers representing its value at various points in time. For sampling rates of 100kHz and slower, the A/D converter samples with 16-bit resolution. Above 100kHz, however, the converter resolution is only eight bits.

Table 7-15 summarizes the basic procedure for testing the A/D converter module and associated circuitry.

7.8.10 A/D Board Digital Circuitry Checks

The digital circuitry located on the A/D board generates signals to control the A/D converter and transfer and store A/D data. Thus, problems with the digital circuity could cause erratic operation. Check the various components associated with digital circuitry using the procedure listed in Table 7-16.

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Table 7-13. Input Amplifier Checks

Step	Item/Component	Required Condition	Remarks
1	Power	Turn power on.	All voltages referenced to signal common (outer shell of VOLTAGE INPUT jack).
2	CPLG Key	Select DC coupling.	Use DC coupling for all measurements.
3	Range	Select 320mV range.	
4	VOLTAGE INPUT jack	Apply +320.00mV	Use accurate calibration source.
5	U387, pin 6	+488.32mV, ±0.1%	Output of fixed gain amp.
6	U386, pin 6	+4.8832V, ±0.1%	Output of X1/X10 amp.
7	VOLTAGE INPUT jack	Apply −320.00mV	Calibration source.
8	U387, pin 6	−488.32mV, ±0.1%	Fixed gain amp.
9	U386, pin 6	−4.8832mV, ±0.1%	X1/X10 amp
10	Range	Select 3.2V range.	
11	VOLTAGE INPUT jack	Apply +3.2000V	Use DC calibrator.
12	U387, pin 6	+4.8832V, ±0.1%	
13	U386, pin 6	+4.8832V, ±0.1%	
14	VOLTAGE INPUT jack	Apply −3.2000V	Use DC calibrator.
15	U387, pin 6	−4.8832V, ±0.1%	
16	U386, pin 6	−4.8832V, ±0.1%	
17	Range	Select 32V range.	
18	VOLTAGE INPUT jack	Apply +32.000V	Use DC calibrator.
19	U387, pin 6	+4.8832V, ±0.1%	
20	U386, pin 6	+4.8832V, ±0.1%	
21	VOLTAGE INPUT jack	Apply −32.000V	Use DC calibrator.
22	U387, pin 6	−4.8832V, ±0.1%	
23	U386, pin 6	−4.8832V, ±0.1%	
24	Range	Select 200V range.	
25*	VOLTAGE INPUT jack	Apply ±200.00V	Use DC calibrator.
26*	U387, pin 6	+3.052V, ±0.1%	
27*	U386, pin 6	+3.052V, ±0.1%	
28	VOLTAGE INPUT jack	Apply −200.00V	Use DC calibrator.
29	U387, pin 6	−3.052V, ±0.1%	
30	U386, pin 6	−3.052V, ±0.1%	

*WARNING: Hazardous voltage used in these steps.

Table 7-14. Input Amplifier Gain Values

Range	Overall Amplifier Gain
320 mV	X15.26
3.2 V	X 1.526
32 V	X 0.1526
200 V	X 0.01526

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Table 7-15. A/D Converter Checks

Step	Item/Component	Required Condition	Remarks
1	Programming	Program 100 samples, 100μsec rate, continuous trigger, DC Coupling, filter off.	All voltages referenced to analog common (outer shell of VOLTAGE INPUT jack).
2	U379, U380, U361, U370, U382, pin 1	10μsec positive pulse when range button is pressed.	Serial control strobe.
3	U379, U380, U361, U370, U382, pin 2	Pulse train when range button is pressed.	Serial control data.
4	U379, U380, U361, U370, U382, pin 3	Pulse train when range button is pressed.	Serial control clock.
5	Range	Select 320mV range.	
6	U379	Pins 4 and 12 low; pin 13 high.	Input amplifier FET control.
7	U380	Pin 11 low	Input amplifier relay control.
8	Range	Select 3.2V range.	
9	U379	Pins 4 and 13 low; pin 12 high.	FET control
10	U380	Pin 11 low.	Relay control
11	Range	Select 32V range.	
12	U379	Pins 4 and 13 low, pin 12 high.	FET control
13	U380	Pin 11 high.	Relay control
14	Range	Select 200V range.	
15	U379	Pins 4 and 12 high, pin 13 low.	FET control
16	U380	Pin 11 high.	Relay control
17	U379, pin 6	High, filter off; low, either filter on.	Filter control
18	U379, pin 14	High, filter off, 50kHz filter; low 500kHz.	Filter control
19	Rate	Program 5μsec interval.	
20	U379, pin 11	High logic level.	8/16 bit A/D select.
21	Rate	Program 100μsec interval.	
22	U379, pin 11	Low logic level.	8/16 bit A/D select.
23	Coupling	Select ground coupling.	
24	U380, pin 12	High logic level.	Coupling control
25	Coupling	Select DC coupling.	
26	U380, pin 12	Low logic level.	Coupling control
27	U374, pin 3	10MHz square wave.	10MHz clock
28	U374, pin 2	5MHz square wave.	5MHz clock
29	U375, pin 6	10μsec positive going pulse rate.	
30	U371, pin 7	2μsec negative going pulse at sample rate.	Data shift enable pulse.
31	U371, pin 14	5MHz square wave.	5MHz data shift clock.
32	Rate, samples	Program 10,000 sample, 10μsec interval.	
33	U371, pin 9	Data burst pulses every 10μsec.	Even serial data.

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Table 7-15. A/D Converter Checks (Cont.)

Step	Item/Component	Required Condition	Remarks
34	U371, pin 12	Data burst pulses every 10μsec.	Odd serial data.
35	U371, pin 16	500nsec negative-going pulse every 10μsec during measurement.	A/D trigger pulse.
36	Range	Select 3.2V range.	
37	VOLTAGE INPUT jack	Apply +3.2767V	Use DC calibrator.
38	TP1 (Near A/D/J1)	+5.00V	Sample/hold input
39	DC calibrator	Select −3.2768V output.	−full range input.
40	TP1	−5.00V	Sample/hold input
41	Display	Adjust for −3.2768V on 194A display.	
42	U376, pins 3-6, 11-14	All pulse low during measurement.	Odd bit A/D data with −full range input.
43	U385, pins 3-6, 11-14	All pulse low during measurement.	Even bit A/D data with +full range input.
44	DC calibrator	Select +3.2767V output.	+full range input.
45	Display	Adjust calibrator for +3.2767V on 194A display.	
46	U376, pins 3-6, 11-14	All pulse high during measurement.	Odd bit data with +full range input.
47	U385, pins 3-6, 11-14	All pulse high during measurement.	Even bit data with +full range input.

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Table 7-16. A/D Module Digital Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	Programming	Program 10,000 samples, 10μsec interval, continuous trigger mode.	All voltages referenced to A/D digital common (TRIGGER jack outer shell).
2	U369, pin 7	Data pulse burst every 10μsec.	Odd bit data.
3	U369, pin 9	Data pulse burst every 10μsec.	Even bit data.
4	U369, pin 14	2μsec negative going pulse every 10μsec.	Data shift enable.
5	U369, pin 12	5MHz square wave.	Data shift clock.
6	U369, pin 5	500nsec negative going pulse every 10μsec during measurement.	A/D trigger pulse.
7	Front panel	Program 100 samples.	
8	U369, pin 16	Positive going pulse when range button is pressed.	Serial control strobe.
9	U369, pin 18	Pulse burst when range button is pressed.	Serial control clock.
10	U369, pin 20	Pulse burst when range button is pressed.	Serial control data.
11	Front panel	Program 10,000 samples.	
12	U352, pins 3, 4, 7, 8, 13, 14, 17, 18	A/D data at sampling rate.	High byte data.
13	U360, pins 3, 4, 7, 8, 13, 14, 17, 18	A/D data at sampling rate.	Low byte data.
14	U306, pins 1 and 8	Pulse train when range button is pressed.	Serial control clock and data.
15	U310, pins 1 and 8	Pulse train when range button is pressed.	Serial control clock and data.
16	U347, pins 1 and 8	Pulse train when range button is pressed.	Serial control clock and data.
17	U356, pins 1 and 8	Pulse train when range button is pressed.	Serial control clock and data.
18	U322, U342, U351, U359, pin 8	5MHz square wave.	Data shift clock.
19	U322, U351, pins 1 and 2	Serial pulse train during measurement.	Odd bit serial A/D data.
20	U342, U359, pins 1 and 2	Serial pulse train during measurement.	Even bit serial A/D data.
21	U351, U322, pins 3-6,10-13	A/D data pulses.	Odd bits of parallel data.
22	U342, U359, pins 3-6,10-13	A/D data pulses.	Even bits of parallel data.
23	U307, U308, U309, pin 2	10MHz square wave.	Sample counter clock.
24	U345, pin 4	2μsec negative pulse every 10μsec.	Trigger counter count pulse.
25	U346, pin 4	2μsec negative pulse every 2msec.	Second stage count pulse.
26	U312, pin 1	200nsec positive pulse every 10μsec.	Address counter count pulse.
27	U312, U334, pins 3-6, 9-13	Address counter pulses, various duration.	Count depends on programmed number of samples.
28	U303, pins 11-18	Check for stuck bit on data bus.	Data bus D0-D7
29	U304, pins 2-9	Check for stuck bit on data bus.	Data bus D0-D7
30	U317-U320, U337-U340, pin 4	200nsec negative pulse every 8μsec when not measuring.	RAM $\overline{RAS}$ during MPU memory access.
31	U317-U320, U337-U340, pin 15	200nsec negative pulse every 60μsec when not measuring.	RAM $\overline{CAS}$ during MPU memory access.
32	U316, pin 1	10MHz square wave.	DMA controller clock.
33	U315, pin 25	1MHz square wave.	2 system clock.
34	U301, U302, pins 3 and 4	Brief data pulse train upon power up.	NVRAM data.

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7.9 FAN FILTER CLEANING/REPLACEMENT

The fan filter, which is located on the rear panel of the instrument, should be checked periodically for dirt build-up and cleaned or replaced, as necessary. Use the procedure below to clean or replace the filter.

WARNING
Disconnect the instrument from the power line and all other equipment before removing the top cover.

1. Remove the two screws that secure the top cover to the rear panel and slide the cover off completely to the rear.
2. Using a pair of needle-noise pliers, carefully remove the filter, as shown in Figure 7-16.
3. Soak the filter in a solution of warm water and mild detergent until clean. Rinse thoroughly in clean water and allow the filter to dry completely before installation.
4. If a replacement filter is required, one may be obtained from Keithley Instruments, Inc. Order part number FL-7.

NOTE
In order to minimize dirt build-up within the instrument, it is recommended that you operate the instrument only with the proper filter installed.

5. Using a screwdriver or pliers, install the filter by guiding it in between the rear panel and the fan guard. Make sure the filter is properly seated at all four corners.

7.10 Z OUTPUT HIGH LEVEL MODIFICATION

As shipped, the Z output high level is programmed for 5V. However, the output can be changed to a nominal 15V value by modification of the I/O circuit board as follows:

1. Remove the I/O board from the instrument as covered in paragraph 7.7.
2. Install the correct pull-up resistor at location R409 (+5V) or R410 (+15V). Figure 7-17 shows the location of these two resistors on the I/O board, while Table 7-17 lists nominal, maximum, and minimum values. The nominal 910Ω value for +5V is recommended for compatibility with TTL circuits.
3. Remove the resistor for the unused voltage value. For example, if you are changing from +15V to +5V, you would install R409 and remove R410.
4. Install the I/O board within the instrument. Be sure to secure the board to the rear with the two screws removed earlier, and check to see that all cables are connectd properly.

7.11 CIRCUIT BOARD JUMPER LOCATIONS

A number of movable jumpers, located on the A/D and mother boards, are used to select such operating aspects as interrupt levels, address decoding, RAM/ROM types, and delay timing. Figure 7-18 shows the locations of these jumpers, as well as the correct position for each, just in case you inadvertently change one or more settings. Keep in mind that future software or hardware revisions could change the locations or settings of these jumpers; thus, it would be a good idea to mark the locations and settings for your particular Model 194A before working on the circuit boards.

NOTE
The instrument may be partially or completely inoperative if one of the jumpers is moved to an improper position.

Table 7-17. Z Output Resistor Values

Installed Resistor	Nominal High Output	Nominal Resistor Value	Keithley Part Number	Minimum Value	Maximum Value
R409	+5V	910Ω, ¼W*	R-76-910	100Ω, 2W	3.9kΩ
R410	+15V	1.5kΩ, ¼W	R-76-1.5k	270Ω, 1W	12kΩ

*Resistance value based on TTL compatibility.

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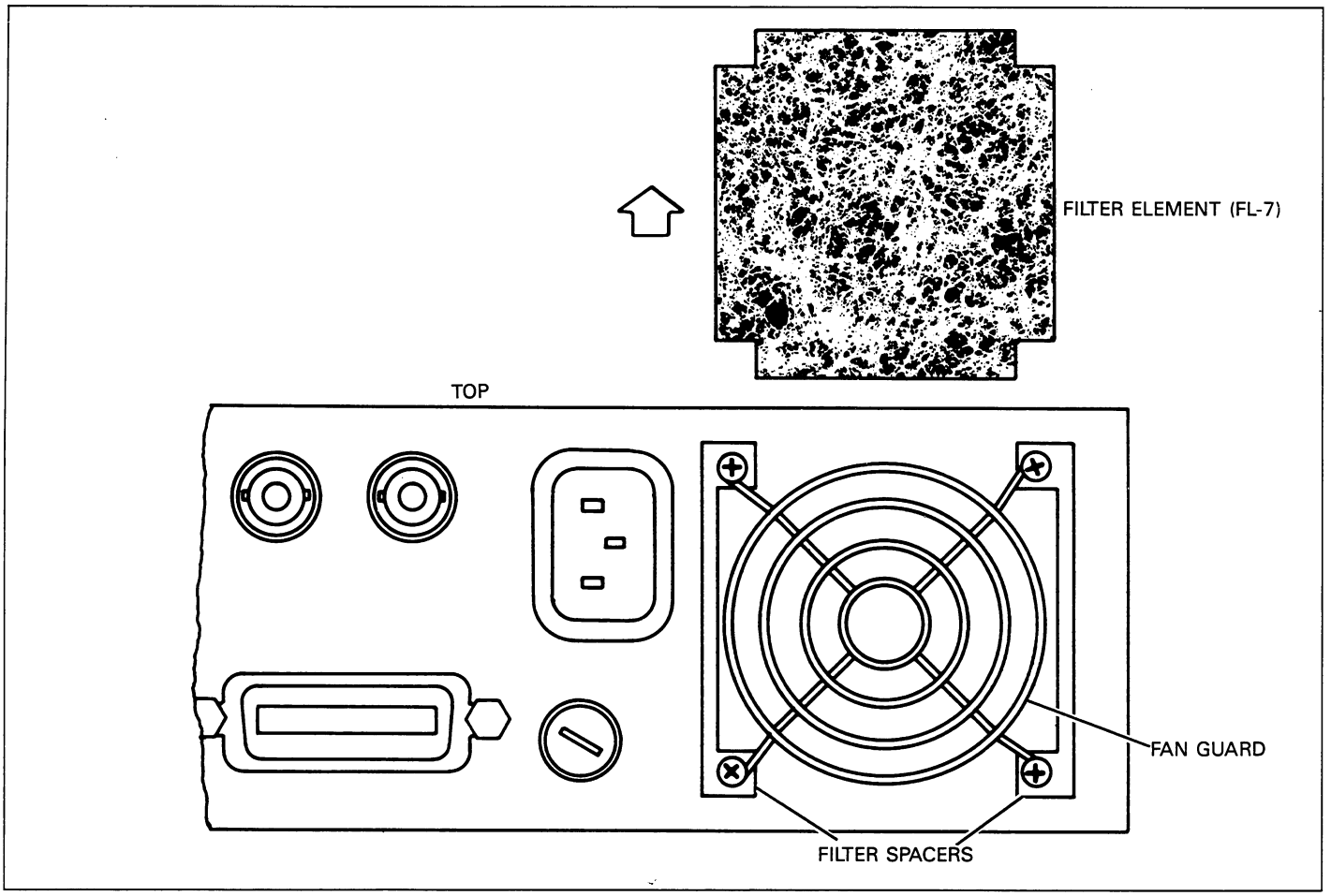


Figure 7-16. Fan Filter Removal

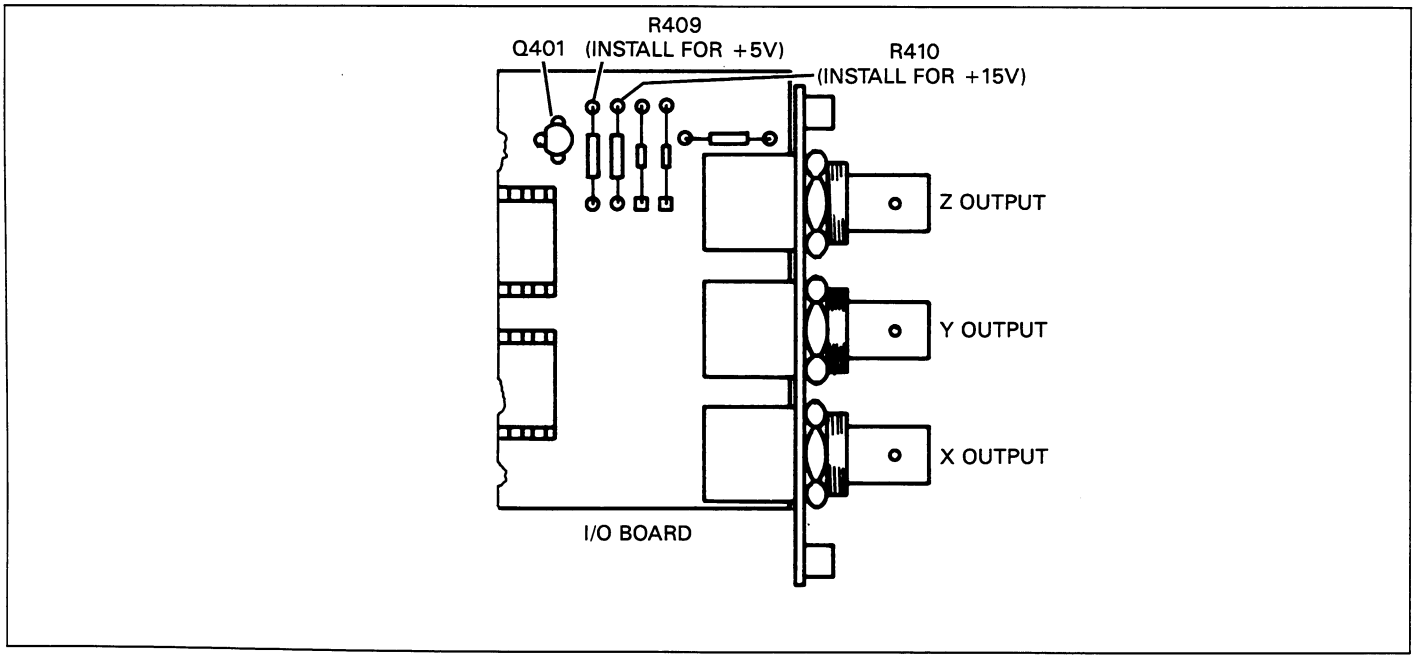


Figure 7-17. Z Output Blanking Level Programming

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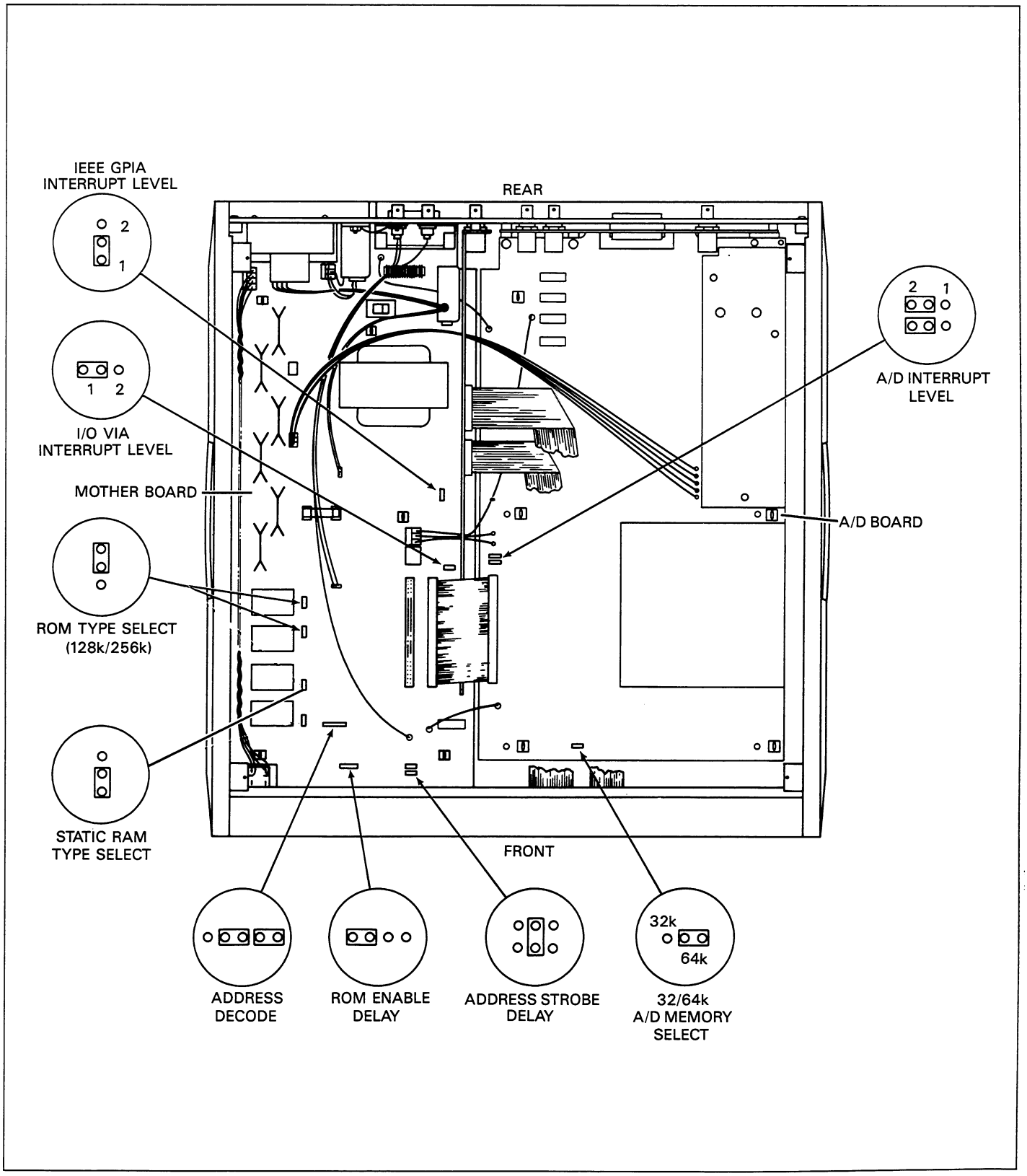


Figure 7-18. Movable Jumper Locations

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SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 194A High Speed Voltmeter and the Model 1944A

8.2 ELECTRICAL PARTS LISTS

Electrical parts for the various circuit boards are listed in Tables 8-1 through 8-54. Parts in each table are listed alphabetically in order of circuit designation. The parts lists are integrated with the component layout drawings and schematic diagrams for the respective circuit boards.

8.3 MECHANICAL PARTS

Parts for the case assembly are listed in Table 8-6. These parts are also shown in Figure 8-1. Miscellaneous mechanical parts are listed in Table 8-7.

8.4 ORDERING INFORMATION

Keithley Instruments, Inc maintains a complete inventory of all normal replacement parts. To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory.

When ordering parts, include the following information.

1. Instrument model number
2. Instrument serial number
3. Part description
4. Circuit designation, including schematic diagram and component layout numbers (if applicable)
5. Keithley part number

8.5 FACTORY SERVICE

If the instrument is to be returned to the factory for service, carefully pack the unit and include the following:

1. Complete the service form which follows this section and return it with the instrument.
2. Advise as to the warranty status of the instrument (see the inside front cover for warranty information).
3. Write the following on the shipping label: ATTENTION REPAIR DEPARTMENT.

8.6 COMPONENT LOCATION DRAWINGS AND SCHEMATIC DIAGRAMS

Component location drawings and schematic diagrams for the various circuit boards can be found on the following pages in the following order:

1. Mother board.
2. Display board.
3. A/D board (channel 1 A/D and Model 1944A option).
4. I/O board.
5. Sample Rate board.

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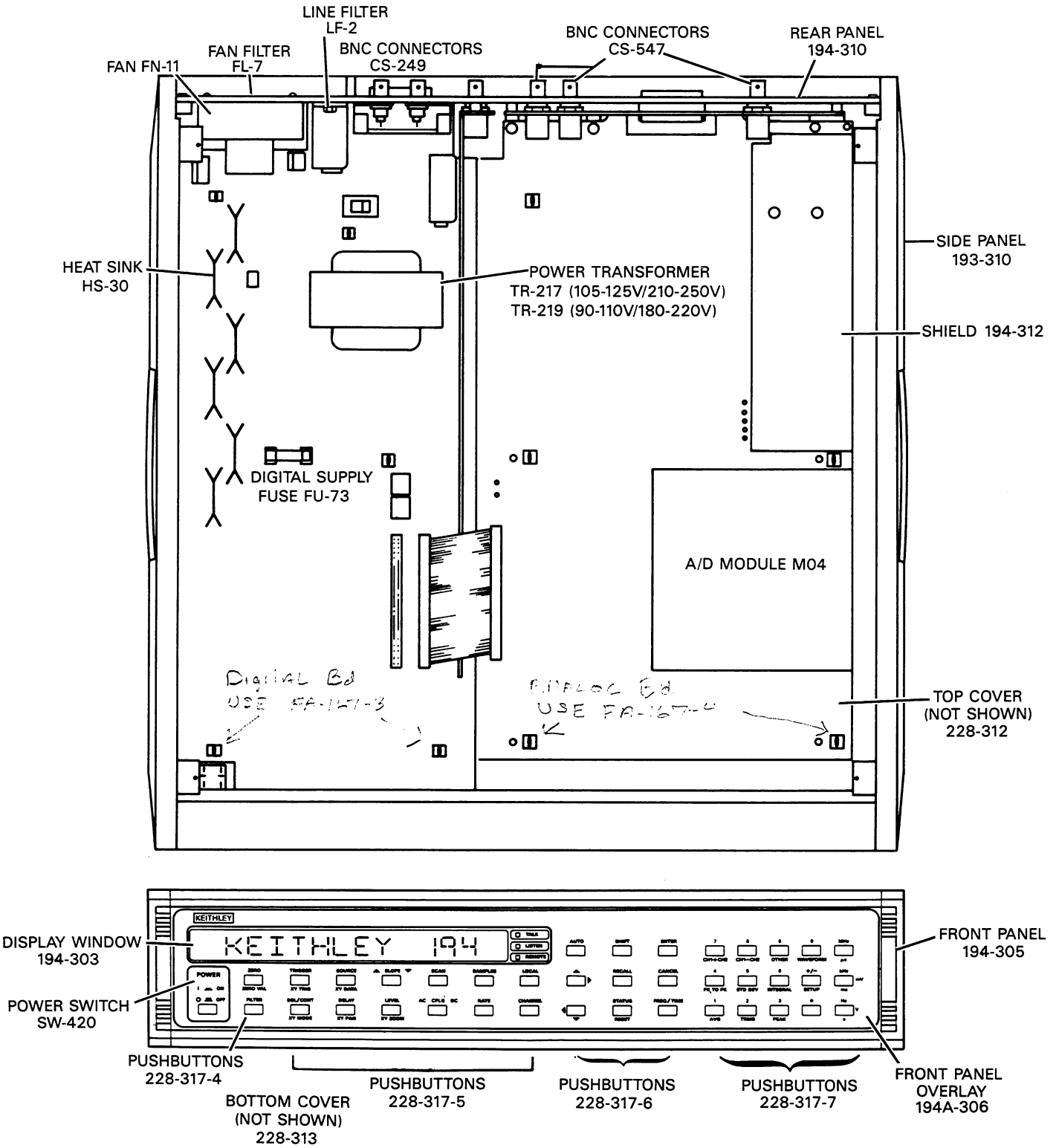


Figure 8-1. Mechanical Parts Locations

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Table 8-1. Mother Board, Parts List

Schematic Designation	Description	Schematic Location	Keithley Part No.
C101	Capacitor, 0.1μF, 20%, 50V	2/D2	C-365-0.1
C102	Capacitor, 0.1μF, 20%, 50V	2/E2	C-365-0.1
C103	Capacitor, 0.1μF, 20%, 50V	2/E2	C-365-0.1
C104	Capacitor, 0.1μF, 20%, 50V	2/F2	C-365-0.1
C105	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/E2	C-314-10
C106	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/E1	C-314-10
C107	Capacitor, 22μF, 35V, Aluminum Electrolytic	1/E1	C-309-22
C108	Capacitor, 0.1μF, 50V, Ceramic Film	1/D2	C-237-0.1
C109	Capacitor, 4700μF, 35V, Electrolytic	1/C2	C-368-4700
C110	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D3	C-314-10
C111	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D3	C-314-10
C112	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D4	C-314-10
C113	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D4	C-314-10
C114	Capacitor, 470μF, 25V, Aluminum Electrolytic	1/C4	C-313-470
C115	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C116	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C117	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C118	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C119	Capacitor, 470μF, 16V, Aluminum Electrolytic	1/C6	C-313-470
C120	Capacitor, 10μF, 25V, Aluminum Electrolytic	2/A6	C-314-10
C121	Capacitor, 22μF, 35V, Electrolytic	1/E2	C-309-22
C122	Capacitor, 100μF, 35V, Aluminum Electrolytic	1/D2	C-295-100
C123	Capacitor, 1000μF, 35V, Aluminum Electrolytic	1/C3	C-309-1000
C124	Capacitor, 1000μF, 35V, Aluminum Electrolytic	1/C3	C-309-1000
C125	Capacitor, 2200μF, 16V, Aluminum Electrolytic	1/C4	C-351-2200
C126	Capacitor, 1000μF, 35V, Aluminum Electrolytic	1/C5	C-309-1000
C127	Capacitor, 1000μF, 35V, Aluminum Electrolytic	1/C5	C-309-1000
C128	Capacitor, 1μF, 50V, Ceramic Film	1/F4	C-237-1
C129	Capacitor, 0.1μF, 50V, Ceramic Film	1/F3	C-237-0.1
C130	Capacitor, 0.1μF, 20%, 50V	2/D4	C-365-0.1
C131	Capacitor, 0.1μF, 20%, 50V	2/C3	C-365-0.1
C132	Capacitor, 0.1μF, 20%, 50V	3/B6	C-365-0.1
C133	Capacitor, 0.1μF, 20%, 50V	3/C5	C-365-0.1
C134	Capacitor, 0.1μF, 20%, 50V	3/C6	C-365-0.1
C135	Capacitor, 0.1μF, 20%, 50V	3/E2	C-365-0.1
C136	Capacitor, 0.1μF, 20%, 50V	3/D2	C-365-0.1
C137	Capacitor, 0.1μF, 20%, 50V	3/B2	C-365-0.1
C138	Capacitor, 0.1μF, 20%, 50V	3/E4	C-365-0.1
C139	Capacitor, 470μF, 25V, Aluminum Electrolytic	1/E2	C-356-470
C140	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/F5	C-314-10
C141	Capacitor, 1μF, 50V, Ceramic Film	1/F2	C-237-1
C142	Capacitor, 2200μF, 16V, Aluminum Electrolytic	1/C5	C-351-2200
C143	Capacitor, 1μF, 50V, Ceramic Film	1/F2	C-237-1
C144	Capacitor, 0.1μF, 250V, Metallized Polyester	1/F5	C-178-0.1
C145	Capacitor, 0.001μF, 500V, Ceramic Disc	1/E4	C-22-0.001
C146	Capacitor, 0.1μF, 20%, 50V	2/B1	C-365-0.1
C147	Capacitor, 0.1μF, 20%, 50V	2/C1	C-365-0.1
C149	Capacitor, 0.1μF, 20%, 50V	2/D4	C-365-0.1
C150	Capacitor, 0.1μF, 20%, 50V	2/B5	C-365-0.1
C151	Capacitor, 0.1μF, 20%, 50V	3/F5	C-365-0.1
C152	Capacitor, 0.1μF, 20%, 50V	3/D6	C-365-0.1
C153	Capacitor, 0.1μF, 20%, 50V	2/B6	C-365-0.1

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Table 8-1. Mother Board, Parts List Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
CR101	Diode, Schottky Rectifier, 7.5A, 45PIV, MBR745	1/D2	RF-65
CR102	Diode, Silicon, 1N4148	2/A6	RF-28
CR103	Diode, Silicon, 1N4148	2/A6	RF-28
CR104	Diode, Rectifier, 1A, 800PIV, 1N4006	1/D2	RF-38
CR105	Diode, Rectifier, 1A, 800PIV, 1N4006	1/E3	RF-38
CR106	Diode, Bridge Rectifier, 1A, 100PIV	1/C4	RF-52
CR107	Diode, Bridge Rectifier, 1A, 100PIV	1/C5	RF-52
CR108	Diode, Silicon, 1N4148	3/F5	RF-28
CR109	Diode, Silicon, 1N4148	3/F5	RF-28
CR110	Diode, Bridge Rectifier, 4A, 100PIV	1/C2	RF-64
CR111	Diode, Bridge Rectifier, 1A, 100PIV	1/C3	RF-52
CR112	Diode, Silicon, 1N4148	1/F4	RF-28
CR113	Diode, Bridge Rectifier, 1A, 100PIV	1/C4	RF-52
CR114	Diode, Silicon, 1N4148	3/F6	RF-28
CR115	Diode, Silicon, 1N4148	3/F6	RF-28
F101	Fuse, ½A, 250V, 3AG, SLO BLO (230V operation)	1/A5	FU-4
F101	Fuse, 1A, 250V, 3AG, SLO BLO (115V operation)	1/A5	FU-10
F102	Fuse, 6A, 8AG	1/D2	FU-73
J1001	Line Filter	1/A5	LF-2
J1002	Connector, BNC	3/G6	CS-249
J1003	Connector, BNC	3/G6	CS-249
J1004	Connector, IEEE-488	2/A1	CS-507
J1012	Connector, Pin	1/A5	CS-288-3
J1013	Connector, Pin	1/A4	CS-288-4
J1014	Connector, Pin	1/C2	CS-339-2
J1015	Pin	3/G6	CS-339-1
J1016	Pin	3/G6	CS-339-1
J1017	Pin	3/G6	CS-339-1
J1021	Connector	1/D5	193-325
J1022	Connector	1/D4	193-325
J1023	Connector, Pin	1/G2	CS-288-3
J1024	Connector, Pin	1/G3	CS-288-3
J1018			CS-454-3
L101	Choke, 160μH	1/E2	CH-22
L102	Choke, 10μH	1/E2	CH-20-1
Q101	Transistor, N-Channel MOS Power, 1RF531	1/D2	TG-184
Q102	Thyristor, Reverse Blocking Triode, MCR682	1/F2	TG-183
Q103	Transistor, Silicon, PNP, 2N3906	1/E5	TG-84
Q104	Transistor, Silicon, NPN, 2N3904	1/F4	TG-47
R101	Resistor, 261kΩ, 1%, $^1/_8$W	2/A6	R-88-261k
R102	Resistor, 20kΩ, 1%, $^1/_8$W	2/A6	R-88-20k
R103	Resistor, 61.9kΩ, 1%, $^1/_8$W	2/A6	R-88-61.9k
R104	Resistor, 3.3kΩ, 5%, ¼W, Composition	2/A6	R-76-33k
R105	Resistor, 510Ω, 5%, ¼W, Composition	2/D3	R-76-510
R106	Resistor, 100Ω, 5%, ¼W, Composition	1/D2	R-76-100
R107	Resistor, 1kΩ, 5%, ¼W, Composition	1/D2	R-76-1k
R108	Resistor, 4.7Ω, 1W, Wire Wound, Fused	1/D2	R-334-4.7
R109	Resistor, 51Ω, 5%, ¼W, Composition	3/F6	R-76-51

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Table 8-1. Mother Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
R110	Resistor, 3.3kΩ, 5%, ¼W, Composition	1/E5	R-76-3.3k
R111	Resistor, 30kΩ, 5%, ¼W, Composition	1/F5	R-76-30k
R112	Resistor, 4.7kΩ, 5%, ¼W, Composition	1/F5	R-76-4.7k
R113	Resistor, 1kΩ, 5%, ¼W, Composition	1/F4	R-76-1k
R114	Resistor, 3.3kΩ, 5%, ¼W, Composition	1/F3	R-76-3.3k
R115	Resistor, 100Ω, 5%, ¼W, Composition	1/F2	R-76-100
R116	Resistor, Thick Film	Sev	TF-10
R117	Resistor, 3.3kΩ, 5%, ¼W, Composition	2/D4	R-76-3.3k
R118	Resistor, 1kΩ, 5%, ¼W, Composition	1/E5	R-76-1k
R119	Resistor, 10kΩ, 5%, ¼W, Composition	1/F5	R-76-10k
R120	Resistor, 470kΩ, 5%, ¼W, Composition	1/F5	R-76-470k
R121	Resistor, 23.2kΩ, 1%, $^1/_8$W	1/E4	R-88-23.2k
R123	Resistor, 3.3kΩ, 5%, ¼W, Composition	3/D5	R-76-3.3k
R124	Resistor, 3.3kΩ, 5%, ¼W, Composition	3/F6	R-76-3.3k
R125	Resistor, 100Ω, 5%, ¼W, Composition	3/F6	R-76-100
R126	Resistor, 10kΩ, 5%, ¼W, Composition	3/F6	R-76-10k
R127	Resistor, Thick Film	Sev	TF-101
R128	Resistor, 200Ω, 1%, $^1/_8$W	1/E4	R-88-200
R129	Resistor, 13kΩ, 1%, $^1/_8$W	1/E5	R-88-13k
R130	Resistor, 75Ω, 10%, 2W, Composition	1/C2	R-3-75
S101	Switch, Power	1/B4	SW-420
S102	Switch, Voltage Select	1/A3	SW-397
T101	Transformer, Power (105-125V, 210-250V operation)	1/B3	TR-217
T101	Transformer, Power (90-110V, 180-220V operation)	1/B3	TR-219
T102	Transformer, MOSFET Drive	1/D2-F4	TR-218
U101*	IC, Microprocessor, 68008-L10	2/B4	LSI-69
U102*	IC, 32k × 8 CMOS static RAM, 8832	2/D2	LSI-76
U103*	IC, ROM	2/E2	194-801**
U104*	IC, ROM	2/F2	194-802**
U105*	IC, ROM	2/G2	194-803**
U106	IC, Micropower, Monolithic, 8211	2/A6	IC-177
U107	IC, 1 of 4 Decoder, 74LS139	2/F4	IC-190
U108	IC, 1 of 8 Decoder, 74LS138	2/E4	IC-182
U109	IC, Octal Buffer, 74LS244	3/B4	IC-230
U110	IC, 8-Bit Parallel-Serial Converter, 74LS165	2/C5	IC-237
U111	IC, Quad 2-Input OR Gate, 74LS32	2/3 Sev	IC-257
U112	IC, Dual JK Flip-Flop, 74LS73	3/A6	IC-270
U113	IC, Dual 4-Input NAND Gate, 74LS20	2/3 Sev	IC-232
U114	IC, Dual JK Flip-Flop, 74LS73	3/C6	IC-270
U115	IC, Octal Buffer, 74LS244	3/E2	IC-230
U116	IC, Octal Buffer, 74LS244	3/D2	IC-230
U117	IC, Octal Bus Transceiver, 74LS645	3/B2	IC-307
U118	IC, Octal Buffer, 74LS244	3/E4	IC-230
U119	IC, Pulse Modulator, TL494C	1/F4	IC-402

*Static Sensitive
**Order same number as present software revision.

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Table 8-1. Mother Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
U120	IC, 8-Bit Parallel-Serial Converter, 74LS165	2/C4	IC-237
U121	IC, Quad 2-Input NAND Gate, 74LS00	2/Sev	IC-163
U122	IC, Quad 2-Input NAND Gate, 74LS00	2/Sev	IC-163
U123	IC, 8-Bit Parallel-Serial Converter, 74LS165	3/E6	IC-237
U124	IC, Octal GPIA Bus Transceiver, 75160A	2/A1	IC-298
U125	IC, Octal GPIA Bus Transceiver, 75161A	2/A2	IC-299
U126	IC, Triple 3-Input AND Gate, 74LS11	2/B5	IC-189
U127*	IC, General Purpose Interface Adapter, 9914	2/B2	LSI-49
U128	IC, D-Type Flip-flop, 74LS74		IC-144
VR101	Regulator, IC, +15V, 78M15	1/E1	IC-194
VR102	Regulator, IC, −15V, 7915	1/E3	IC-174
VR103	Regulator, IC, −15V, 7915	1/D3	IC-174
VR104	Regulator, IC, +15V, 78M15	1/D3	IC-194
VR105	Regulator, IC, −5V, 7905	1/D4	IC-184
VR106	Regulator, IC, +5V, 7805	1/D4	IC-93
VR107	Regulator, IC, −15V, 7915	1/D5	IC-174
VR108	Regulator, IC, +15V, 78M15	1/D4	IC-194
VR109	Regulator, IC, −5V, 7905	1/D6	IC-184
VR110	Regulator, IC, +5V, 7805	1/D5	IC-93
VR111	Regulator, Zener Diode, 6.2V, 1N753	1/F2	DZ-21
W102	Connector Pin	2/E3	CS-339-3
W103	Connector Pin	2/E3	CS-339-3
W104	Connector Pin	2/F3	CS-339-3
W105	Connector Pin	2/F4	CS-339-5
W106	Connector Pin	2/C4	CS-339-4
W107	Jumper		J-3
W108	Jumper	1/E2	J-3
W110	Connector Pin		CS-339-3
W111	Connector Pin		CS-339-3
W112	Connector Pin		CS-389-6
Y101	Crystal, Oscillator Circuit, 20MHz	3/A6	CR-25-3

*Static Sensitive

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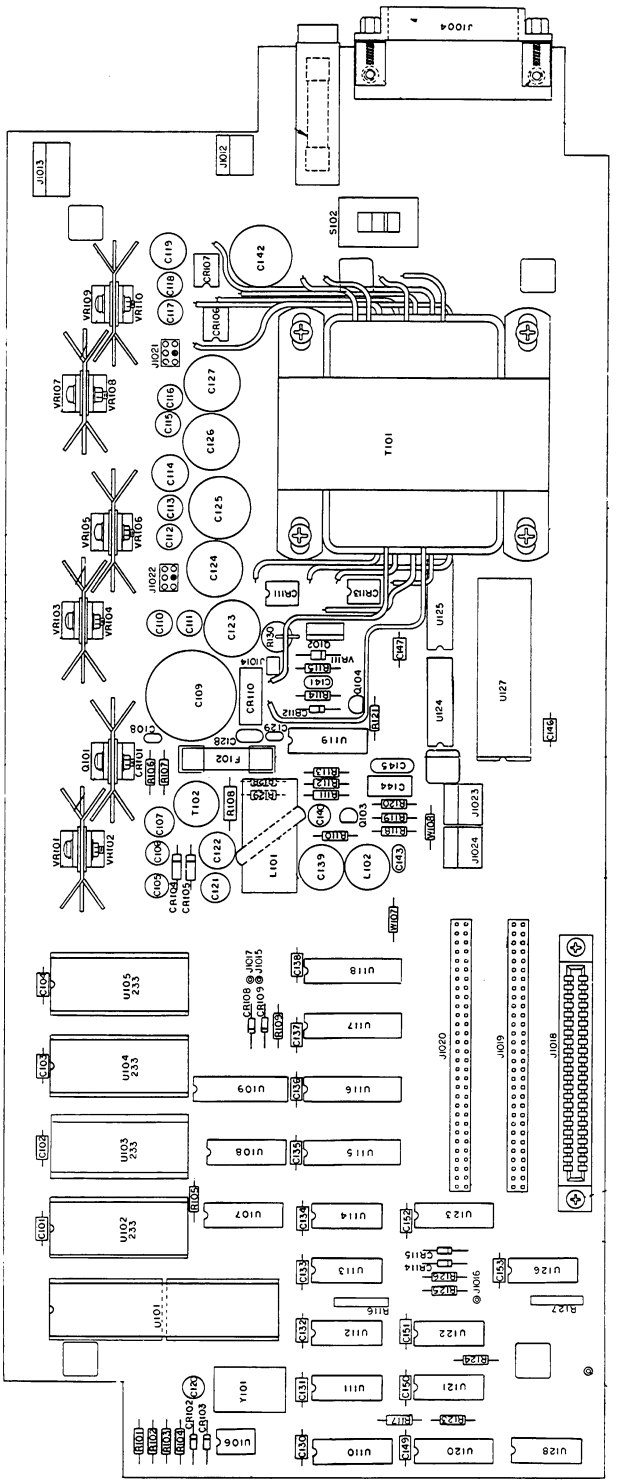


Figure 8-2. Mother Board, Component Location Drawing, Dwg. No. 194-100

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Table 8-2. Display Board, Parts List

Schematic Designation	Description	Schematic Location	Keithley Part No.
DS201	LED Display, Dual 14-Segment	B2	DD-39
DS202	LED Display, Dual 14-Segment	C2	DD-39
DS203	LED Display, Dual 14-Segment	E2	DD-39
DS204	LED Display, Dual 14-Segment	F2	DD-39
DS205	LED Display, Dual 14-Segment	B4	DD-39
DS206	LED Display, Dual 14-Segment	C4	DD-39
DS207	LED Display, Dual 14-Segment	E4	DD-39
DS208	LED, Red	C1	PL-71
DS209	LED, Red	C2	PL-71
DS210	LED, Red	A2	PL-71
DS211	LED, Red	D2	PL-71
DS212	LED, Red	F2	PL-71
DS213	LED, Red	F2	PL-71
DS214	LED, Red	D2	PL-71
DS215	LED, Red	G2	PL-71
DS216	LED, Red	C4	PL-71
DS217	LED, Red	C4	PL-71
DS218	LED, Red	A3	PL-71
DS219	LED, Red	F4	PL-71
DS220	LED, Yellow	D4	PL-72
DS221	LED, Red	D4	PL-71
P1027	Cable Assembly, 26 Pin	A2/A5	CA-32-3
P1028	Cable Assembly, 20 Pin	A1/A4	CA-32-2
S201	Switch, Pushbutton	C6	SW-435
S202	Switch, Pushbutton	C6	SW-435
S203	Switch, Pushbutton	B6	SW-435
S204	Switch, Pushbutton	B6	SW-435
S205	Switch, Pushbutton	C6	SW-435
S206	Switch, Pushbutton	C6	SW-435
S207	Switch, Pushbutton	B6	SW-435
S208	Switch, Pushbutton	C6	SW-435
S209	Switch, Pushbutton	B6	SW-435
S210	Switch, Pushbutton	B6	SW-435
S211	Switch, Pushbutton	C6	SW-435
S212	Switch, Pushbutton	C6	SW-435
S213	Switch, Pushbutton	B6	SW-435
S214	Switch, Pushbutton	C6	SW-435
S215	Switch, Pushbutton	C6	SW-435
S216	Switch, Pushbutton	C6	SW-435
S217	Switch, Pushbutton	B6	SW-435
S218	Switch, Pushbutton	B6	SW-435
S219	Switch, Pushbutton	B6	SW-435
S220	Switch, Pushbutton	C6	SW-435
S221	Switch, Pushbutton	C6	SW-435
S222	Switch, Pushbutton	C6	SW-435
S223	Switch, Pushbutton	B6	SW-435

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Table 8-2. Display Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
S224	Switch, Pushbutton	B6	SW-435
S225	Switch, Pushbutton	B6	SW-435
S226	Switch, Pushbutton	C6	SW-435
S227	Switch, Pushbutton	C6	SW-435
S228	Switch, Pushbutton	C6	SW-435
S229	Switch, Pushbutton	B6	SW-435
S230	Switch, Pushbutton	B6	SW-435
S231	Switch, Pushbutton	B6	SW-435
S232	Switch, Pushbutton	C6	SW-435
S233	Switch, Pushbutton	C6	SW-435
S234	Switch, Pushbutton	C6	SW-435
S235	Switch, Pushbutton	B6	SW-435
S236	Switch, Pushbutton	B6	SW-435
S237	Switch, Pushbutton	B6	SW-435
S238	Switch, Pushbutton	C6	SW-435

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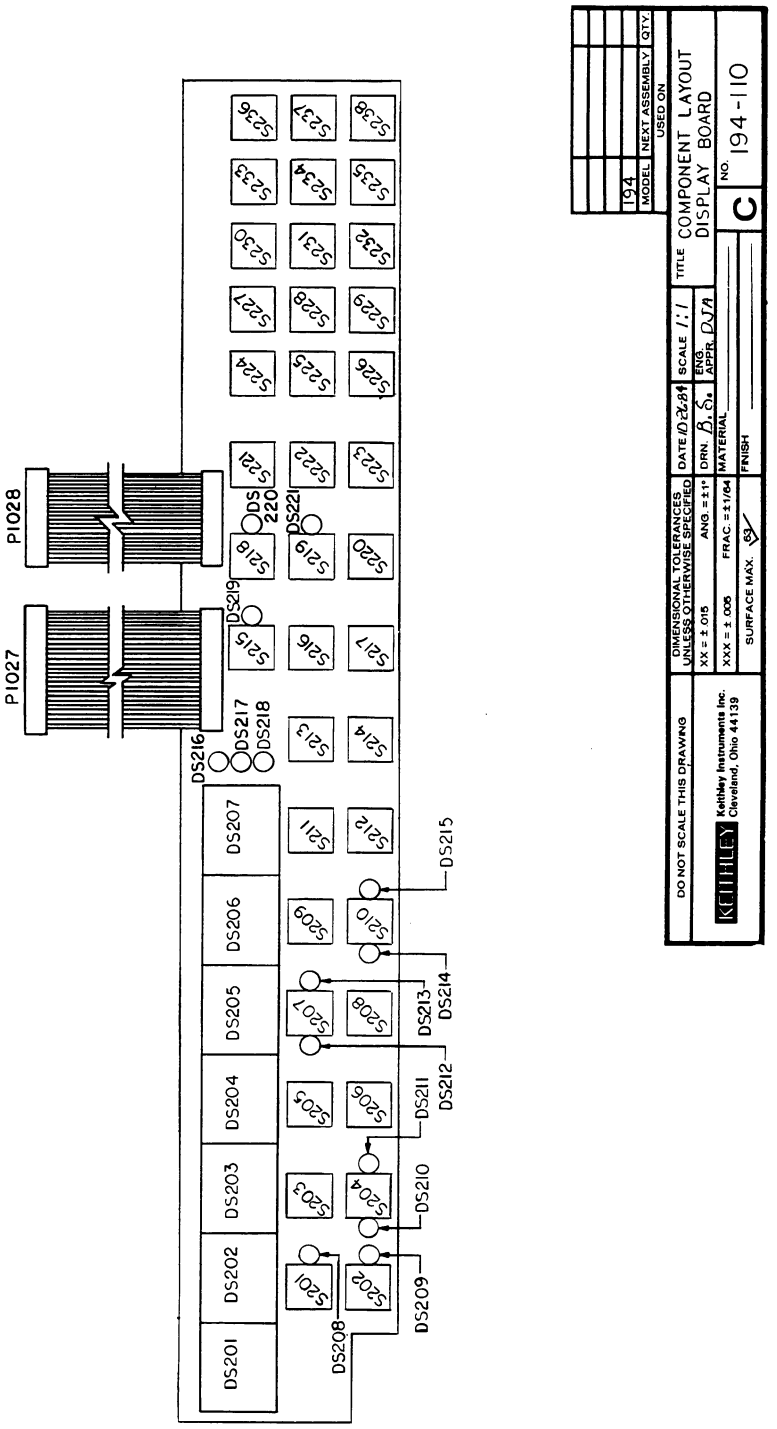


Figure 8-4. Display Board, Component Location Drawing, Dwg. No. 194-110

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Table 8-3. A/D Board, Parts List

Schematic Designation	Description	Schematic Location	Keithley Part No.
C301	Capacitor, 0.1μF, 20%, 50V	4/D1	C-365-0.1
C302	Capacitor, 0.1μF, 50V, Ceramic Film	4/C1	C-237-0.1
C303	Capacitor, 10μF, 25V, Aluminum Electrolytic	2/F6	C-314-10
C304	Capacitor, 0.1μF, 50V, Ceramic Film	3/F5	C-237-0.1
C305	Capacitor, 0.1μF, 20%, 50V	3/B1	C-365-0.1
C307	Capacitor, 0.1μF, 20%, 50V	3/C2	C-365-0.1
C309	Capacitor, 0.1μF, 20%, 50V	3/D1	C-365-0.1
C310	Capacitor, 0.1μF, 20%, 50V	3/E1	C-365-0.1
C311	Capacitor, 0.1μF, 50V, Ceramic Film	3/F4	C-237-0.1
C312	Capacitor, 0.1μF, 50V, Ceramic Film	4/E6	C-237-0.1
C313	Capacitor, 0.1μF, 50V, Ceramic Film	4/D5	C-237-0.1
C314	Capacitor, 0.1μF, 50V, Ceramic Film	4/D5	C-237-0.1
C315	Capacitor, 0.1μF, 50V, Ceramic Film	4/C5	C-237-0.1
C316	Capacitor, 0.1μF, 50V, Ceramic Film	3/E5	C-237-0.1
C317	Capacitor, 0.1μF, 50V, Ceramic Film	3/D5	C-237-0.1
C318	Capacitor, 0.1μF, 50V, Ceramic Film	3/D5	C-237-0.1
C319	Capacitor, 0.1μF, 50V, Ceramic Film	4/D6	C-237-0.1
C320	Capacitor, 0.1μF, 50V, Ceramic Film	4/C6	C-237-0.1
C321	Capacitor, 0.1μF, 50V, Ceramic Film	4/C6	C-237-0.1
C323	Capacitor, 0.1μF, 20%, 50V	3/E6	C-365-0.1
C325	Capacitor, 0.1μF, 20%, 50V	2/C4	C-365-0.1
C327	Capacitor, 0.1μF, 20%, 50V	4/D2	C-365-0.1
C329	Capacitor, 0.1μF, 20%, 50V	4/C4	C-365-0.1
C330	Capacitor, 0.1μF, 20%, 50V	2/E5	C-365-0.1
C331	Capacitor, 0.1μF, 20%, 50V	2/F5	C-365-0.1
C332	Capacitor, 0.1μF, 20%, 50V	3/F2	C-365-0.1
C333	Capacitor, 0.1μF, 20%, 50V	3/G3	C-365-0.1
C334	Capacitor, 0.1μF, 20%, 50V	4/F1	C-365-0.1
C335	Capacitor, 0.1μF, 20%, 50V		C-365-0.1
C336	Capacitor, 0.1μF, 50V, Ceramic Film	3/D4	C-237-0.1
C337	Capacitor, 0.1μF, 20%, 50V	3/D2	C-365-0.1
C338	Capacitor, 0.1μF, 50V, Ceramic Film	3/C3	C-237-0.1
C339	Capacitor, 0.1μF, 20%, 50V	3/D3	C-365-0.1
C340	Capacitor, 0.1μF, 50V, Ceramic Film	3/B3	C-237-0.1
C341	Capacitor, 0.1μF, 20%, 50V	2/F4	C-365-0.1
C342	Capacitor, 0.1μF, 50V, Ceramic Film	2/G3	C-237-0.1
C343	Capacitor, 0.1μF, 20%, 50V	2/G2	C-365-0.1
C346	Capacitor, 0.1μF, 50V, Ceramic Film	1/A3	C-237-0.1
C347	Capacitor, 0.1μF, 20%, 50V	1/B2	C-365-0.1
C348	Capacitor, 0.1μF, 50V, Ceramic Film	1/B2	C-237-0.1
C349	Capacitor, 0.1μF, 20%, 50V	1/C2	C-365-0.1
C350	Capacitor, 0.1μF, 20%, 50V	2/A3	C-365-0.1
C353	Capacitor, 0.1μF, 20%, 50V	3/D6	C-365-0.1
C354	Capacitor, 0.1μF, 20%, 50V	2/D6	C-365-0.1
C355	Capacitor, 0.1μF, 50V, Ceramic Film	4/A4	C-237-0.1
C356	Capacitor, 0.1μF, 20%, 50V	1/C1	C-365-0.1
C357	Capacitor, 0.1μF, 20%, 50V		C-365-0.1
C359	Capacitor, 0.1μF, 50V, Ceramic Film	2/A6	C-237-0.1
C362	Capacitor, 0.1μF, 50V, Ceramic Film	1/A1	C-237-0.1
C363	Capacitor, 0.1μF, 20%, 50V	1/C2	C-365-0.1
C364	Capacitor, 0.1μF, 50V, Ceramic Film	1/E5	C-237-0.1
C365	Capacitor, 0.1μF, 50V, Ceramic Film	1/F4	C-237-0.1

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Table 8-3. A/D Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
C366	Capacitor, 0.1μF, 50V, Ceramic Film	1/E1	C-237-0.1
C367	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C368	Capacitor, 0.1μF, 50V, Ceramic Film	1/D5	C-237-0.1
C369	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D6	C-314-10
C370	Capacitor, 0.1μF, 50V, Ceramic Film	1/D6	C-237-0.1
C371	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D6	C-314-10
C372	Capacitor, 10μF, 25V, Aluminum Electrolytic	1/D5	C-314-10
C373	Capacitor, 0.1μF, 50V, Ceramic Film	1/D5	C-237-0.1
C374	Capacitor, 4-40pF Trimmer	2/E2	C-358-4-40p
C375	Capacitor, 39pF	2/D2	C-348-39p
C376	Capacitor, 0.1μF, 50V, Ceramic Film	2/D1	C-237-0.1
C377	Capacitor, 0.1μF, 50V, Ceramic Film	2/A2	C-237-0.1
C378	Capacitor, 18pF	2/B2	C-348-18p
C379	Capacitor, 1000pF	2/D2	C-372-1000p
C380	Capacitor, 18pF	2/A1	C-348-18p
C381	Capacitor, 0.1μF, 50V, Ceramic Film	2/B2	C-237-0.1
C382	Capacitor, 0.1μF, 50V, Ceramic Film	2/B2	C-237-0.1
C383	Capacitor, 5pF	2/D2	C-349-5p
C384	Capacitor, 0.1μF	2/F2	C-285-0.1
C385	Capacitor, 470pF	2/C2	C-64-470p
C386	Capacitor, 3-10pF Trimmer		C-346-3-10p
C387	Capacitor, 10pF	2/A1	C-64-10p
C389	Capacitor, 100pF		C-64-100p
CR301	Diode, Rectifier, 1.5A, 400PIV, PF40	3/F1	RF-46
CR302	Current Regulator	2/C1	TG-159
CR303	Current Regulator	2/C1	TG-159
J1008	Connector, BNC	3/F1	CS-547
J1009	Connector, BNC	3/F1	CS-547
J1010	Connector, 25 Pin D	2/F6	CS-484
J1011	Connector, BNC	2/F1	CS-506
J1029	Connector, 26 Pin	1/C1	CS-509-1
J1030	Connector, 34 Pin	1/D1	CS-509-2
J1044	Connector		CS-446-5
J1045	Connector		CS-446-6
J1046	Connector		CS-446-5
K301	Relay, Reed	2/C2	RL-59
K302	Relay, Reed	2/D1	RL-48
K303	Relay, Reed	2/E1	RL-59
K304	Relay, Reed		RL-59
L301	Choke, Ferrite		CH-31
L302	Choke, Ferrite		CH-31
L303	Choke, Ferrite		CH-30
P1019	Cable Assembly	4/G1	CA-27-5
P1021	Connector	1/C5	CS-335-6
P1023	Connector	2/F6	CS-287-3
P1025	Connector	2/G6	CS-415
P1040	Connector		CS-236
P1042	Connector		CS-236

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Table 8-3. A/D Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
Q301*	Transistor, N-Channel JFET, 2N5434	2/D2	TG-174
Q302	Transistor, Silicon, NPN, 2N5089	2/C1	TG-62
Q303	Transistor, Silicon, NPN, 2N5089	2/C2	TG-62
Q304*	Transistor, N-Channel, JFET, Selected 2N4392	2/B1	TG-77
Q305*	Transistor, N-Channel, JFET, Selected 2N4392	2/A2	TG-77
Q306*	Transistor, N-Channel, JFET, Selected 2N4392	2/A3	TG-77
Q307*	Transistor, N-Channel, JFET, Selected 2N4392	2/B1	TG-77
R301	Resistor, 100Ω, 5%, ¼W, Composition	3/F1	R-76-100
R302	Resistor, 22kΩ, 5%, ¼W, Composition		R-76-22k
R303	Resistor, 100Ω, 5%, ¼W, Composition	3/F1	R-76-100
R304	Resistor, 1kΩ, 5%, ¼W, Composition	4/B6	R-76-1k
R305	Resistor, Thick Film	1/G4	TF-203
R306	Resistor, Thick Film	1/Sev	TF-183-3
R307	Resistor, Thick Film	2/A5	TF-183-3
R308	Resistor, Thick Film	2/A4	TF-203
R309	Resistor, 10kΩ, 5%, ¼W, Composition	1/E5	R76-10k
R310	Resistor, 10kΩ, 5%, ¼W, Composition	1/E5	R-76-10k
R311	Resistor, 100kΩ, 5%, ¼W, Composition	2/D2	R-76-100k
R312	Resistor, 11kΩ, 0.1%, $^1/_{10}$W, Metal Film	2/D1	R-263-11k
R313	Resistor, 110kΩ, 0.1%, $^1/_{10}$W, Metal Film	2/D1	R-263-110k
R314	Resistor, 1.8kΩ, 0.1%, $^1/_{10}$W, Metal Film	2/A2	R-263-1.8k
R315	Resistor, 100kΩ, 5%, ¼W, Composition	2/B2	R-76-100k
R316	Resistor, 100kΩ, 5%, ¼W, Composition	2/A2	R-76-100k
R317	Resistor, 100kΩ, 1%, $^1/_8$W	2/A2	R-88-100k
R318	Resistor, 990kΩ, 0.1%, ¼W, Metal Film	2/D1	R-264-990k
R319	Resistor, 200Ω, 0.1%, $^1/_{10}$W, Metal Film	2/A3	R-263-200
R320	Resistor, 11kΩ, 1%, $^1/_8$W,	2/B1	R-88-11k
R321	Resistor, 100kΩ, 5%, ¼W, Composition	2/B1	R-76-100k
R322	Resistor, 526Ω, 0.1%, $^1/_{10}$W, Metal Film	2/B2	R-263-526
R323	Resistor, 1kΩ, 0.1%, $^1/_{10}$W, Metal Film	2/B2	R-263-1k
R324	Resistor, 4.7kΩ, 10%, 2W, Composition	2/C2	R-3-4.7k
R325	Resistor, 4.7kΩ, 10%, 2W, Composition	2/C2	R-3-4.7k
R326	Resistor, 100kΩ, 5%, ¼W, Composition	2/A3	R-76-100k
R327	Resistor, 1.1kΩ, 1%, $^1/_8$W	2/B1	R-88-1.1k
R328	Resistor, 499Ω, 1%, ½W, Metal Film	2/E1	R-94-499
R329	Resistor, 499Ω, 1%, ½W, Metal Film	2/E1	R-94-499
R330	Resistor, 10kΩ, 5%, ¼W, Composition	1/E2	R-76-10k
U301	IC, 16 × 16 Bit NVRAM, 2443	4/D1	IC-353
U302	IC, 16 × 16 Bit NVRAM, 2443	4/D1	IC-353
U303	IC, Octal Bus Transceiver, 74LS645	4/C1	IC-307
U304	IC, Octal Bus Transceiver, 74LS645	4/G5	IC-307
U305	IC, Octal Buffer, 74LS244	Sev	IC-230
U306	IC, 8-Bit Shift Register, 74LS164	3/B1	IC-127
U307	IC, 4-Bit Binary Counter, 74LS161	3/B2	IC-390
U308	IC, 4-Bit Binary Counter, 74LS161	3/B2	IC-390
U309	IC, 4-Bit Binary Counter, 74LS161	3/C2	IC-390
U310	Not Used		
U311	IC, 8-Input Multiplexer, 74LS151	3/E1	IC-156
U312	IC, Dual 4-Bit Binary Ripple Counter, 74LS393	3/F4	IC-213

*Static Sensitive.

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Table 8-3. A/D Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
U313	IC, Octal Buffer, 74LS244	3/F3	IC-230
U314	IC, Octal Buffer, 74LS244	4/F3	IC-230
U315*	IC, Peripheral Interface Adapter, 65C21	4/B4	LSI-61
U316*	IC, Dynamic Memory Controller, 4500	4/B5	LSI-64
U317*	IC, 64k Dynamic RAM, 6665A	4/E6	LSI-63
U318*	IC, 64k Dynamic RAM, 6665A	4/D5	LSI-63
U319*	IC, 64k Dynamic RAM, 6665A	4/D5	LSI-63
U320*	IC, 64k Dynamic RAM, 6665A	4/C5	LSI-63
U321	IC, Octal D-Type Flip Flop, 74LS374	3/F5	IC-242
U322	IC, 8-Bit Shift Register, 74LS164	3/D5	IC-127
U323*	IC, Versatile Interface Adapter, 6522	4/B2	LSI-28
U324	IC, Quad 2-Input OR Gate, 74LS32	4/F4	IC-257
U325	IC, Quad 2-Input OR Gate, 74LS32	3/Sev	IC-257
U326	IC, Dual D-Type Flip-Flop, 74LS74	3/E4	IC-144
U327	IC, Quad 2-Input NAND Gate,74LS00	Sev	IC-163
U328	IC, Dual D-Type Flip-Flop, 74LF74	4/D3	IC-446
U329	IC, Quad 2-Input Multiplexer, 74LS157	4/D3	IC-269
U330	IC, Dual D-Type Flip-Flop, 74LF74	4/E3	IC-446
U331	IC, Dual D-Type Flip-Flop, 74LF74	4/D4	IC-446
U332	IC, Dual D-Type Flip-Flop, 74LS74	2/E6	IC-144
U333	IC, Quad 2-Input AND Gate, 74LS08	2/Sev	IC-215
U334	IC, Dual 4-Bit Binary Ripple Counter, 74LS393	3/F3	IC-213
U335	IC, Octal Buffer, 74LS244	3/G3	IC-230
U336	IC, Octal Buffer, 74LS244	4/F2	IC-230
U337*	IC, 64k Dynamic RAM, 6665A	4/E5	LSI-63
U338*	IC, 64k Dynamic RAM, 6665A	4/D6	LSI-63
U339*	IC, 64k Dynamic RAM, 6665A	4/D6	LSI-63
U340*	IC, 64k Dynamic RAM, 6665A	4/C6	LSI-63
U341	IC, Octal D-Type Flip-Flop, 74LS374	3/F6	IC-242
U342	IC, 8-Bit Shift Register, 74LS164	3/D6	IC-127
U343	IC, Quad 2-Input NAND Gate, 74LS00	3/C4	IC-163
U344	IC, Dual D-Type Flip-Flop, 74LS74	3/D2	IC-144
U345	IC, 4-Bit Up/Down counter, 74LS193	3/C3	IC-214
U346	IC, 4-Bit, Up/Down Counter, 74LS193	3/C3	IC-214
U347	IC, 8-Bit Shift Register, 74LS164	3/B3	IC-127
U348	IC, 8-Bit Shift Register, 74LS164	2/F3	IC-127
U349	IC, 4-Bit Magnitude Comparator, 74LS85	2/G3	IC-389
U350	IC, 4-Bit Magnitude Comparator, 74LS85	2/G3	IC-389
U351	IC, 8-Bit Shift Register, 74LS164	3/C5	IC-127
U352	IC, Octal D-Type Flip-Flop, 74LS374	2/D6	IC-242
U353	IC, 8-Input Multiplexer, 74LS151	2/E4	IC-156
U354	IC, Dual D-Type Flip-Flop, 74LS74	2/D4	IC-144
U355	IC, Quad 2-Input NAND Gate, 74LS00	Sev	IC-163
U356	IC, 8-Bit Shift Register, 74LS164	3/B5	IC-127
U357	IC, 4-Bit Magnitude Comparator, 74LS85	3/C6	IC-389
U358	IC, 4-Bit Magnitude Comparator, 74LS85	3/C5	IC-389
U359	IC, 8-Bit Shift Register, 74LS164	3/C6	IC-127
U360	IC, Octal D-Type Flip-Flop, 74LS374	3/E6	IC-242
U361*	IC, CMOS Shift Register, 4094	1/A4	IC-251
U362*	IC, 12-Bit Digital-Analog Converter, DAC80CV1-N	1/B3	IC-323
U363*	IC, 12-Bit Digital-Analog Converter, DAC80CV1-N	1/B1	IC-323

*Static Sensitive

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Table 8-3. A/D Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
U364*	IC, 4-Digit CMOS Display Decoder/Driver, HP-2630	2/A6	IC-327
U365*	IC, 4-Digit CMOS Display Decoder/Driver, HP-2630	2/A5	IC-327
U366*	IC, 4-Digit CMOS Display Decoder/Driver, HP-2630	2/A4	IC-327
U367*	IC, 4-Digit CMOS Display Decoder/Driver, HP-2630	2/A3	IC-327
U368	IC, Dual D-Type Flip-Flop, 74LS74	3/D4/C4	IC-144
U369	IC, Octal Buffer, 74LS244	2/Sev	IC-230
U370	IC, CMOS Shift Register, 4094	1/A3	IC-251
U371	IC, Octal Buffer, 74LS244	1/G4	IC-230
U372	IC, Quad 2-Input NAND Gate, 74LS00	2/Sev	IC-163
U373	IC, Dual D-Type Flip-Flop, 74LS74	2/B4	IC-144
U374	IC, Dual D-Type Flip-Flop, 74LS74	1/E4	IC-144
U375	IC, Dual D-Type Flip-Flop, 74LS74	1/F4	IC-144
U376	IC, 8-Bit Shift Register, 74LS165	1/F1	IC-237
U377	IC, Quad Comparator, LM339	1/E6	IC-219
U378	IC, Quad Comparator, LM339	1/F6	IC-219
U379	IC, CMOS Shift Register, 4094	1/F6	IC-251
U380	IC, CMOS Shift Register, 4094	1/C5	IC-251
U381	IC, Darlington Transistor Array, 2003A	1/C4	IC-206
U382	IC, CMOS Shift Register, 4094	1/A1	IC-251
U383	IC, Quad 2-Input NAND Gate, 74LS00	Sev	IC-163
U384	IC, 8-Bit Shift Register, 74LS165	1/G3	IC-237
U385	IC, 8-Bit Shift Register, 74LS165	1/F3	IC-237
U386	IC, Op Amp, HA-5160	2/A2	IC-388
U387	IC, Op Amp, HA-5160	2/B2	IC-388
U388*	Module, A/D Converter	1/D2	MO-4
VR301	Diode, Zener, 1N5378	2/D2	DZ-72-2
VR302	Diode, Zener, 1N5378	2/D1	DZ-72-2
W301	Connector Pin	4/N5	CS-339-3
W302	Connector Pin	4/N5	CS-339-3
W303	Connector Pin		CS-339-3
W304	Connector Pin		CS-339-4
W307	Connector		
Y301	Crystal, Oscillator Circuit, 10.1MHz	1/D4	CR-25-5

*Static sensitive

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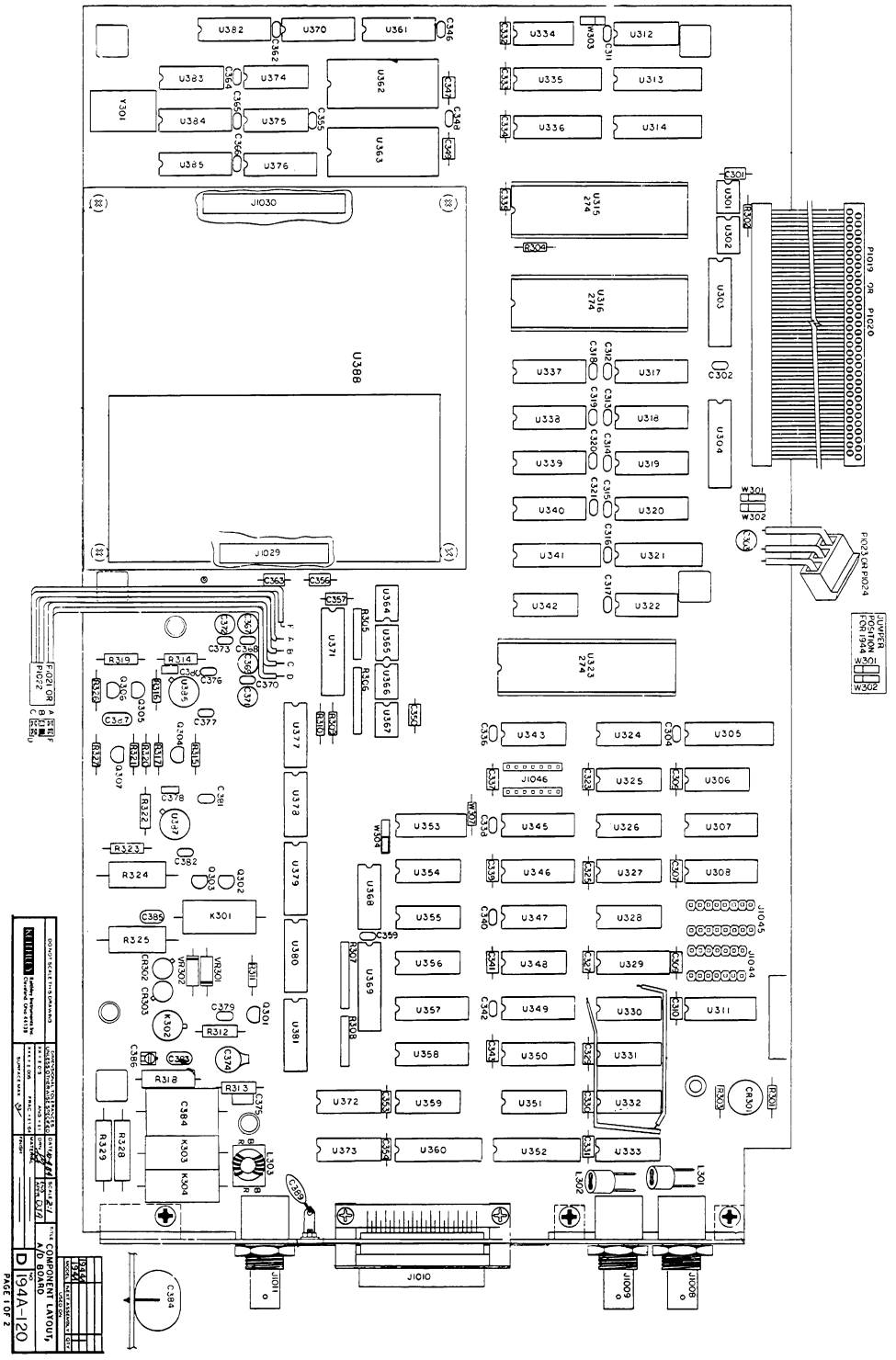


Figure 8-6. A/D Board, Component Location Drawing, Dwg. No. 194A-120

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Table 8-4. I/O Board, Parts List

Schematic Designation	Description	Schematic Location	Keithley Part No.
C401	Capacitor, 0.1μF, 20%, 50V	A2	C-365-0.1
C402	Capacitor, 0.1μF, 20%, 50V	A3	C-365-0.1
C403	Capacitor, 0.1μF, 20%, 50V	A3	C-365-0.1
C404	Capacitor, 0.1μF, 20%, 50V	C3	C-365-0.1
C405	Capacitor, 0.1μF, 20%, 50V	D2	C-365-0.1
C406	Capacitor, 0.1μF, 20%, 50V	D3	C-365-0.1
C407	Capacitor, 0.1μF, 20%, 50V	C5	C-365-0.1
C408	Capacitor, 0.1μF, 20%, 50V	C6	C-365-0.1
C409	Capacitor, 0.1μF, 20%, 50V	E1	C-365-0.1
C410	Capacitor, 0.1μF, 20%, 50V	F3	C-365-0.1
C411	Capacitor, 0.1μF, 20%, 50V	F4	C-365-0.1
C412	Capacitor, 0.1μF, 20%, 50V	F5	C-365-0.1
C413	Capacitor, 0.1μF, 20%, 50V	F6	C-365-0.1
C414	Capacitor, 1μF, 20%, 50V, Ceramic Film	G2	C-237-1
C415	Capacitor, 1μF, 20%, 50V, Ceramic Film	G2	C-237-1
C416	Capacitor, 1μF, 20%, 50V, Ceramic Film	G3	C-237-1
C417	Capacitor, 1μF, 20%, 50V, Ceramic Film	G4	C-237-1
C418	Capacitor, 1μF, 20%, 50V, Ceramic Film	G4	C-237-1
C419	Capacitor, 1μF, 20%, 50V, Ceramic Film	G5	C-237-1
CR401	Diode, Silicon, 1N4148	G2	RF-28
CR402	Diode, Silicon, 1N4148	G2	RF-28
CR403	Diode, Silicon, 1N4148	G4	RF-28
CR404	Diode, Silicon, 1N4148	G4	RF-28
CR405	Diode, Silicon, 1N4148	G5	RF-28
CR406	Diode, Silicon, 1N4148	G5	RF-28
J1005	Connector, BNC	H5	CS-547
J1006	Connector, BNC	H4	CS-547
J1007	Connector, BNC	H2	CS-547
J1027	Connector, 26 Pin	E2, E3	CS-389-3
J1028	Connector, 20 Pin	D4	CS-389-8
L401	Choke, Ferrite		CH-31
L402	Choke, Ferrite		CH-31
L403	Choke, Ferrite		CH-31
Q401	Transistor, Silicon, NPN, 2N3904	G5	TG-47
R401	Resistor, Thick Film	D2	TF-183-4
R402	Resistor, Thick Film	D2	TF-183-4
R403	Resistor, Thick Film	D3	TF-183-4
R404	Resistor, Thick Film	D3	TF-183-4
R405	Resistor, Thick Film	E2	TF-112-5
R406	Resistor, Thick Film	E3	TF-112-5
R407	Resistor, 100Ω, 5%, ¼W, Composition	H2	R-76-100
R408	Resistor, 100Ω, 5%, ¼W, Composition	H4	R-76-100
R409	Resistor, 910Ω, 5%, ¼W, Composition (+5V Pull-up)	G5	R-76-910
R410	Resistor, 1.5kΩ, 5%, ¼W, Composition (+15V Pull-up)	G5	R-76-1.5k
R411	Resistor, 100Ω, 5%, ¼W, Composition	H5	R-76-100
U401	IC, Octal Bus Transceiver, 74LS645	A1	IC-307

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Table 8-4. I/O Board, Parts List (Cont.)

Schematic Designation	Description	Schematic Location	Keithley Part No.
U402	IC, Octal Buffer/Line Driver, 74LS244	A2	IC-230
U403	IC, Hex Schmitt Trigger/Inverter, 74LS14	A3/A4	IC-137
U404*	IC, Peripheral Interface Adapter, 65C21	C2	LSI-61
U405	IC, Octal Driver, UDN2595A	D2	IC-406
U406	IC, Octal Driver, UDN2595A	D3	IC-406
U407*	IC, Peripheral Interface Adapter, 65C21	C4	LSI-61
U408	IC, Darlington Array, UNL2003A	D4	IC-206
U409	IC, Darlington Array, UNL2003A	D4	IC-206
U410*	IC, Versatile Interface Adapter, 6522A	C5/C6	LSI-45
U411	IC, 1 of 8 Decoder, 74LS138	F1	IC-182
U412	IC, 8-Bit Register, 74LS273	F2	IC-263
U413	IC, 8-Bit Register, 74LS273	F3	IC-263
U414	IC, 8-Bit Register, 74LS273	F4	IC-263
U415	IC, 8-Bit Register, 74LS273	F5	IC-263
U416*	IC, 12-Bit D/A Converter, DAC-80-CBI-V	G2	IC-323
U417*	IC, 12-Bit D/A Converter, DAC-80-CBI-V	G4	IC-323
W401	Jumper		CS-339-3

*Static Sensitive.

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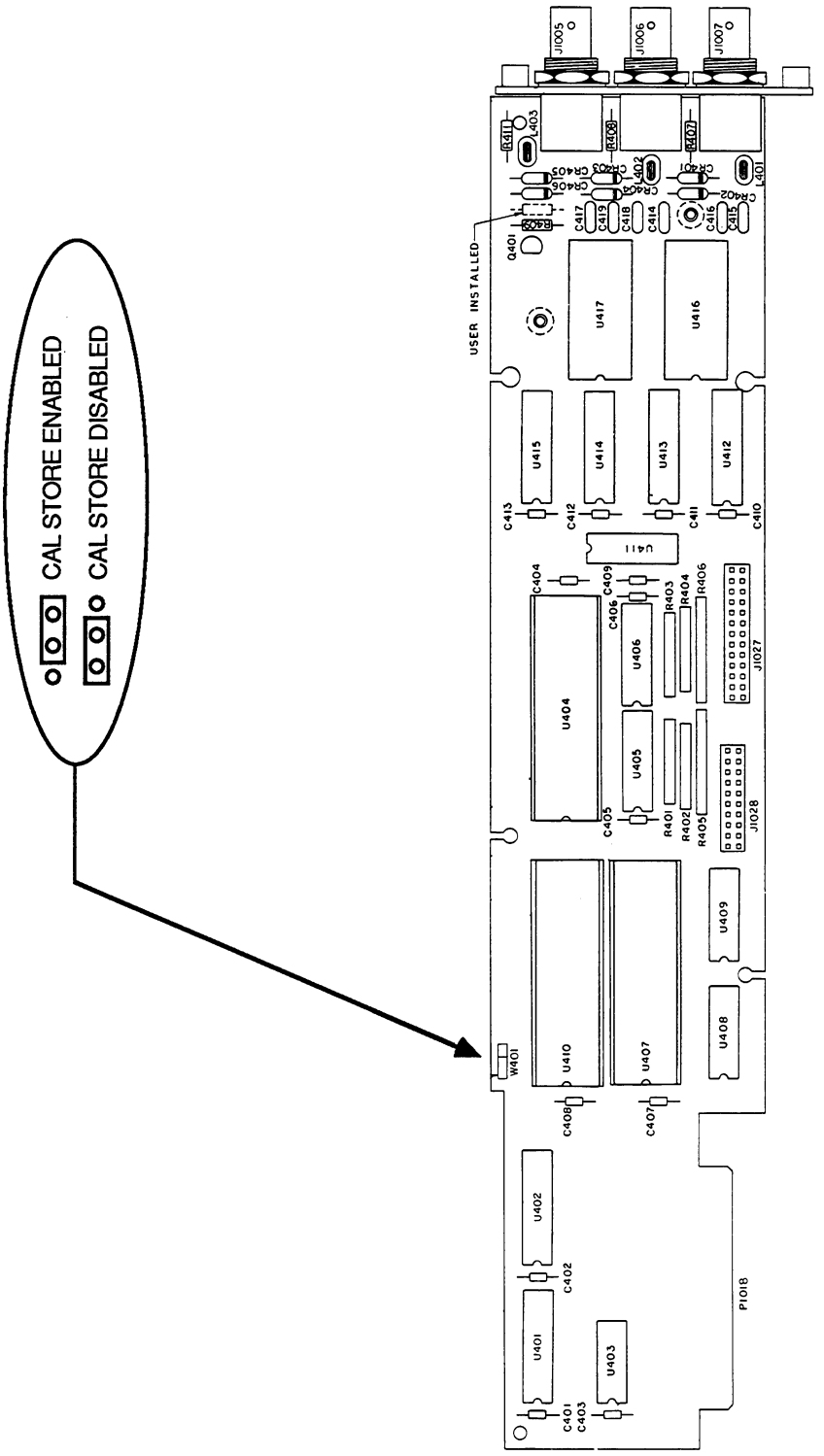


Figure 8-8. I/O Board, Component Location Drawing, Dwg. No. 194-160
CAL LOCK Jumper Locations and Positions

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Table 8-5. Sample Rate Board, Parts List

Schematic Designation	Description	Keithley Part Number
C602-C607	Capacitor, 0.1μF, 20%, 50V, Ceramic Film	C-237-.1
C609	Capacitor, 10μF, 16V, Aluminum Electrolytic	C-321-10
C610	Capacitor, 4.7μF, 25V, Aluminum Electrolytic	C-314-4.7
CR601	Diode, W04M	RF-46
CR602	Diode, 1N4148	RF-28
P1044	Connector	CS-444-5
P1045	Connector	CS-444-6
P1046	Connector	CS-444-5
R601, R602	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R603, R604	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R605, R606	Resistor, 1MΩ, 1%, $^1/_8$W	R-88-1M
U601-U603	IC, 8-Bit Shift Register, 74LS164	IC-127
U604-U607	IC, 4-Bit Binary Counter, 74LS161	IC-390
U608, U609	IC, Dual D-type Flip-FLop, 74LS74	IC-144
U611	IC, Quad 2-Input AND Gate, 74LS08	IC-215
U612	IC, ICM7555	IC-400
U613	IC, Quad 2-Input OR Gate, 74LS32	IC-257

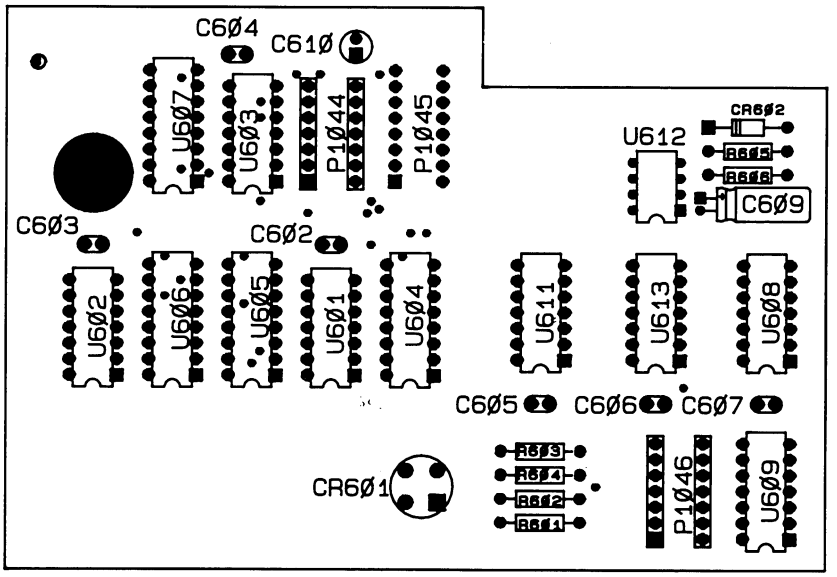


Figure 8-10. Sample Rate Board, Component Location Drawing, Dwg. No. 194A-170

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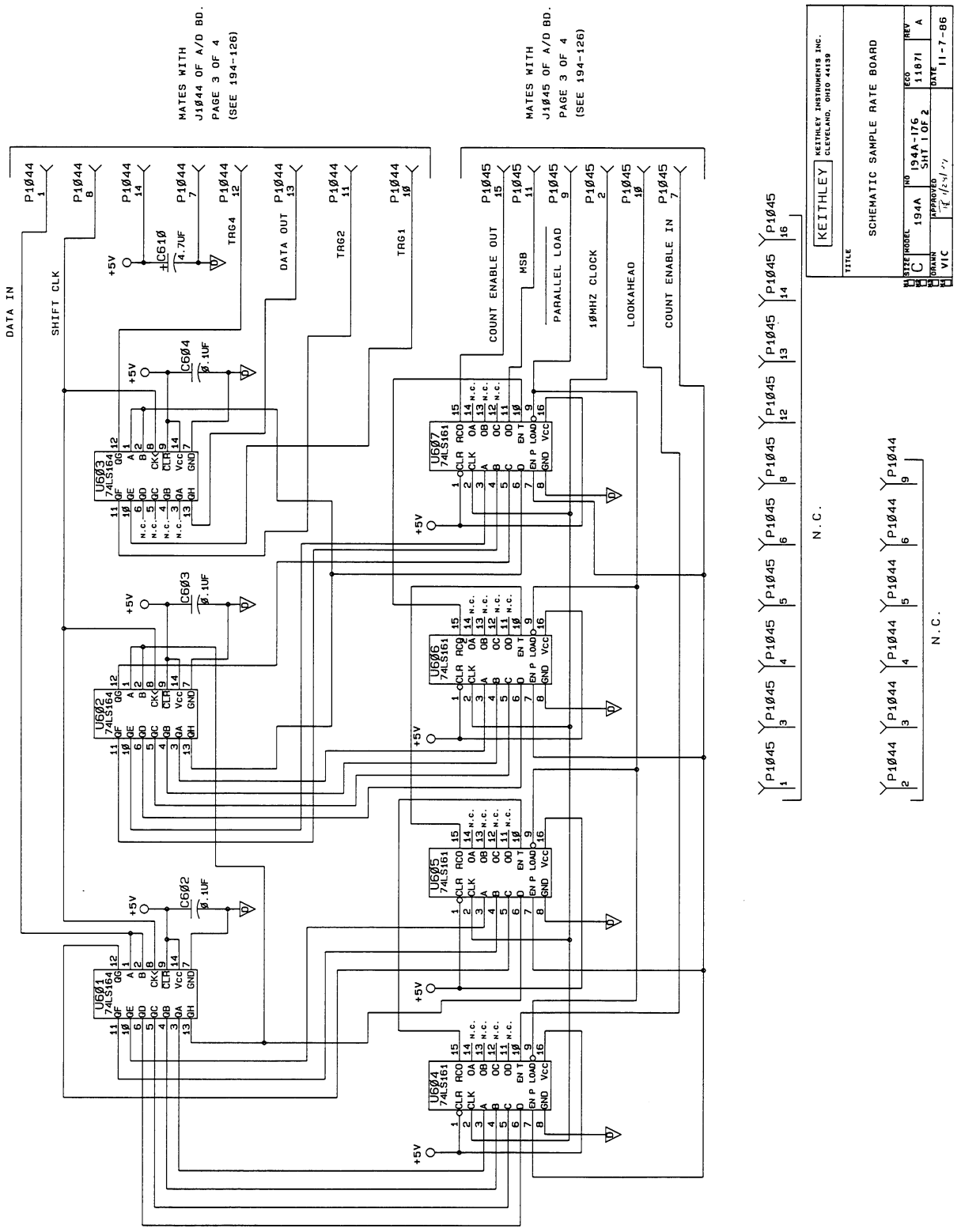


Figure 8-11. Sample Rate Board, Schematic Diagram, Dwg. No. 194A-176 (sheet 1 of 2)

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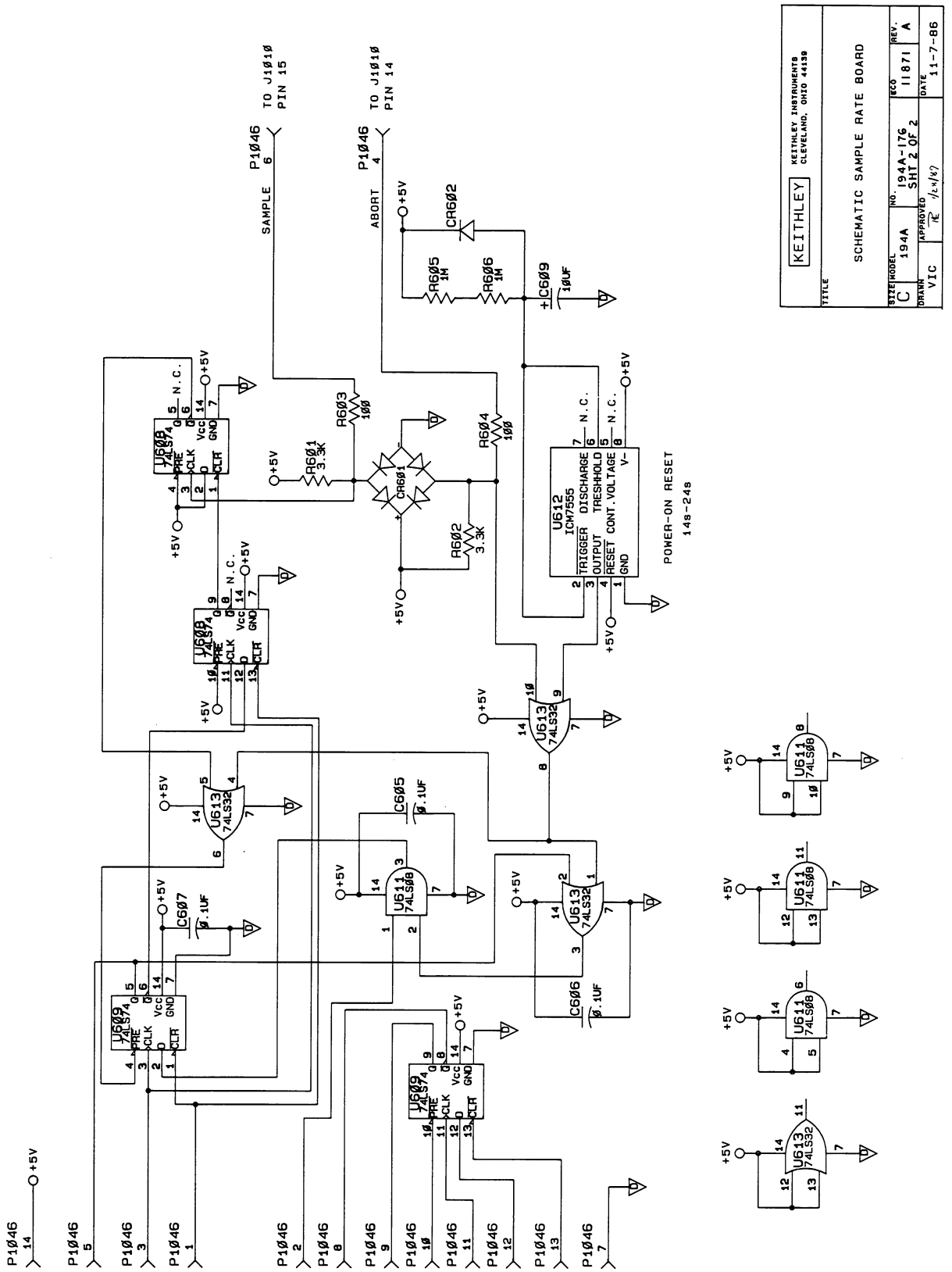


Figure 8-11. Sample Rate Board, Schematic Diagram, Dwg. No. 194A-176 (sheet 2 of 2)

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Table 8-6. Case Assembly, Parts List

Quantity	Description	Keithley Part Number
2	Side Panel Assembly	193-310
2	Front Bezel Assembly	222-303
1	Front Panel	194-305
1	Front Panel Overlay	194-306
1	Display Window, Red	194-303
1	Switch, Power	SW-420
1	Pushbutton, Power	29465-3
1	Rear Panel	194-310
1	Fan Set	FN-11
1	Fan Guard	194-315
1	Fan Filter	FL-7
2	Fan Filter Spacers	194-332
1	Line Filter	LF-2
3	Mounting Rails	228-319
1	Top Cover	228-312
1	Bottom Cover	228-313
2	Rear Foot	706-316
2	Front Foot Assembly	706-317
2	Decorative Strip Assembly	193-322
2	Decorative Strip Assembly	193-332
2	Connector, BNC (CLK IN & OUT)	CS-249

Table 8-7. Miscellaneous Mechanical, Parts List

Quantity	Description	Circuit Board	Keithley Part Number
2	Pushbutton (ZERO, FILTER)	Display	228-317-4
12	Pushbutton (TRIGGER through CHANNEL)	Display	228-317-5
9	Pushbutton (AUTO through FREQ/TIME)	Display	228-317-6
15	Pushbutton (Data Entry)	Display	228-317-7
1	Mounting Kit for DS220	Display	MK-22-2
1	IEEE Hardware Kit	Mother	CS-378
2	Fuse Holder (Digital Fuse)	Mother	FH-12
1	Fuse Holder (Line Fuse)	Mother	FH-21
1	Fuse Carrier (Line Fuse)	Mother	FH-25
1	Shield, Input Amplifier	A/D	194-312
1	Cover Plate	A/D	194-323
4	Standoff (Mounting)	A/D	ST-176-1
1	Line Cord	—	CO-7
6	Heat Sink	Mother	HS-30
2	Programming Card Slide Bracket	—	194-325
1	Shield, A/D board	A/D	194-334

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APPENDIX A

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

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ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

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ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	^	MTA 30
95	5F	—	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

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ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60	∩	MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	¦	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

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APPENDIX B

Setup Configuration Worksheets

The following worksheets will allow you to record instrument operating modes for the various setup values.

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Setup Configuration Worksheets

Worksheet 1

Operating Mode	Setup 1	Setup 2
Range		
Autorange (on/off)		
Zero		
Zero Value		
Filter		
Single/cont Trigger Arming		
Trigger Source		
Trigger Delay (samples or period)		
Trigger Slope		
Trigger Level		
Sampling Rate (interval or frequency)		
Number of Samples (or duration)		
Input Coupling		
Math Function		
IEEE-488 Primary Address		

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Setup Configuration Worksheets

Worksheet 2

Operating Mode	Setup 1	Setup 2
Range		
Autorange (on/off)		
Zero		
Zero Value		
Filter		
Single/cont Trigger Arming		
Trigger Source		
Trigger Delay (samples or period)		
Trigger Slope		
Trigger Level		
Sampling Rate (interval or frequency)		
Number of Samples (or duration)		
Input Coupling		
Math Function		
IEEE-488 Primary Address		

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Setup Configuration Worksheets

Worksheet 3

Operating Mode	Setup 1	Setup 2
Range		
Autorange (on/off)		
Zero		
Zero Value		
Filter		
Single/cont Trigger Arming		
Trigger Source		
Trigger Delay (samples or period)		
Trigger Slope		
Trigger Level		
Sampling Rate (interval or frequency)		
Number of Samples (or duration)		
Input Coupling		
Math Function		
IEEE-488 Primary Address		

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APPENDIX C

Controller Programs

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you send a device-dependent command string to the instrument and obtain and display an instrument reading string.

Programs for the following controllers are included:

- IBM PC or XT (with Keithley Model 8573 IEEE-488 Interface)
- Apple II (equipped with the Apple II IEEE-488 Interface)
- Hewlett-Packard Model 85
- Hewlett-Packard Model 9816
- Hewlett-Packard Model 9825A
- DEC LSI 11
- PET/CBM 2001

NOTE

The Model 194A uses commas to separate parameters in some commands. Many controllers also use commas to delimit input strings. A / or < > may be substituted for the comma in a Model 194A command string to delimit two parameter commands. For example, S0/100X may be used in place of S0,100X.

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IBM PC OR XT (KEITHLEY MODEL 8573 INTERFACE)

The following program sends a command string to the Model 194A from an IBM PC or XT computer and displays the instrument reading string on the CRT. The computer must be equipped with the Keithley Model 8573 IEEE-488 Interface and the DOS 2.00 operating system. Model 8573 software must be installed and configured as described in the instruction manual.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disc in the default drive, type LOAD"DECL", and press the return key.
5. Add the lines below to lines 1-6 which are now in memory. Modify the address in lines 1 and 2, as described in the Model 8573 Instruction Manual.
6. Run the program and type in the desired command string. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the return key.
7. The instrument reading string will then appear on the display. For example, the display might show NDCV+1.2345E+0.
8. To exit the program, type in EXIT at the command prompt and press the return key.

PROGRAM	COMMENTS
`10 CLS`	Clear screen.
`20 NA$=''GPIB0'':CALL IBFIND (NA$,BRD0%)`	Find board descriptor.
`30 NA$=''DEV1'':CALL IBFIND (NA$,M194%)`	Find instrument descriptor.
`40 V%=9:CALL IBPAD(M194%,V%)`	Set primary address to 9.
`50 V%=&H102:CALL IBPOKE(BRD0%,V%)`	Set timeouts.
`60 V%=1:CALL IBSRE(BRD0%,V%)`	Set REN true.
`70 INPUT''COMMAND STRING'';CMD$`	Prompt for command.
`80 IF CMD$=''EXIT'' THEN 150`	See if program is to be halted.
`90 IF CMD$='' '' THEN 70`	Check for null input.
`100 CALL IBWRT(M194%,CMD$)`	Address 194A to listen, send string.
`110 RD$=SPACE$(100)`	Define reading input buffer.
`120 CALL IBRD(M194%,RD$)`	Address 194A to talk, get reading.
`130 PRINT RD$`	Display the string.
`140 GOTO 70`	Repeat.
`150 V%=0:CALL IBONL(M194%,V%)`	Close the instrument file.
`160 CALL IBONL(BRD0%, V%)`	Close the board file.

NOTE: For conversion to numeric variable, make the following changes:

```
130 RD=VAL(MID$(RD$,5,14))
135 PRINT RD
```


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APPLE II (APPLE II IEEE-488 INTERFACE)

The following program sends a command string to the Model 194A from an Apple II computer and displays the instrument reading string on the computer CRT.

The computer must be equipped with the Apple II IEEE-488 Interface installed in slot 3.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the IEEE-488 interface installed in the Apple II computer.
3. Enter the lines in the program below, using the RETURN key after each line.
4. Run the program and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the return key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`10 Z$=CHR$(26)`	Terminator.
`20 INPUT''COMMAND STRING'';B$`	Prompt for and enter command string.
`30 PR#3`	Set output to IEEE-488 bus.
`40 IN#3`	Define input from IEEE-488 bus.
`50 PRINT''RA''`	Enable remote.
`60 PRINT''WT)'';Z$;B$`	Address 194A to listen, send string.
`70 PRINT''LF1''`	Line feed on.
`80 PRINT''RDI'';Z$;:INPUT'' '';A$`	Address 194A to talk, input data.
`90 PRINT''UT''`	Untalk the 194A.
`100 PR#0`	Define output to CRT.
`110 IN#0`	Define input from keyboard.
`120 PRINT A$`	Display reading string.
`130 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, make the following changes:

```
120 A=VAL(MID$(A$,5,14))
125 PRINT A
```

2. The Apple II INPUT statement terminates on commas. To avoid problems, program the Model 194A for the G0 or G1 data format to eliminate commas.

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HEWLETT-PACKARD MODEL 85

The following program sends a command string to the Model 194A from an HP-85 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and an I/O ROM.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the HP82937A GPIB interface installed in the HP-85 computer.
3. Enter the lines in the program below, using the END LINE key after each line.
4. Press the HP-85 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the END LINE key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`10 DIM A$[25],B$[25]`	Dimension strings.
`20 REMOTE 709`	Place 194A in remote.
`30 DISP''COMMAND STRING'';`	Prompt for command.
`40 INPUT A$`	Input command string.
`50 OUTPUT 709; A$`	Address 194A to listen, send string.
`60 ENTER 709; B$`	Address 194A to talk, input reading.
`70 DISP B$`	Display reading string.
`80 GOTO 30`	Repeat
`90 END`	

NOTE: For conversion to numeric variable, change line 70 as follows:

```
70 DISP VAL(B$[5])
```


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HEWLETT-PACKARD MODEL 9816

The following program sends a command string to the Model 194A from a Hewlett-Packard Model 9816 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and BASICA 2.0.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the HP82937A GPIB interface installed in the 9816 computer.
3. Type EDIT and press the EXEC key.
4. Enter the lines in the program below, using the ENTER key after each line.
5. Press the 9816 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the ENTER key.
6. The instrument reading string will then appear on the CRT. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`10 REMOTE 709`	Place 194A in remote.
`20 INPUT''COMMAND STRING'';A$`	Prompt for and input command.
`30 OUTPUT 709; A$`	Address 194A to listen, send string.
`40 ENTER 709; B$`	Address 194A to talk, input reading.
`50 PRINT B$`	Display reading string.
`60 GOTO 20`	Repeat.
`70 END`	

NOTE: For conversion to a numeric variable, change the program as follows:

```
40 ENTER 709;B
50 PRINT B
```


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HEWLETT-PACKARD MODEL 9825A

Use the following program to send a command string to the Model 194A from a Hewlett-Packard Model 9825A and display the instrument reading string on the computer printer. The computer must be equipped with the HP98034A HPIB Interface and a 9872A extended I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the 98034A HPIB interface installed in the 9825A.
3. Enter the lines in the program below, using the STORE key after each line. Line numbers are automatically assigned by the 9825A.
4. Press the 9825A RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the CONT key.
5. The instrument reading string will then appear on the computer print out. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`0 dim A$[25],B$[20]`	Dimension data strings.
`1 dev''194'',709`	Define 194A at address 9.
`2 rem''194''`	Place 194A in remote.
`3 ent''COMMAND STRING'',B$`	Prompt for command string.
`4 wrt''194'',B$`	Address 194A to listen, send string.
`5 red''194'',A$`	Address 194A to talk, input data.
`6 prt A$`	Print data string on printer.
`7 gto 3`	Repeat.

NOTE: For conversion to numeric variable, modify the program as follows:

```
6 prt val(A$[5])
```


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DEC LSI 11

The following program sends a command string to the Model 194A from a DEC LSI 11 minicomputer and displays the instrument reading string on the DEC CRT terminal. The LSI 11 must be configured with 16K words of RAM and an IBV 11 IEEE-488 interface. The software must be configured with the IB software as well as FORTRAN and the RT 11 operating system.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the IBV 11 IEEE-488 interface cable.
3. Enter the program below, using the editor under RT 11 and the name IEEE.FOR.
4. Compile using the FORTRAN compiler as follows: FORTRAN IEEE.
5. Link with the system and IB libraries as follows: LINK IEEE,IBLIB.
6. Type RUN IEEE and press the RETURN key.
7. The display will read "ENTER ADDRESS".
8. Type in 9 and press the RETURN key.
9. The display will read "TEST SETUP".
10. Type in the desired command string and press the RETURN key. For example, to program the instrument for the autorange and average modes, type in R0F1X and press RETURN.
11. The instrument data string will appear on the computer display. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`  PROGRAM IEEE`	
`  INTEGER*2 PRIADR`	
`  LOGICAL*1 MSG(80),INPUT(80)`	
`  DO 2 I = 1,10`	
`  CALL IBSTER(I,0)`	Turn off IB errors.
`2 CONTINUE`	
`  CALL IBSTER(15,5)`	Allow 5 error 15's.
`  CALL IBTIMO(120)`	Allow 1 second bus timeout.
`  CALL IBTERM(10)`	Set line feed as terminator.
`  CALL IBREN`	Turn on remote.
`4 TYPE 5`	
`5 FORMAT (1X,'ENTER ADDRESS:',$)`	Input primary address.
`  ACCEPT 10,PRIADR`	
`10 FORMAT (I2)`	
`12 TYPE 15`	
`15 FORMAT (1X,'TEST SETUP:',$)`	Prompt for command string.
`  CALL GETSTR (5,MSG,72)`	Program instrument.
`  CALL IBSEOI (MSG,-1,PRIADR)`	Address 194A to listen, send string.
`18 I=IBRECV (INPUT,80,PRIADR)`	Get data from instrument.
`  INPUT (I+1) = 0`	
`  CALL PUTSTR (7,INPUT,'0')`	
`  CALL IBUNT`	Untalk the 194A.
`  GOTO 12`	Repeat.
`  END`	

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PET/CBM 2001

The following program sends a command string to the Model 194A from a PET/CBM 2001 computer and displays the instrument reading string on the computer CRT. As the PET/CBM computer has a standard IEEE-488 interface, no additional equipment is necessary.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 194A to 9.
2. With the power off, connect the Model 194A to the PET/CBM IEEE-488 interface.
3. Enter the lines of the program below, using the RETURN key after each line is typed.
4. Type RUN and press the RETURN key. Type in the desired command string at the command prompt. For example, to place the instrument in the autorange and average modes, type in R0F1X and press the RETURN key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+1.2345E+0.

PROGRAM	COMMENTS
`10 OPEN 1,9`	Open file 1, primary address 9.
`20 INPUT''COMMAND STRING'';B$`	Prompt for, input command string.
`30 PRINT#1,B$`	Address 194A to listen, send string.
`40 INPUT#1,A$`	Address 194A to talk, input data.
`50 IF ST = 2 THEN 40`	If bus timeout, input again.
`60 PRINT A$`	Display reading string.
`70 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, modify the program as follows:

```
60 A = VAL(MID$(A$,5,14))
70 PRINT A
80 GOTO 20
```

2. The PET INPUT# statement terminates on a comma. Thus, when reading Model 194A command strings which include commas, you should input each portion of the string into a separate string variable. For example, in the G2 (default) mode, to obtain and display the channel number, the program above can be modified as follows:

```
40 INPUT#1, A$,C$
60 PRINT A$",",C$
```


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APPENDIX D

Front Panel Modes and Equivalent IEEE-488 Commands

Front Panel Mode*	Equivalent IEEE-488 Command(s)
ZERO	Z4
(ZERO VAL)	Z5
FILTER	P
TRIGGER	T
(XY TRIG)	O0,O9
SGL/CONT	T
(XY MODE)	O2
SOURCE	T
(XY DATA)	O3
DELAY	W
(XY PAN)	O8
SLOPE	T20-T23
LEVEL	T20-T23
(XY ZOOM)	O7
CPLG	I
SAMPLES	N
RATE	S
LOCAL	GTL†
CHANNEL	C
AUTO	R0
Uprange	R1-R4
Downrange	R1-R4
SHIFT	None**
RECALL	F0,B
STATUS	U
(RESET)	A1
ENTER	None**
CANCEL	None**
FREQ/TIME	None**
Data Entry [0-9,.,+/-,MHz,kHz,Hz]	None**
(CH1÷CH2)	F21
(CH1-CH2)	F20
(OTHER)	None**
(WAVEFORM)	F0
(PK TO PK)	F5
(STD DEV)	F6
(INTEGRAL)	F7
(SETUP)	A,L
(AVG)	F1
(TRMS)	F2
(PEAK)	F3,F4

*Shifted modes shown in parentheses.
**Many of these modes are an intrinsic part of other commands. To emulate the front panel mode precisely, use the hit (H) command.
†Not a device-dependent command.

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APPENDIX E

Device-Dependent Commands

FUNCTION	F0	Waveform (sample at trigger point)
	F1	Average
	F2	TRMS
	F3	+Peak
	F4	-Peak
	F5	Peak-to-peak
	F6	Standard deviation
	F7	Integral
	F20	CH1-CH2
	F21	CH1/CH2
RANGE	R0	Auto
	R1	320mV
	R2	3.2V
	R3	32V
	R4	200V
	R12	Cancel auto (stay on present range)
RATE	S0,m	m=sampling rate in sec. (1E-6≤m≤1sec)
	S1,m	m=sampling rate in Hz (1≤m≤1E6Hz)
NUMBER SAMPLES*	N0,m	m=number of samples (1≤m≤65,535, 8-bit, 1≤m≤32,767, 16-bit)
	N1,m	m=measurement duration in sec (0≤m≤65.534E3, 8-bit; 0≤m≤32,766, 16-bit)
TRIGGER	T0	Continuous, talk
	T1	Single, talk
	T2	Continuous, GET
	T3	Single, GET
	T4	Continuous, X
	T5	Single, X
	T6	Continuous, external
	T7	Single, external
	T20,m	Continuous, +slope, level m (−200≤m≤+200V)
	T21,m	Single, +slope, level m (−200≤m≤+200V)
	T22,m	Continuous, -slope, level m (−200≤m≤+200V)
	T23,m	Single, -slope, level m (−200≤m≤+200V)
	T24	Continuous, other channel
	T25	Single, other channel
	T26	Continuous, immediate
	T27	Single, immediate
	T30	Start plotter
	T31	Stop plotter
DELAY*	W0±m	Delay in number of samples (65,536≤m≤1E7)
	W1,±m	Delay in sec. (65,536≤m≤1E7)

NOTE: The following characters may be used as a delimiter in place of comma: ! @ # $ % ∧ & ( ) = \ / < > ? : ; <space>

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Device-Dependent Command Summary

DATA FORMAT	G0	ASCII, 1 rdg, prefix on, suffix off
	G1	ASCII, 1 rdg, prefix off, suffix off
	G2	ASCII, 1 rdg, prefix on, suffix on
	G3	ASCII, n rdgs, prefix on, suffix off
	G4	ASCII, n rdgs, prefix off, suffix off
	G5	ASCII, n rdgs, prefix on, suffix on
	G6	Binary, n rdgs, prefix off, suffix off
	G7	Binary, n rdgs (byte count), prefix off, suffix off
ANALOG OUTPUT	O0	Abort plotter
	O1	Test Analog Output (all outputs=full scale)
	O2,0	XY Mode off
	O2,1	CRT Mode
	O2,2	Scope Mode
	O2,3	Future Expansion
	O2,4	Slow Plot (XY Analog Plotter)
	O2,5	Strip chart
	O3,0	Measurement Buffer
	O3,1	64k RAM Buffer
	O3,2	Display Readings
	O3,3	IEEE-488 Reading Buffer
	O4,m	m=X Output Full Scale Voltage ($1 \leq m \leq 10$)
	O5,m	m=Y Output Full Scale Voltage ($1 \leq m \leq 10$)
	O6,m	m=Z Output Blanking Level (1=High, 0=Low)
	O7,m	m=XY Zoom Value ($0.1 \leq m \leq 1000$)
	O8,m	m=XY Pan Value ($-65{,}536 \leq m \leq 65{,}536$)
	O9	Start Plotter
BUFFER POINTER	B0	Clear waveform output, decrement reading buffer pointer.
	B1,m	Set measurement buffer start pointer to m.
	B2,m	Set measurement buffer end pointer to m.
	B3,m	Set reading buffer start pointer to m.
READING BUFFER	Q0	Reading buffer off.
	Q1	Linear reading buffer on.
	Q2	Circular reading buffer on.
FILTER	P0	Filter off
	P1	500kHz filter
	P2	50kHz filter
ZERO	Z0	Disable zero
	Z1	Enable zero
	Z2	Use next measurement as baseline
	Z3,m	Use value m as baseline value ($-200 \leq m \leq +200V$)
	Z4	Z1 + Z2
	Z5,m	Z1 + Z3 ($-200 \leq m \leq +200V$)
INPUT COUPLING	I0	DC coupling
	I1	AC coupling
	I2	Ground coupling

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Device-Dependent Command Summary

STATUS	U0	Current channel status
	U1	Error status
	U2	Data status
	U3	Zero (Z) parameter
	U4	Delay (W) parameter
	U5	Number samples (N) parameter
	U6	Sample rate (S) parameter
	U8	Trigger level
	U9	Measurement buffer start pointer
	U10	Measurement buffer end pointer
	U11	Reading buffer start pointer
	U12	Get Translator list
SRQ	M0	SRQ disabled
	M1	Overflow
	M2	Data condition
	M4	Button pressed
	M8	Reading done
	M16	Ready
	M32	Error
CHANNEL	C1	Channel 1 A/D module
	C2	Channel 2 A/D module
	C12	Composite channel 1 & 2 display.
EOI, HOLD OFF	K0	EOI and hold off on X enabled
	K1	EOI disabled, hold off on X enabled
	K2	EOI enabled, hold off on X disabled
	K3	Both EOI and hold off on X disabled
TERMINATOR	Ym	Program m as single terminator
	Yn,m	Program mn as dual terminator
	Y (DEL)	No terminator
SAVE*	L1	Save setup 1
	L2	Save setup 2
	L4,m	Calibrate using value m ($-200 \leq m \leq +200$V)
	L5	Store cal in NVRAM
RECALL	A0	Recall factory setup
	A1	Recall setup 1
	A2	Recall setup 2
	A3	Recall setup 3
HIT BUTTON	Hn	Act as if button n (1-38) has been pressed
DISPLAY	Daaaa	Display ASCII characters aaaa (14 maximum)
	DX	Return to normal display mode
SELF TEST	J1	U1 self test byte =1: fail
EXECUTE	X	Execute other device-dependent commands.

*m parameter is in microvolts.

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APPENDIX F

Engineering Units and Scientific Notation Conversion

Engineering Symbol	Prefix	Scientific Notation
femto-	f	10^{-15}
pico-	p	10^{-12}
nano-	n	10^{-9}
micro-	μ	10^{-6}
milli-	m	10^{-3}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}
peta-	P	10^{15}

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APPENDIX G
IEEE-488 BUS OVERVIEW

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 with a minimum number of bus lines. In keeping with this goal, the bus has eight data lines that are used both for data and many commands. Additionally, the bus has five management lines, which are used to control bus operation, and three handshake lines that are used to control the data byte transfer sequence.

A typical configuration for controlled bus operation is shown in Figure G-1. A typical system will have one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), and a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener. The Model 194A has both talker and listener capabilities.

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

The bus is limited to 15 devices, including the controller. Thus, any number of devices may be present on the bus at one time. Although several active listeners may be present simultaneously, only one active talker may be present on the bus, or communications would be scrambled.

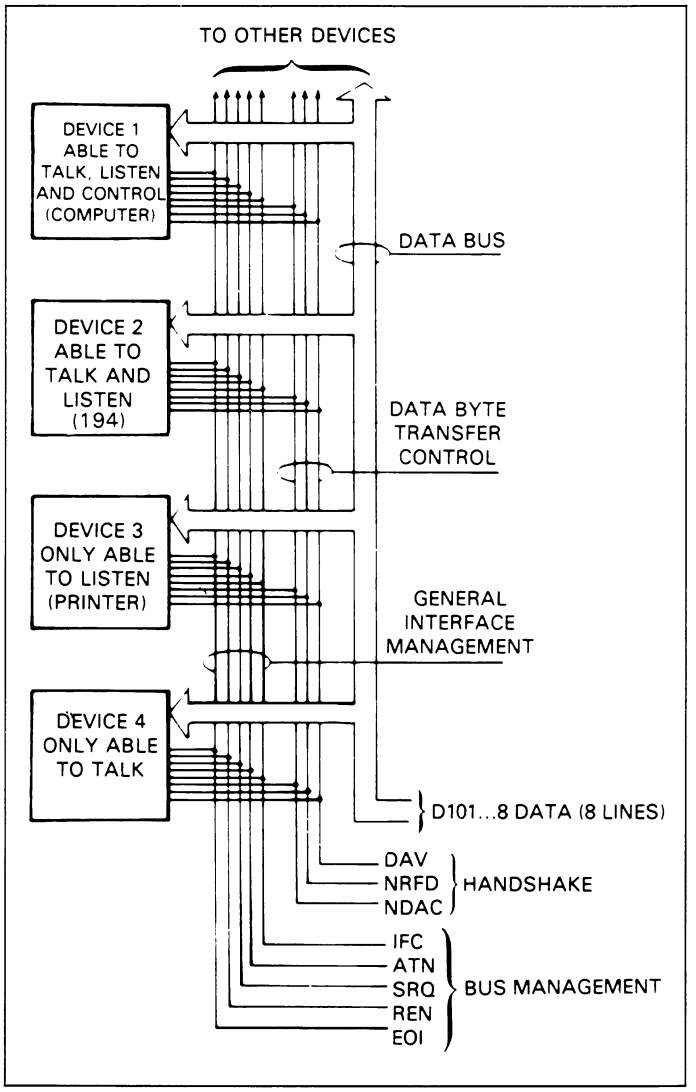


Figure G-1. IEEE Bus Configuration

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A device is placed in the talk or listen mode from the controller 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 switches or programmed in from the front panel (as in the case of the Model 194A). The actual listen command value sent over the bus is derived by ORing the primary address with $20 (the $ symbol preceding the number designates a hexadecimal, or base 16 value). For example, if the primary address is 9 (the default Model 194A value), the actual listen command byte value is $29 ($09 + $20 = $29). In a similar manner, the talk command byte is derived by ORing the primary address with $40. With a primary address of 9, the actual talk command byte would be $49 ($40 + $09 = $49).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary address byte values lie in the range of $60-$7F. Note, however, that many devices, including the Model 194A, do not use secondary addressing.

Once the device is properly addressed, bus transmission sequences are set to take place. For example, if an instrument is addressed to talk, it will usually output its data string on the bus one byte at a time. The listening device (frequently the controller) will then read this information as transmitted.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three categories: data lines, management lines, and handshake lines. The eight data lines handle bus data and many commands, while the management and handshake lines ensure orderly bus operation. Each bus line is active low with approximately zero volts representing logic 1 (true). The following paragraphs briefly describe the operation of these lines.

Data Lines

The bus uses eight data lines to transmit and receive data in bit-parallel, byte serial fashion. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining bus lines, low is considered to be true.

Bus Management Lines

The five bus management lines ensure proper interface control and management. These lines are used to send uniline commands.

ATN (Attention)—The state of ATN determines how information on the data lines is to be interpreted.

IFC (Interface Clear)—IFC allows the clearing of active talkers or listeners from the bus.

REN (Remote Enable)—REN is used to place devices in the remote mode. Usually, devices must be in remote before they can be programmed over the bus.

EOI (End Or Identify)—EOI is used to mark the end of a multi-byte data transfer sequence. EOI is also used along with ATN, to send the IDY (identify) message for parallel polling.

SRQ (Service Request)—SRQ is used by devices to request service from the controller.

Handshake Lines

Three handshake lines that operate in an interlocked sequence are used to ensure 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. These handshake lines are:

DAV (Data Valid)—The source (talker) controls the state of DAV to indicate to any listeners when data is valid.

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

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

Figure G-2 shows the basic handshake sequence for the transmission of one data byte. This sequence is used to transfer data, talk and listen addresses, as well as multiline commands.

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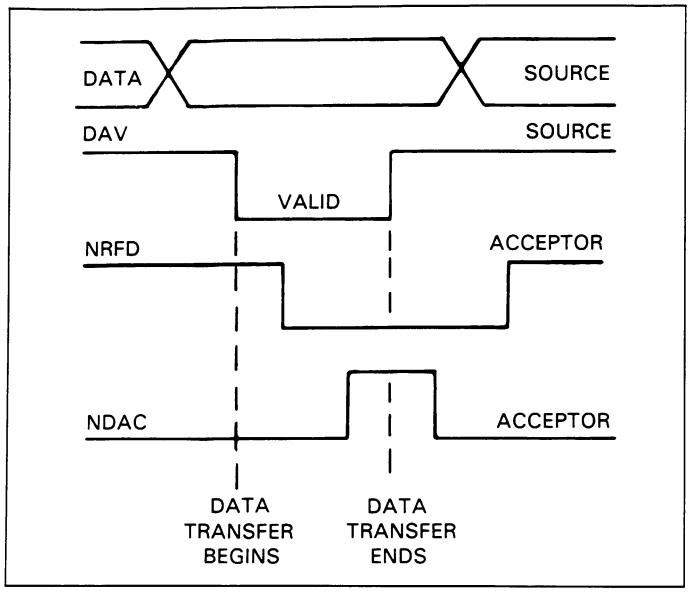


Figure G-2. IEEE Handshake Sequence

BUS COMMANDS

Commands associated with the IEEE-488 bus can be grouped into the following three general categories. Refer to Table G-1.

Uniline Commands—These commands are asserted by setting the associated bus line true. For example, to assert REN (Remote Enable), the REN line would be set low (true).

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

Device-dependent Commands—Commands whose meanings depend on the device in question. These commands are transmitted via the data lines while ATN is false.

Table G-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices 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 local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial 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	Returns device 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 194A for various modes.

*Don't Care.

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Uniline Commands

The five uniline commands include REN, EOI, IFC, ATN, and SRQ. Each command is associated with a dedicated bus line, which is set low to assert the command in question.

REN (Remote Enable)—REN is asserted by the controller to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be asserted before attempting to program instruments over the bus.

EOI (End or Identify)—EOI may be asserted either by the controller or by external devices to identify the last byte in a multi-byte transfer sequence, allowing data words of various lengths to be transmitted.

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

ATN (Attention)—The controller asserts ATN while sending addresses or multiline commands.

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

Universal Multiline Commands

Universal multiline commands are those commands that required no addressing as part of the command sequence. All devices equipped to implement these commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out front panel or local operation of the instrument.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, devices 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 on the bus is requesting 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.

Addressed Multiline Commands

Addressed multiline commands are those commands that must be preceded by an appropriate listen address before the instrument will respond to the command in question. Note that only the addressed device will respond to the command. Both the command and the address preceding it are sent with ATN true.

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

GTL (Go To Local)—GTL is used to remove instruments from the remote mode and place them in local. With many instruments, GTL may also restore operation of front panel controls if previously locked out.

GET (Group Execute Trigger)—GET is used to trigger devices to perform a specific action that will depend on device configuration (for example, perform a measurement sequence). Although GET is an addressed command, many devices may respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups, and a secondary address group. ATN is true when these commands are asserted. These commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 194A) do not use these commands.

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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 UNL.

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

Device-Dependent Commands

The purpose of device-dependent commands will depend on instrument configuration. Generally, these commands are sent as one or more ASCII characters that command the device to perform a specific action. For example, the command string R0X is used to control the measurement range of the Model 194A.

The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure G-3. Hexadecimal and and decimal values for the various commands are listed in Table G-2.

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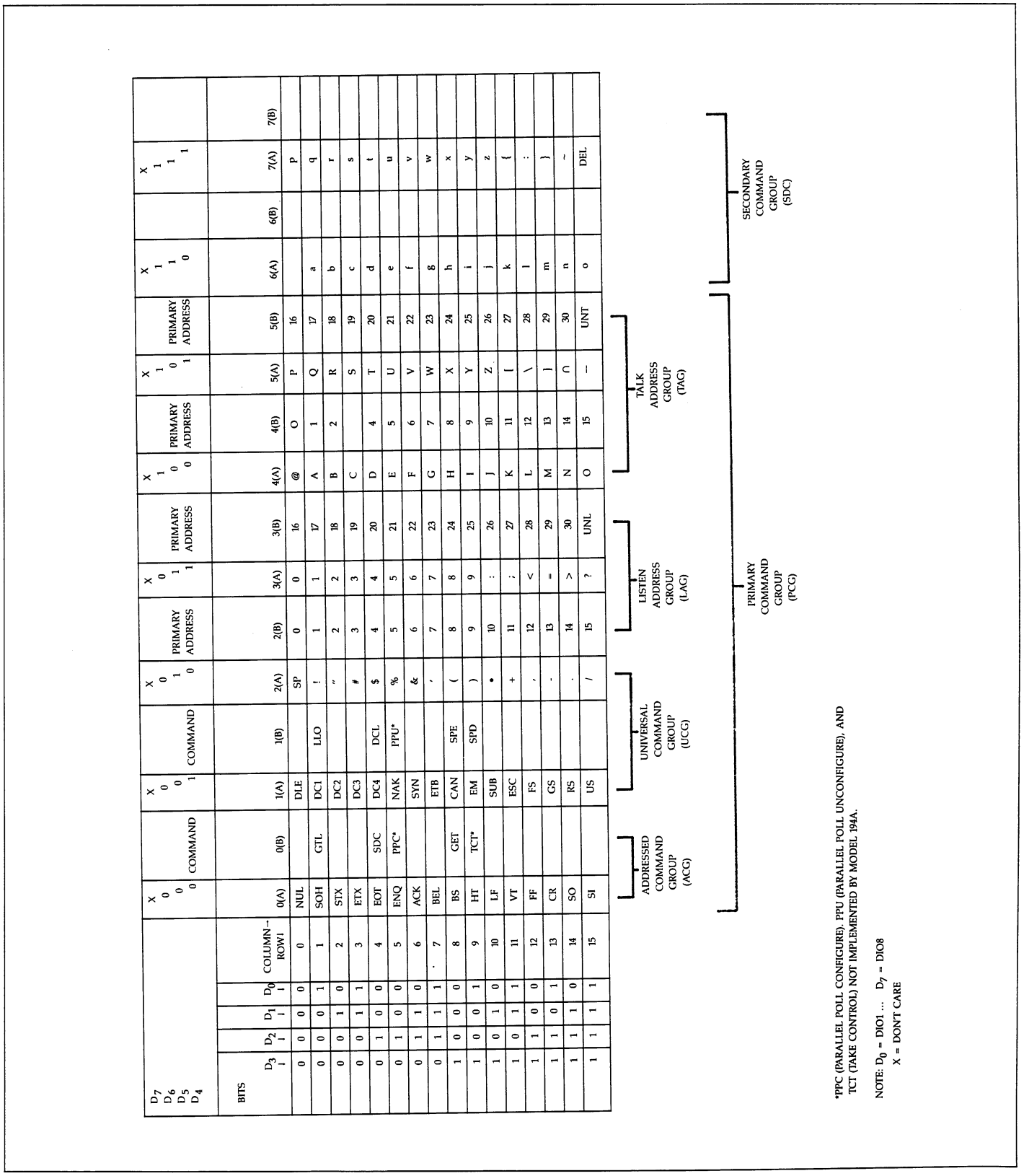


Figure G-3. Command Codes

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Table G-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
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table 4-3 lists a typical bus sequence for sending an addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table G-3. Typical Addressed Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	)	29	41
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 9.

Table G-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

Table G-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	)	29	41
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 9.

IEEE Command Groups

Command groups supported by the Model 194A are listed in Table G-5. Device-dependent commands are not included in this list.

Table G-5. IEEE Command Group

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 GROUN
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 CLEAR

STATUS COMMAND GROUP
RQS=REQUEST SERVICE
SRQ=SERIAL POLL REQUEST
STB=STATUS BYTE
EOI=END

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APPENDIX H

Glossary of Terms

Abort—To terminate or break off an operation.

Accuracy—The maximum error in terms of measurement made by an instrument. For digital instruments, accuracy is usually specified as a percent of reading plus so many counts of error.

A/D (Analog-to-Digital) Converter—A device that converts an analog signal into binary or digital values.

Aliasing—The introduction of errors into data resulting from the discrete sampling of continuous signals when the sampling rate is too low for the frequency being sampled. Generally, the sampling rate must be at least twice as high as the highest sampled sinusoidal frequency to avoid aliasing.

Analog—Pertaining to electronic devices in which the output varies as a continuous function of the input.

Analog Output—An output that provides an analog signal derived from the digital information within the instrument.

Aperture Delay—The time period that occurs between the instant the sample and hold in the A/D converter is triggered to hold the signal and the actual time that it does.

Aperture Uncertainty—A measure of the instability of the time base which controls the sample and hold circuitry.

ASCII—Abbreviation for American Standard Code for Information Interchange (pronounced ask-ee). A standard code used extensively in computers and data transmission in which 128 letters, numbers, symbols, and special control characters are represented by 7-bit binary numbers.

Average Reading—The sum of all the samples in a measurement divided by the number of samples in that measurement.

Bandwidth—The range of frequencies to which an instrument will respond within certain limits. Usually, bandwidth is defined by the -3dB (0.707V) points.

BASIC—Abbreviation for Beginners All-purpose Symbolic Instruction Code. A high-level programming language used in many small computers.

Binary—A number system based on the number 2; used extensively in computer-based equipment.

Bit—An abbreviation for binary digit. A unit of binary information is equal to one binary decision, or the designation of one of two possible states, generally represented by 1 and 0.

BNC—A type of coaxial connector used in situations requiring shielded cable for signal connections.

Buffer—A dedicated area of memory in which some form of binary data is stored for later access. The measurement buffer stores individual samples, and the reading buffer stores mathematically processed readings.

Bus—In computerized equipment, one or more conductors used as a path over which information is transmitted from any of several sources to any of several destinations.

Byte—A group of bits processed together in parallel; by definition a byte is made up of eight bits.

Card—A slot location on the rear panel of the instrument into which A/D modules can be installed. Card is also used as another name for module.

Channel—One of two A/D modules installed in the two card locations.

Chassis Ground—A connection to a common metal structure within the instrument. Generally, chassis ground is connected through power line ground to earth ground via a 3-wire power cord for safety purposes.

Clock—A pulse generator or signal waveform used to achieve synchronization of digital circuits.

Coaxial Cable—A cable in which one conductor completely surrounds the other, the two being coaxial and separated by continuous solid dielectric.

Command—A signal, originating within a computer, that triggers or initiates some form of action within the instrument.

Common-mode Rejection Ratio—A measure of the attenuation of a noise voltage appearing between input low and input high resistively coupled, and chassis ground, usually specified in dB.

Common Mode Voltage—A voltage applied between input low and chassis ground of the instrument.

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Complex Waveform—A periodic waveform made up of a combination of several frequencies or several sine waves superimposed on one another.

Controller—A device which governs the operation of the IEEE-488 bus; generally a controller is a small computer or microcomputer.

Conversion—A single piece of binary data that is the result of the A/D converter transformation process. A conversion is one sample.

Count—The minimum step size that an instrument display can resolve. Display size is often defined in counts, as in a 32,767 count display.

Crosstalk—Unwanted coupling of a signal from one channel to another by conduction or radiation.

CRT—Cathode Ray Tube. A term generally used when referring to a computer or terminal display screen.

Cursor—A flashing display digit or segment used to indicate the next digit affected by data entry.

DAC—Abbreviation for Digital-to-Analog Converter. A device which converts digital or binary information into an analog signal.

Data Entry—The process of keying in data from the front panel using the numeric keys.

dB—Abbreviation for decibel, which is a logarithmic unit used to measure and compare voltage, current, and power levels.

Differential Non-linearity—The maximum deviation of an actual quantized step width from the ideal quantized step.

Digital—Circuitry in which the data-carrying signals are restricted to one of two voltage levels. These voltage levels are used to represent the binary values 1 and 0.

Digitize—To convert an analog signal into a series of binary numbers representing its amplitude at discrete intervals of time.

DMA—Abbreviation for Direct Memory Access. A method where digital bytes or words are stored in or accessed from memory locations directly without requiring microprocessor intervention. DMA is generally faster than other forms of memory access.

Earth Ground—A connection from an electrical circuit or instrument to the earth through a water pipe or metal rod driven into the ground.

EMI—Abbreviation for Electromagnetic Interference. A term that defines unwanted electromagnetic radiation from a device which could interfere with desired signals in electronic receiving equipment such as television and radio. RFI (Radio Frequency Interference) and EMI are often used interchangeably.

Fourier Series—A mathematical analysis that permits any complex waveform to be resolved into a fundamental, plus a finite number of terms involving its harmonics.

GPIB—Abbreviation for General Purpose Interface Bus. Another term for the IEEE-488 bus.

Hexadecimal—A number system based on the number 16 that uses values 0-9, and A through F to represent the 16 possible values of a 4-bit binary number. Hexadecimal numbers are represented by preceding them with a $ or following them with a letter H. Thus, $7F and 7FH would be equivalent.

High Speed—Pertaining to the instrument's ability to take a large number of samples in a short period of time.

IC—Abbreviation for Integrated Circuit. A combination of interconnected circuit elements inseparably contained on or within a single substrate.

IEEE-488 Bus—A parallel instrumentation data and control bus standardized by the Institute of Electrical and Electronic Engineers.

Integral Reading—A reading in volt-seconds that defines the approximate area under a curve bounded by the amplitude of the samples and the time duration of the measurement.

I/O—Abbreviation for input/output, which refers to the transmission of information from an instrument to an external device (output), or the transfer of information from an external device to an instrument (input).

K—Abbreviation for kilo. In computer terms, 1K equals 1024. For example, a 16K byte memory has 16,384 bytes.

LED—Light Emitting Diode. A PN junction diode that emits light when forward biased. LEDs are used in front panel annunciators as well as the individual segments of numeric displays on instrumentation.

Listener—A device which, when connected to the IEEE-488 bus, is capable if receiving information over that bus.

Measurement—A set of raw samples, stored in memory, that are not mathematically processed in any way.

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Measurement Trigger—A stimulus that initiates acquisition of a set of samples.

Microprocessor—The control and processing portion of a small computer, microcomputer, or computerized device, which is usually contained within one LSI (Large Scale Integration) IC.

Missing Codes—Pertaining to binary values not produced by an A/D converter as the analog input signal rises or falls in a linear manner.

Module—A complete subassembly of the instrument combined in a single package (for example, an A/D converter module).

Monotonicity—The measure of the ability of an A/D converter to produce an output in response to a continuously increasing analog input signal without missing codes.

Noise—Any unwanted signal appearing in an electronic device.

Normal Mode Voltage—A voltage applied between the input high and input low terminals of an instrument.

NVRAM—Abbreviation for Non-volatile Random Access Memory. A special type of electrically alterable ROM that is used to store information such a calibration constants on a semi-permanent basis. Stored information is retained when power is removed from the device.

Oscilloscope—An instrument in which the horizontal and vertical deflection of the electronic beam of a cathode ray tube are, respectively, proportional to a pair of applied voltages. The vertical axis displayed on the CRT generally represents the voltage amplitude of the applied signal, while the horizontal axis is usually related to time.

Parallel—The simultaneous storage, transmission, or logical operation on a group of bits at one time.

Peak Reading—The most positive sample in a measurement.

Peak-to-Peak Reading—The most negative sample (least positive) subtracted from the most positive sample in a measurement.

Periodic Waveform—An electronic waveform that repeats itself regularly in time and form.

Plotter—A device that produces an inscribed display of the variation of a dependent variable (Y axis) as a function of an independent variable (X axis). The Y axis generally represents voltage amplitude, while the X axis is usually related to time.

Pointer—A value that defines the first and last measurement or reading buffer location to be accessed when requesting data from the instrument. The start pointer defines the first location to be accessed, and the end pointer dictates the last location to be accessed.

Programmable Instrument—An instrument whose operation can be determined by keystroke sequences entered from the front panel or with commands sent over the IEEE-488 bus.

RAM—Abbreviation for Random Access Memory. A type of memory where information can be stored (written) and accessed (read). RAM memory is usually volatile, meaning that data is lost when the power is turned off.

Random Access—Access to any location in instrument memory where each location can be accessed in the same amount of time.

Reading—A measurement that is mathematically processed in some manner (for example, averaged). The result is then shown on the front panel display or sent over the IEEE-488 bus.

Real Time—An operation or sequence that is performed during the actual time period, rather than being stored, slowed down, or speeded up.

Resolution—The smallest increment of change in voltage that can be detected by the instrument.

ROM—Abbreviation for Read Only Memory. A type of memory which permanently stores program information for a microprocessor. ROM memory is non-volatile, which means that programmed information remains intact after power is removed.

Sample—One A/D conversion process. A sample represents the signal amplitude at one particular point in time.

Sampling Interval—The time period that transpires between individual samples.

Sampling Rate—A term that defines how rapidly individual samples are taken.

Sample Trigger—A stimulus that initiates each A/D conversion.

Scanner—A device that selects among a number of signals and routes the selected signal to a single output. A scanner is also frequently referred to as a multiplexer.

Sequential Access—Serial access to instrument memory where lower or higher memory locations must be passed through before reaching the desired location.

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Serial—The technique for handling a binary data word which has more than one bit. The bits are processed one at a time in single-file sequence.

Settling Time—The time interval, following the initiation of a specified stimulus to the instrument input, required for the instrument response to reach and maintain a final value within specified limits.

Sinusoidal—Varying in proportion to the sine of an angle or time function (for example, ordinary alternating current).

Slew Rate—The maximum charge rate of the signal-sampling capacitor in the sample and hold circuitry.

Software—The program instruction coding within an instrument or computer that makes the unit operate.

Standard Deviation Reading—A measure of the variation of the samples from the average of the measurement.

Talker—A device that can transmit information over the IEEE-488 bus.

Transient Waveform—An electronic signal that results in a sudden change in circuit conditions which persists only for a brief period of time.

Translator Mode—A mode which allows English-like words to be used in place of instrument bus commands.

Trigger—An external stimulus of some sort that initiates one or more measurement or scan sequences.

TRMS Reading—The True Root-Mean-Square, or effective value of a voltage waveform is a voltage with the same heating value as an equivalent DC voltage.

Waveform Reading—A single sample that occurs at the trigger point.

Window—When referring to signal sampling, the aperture that defines the start and stop limits of the measurement sequence.

Word—A group of characters stored in one location in a computer or computerized device. Generally, a word is made up of two or more bytes.

XY Mode—A mode that allows measurement data to be displayed on a graphing device such as a plotter or oscilloscope.

Zero—A mode that allows a baseline measurement to be subtracted from subsequent measurements.

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KEITHLEY

Service Form

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

Name and Telephone No. _____

Company _____

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

_____

_____

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

Display or output (check one)

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

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

(attach any additional sheets as necessary)

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

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

_____

_____

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

Relative humidity? _____ Other? _____

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

_____

_____

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

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