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KEITHLEY

# Model 590 CV Analyzer

## Instruction Manual

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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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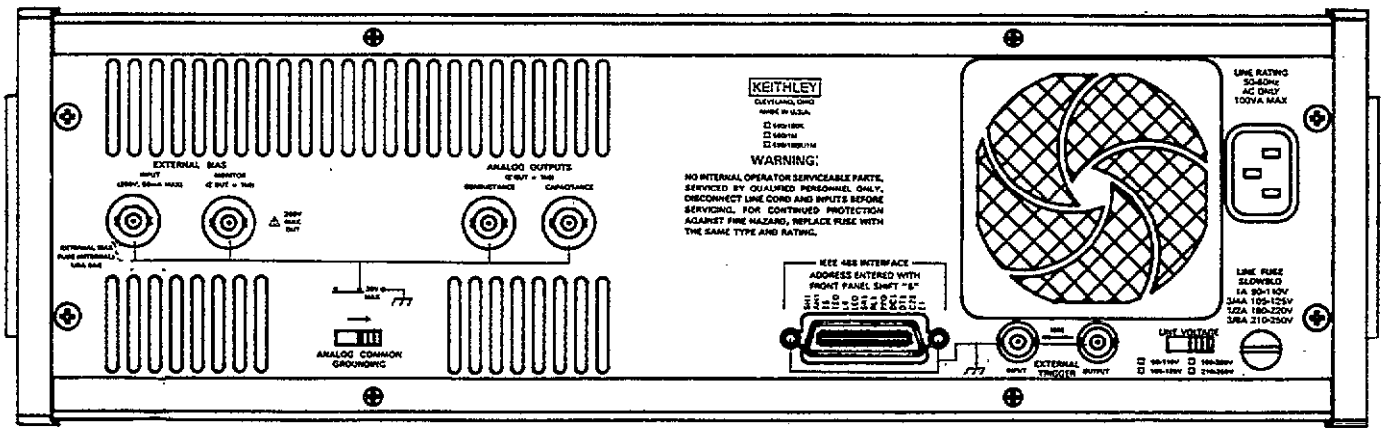
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**2/03**

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# Model 590 CV Analyzer
# Instruction Manual

Replace all Model 590 rear panels that appear in this manual with the artwork below.




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# Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 590-901-01) ..... 1987
Revision B (Document Number 590-901-01) .....
Revision C (Document Number 590-901-01) .....
Addendum C (Document Number 590-901-02) ..... October 1995
Addendum C (Document Number 590-901-03) ..... February 1996
Addendum C (Document Number 590-901-04) ..... April 1996
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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 and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

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 properly, 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.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

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.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators 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.**

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.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

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.

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.

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If  or  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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# SAFETY PRECAUTIONS

The following safety precautions should be observed before using the Model 590.

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

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

Do not exceed 30V RMS (42.4V peak) between analog common and earth ground.

Inspect your connecting cables for possible wear, cracks, or breaks before each use.

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

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

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

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# SPECIFICATIONS

## 590/100k and 590/100k/1M FRONT PANEL SPECIFICATIONS

(4½ Digits)

| RANGE | RESOLUTION | ACCURACY (1 Year)[2] 18°-28°C ±(%rdg + counts) | P-P NOISE[5] FILTER ON | TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C | SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts) |
|---|---|---|---|---|---|
| 2 pF | 0.1 f F | 0.12% + (500 × $G/G_{FS}$ + 200) | 6 f F | 0.02% + (20 × $G/G_{FS}$) | 0.1 % + (3 × $G/G_{FS}$) |
| 2 µS | 0.1 nS | 0.12% + ( 50 × $C/C_{FS}$ + 200) | 4 nS | 0.02% + ( 7 × $C/C_{FS}$) | 0.1 % + (3 × $C/C_{FS}$) |
| 20 pF | 1 f F | 0.12% + (260 × $G/G_{FS}$ + 10) | 6 f F | 0.02% + (20 × $G/G_{FS}$) | 0.1 % + (3 × $G/G_{FS}$) |
| 20 µS | 1 nS | 0.12% + ( 22 × $C/C_{FS}$ + 10) | 4 nS | 0.02% + ( 7 × $C/C_{FS}$) | 0.1 % + (3 × $C/C_{FS}$) |
| 200 pF | 10 f F | 0.12% + (260 × $G/G_{FS}$ + 5) | 90 f F | 0.02% + (20 × $G/G_{FS}$) | 0.1 % + (3 × $G/G_{FS}$) |
| 200 µS | 10 nS | 0.12% + ( 22 × $C/C_{FS}$ + 5) | 60 nS | 0.02% + ( 7 × $C/C_{FS}$) | 0.1 % + (7 × $C/C_{FS}$) |
| 2 nF | 100 f F | 0.12% + (260 × $G/G_{FS}$ + 5) | 900 f F | 0.02% + (20 × $G/G_{FS}$) | 0.02% + (2 × $G/G_{FS}$) |
| 2 mS | 100 nS | 0.12% + ( 22 × $C/C_{FS}$ + 5) | 0.6 µS | 0.02% + ( 7 × $C/C_{FS}$) | 0.02% + (3 × $C/C_{FS}$) |
| 20 nF* | 1 pF | 0.25% + (260 × $G/G_{FS}$ + 5)[3] | 9 f F | 0.1 % + (30 × $G/G_{FS}$) | 0.02% + (2 × $G/G_{FS}$) |
| 20 mS | 1 µS | 0.25% + ( 22 × $C/C_{FS}$ + 5) | 6 µS | 0.1 % + (10 × $C/C_{FS}$) | 0.02% + (2 × $C/C_{FS}$) |

Accuracy is maximum limit for Q≥20; typical for Q<20.
*Using Model 5904 20nF/20mS Input Adapter.

## 590/1M and 590/100k/1M FRONT PANEL SPECIFICATIONS

(4½ Digits)

| RANGE | RESOLUTION | ACCURACY (1 Year)[2] 18°-28°C ±(%rdg + counts) | P-P NOISE[5] FILTER ON | TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C | SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts) |
|---|---|---|---|---|---|
| 20 pF | 1 f F | 0.29% + (300 × $G/G_{FS}$ + 10) | 6 f F | 0.02% + (20 × $G/G_{FS}$) | 0.5 % + (25 × $G/G_{FS}$) |
| 200 µS | 10 nS | 0.29% + (120 × $C/C_{FS}$ + 10) | 40 nS | 0.02% + ( 8 × $C/C_{FS}$) | 0.5 % + (10 × $C/C_{FS}$) |
| 200 pF | 10 f F | 0.29% + (300 × $G/G_{FS}$ + 5) | 100 f F | 0.02% + (20 × $G/G_{FS}$) | 0.35% + (40 × $G/G_{FS}$) |
| 2 mS | 100 nS | 0.29% + (120 × $C/C_{FS}$ + 5) | 700 nS | 0.02% + ( 8 × $C/C_{FS}$) | 0.35% + (16 × $C/C_{FS}$) |
| 2 nF | 100 f F | 0.29% + (300 × $G/G_{FS}$ + 5) | 200 f F | 0.02% + (20 × $G/G_{FS}$) | 0.35% + (40 × $G/G_{FS}$) |
| 20 mS | 1 µS | 0.29% + (120 × $C/C_{FS}$ + 5) | 1 µS | 0.02% + ( 8 × $C/C_{FS}$) | 0.35% + (16 × $C/C_{FS}$) |

Accuracy is maximum limit for Q≥20; typical for Q<20.

**NOTES:**

1. G = conductance reading; C = capacitance reading; $G_{FS}$ = full scale conductance; $C_{FS}$ = full scale capacitance. Range and accuracy designations based on parallel RC model.
2. Front panel accuracy is relative to calibration source accuracy. Add front panel accuracy and source accuracy for total accuracy. Factory calibration source accuracy is 0.06% for 100kHz and 0.08% for 1MHz. CAL is to be used to cancel initial zero, gain, and phase error terms within 8 hours of measurement or whenever ambient temperature changes by more than 2°C.
3. The 5904 must be calibrated with a particular 590/100k to achieve specified accuracy.
4. "Shunt Capacitance Loading" is additional accuracy with equal shunt load on Output and Input, per 100pF shunt load.
5. Noise specified with 500pF shunt loading on Output and Input. Noise on 2pF and 20pF ranges is typical with 100pF shunt load; 500pF will increase noise no more than ×2. Measured at 10 rdg/s rate.

**CAPACITANCE NON-LINEARITY:** <0.1% of range, for Q>20 or D<0.05, 18°-28°C.

**TEST VOLTAGE:** 15mV rms ±10%.

**TEST FREQUENCY: 590/100k:** 100kHz. **590/1M:** 1MHz. Tolerance: ±0.1%.

## BIAS SOURCE

**INTERNAL BIAS SOURCE OUTPUT:** −20.000V to +20.000V in 5mV steps.

**ACCURACY (1 Year, 18°-28°C):** ±(0.05% setting + 10mV) exclusive of loading errors.

**DC OUTPUT RESISTANCE:** 5Ω maximum.

**TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C):** ±(0.005% + 1mV)/°C.

**MAXIMUM OUTPUT CURRENT:** ±50mA.

**SETTLING TIME:** <1ms to 1% of final value.

**NOISE:** Typically <200µV p-p, 0.1Hz-1MHz; 3mV p-p to 75MHz.

**BIAS WAVEFORM:**

DC: Outputs the programmed value.
STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V.
DUAL STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V, then back to FIRST BIAS V.
PULSE: Outputs pulse train; amplitude increments by BIAS STEP V from FIRST BIAS V to LAST BIAS V (each pulse is from DEFAULT BIAS V to FIRST BIAS V for duration of STEP TIME, then back to DEFAULT BIAS V). Also programmable for single pulse.
EXT: Allows application of external bias source (via VOLTAGE BIAS INPUT).

**BIAS PARAMETERS:** FIRST BIAS V, LAST BIAS V, DEFAULT BIAS V, BIAS STEP V, START TIME, STOP TIME, STEP TIME, COUNT.

**BIAS STEP V:** Programmable in 5mV steps to 20V. Polarity selectable + or −.

**START TIME:** After transition from DEFAULT BIAS V to FIRST BIAS V, START TIME must elapse before first measurement. Programmable in increments of 1024µs from 1 to 65,536 increments. **Accuracy:** ±(0.1% + 1ms).

**STEP TIME:** The period between the transition of BIAS STEP V and the start of the next measurement. Programmable in increments of 1024µs from 1 to 65,536 increments. **Accuracy:** ±(0.1% + 1ms).

**STOP TIME:** The period between the end of the final measurement and the transition from LAST BIAS V to DEFAULT BIAS V. Programmable in increments of 1024µs from 1 to 65,536 increments. **Accuracy:** ±(0.1% + 1ms).

**EXTERNAL VOLTAGE BIAS INPUT:** Rear panel input terminals allow application of external bias source up to ±200V, ±50mA. **Input Impedance:** 100kΩ paralleled by 1µF.

**VOLTAGE BIAS MONITOR:** Rear panel output terminals allow monitor of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. **Level:** 1V = 1V out. **Output Resistance:** 1kΩ.

**VOLTAGE BIAS DISPLAY:** Front panel 4½-digit display allows direct readback of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. **Accuracy:** ±(0.05% + 5 counts). **Temperature Coefficient:** ±(0.005% + 0.1 count)/°C.

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## ANALYSIS CAPABILITY

**(Programming and output available from front panel or IEEE-488 bus)**

**READING BUFFERS A and B:** Two data buffers allow storage and mathematical manipulation on up to 450 measurement triplets: capacitance, conductance, and voltage. In C vs. t, capacitance and index only are stored (up to 1350 points).

**$1/C^2$:** Performs the inverse of $C^2$ on the capacitance data stored in reading buffer.

**$C/C_o$:** Allows normalization of capacitance readings stored in reading buffer to a user-programmable reference value $C_o$.

**$C_{MAX}$:** Searches reading buffer for the maximum capacitance value.

**$C_A - C_B$:** Sequentially computes the difference between corresponding capacitance readings stored in reading buffer A and reading buffer B.

**$|V_A - V_B|$:** Calculates the corresponding difference in applied voltage for values of capacitance in reading buffer B equal to each value in reading buffer A.

**C vs. t:** Allows fast measurement of capacitance vs. time (1000 rdg/s).

## CABLE COMPENSATION

**(Up to 8 setups can be stored in non-volatile memory)**

**CALIBRATION CAPACITOR COMPENSATION:** Corrects for errors due to cables or switching matrix up to 5 meters effective (electrical equivalent) length. Two measurements are made with cables and matrix terminated with precision reference capacitors in place of the DUT. Model 5907 Cable/Matrix Calibration Capacitor Set required. Bus programmable only. 1MHz only. **Accuracy:** ±(0.5% + applicable front panel specification), typical.

**SINGLE-ENDED CABLE and S-PARAMETER COMPENSATION** can also be made. See manual for detailed information.

## IEEE-488 BUS IMPLEMENTATION

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

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

**INTERFACE FUNCTIONS:** SH1, AH1, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, E1, C0 (for stand alone plotting C28 is used).

**PROGRAMMABLE PARAMETERS:** Range, Function, Zero, Filter, Frequency, Bias Waveform, Bias Parameters, Plotting, Plotter Parameters, EOI, Trigger, Terminator, 450 Data Point Storage, Calibration, Cable Correction, Display, Status, Service Request, Self Test, Output Format.

**TRANSLATOR:** Up to 250 bytes of definitions allow variable passing, definition decomposition and listing.

## GENERAL

**DISPLAY:** Three 4½-digit displays for capacitance, conductance, and voltage bias.

**RANGE:** Manual or autoranging (for rates up to 18 rdg/s); 10% overrange allowable.

**OVERRANGE INDICATION:** Display reads OFLO.

**AVAILABLE MEASUREMENT RATES (to internal buffer):**
**4½-Digit:** 1, 10, and 18 rdg/s. **3½-Digit:** 75 and 1000 rdg/s.

**FILTER:** 1-pole analog; pole at 37Hz. Filters both capacitance and conductance signals. For FILTER off, multiply p-p noise specification by 5.

**CAL:** Initiates self-calibration to internal reference capacitor. Used to cancel initial zero, gain, and phase errors.

**ZERO:** Allows zeroing of on range readings. Allows relative readings to be made with respect to a baseline value.

**MAXIMUM OVERLOAD:** OUTPUT, Voltage Bias Input: 200V internally fused at ⅛A. INPUT: Clamped by diodes to ±0.7V. Maximum current 200mA. Analog Outputs: 15V.

**MAXIMUM COMMON MODE VOLTAGE (INPUT and OUTPUT, Voltage Bias Input):** 30V rms, dc to 60Hz. Rear panel switch allows connection of INPUT low to chassis.

**ANALOG OUTPUTS (Capacitance and Conductance): Level:** 2V output at full range. **Initial Offset:** ±25mV. **Output Resistance:** 1kΩ. **Response Time:** 1ms to 1% of final value with filter off; 25ms maximum with filter on.

**PLOTTER:** Digital plotter output controls HP7470A plotter or equivalent using HPGL via IEEE-488 for real-time plotting of all measurements as well as results of math computations, with grids and labels. Talks to plotter on address 05. HPGL commands used are IN, IP, IW, PA, PD, PU, SC, SI, SP.

**FRONT PANEL SETUPS:** Up to 7 front panel setups can be stored in non-volatile memory.

**EXTERNAL TRIGGER:** TTL compatible External Trigger Input and Output.

**INPUT CONNECTORS:** Isolated BNC for INPUT and Voltage Bias Input.

**OUTPUT CONNECTORS:** Isolated BNCs for OUTPUT, Voltage Bias Monitor, and Analog Outputs. Non-isolated BNCs for External Trigger.

**ENVIRONMENT: Operating:** 0°-50°C, relative humidity 70% non-condensing up to 35°C. **Storage:** −25° to +65°C.

**WARMUP:** 1 hour to rated accuracy.

**COOLING:** Internal fan and filter for forced air cooling.

**POWER:** 105-125V or 210-250V (external switch selected), 50Hz to 60Hz, 100VA maximum. 90-110V and 180-220V version available upon request.

**DIMENSIONS, WEIGHT:** 133mm high × 435mm wide × 448mm deep (5¼ in. × 17⅛ in. × 17⅝ in.). Net weight 9.1kg (20 lbs.).

**ACCESSORIES SUPPLIED:** Two Model 7051-5 BNC cables.

**ACCESSORIES AVAILABLE:**

| | |
|---|---|
| Model 5904: | 20nF/20mS Adapter |
| Model 5905: | Calibration Sources and Adapters for 590/1M. |
| Model 5906: | Calibration Sources and Adapters for 590/1M, 590/100k, 590/100k/1M, and 5904 |
| Model 5907: | Cable/Matrix Calibration Sources |
| Model 7007-1: | Shielded IEEE-488 Digital Cable, 1m (3.3 ft.) |
| Model 7007-2: | Shielded IEEE-488 Digital Cable, 2m (6.6 ft.) |
| Model 7051-2: | BNC to BNC Cable, 0.5m (2 ft.) |
| Model 7051-5: | BNC to BNC Cable, 1.5m (5 ft.) |
| Model 7051-10: | BNC to BNC Cable, 3m (10 ft.) |

Specifications subject to change without notice

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## 590/100K ANALOG OUTPUT PERFORMANCE

| RANGE | ACCURACY (1 Year) 18° -28°C ±(% reading + mV) | P-P NOISE[3] ANALOG FILTER ON | TEMPERATURE COEFFICIENT 0° -18° & 28° -50°C ±(% reading + mV) | SHUNT CAPACITANCE LOADING EFFECT[4] ±(% reading + mV) |
|---|---|---|---|---|
| 20 pF | 1% + (50 × $G/G_{FS}$ + 1 ) | 6 fF | 0.2% + (10 × $G/G_{FS}$ + 0.1) | 0.1 % + (0.3 × $G/G_{FS}$) |
| 20 µS | 1% + (20 × $C/C_{FS}$ + 1 ) | 4 nS | 0.2% + ( 4 × $C/C_{FS}$ + 0.1) | 0.1 % + (0.3 × $C/C_{FS}$) |
| 200 pF | 1% + (50 × $G/G_{FS}$ + 0.5) | 90 fF | 0.2% + (10 × $G/G_{FS}$ + 0.1) | 0.1 % + (0.3 × $G/G_{FS}$) |
| 200 µS | 1% + (20 × $C/C_{FS}$ + 0.5) | 60 nS | 0.2% + ( 4 × $C/C_{FS}$ + 0.1) | 0.1 % + (0.7 × $C/C_{FS}$) |
| 2 nF | 2% + (50 × $G/G_{FS}$ + 0.5) | 900 fF | 0.4% + (10 × $G/G_{FS}$ + 0.2) | 0.02% + (0.2 × $G/G_{FS}$) |
| 2mS | 2% + (20 × $C/C_{FS}$ + 0.5) | 0.6µS | 0.4% + ( 4 × $C/C_{FS}$ + 0.2) | 0.02% + (0.3 × $C/C_{FS}$) |
| 20 nF* | 3% + (50 × $G/G_{FS}$ + 0.5) | 9 pF | 0.6% + (10 × $G/G_{FS}$ + 0.1) | 0.1 % + (0.2 × $G/G_{FS}$) |
| 20mS | 3% + (20 × $C/C_{FS}$ + 0.5) | 6 µS | 0.4% + ( 4 × $C/C_{FS}$ + 0.1) | 0.1 % + (0.2 × $C/C_{FS}$) |

Accuracy stated for Q≥20 . Typical error for Q<20 .

*Using Model 5904 20nF/20mS INPUT ADAPTER.

**NOTES:**

1. G = conductance reading; C = capacitance reading; $G_{FS}$ = full scale conductance; $C_{FS}$ = full scale capacitance.
2. Range and accuracy designations based on parallel RC model.
3. "Shunt Capacitance Loading" is additional accuracy error with equal shunt load on Test Output and Test Input, per 100pF load.
4. Noise specified with 500pF shunt loading on Test Output and Test Input. Noise on 2pF and 20pF ranges is typical with 100pF shunt loading; 500pF will increase noise no more than ×2.
5. 5904 must be calibrated with a particular 590/100K to achieve this accuracy level.

**TEST VOLTAGE:** 15mV rms ±10%.
**TEST FREQUENCY:** 100kHz. Tolerance: ±0.1%.

## 590/1M ANALOG OUTPUT PERFORMANCE

| RANGE | | ACCURACY (1 Year) 18° -28°C ±(% reading + mV) | P-P NOISE[5] ANALOG FILTER ON | TEMPERATURE COEFFICIENT 0° -18°C & 28° -50°C ±(% reading + mV) | SHUNT CAPACITANCE LOADING EFFECT[4] ±(% reading + mV) |
|---|---|---|---|---|---|
| 20 pF | | 2% + ( 75 × $G/G_{FS}$ + 1) | 1.2 mV | 0.15% + (15 × $G/G_{FS}$) | 0.5 % + (2.5 × $G/G_{FS}$) |
| 200 µS | | 2% + ( 30 × $C/C_{FS}$ + 1) | 0.75mV | 0.15% + ( 6 × $C/C_{FS}$) | 0.5 % + (1.0 × $C/C_{FS}$) |
| 200 pF | | 2% + ( 75 × $G/G_{FS}$ + 1) | 1.4 mV | 0.15% + (15 × $G/G_{FS}$) | 0.35% + (4.0 × $G/G_{FS}$) |
| 2mS | | 3% + ( 30 × $C/C_{FS}$ + 1) | 0.9 mV | 0.15% + ( 6 × $C/C_{FS}$) | 0.35% + (1.6 × $C/C_{FS}$) |
| 2 nF | Up to 1nF | 5% + (150 × $G/G_{FS}$ + 1) | 0.3 mV | 0.15% + (15 × $G/G_{FS}$) | 0.35% + (4.0 × $G/G_{FS}$) |
| 20mS | Up to 10mS | 5% + ( 40 × $C/C_{FS}$ + 1) | 0.2 mV | 0.15% + ( 6 × $C/C_{FS}$) | 0.35% + (1.6 × $C/C_{FS}$) |
| 2 nF | Above 1nF | 5% + (300 × $G/G_{FS}$ + 1) | 0.3 mV | 0.15% + (15 × $G/G_{FS}$) | 0.35% + (4.0 × $G/G_{FS}$) |
| 20mS | Above 10mS | 7% + ( 40 × $C/C_{FS}$ + 1) | 0.2 mV | 0.15% + ( 6 × $C/C_{FS}$) | 0.35% + (1.6 × $C/C_{FS}$) |

**NOTES:**

1. G = conductance reading; C = capacitance reading; $G_{FS}$ = full scale conductance; $C_{FS}$ = full scale capacitance.
2. Range and accuracy designations based on parallel RC model.
3. "Shunt Capacitance Loading" is additional accuracy error with equal shunt load on Test Output and Test Input, per 100pF load.
4. Noise specified with 500pF shunt loading on Test Output and Test Input. Noise on 2pF and 20pF ranges is typical with 100pF shunt loading; 500pF will increase noise no more than ×2.

**TEST VOLTAGE:** 15mV rms ±10%.
**TEST FREQUENCY:** 1MHz. Tolerance: ±0.1%.

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

# SECTION 1
## General Information

Includes an overview of front and rear panel configuration and basic test procedures. Use the information in this section to get your Model 590 up and running as quickly as possible.

# SECTION 2
## Getting Started

This section contains detailed information on operating all available versions of the Model 590. Use this section as a reference to all front panel operation.

# SECTION 3
## Operation

Section 4 contains information on connecting the Model 590 to the IEEE-488 bus and programming the instrument from a computer.

# SECTION 4
## IEEE-488 Programming

Outlines procedures necessary to verify that the Model 590 and the 100kHz and 1MHz modules are 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 are the IEEE-488 interface, and the capacitance modules.

# SECTION 6
## Principles of Operation

Details maintenance procedures for the Model 590, including fuse replacement, line voltage selection, calibration, and troubleshooting.

# SECTION 7
## Maintenance

Includes replacement parts information, schematic diagrams, and component location drawings for the Model 590.

# SECTION 8
## Replaceable Parts

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# SECTION 1
# GENERAL INFORMATION

## 1.1 INTRODUCTION

This section contains information on Model 590 features, warranty, manual addenda, specifications, and safety terms and symbols. Also included are procedures for unpacking and inspecting the instrument, as well as a brief description of available accessories.

The information in Section 1 is arranged as follows:


**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 Optional Accessories**


## 1.2 FEATURES

The Model 590 CV Analyzer is a sophisticated instrument designed as a complete solution for individuals requiring capacitance and conductance versus voltage measurements in semiconductor testing. The unit can test devices at either 100kHz or 1MHz, depending on installed modules. The Model 590/100k tests at 100kHz, while the Model 590/1M operates at 1MHz. The Model 590/100k/1M can test at both 100kHz and 1MHz. Test voltage for both frequencies is 15mV RMS.

The Model 590/100k measures capacitance and conductance on four ranges: 2pF/2$\mu$S, 20pF/20$\mu$S, 200pF/200$\mu$S, and 2nF/2mS (the optional Model 5904 Input Adapter can extend the 100kHz measurement range to 20nF/20mS). Similarly, the Model 590/1M measures capacitance and conductance at 1MHz on three ranges: 20pF/200mS, 200pF/2mS, and 2nF/20mS. The Model 590/100k/1M includes both measurement capabilities.

Key Model 590 features include:

- A standard internal ±20V bias source that can generate staircase, pulse train, or DC waveforms. Provision to connect an external bias source of up to ±200V DC are also included.
- Two 450-word internal buffers to store capacitance (C), conductance (G), and bias voltage (V) data taken during testing. Two complete sets of C, G, V data can be stored; one set can be saved for plotting while another test is being performed.
- Standard plotter driver software allows the Model 590 to control an intelligent digital plotter over the IEEE-488 bus, simplifying a variety of different plot types, including C vs V, G vs V, $1/C^2$ vs V, and $C/C_O$ vs V.
- Nominal reading rates of 1, 10, 18, 75, or 1000 readings per second allow you to choose the best compromise between resolution, noise performance, and speed.
- Selectable analog filtering is included to minimize noise.
- External trigger input and output capabilities are included to synchronize the Model 590 with other equipment such as external bias sources.
- Analog outputs of capacitance, conductance, and bias voltage are included to allow the monitoring or analog plotting of these readings with external equipment.
- Isolated analog and digital sections, which allow measurements with common mode voltages up to 30V RMS.
- Internal calibration reference sources for maximum accuracy.
- Built-in correction software to compensate for cable transmission line effects that would otherwise degrade accuracy. Up to seven sets of cable parameters can be stored for later recall at the touch of a button. The unit can also compensate for non-uniform transmission lines with the aid of external standards.
- Internal math ability to simplify calculation of such parameters as parallel/series model, capacitance difference and ratio, and maximum and minimum capacitance values.
- Up to seven different instrument configurations can be stored and later recalled to simplify instrument configuration. The factory configuration can also be recalled at the touch of a button.
- A standard IEEE-488 interface is included, allowing the instrument to be programmed from a computer. Enhanced Keithley Translator software simplifies programming.



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## 1.3 WARRANTY INFORMATION

Warranty information for your Model 590 may be found inside the front cover of this manual. Should it become necessary for you 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 Austria. Information concerning the operation, application, or service of your instrument may be directed to the applications engineer at one of these locations.

## 1.4 MANUAL ADDENDA

Information conerning changes or improvements to the instrument which occur after this manual has been printed will be found on an addendum sheet included with the instrument. Please be sure to read this information before attempting to operate or service the instrument.

## 1.5 SAFETY TERMS AND SYMBOLS

The following safety terms 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 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 instument. Such damage may invalidate the warranty.

## 1.6 SPECIFICATIONS

Detailed Model 590 specifications are located at the front of this manual.

## 1.7 UNPACKING AND INSPECTION

The Model 590 was carefully inspected and packed before shipment. Upon receiving the instrument, carefully unpack all items from the shipping carton and inspect for any obvious signs of physical damage that might have occurred during shipment. Report any damage to the shipping agent immediately. Retain the original packing material in case reshipment becomes necessary.

### 1.7.1 Shipment Contents

The following items are included with every Model 590 shipment:

Model 590 CV Analyzer
Model 590 Instruction Manual
Model 7051 RG-58, BNC test cables (2)
Additional accessories as ordered.

### 1.7.2 Module Complement

Modules ordered with the unit will be shipped already installed and calibrated. Available models include:

| | |
|---|---|
| 590/100k | 100kHz capacitance module only |
| 590/1M | 1MHz capacitance module only |
| 590/100k/1M | Both 100kHz and 1MHz capacitance modules. |

Note that the module complement is indicated by model on the rear panel.

### 1.7.3 Additional Instruction Manuals

If an additional instruction manual is required, order the manual package, Keithley Part Number 590-901-00. The manual package includes an instruction manual and all pertinent addenda.

## 1.8 PREPARATION FOR USE

### 1.8.1 Line Power

The Model 590 is intended 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 voltage range is marked on the rear panel.

### 1.8.2 Line Voltage Selection

The operating voltage is selected by a switch located on the rear panel. Before using the instrument, make sure that the switch is in the correct position for the line voltage in your area.



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

### 1.8.3 Line Frequency

The Model 590 may be operated from either 50 or 60Hz power sources.

### 1.8.4 IEEE-488 Primary Address

If the Model 590 is to be programmed over the IEEE-488 bus, it must be set to the correct primary address. The primary address has been set to 15 at the factory, but it can easily be changed from the front panel, as described in Section 4.

## 1.9 REPACKING FOR SHIPMENT

Before shipment, the unit should be carefully packed in its original packing carton using all original packing materials.

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

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

## 1.10 OPTIONAL ACCESSORIES

The following accessories for the Model 590 are available from Keithley Instruments, Inc. Contact your Keithley representative or the factory for information on obtaining these accessories.

### 1.10.1 General Accessories

Model 2288 Fixed Rack Mount Kit—The Model 2288 Kit includes two flanged brackets and hardware for mounting the Model 590 in a standard 19-inch equipment rack or cabinet.

Model 2289 Slide Rack Mount Kit—The Model 2289 Kit consists of two sets of flanged brackets, equipment slides, and hardware for mounting the Model 590 in a standard 19-inch equipment rack or cabinet.

Model 5904 Adapter—The Model 5904 extends the 100kHz measurement range of the instrument to 20nF/20ms. The Model 5904 mounts directly on the INPUT and OUTPUT jacks and includes BNC connectors for test cable connections. Note that the Model 5904 and Model 590 must be calibrated as a matched pair for stated accuracy.

Model 7007-1 IEEE-488 Cable—The Model 7007-1 1m (3.3 ft.) shielded IEEE-488 interface cable is equipped with a shielded IEEE-488 connector (metric) on each end.

Model 7007-2 IEEE-488 Cable—The Model 7007-2 2m (6.6 ft.) shielded IEEE-488 interface cable is equipped with a shielded IEEE-488 metric-screw connector on each end.

Model 7051 BNC to BNC Cables—The Model 7051 cables are made up RG-58 50Ω cable terminated with a male BNC connector on each end. Three lengths are available: The Models 7051-2, 7051-5, and 7051-10 are 0.5m (2 ft), 1.5m (5 ft), and 3m (10 ft) in length respectively.

### 1.10.2 Calibration and Verification Sources

The calibration sources listed below are intended for use in field calibration or accuracy verification of the Model 590. Each source is mounted in a shielded test fixture, which is equipped with BNC connectors. These fixtures are intended to connect directly to the front panel test INPUT and OUTPUT jacks to avoid cable errors (except for the Model 5907 sources, which connect to cables through supplied adapters).

Sources used with each model are summarized in Table 1-1. Table 1-2 summarizes nominal source values.

**Table 1-1. Calibration Source Sets by Model Number**

| Analyzer Model | 5905 | 5906 | 5907* |
|---|---|---|---|
| 590/100k | | X | |
| 590/1M | X | | X |
| 590/100k/1M | | X | X |

*Used for cable correction only; not needed for normal calibration.



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Model 5905 Calibration Sources—The Model 5905 set contains all the capacitance and conductance sources necessary to calibrate or verify accuracy for the Model 590/1M. See Table 1-2 for sources.

Model 5906 Calibration Sources—The Model 5906 sources are necessary to calibrate or verify the Model 590 when used with a Model 5904 20μF/20mS Adapter, and are also needed to complete calibration or accuracy verification of a Model 590/100k or a Model 590/100k/1M.

Model 5907 Calibration Sources—The Model 5907 sources are intended for cable correction when using the calibration capacitor method of cable correction. The Model 5907 includes both 470pF and 1.8nF capacitance sources, and adapters for connecting the sources to the ends of the test cables.

## Table 1-2. Calibration Sources and Nominal Values

| Model Number | Capacitance Sources | Conductance Sources |
|---|---|---|
| 5905* | 4.7pF, 18pF, 47pF, 180pF, 470pF | 180μS, 1.8mS, 18mS |
| 5906† | 0.5pF, 1.5pF, 4.7nF | 1.8μS, 18μS |
| 5907** | 470pF, 1.8nF | |

*Model 5905 and 5906 include right angle adapter and BNC short for driving point cable correction calibration.

**Model 5907 includes two female BNC-to-BNC adapters to connect source to cables.

†Model 5906 also includes all sources in Model 5905.



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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 590 up and running as quickly as possible. It includes a brief description of operating controls and test connections. Once you are 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 and test connection, outlines display operation, and lists where to find more detailed information in Section 3.

**2.3 Rear Panel Familiarization:** Outlines each aspect of the Model 590 rear panel including connectors and switches.

**2.4 Power Up Procedure:** Describes how to connect the instrument to line power, properly select line voltage, and the type of display messages to expect during the power up cycle.

**2.5 Basic Measurement Techniques:** Gives step-by-step procedures for making simple one-point measurements, CV measurements, plotting data, and performing C vs t measurements.

## 2.2 FRONT PANEL FAMILIARIZATION

An overview of the Model 590 is given in the following paragraphs. The front panel of the instrument is shown in Figure 2-1, along with a brief description of each item. Table 2-1 is a cross reference to other sections of the manual where more detailed information may be found.



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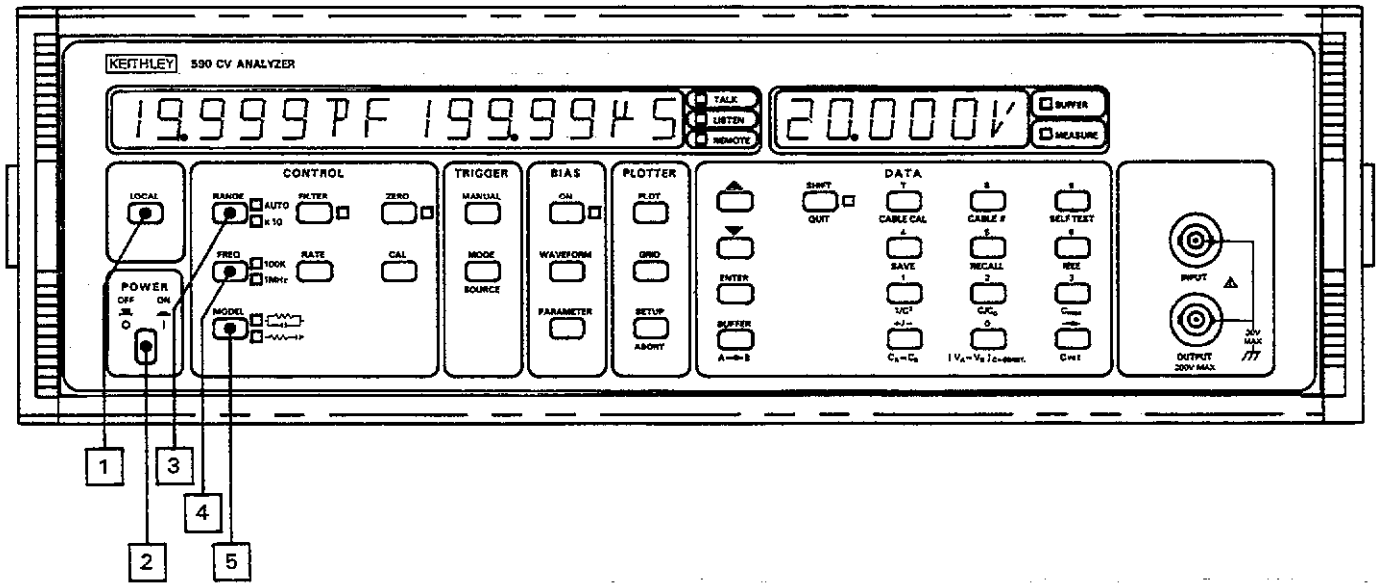
## Table 2-1. Model 590 Front Panel Cross Reference

| Item | Description | Paragraph |
|---|---|---|
| 1 LOCAL | Cancel remote, restore local operation. | 4.7 |
| 2 POWER | Control AC power. | 2.4 |
| 3 RANGE | Select range, auto, x10 attenuator. | 3.5 |
| 4 FREQ | Select 100kHz or 1MHz test frequency. | 3.6 |
| 5 MODEL | Select series R and C or parallel C and G. | 3.7 |
| 6 FILTER | Control single-pole analog low-pass filter. | 3.8 |
| 7 RATE | Select 1, 10, 75, or 1000 reading per second rate. | 3.9 |
| 8 ZERO | Enable, disable baseline suppression. | 3.10 |
| 9 CAL | Calibrate unit to internal standard. | 3.11 |
| 10 MANUAL | Initiate reading or sweep. | 3.12 |
| 11 MODE/SOURCE | Program trigger mode and source. | 3.12 |
| 12 ON | Turn DC bias on or off. | 3.14 |
| 13 WAVEFORM | Program bias waveform type. | 3.14 |
| 14 PARAMETER | Program bias voltages and times. | 3.14 |
| 15 PLOT | Plot over IEEE-488 bus. | 3.16 |
| 16 GRID | Draw grid and label graph. | 3.16 |
| 17 SETUP/ABORT | Select grid type, labels, line type, pen type, buffer, and scaling. ABORT stops plotting or grid generation. | 3.16 |
| 18 ▲ (Increment) | Scroll through menu. | 3.13 |
| 19 ▼ (Decrement) | Scroll through menu. | 3.13 |
| 20 ENTER | Enter parameters. | 3.13 |
| 21 BUFFER | Display buffer A or buffer B data. | 3.15 |
| 21 A → B | Transfer buffer A data to buffer B. | 3.15 |
| 22 SHIFT/QUIT | Add second function to some keys, cancel menu, buffer, or parameters. | Several |
| 23-34 Data Entry → | Program numeric data. Scroll cursor when programming parameters. | 3.13 |
| 23 CABLE CAL* | Calibrate cable for 100kHz or 1MHz use (driving point only). | 3.20 |
| 24 CABLE #* | Select cable correction parameter set. | 3.20 |
| 25 SELF TEST* | Perform test of internal components. | 3.18 |
| 26 SAVE* | Store up to seven instrument setups in NVRAM. | 3.17 |
| 27 RECALL* | Recall up to eight instrument setups from NVRAM. | 3.17 |
| 28 IEEE* | Program IEEE-488 primary address (0-30). | 4.5 |
| 29 $1/C^2$ | Invert C and square value. | 3.19 |
| 30 $C/C_O$ | Display normalized capacitance. | 3.19 |
| 31 $C_{max}$ | Display maximum capacitance. | 3.19 |
| 32 $C_A$-$C_B$ | Display different between buffers A & B | 3.19 |
| 33 [$V_A$-$V_B$] C=Const. | Plot $\Delta V$ at constant C. | 3.19 |
| 34 C vs t | Display C as a function of time (buffer index). | 3.20 |
| 35 Capacitance Display | Display capacitance reading. | 3.4 |
| 36 Conductance Display | Display conductance reading. | 3.4 |
| 37 TALK, LISTEN, REMOTE | Show IEEE-488 bus status | 4.7 |
| 38 Bias Voltage Display | Display programmed or measured bias voltage. | 3.14 |
| 39 BUFFER and MEASURE | Indicate display and reading status. | 2.2 |
| 40 INPUT | BNC connector to measure test signal. | 3.3 |
| 41 OUTPUT | BNC output applies 100kHz or 1MHz test voltage and bias voltage to circuit under test. | 3.3 |

*Press SHIFT first to access these modes.



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1 **LOCAL**—Pressing this key when the unit is in remote (REMOTE on) returns the instrument to the local mode (REMOTE OFF) and restores operation of other front panel controls unless LLO (local lockout) is in effect.

2 **POWER**—POWER controls AC line power to the instrument. The unit will be off when the switch is out (0 position) and on when the switch is in (1 position). Before applying power, make sure the line selection switch on the rear panel is in the correct position for the AC line voltage in your area.

## CONTROL GROUP

3 **RANGE**—Press RANGE briefly to manually select range: 2pF (100kHz only), 20pF, 200pF, or 2nF. Pressing and holding RANGE for more than a half second places the unit in autoranging, as shown by AUTO indicator. Press RANGE again to cancel auto and stay on present range. SHIFT RANGE switches in X10 attenuator to extend 100kHz measurement range to 20nF with external optional input transformer (Model 5904). Press SHIFT RANGE again to cancel X10.

**NOTE**

Autoranging is included for convenience only and should not be used for time critical measurements.

Ranges Include:

| 100kHz | 1MHz |
|---|---|
| 2pF/2μS | |
| 20pF/20μS | 20pF/200μS |
| 200pF/200μS | 200pF/2mS |
| 2nF/2mS | 2nF/20mS |
| 20nF/20mS* | |

*Requires Model 5904 Input Transformer and X10 attenuator

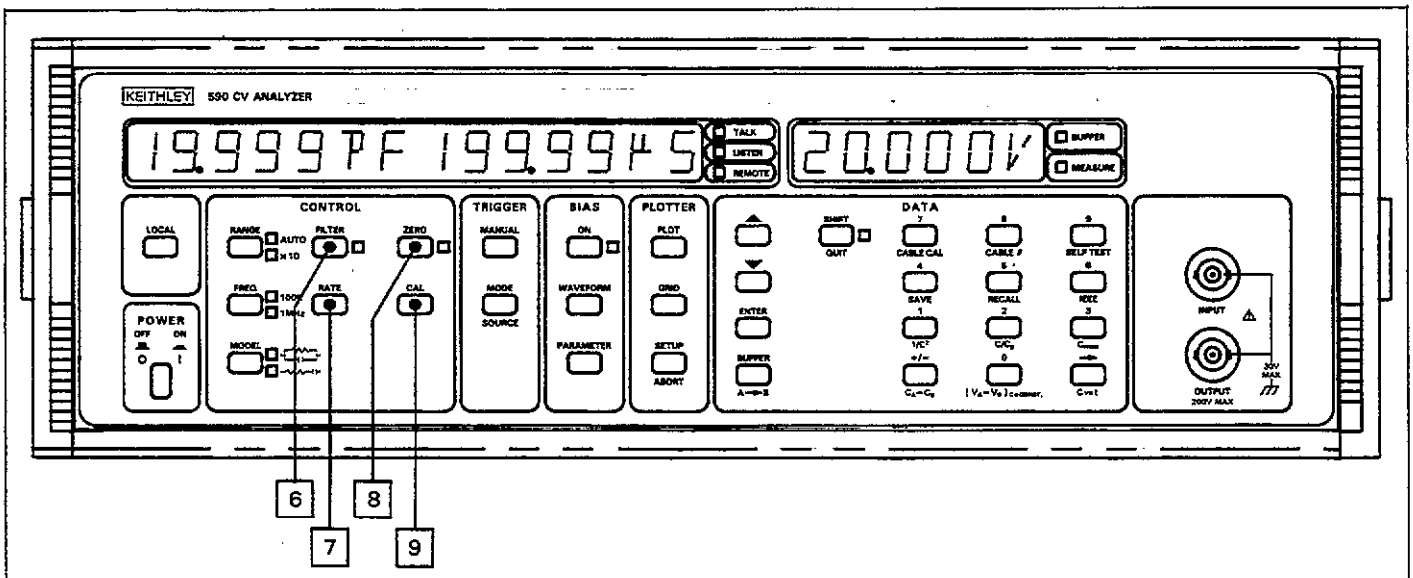
4 **FREQ**—Press FREQ to select test frequency, 100kHz or 1MHz at 15mV RMS. The excitation voltage is applied to the circuit under test along with the programmed bias voltage through the OUTPUT jack. The associated indicator will indicate the selected frequency. CONFLICT message will be displayed if you attempt to use the X10 attenuator at 1MHz. FREQ can also be used to disconnect internal test voltages from the device under test. The unit will display DISCONNECT in this case.

5 **MODEL**—MODEL selects series or parallel device model (series resistance and capacitance or parallel conductance and capacitance). The instrument always measures and stores buffer data in parallel form, but the series equivalent is calculated and displayed when the series model is selected. The selected model is shown by the associated indicator.

**Figure 2-1A. Model 590 Front Panel**



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Full Scale Conductance/Resistance:

| 100kHz G | 100kHz R | 1MHz G | 1MHz R |
|---|---|---|---|
| 2μS | 2MΩ | | |
| 20μS | 200kΩ | 200μS | 200kΩ |
| 200μS | 20kΩ | 2mS | 20kΩ |
| 2mS | 2kΩ | 20mS | 2kΩ |
| 20mS | 200Ω | | |

6 **FILTER**—FILTER toggles the single-pole low-pass analog filter on and off, as shown by the indicator adjacent to the FILTER button. The approximate −3dB point for the filter is 37Hz, and the effects of the filter are reflected both at the analog outputs on the rear panel and on the display. Note that the filter increases instrument response time.

7 **RATE**—Press RATE then ▲/▼ (or RATE) to scroll through the rate selection menu: 1, 10, 75, or 1000 readings per second (or press the numeric key indicated below). Press ENTER to select RATE, or QUIT to return to the previous rate. The slower rates will provide more resolution and quieter readings, as indicated below.

| Key# | Rate | Resolution | Readings | Digital Filtering |
|---|---|---|---|---|
| 0 | 1000/sec | 3½* | C only | No |
| 1 | 100/sec | 3½* | C, G, V | No |
| 2 | 10/sec | 4½ | C, G, V | Yes |
| 3 | 1/sec | 4½ | C, G, V | Yes |

*Data displayed only after sweep is finished and calculated.

**NOTE**
Reading rates are slightly different than indicated because of the way the unit generates its time base. See paragraph 3.9.

8 **ZERO**—ZERO provides means for supression of a constant value from the readings, or it can be used to cancel internal offsets to maximize accuracy. Enabling ZERO stores the next reading as the baseline value, which is then subtracted from subsequent readings and stored in the buffer header. Note that enabling zero reduces the dynamic range of the measurement, and that the zero value is carried from one range to another.

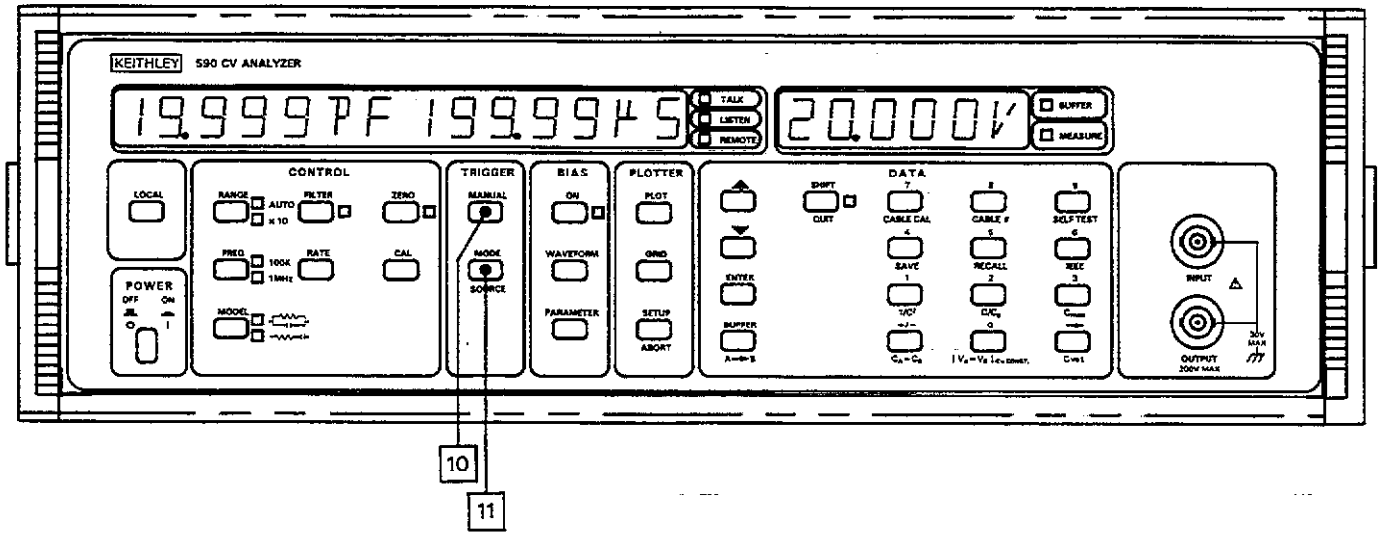
9 **CAL**—Pressing CAL performs an automatic one point calibration of the selected module on the current range using an internal 20pF or 200pF (depending on range) capacitance source, and is intended to compensate for short-term thermal drift. CAL should be used for each range at both frequencies for optimum accuracy.

**NOTE**
Do not press and hold CAL during the power-up cycle, as the instrument will go into its diagnostic program.

**Figure 2-1A. Model 590 Front Panel (Cont.)**



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## TRIGGER GROUP

10 **MANUAL**—Pressing MANUAL will initiate a one-shot or sweep sequence depending on the selected trigger mode. This key is operational regardless of the selected trigger source. Pressing MANUAL while a reading or sweep is in progress will result in a trigger overrun error message.

11 **MODE/SOURCE**—Press MODE then ▲/▼, MODE, or numeric key (see list below) to select a trigger mode: one-shot or sweep, then press ENTER. In one-shot, the instrument will process one reading per trigger, while in sweep the unit will process a complete reading sweep (one complete reading sequence at all programmed bias steps, with up to 450 readings stored in buffer A). Both modes are available with all trigger sources.

Press SOURCE (SHIFT MODE) then MODE or ▲/▼ to scroll through available trigger sources (or press the appropriate numeric key in the list below). Press ENTER to program displayed source: front panel (MANUAL button), external (a negative-going TTL-compatible pulse applied to the rear panel trigger input jack), as well as GET, X and talk commands sent over the IEEE-488 bus.

Front panel trigger messages include:

| Key # | Numeric Message | Description |
|---|---|---|
| 0 | TRIGGER MODE 1-SHOT | One reading per trigger |
| 1 | TRIGGER MODE SWEEP | One sweep per trigger |
| 0 | TRIGGER SOURCE FP | Front Panel MANUAL button* |
| 1 | TRIGGER SOURCE EXT | External trigger pulse |
| 2 | TRIGGER SOURCE TALK | IEEE talk command |
| 3 | TRIGGER SOURCE GET | IEEE GET command |
| 4 | TRIGGER SOURCE X | IEEE X command |

*Always enabled regardless of selected source.

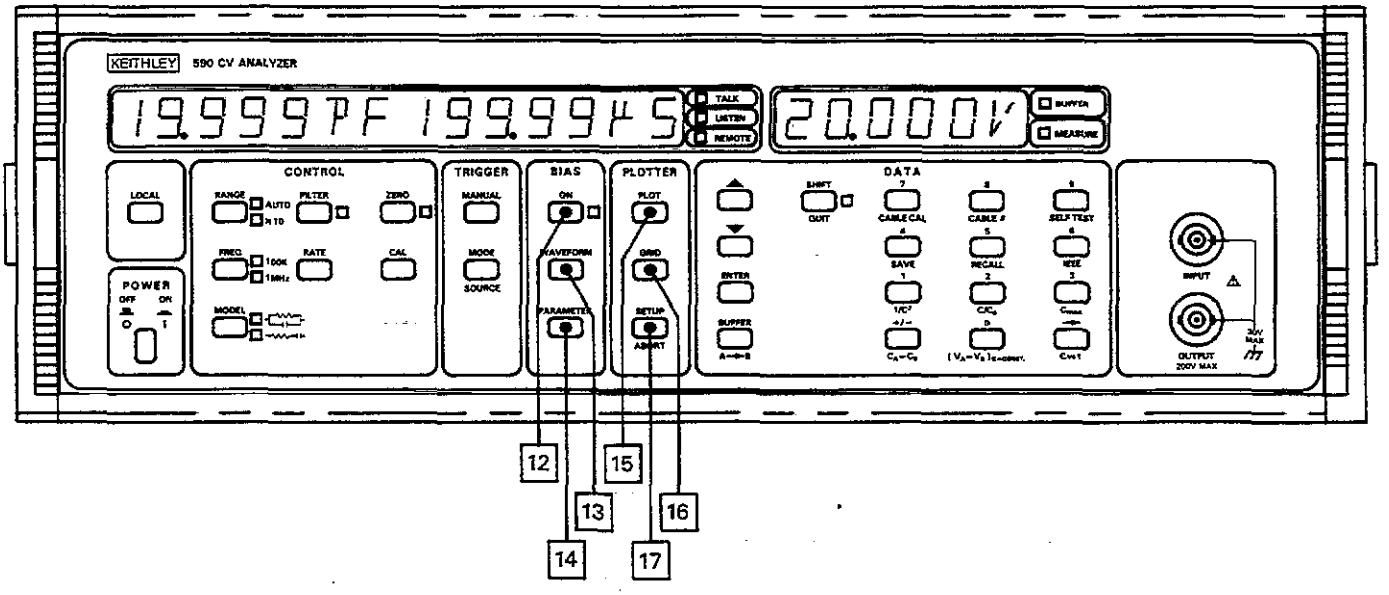
**Figure 2-1B. Model 590 Front Panel**



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## BIAS GROUP

12 **ON**—The ON key turns the internal or external bias voltage, which is applied through the OUTPUT jack, on or off. The status (on or off) is shown on the associated indicator. When the bias is off, the voltage is disconnected with internal relay contacts and provides a high impedance connection to test common. **WARNING: maximum external bias input is 200V. The external bias voltage will appear at the front panel OUTPUT jack when the bias is turned on.**

13 ***WAVEFORM***—*WAVEFORM selects the type of* bias waveform to be programmed, or the external bias source, as indicated below. Use WAVEFORM, ▲/▼ , or appropriate numeric key to select the waveform type, then press ENTER.

Available waveforms include:

| Numeric Key | Display Message | Description |
|---|---|---|
| 0 | DC | Constant DC level in the range of ±20V. |
| 1 | STAIR | Single staircase (step either up or down). |
| 2 | DSTAIR | Dual staircase (step up then down or down then up). |
| 3 | PULSE | Pulse train (constant level or step up or down). |
| 4 | EXT | Voltage from external source (BIAS INPUT jack). |

14 **PARAMETER**—Parameters for each bias waveform are independently programmable. However, if a particular parameter does not apply to the waveform, no prompt will be made for that particular parameter. Use PARAMETER or ▲/▼ to select parameter to be programmed, then key in the value using the numeric keys. Press ENTER when finished programming all parameters.

**Figure 2-1B. Model 590 Front Panel (Cont.)**

| Message | Programmed Limits | Resolution |
|---|---|---|
| START TIME | 1ms to 65sec | 1msec |
| STOP TIME | 1ms to 65sec | 1msec |
| STEP TIME | 1ms to 65sec | 1msec |
| FIRST BIAS V | −20V to 20V | 5mV |
| LAST BIAS V | −20V to 20V | 5mV |
| STEP BIAS V | −20V to 20V | 5mV |
| DEFAULT | −20V to 20V | 5mV |
| BIAS V COUNT* | 1 to 450 (1,350 at 1000/sec rate) | |

*Selects number of readings stored for external and DC bias waveform.

**Voltages can be programmed to 1mV, but are set in 5mV steps.

NOTES:
1. Multiply programmed times by 1.024 for actual time intervals.
2. Minimum stop time with pulse waveform is 50msec (10/sec rate).

## PLOTTER GROUP

15 **PLOT**—Pressing PLOT plots the data located in the selected buffer (A or B) on an intelligent plotter over the IEEE-488 bus using the current SETUP parameters.

**NOTE**

Disconnect the controller from the IEEE-488 bus of the Model 590 before using PLOT or GRID.

16 **GRID**—Pressing GRID draws labels, axes, and other parameters as appropriate for the selected buffer and the SETUP parameters.

17 **SETUP/ABORT**—Pressing SETUP enters the plotter setup menu which allows selection of the parameters below. Use ▲ or ▼ to scroll through menu selections then press the appropriate number (below) when desired selection is displayed, then ENTER.

Press ABORT (SHIFT SETUP) to halt plotting or grid generation.

Parameters include:

| Parameter | Line Type | Grid Type | Label Type |
|---|---|---|---|
| 0 | Dot at points | Full grid | Full labels |
| 1 | Spaced dots | Axis only | Labels axis and divisions |
| 2 | Dashes | — | Labels axis only |
| 3 | Long dash | — | No labels |
| 4 | Dash dot | — | — |
| 5 | Long dash short dash | — | — |
| 6 | Long dash short dash, long dash | — | — |
| 7 | Solid line | — | — |

| Parameter | Plot Type | Pen Type | Buffer |
|---|---|---|---|
| 0 | C vs V | No pen | A |
| 1 | G vs V* | #1 | B |
| 2 | $1/C^2$ vs V | #2 | — |
| 3 | $C/C_O$ vs V | — | — |
| 4 | C vs t** | — | — |
| 5 | $C_A$-$C_B$ vs V | — | — |
| 6 | $[V_A - V_B]C = CONST$ | — | — |

*R vs V with series model.

**Plots buffer index.

| Parameter | X Axis | Y Axis |
|---|---|---|
| 0* | Auto scaling | Auto scaling |
| 1** | User-defined scaling | User-defined scaling |

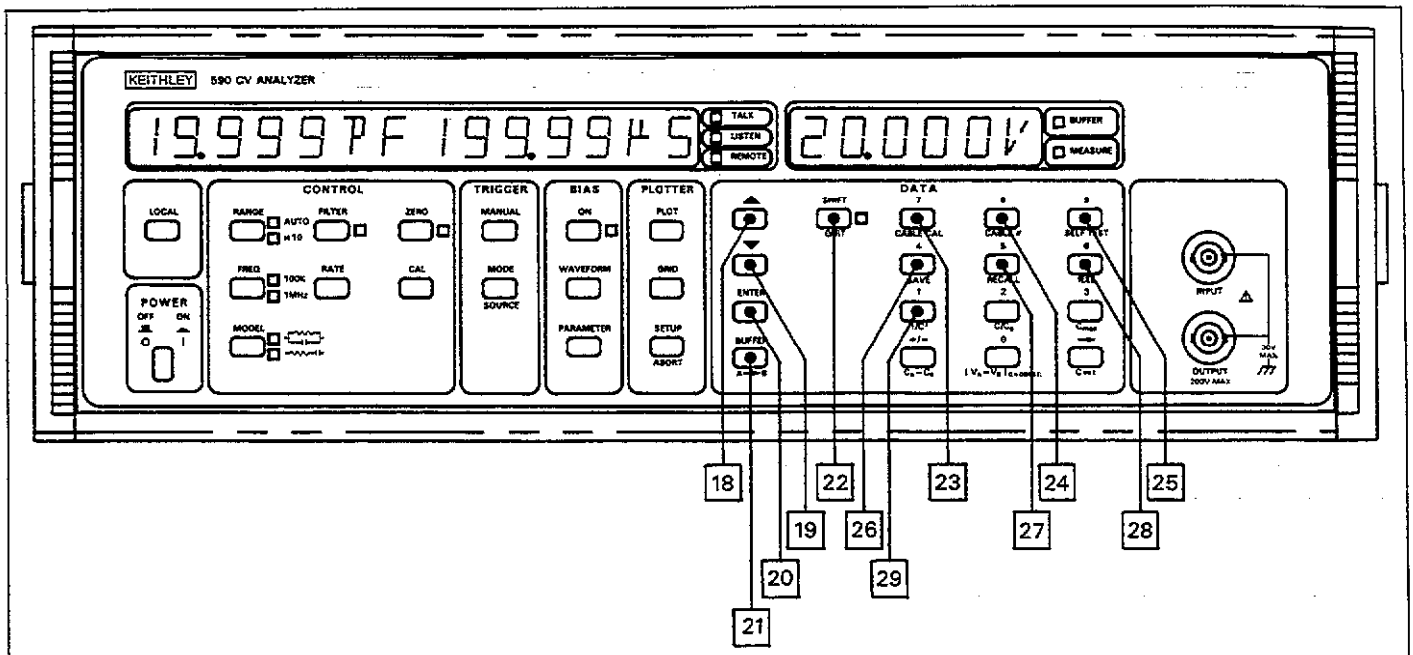
*X axis scaled to minimum and maximum values Y axis scaled according to range of function.

**Use numeric keys to enter scaling factors, then press ENTER.

**Figure 2-1B. Model 590 Front Panel (Cont.)**



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## DATA GROUP

18 **Increment (▲)**—Increment is used to scroll through menu selections for other front panel operating modes such as TRIGGER MODE, PLOTTER SETUP, and BIAS WAVEFORM. Increment is also used to scroll through buffer locations when displaying buffer data.

19 **Decrement (▼)**—Like the increment key, decrement is used to scroll through parameter menus and buffer locations, but in the opposite direction.

20 **ENTER**—ENTER is used as the last step in the menu and parameter selection process to actually perform the operation being programmed.

21 **BUFFER**—Pressing BUFFER allows you to view the contents of buffer A or buffer B on the front panel displays. Once in this mode, select the desired buffer (A or B) and use ▲ or ▼ to sequentially access various buffer locations. The capacitance (C), conductance (G), and measured bias voltage (V) for each buffer location will then appear on the display as you access them. The BUFFER LED will be on while the unit is displaying buffer data. Pressing BUFFER while accessing the buffer displays the last valid buffer location. Pressing ENTER displays the first valid buffer location (location #1). Press QUIT to exit the buffer.

21 **A → B (SHIFT BUFFER)**—A → B places the entire contents of buffer A into buffer B, including capacitance, conductance, and bias voltage values. Buffer A is the buffer into which A/D readings are stored, and buffer B is the plotter buffer. Buffer A will be cleared after the data is transferred.

22 **SHIFT/QUIT**—SHIFT adds a secondary function to certain other front panel keys, including SETUP and RANGE (SHIFT RANGE enables or disables the X10 attenuator. The shifted modes are marked below the keys in questions. While shift is enabled, the indicator to the right of that key will be on. To cancel shift, either select the mode in question, or press SHIFT a second time. If you press a key which has no second function after enabling shift, the primary function of that key will be performed. For example, SHIFT MODEL is the same as MODEL.

Press QUIT to return to normal operation while selecting menu options, programming parameters, or viewing buffer data.

**Figure 2-1C. Model 590 Front Panel**



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23 to 34 **NUMERIC DATA KEYS (0-9, ±,→)** — These keys are used to enter numeric data when programming such items as bias parameters. If you wish to restore the previously programmed values, press the QUIT (SHIFT ENTER) key instead. Pressing the → key allows you to move the display cursor to the right while programming parameters.

**NOTE**

Do not press → during power up, or instrument calibration may be altered if the CAL switch is in the unlocked position.

23 **CABLE CAL***—Pressing this key performs open-circuit cable correction. Note that the opposite ends of the connecting cables must be left open during the correction process. Once the correction is complete, you will be given an opportunity to store the correction scheme for the particular cable (1-7) you are using at the update option. Two other forms of cable correction are available only over the IEEE-488 bus, as discussed in Section 4.

**NOTE**

Using cable correction can reduce the dynamic range of the capacitance and conductance readings.

24 **CABLE #***—Use this key to select which of eight previously stored cable correction set ups you wish to use (0-7). Once selected, the unit will automatically use the previously stored cable correction parameters when making measurements. Note that correction set up #0 turns off cable correction and installs default values.

25 **SELF TEST***—Use this key to perform a self test on many internal components, including the display. If no problems are found, the instrument will return to normal operation; however, if an error occurs, an INVALID message will be displayed.

26 **SAVE***—SAVE allows you to save up to seven complete instrument configurations in NVRAM. To use this feature, simply select the operating configuration and then press the SAVE button. Key in the position (1-7) that you wish to save. Note that state 1 is the configuration the unit will assume upon power up.

27 **RECALL***—Use RECALL to assume machine operating configurations that were stored with the SAVE key, or the factory configuration. Upon entering this mode, you will be prompted for a configuration number. Key in the value (0-7) and press ENTER. Note that state 0 is a factory default configuration permanently stored in ROM and cannot be altered. State 1 is the configuration the instrument assumes upon power up. RECALL can also be used to restore normal buffer display after using a math function.

28 **IEEE***—Press IEEE to verify or program the IEEE-488 primary address. Use the number keys to select a primary address value (0-30). Press ENTER to program the new address. The programmed address will go into effect immediately.

**MATHEMATICAL FUNCTIONS**

The following calculations are performed on data presently stored in the data buffers and are not stored in memory. In order to use these functions, you must select buffer display with the BUFFER key. If reading normal instrument data, pressing one of these keys will have no effect.

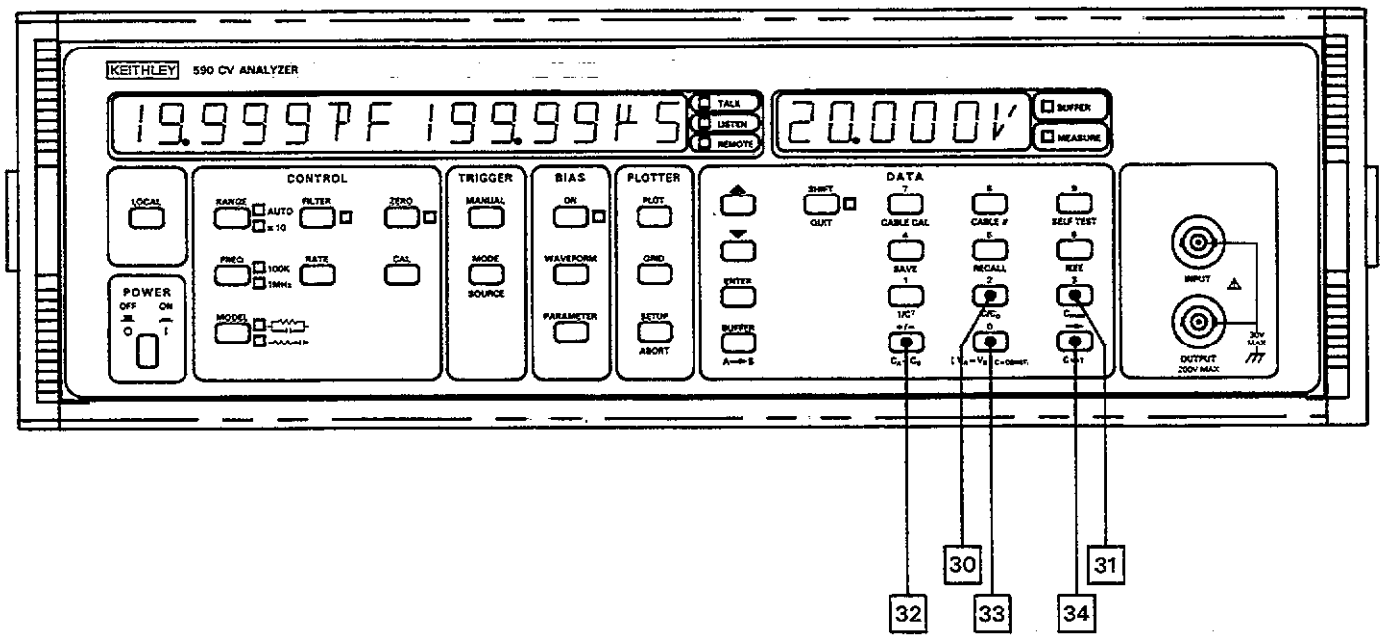
29 **1/C²**—Pressing 1/C² inverts the capacitance value in each data word of the selected buffer and then squares it; the value for each point will be displayed as you access that word location.

*SHIFT must be pressed first to access these modes.

**Figure 2-1C. Model 590 Front Panel (Cont.)**



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30 **C/C$_O$**—This feature allows you to display normalized capacitance data. Each capacitance value in the selected buffer will then be divided by $C_O$ and then displayed. The maximum capacitance presently stored in the buffer is automatically used for $C_O$.

31 **$C_{max}$**—Pressing $C_{max}$ displays the maximum capacitance value stored in the selected buffer.

32 **$C_A$-$C_B$**—This key allows you to subtract each capacitance value in buffer B from the corresponding values in buffer A.

33 **[$V_A$ -$V_B$] C=CONST.**—This function rotates the C-V plot axis by 90° and gives a display of the change in voltage (ΔV) as a function of constant capacitance.

34 **C vs t**—This mode uses the bias waveform parameters in effect when the readings were taken to display capacitance versus time. While in C vs t, you can use ▲/▼ to scroll through various buffer locations. The buffer location number will be shown in the bias voltage display. You can calculate the time at a specific location as follows:

$$t_B = t_{start} + (t_{step} + 1/R)\ (B)$$

Where: $t_B$ = time at a specific buffer location
$t_{start}$ = programmed start time
$t_{step}$ = progammed step time
R = reading rate (readings per second)*
B = buffer location number

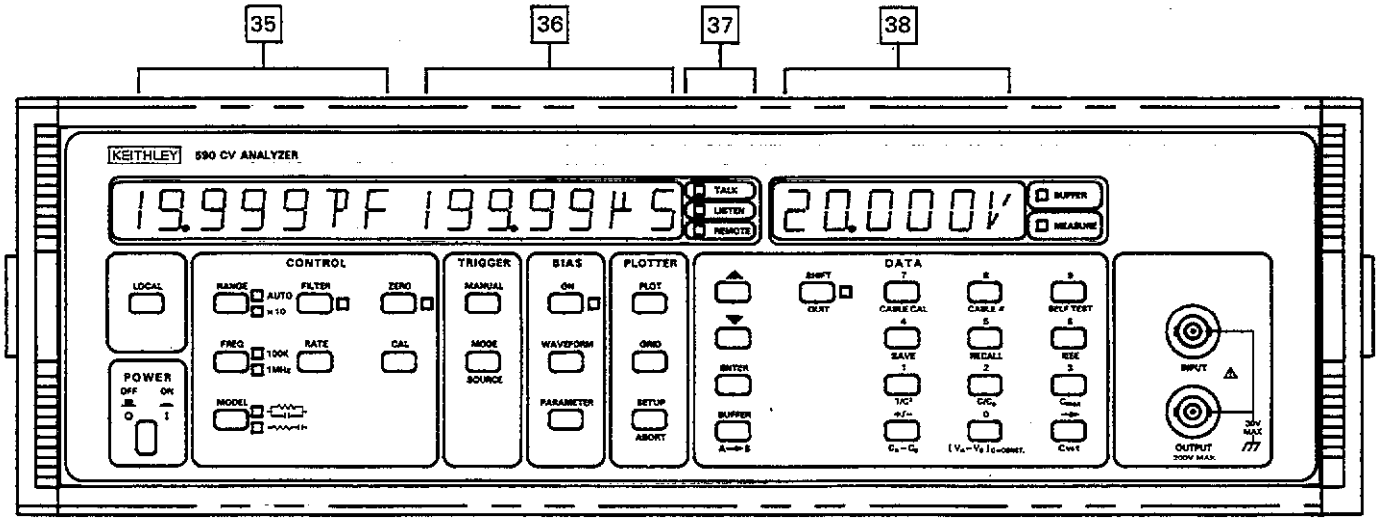
*Use actual rate, not the nominal displayed value. Also multiply times by 1.024.

Programmed times must be multiplied by 1.024 to obtain actual times.

**Figure 2-1C. Model 590 Front Panel (Cont.)**



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35 **CAPACITANCE DISPLAY**—The normal capacitance display is a 4½-digit 21,999, −19,999 count value. The decimal point along with the associated engineering units indicate the range. The displayed engineering units are pF and nF. The display will show dashes when no valid reading is available (for example, if the A/D configuration is changed, or of no valid buffer data is stored when accessing the buffer). Note that display resolution is 3½ digits at the 75 and 1000 reading per second rates.

36 **CONDUCTANCE DISPLAY**—The nominal conductance display is a 4½-digit (3½ digits at the 75 and 1000 reading per second rates), 21,999, −19,999 count value, with engineering units also displayed in µS or mS for conductance (parallel model) or kΩ or MΩ for resistance (series model). Again, the decimal point indicates the selected range in conjunction with the displayed engineering units. Like the capacitance display, dashes will appear if no valid reading is available.

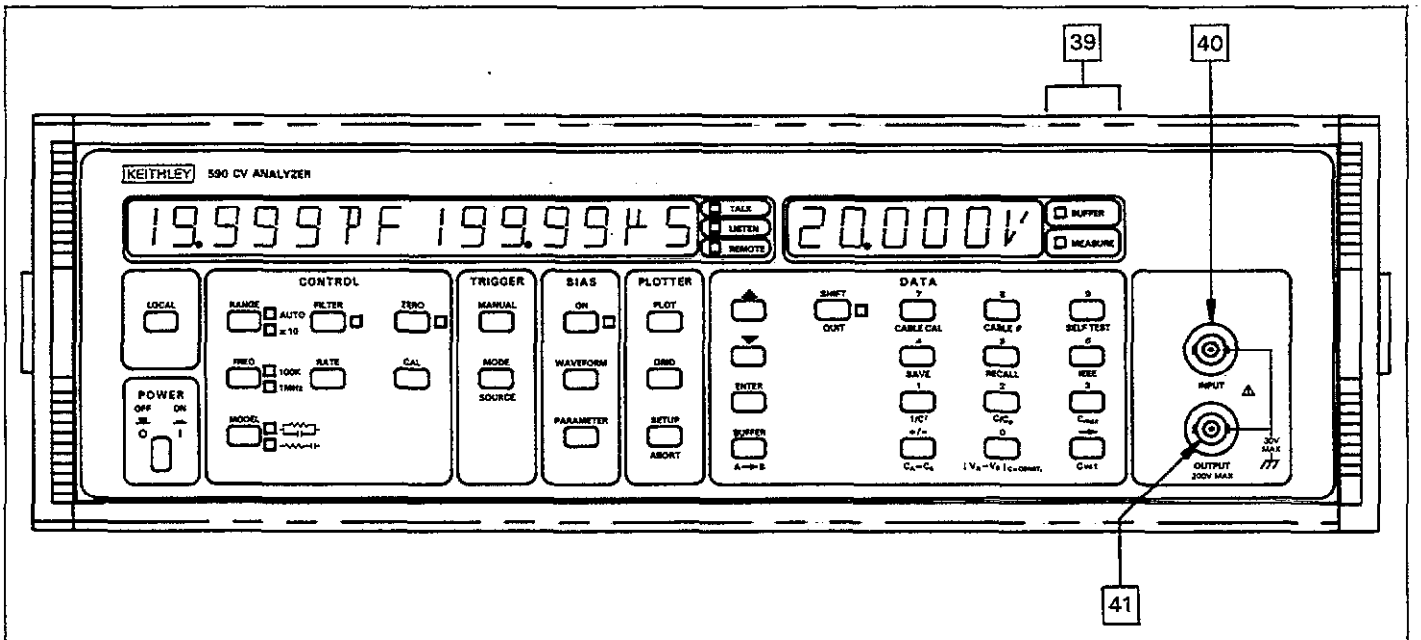
37 **IEEE-488 STATUS INDICATORS**—The TALK, LISTEN, and REMOTE LEDs indicate when the Model 590 has been placed in these modes when the unit is being programmed over the IEEE-488 bus. The TALK and LISTEN indictors show when the unit has been addressed to talk or listen, respectively. These talk and listen commands are derived from the unit's primary address. REMOTE will turn on to indicate when the instrument is placed in remote by addressing the unit to listen with the REN line true. Note that all front panel controls except LOCAL and POWER will be inoperative when REMOTE is on. Local operation can be restored by pressing LOCAL unless the IEEE-488 LLO (Local Lockout) command is in effect.

38 **BIAS VOLTAGE DISPLAY**—The 4½-digit bias voltage display indicates the programmed or actual measured value of the internal ±20V bias source or the applied external bias voltage. While programming bias parameters, the display will show the programmed value. When the unit is displaying readings or stored buffer values, the display will show the bias voltage as measured by an internal A/D converter. This display will also show buffer location in C vs t. Note that display resolution is 3½ digits at the 75 and 1000 reading per second rates.

**Figure 2-1D. Model 590 Front Panel**



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39 **BUFFER AND MEASURE**—BUFFER will be on while the instrument is displaying buffer data. MEASURE will turn on during a reading (one-shot mode) or sweep (sweep mode) to indicate a reading or sweep is in progress.

40 **INPUT**—INPUT is a BNC connector intended for applying the measured test signal to the unit. The center conductor of the jack is input high and the shell of the jack, which is connected to analog common, is input low (see below). The shell can be floated up to 30V RMS above chassis ground, assuming the grounding switch on the rear panel is in the floating position.

41 **OUTPUT**—OUTPUT provides a composite of the 100kHz or 1MHz (depending on selected frequency), 15mV RMS test voltage and the DC bias voltage, either internal or external **(WARNING: *up to 200V DC may be present between output high and output low when an external bias source is connected and selected).*** The center conductor is high, and the outer shell of the BNC jack is low, and is connected to analog common (see above). Maximum common-mode voltage for OUTPUT is 30V RMS when the rear panel grounding switch is in the floating position.

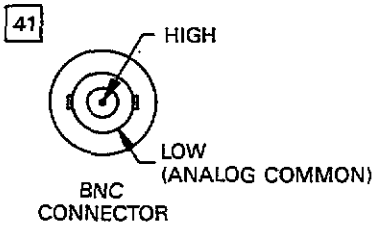



**Figure 2-1D. Model 590 Front Panel (Cont.)**



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## 2.3 REAR PANEL FAMILIARIZATION

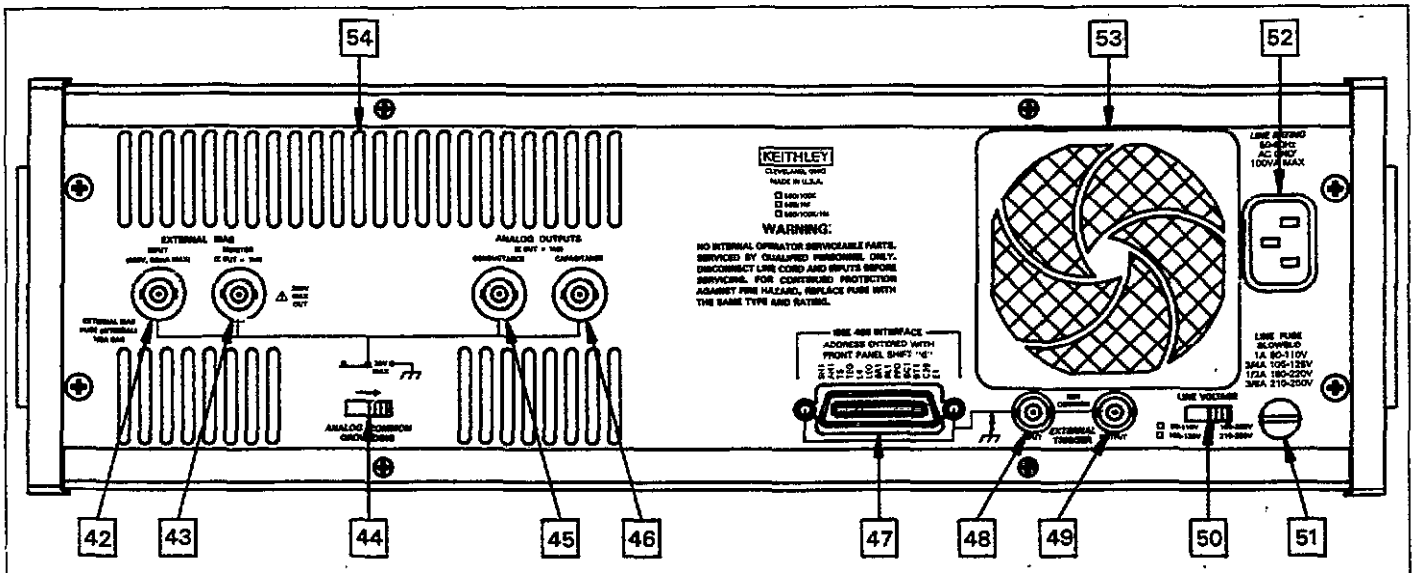
The rear panel of the Model 590 is shown in Figure 2-2, which also gives a brief description of each item. Table 2-2 lists paragraphs in this manual where more detailed information on each subject may be found.

**Table 2-2. Model 590 Rear Panel Cross Reference**

| Item | Description | Paragraph |
|---|---|---|
| 42 VOLTAGE BIAS INPUT | Apply 200V maximum DC bias voltage. | 3.14 |
| 43 VOLTAGE BIAS MONITOR | Monitor internal or external bias voltage. | 3.14 |
| 44 Grounding Switch | Select floating or grounded operation of analog common. | 3.3 |
| 45 CONDUCTANCE | Scaled 0-2V conductance value. | 3.22 |
| 46 CAPACITANCE | Scaled 0-2V capacitance value. | 3.22 |
| 47 IEEE-488 INTERFACE | Interface unit to IEEE-488 bus. | 4.3 |
| 48 EXTERNAL TRIGGER INPUT | Input TTL pulses to trigger readings. | 3.12 |
| 49 EXTERNAL TRIGGER OUTPUT | Output TTL pulses to trigger other instruments. | 3.12 |
| 50 LINE VOLTAGE Selection Switch | Select operating voltage range. | 2.4 |
| 51 LINE FUSE | Protect AC line input. | 7.2 |
| 52 Line Receptacle | Connection for AC input. | 2.4 |
| 53 Fan Filter | Filter cooling air. | 7.8 |
| 54 Exhaust Vents | Exhaust cooling air. | 2.1 |

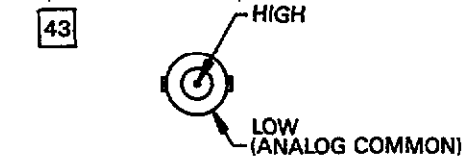


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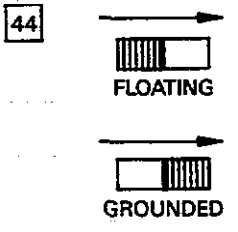

42 **VOLTAGE BIAS INPUT**—This BNC connector is intended to apply external bias voltage up to ±200V DC, 50mA maximum. Note that the input is internally fused to protect the instrument from over current conditions. The voltage applied to BIAS INPUT will be applied to the circuit under test through the OUTPUT jack only when external biasing is selected with the WAVEFORM key and when the bias voltage is turned on (BIAS ON).

43 **VOLTAGE BIAS OUTPUT**—This BNC output jack provides a means to monitor the selected bias voltage (external or internal) applied to the circuit under test. The output resistance is 1kΩ; thus, the input resistance of the monitoring instrument should be greater than 100kΩ to minimize the effects of loading.




VOLTAGE BIAS AND ANALOG OUTPUT BNC JACKS

44 **GROUNDING SWITCH**—The position of this switch controls floating or grounded operation of the following jacks: OUTPUT, INPUT, VOLTAGE BIAS INPUT, VOLTAGE BIAS OUTPUT, and the two ANALOG OUTPUT jacks. When the switch is in the floating position, the outer rings of these jacks can be floated up to 30V RMS above ground. When the switch is in the grounded position, the rings are connected to chassis ground.




45 **CONDUCTANCE ANALOG OUTPUT**—This output jack provides a scaled voltage proportional to the conductance reading. The range of the output is 0-2V, full scale. For example, the nominal output value will be 1V with a 10μS reading on the 20pF/20μS range. Output impedance is 1kΩ.

46 **CAPACITANCE ANALOG OUTPUT**—This BNC jack provides a scaled output voltage that is proportional to the capacitance reading. The output range of the CAPACITANCE output is 0-2V full scale. For example, the nominal output voltage with a 140pF reading on the 200pF/200μS range will be 1.4V. Output impedance is 1kΩ.

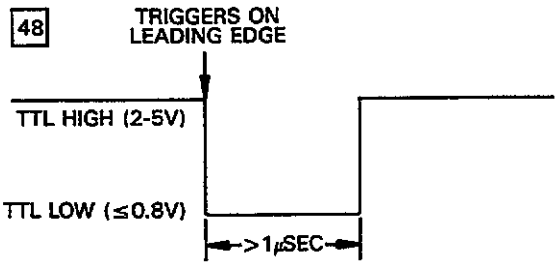
**Figure 2-2. Model 590 Rear Panel**



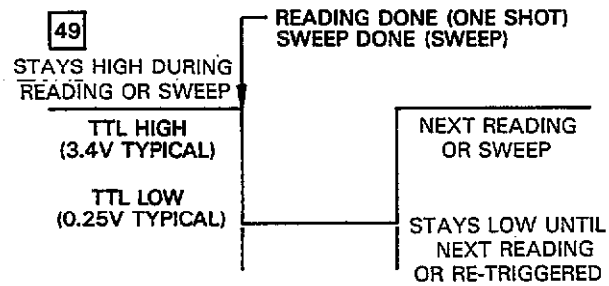
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47 **IEEE-488 INTERFACE**—This connector provides a means to interface the Model 590 to the IEEE-488 bus. When connected to a controller, instrument operating modes can be programmed over the bus. CV plots can also be generated via the bus when the instrument is used in conjunction with an HP7470A or similar digital plotter. IEEE-488 interface function codes are marked adjacent to the connector.

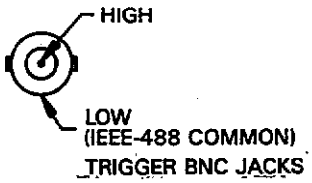
48 **EXTERNAL TRIGGER INPUT**—EXTERNAL TRIGGER INPUT is a BNC jack to be used for applying a trigger pulse to initiate a one-shot or sweep reading, depending on the trigger mode programmed with the TRIGGER MODE key. Note that external trigger must be enabled, also with the MODE key. Inputs to this jack must be TTL-compatible, negative-going pulses with a duration greater than 1μsec. The center conductor is high and the outer ring, which is connected to IEEE common is low, as shown below.




49 This BNC jack provides a TTL-compatible, negative-going pulse when the instrument completes a one-shot reading or reading sweep, depending on the selected trigger mode. The center conductor is high, and the outer ring is low (see above).

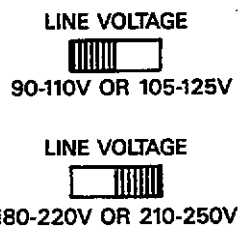



49




50 **LINE VOLTAGE SELECTION SWITCH**—The position of this switch determines the operating voltage range of the instrument: 105-125V or 210-250V (a special transformer is available for 90-110V and 180-220V ranges). The factory voltage range is marked below the switch. **CAUTION: Do not operate the instrument on a line voltage outside the indicated range, or instrument damage may occur.**

50




51 **LINE FUSE**—The line fuse protects the AC power line input of the instrument. When replacing the fuse, use only the type and rating specified on the rear panel of the unit. **CAUTION: Replacing the fuse with one that has a larger rating than specified may cause instrument damage.**

52 **AC INPUT RECEPTACLE**—This receptacle is the AC power line input for the unit. Use only the supplied power cord or the equivalent with a properly grounded AC outlet to ensure continued protection against shock hazards.

53 **FAN FILTER**—The fan filter keeps dirt from being drawn into the instrument by the internal cooling fan. The filter opening should be kept free of obstructions to ensure proper instrument cooling. Clean the filter periodically to assure proper air flow (See Section 7).

54 **EXHAUST VENTS**—The exhaust vents direct air from the inside of the instrument under pressure generated by the internal cooling fan. They too must be kept free of obstructions to ensure proper cooling.

**Figure 2-2. Model 590 Rear Panel (Cont.)**



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## 2.4 POWER UP PROCEDURE

The steps in the following paragraphs will take you through the basic procedures for selecting the line voltage, connecting the instrument to line power, and turning on the instrument.

### 2.4.1 Line Voltage Selection

The Model 590 can be operated on line voltages in the range of 105-125V or 210-250V, 50 or 60Hz (a special power transformer can be installed for 90-110V and 180-220V ranges). Before connecting the unit to line power, make sure the line voltage selection switch is in the correct position for the power line voltage in your area. See Figure 2-2 for the location of this switch.

**CAUTION**

**Operating the instrument on a line voltage outside the indicated range may cause damage, possibly voiding the warranty.**

### 2.4.2 Line Power Connections

Using the supplied power cord, connect the instrument to an appropriate 50 or 60Hz AC power source. The female end of the cord connects to the AC receptacle on the rear panel of the instrument. The other end of the power cord should be connected to a grounded AC outlet.

**WARNING**

**The Model 590 must be connected to a grounded outlet in order to maintain continued protection against possible shock hazards. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

### 2.4.3 Power Switch

To turn on the power, simply push in the front panel POWER switch. Power is on when the switch is at the inner position. To turn power off, press POWER a second time.

**NOTE**

Do not press and hold the CAL button during the power up cycle, as doing so will cause the instrument to enter the diagnostic program. Refer to Section 7 for more information. Also, do not press and hold the → key during power up as instrument calibration may be compromised if the CAL switch is in the unlocked position.

### 2.4.4 Power Up Self Test and Display Messages

During the power up cycle, the instrument will perform the following:

1. A RAM and ROM checksum test. If an error is found as the result of one of these tests the instrument will display either all 0s for a ROM failure, or all As for a RAM failure. Either type of error is considered fatal, and the instrument will lock up. Refer to Section 7 for troubleshooting procedures.

   **NOTE**

   If the instrument is still under warranty (less than one year from the date of shipment), and a problem develops, it should be returned to Keithley Instruments, Inc. for repair. See paragraph 1.9 for information on returning the unit.

2. Assuming the unit successfully passes the self test, it will then briefly display the model number and software revision level, as in this example:

   590 REV D14

   In this instance, the software revision level is D1, but your particular instrument may be different. In any case, the software revision level should be recorded in case it becomes necessary to replace one of the ROMs in the future.
3. Next, the programmed primary address will be displayed as in the example below:

   IEEE ADDRESS 15

   In this example, the factory default primary address of 15 is being displayed. The actual displayed address will, of course, depend on the programmed value.
4. Following these display messages, the unit will begin normal operation in accordance with the power up configuration discussed in the following paragraph.

### 2.4.5 Power Up Configuration

After the self testing and power up display messages are completed, the Model 590 will assume specific operating modes. The exact configuration is taken from save/recall position 1. Table 2-3 summarizes the factory default configuration for the unit. Note that many of these may be different if you modify save/recall state 1. See paragraph 3.17 for more details.



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### Table 2-3. Power Up Default Conditions

| Mode | Condition |
|---|---|
| Range | 2nF |
| Frequency* | 100kHz |
| Model | Parallel |
| Filter | On |
| Rate | 10 readings/sec |
| Zero | Off |
| Trigger Mode | Sweep |
| Trigger Source | Front Panel (MANUAL) |
| Bias Source | Off |
| Bias Waveform | DC |
| Start Time | 1msec |
| Stop Time | 1msec |
| Step Time | 1msec |
| First Bias | 0V |
| Last Bias | 0V |
| Bias Step | 0V |
| Default Bias | 0V |
| Count (#readings DC or external) | 450 |
| Plotter Grid Type** | 0 (Full Grid) |
| Plotter Pen Type** | 1 (Pen #1) |
| Plotter Line Type** | 7 (Solid Line) |
| Plotter Label Type** | 0 (Full Labels) |
| Plot Type** | 0 (C vs V) |
| Buffer to Plot** | 0 (Buffer A) |
| XY scaling** | off |
| IEEE Primary Address** | 15 |
| Cable #** | 7 (to front panel) |

*590/100k or 590/100k/1M units

NOTE: This configuration can be altered with SAVE 1 except **. To restore this configuration, use RECALL 0.

### 2.4.6 Warm Up Period

The Model 590 can be used immediately when it is first turned on. Note, however, that the unit must be allowed to warm up for at least one hour to achieve rated accuracy. Note, however, that you must use the CAL key to obtain rated accuracy if the ambient temperature changes by more than 2°C.

## 2.5 BASIC MEASUREMENT TECHNIQUES

The following paragraphs will take you through simple step-by-step procedures to take one-point measurements, obtain simple CV plots, and perform fundamental C vs t measurements. These procedures are intended only to serve as a starting point, and they may not serve your specific needs. Refer to Section 3 for detailed information on making these type of measurements.

### 2.5.1 Test Connections

Use the basic test connections shown in Figure 2-3 for the examples in this section. Paragraph 3.2 covers connecting methods in more detail.



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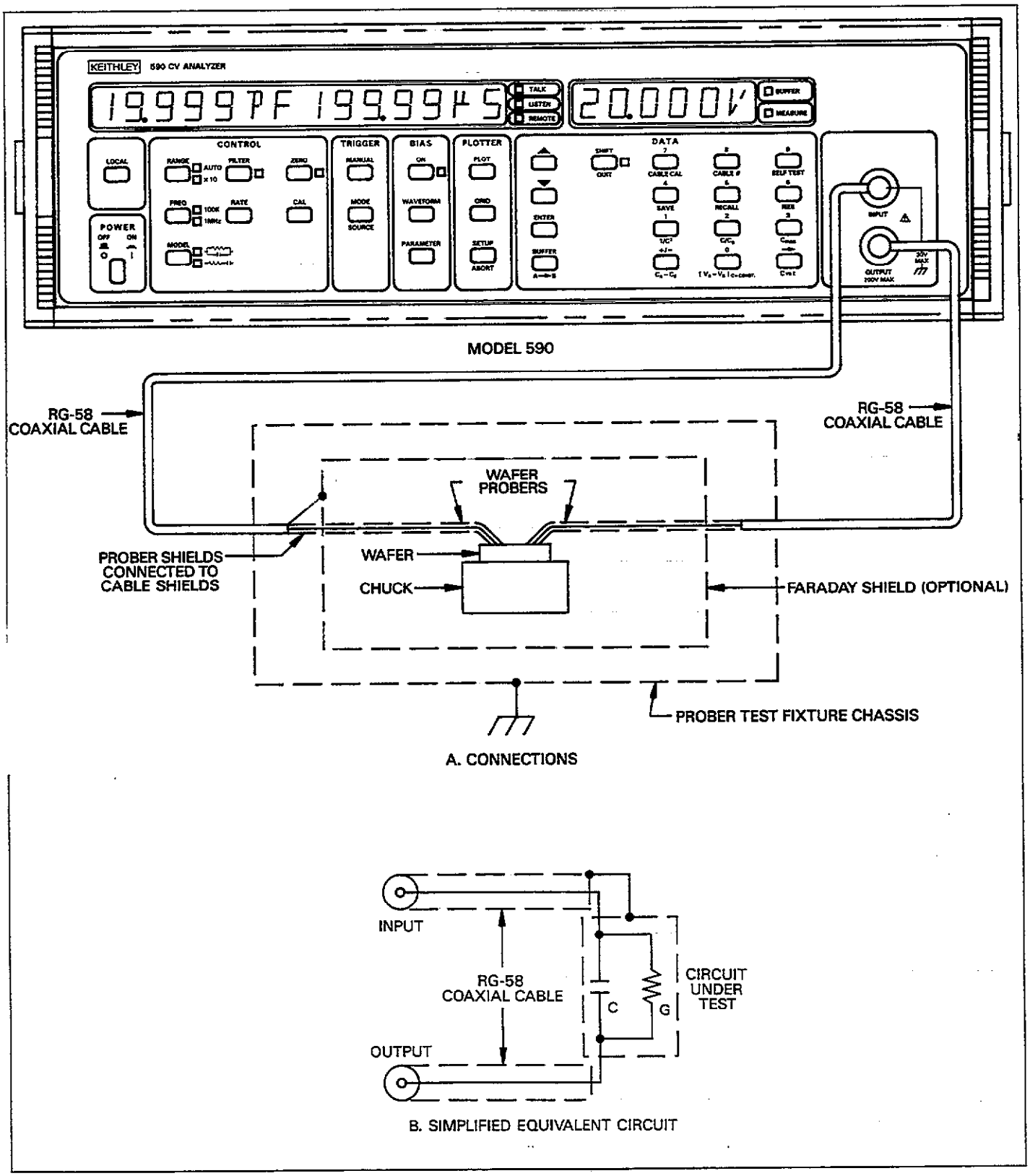



**Figure 2-3. Typical Test Connections**



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**Table 2-4. Initial Control Settings for One Point Measurements**

| Mode | Control | Setting | Comments |
|---|---|---|---|
| Range | RANGE | As required | Use most sensitive range possible |
| Frequency | FREQ | 100kHz or 1MHz | Use cable correction at 1MHz. |
| Model | MODEL | Parallel | Unit always measures using parallel model. |
| Reading Rate | RATE | 1 reading per second | Maximum resolution/minimum noise. |
| Trigger | MODE | 1-shot | Allows display to freeze single measurement. |
| Analog Filter | FILTER | On | Minimize noise |
| Zero Baseline | ZERO | Off | Use only to subtract baseline. |
| Bias Waveform | WAVEFORM | DC | Static bias level for one-point measurement. |
| First Bias | PARAMETER | −20V to +20V | Select desired bias level. |
| Bias Voltage Status | ON | On | Enable bias voltage before measuring. |

## 2.5.2 Basic One-Point Measurements

Ordinarily, the Model 590 would be used to take a number of readings with the resulting data plotted as a group of points. In some instances however, you may wish to take a single reading with or without a specific bias voltage and display the result. Table 2-4 summarizes recommended control settings for basic single-point measurements. Use the basic procedure below to display single-point readings on the front panel.

### Step 1: Select Test Frequency

If your unit is equipped with both 100kHz and 1MHz modules (see rear panel), you can select the test frequency by pressing the FREQ button. Measurements made through cables at 1MHz should use cable correction, as discussed in paragraph 3.21. Cable correction is not necessary when the device under test is connected directly to the front panel test jacks.

### Step 2: Select a Range

Use the RANGE button to select a range consistent with the anticipated measurement, or use autoranging, if desired. For best accuracy, select the most sensitive range possible for the expected capacitance and conductance readings.

### Step 3: Select Parallel or Series Model

The test circuit can be modeled either as a parallel conductance and capacitance, or as a series resistance and capacitance. You can select the display model with the MODEL key. Note that the instrument always measures in parallel form, and the resulting data is internally converted to serial form when that model is selected. The analog output always reflects parallel model.

### Step 4: Select a Reading Rate

Since speed is not generally a requirement for single-point measurements, you would probably use a reading rate of one per second for maximum resolution and minimum noise.

### Step 5: Select the Trigger Mode

To display a single reading, place the instrument in the one-shot trigger mode by pressing the TRIGGER MODE key repeatedly until the 1-SHOT message is displayed. Press ENTER to select the new trigger mode.

### Step 6: Program the DC Bias Source

If you intend to apply a DC bias voltage to your test circuit, use the WAVEFORM key to select a DC bias waveform, then program the first bias voltage with the PARAMETER and data entry keys. The programmable range of the internal bias source is ±20V. Before measuring, turn on the bias source with the BIAS ON key, unless you are not using the bias voltage, in which case you should leave it turned off.

### Step 7: Trigger a Reading

Press the TRIGGER MANUAL key to trigger and display a single set of capacitance, conductance, and bias voltage readings. The reading set will remain on the display until you press MANUAL again to trigger a new set of readings.



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**Table 2-5. Initial Control Settings for Plotting**

| Mode | Control | Setting | Comments |
|---|---|---|---|
| Range | RANGE | As required | Use most sensitive range possible. |
| Frequency | FREQ | 100kHz or 1MHz | Use cable correction at 1MHz. |
| Model | MODEL | Parallel | Unit measures parallel model. |
| Reading Rate | RATE | 10 per second | Best speed-resolution compromise. |
| Analog Filter | FILTER | Off | Not necessary unless readings are noisy. |
| Zero Baseline | ZERO | Off | Use only to subtract baseline. |
| Trigger | MODE | Sweep | One complete reading sweep. |
| Bias Waveform | WAVEFORM | Single staircase | Often used waveform. |
| Bias Start Time | PARAMETER | 1msec | * |
| Bias Stop Time | PARAMETER | 1msec | * |
| Bias Step Time | PARAMETER | 10msec | * |
| First Bias | PARAMETER | −5V | * |
| Last Bias | PARAMETER | +5V | * |
| Step Bias | PARAMETER | 0.1V | * |
| Default Bias | PARAMETER | 0V | * |

*These values depend on required bias parameters.

## 2.5.3 Basic Plotting Techniques

Use the basic procedure below to take a set of data points and graph the results on a plotter. Table 2-5 summarizes control settings for a basic CV plot. This method is usable only with a digital plotter. CV plots can also be obtained by using an X-Y recorder with the analog outputs (see paragraph 3.22).

### Step 1: Connect the Plotter

Connect an HP7470A plotter (or any other similar plotter using HPGL) to the instrument with a suitable IEEE-488 cable.

**NOTE**

When performing stand-alone plotting, the plotter must be in the addressable mode using a primary address of 5. Also, disconnect the controller from the bus when plotting from the front panel.

### Step 2: Select Control Functions

Using the appropriate front panel controls, select the range, test frequency, and model. Select a 10 reading per second rate with the RATE key.

### Step 3: Select the Sweep Trigger Mode

Using the MODE key, select the sweep trigger mode. This mode will allow you to take one complete set of data points for later plotting.

### Step 4: Select the Bias Waveform

Use the WAVEFORM key to select the required type of bias waveform. Typically, you will probably use either the single or dual staircase waveforms.

### Step 5: Program Waveform Parameters

For most waveform types, you can program start and stop hold times; step delay times; and start, stop, and default voltage levels. Each of these parameters can be programmed through use of the PARAMETER and data entry keys. Recommended values for the purposes of this demonstration are listed in Table 2-5. After programming these parameters, make sure the bias voltage is turned on.

### Step 6: Trigger a Reading Sweep

With your circuit connected to the test jacks, press the MANUAL button to trigger a reading sweep. The instrument will cycle through the programmed bias steps, measure the capacitance, conductance, and actual bias voltage values, and store the data in the A/D buffer.



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### Step 7: Place the Data in the Plot Buffer

Before data can be plotted, it should be transferred from the A/D buffer to the plot buffer. To do so, press the A → B (SHIFT BUFFER) button. Once the transfer is complete, you can trigger a new reading sweep without overwriting your old data. Note that this step is not absolutely necessary (since you can plot directly from buffer A), but it is a good idea to transfer data to avoid possibly overwriting it.

### Step 8: View the Data

If desired, you can view data points before plotting by pressing BUFFER. Select buffer B (if transferred in step 7), then use ▲ and ▼ to scroll through data points. Press QUIT to cancel buffer access.

### Step 9: Set Up Plotter Parameters

Use the SETUP key to select the following plotter parameters: grid type, pen type, line type, label type, plot type, buffer, and XY scaling. Table 2-6 lists recommended settings for simple plots. Use the number keys to select the appropriate parameter, then press ENTER after all parameters are programmed.

**Table 2-6. Initial Plotter Set Up**

| Mode* | Parameter** | Description |
|---|---|---|
| Grid Type | 0 | Full Grid |
| Pen Type | 1 | Pen #1 |
| Line Type | 4 | Dash-dot |
| Label type | 0 | Full Labels |
| Plot Type | 0 | C vs V |
| Buffer | 1 | Buffer B |
| X Scale | 0 | Auto scaling |
| Y Scale | 0 | Auto scaling |

*Use SETUP or ▲ / ▼ to scroll through modes.
**Press number key then ENTER to program value.

### Step 10: Plot the Data

To plot your data, press the PLOT key. Data previously placed in the plot buffer will then be graphed. Figure 2-4 shows an example of a graph made in this manner. To stop plotting, press the ABORT key.

### Step 11: Draw the Grid

Make sure that you have paper and proper pens installed in the plotter, then press GRID. The instrument will then command the plotter to draw the grid using previously selected setup parameters.



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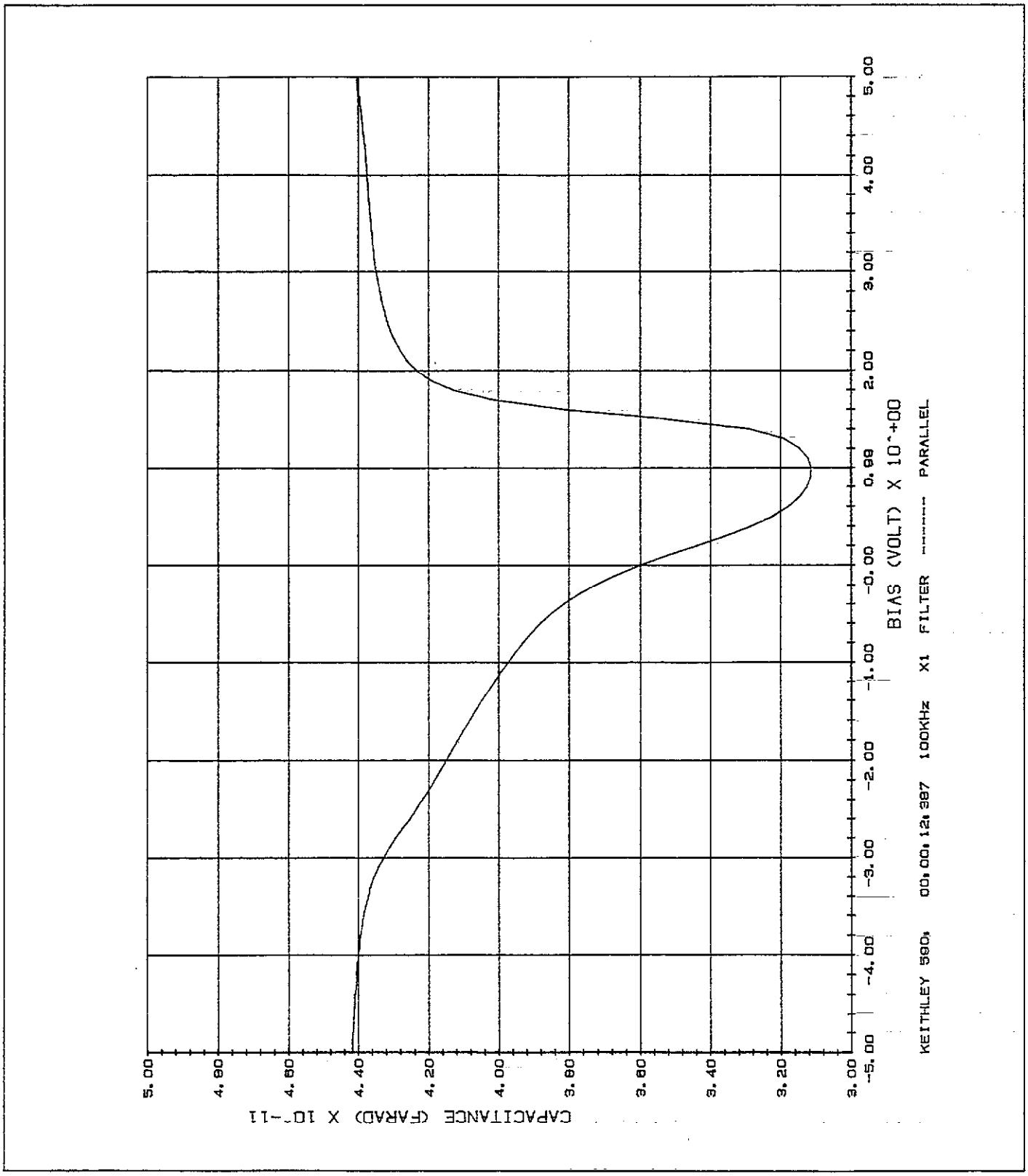



**Figure 2-4. Plotting Example**



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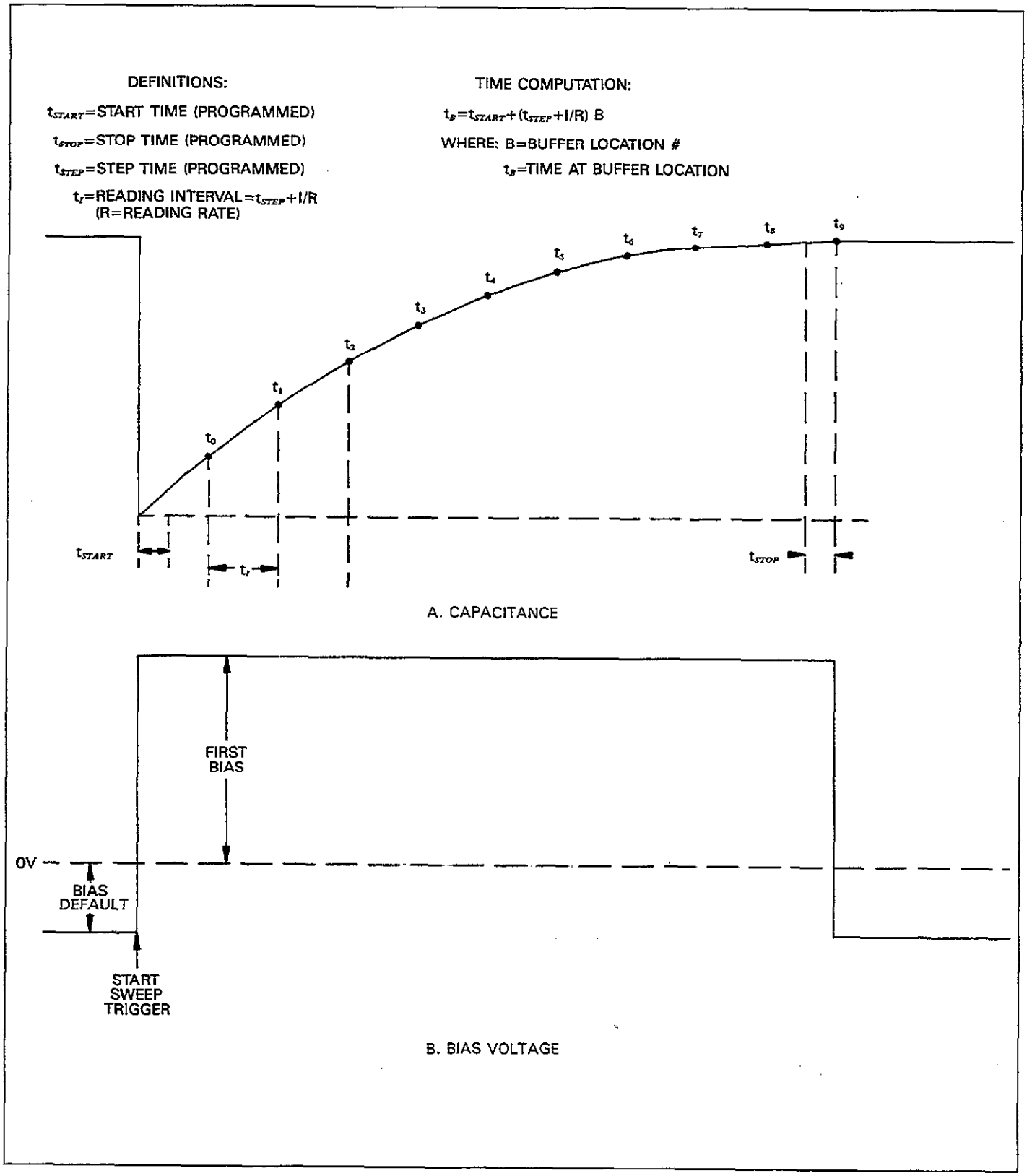



**Figure 2-5. C vs t Waveform**



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**Table 2-7. Basic Settings for C vs t Measurements**

| Mode | Control | Setting | Comments |
|---|---|---|---|
| Range | RANGE | As required | Do not overrange reading. |
| Frequency | FREQ | 100kHz or 1MHz | Use cable correction at 1MHz. |
| Model | MODEL | Parallel | Unit measures parallel model. |
| Reading Rate | RATE | 1000/sec | Fastest rate. |
| Analog Filter | FILTER | Off | Filter increases response time. |
| Zero | ZERO | Off | Use only to subtract baseline. |
| Trigger | MODE | Sweep | One complete sweep. |
| Waveform | WAVEFORM | DC | Single level for C vs t. |
| Start Time | PARAMETER | 1msec | Minimum start time. |
| Stop Time | PARAMETER | 1msec | Minimum stop time. |
| Step Time | PARAMETER | 10msec | Nominal step time. |
| Default Bias | PARAMETER | 0V | * |
| First Bias | PARAMETER | +5V | * |
| Count | PARAMETER | 100 | Select number of readings. |

*These values depend on required bias levels.

## 2.5.4 Fundamental C vs t Measurements

Use the following basic setup procedure for simple C vs t measurements. The procedure assumes that you have a test circuit already connected to the instrument. Table 2-7 summarizes typical control settings for these measurements. Figure 2-5 shows a typical C vs t waveform and also defines certain terms. For complete details on C vs t measurements, refer to paragraph 3.20.

### Step 1: Select Measurement Frequency

If your unit is equipped to measure both at 100kHz and 1MHz, select the desired frequency with the FREQ key.

### Step 2: Select a Range

Use the RANGE key to select the desired measurement range. Be sure to choose a range high enough to handle the largest reading you expect. Autoranging is not recommended for C vs t measurements, especially at the faster reading rates.

### Step 3: Program the Sweep Trigger Mode

Press the MODE key until the SWEEP trigger mode message is displayed. Press ENTER to program the sweep mode.

### Step 4: Select a DC Bias Waveform

Press WAVEFORM repeatedly until you see the DC waveform display message. Press ENTER to program the waveform type.

### Step 5: Select a Reading Rate

Use the RATE key to program the desired reading rate: 1, 10, 75, or 1000 readings per second. Keep in mind that the interval between measurements is the sum of the reading interval (reciprocal of the reading rate) and the programmed step time. For the fastest possible C vs t measurements, select a rate of 1000 readings per second .

### Step 6: Program Bias Waveform Parameters

Using the PARAMETER and data entry keys, program the default bias, first bias, start, stop, and step times. Typically, the default bias is set to zero and the first bias is programmed to the amplitude of the pulse bias step, as shown in Figure 2-5.

The programmed step time depends on the required time interval between measurements (the total time interval is the sum of the step time and the reciprocal of the reading rate). For the fastest possible measurements, program a minimum step time along with the 1000 reading per second rate.



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### Step 7: Trigger a Reading Sweep

Press MANUAL to trigger a reading sweep. The instrument will then perform the sweep and make measurements at the programmed intervals. As measurements are taken, readings will be placed in the A/D buffer for later recall. Note that valid data will not be displayed until the sweep has been completed at the 100 and 1000 reading per second rates.

### Step 8: Transfer Buffer Contents

Press the A → B button (SHIFT BUFFER) to place data just taken into buffer B. Again, this step is not essential, but it is recommended to avoid possible lost data.

### Step 9: Access Buffer Data

Press BUFFER to access data taken during the reading sweep. Select buffer B then use ▲ or ▼ to scroll through the various buffer locations. Note that data for each particular location includes a capacitance, conductance, and bias voltage value (except for the 1000 reading per second rate, which includes only capacitance data).

### Step 10: Display and Compute C vs t Information

Press C vs t to display the reading buffer location numbers. The buffer location will replace the bias voltage information on the display. Use ▲/▼ to scroll through buffer locations and display location information at those points.

Cumulative time at a specific location can be computed as follows:

$$t_B = 1.024\ t_{start} + (1.024\ t_{step} + 1/R)\ (B)$$

Where: $t_B$ = time at a specific buffer location
$t_{start}$ = programmed start time
$t_{step}$ = programmed step time
R = actual reading rate
B = buffer location number
1.024 = multiplier to obtain actual times

Note that the actual (not nominal) rates should be used (see paragraph 3.9).



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# SECTION 3
# OPERATION

## 3.1 INTRODUCTION

This section contains a complete, detailed description of each front and rear panel aspect of the Model 590. The section is arranged as follows:

**3.2 Display Messages:** Lists display messages that may be encountered during front panel operation of the instrument.

**3.3 Test Connections:** Details operation of the test INPUT and OUTPUT jacks on the front panel, and gives an example of typical test connections.

**3.4 Readings and Hardware Control Aspects:** Shows how to interpret both capacitance and conductance readings from the front panel display, and details some aspects of hardware control.

**3.5 Range Selection:** Covers manual and auto range selection, as well as use of the X10 attenuator and optional Model 5904 Adapter to extend the measurement range of the unit to 20nF at 100kHz.

**3.6 Frequency Selection:** Details methods for 100kHz and 1MHz test frequency selection, as well as some precautions necessary when using each frequency.

**3.7 Series/ Parallel Model:** Describes parallel (G and C) and series (C and R) model selection, discusses series-parallel equivalents.

**3.8 Filter:** Covers enabling and disabling the single-pole analog filter and gives a typical response curve.

**3.9 Reading Rate:** Describes selection of the 1, 10, 100, and 1000 reading per second rates from the front panel.

**3.10 Zero:** Gives the basic procedure for using zero to store a reading as a baseline value and then suppress that value from subsequent readings.

**3.11 Drift Correction:** Covers use of the front panel CAL key to perform drift correction using internal capacitance reference standards.

**3.12 Triggering:** Details methods of selecting the trigger source and mode and describes the operation of the rear panel trigger input and output jacks.

**3.13 Data Keys:** Describes the operation of the numeric keypad group for entering such parameters as bias voltages and times.

**3.14 Bias Voltage:** Gives the basic procedure for programming bias waveforms, voltages, and times, as well as the use of the rear panel external bias input and bias monitor output jacks.

**3.15 Buffer Operation:** Outlines methods to access the two 450-word data buffers from the front panel, and how to transfer the contents of buffer A to buffer B.

**3.16 Plotting Data:** Details use of an external intelligent plotter to generate CV and other plots.

**3.17 Save and Recall:** Discusses procedures necessary to save and recall instrument configurations in NVRAM.

**3.18 Self Test:** Outlines the self test program that can help determine if any internal problems are present.

**3.19 Mathematical Functions:** Describes the many mathematical functions that can be used as an aid in analyzing data located in one of the buffers.

**3.20 C vs t Measurements:** Details the procedure and principles behind making capacitance versus time measurements.

**3.21 Cable Correction:** Covers cable correction that should be used to optimize accuracy when making measurements at 1MHz.

**3.22 Analog Outputs:** Details operation of the capacitance and conductance analog outputs, and using an analog plotter.

**3.23 Measurement Considerations:** Discusses some important considerations to take into account when making measurements with the Model 590.

## 3.2 DISPLAY MESSAGES

During Model 590 operation and programming, you will encounter a number of messages on the front panel display. Typical messages will be either of the informational or error variety, as discussed in the following paragraphs.



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**Table 3-1. Error Messages**

| Message | Description | Corrective Action |
|---|---|---|
| —.———pF,—.———μS,—.———V | No valid reading available | Trigger reading |
| OVFL | C, G, or V overrange | Move up range |
| OVERLOAD | Module input overloaded | Move up range |
| CONFLICT | Mode selection conflict, or already plotting | Do not use modes together |
| INVALID | Parameter invalid, or self test error | Program valid parameter |
| NEED 100kHz | 100kHz CV module not installed | Do not select 100kHz module |
| NEED 1MHz | 1MHz CV module not installed | Do not select 1MHz module |
| TRIG-OVERRUN | Unit triggered while processing reading or sweep. | Wait until reading or sweep is done. |
| MULTIPLIER FAIL | Self test indicates multiplier failure | See troubleshooting in |

## 3.2.1 Error Messages

Error messages are those messages which require some form of corrective action on your part in order to properly take a reading or program the instrument. For example, the OVFL message indicates that the capacitance or conductance value being measured is too high for the selected measuring range.

Table 3-1 lists Model 590 error messages. Many of these messages are also covered in pertinent paragraphs of the manual. Where applicable, the necessary corrective action is also given in the table.

## 3.2.2 Informational Messages

Informational messages are included as an aid in programming the unit. No corrective action is necessary in this case, but you may still be required to enter a parameter at the prompt. Table 3-2 lists Model 590 informational messages. Again, most of these are covered in other parts of the manual.



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## Table 3-2. Informational Messages

| Message | | Key(s) | Description |
|---|---|---|---|
| TRIGGER MODE 1-SHOT | | MODE | One reading per trigger |
| TRIGGER MODE SWEEP | | MODE | One sweep per trigger |
| TRIGGER SOURCE FP | | SOURCE | MANUAL button triggering |
| TRIGGER SOURCE EXT | | SOURCE | External trigger pulse triggering |
| TRIGGER SOURCE TALK | | SOURCE | IEEE talk command triggering |
| TRIGGER SOURCE GET | | SOURCE | IEEE GET command triggering |
| TRIGGER SOURCE X | | SOURCE | IEEE X command triggering |
| BIAS WAVEFORM DC | | WAVEFORM | DC bias level |
| BIAS WAVEFORM STAIR | | WAVEFORM | Single staircase bias waveform |
| BIAS WAVEFORM DSTAIR | | WAVEFORM | Dual staircase bias waveform |
| BIAS WAVEFORM PULSE | | WAVEFORM | Pulse bias waveform |
| BIAS WAVEFORM EXT | | WAVEFORM | External bias source |
| START TIME | | PARAMETER | Initial delay at first bias step |
| STOP TIME | | PARAMETER | Final delay after last bias step |
| STEP TIME | | PARAMETER | Delay time for each bias step |
| 1ST BIAS V | | PARAMETER | Initial bias voltage in waveform |
| LAST BIAS V | | PARAMETER | Final bias voltage in waveform |
| STEP BIAS V | | PARAMETER | Bias step size of each bias increments |
| DEFAULT BIAS V | | PARAMETER | Bias voltage before and after sweep |
| GRID TYPE 0-1 | 0 | SETUP | Plotter grid type |
| PEN TYPE 0-2 | 1 | SETUP | Plot pen number |
| LINE TYPE 0-7 | 7 | SETUP | Plotter line type |
| LABEL TYPE 0-3 | 3 | SETUP | Plotter label type |
| PLOT TYPE 0-6 | 0 | SETUP | Plot type |
| BUFFER 0=A 1=B | 0 | SETUP | Buffer to plot |
| X SCALE N=0 Y=1 | | SETUP | X axis scaling |
| Y SCALE N=0 Y=1 | | SETUP | Y axis scaling |
| UPDATE N=0 Y=1 | | CABLE CAL | Update parameter? |
| BUFFER A=0 B=1 | | BUFFER | Buffer selection |
| IEEE ADDRESS | | IEEE | Display IEEE primary address |
| SETUP NUMBER? | | SAVE, RECALL | Setup position to save or recall |
| CABLE NUMBER? | | CABLE # | Cable # to save, recall |
| BUSY | | CAL | Unit performing calibration |
| READING RATE 10 | | RATE | Display/program reading rate |
| SELF TEST | | SELF TEST | Unit running self test |
| CALCULATING DATA | | | Unit computing at end of sweep. |
| DISCONNECT | | FREQ | Test voltages disconnected from test jacks. |

## 3.3 TEST CONNECTIONS

The following paragraphs discuss methods for making the test connections necessary to measure capacitance and conductance with the Model 590. Grounded and floating operation of the test jacks are also covered.

### 3.3.1 BNC Test Jacks

Both test INPUT and OUTPUT are BNC jacks, as shown in Figure 3-1. The center conductor is high, and the outer ring or shell of the jack (connected to analog common) is low.

**WARNING**

**The INPUT and OUTPUT jacks may be floated up to 30V RMS above chassis ground when the rear panel grounding switch is in the floating position. Exceeding this value may create a shock hazard.**



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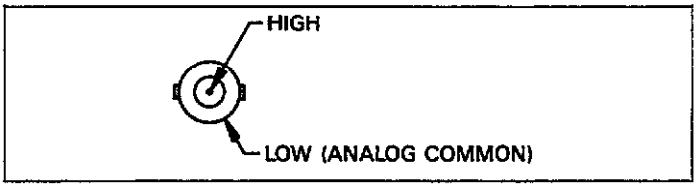



**Figure 3-1. Input and Output Jack Configuration**

## 3.3.2 Typical Test Configuration

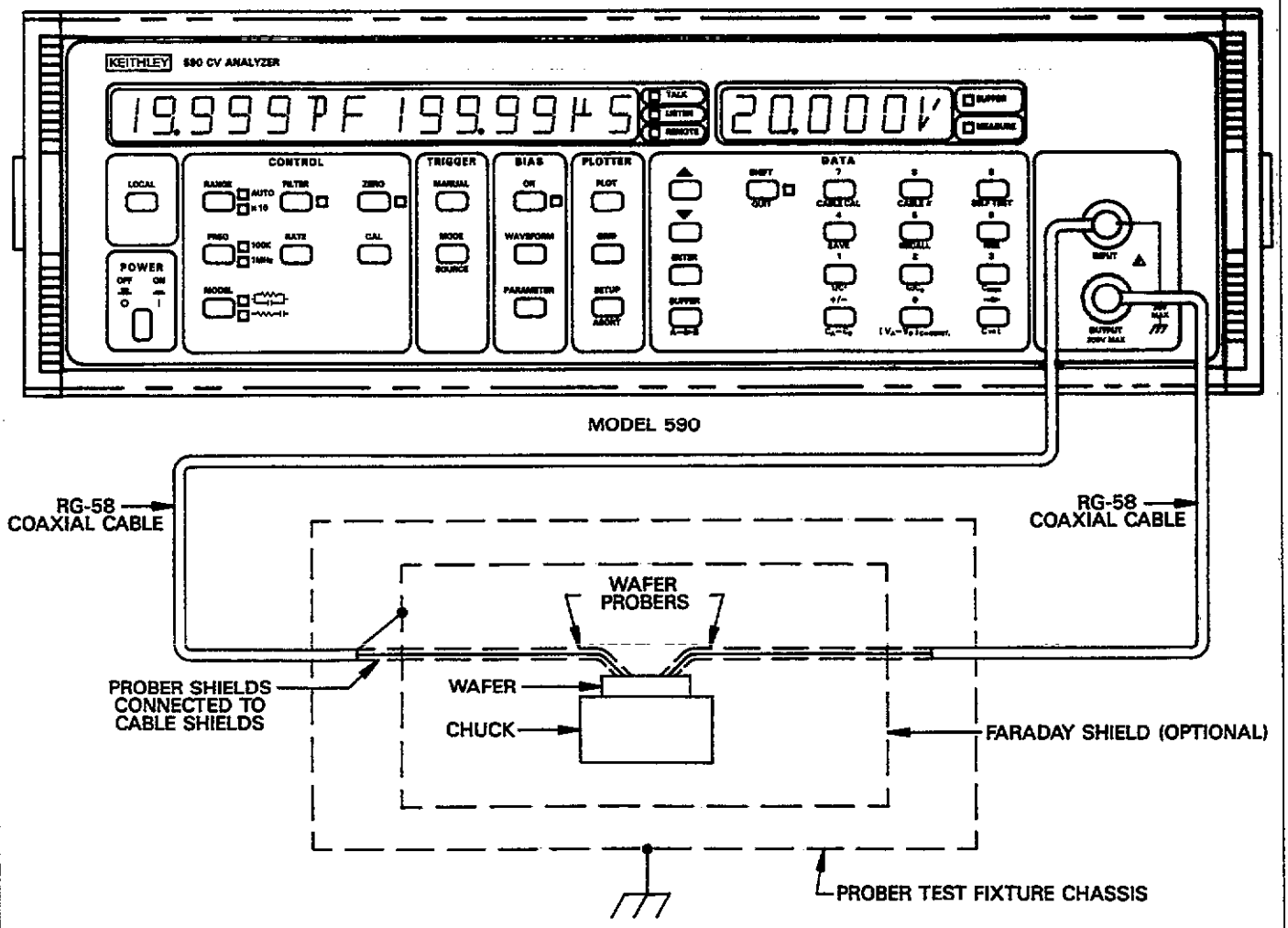
Use the test INPUT along with the test OUTPUT to make measurements, as shown in the typical example of Figure 3-2. Figure 3-3 shows the equivalent circuit of the test setup.

When making measurements, keep the following points in mind:

1. Use only RG-58 type of coaxial cable for both OUTPUT and INPUT. Maximum recommended cable length is five meters. The Keithley Model 7051 cables can be used for connections.
2. When measuring through cables at 1MHz, you should use cable correction to compensate for cable transmission line effects. Paragraph 3.21 covers cable correction programming in detail.
3. The maximum common mode voltage for both the test OUTPUT and INPUT is 30V RMS, 42.4V peak when the rear panel grounding switch is in the floating position. Analog common cannot be floated above ground when the switch is in the grounded position.
4. Excessive shunt capacitance in the cable or test fixture may degrade accuracy of the measurement and increase noise. Consult the specifications for degradation and noise figures.



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**TEST CONNECTION PROCEDURE:**

1. Connect the RG-58 BNC cable between the test OUTPUT and the test input terminal of the test fixture (not supplied).
2. Connect a second RG-58 BNC cable between test INPUT and the output of the test fixture.
3. Select grounded or floating operation with rear panel switch. **(WARNING: maximum common mode voltage is 30V RMS).**
4. Make sure probe shields are carried through as close to the wafer as possible. These shields should be connected to the BNC connecting cable shields.
5. A faraday shield, surrounding the wafer and chuck, incorporated into the test fixture, may be necessary to minimize noise. This shield must be insulated from the prober chassis and connected to analog common via the BNC cable shields.
6. The prober chassis should be connected to earth ground as indicated above.

**Figure 3-2. Typical Test Connections**



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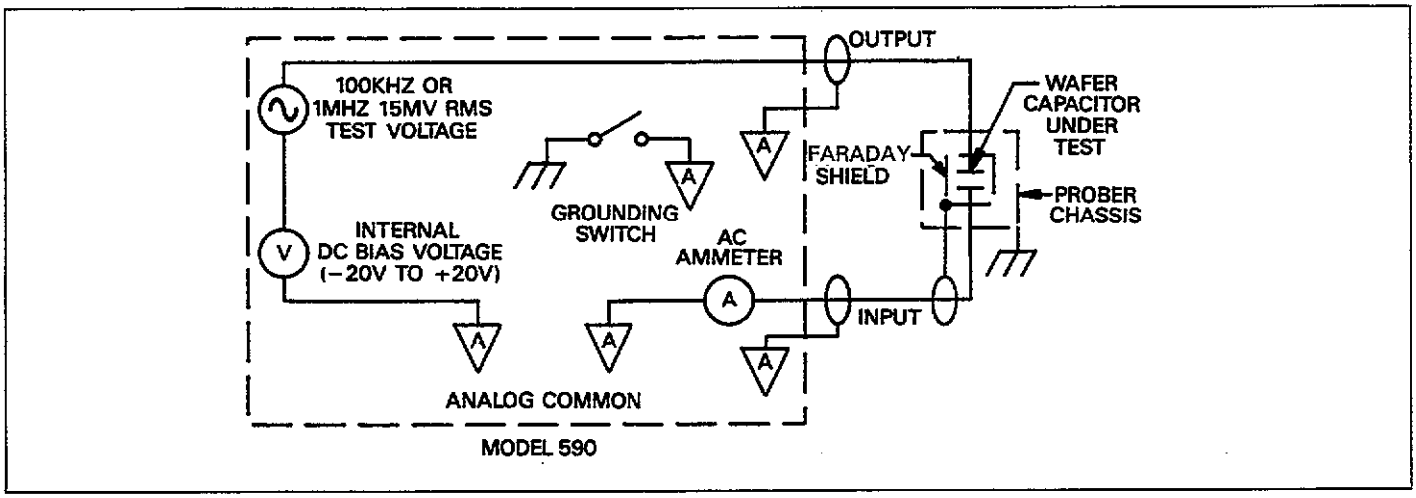



**Figure 3-3. Equivalent Circuit of Test Connections**

## 3.3.3 Grounded and Floating Operation

The outer rings of the TEST INPUT and OUTPUT jacks are connected to analog common, which can either be connected to chassis ground or floated up to 30V RMS above ground potential.

**WARNING**
**Do not exceed 30V RMS, 42.4V peak common mode voltage, or a possible shock hazard may result.**

To select grounded or floating operation, simply place the rear panel grounding switch in the appropriate position, as shown in Figure 3-4. Note that the rear panel BIAS and analog outputs will also be affected by this switch.

Grounded operation can be used in cases where it is not necessary to float analog common or if noise caused by ground loops is not a problem. If analog common must be floated above chassis ground potential, or if ground loop problems occur (as may happen if other, grounded instruments are connected to the test fixture), the instrument should be operated with analog common floating. See paragraph 3.23.1 for a detailed discussion of ground loops.

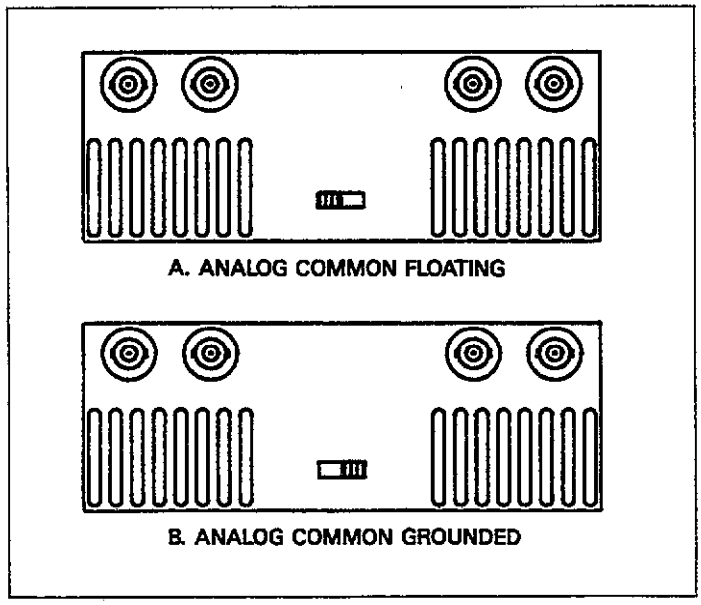



**Figure 3-4. Floating/Grounded Operation of Analog Common**



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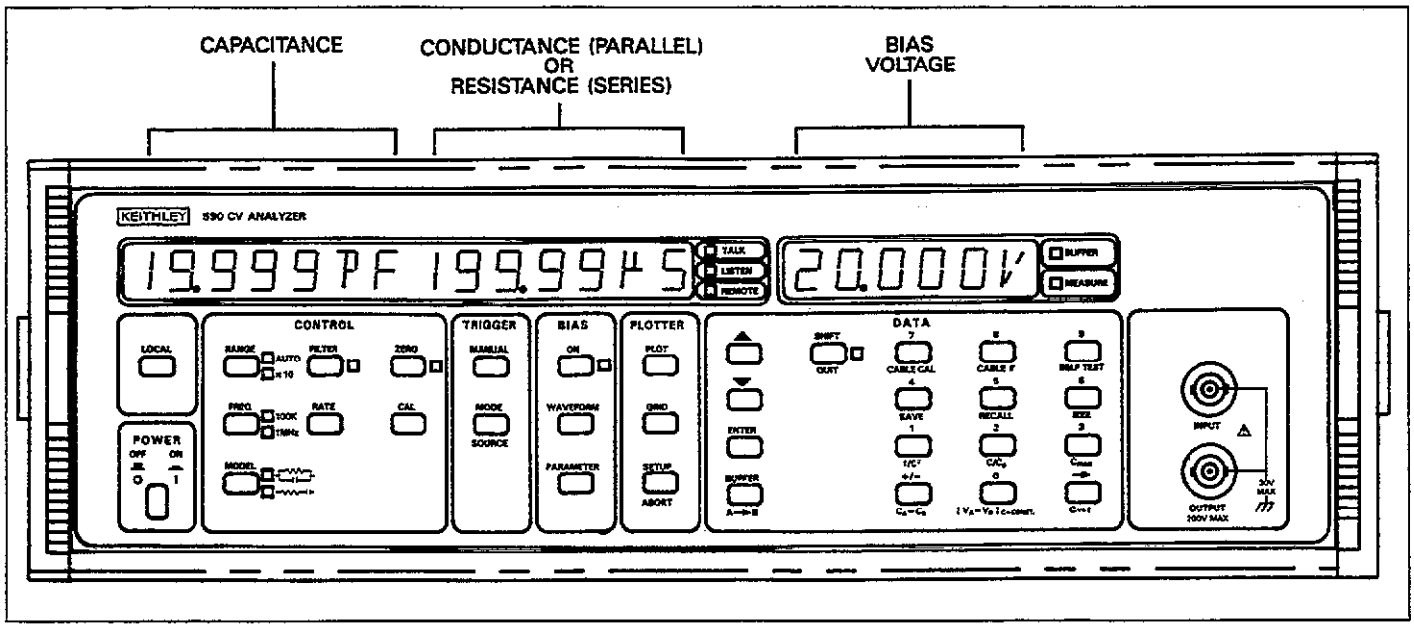



**Figure 3-5. Capacitance, Conductance (Resistance), and Bias Voltage Displays**

## 3.4 READINGS AND HARDWARE CONTROL

The following paragraphs discuss capacitance and conductance readings and some hardware control notes.

### 3.4.1 Capacitance and Conductance Displays

Capacitance and conductance readings are shown on the front panel display, as shown in Figure 3-5. The capacitance reading appears in the left portion of the display, and the conductance reading appears in the right portion of the display. Both readings are a 3½-digit or 4½-digit signed value, depending on the selected reading rate.

The capacitance and conductance displays will show either the current reading, or a reading from one of the buffers, depending on the selected mode. During normal operation, the current reading will be displayed; however, capacitance and conductance readings from buffer A or buffer B will be displayed when you select that option with the buffer key.

The capacitance reading includes capacitance engineering units in pF or nF. 1pF equals $10^{-12}$ farads, while 1nF is $10^{-9}$ farads. Conductance readings are in units of siemens (the siemen is the internationally recognized unit of conductance, replacing the previously used mho). The display will show conductance in µS or mS when parallel model is selected. Note, however, that the unit will display resistance in this position when series model is selected, as discussed in paragraph 3.7.

Note that conductance is simply the reciprocal of resistance and is calculated as follows:

$$G + j\omega C = \frac{1}{R + J\omega C'}$$

Where: G is the conductance in siemens
R is the resistance in ohms
C is the parallel capacitance
C′ is the series capacitance.

NOTES:

1. The display will show dashes in place of numeric values if no valid reading is available. To display readings, trigger the unit with an appropriate trigger stimulus, as determined by the programmed trigger source.
2. The update rate of the displays in the sweep trigger mode depends on the relative reading rate selected with the RATE key. MEASURE indicates the relative reading rate. Only one reading set per trigger stimulus will be displayed in the one-shot trigger mode.



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3. No valid data will be displayed until a sweep is completed at the 75 and 1000 reading per second rates.
4. When BUFFER is on, the unit is displaying buffer location data instead of the current reading.
5. Display resolution is 4½ digits (±20,000 counts nominal) at 1 and 10 readings per second, and 3½ digits (±2,000 counts nominal) at the 75 and 1000 reading per second rates.
6. The actual display count limits are +21,999, −19,999 counts. Note that accuracy above +20,000 counts is typical.
7. Shunt loading and cable correction reduce the dynamic range of capacitance and conductance measurements.

## 3.4.2 Bias Voltage Display

The bias voltage display is located at the right of the front panel, as shown in Figure 3-5. Depending on several factors, this display will show one of the following:

1. The current bias voltage: During normal operation, the unit measures the actual bias voltage applied to the circuit under test through the test OUTPUT jack. If the internal bias source is selected, the display will show the actual bias voltage at that particular waveform step. If external bias is selected, the unit will measure and display that voltage.
2. A buffer bias voltage value: When accessing buffer information (with the BUFFER key), the display will show the voltage bias step that was applied to the test circuit at that particular point in time.
3. Buffer location: When displaying C vs t information, this display will show a particular buffer location number. Time information can be computed from the display as discussed in paragraph 3.21.

NOTES:

1. The voltage display will show dashes when no valid reading is available.
2. The voltage display resolution is 4½ digits (±20,000 counts nominal) at the 1 and 10 reading per second rates, and 3½ digits (±2,000 counts nominal) at the 75 and 1000 per second rates. The display update rate depends on the reading rate (the relative reading rate is indicated by MEASURE). Note however, that no voltage data will be displayed during a reading sweep when the 75 or 1000 reading per second rate is selected.
3. The actual display count limitation is +21,999, −19,999 counts. Accuracy above +20,000 counts is typical.
4. The bias voltage must be turned on in order to read the bias voltage.

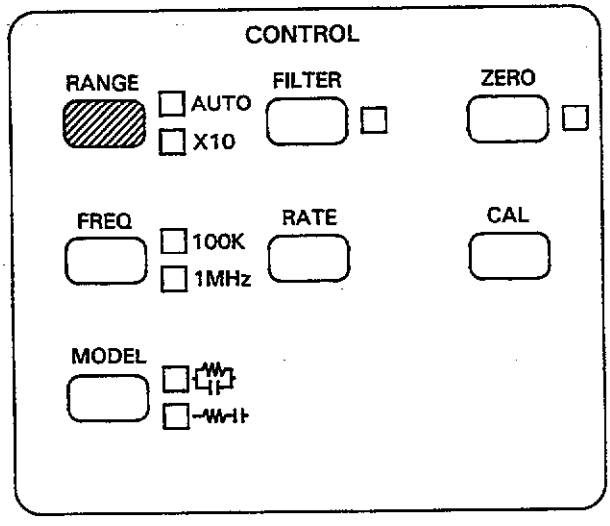
## 3.4.3 Hardware Control Considerations

Those keys which generally affect hardware operation include: RANGE, FILTER, ZERO, FREQ, RATE, and CAL. When using these keys, keep in mind the following points:

1. Changing one of these modes will abort an active sweep.
2. The A/D buffer pointer will be reset and data will be cleared from the A/D buffer (buffer A).

## 3.5 RANGE SELECTION

The following paragraphs discuss manual and auto range selection, as well as the use of the X10 attenuator with optional input transformer to extend the measurement range of the 100kHz module to 20nF.




## 3.5.1 Available Ranges

The available ranges depend on the measurement frequency, as summarized in Table 3-3. Note that the 20nF range is not available when measuring at 1MHz. The optional Model 5904 input transformer must be used in conjunction with the X10 attenuator to extend the 100kHz measurement range to 20nF. Also, there is no 2pF, 1MHz range.

Table 3-3 also shows full scale displayed values for each range. These values show 4½-digit resolution, which is available only at the 1, 10, and 18 per second reading rates (the 18/sec rate is available only over the IEEE-488 bus).



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### Table 3-3. Range Summary

| 100kHz | | 1MHz | |
|---|---|---|---|
| Range | Full Range Reading* | Range | Full Range Reading* |
| 2pF/2μS | 1.9999pF/1.9999μS | | |
| 20pF/20μS | 19.999pF/19.999μS | 20pF/200μS | 19.999pF/199.99μS |
| 200pF/200μS | 199.99pF/199.99μS | 200pF/2mS | 199.99pF/1.9999mS |
| 2nF/2mS | 1.9999nF/1.9999mS | 20pF/200μS | 19.999pF/199.99μS |
| 20nF/20mS** | 19.999nF/19.999mS | — | — |

*4½-digit value for specified accuracy shown. Unit displays 3½ digits with 75 and 1000 per second rates. Maximum display extends to +21,999 counts (+2,199 counts, 3½ digits) with typical accuracy above 20,000 (2,000) counts.

**20nF/20mS range requires 5904 adapter and x10 attenuator, and is not available at 1MHz.

### Table 3-4. Range Error Messages

| Message | Description | Corrective Action |
|---|---|---|
| OVFL | Capacitance or conductance reading overrange | Move up range or apply smaller C or G |
| OVERLOAD | Module input overload | Move up range or apply smaller C or G |
| CONFLICT | X10 attenuator cannot be used at 1MHz | Do not use conflicting modes |

## 3.5.2 Invalid Reading Indications

Basically, there are two conditions that may cause an invalid reading indication. First, either the capacitance or conductance reading (or possibly both) may exceed the count capability of the associated display area. In this case, the display for that parameter will display the following message:

OVFL

To correct this condition, select a higher range.

A more serious situation exists in cases where the input amplifier of the CV module is saturating. In this case, the unit will display the following error message:

OVERLOAD

Module saturation means that the test signal current is too high for the test input amplifier. Under these circumstances, neither the capacitance nor conductance reading is valid due to the non-linear characteristics of the input circuits when saturated.

To correct this error, move the instrument up range until a valid reading is noted by the absence of error messages. Table 3-4 summarizes error messages associated with improper range selection.

NOTES:

1. If an overload error occurs, the unit will cease waveform and buffer activity.
2. An overload condition is not flagged at the analog outputs. An on-range reading may occur at the analog outputs under overload conditions.
3. An overload situation could be caused by an extraneous signal appearing on the test INPUT jack. This signal could come from external RFI or EMI sources not associated with the 100kHz or 1MHz test frequencies, or the DC bias voltage.



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### 3.5.3 Manual Range Selection

To select ranges manually, simply press the RANGE button briefly (< ½ second) to move the instrument up range. Each time you press RANGE, the instrument will move up one range. Once the highest range is reached, the unit will switch to the lowest range the next time you press RANGE briefly.

Pressing RANGE briefly will also cancel autorange, if that mode is presently enabled. In this case, the unit will stay on the presently selected range.

NOTES:

1. Better overall accuracy and resolution can be obtained by using the lowest range possible for the measured capacitance and conductance.
2. Since capacitance and conductance ranges are paired together, it may be necessary to measure the capacitance or conductance on a less than optimum range in order to keep both readings on scale.

### 3.5.4 Using Autoranging

The Model 590 has a convenient autoranging feature which simplifies range selection. To enable autoranging, simply press and hold the RANGE button for more than one-half second. The instrument will then go into the autorange mode, as indictated by the AUTO LED. To cancel autoranging, briefly press the RANGE button a second time. The instrument will then stay on the presently selected range.

Keep in mind that autoranging is included for convenience only and should not be used for critical measurements because of possible effects on the readings.

Figure 3-6 shows a flow chart of autoranging operation.

NOTES:

1. Accuracy with other ranges than 20nF with the X10 adapter is not specified. Therefore, the use of autoranging with the Model 5904 X10 adapter is not recommended.
2. When taking data with rapidly changing bias waveforms, manual ranging should be used to ensure consistent timing for each point. Measurement time can vary widely during autoranging.
3. The instrument will not autorange into the X10 mode.
4. Autoranging cannot be used with the 75 and 1,000 per second reading rates. The unit will generate a CONFLICT error under these conditions.

### 3.5.5 Using the 20nF/20mS Range

By using the internal X10 attenuator in conjunction with the optional Model 5904 20μF/20mS Adapter, the 100kHz measurement range of the Model 590 can be extended to 20nF, as described below.

**X10 Attenuator**

Use the procedure below to enable the X10 attenuator.

1. Connect the Model 5904 20μF/20mS Adapter to the test jacks (see below).
2. Using the RANGE key, place the instrument on the 2nF (highest range).
3. Select a measurement frequency of 100kHz with the FREQ key.
4. Press SHIFT RANGE to enable the attenuator. The X10 LED next to the RANGE key will illuminate to indicate that the instrument is in that mode.
5. Take the readings from the display. The instrument will automatically scale the readings and display the proper values.
6. To disable the X10 attenuator, press SHIFT RANGE a second time.

NOTES:

1. The X10 attenuator is intended for use with the optional Model 5904 20μF/20mS Adapter (see below). Since the instrument has no way of sensing if the adapter is connected, incorrect readings will result if you enable the X10 attenuator without connecting the adapter, or use the input adapter without the X10 attenuator enabled.
2. The X10 attenuator may be used with other ranges, if desired, but accuracy for those ranges is not specified. The instrument will automatically scale the reading to reflect the X10 attenuation factor. In this situation, the available ranges will be 20pF/20μS, 200pF/200μS, 2nF/2mS, and 20nF/20mS. The unit can be calibrated for Model 5905 used on the 20pF through 2nF ranges, if desired. See paragraph 7.3.
3. The X10 attenuator is not available for use at 1MHz. The following message will be displayed if you attempt to enable the attenuator with a 1MHz test frequency selected, or if you attempt to enable to select a 1MHz test frequency with the X10 attenuator enabled:

CONFLICT



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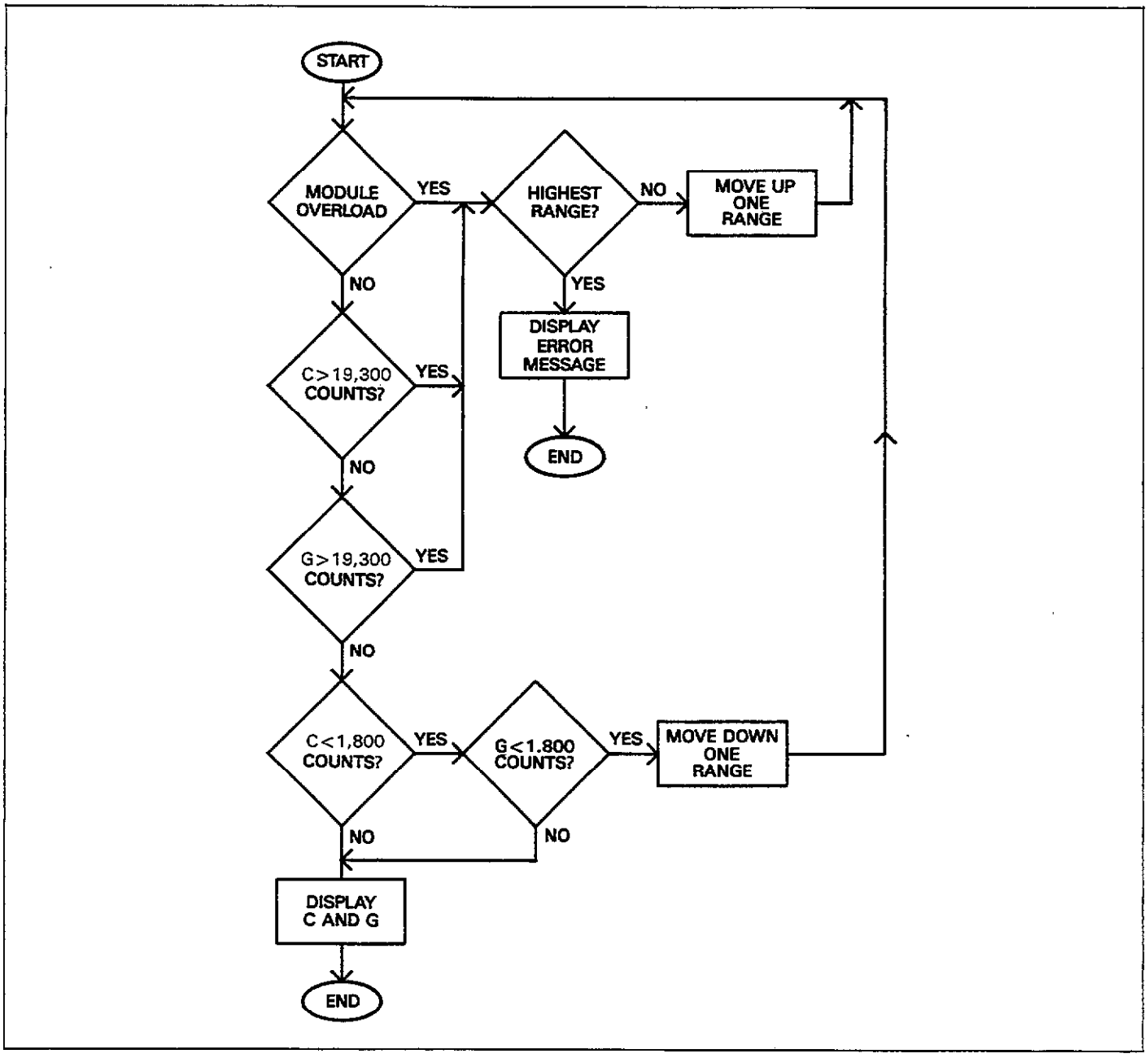



**Figure 3-6. Flow Chart of Autoranging Operation**

4. The Model 5904 must be calibrated with a particular Model 590 to achieve stated front panel accuracy.

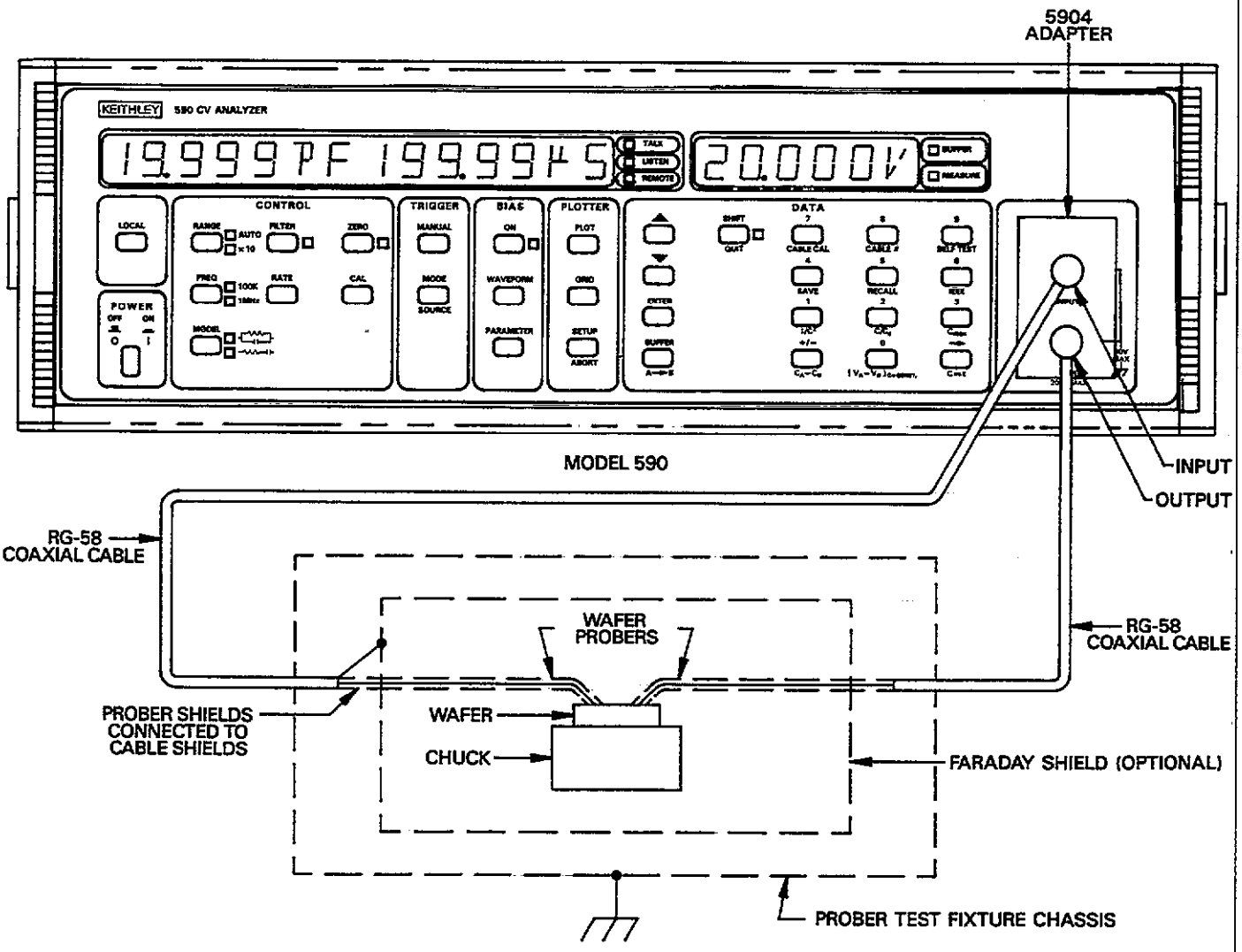
### Input Transformer Connections

Figure 3-7 shows typical connections when using the Model 5904 Input Transformer. Keep the following points in mind when configuring your test setup.

1. Use only RG-58 type coaxial cable to make the test connections. Maximum recommended cable length is five meters.
2. The maximum common-mode voltage for floating operation is 30V RMS, 42.4V peak.
3. Excessive shunt capacitance will degrade accuracy and increase noise.



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**TEST CONNECTION PROCEDURE:**

1. Mount the Model 5904 adapter on the test OUTPUT and INPUT jacks. Be sure not to install the adapter upside down.
2. Connect an RG-58 BNC cable between the test output of the adapter and the test input of the test fixture.
3. Connect a second RG-58 BNC cable between the test fixture output and the test input of the adapter mounted on the instrument.
4. Select grounded or floating operating with the rear panel switch. **(WARNING: maximum common mode voltage is 30V RMS.)**
5. Probe shields, connected to cable shields, should be carried through as close to the wafer as possible.
6. A faraday shield may be necessary to minimize noise. This shield must be insulated from the prober chassis and connected to analog common via the cable shields.
7. The prober shield should be connected to earth ground as indicated above.

**NOTE**

Enable the X10 attenuator (SHIFT RANGE) when using the input adapter or else reading scaling will be off by a factor of 10.

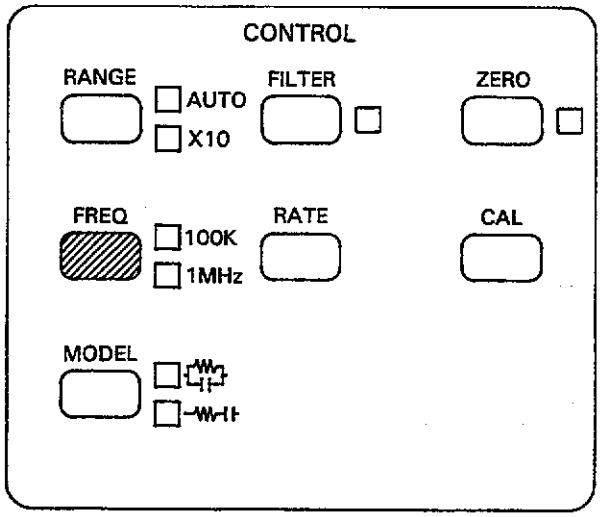
**Figure 3-7. Typical Test Connections Using Model 5904 20μF/20mS Adapter**



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## 3.6 FREQUENCY SELECTION

An internal signal source supplies a 100kHz or 1MHz, 15mV RMS test voltage. Available frequencies as well as the frequency selection procedure are covered below.




### 3.6.1 Frequencies Available by Model

There are three available models of the 590. The Models 590/100k and 590/1M supply test voltages at frequencies of 100kHz and 1MHz respectively. The Model 590/100k/1M will operate at either 100kHz or 1MHz. Table 3-5 summarizes the available models, installed modules, and test frequencies. Available test frequencies are marked on the rear panel.

**Table 3-5. Test Voltage Frequency by Model**

| Model | Test Voltage(s) |
|---|---|
| 590/100k | 100kHz, ±0.1%; 15mV RMS*, ±10% |
| 590/1M | 1MHz, ±0.1%; 15mV RMS,* ±10% |
| 590/100k/1M | 100kHz, 1MHz, ±0.1%; 15mV RMS*, ±10% |

*Open circuit value

### 3.6.2 Test Voltages

The nominal test output voltage for both 100kHz and 1MHz is 15mV RMS, with a tolerance of ±10%. The frequency accuracy of both the 100kHz and 1MHz test voltages is ±0.1%.

### 3.6.3 Selecting a Frequency

If your instrument is equipped for 100kHz and 1MHz operation, you can select the desired operating frequency simply by pressing the FREQ button. Doing so will cause the unit to change to the other frequency, as indicated by the associated LED. Pressing FREQ again will select the disconnect mode, as discussed in paragraph 3.6.5.

Figure 3-8 shows a flowchart outlining frequency selection.

NOTES:

1. Cable correction should be used when measuring through cables at 1MHz. See paragraph 3.21 for more information.
2. The 2pF range is not available at 1MHz.

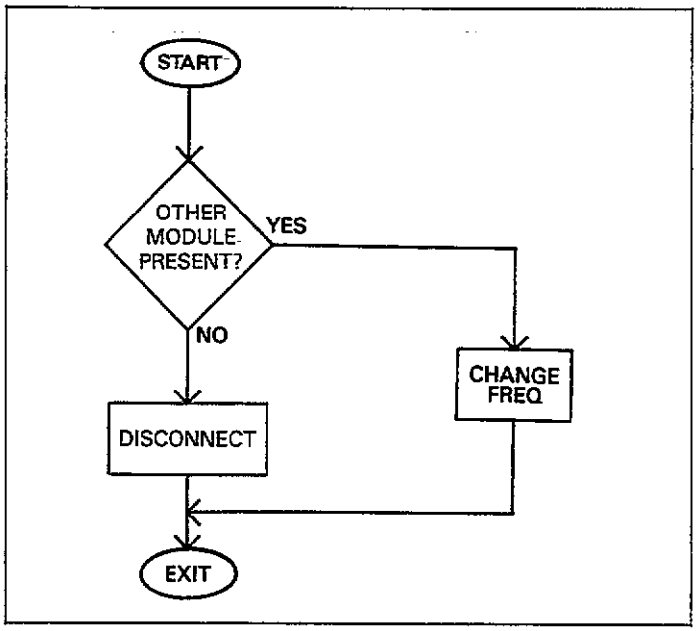



**Figure 3-8. Frequency Selection Flow Chart**



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### 3.6.4 Frequency Error Messages

Error messages associated with frequency selection are summarized in Table 3-6.

**Table 3-6. Frequency Error Messages**

| Message | Description |
|---|---|
| NEED 100k | 100kHz module not installed |
| NEED 1M | 1MHz module not installed |
| CONFLICT | X10 attenuator enabled when selecting 1MHz, or CAL or CABLE CAL pressed in disconnect |

### 3.6.5 Disconnecting the Test Voltage

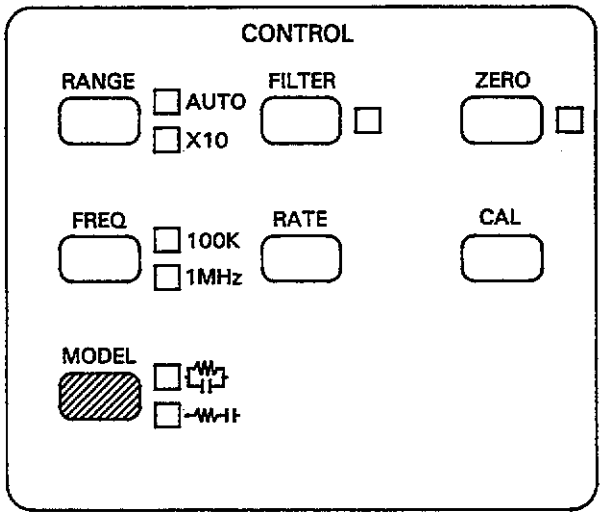
A second feature of the FREQ key allows you to disconnect the test and bias voltages from the device under test without having to remove the connecting cables attached to the test INPUT and OUTPUT jacks. To disconnect the voltages simply press FREQ until the DISCONNECT message is displayed. Internal relays will then disconnect the test and bias voltages from the front panel test INPUT and OUTPUT jacks, allowing the center conductors of these jacks to float. In addition to the DISCONNECT messages, both the 100kHz and 1MHz LEDs will turn off while the unit is in the disconnect mode. To return to normal operation, simply press FREQ again.

NOTES:

1. Calibration, pressing, CAL, or CABLE CAL are illegal when the unit is in disconnect; the instrument will display a CONFLICT message under these conditions.
2. The first trigger received while in disconnect will be ignored, but the second trigger will cause a trigger overrun condition.
3. No valid data will be stored or be made available over the bus while in the disconnect mode.

## 3.7 SERIES/PARALLEL MODEL

The following paragraphs cover measurement model, how to select the model, and discuss series-parallel equivalents.




### 3.7.1 Measurement Model

The Model 590 measures the capacitance, C, and the conductance, G, of an equivalent parallel circuit connected between the test OUTPUT and test INPUT jacks. Figure 3-9 shows an equivalent circuit of the test configuration.

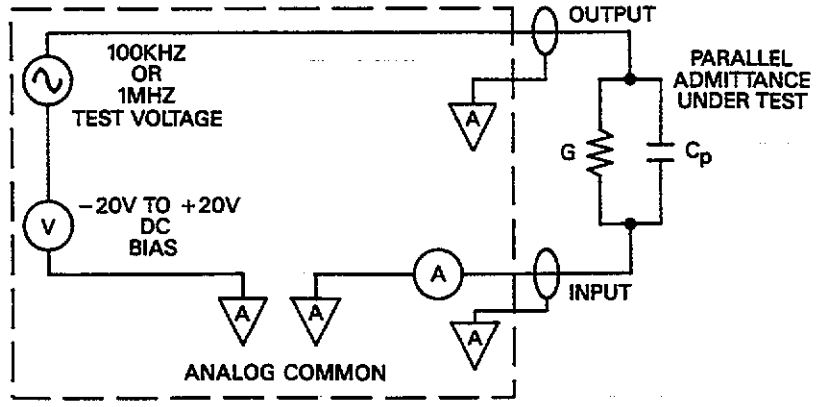



**Figure 3-9. Equivalent Circuit of Parallel Capacitance and Conductance**



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## 3.7.2 Model Selection

To alternate between series and parallel models, press the MODEL key on the front panel. One of the associated LEDs will indicate whether series or parallel model is in effect. When the series model is in effect, the unit mathematically converts parallel measured data to serial form (data is always stored internally in parallel form).

NOTES:

1. Buffer data is always stored in parallel form. Series conversion is performed when buffer data is displayed, if that model is selected.
2. The analog outputs are always in parallel form.

## 3.7.3 Conductance and Resistance Ranges

With a parallel model, the unit displays conductance. With a series model, however, the unit displays resistance. Equivalent full range conductance and resistance ranges for both frequencies are shown in Table 3-7.

## 3.7.4 Series and Parallel Equivalent Circuits

A complex impedance can be represented by a simple series or parallel equivalent circuit made up of a single resistive element and a single reactive element, as shown in Figure 3-10. In the parallel form of (a), the resistive element is represented as the conductance, G, while the reactance is represented by the susceptance, B. The two together mathematically combine to give the admittance, Y, which is simply the reciprocal of the circuit impedance.

In a similar manner, the resistance and reactance of the series form of (b) are represented by R and X, respectively. The impedance of the series circuit is Z.

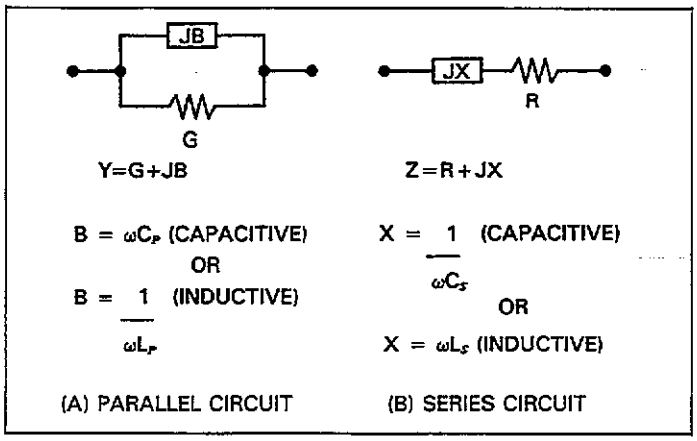



**Figure 3-10. Series and Parallel Impedances**

The net impedances of the equivalent series and parallel circuits at a given frequency are equal. However, the individual components are not. We can demonstrate this relationship mathematically as follows:

$$R + jX = \frac{1}{G + jB}$$

To eliminate the imaginary form in the denominator of the right-hand term, we can multiply both the denominator and numerator by the conjugate of the denominator as follows:

$$R + jX = \frac{1}{G + jB} \times \frac{G - jB}{G - jB}$$

**Table 3-7. Resistance and Conductance Ranges**

| 100kHz | | 1MHz | |
|---|---|---|---|
| **Parallel Range** | **Series Range** | **Parallel Range** | **Series Range** |
| 2pF/2μS | 2pF/2MΩ | | |
| 20pF/20μS | 20pF/200kΩ | 20pF/200μS | 20pF/200kΩ |
| 200pF/200μS | 200pF/20kΩ | 200pF/2mS | 200pF/20kΩ |
| 2nF/2mS | 2nF/2kΩ | 2nF/20mS | 2nF//2kΩ |
| 20nF/20mS* | 20nF/200Ω* | | |

*5904 and X10 attenuator required.



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Performing the multiplication and combining terms, we have:

$$R + jX = \frac{G - jB}{G^2 + B^2}$$

If we assume the reactance is capacitive, we can substitute $-1/\omega C_s$ for the reactance and $\omega C_p$ for the susceptance ($C_s$ is the equivalent series capacitance, and $C_p$ is the equivalent parallel capacitance). The above equation then becomes:

$$R - j\frac{1}{\omega C_s} = \frac{G - j\omega C_p}{G^2 + \omega^2 C_p^2}$$

In a lossless circuit (R and G both 0), $C_p$ and $C_s$ would be equal. A practical circuit, however, does have loss because of the finite values of R or G. Thus, $C_s$ and $C_p$ are not equal--the greater the circuit loss, the larger the disparity between these two values.

Series and parallel capacitance values can be converted to their equivalent forms by taking into account a dissipation factor, D. D is simply the reciprocal of the Q of the circuit. For a parallel circuit, the dissipation factor is:

$$D = \frac{1}{Q} = \frac{G}{\omega C_p}$$

For the series circuit, the dissipation factor is defined as:

$$D = \frac{1}{Q} = \omega C_s R$$

By using the dissipation factor along with the formulas summarized in Table 3-8, you can convert from one form to another. Note that $C_s$ and $C_p$ are virtually identical for very small values of D. For example, if D is 0.01 $C_s$ and $C_p$ are within 0.01% of one another.

Example:

Assume that we make a measurement on a parallel equivalent circuit and obtain values for $C_p$ and G of 160pF and 30$\mu$S respectively. From these values, we can calculate the dissipation factor, D, as follows:

$$D = \frac{30 \times 10^{-6}}{2\pi(100 \times 10^3)(160 \times 10^{-12})}$$

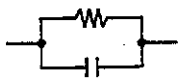
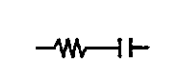
$$D = 0.3$$

The equivalent series capacitance is then calculated as follows:

$$C_s = (1 + 0.09)\ 160pF$$

$$C_s = 174.4pF$$

## Table 3-8. Converting Series-Parallel Equivalent Circuits

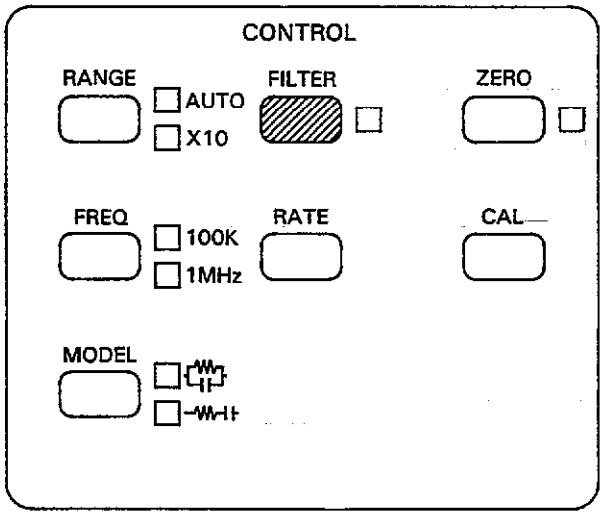
| Model | Circuit | Dissipation Factor | Capacitance Conversion | Resistance Conductance Conversion |
|---|---|---|---|---|
|  | Parallel $C_p$, G | $D = \frac{1}{Q} = \frac{G}{\omega C_p}$ | $C_s = (1+D^2)\ C_p$ | $R = \frac{D^2}{(1+D^2)G}$ |
|  | Series $C_s$, R | $D = \frac{1}{Q} = \omega C_s R$ | $C_p = \frac{C_s}{1 + D^2}$ | $G = \frac{D^2}{(1+D^2)R}$ |



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## 3.8 FILTER

The analog filter can be used to minimize the amount of noise appearing in the displayed readings, and at the analog outputs. The following paragraphs describe control of the analog filter; a typical filter response curve is also given.




### 3.8.1 Filter Control

To enable or disable the analog filter, simply press the FILTER key on the front panel. The on/off status of the filter is indicated by the associated LED.

NOTES:

1. The analog filter increases instrument response time to changes in input signals for the conductance and capacitance readings. Thus, inaccurate readings may result if the filter is used while measuring with rapidly changing bias waveforms. Table 3-9 summarizes nominal response times to various percentage of final values.
2. The effects of the analog filter are reflected at the capacitance and conductance analog outputs on the rear panel of the instrument.
3. The analog filter has no effect on the voltage bias reading.
4. Pressing FILTER will abort a sweep.

**Table 3-9. Typical Filter Response Times**

| Percent of Final Reading | Typical Filter Response |
|---|---|
| 10% | 10msec |
| 1% | 20msec |
| 0.1% | 30msec |
| 0.01% | 40msec |

### 3.8.2 Typical Filter Response

A typical response curve for the single-pole analog low-pass filter is shown in Figure 3-11. Note that the filter response rolls off at 6dB per octave (20dB per decade) above the −3dB point of approximately 37Hz.

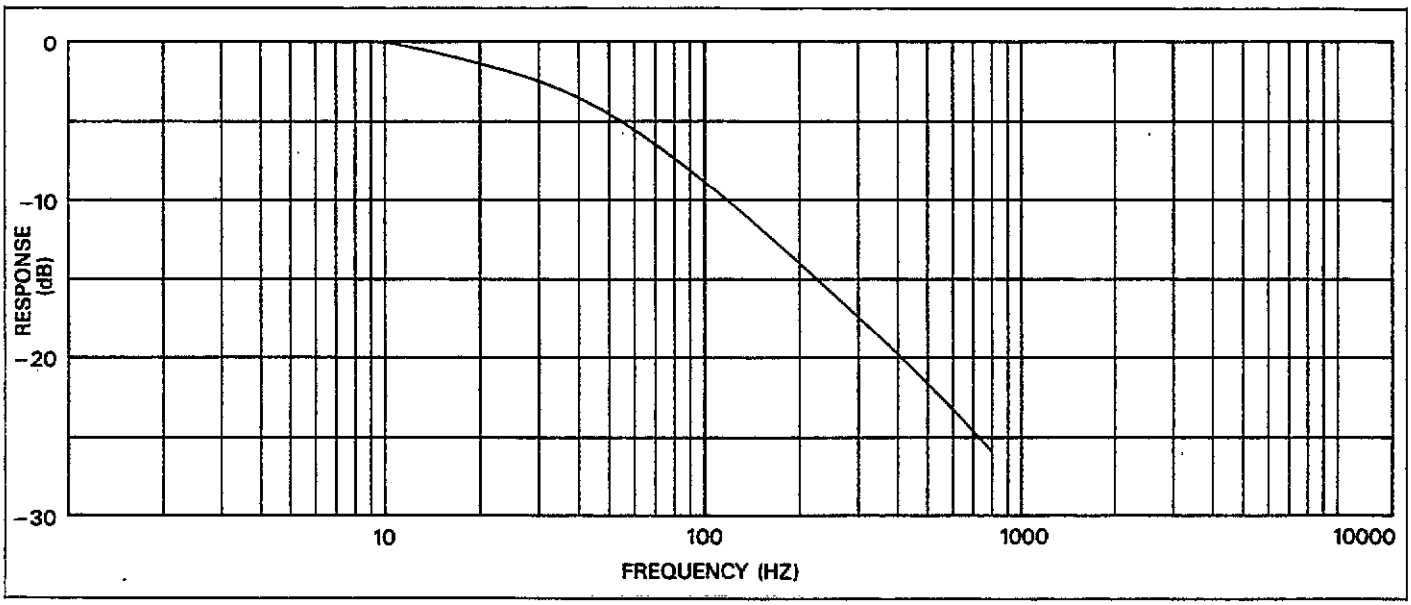



**Figure 3-11. Typical Analog Filter Response**



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### 3.8.3 Using the Filter

Noise in the reading is usually seen as an unsteady display value that jumps around. In this situation, it is generally beneficial to leave the filter enabled to stabilize the readings. However, using the filter with rapidly changing waveforms can degrade accuracy because of increased response time, as indicated above.

If additional filtering is required, use a reading rate that incorporates digital filtering, as discussed in paragraph 3.9.

## 3.9 READING RATES

From the front panel, you can select reading rates of 1, 10, 75, or 1000 readings per second. A fifth rate, which is available only over the IEEE-488 bus, produces 18 readings per second with 4½-digit display resolution.

**NOTE**

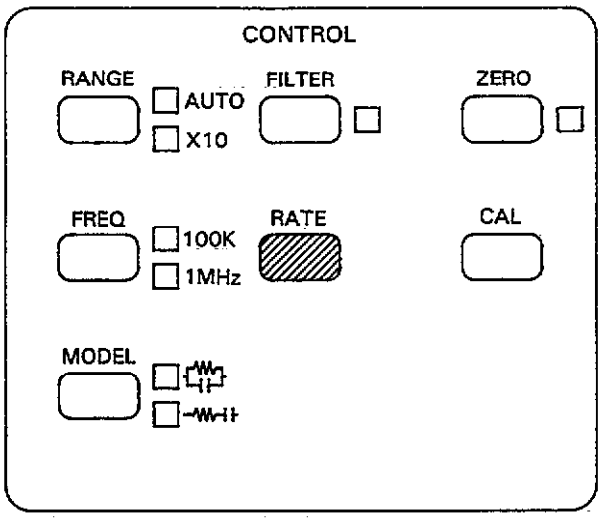
Because of the way the unit generates its time base, the actual reading rates are slightly different than indicated. Table 3-10 lists actual intervals along with other pertinent information.

### 3.9.1 Selecting a Reading Rate

Display or select the reading rate as follows:

1. Press the RATE key. The instrument will display the reading rate now in effect. For example, the display might show:

   READING RATE 10




   In this case, a rate of 10 readings per second is in effect.
2. To return to normal operation without changing the rate, press QUIT. The instrument will then return to normal operation with the active sweep (if any) unaffected.
3. To scroll through available reading rates, press and hold the RATE or ▲/▼ key, or press the numeric key associated with that rate, as summarized in Table 3-10.
4. When the desired rate is shown, press the ENTER key to program the displayed reading rate. The instrument will return to normal operation.

NOTES:

1. Re-programming the rate will abort an active sweep.. Any stored data from the previous sweep will be lost.
2. No valid data will be displayed until the sweep is completed and calculations are performed at the 75 and 1000 per second rates.

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

| Numeric Key# | Nominal Reading Rate | Readings | Display Resolution | Integration Period | Integrations Averaged | Actual Reading Interval (msec) | Effective Rate |
|---|---|---|---|---|---|---|---|
| 0 | 1000/sec | C only | 3½ digits* | 120μsec | 1 | 1.024 | 976.56/sec |
| 1 | 75/sec | C, G, V | 3½ digits* | 240μsec | 1 | 13.3 | 75.18/sec |
| 2 | 10/sec | C, G, V | 4½ digits | 2.4msec | 2 | 102.3 | 9.77/sec |
| 3 | 1/sec | C, G, V | 4½ digits | 16.7msec | 4 | 1024 | 0.977/sec |

*Data displayed after sweep is completed.



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3. During the reading calculation period at the end of a sweep (75 and 1000/sec rates only), the front panel keys will be inoperative. The amount of time necessary for these calculations depends on the the number of data points taken in the sweep. A CALCULATING DATA message will be displayed.
4. Autoranging cannot be used at the 75 or 1,000/sec reading rates. The unit will display a CONFLICT error if you attempt to program either of these rates with autoranging enabled.
5. A CONFLICT error will occur if you attempt to select 1- 75 /sec rates with more than 450 readings per sweep programmed.

### 3.9.2 Display Resolution

The display resolution for the 1 and 10 reading per second rates is 4½ digits. Display resolution at the 75 and 1000 per second rate is 3½ digits. Note, however, that data will be displayed only when the sweep is finished at the two fastest rates.

### 3.9.3 Digital Filtering

Digital filtering is used at the 1 and 10/sec rates in order to minimize noise. A basic averaging scheme is used in both cases, with 4 integrations averaged at the 1/sec rate, and two integrations averaged at the 10/sec rate. Since the degree of filtering depends on the amount of averaging, the best noise performance can be expected at the slowest rate.

### 3.9.4 General Rate Selection Considerations

The primary factors affected by the reading rate (other than the absolute number of readings per second) are the integration period and the amount of resolution. Since reading noise is affected both by the integration period and the amount of digital filtering, the reading will have the least noise at the 1 per second rate (longest integration period and most digital filtering), and the most noise at the 75 and 1000 per second rates (shortest integration period and no digital filtering).

Optimum rate selection, then, for your particular application will depend on required resolution and speed, as well as the amount of noise tolerable in the readings. For example, if speed is your primary requirement and you require capacitance, conductance, and bias voltage readings, you would obviously select the 75 reading per second rate (the fastest rate to obtain C, G, and V measurements), but at the expense of resolution. At the other extreme, you would opt for the 1 reading per second rate in situations requiring maximum resolution and minimum noise.

### 3.9.5 1000 Reading Per Second Rate Considerations

When using the 1000 reading per second rate, the following points should be kept in mind.

1. Only capacitance data is taken; neither conductance nor bias voltage data is taken.
2. Data is placed into the buffer in raw form and will be made available only when the reading sweep has been completed.
3. The only available bias waveforms are DC and external. A CONFLICT error will occur if you attempt to select other waveforms.
4. MEASURE will be on during integration.
5. Attempting to program control the Model 590 during the sweep may destroy the timing integrity of the waveform.
6. Up to 1,350 readings can be stored in the buffer at the 1000/sec rate.

### 3.9.6 1000 Readings Per Second Instrument Settings

To obtain a rate of 1000 readings per second, you must select the following instrument settings:

- Trigger mode: Sweep (paragraph 3.12)
- Trigger source: internal (paragraph 3.12)
- Bias waveform: DC or external (paragraph 3.14.1)
- Step time: 1ms (paragraph 3.14.2)

### 3.9.7 Typical Reading Rates

Typical reading rates are summarized below.

| | Internal Trigger Rate | | External Trigger Rate | |
|---|---|---|---|---|
| Rate | 1ms Delay | 2ms Delay | 1ms Delay | 2ms Delay |
| 1000 | 1000 | 333 | 483 | 198 |
| 75 | 75 | 64.6 | 68 | 63 |
| 18 | 16.4 | 16.1 | 16 | 16 |
| 10 | 10 | 9.5 | 9.6 | 9.5 |
| 1 | 1 | 0.97 | | |

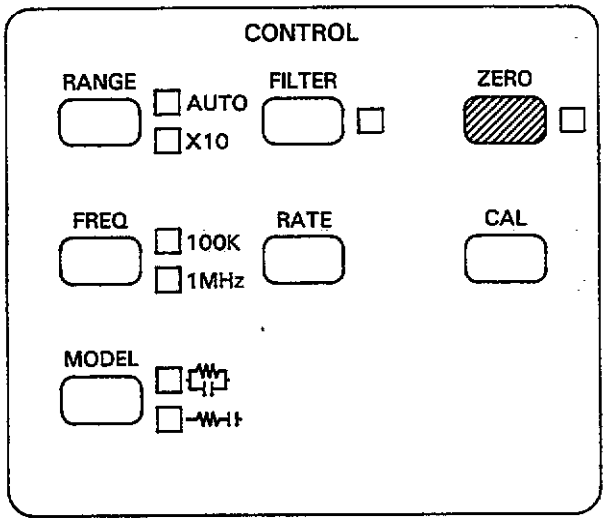
Note: All rates include both start and stop times of 1ms.



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## 3.10 USING ZERO

Zero can be used to store a set of capacitance and conductance readings as baseline values. Once stored, the baseline values are then subtracted from subsequent readings.




Zero is described in the following paragraphs.

### 3.10.1 Enabling and Disabling Zero

To enable or disable zero, press the ZERO button; the indicator to the right of the ZERO key indicates the state of zero.

When zero is first enabled, the first capacitance and conductance readings triggered after zero is enabled will be stored as the baseline values, which will then be subtracted from subsequent readings as long as zero is enabled. These zero values will also be stored in the buffer header to be used when accessing buffer data.

### 3.10.2 Storing Capacitance and Conductance Baseline Values

Use the following basic procedure to store capacitance and conductance parameters as your baseline.

1. Make sure that zero is disabled (ZERO off).
2. Use the FREQ key select the test frequency.
3. Select the reading rate and range, as required.
4. Connect the capacitance and conductance values to the instrument via the front panel INPUT and OUTPUT jacks. See paragraph 3.3 for detailed information on test connections.
5. Press ZERO to enable zero.
6. Trigger the reading or sweep by applying the appropriate trigger stimulus. From the front panel, you can do so simply by pressing the MANUAL button. The process of triggering the instrument will store the first set of capacitance and conductance readings as baseline values.
7. Connect the test circuit to be measured to the test jacks. If necessary, trigger the instrument. The stored baseline values will be subtracted from the actual readings, and the result will be displayed.
8. To disable zero, press ZERO a second time. Stored baseline values will be lost once zero is disabled.

### 3.10.3 Using Zero to Optimize Instrument Accuracy

The accuracy specifications given at the front of this manual assume that the instrument has been properly zeroed using the fundamental procedure below. In order to optimize accuracy, it is recommended that you repeat the procedure below every hour, especially in situations where the ambient temperature varies considerably.

1. If your instrument is equipped with both 100kHz and 1MHz modules, select the desired test frequency with the FREQ key.
2. Select the desired reading rate and measurement range using the RATE and RANGE keys.
3. Check to see that zero is initially disabled (ZERO off).
4. Connect the cables and test fixture to the test INPUT and OUTPUT jacks, but leave the DUT (device under test) disconnected at this time.
5. Press ZERO and trigger a reading or sweep by pressing MANUAL. The capacitance and conductance displays should then show a zero reading.
6. Connect the DUT to be measured to the fixture probes (or other similar test fixture connections).
7. Readings using the zeroed value can now be triggered and read in the normal manner. For optimum accuracy, it is recommended that the instrument be re-zeroed using the above procedure whenever the range, reading rate, or frequency is changed.



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### 3.10.4 Zero Considerations

Keep the following points in mind when using zero:

1. Zero reduces the dynamic range of the displayed readings. For example, if a 100pF baseline value is in effect on the 200pF range, a capacitance of 100pF will overrange the reading even though a 100pF reading is well within the limits of the 200pF range.
2. Zero calculations are performed on a parallel or series model, as appropriate.
3. Zero affects only displayed data; it does not modify the way it is measured and stored within the instrument.
4. Zero is not affected by pressing other keys.
5. Changing range or frequency leaves the same zero value active.
6. If the buffer is enabled (BUFFER KEY), the zero values will be obtained from the buffer header. Figure 3-12 shows a flow chart of zero operation both with and without buffer operation.
7. The accuracy specifications listed at the front of this manual assume that the instrument has been properly zeroed using the procedure in paragraph 3.10.2 above.
8. Zero stores baseline values for capacitance and conductance only; no bias voltage baseline values are stored.
9. The zero value is scaled and applied to a new range if changed.

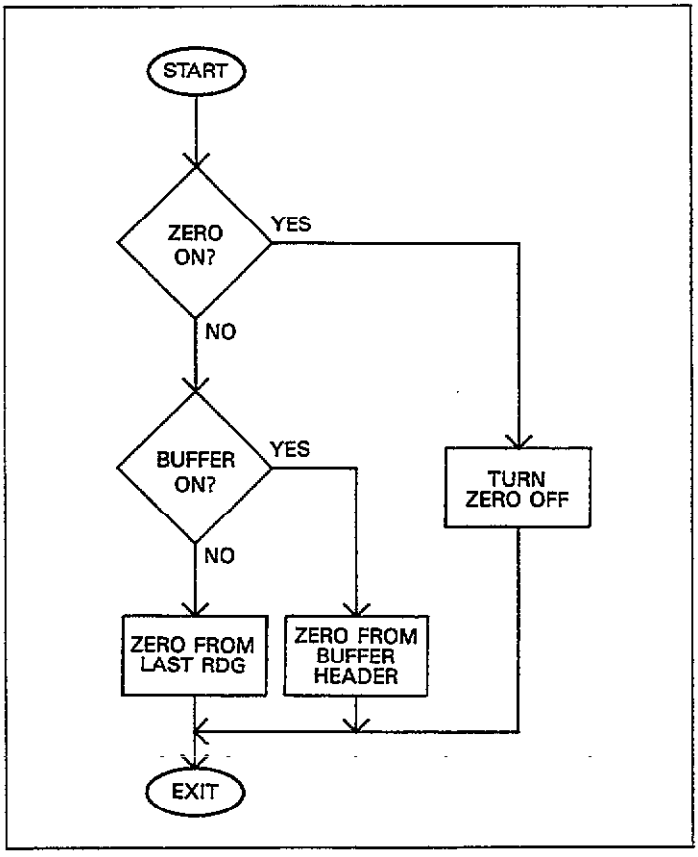



**Figure 3-12. Zero Operation Flowchart**

### 3.10.5 Examples of Zero Operation

Table 3-11 lists some examples to help clarify zero operation. This table lists stored baseline values, applied signals, and resulting front panel display values for those combinations.

**Table 3-11. Examples of Zero Operation**

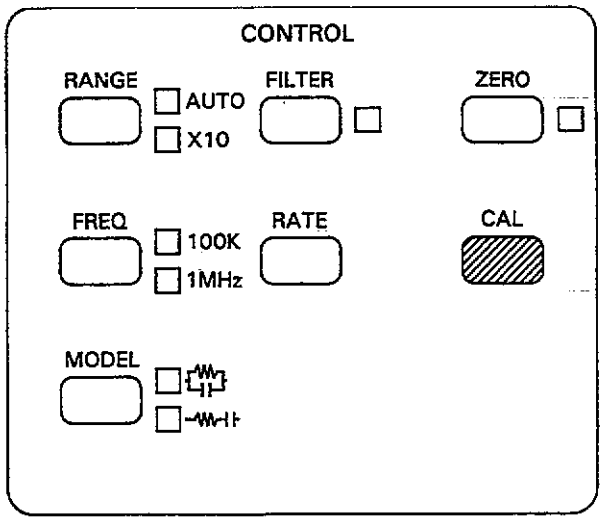
| Stored Baseline | Applied Signal | Displayed Readings |
|---|---|---|
| 5.00pF/2.6μS | 19.000pF/4.6μS | 14.000pF/2.00μS |
| 1.2nF/10mS | 680pF/15mS | −0.520nF/5.000mS |
| 110pF/150mS | 180pF/100mS | 70.00pF/−50mS |



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## 3.11 DRIFT CORRECTION

The front panel CAL button provides a means to perform internal drift correction, as described in the following paragraphs.




### 3.11.1 Correction Procedure

Perform internal drift correction using the procedure below. A flowchart outlining the basic sequence is shown in Figure 3-13.

1. Select the 1 reading per second rate, or the slowest rate you intend to use (see note below).
2. If your instrument is equipped with both 100kHz and 1MHz modules, use FREQ to select the desired measurement frequency.
3. Select the first range to be calibrated with the RANGE key.
4. Press the CAL key. The instrument will cycle through the internal correction sequence, a procedure that could take up to 10 seconds, depending on the selected rate. During the calibration process, the following message will be displayed:

   BUSY

5. Repeat steps 3 and 4 for all ranges you intend to use.
6. Select the other test frequency, if installed, and repeat steps 3 through 5 above for that frequency.

NOTES:

1. The unit should be corrected using the above procedure for each range and frequency you intend to use.
2. For optimum measurement accuracy, the correction procedure outlined above should be repeated at least once per hour, especially in situations where the ambient temperature varies widely.
3. During the correction sequence, the unit takes 10 readings of the internal transfer standards. Thus, at the 1 reading per second rate, up to 10 seconds must be allowed for each correction. If greater speed is a requirement, use the 10 reading per second rate, which will degrade correction accuracy only slightly.
4. Correction should be performed at a reading rate that yields 4½-digit resolution (1 or 10 readings per second) in order to achieve good accuracy. For maximum accuracy, always correct the unit at a 1 reading per second rate, unless speed is a requirement as indicated above.
5. It is not necessary to disconnect external circuits from the test INPUT and OUTPUT, as the instrument automatically does so during correction.
6. New correction constants obtained by this method is only temporary and will be lost when the power is turned off.
7. Pressing CAL will abort an active measurement sweep.
8. Upon power up, default values of 0 and 1 are installed for drift correction coefficents, effectively resulting in no correction until CAL is used.
9. The CAL key is inoperative in autoranging or if cable correction constants are in effect. A CONFLICT error will occur if you press CAL under these conditions.



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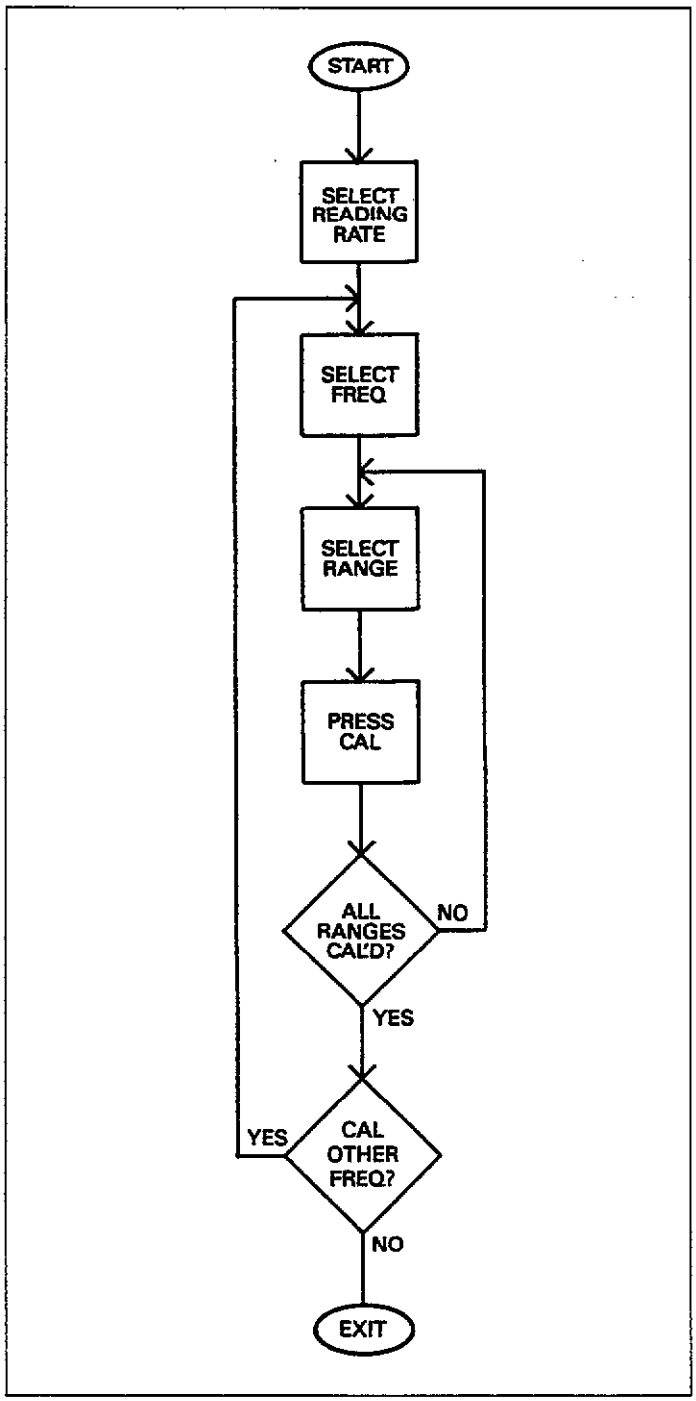



**Figure 3-13. Front Panel CAL Sequence**

## 3.11.2 Internal Correction Sequence

The general internal sequence the instrument follows when performing drift correction is outline below. Figure 3-14 shows an outline of the sequence.

The internal sequence is as follows:

1. The instrument recalls correction constants for the selected range and frequency from NVRAM. These constants are derived during full instrument calibration, as discussed in paragraph 7.3.
2. The unit disconnects the test INPUT and OUTPUT jacks from internal circuitry. An open circuit measurement is then made to be used as a zero offset value.
3. The instrument then measures an internal 20pF or 200pF capacitor (depending on the selected range). Ten measurements per reading are made and then averaged in order to obtain a more accurate value.
4. The correction constant recalled in step 1 is divided by the results of the measurement in step 3. The resulting value is then stored in RAM and used by the instrument as a compensating factor when taking normal readings. This new correction values will then remain in effect for the selected range and frequency for all subsequent measurements until the power is turned off, or until CAL is pressed again.



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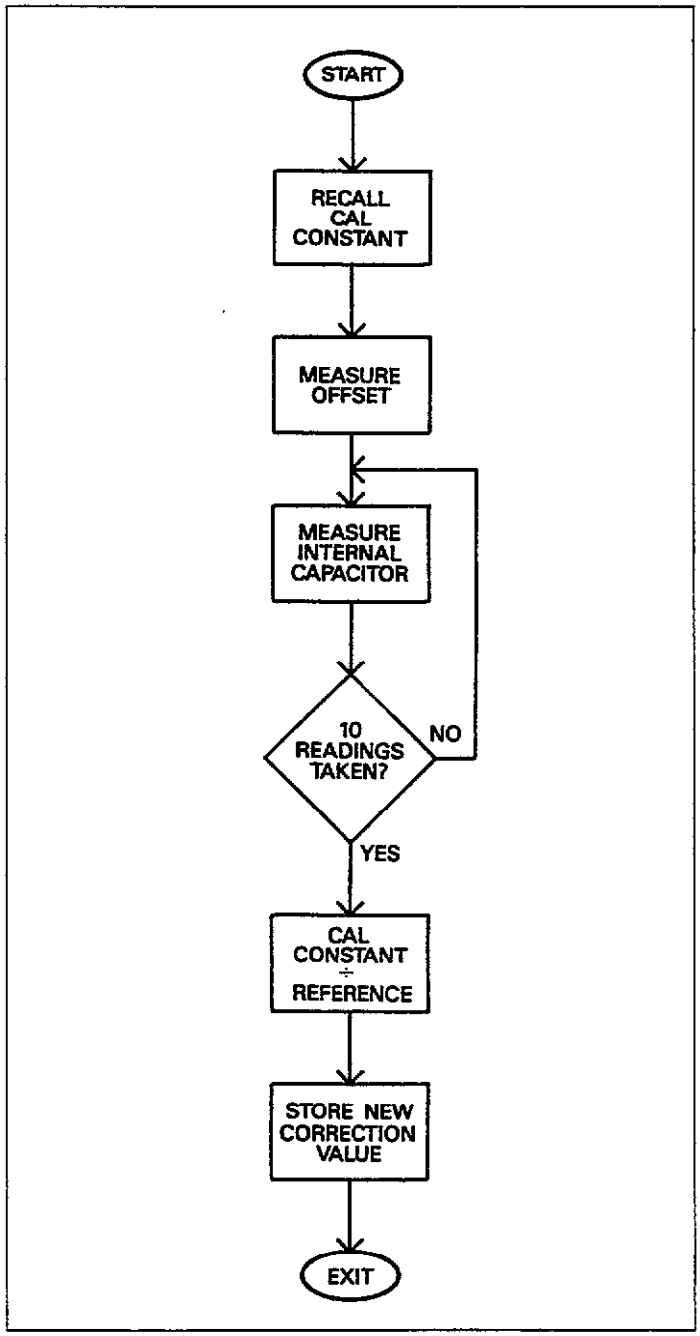
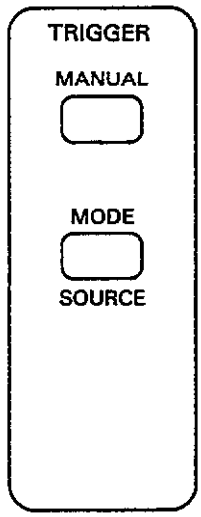



**Figure 3-14. Internal Drift Correction Sequence**

## 3.12 TRIGGERING THE INSTRUMENT

A trigger stimulus is used to initiate either one reading, or a group of readings (called a sweep), depending on the selected trigger mode. Basically, two trigger modes are available: one-shot and sweep. The trigger stimulus itself depends on the programmed trigger source: front panel, external trigger input, or IEEE-488 GET, X , or talk command triggers.




The following paragraphs discuss trigger source and mode, as well as trigger overrun conditions, and external trigger input and output pulses.

### 3.12.1 Selecting a Trigger Mode

**Available Trigger Modes**

There are two basic trigger modes available, including:

1. One-shot: with each trigger, the instrument takes a single set of capacitance, conductance, and bias voltage readings, and stores the resulting data at a single word location in the A/D buffer. Data is also made available to the display and IEEE-488 bus when ready. A pulse occurs at the external trigger output after each single set of readings is completed. When the waveform is complete (or the programmed number of points are taken), the next trigger will reset the buffer and begin storing readings at location one. For IEEE bus operation, an SRQ can be generated to signal to the controller that no more triggers should be sent. See Section 4 for IEEE-488 bus information.
2. Sweep: a single trigger stimulus causes the instrument to cycle through the programmed bias waveform sequence. A single set of capacitance, conductance, and bias voltage readings will be taken and stored in the A/D buffer at each bias step. As each step occurs, the resulting data will appear on the front panel and will be made available for transmission over the IEEE-488 bus. The instrument will intitiate a pulse at the external trigger output jack at the end of the sweep. The display will continue to update after the sweep has been completed.



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More information on the how the trigger modes affect the buffer is located in paragraph 3.14.

**Selection Procedure**

Use the procedure below to select the desired trigger mode.

1. Press the MODE button and note the following message is displayed:

   TRIGGER MODE

2. Now press MODE or ▲/▼ repeatedly until the desired trigger mode message is displayed, or press the associated numeric key, as summarized in Table 3-12. For example, for the sweep mode, the front panel display message is:

   TRIGGER MODE SWEEP

   Similarly, the instrument will display the following message for the one-shot mode:

   TRIGGER MODE 1 SHOT

3. Once the desired mode is displayed, press the ENTER key. The instrument will then return to the previous display with the new trigger mode in effect.
4. If you wish to cancel trigger mode selection without changing the selected mode, press QUIT.

NOTES:

1. To abort an active sweep, press the MODE key. The presently active sweep will be aborted, and the instrument will display the TRIGGER MODE message. Press ENTER to return to normal display, and initiate another trigger to begin another sweep, if desired.
2. Pressing RANGE, FREQ, FILTER, ZERO, CAL, TRIGGER MODE, any BIAS key, or re-programming the reading rate will abort an active sweep without re-triggering a sweep. In either case, any data stored in the A/D buffer will be cleared. To avoid loosing data in this situation, always transfer data to buffer B with the A → B key before pressing other keys.
3. Triggering a sweep will clear data presently stored in the A/D buffer (buffer A).
4. Only capacitance data is taken at the 1000 reading per second rate.
5. At the 75 and 1000/sec rates, a CALCULATING DATA message will be displayed at the end of a sweep before the unit returns to normal operation.

## 3.12.2 Programming the Trigger Source

**Available Trigger Sources**

The programmed trigger source provides the stimulus to initiate a one-shot or sweep depending on the selected trigger mode. Trigger sources include:

1. Front panel MANUAL button. Note that this button is always operational regardless of the selected source (unless the unit is placed in remote over the IEEE-488 bus).
2. External trigger pulse. An appropriate pulse, applied to the external trigger input jack on the rear panel, provides the trigger stimulus.
3. IEEE command triggers. IEEE-488 GET, X, or talk commands provide the stimulus when the appropriate source is selected.

Note that all trigger sources are available with all trigger modes, as summarized in Table 3-13.

**NOTE**

In order to ensure rapid response to a new trigger after a sweep, press MODE ENTER to turn off the A/D converter.

**Table 3-12. Trigger Modes**

| Numeric Key # | Display Message | Description |
|---|---|---|
| 0 | TRIGGER MODE 1 SHOT | One-shot (one reading per trigger) |
| 1 | TRIGGER MODE SWEEP | Single-sweep (one sweep per trigger) |



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**Table 3-13. Trigger Mode and Source Combinations**

| Source/Mode | Front Panel | External Trigger | IEEE Talk | IEEE GET | IEEE X |
|---|---|---|---|---|---|
| *One-shot* | X | X | X | X | X |
| Sweep | X | X | X | X | X |

**Selection Procedure**

*Select the desired trigger source as follows:*

1. Press SOURCE (SHIFT MODE) and note that the following message is displayed:

   TRIGGER SOURCE

2. Press the MODE or ▲/▼ key repeatedly until the desired trigger source is displayed (or press the associated numeric key, as indicated in Table 3-14). For example, for external triggering, the display will show:

   TRIGGER SOURCE EXT

3. Once the desired trigger source is displayed, press the ENTER key. The instrument will then return to the previous display with the new trigger source in effect. At this point, the selected trigger stimulus must be applied to initiate the reading or sweep.
4. To return the display to normal without changing the previously selected source, press the QUIT button instead.

## 3.12.3 Front Panel Triggering

To trigger the instrument from the front panel, simply press the MANUAL button. Note that this button is always operational regardless of the selected trigger source (unless the unit is placed in remote over the IEEE-488 bus, in which case all front panel buttons except LOCAL will be locked out). Thus, front panel trigger source selection provides a means to lock out all other trigger sources when only front panel triggering is desired.

The number of readings the instrument takes after MANUAL is pressed will depend on the selected trigger mode. In the one-shot mode, you must press MANUAL for each reading. Pressing MANUAL with the sweep mode active performs a complete reading sequence, with a group of capacitance, conductance, and bias voltage readings taken and stored with each bias step. If you press MANUAL and the instrument is not ready, an error message will be displayed, as discussed in the following paragraph.

## 3.12.4 Trigger Overrun Conditions

Once the instrument is triggered, it will begin a reading or sweep, as discussed above. If another trigger is received while the unit is processing a reading or sweep (depending on trigger mode), a trigger overrun condition will occur, in which case the instrument will display the following error message:

TRIG-OVERRUN

Figure 3-15 shows a flowchart of trigger overrun operation.

**Table 3-14. Trigger Source Display Messages**

| Numeric Key # | Message | Trigger Source |
|---|---|---|
| 0 | TRIGGER SOURCE FP | MANUAL key only.* |
| 1 | TRIGGER SOURCE EXT | Pulse applied to EXTERNAL TRIGGER INPUT. |
| 2 | TRIGGER SOURCE TALK | IEEE talk command. |
| 3 | TRIGGER SOURCE GET | IEE GET command. |
| 4 | TRIGGER SOURCE X | IEEE X command. |

*MANUAL key is always operational.



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NOTES:

1. A reading or sweep is not aborted by a trigger overrun condition.
2. Only an active trigger source can create a trigger overrun situation. For example, if you select the external trigger source, either an external trigger pulse or pressing MANUAL can create a trigger overrun (recall that MANUAL is always active).
3. The instrument will not generate an overrun error if triggered during the stop time. At the end of the sweep, a new sweep will be started in this situation.

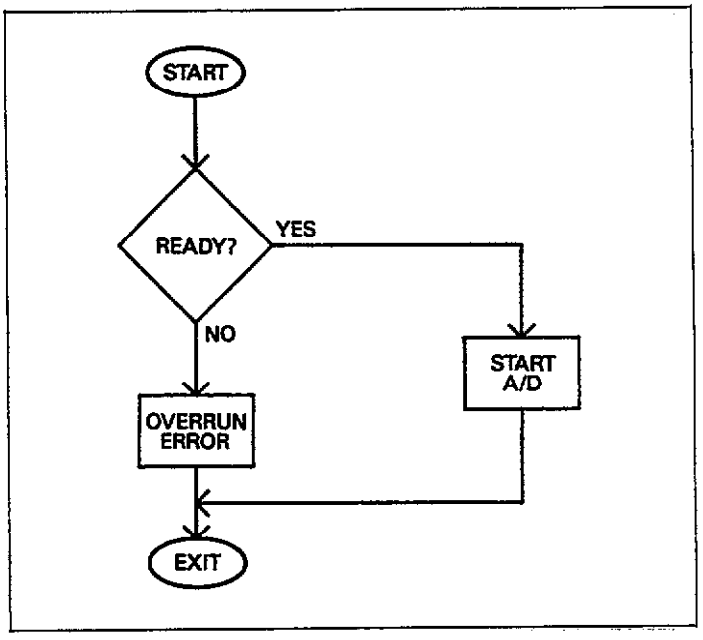



**Figure 3-15. Trigger Overrun Operation**

## 3.12.5 External Trigger Input

To use external triggering, first select that source with the MODE key as described in paragraph 3.12.2. The instrument will then be triggered when an input pulse with the specifications shown in Figure 3-16 is applied to the EXTERNAL TRIGGER INPUT jack. The unit is triggered on the leading edge of the pulse, as shown on the diagram.

Note that the center conductor of the jack is high, and the outer ring, which is connected to IEEE common is low, as shown in Figure 3-16.

As previously described, the effect of the external trigger pulse depends on the selected trigger mode. In the one-shot mode, a separate pulse is required for each reading set. In the sweep mode, however, one trigger pulse initiates a complete sweep sequence.

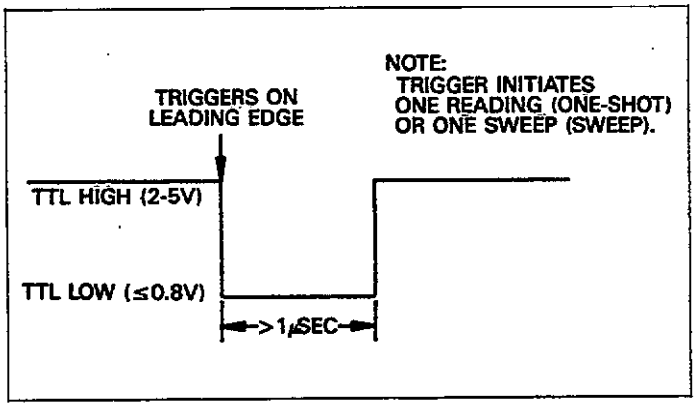



**Figure 3-16. External Trigger Input Pulse Specification**

## 3.12.6 External Trigger Output

The external trigger output provides a negative-going, TTL-compatible pulse as shown in Figure 3-18. The leading edge of the trigger pulse indicates end of reading or end of sweep as the case may be.

The occurrence of this pulse occurs depends on the selected trigger mode as follows:

1. At the end of each reading in the one-shot mode.
2. At the end of the sweep in the sweep mode (1, 10, and 18/sec reading rates).
3. In the 75/sec and 1000/sec rates, the pulse occurs after all calculations are done in the sweep mode.

The center conductor of the external trigger output is high and the outer ring, which is connected to IEEE common is low, as shown in Figure 3-17.



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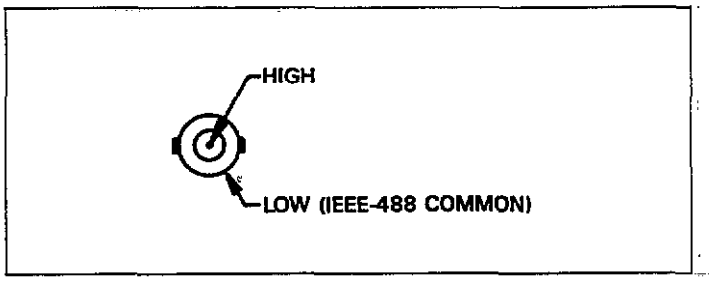



**Figure 3-17. Trigger Input and Output Jack Configuration**

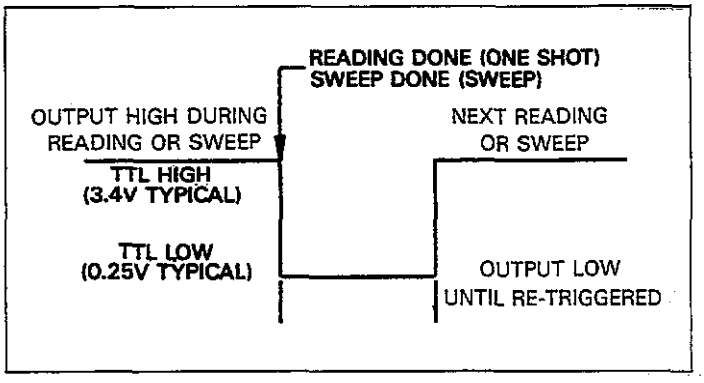



**Figure 3-18. External Trigger Output Pulse Specification**

## 3.12.7 External Triggering Example

As an example of external triggering operation, let us assume that the Model 590 is to be used with a Keithley Model 230 Programmable Voltage Source. The Model 230 is capable of output voltages as high as ±101V. Thus, this instrument is ideal for testing devices which require higher bias levels than the nominal ±20V level of the Model 590.

Figure 3-19 shows the basic circuit configuration for using the Model 590 along with Model 230 as an external bias voltage source. Connect and program the instruments as follows:

1. Using suitable coaxial cable, connect the 230 OUTPUT to the 590 VOLTAGE BIAS INPUT on the rear panel.
2. Using a BNC coaxial cable, connect the 230 EXTERNAL TRIGGER OUTPUT to the 590 EXTERNAL TRIGGER INPUT.
3. Select the STEP program mode on the Model 230 and program the various memory locations for voltage levels, current limits, and required dwell times. The dwell time should be programmed to the desired step time. Consult the Model 230 Instruction Manual for details.
4. Press the 590 MODE key and program the unit for the one-shot trigger mode. Press SHIFT MODE and select the external trigger source.
5. Press the 590 WAVEFORM key repeatedly until the the EXT display message is shown, then press the ENTER key. This step sets up the unit for use with the external bias source.
6. Connect the circuit under test to the 590 test INPUT and OUTPUT jacks.
7. Select the 590 range, frequency, model, and reading rate, as required.
8. Press the 230 RESET key and turn on its output with the OPERATE key.

**WARNING**
**Up to ±101V may be present at the 590 TEST OUTPUT after the next step.**

9. Press the BIAS ON key to turn on the voltage applied through the test OUTPUT jack.
10. Start the measurement sequence by pressing the 230 START/STOP key. This action will trigger a 590 reading. At the end of the dwell time for location, a 590 reading will be triggered and stored.

**NOTE**
See paragraph 4.12 for an example program that demonstrates this process.



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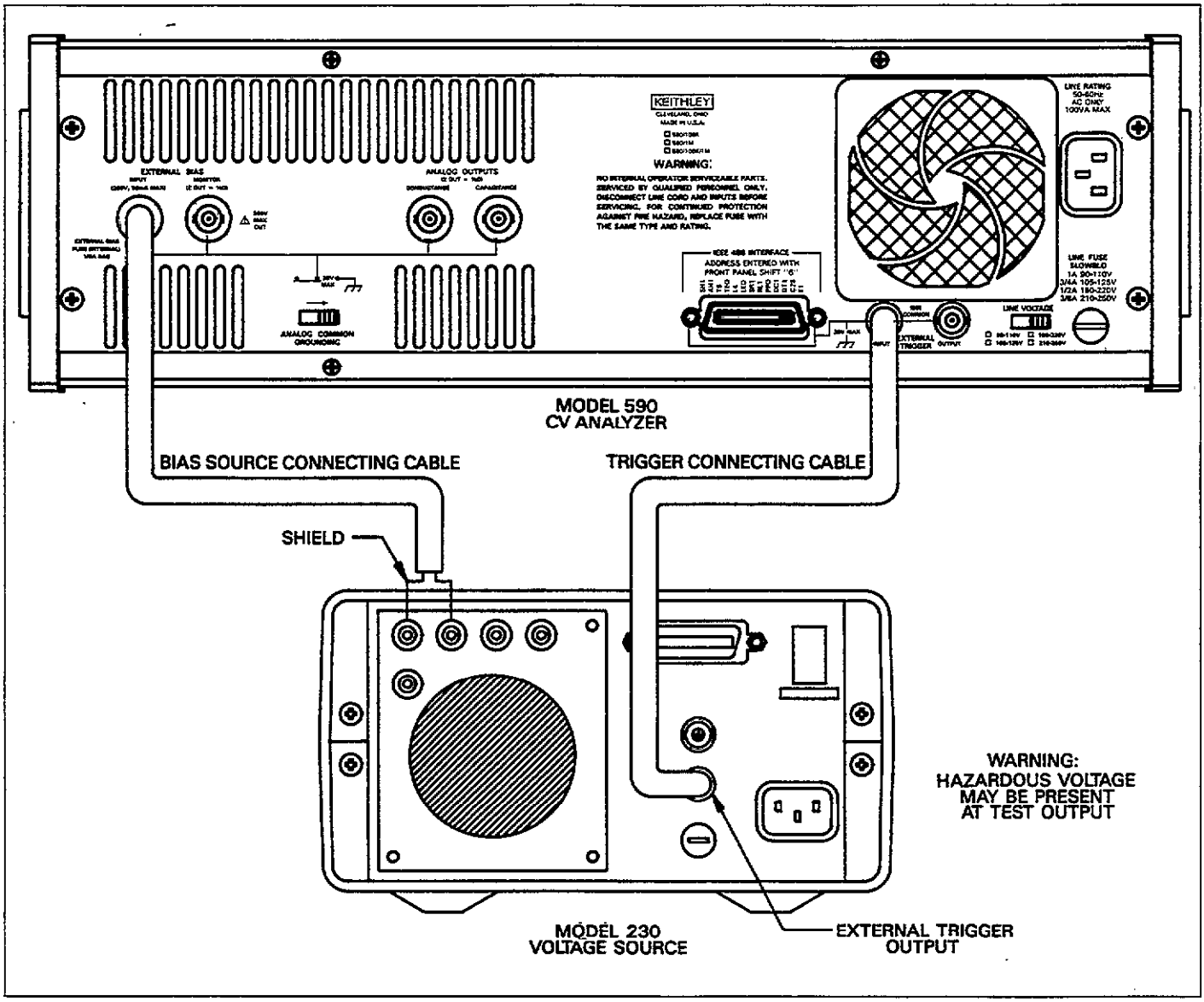



**Figure 3-19. External Triggering Connections**

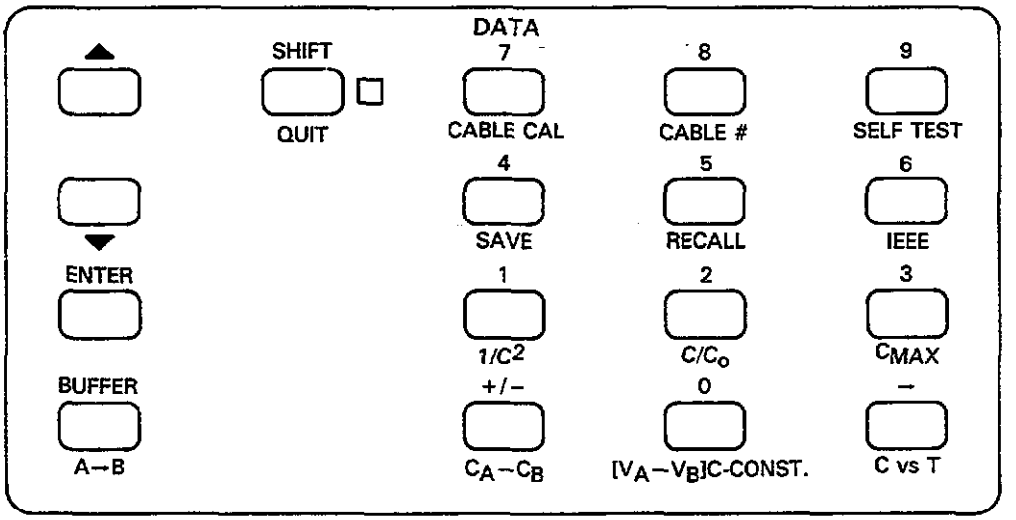
## 3.12.8 IEEE-488 Bus Triggering

To trigger a reading or sweep with an IEEE-488 trigger source, you must send the appropriate IEEE-488 command over the bus: X, talk, or GET, depending on the selected source. See Section 4 for complete details.

If one of these commands has been selected as the trigger source, you can also trigger the instrument by pressing the MANUAL button unless the instrument is in remote.



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## 3.13 DATA KEYS

The following paragraphs describe the operation of the 0-9. +/−, ▲ and ▼ keys, the SHIFT key, and ENTER and QUIT. BUFFER and A → B are discussed under buffer operation in paragraph 3.15.9.

### 3.13.1 Increment and Decrement

One purpose of increment (▲) and decrement (▼) is to scroll through various buffer locations when viewing buffer data on the front panel. To use these keys with the buffer, simply press BUFFER, select the buffer to access at the prompt, then use ▲ or ▼ to sequentially scroll through buffer locations

A second purpose of ▲/▼ is to provide an alternate method of scrolling through menus when using RATE, WAVEFORM, PARAMETER, MODE, and SETUP.

### 3.13.2 SHIFT/QUIT Key Operation

The SHIFT key is used to add secondary functions to some other front panel keys such as MODE (SOURCE). To access one of these shifted modes, simply press the SHIFT button followed by the desired key. Note that the indicator adjacent to the SHIFT key will be on when shift is active.

To cancel shift without selecting a corresponding mode, press the SHIFT key a second time. If you press a key which has no shifted function with shift enabled, the primary function of that key will be performed. For example, pressing SHIFT FILTER performs the same operation as simply pressing FILTER.

*When programming parameters or selecting menu options,* you can return to normal display without making a change by pressing QUIT. QUIT can also be used to exit buffer display.

### 3.13.3 Numeric Input

The numeric keys, which include 0-9 and ± are used to program numeric data when programming such parameters as bias waveform voltages. Also, some plotter setups are entered in numeric form.

To use these keys, simply press the desired mode button and then enter your data with the number keys.

### 3.13.4 Display Cursor

During the process of programming numeric parameters, *the display digit affected by a key press will brighten to* act as a display cursor. As you type in digits, the cursor will move to the right, and it will wrap around to the left after passing through the right most digit. The → key can be used to move the cursor to the right.



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## 3.13.5 ENTER

Use the ENTER key to update the active variables to the new values. A single press of ENTER will save all parameters just modified, and the unit will return to normal display.

## 3.13.6 Multiple Parameter Entry

When programming two or more parameters, you need not press ENTER after each entry. Instead, press the ▲ or ▼ key to scroll to the next parameter to be programmed. After changing the last parameter, press the ENTER key to modify all parameters just entered. If you press QUIT at any point, none of the parameters will be changed.

## 3.13.7 Invalid Parameter Entry

Parameters are check for validity when you scroll to the next parameter set and when the ENTER key is pressed. If a parameter outside the allowed range is programmed, the unit will briefly display the following message:

INVALID

The unit will then return to the erroneous value.

## 3.13.8 Data Key Examples

The examples below will help to clarify data key operation.

**Example 1: Using Increment and Decrement to Access the Buffer**

One purpose of ▲/▼ is to scroll through buffer locations and display data stored there. The following procedure demonstrates the basic process.

1. Using the MODE key, select the sweep trigger mode.
2. Press MANUAL to trigger a reading sweep.
3. Press BUFFER and select the A/D buffer at the prompt by pressing 0. Note that the BUFFER LED turns on to indicate that you are reading buffer data.
4. The instrument will then show data stored at the first buffer location. A typical display is:

   1.8000pF 00.11μS +5.100V

5. Press the C vs t button to display buffer location numbers in the voltage display area.
6. Press and hold ▲ and note that the instrument scrolls through buffer locations in ascending order.
7. Release ▲, then press and hold ▼. Note that the instrument scrolls through buffer locations in descending order.
8. Press QUIT to return to the normal display.

**Example 2: Using Increment/Decrement to Scroll Through Menus**

As discussed previously, the second purpose for ▲/▼ is for scrolling through parameter menus, as in the following example.

1. Press the WAVEFORM key and note that a bias waveform type is shown on the front panel display. For example, the display might show:

   BIAS WAVEFORM DC

2. Press and hold the ▲ key and note that you can scroll through bias waveform types.
3. Now press and hold the ▼ key and note that you can scroll through available bias waveforms in the opposite direction.
4. Press QUIT to return to normal display without changing the previously programmed waveform.
5. Press ENTER to return to the normal display with the newly selected waveform in effect.

**Example 3: Programming Single Numeric Parameters**

To program a numeric parameter, simply press PARAMETER and then key in the desired value, as in the example below.

1. Using the WAVEFORM key, select a single staircase waveform.
2. Press the PARAMETER key repeatedly until the following message is displayed:

   1ST BIAS V +00.000

3. Now key in the desired voltage with the numeric keys. For example, to program a value of 4V, press: 0 4 0 0 0. Note that the digit affected by a keypress is highlighted on the display.
4. To complete programming, press the ENTER key. The voltage value will be programmed, and the unit will return to the normal display mode.



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**Example 4: Programming Multiple Parameters**

When programming more than one parameter, it is not necessary to press ENTER after each modification; instead, you can scroll through the parameter menu, stopping at each point to make the desired changes. The example below demonstrates this process by programming start, stop, and step times.

1. Use the WAVEFORM key to select a single staircase waveform.
2. Press PARAMETER and note that the following prompt for start time is displayed:

   START TIME +00.001

   In this instance, the default time of 1msec is displayed.
3. Key in the desired start time using the numeric keys. For example, to program a 2.5sec start time, press the following keys: 0 2 5 0 0.
4. Press the PARAMETER or ▲ key. The unit will now display the programmed stop time:

   STOP TIME +00.001

   Again, the default 1msec value is displayed in this example.
5. Key in the desired value with the numeric keys. For example, to program a 5.04sec stop time press the following keys: 0 5 0 4 0.
6. Press PARAMETER or ▲ again to display the programmed step time, as in the example below:

   STEP TIME +00.001

7. Key in the desired value; for example, to program a 50msec step time, press the following keys: 0 0 0 5 0.
8. Press the ENTER key to complete programming of all three values. The unit will then return to normal display.

**Example 5: Using the +/− Key**

The +/− key is used to select positive or negative bias voltage parameters, as in the following example.

1. Select a single staircase waveform using the WAVEFORM key.
2. Press the PARAMETER key until the following message is displayed:

   1ST BIAS V +00.000
3. Program a 5V voltage as follows: 0 5 0 0 0.
4. Press the +/− key a number of times and note that the display alternates between a positive and negative value.

**Example 6: Demonstrating an INVALID Error Message**

If you attempt to program a parameter outside the allowed range, the instrument will display the INVALID error message, as in the example below.

1. Press PARAMETER repeatedly until the following message is displayed:

   1ST BIAS +05.000

   The 5V value is due to Example 3 above.
2. Attempt to program a bias voltage above the allowed +20V value by pressing the following keys in sequence: 3 0 0 0 0.
3. Now press ENTER to complete programming. Note that the instrument briefly displays the message below and then returns to the previously programmed parameter:

   INVALID

4. Press ▲ or ▼ to attempt to scroll to the next parameter item. Again, the instrument briefly displays the INVALID error message and returns to the previously programmed parameter.

**Example 7: Using ENTER and QUIT**

The ENTER key is the last step in the parameter or menu selection process. In contrast, the QUIT key allows you to cancel a mistake in parameter programming or menu selection without actually changing previously programmed values. The example below demonstrates operation of ENTER and QUIT.

1. Press the MODE key and note the programmed trigger mode. For example, the display might show:

   TRIGGER MODE SWEEP

2. Press MODE again to change the trigger mode.
3. Press ENTER to invoke the trigger mode change.
4. Press MODE and note that the new trigger mode programmed in steps 2 and 3 is now in effect. For example, if you changed from the sweep to one-shot mode, the display will show.

   TRIGGER MODE 1 SHOT



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5. Press MODE to change the trigger mode.
6. Press QUIT to cancel the current selection.
7. Now press MODE again and note that the trigger mode was not changed because you used the QUIT button.

**Example 8: Using the → Key to Move Cursor**

→ can be used during parameter programming to move the cursor. The example below will demonstrate this process.

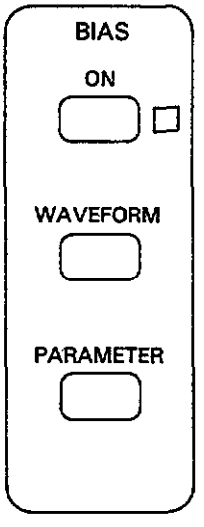
1. Press PARAMETER and note that the instrument displays the start time, as in this example:

START TIME +00.001

2. Press the → key and note that the cursor moves to the right.

## 3.14 BIAS VOLTAGE

The following paragraphs contain information on selecting a bias waveform, programming bias waveform parameters, and turning on the bias voltage. Details on waveform definitions, external bias input, and bias voltage monitor are also included.




### 3.14.1 Selecting a Bias Waveform

**Available Waveforms**

Bias waveforms available include:

DC: any DC level in the range of −20V to +20V.
Single staircase: stepping either up or down.
Dual staircase: stepping up then down or down then up.
Pulse train: step up or down.
External: external voltage applied to the BIAS INPUT jack.

Table 3-15 shows the general configuration of these waveforms. Waveforms and parameters are defined in detail in paragraph 3.14.4.

**Selecting a Waveform**

To select the required bias waveform, press and hold the WAVEFORM or ▲/▼ key until the desired waveform is displayed, as summarized in Table 3-15. Press ENTER to select the displayed waveform type.

If you wish to return to the previously programmed waveform, press QUIT instead.

**Typical Waveform Uses**

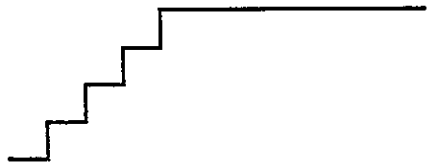
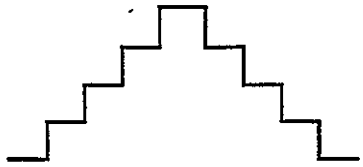
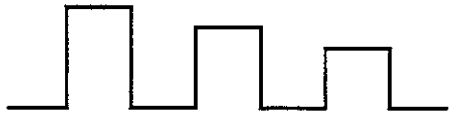
Typical uses for the various waveforms include:

1. DC
   A. One-shot: external time base C-t.
   B. Sweep: internal time base C-t, or "dumb" C-meter.
2. Single staircase
   A. One-shot: external time base C-V.
   B. Sweep: internal time base C-V.
3. Dual staircase
   A. One-shot: external time base C-V with hysteresis.
   B. Sweep: internal time base C-V with hysteresis.
4. Pulse
   A. One-shot: external time base C-V, return to default between points.
   B. Sweep: internal time base C-V, return to default between points.
5. External
   A. One-shot: external time base, external bias control.
   B. Sweep: internal time base, external bias control.



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**Table 3-15. Bias Waveform Summary**

| Numeric Key # | Display Message | Description | General Waveform Configuration |
|---|---|---|---|
| 0 | BIAS WAVEFORM DC | Static DC levels |  |
| 1 | BIAS WAVEFORM STAIR | Single Staircase |  |
| 2 | BIAS WAVEFORM DSTAIR | Dual Staircase |  |
| 3 | BIAS WAVEFORM PULSE | Pulse Train |  |
| 4 | BIAS WAVEFORM EXT | External Bias Voltage | |

## 3.14.2 Programming Waveform Parameters

**Parameter Types**

Programmable parameters include such values as start and stop hold times, as well as first and last bias values. Table 3-16 summarizes programmable parameters, display messages, and the allowable range for each parameter.

NOTES:

1. All parameters are not programmable for every waveform type. The instrument will prompt only for those parameters which apply to the particular waveform. Table 3-16 indicates which parameters apply to the various waveforms.
2. The buffer can store a maximum of 450 readings (1,350 at 1000/sec rate). Programming reading sweeps longer than this will result in lost data. If more than 450 (1,350) readings are programmed (a function of first and last voltage, as well as bias step size), only the first 450 (1,350) will be stored in the buffer.
3. The number of readings stored as part of the sweep for all waveforms except DC and external depends on start, stop, and step voltages (see discussion below). The number of readings stored with external and DC waveforms depends on the COUNT parameter (COUNT $\leq$450 or $\leq$1,350).
4. Voltage parameters can be programmed to 1mV resolution, but actually have 5mV minimum steps.



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## Table 3-16. Programmable Bias Voltage Parameters

| Display Message | Description | Limits* | Resolution* | DC | Staircase | Single Staircase | Dual Pulse | External |
|---|---|---|---|---|---|---|---|---|
| START TIME | Start time* | 1msec to 65sec | 1msec | X | X | X | X | X |
| STOP TIME | Stop time* | 1msec to 65sec | 1msec | X | X | X | X | X |
| STEP TIME | Step time* | 1msec to 65sec | 1msec | X | X | X | X | X |
| 1ST BIAS V | First bias voltage | −20V to +20V | 5mV | X | X | X | X | |
| LAST BIAS V | Last bias voltage | −20V to +20V | 5mV | | X | X | X | |
| BIAS STEP V | Step voltage | −20V to +20V | 5mV | | X | X | X | |
| DEFAULT BIAS V | Default bias voltage | −20V to +20V | 5mV | X | X | X | X | |
| COUNT | #Readings per sweep | 1 to 450 (1,350 at 1,000/sec rate) | | X | | | | X |

NOTE: Voltage parameters can be programmed to 1mV, but are set in 5mV steps.
* Programmed times must be multiplied by 1.024 to obtain actual times.
X Indicates parameter applies to waveform.

5. Bias voltages of −20.000V can be programmed, but the read-back display limit is −19.999V. Buffer data will reflect voltage values above −19.999V, however.
6. The unit will display a CONFLICT error if you attempt to program more than 450 readings per sweep.

### Selecting Parameters

Select your bias parameters as follows:

1. Press and hold WAVEFORM or ▲ (or press the associated numeric key, as indicated in Table 3-15) to select the desired waveform. For example, for a single staircase, the display will show:

   BIAS WAVEFORM STAIR

2. Press ENTER to program the waveform.
3. Press and hold PARAMETER or ▲/▼ until the parameter you wish to program is displayed. For example, to program start time, the display will show:

   START TIME +00.001

4. Using the number keys, program the desired value. For example, to program a step delay of 0.1sec, press: 0 0 1 0 0.
5. Press PARAMETER or ▲ to advance to the next parameter, then key in the desired value. If you key in an invalid parameter, the instrument will briefly display the following error message:

   INVALID

6. Once you have programmed all parameters, press the ENTER key. The instrument will then return to normal display.
7. To return to normal display without modifying parameters, press QUIT instead of ENTER.

### Number of Readings in a Sweep

The number of readings in a sweep for DC and external waveforms is determined solely by the COUNT parameter. Thus, to control the size of the sweep, you should program COUNT for the desired number in the range of 1-450 (1,350 at 1,000/sec rate).

In contrast, the number of readings in the sweep for the staircase or pulse waveforms will depend on the programmed first and last bias levels, as well as the step size with a maximum of 450. For example, the total number of readings in a given sweep with a single staircase waveform can be computed as follows:

$$n = \left| \frac{(V_L - V_F)}{V_S} \right| + 1$$

where: n = number of readings
$V_L$ = last bias
$V_F$ = first bias
$V_S$ = step bias.

(If $(V_L - V_F)/V_S$ is not an integer, add one to the above calculation).



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Example: Assume that first and last bias values are −5V and +5V respectively, and that the bias step is 0.1V. The number of readings in the sweep is:

$$n = \frac{(+5 - (-5))}{0.1} + 1$$

$$n = 101 \text{ readings per sweep}$$

**Minimum Voltage Steps**

Although bias voltage parameters can be entered in 1mV steps, the actual minimum step size is 5mV due to hardware constraints. The actual bias voltage is calculated as follows:

$$V_B = \left\lfloor \frac{V_P}{5} \right\rfloor \times 5$$

Where: $V_B$ = Actual bias voltage (mV)
$V_P$ = Programmed bias voltage (mV)
$\lfloor\ \rfloor$ = Take the integer of $V_P/5$

Example: Assume a 10.223V voltage is programmed. The actual bias voltage is:

$$V_B = \left\lfloor \frac{10{,}223}{5} \right\rfloor \times 5 = 10{,}220\text{mV}$$

$$V_B = 10.22\text{V}$$

## 3.14.3 Controlling the Bias Voltage (BIAS ON)

Use the BIAS ON key to turn the bias voltage on or off. The indicator to the right of the ON key shows the state of the bias source. Note that this key controls both internal and external bias sources (when selected). Figure 3-20 shows a flowchart of ON key operation.

**WARNING**
**Up to 200V DC may be present at the test OUTPUT jack when the bias is turned on while using an external bias source.**

The exact configuration of internal circuitry differs depending on whether the internal or external bias source is used, as shown in Figure 3-21(a). Figure 3-21(b) shows an equivalent circuit of software implementation of bias control.

NOTES:

1. Pressing ON will abort any active sweep and reset the A/D buffer.
2. When external bias is turned on, and the unit is not triggered, the following will be displayed:

EXT.–V

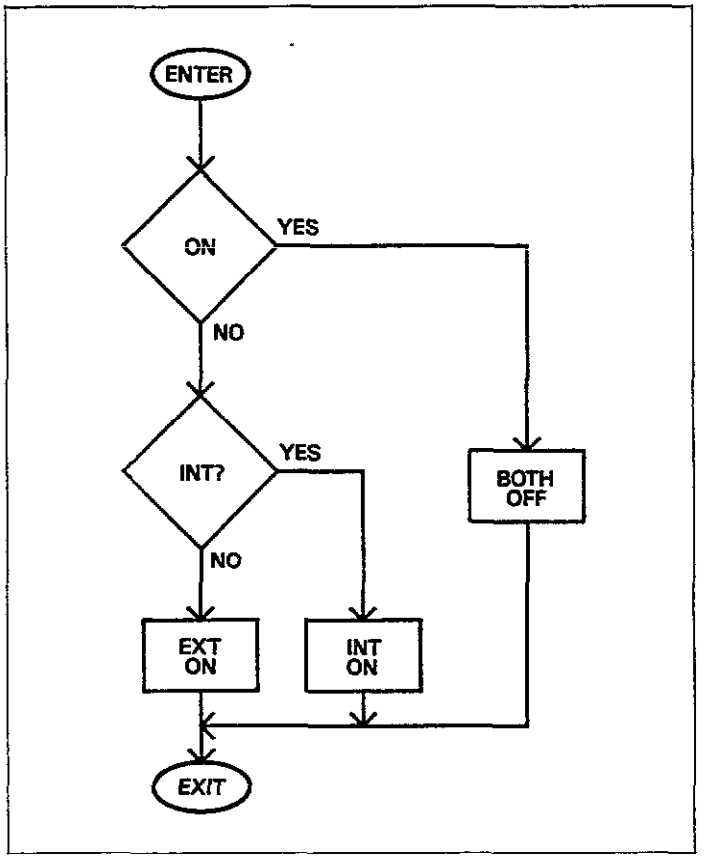



**Figure 3-20. Bias ON Key Operation**



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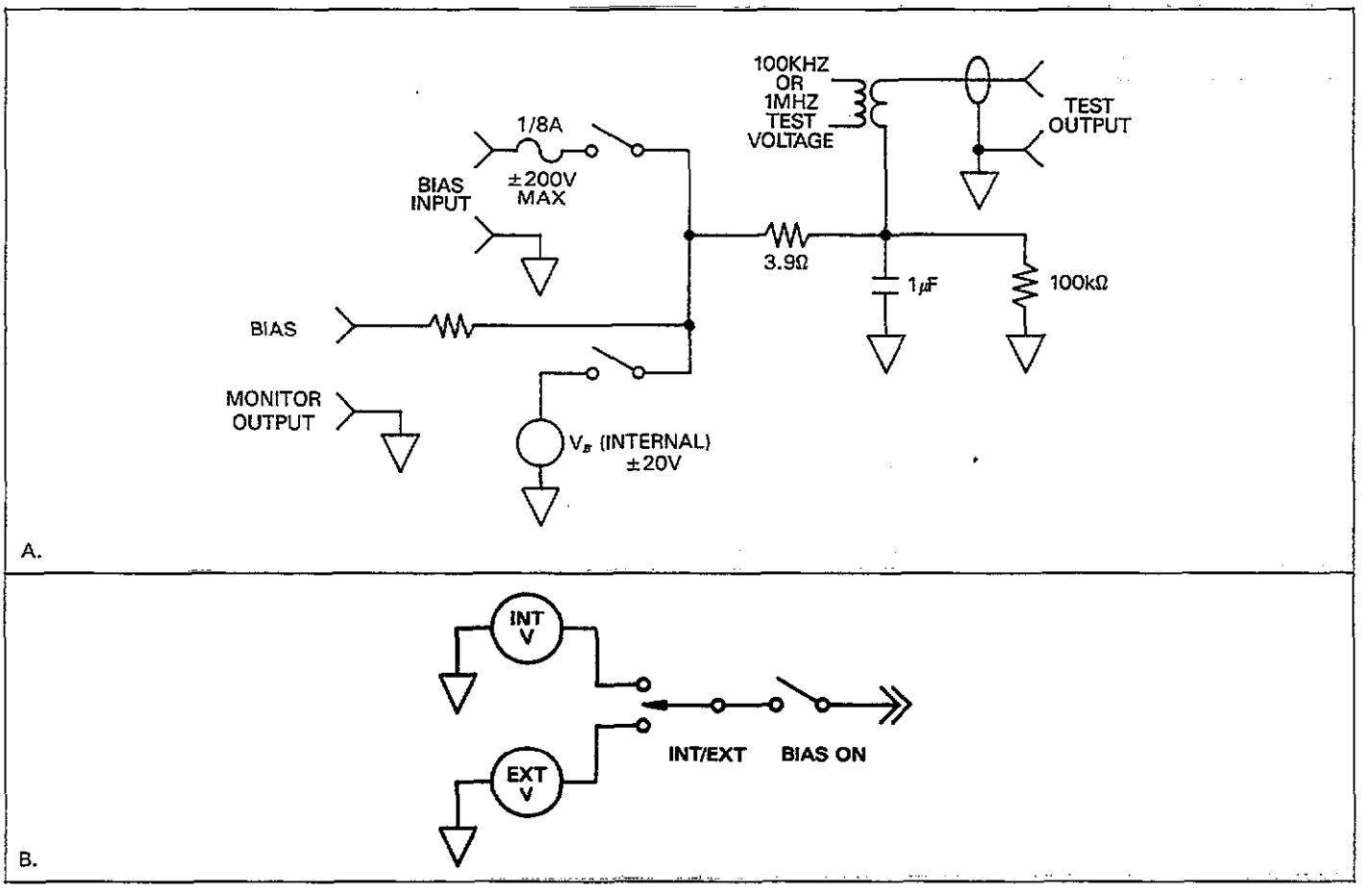



**Figure 3-21. Bias Switching Network (a) Software Implementation of Bias ON (b)**

### 3.14.4 Bias Waveform and Parameter Definitions

Definitions for the various bias waveforms and associated parameters are located in Figures 3-22 through 3-31. Where applicable, a separate definition is included for each waveform and trigger mode combination.

Parameters are further defined as follows:

Start Time: The time period, occurring on the first bias step, from the point the instrument is first triggered until the first step time.

Stop Time: The time period after the reading taken during that last bias step before the instrument returns to the default bias voltage.

Step Time: The time period after a transition to a new bias step before the instrument begins a measurement (except for the first step, which also includes the start time).

First Bias: The initial voltage setting of the bias waveform.

Last Bias: The final voltage setting of the bias waveform.

Step Bias: The incremental change of each step in the bias voltage waveform.

Default Bias: The bias voltage value both before and after a sweep, or between pulses (pulse train only).

Count: This parameter sets the number of readings per sweep for the DC and external bias waveforms only.



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NOTES:

1. To program a negative going staircase (or negative then positive dual staircase) set the first bias more positive than the last bias, and use negative step bias values. For example, to step from +5V to −5V in 100mV increments, program the following values:

   First Bias: +5V
   Last Bias: −5V
   Step Bias: −0.1V

2. The final step bias value may be smaller than the programmed Step Bias, depending on First Bias, Last Bias, and Step Bias Values.

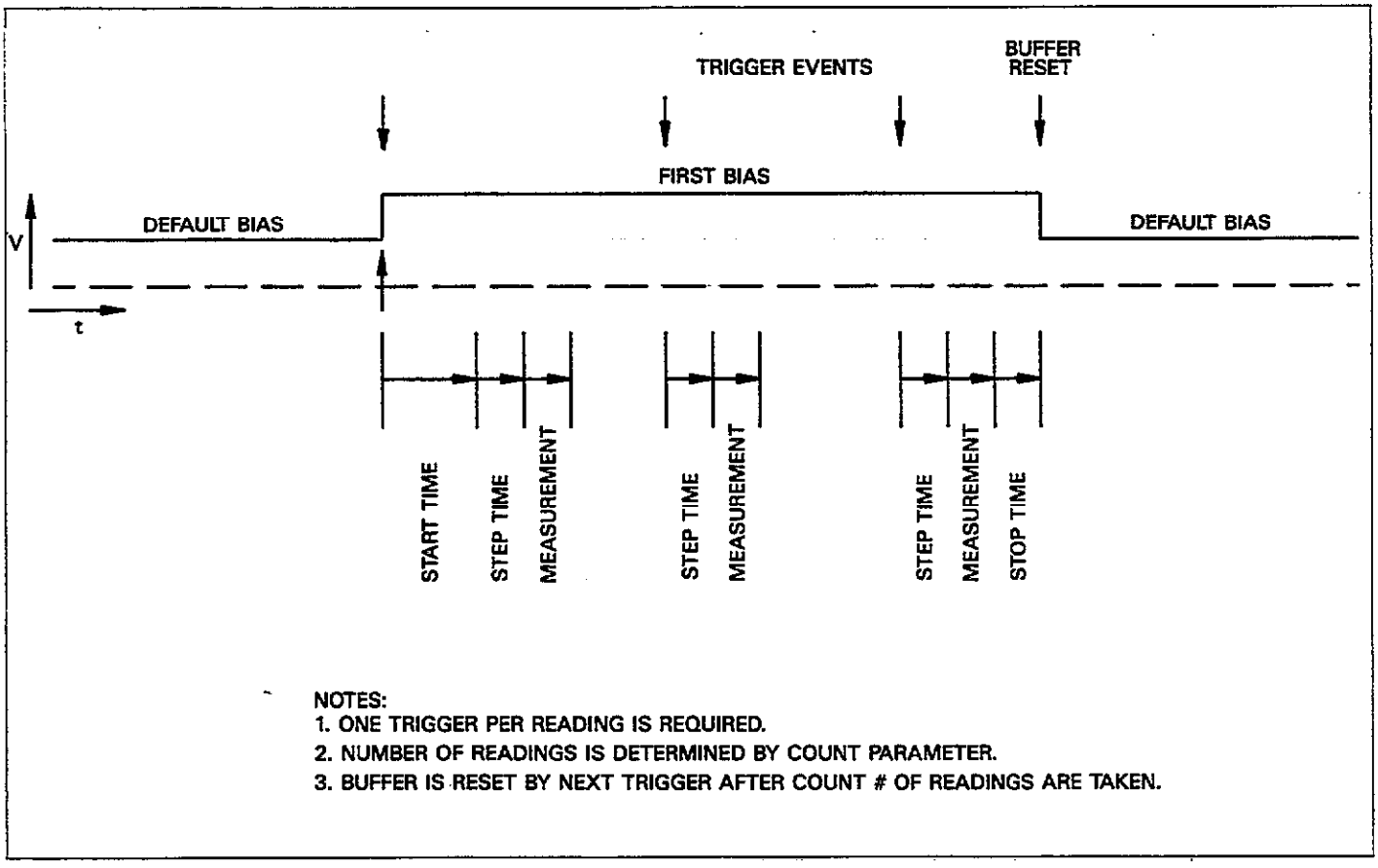



**Figure 3-22. DC, One-Shot**



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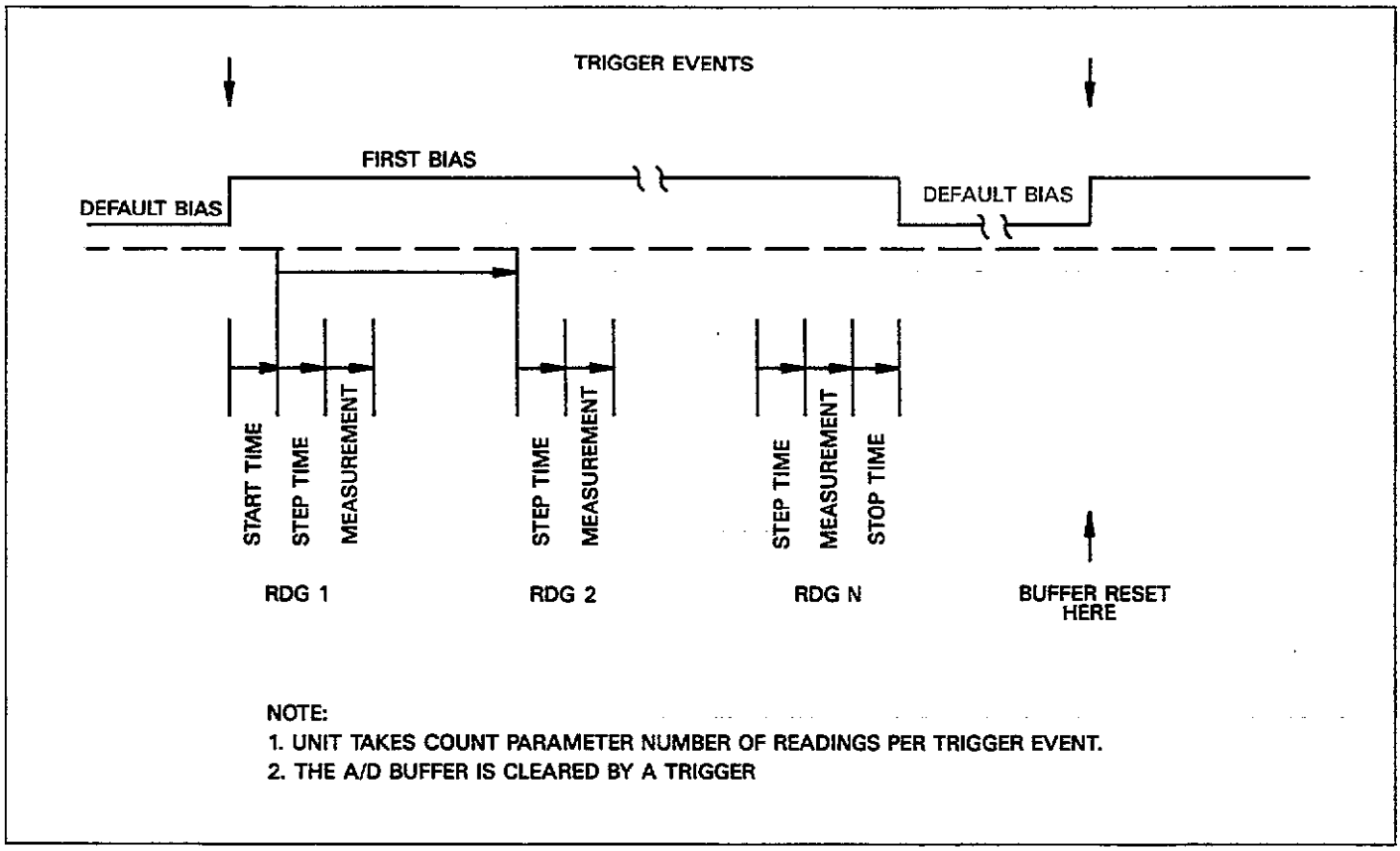



**Figure 3-23. DC, Single Sweep**



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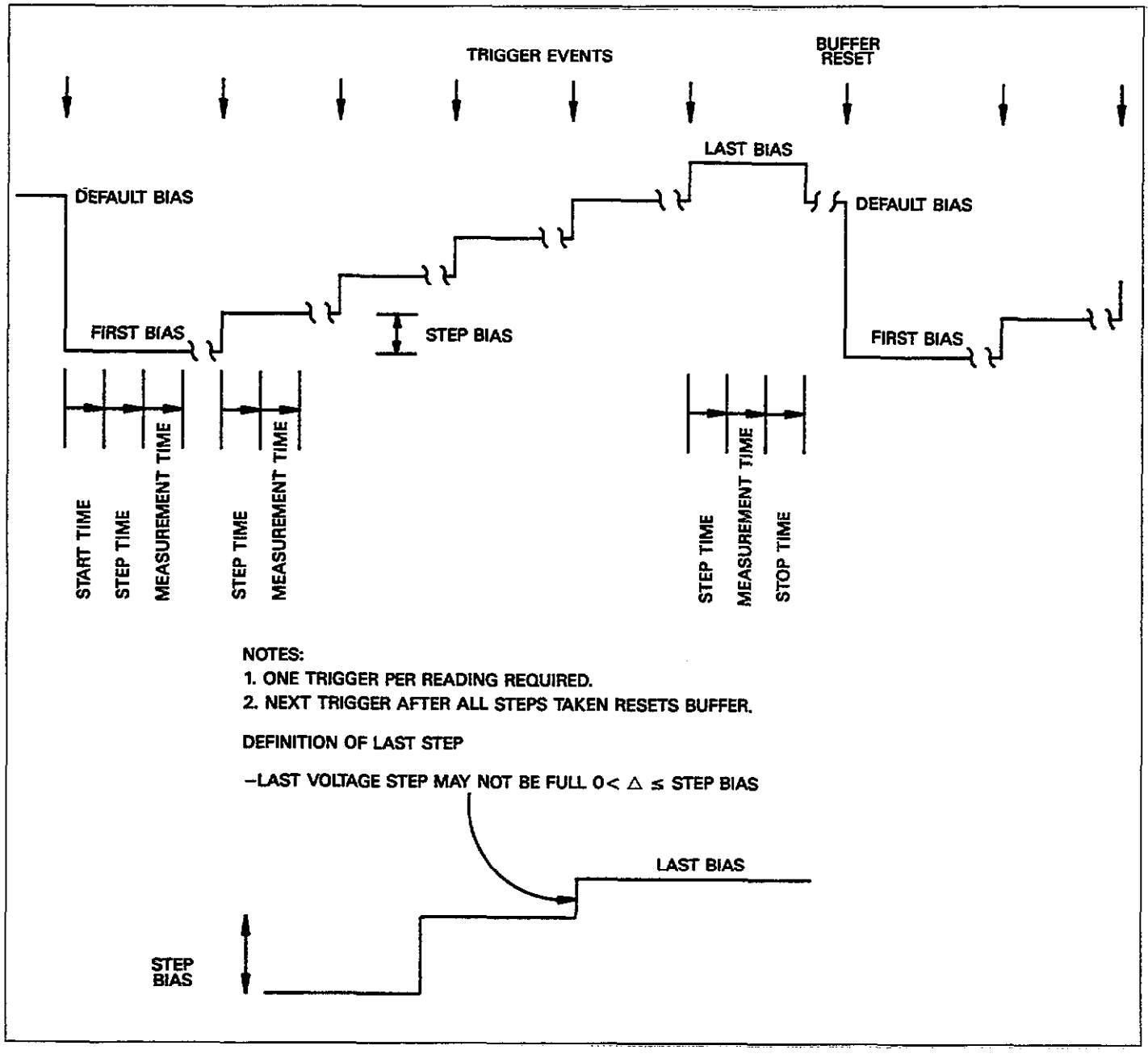



**Figure 3-24. Single Staircase, One-Shot**



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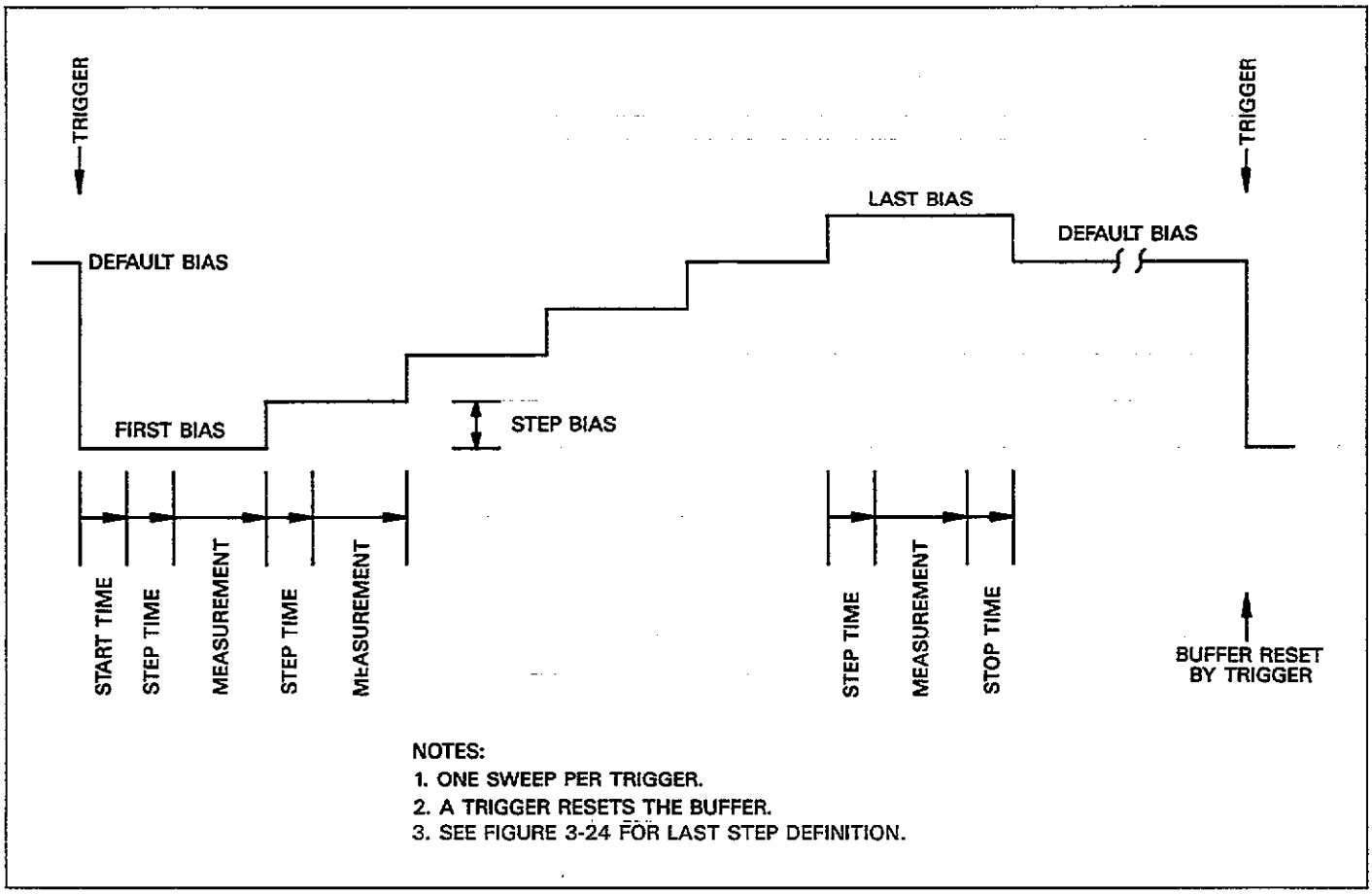



**Figure 3-25. Single Staircase, Sweep**



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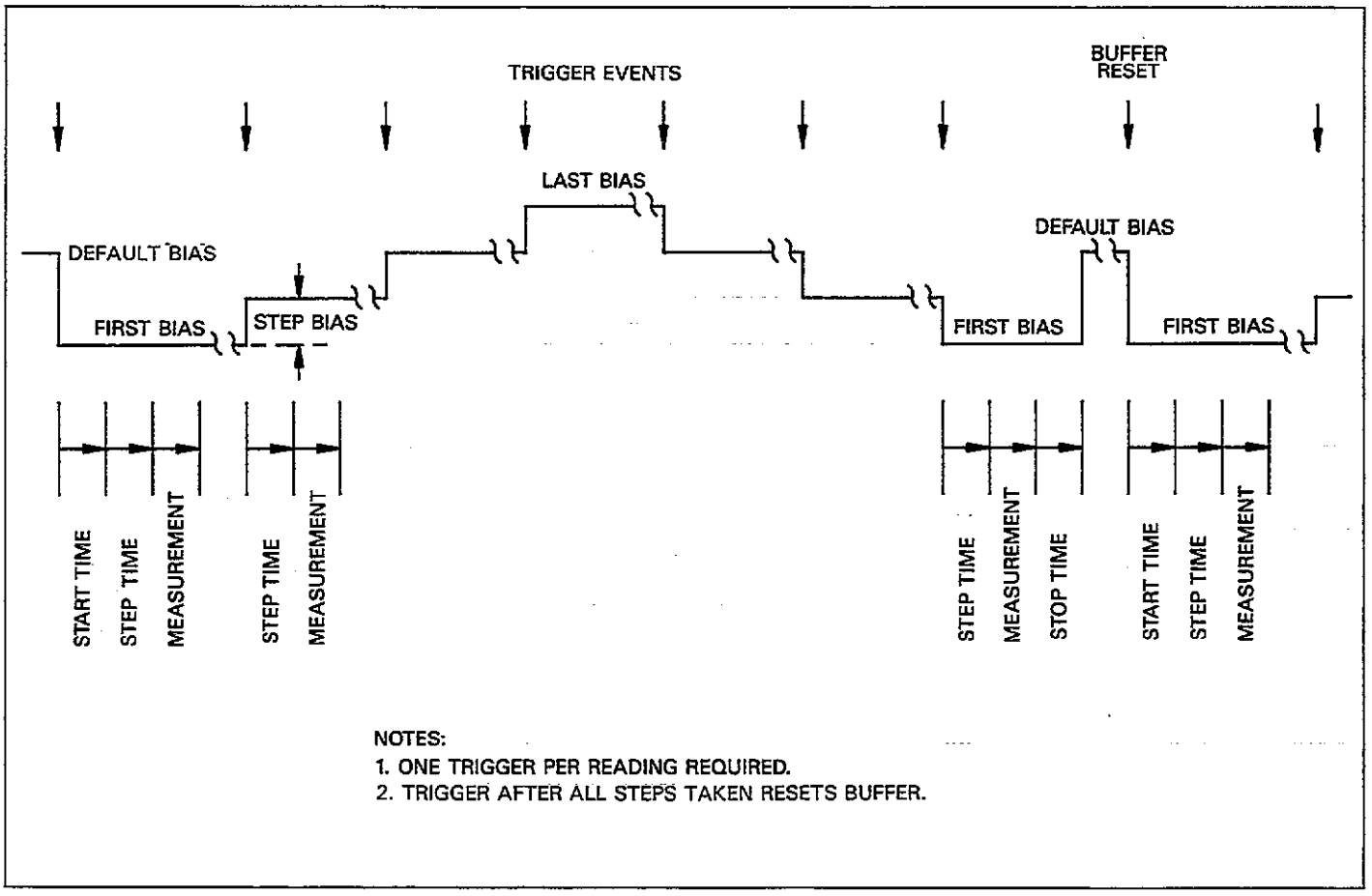



**Figure 3-26. Dual Staircase, One-Shot**



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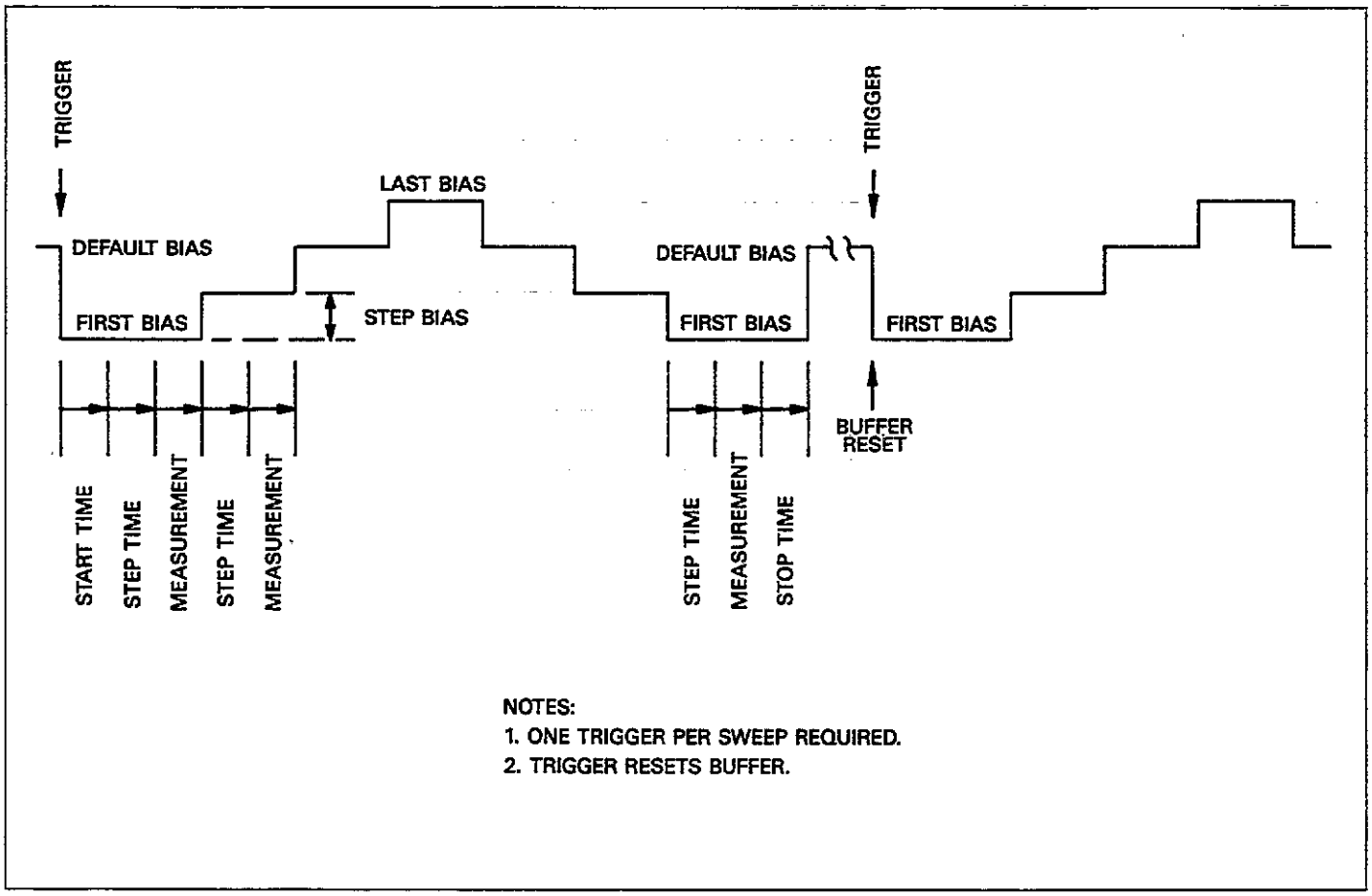



**Figure 3-27. Dual Staircase, Single Sweep**



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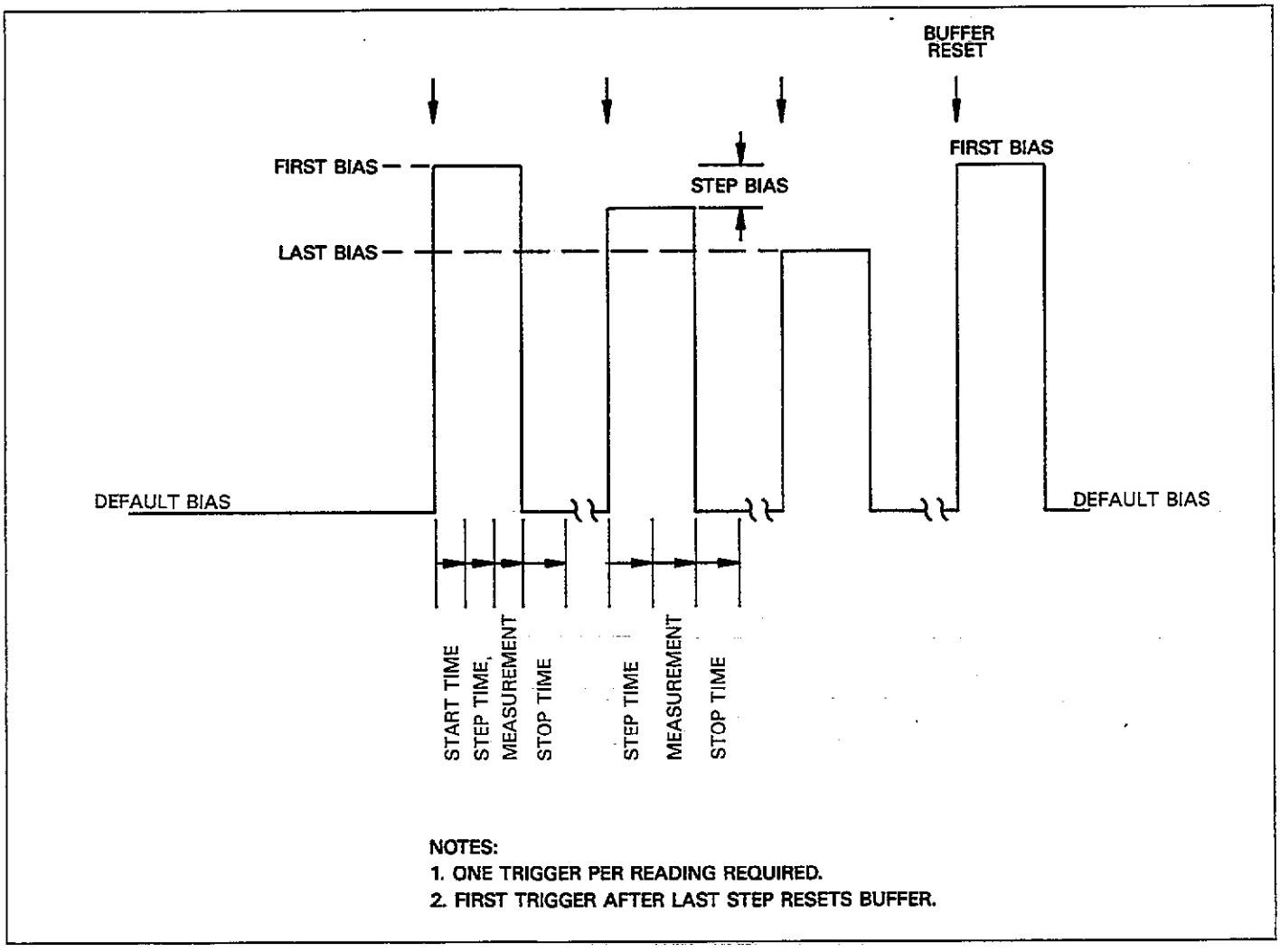



**Figure 3-28. Pulse Train, One-Shot**



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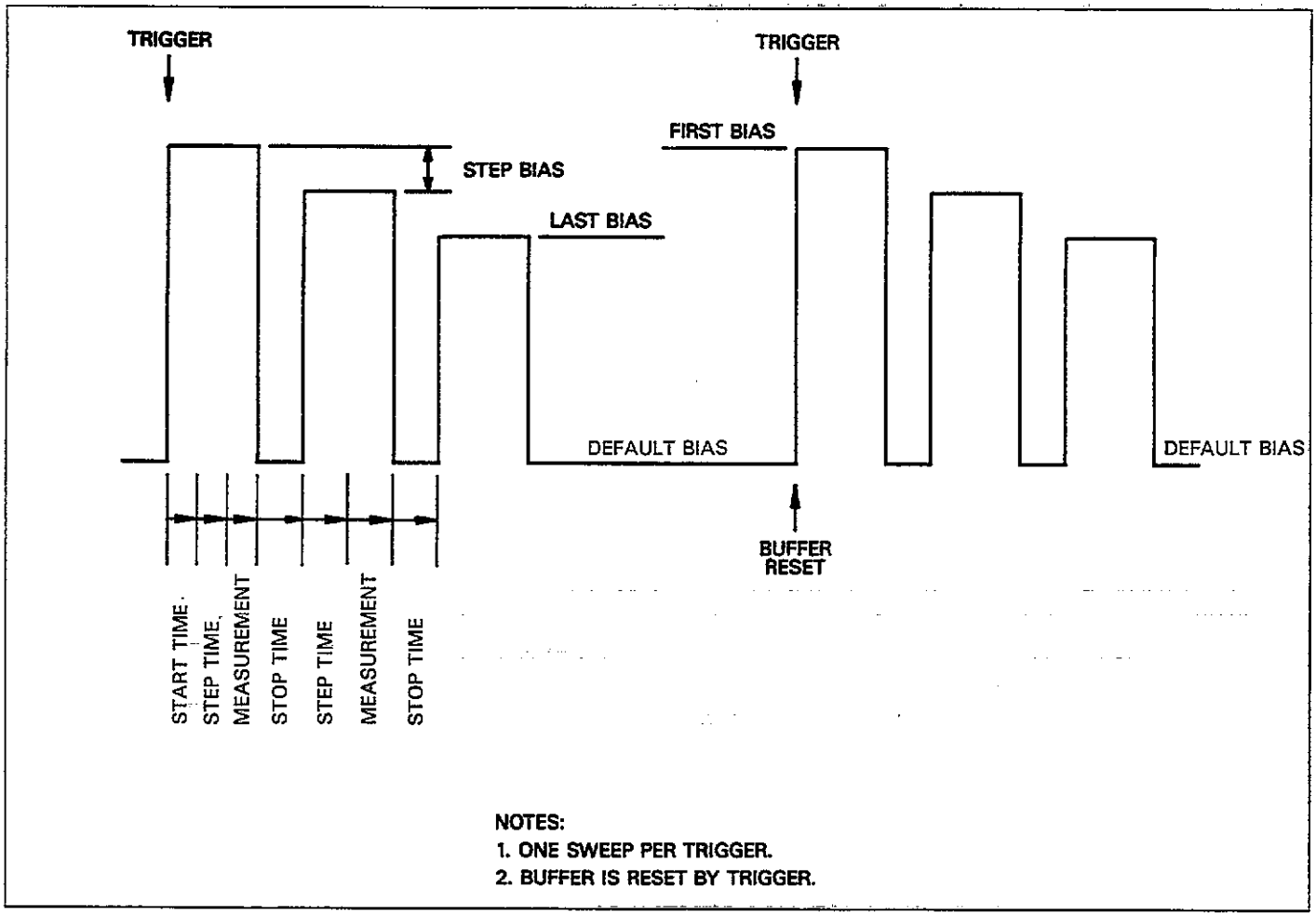



**Figure 3-29. Pulse Train, Single Sweep**



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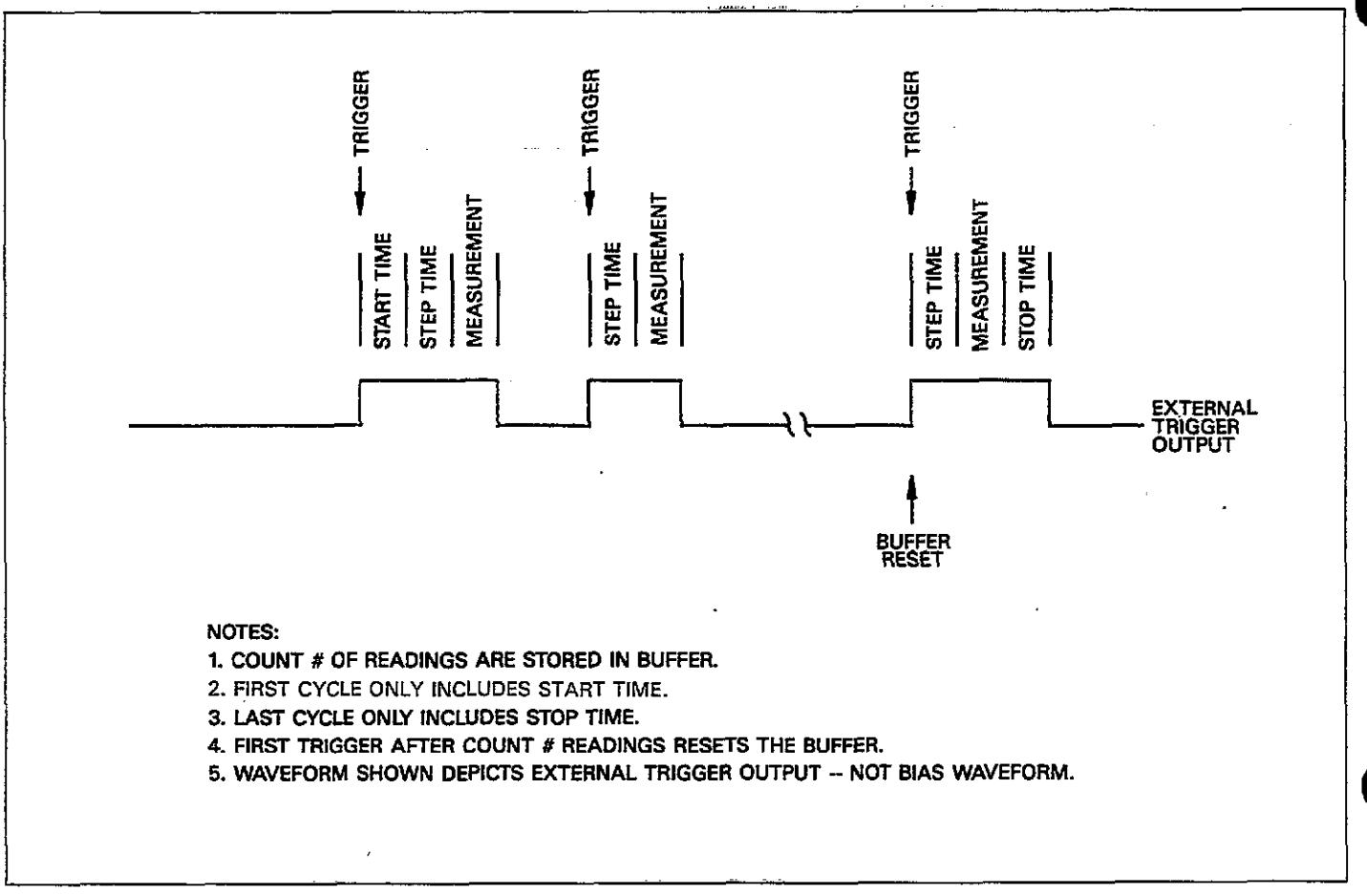



**Figure 3-30. External, One-Shot**



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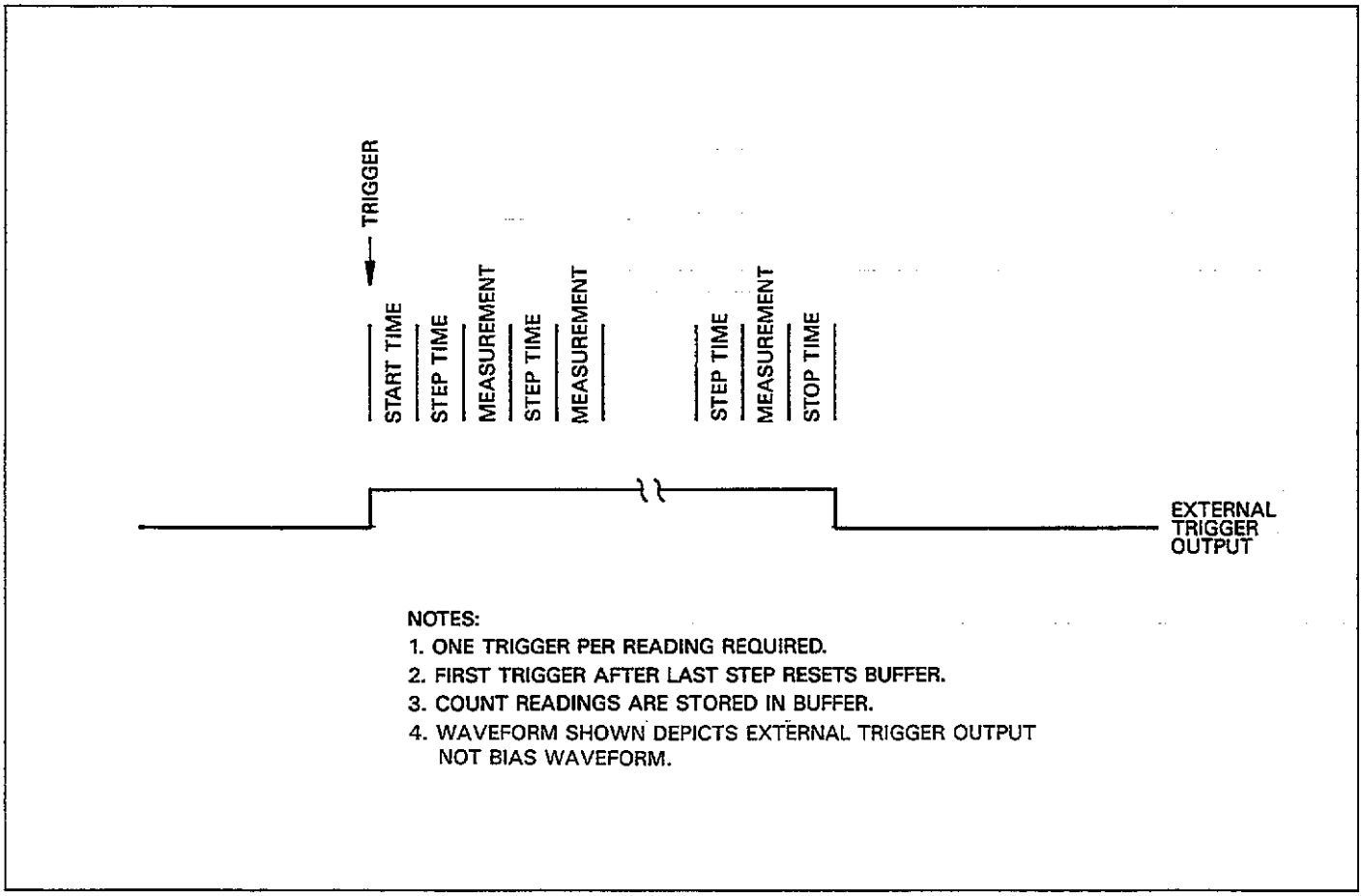



**Figure 3-31. External, Single-Sweep**



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## 3.14.5 Bias Step and Sweep Duration

The duration of each bias step depends not only on values of programmed parameters such as start time, step time, and stop time, but also on the selected reading rate, as discussed below.

**NOTE**

For simplicity, the following examples use the nominal reading rates in the calculations. For best accuracy, use the actual reading rates, as discussed in paragraph 3.9.

### First Bias Step Duration

As shown in Figure 3-32, the duration of the first bias step is the sum of the following:

1. The programmed start time.
2. The selected step time.
3. The measurement time. The measurement time is simply the reciprocal of the reading rate. During this period, the instrument measures C, G, and V values (except at the 1000/sec rate, which measures only capacitance) and stores the values in the current buffer location.

### Bias Step Duration

As shown in Figure 3-32, this time period is the duration of all bias steps in the waveform except for the first and last step. This time period is the sum of:

1. The programmed step time.
2. The measurement time. Again, the measurement time is the reciprocal of the reading rate.

### Last Bias Step Duration

The last bias step duration is simply the sum of the following (refer to Figure 3-32):

1. The programmed step time.
2. The measurement time. As discussed above, the measurement time is the reciprocal of the reading rate.
3. The programmed stop time.

### Computing Sweep Times and C vs t Information

When computing sweep times or C vs t information, you must multiply the programmed start, stop, and step times by a factor of 1.024 in order to accurately compute these factors. For example, time at a specific buffer location is computed as follows (DC and staircase waveform):

$$t_B = 1.024t_{start} + B\ (1.024t_{step} + 1/R)$$

Where: $t_B$ = time at a specific buffer location
$t_{start}$ = programmed start time
$t_{stop}$ = programmed step time
R = actual reading rate (see list above for actual rates)
B = Buffer location number

For pulse waveforms, the time is:

$$t_B = 1.024t_{start} + B\ (1.024t_{step} + 1/R + 1.024t_{stop})$$

Where: $t_{stop}$ = programmed stop time (other parameters as indicated above)

Note that accuracy is ± (0.3% + 1.024msec) except for stop times less than 2msec, which are not specified.

Example: Assume that the instrument is being operated at the nominal 10/sec rate with a programmed start time of 100msec and a step time of 50msec. The time at buffer location 40 would be:

$$t_B = 1.024\ (0.1) + 40\ [1.024\ (0.05) + 1/9.77]$$
$$t_B = 6.24\text{sec}$$

In a similar manner, elapsed times indicated in the U8 and U15 status words (Section 4), and shown on plots (paragraph 3.16) must also be multiplied by a factor of 1.024 in order to determine the actual elapsed times.



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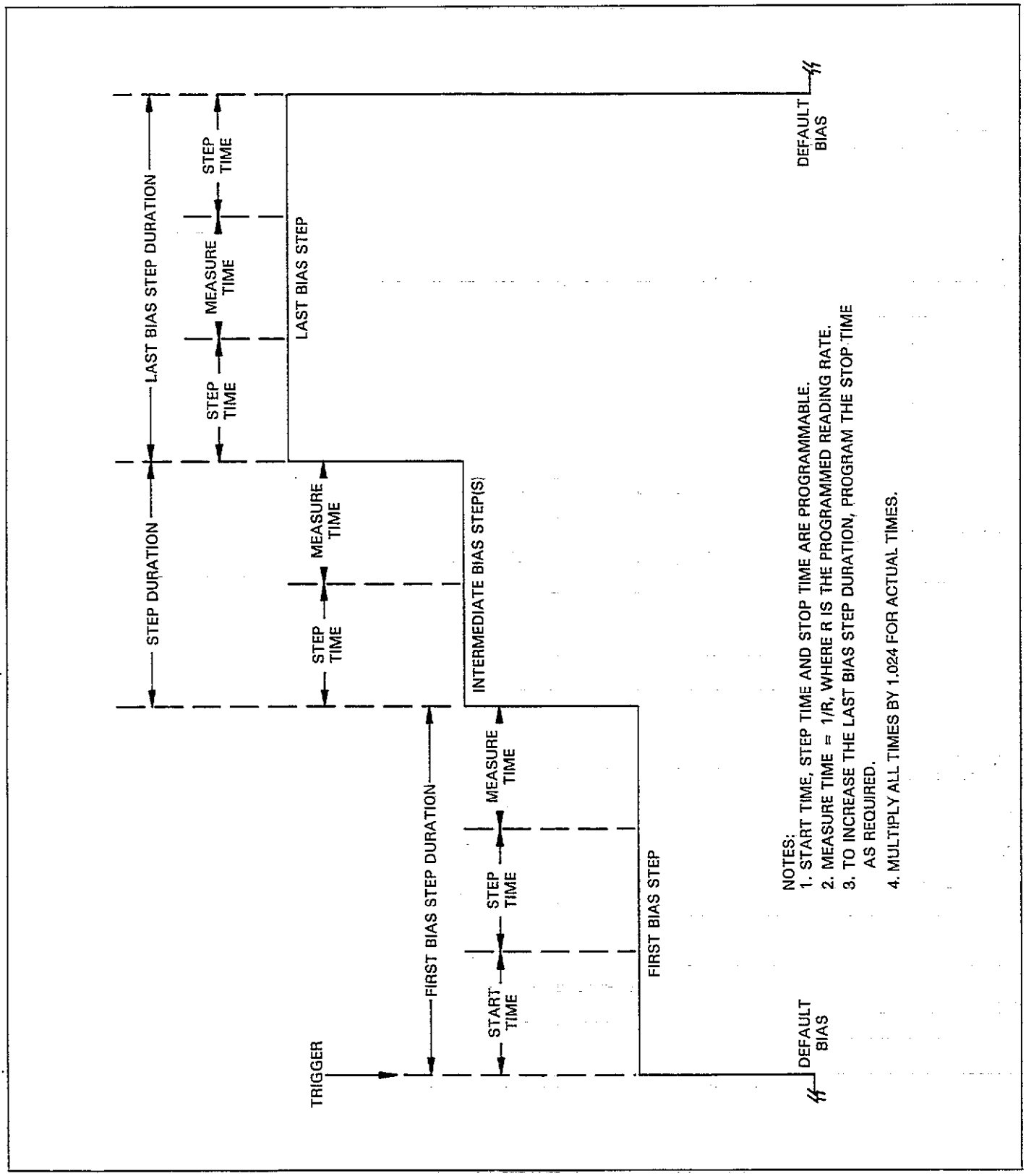



**Figure 3-32. Bias Step Durations**



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## 3.14.6 Using External Bias Sources

The Model 590 may be used with an external bias voltage source, as described below.

### *Source Connections*

Figure 3-33 shows a typical configuration using an external voltage source. Note that the source output is connected to the VOLTAGE BIAS INPUT jack on the rear panel of the Model 590. When making the connections, use good quality shielded cable to minimize EMI radiation. The center conductor of the jack is input high, while the outer ring or shell is input low.

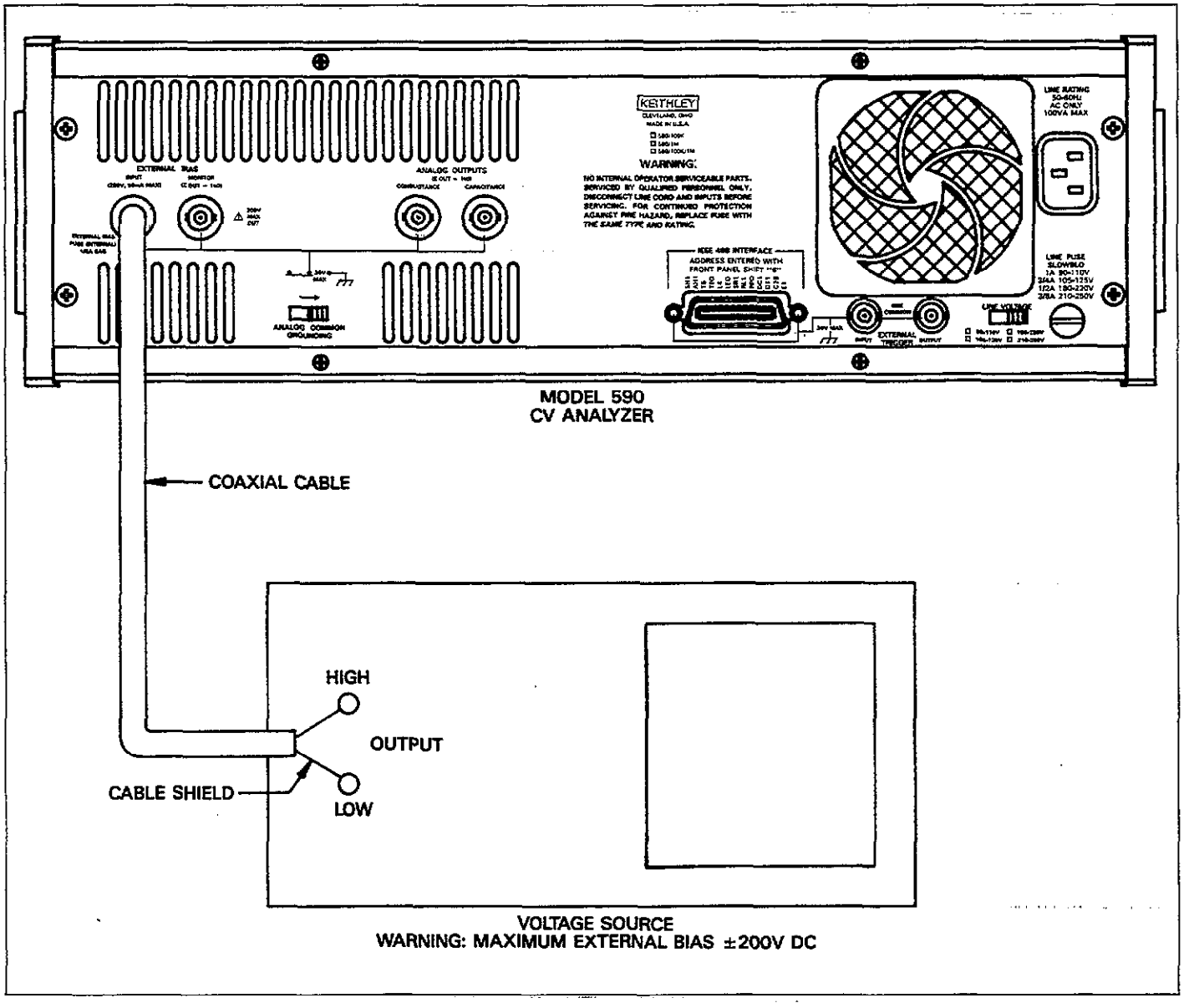



**Figure 3-33. External Bias Source Connections**



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**WARNING**

**Maximum external bias voltage is ±200V DC. Exceeding this value may create a shock hazard or cause damage to the instrument.**

**CAUTION**

**The output terminals of some voltage sources are shorted when those sources are placed in standby. Thus, placing the external bias source in standby nay cause the Mode 590 bias input fuse to blow. To avoid blowing the fuse, always turn off the Model 590 bias source (with the BIAS ON key) before placing the external bias source in standby.**

**CAUTION**

**The outer ring of the BIAS INPUT jack is connected to analog common and can be floated a maximum of 30V RMS above chassis ground only when the rear panel grounding switch is in the floating position. Exceeding this value may cause instrument damage. Analog common cannot be floated above chassis ground when the grounding switch is in the grounded position.**

Controlling External Bias

To enable the external bias source you must do two things: select external bias with the WAVEFORM key, and turn on the external bias with the BIAS ON key. The basic procedure is as follows:

1. Press WAVEFORM repeatedly until the instrument displays the following:
   BIAS WAVEFORM EXT
2. Press ENTER to select external bias.
3. Program or select the desired value on your external voltage source and turn on its output.
4. Turn on the bias voltage by pressing the BIAS ON key on the front panel of the Model 590. The voltage will then be applied to the OUTPUT jack.
5. To turn off the external bias source, press the BIAS ON key again.

## 3.14.7 Monitoring the Bias Voltage

By connecting a suitable monitoring device to the VOLTAGE BIAS MONITOR jack, you can measure or record the actual bias votlage, whether that voltage is being generated internally or externally. Typical examples include a DMM, chart recorder, or analog plotter.

Figure 3-34 shows typical connections for bias voltage monitoring. Note that the center conductor of MONITOR is high, the the outer ring is low.

**WARNING**

**Up to 200V may be present at the MONITOR output.**

**CAUTION**

**The maximum common-mode voltage (voltage between the outer shell of MONITOR and chassis ground) is 30V RMS when the grounding switch is in the floating position. MONITOR low cannot be floated above ground when the grounding switch is in the grounded position.**

NOTES:

1. Use only shoelded cable to minize the possibility of EMI radiation.
2. The source resistance of MONITOR is 1kΩ. Thus, to minimize accuracy degradation due to loading, the input resistance of the monitoring device shoud be as high as possible. For example, to keep accuracy degradation under 1%, the input resistance of the monitoring device should be at least 100kΩ.

## 3.14.8 External bias voltage measurement range

**Available ranges**

There are two external bias voltage measurement ranges, 20V and 200V. For best voltage measurement accuracy, use the 20V range whenever possible.

**Selecting the 20V voltage measurement range**

Select the 20V external bias voltage measurement range as follows:

1. Press the WAVEFORM key.
2. Repeatedly press the up or down arrow key until the following message is displayed:
   BIAS WAVEFORM EXT20
3. Press ENTER to complete the selection.

**Selecting the 200V measurement range**

Select the 200V external bias voltage measurement range as follows:

1. Press the WAVEFORM key.
2. Repeatedly press the up or down arrow key until the following message is displayed:
   BIAS WAVEFORM EXT200
3. Press ENTER to complete the selection.



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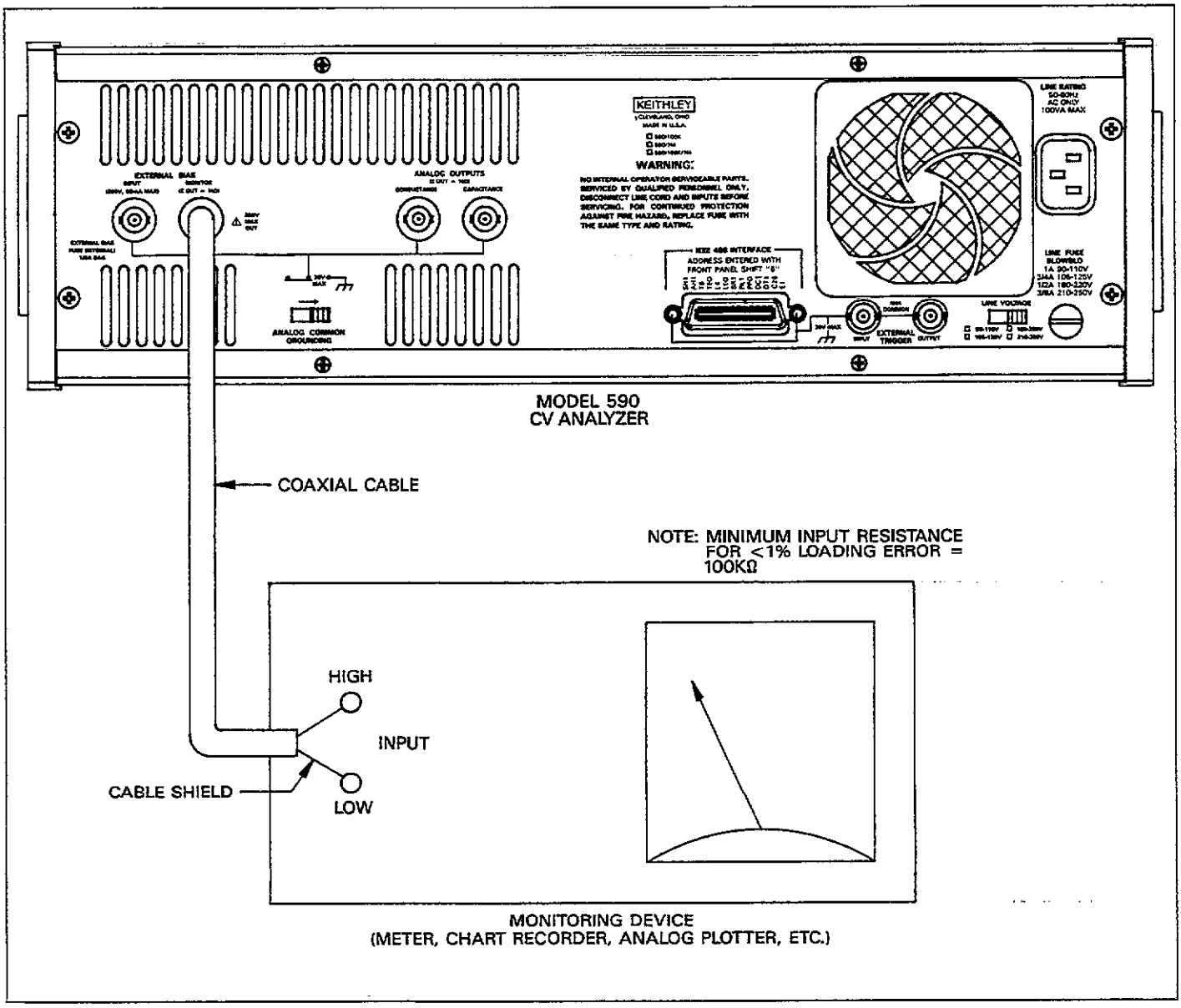
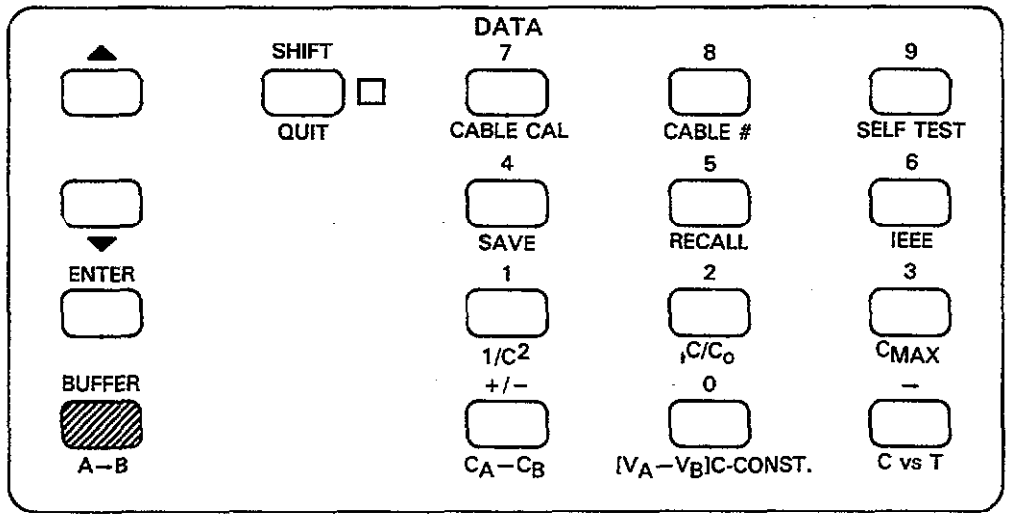



**Figure 3-34. Bias Monitor Connections**



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## 3.15 BUFFER OPERATION

The following paragraphs describe basic operation of the two 450 word buffers and how they are affected by triggers. Additional discussions cover how to display data from the A/D buffer on the display and how to transfer buffer contents.

### 3.15.1 Buffer Definitions

Reading—A single group of data normally consisting of a capacitance, conductance, and bias voltage value (except at 1000 readings per second, which includes only capacitance data).

Buffer A—The 450 word buffer into which readings processed by the A/D converter are placed during a reading sweep. For that reason, buffer A is often referred to as the A/D buffer in this manual. Each word in buffer A normally contains capacitance, conductance, and bias voltage data.

Buffer B—This 450 word buffer provides additional storage for sweep data. Since plotting is usually done from this buffer, buffer B is frequently referred to as the plotter buffer in this manual. Note that the A/D converter cannot directly place data into this buffer; you must transfer buffer contents with the A → B key. It is recommended that you transfer data immediately after the sweep is completed in order to avoid overwriting it by mistake.

Last Reading Register—As the name implies, this register stores the last available reading made available by the A/D converter. Register data is then displayed on the front panel and made available for transmission over the IEEE-488 bus.

Buffer Location Numbers—Buffer locations are numbered 1 through 450 inclusive, for a total of 450 locations. Each location stores a capacitance, conductance, and bias voltage reading. The unit stores data sequentially in lowest to highest order, beginning at location 1.

**NOTE**

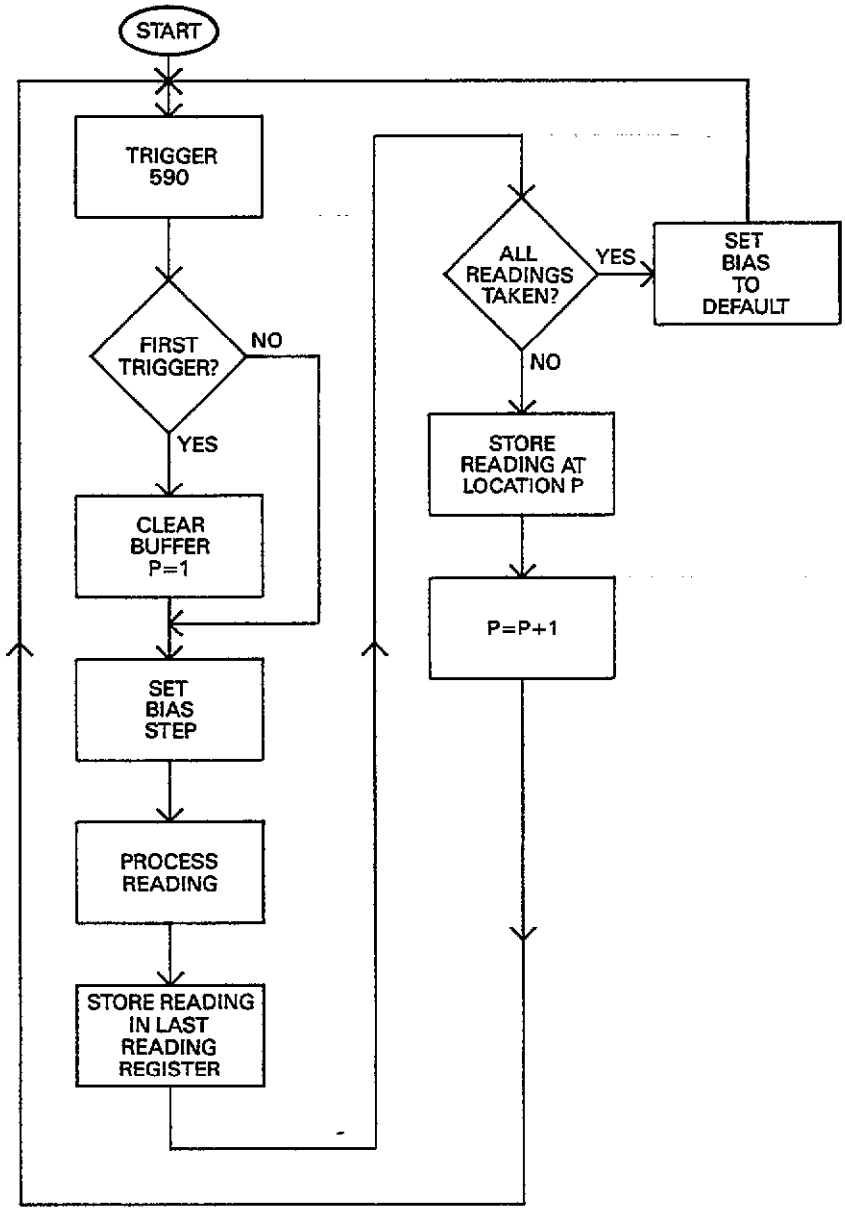
Buffer size is 1,350 capacitance only readings at the 1,000/sec reading rate.

### 3.15.2 How Trigger Modes Affect the A/D Buffer

The way that data is placed into the A/D buffer varies somewhat, depending on the trigger mode in use, as described below. Figures 3-35 and 3-36 show buffer operation flow charts for the one-shot and sweep trigger modes respectively.



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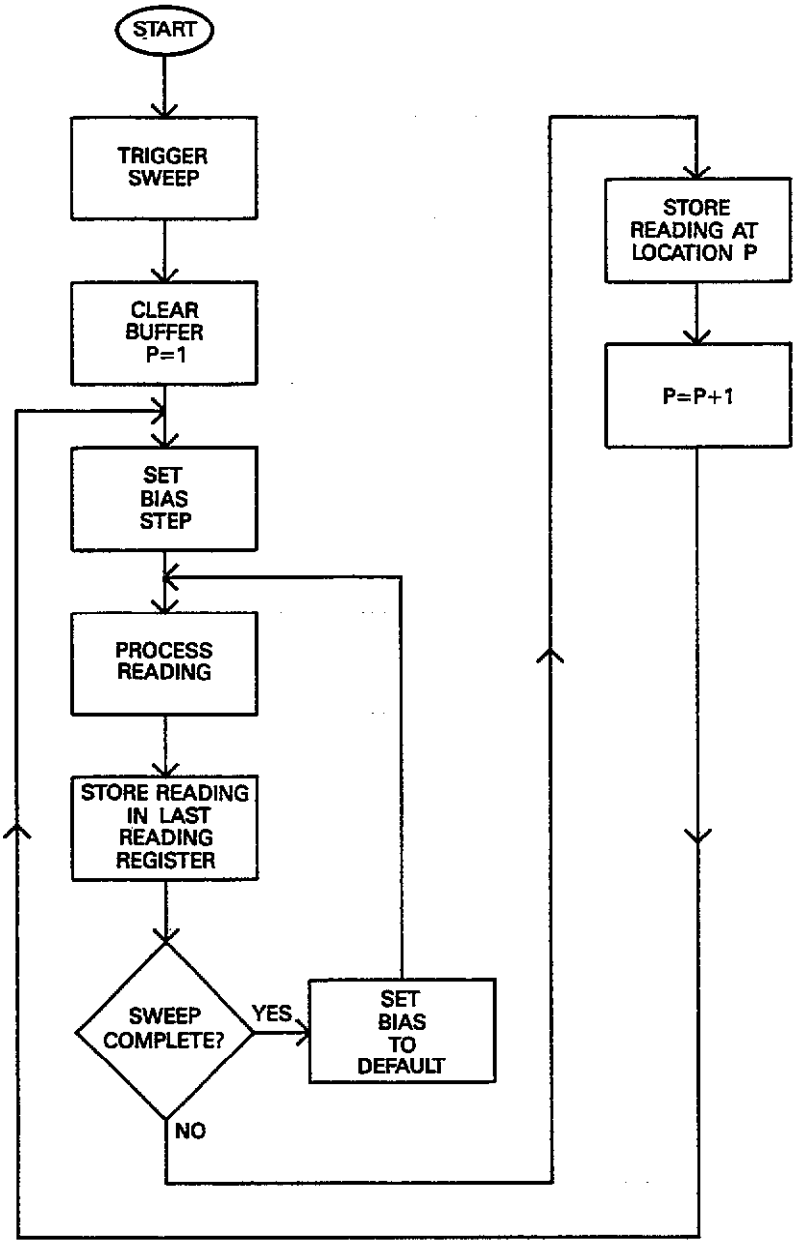



NOTES:
1. BUFFER POINTER P INDICATES BUFFER LOCATION.
2. ONE TRIGGER PER READING REQUIRED.
3. BIAS STEP BLOCK IS NOT APPLICABLE TO DC AND EXTERNAL WAVEFORMS.

**Figure 3-35. Buffer Operation in One-Shot Mode**



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NOTES:
1. BUFFER POINTER P INDICATES BUFFER LOCATION.
2. ONE TRIGGER PER SWEEP REQUIRED.
3. BIAS STEP BLOCK IS NOT APPLICABLE TO DC AND EXTERNAL WAVEFORMS.

**Figure 3-36. Buffer Operation in Sweep Mode**



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### One-shot

Initially, readings are placed into the buffer beginning with location 1 and the last reading register as triggered. Recall that a separate trigger is required for each reading in the one-shot trigger mode.

Readings continue to process, one per trigger, until all possible readings are taken. For the two staircase and pulse waveforms, this number depends on the programmed first, last, and step bias values. With the DC and external waveforms, however, the number of readings to be taken depends on the COUNT parameter, up to the maximum buffer size.

Once all steps are completed (as determined either by bias voltage parameters or the COUNT variable), the unit sets the bias voltage to the default value. Note, however, that the very next trigger will clear the buffer and begin storage again at location 1, destroying all points in the previous sweep. Thus, it is imperative that you keep track of the number of triggers in order to avoid loosing your data.

### Sweep

Once the unit is triggered, it will store n readings in the buffer in first to last location order. Here n represents the number of readings in the sweep. For the staircase and pulse waveforms, n is determined by the first, last, and step bias voltage parameters. However, n is equal to the COUNT variable for the DC and external waveforms. As readings are stored in the buffer locations, they are also placed in the last reading register for use by the display and the IEEE-488 bus.

After n readings are taken and stored, the unit sets the bias voltage to the default level and then continues to take readings at that level until another trigger is received. These readings are stored in the last reading register only (and will consequently update the display), but will not be stored in the buffer.

With the next trigger stimulus, the buffer will be cleared, and the instrument will begin storing readings in the buffer again beginning at location 1.

NOTES:

1. In the sweep trigger mode, the same trigger that initiates the sweep will also reset the buffer for storage of new readings.
2. In the one-shot trigger mode, the first trigger after the sweep is completed will clear the buffer and store a new reading beginning at location 1.
3. Pressing RANGE, FREQ, ZERO, CAL or BIAS ON; or changing the rate, trigger mode, source, waveform or parameter will abort an active sweep and clear the A/D buffer.
4. Accessing a buffer which contains no valid data will cause the unit to display an invalid reading indication, as in the example below:

   —.————nF —.————mS ——.———V

5. Data will not be available until a sweep is completed at the 75 and 1000/sec reading rates. In one shot, the unit must receive sufficient triggers to complete a sweep before buffer data is valid.

## 3.15.3 Accessing Buffer Information

By using the BUFFER and ▲/▼ keys, you can display any of the 450 words located in either of the two buffers. During buffer access, the BUFFER LED will turn on to indicate that the instrument is displaying buffer data.

Use the following procedure to access data in either buffer.

1. Press BUFFER. The instrument will prompt you for the buffer to access:

   BUFFER A=0 B=1 ?

2. Press 0 or 1, as required. The instrument will then display the data stored in the first buffer location (location 1). For example, the display might show:

   18.000pF 00.120μS 05.000V

   Note that the BUFFER indicator turns on to show that you are reading buffer data instead of current readings.

3. To sequentially access the various buffer locations in ascending order, press the ▲ or BUFFER key. With each key press, you will access the next higher location until the highest location is reached, at which point the unit will stop incrementing and stay on the highest location. For easier scrolling, you can simply press and hold the key in question.
4. To sequentially access buffer locations in descending order, press the ▼ key. The unit will then decrement by one location with each key press. Once the lowest location (1) is reached, pressing decrement will have no



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further effect. Again, you can press and hold decrement to scroll through buffer locations more easily.

5. To display the first buffer location (location 1), press ENTER. To display the last valid buffer location (the highest location that contains valid data), press BUFFER.
6. To cancel buffer operation and return to the normal display mode, press QUIT. The BUFFER indicator will turn off to verify that the instrument is reading normal instrument data.

NOTES:

1. To display buffer locations, press the C vs t key when accessing a buffer. Buffer location numbers will then appear in the bias voltage display area.
2. The instrument will continue to process readings during buffer access if a sweep is active (except 75 and 1,000/sec rates).
3. Press RECALL to return to normal buffer display after using a math function.

### 3.15.4 Transferring Buffer Contents

Buffer A is the buffer into which A/D data is stored, while buffer B is the one normally used when plotting. Thus, to save data from being overwritten by a new sweep, you should transfer data from buffer A to buffer B before triggering a new sweep.

To transfer buffer data, simply press the A → B (SHIFT BUFFER) key. All valid data from buffer A will then be placed in buffer B, including capacitance, conductance, and bias voltage values. Any other pertinent information associated with the stored data such as whether or not zero was enabled when buffer data was stored will also be transferred to the buffer B header.

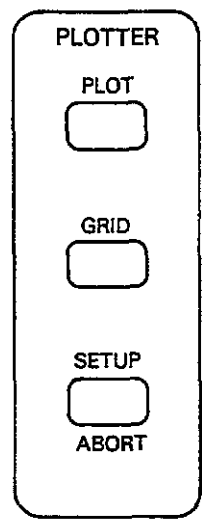
NOTES:

1. Since pressing some front panel keys will clear A/D buffer data, it is recommended that you always transfer data to buffer B immediately after a sweep is completed. There is no way to recover such data once buffer A is cleared.
2. Transferring buffer contents with the A → B key will clear buffer A of any data and abort an active sweep.
3. No data will be transferred by pressing A → B if no valid data is stored in the A/D buffer; however, buffer B will still be cleared of relevant data in this situation.

## 3.16 PLOTTING DATA

The following paragraphs contain information on connecting the Model 590 to an intelligent plotter, selecting plotter parameters, drawing grids, and generating plots. Actual examples of plots are also given.

Refer to paragraph 3.22 for information on plotting through the analog outputs using an X-Y recorder.




### 3.16.1 Recommended Plotters

The Model 590 software is designed to be used with the Hewlett-Packard 7470A plotter. Other similar plotters utilizing the syntax described in the following paragraphs may be substituted. Table 3-17 summarizes recommended plotters.

**Table 3-17. Recommended Plotters**

| Manufacturer | Model |
|---|---|
| Hewlett-Packard | 7470A* |
| Hewlett-Packard | 7475A |
| Hewlett-Packard | 9872A |

*This model is preferred.



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## 3.16.2 Plotter Language Syntax

The Model 590 uses a subset of HP-GL using the more rigorous HP9872 syntax. Commands implemented by the 590 are summarized in Table 3-18. General HP-GL syntax is shown in Figure 3-37.

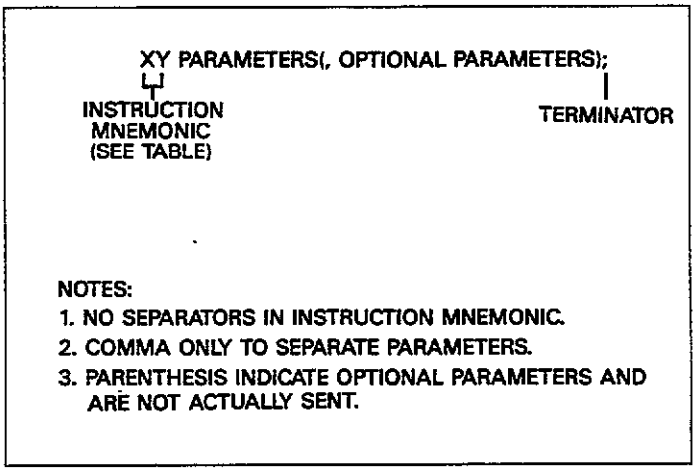



**Figure 3-37. HP-GL Syntax Used by Model 590**

**Table 3-18. HP-GL Instructions Used by Model 590**

| Instruction | Description |
|---|---|
| CP spaces, lines | Character plot |
| DF | Set default values |
| DI run, rise | Absolute direction |
| IN | Initialize |
| LB C...C | Label ASCII string |
| LT t(,1) | Designate line type and length |
| PA x, y (,x, y(....)) | Plot absolute |
| PD (x, y(,...)) | Pen down |
| PR x, y(,x, y(,...)) | Plot relative |
| PU (x, y(,...)) | Pen up |
| SC Xmin, Xmax, Ymin, Ymax | Scale |
| SI width, height | Absolute character size |
| SP n | Select pen |
| TL tp(,tn) | Tick length |
| XT | X-axis tick |
| YT | Y-axis tick |

## 3.16.3 Plotter Primary Address

The plotter should be operated in the addressable mode with a primary address of 5. Consult the plotter instruction manual for details on setting the primary address. Note that the Model 590 has no provisions for programming the plotter primary address; the instrument assumes that the primary address of the plotter is 5.

NOTES:

1. To avoid address conflicts, make sure that no other active devices on the bus have a primary address of 5.
2. When generating a plot or grid from the front panel, the Model 590 automatically addresses the plotter to listen.
3. Disconnect the controller from the bus when plotting from the front panel.

## 3.16.4 Plotter Bus Connections

The Model 590 should be connected to the plotter via the IEEE-488 bus, as shown in Figure 3-38. Shielded cable, such as the Keithley Model 7007, should be used to minimize the possibility of EMI radiation.



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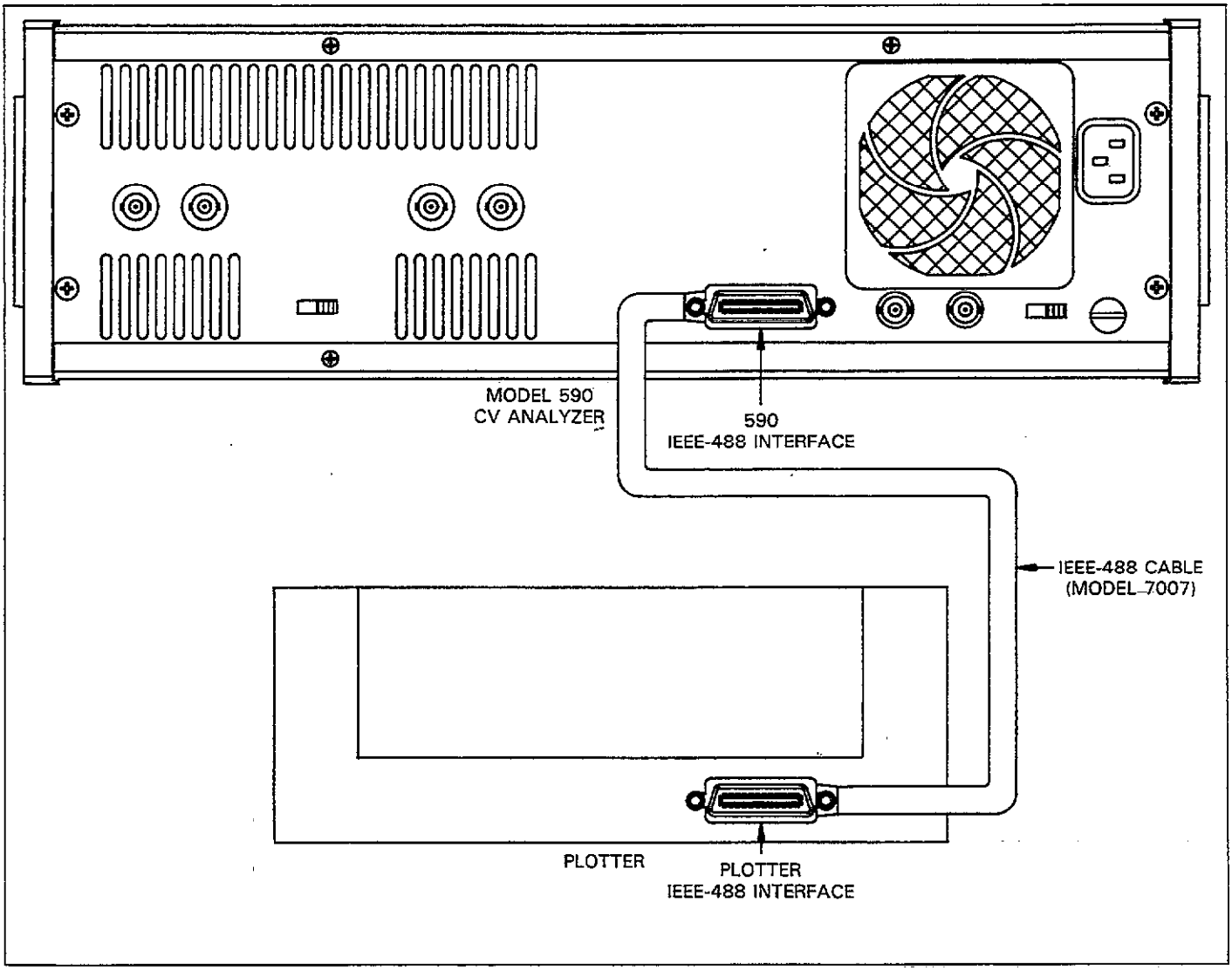



**Figure 3-38. IEEE-488 Plotter Connections**



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## 3.16.5 Programming Plotter Setup Parameters

Through use of the SETUP key, you have control over a number of setup parameters, including plot type, pen type, line type, grid type, label type XY axis scaling, as well as which of the two buffers to plot. Parameters associated with the SETUP key are summarized in Table 3-19. Figure 3-39 shows a general flowchart of the various plotting functions.

**NOTE**
Only the C vs t plot type can be used at 1000 readings per second.

### Table 3-19. Plotter Setup Parameters

| Parameter | Description |
|---|---|
| PLOT TYPE | 0 = C vs V*<br>1 = G vs V (R vs V, series model)<br>2 = $1/C^2$ vs V<br>3 = $C/C_O$ vs V<br>4 = C vs t (Buffer index)<br>5 = $C_A - C_B$ vs V<br>6 = $[V_A - V_B]C$ = CONST |
| PEN TYPE | 0 = No Pen<br>1 = Pen #1*<br>2 = Pen #2 |
| LINE TYPE | 0 = Dots at plotted points<br>1 = Spaced dots<br>2 = Dashes<br>3 = Long dash<br>4 = Dash dot<br>5 = Long dash/short dash<br>6 = Long dash/short dash/short dash<br>7 = Solid line* |
| GRID TYPE | 0 = Full grid*<br>1 = Axis only |
| LABEL TYPE | 0 = Full labels*<br>1 = Label axis and divisions (no title)<br>2 = Label axis only<br>3 = No labels |
| BUFFER | 0 = Buffer A (A/D)*<br>1 = Buffer B (Plot) |
| X SCALE** | 0 = Auto scale*<br>1 = User-programmed scale |
| Y SCALE** | 0 = Auto Scale*<br>1 = User-programmed scale |

*Default values.
**See text for discussion on programming scaling parameters
NOTE: Plotter setup parameters are not stored by SAVE/RECALL.

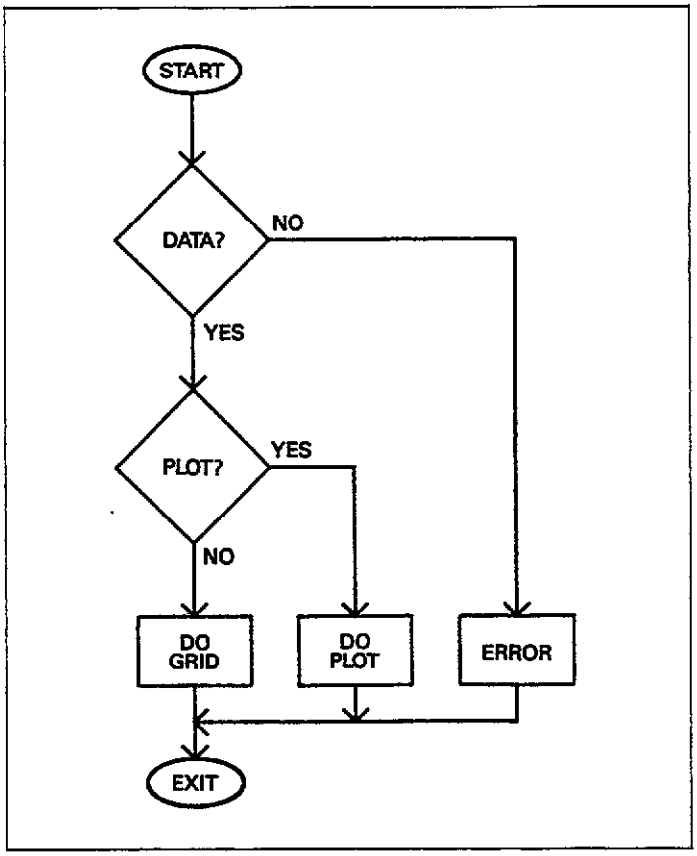



**Figure 3-39. Plotting Flowchart**

Program parameters as follows:

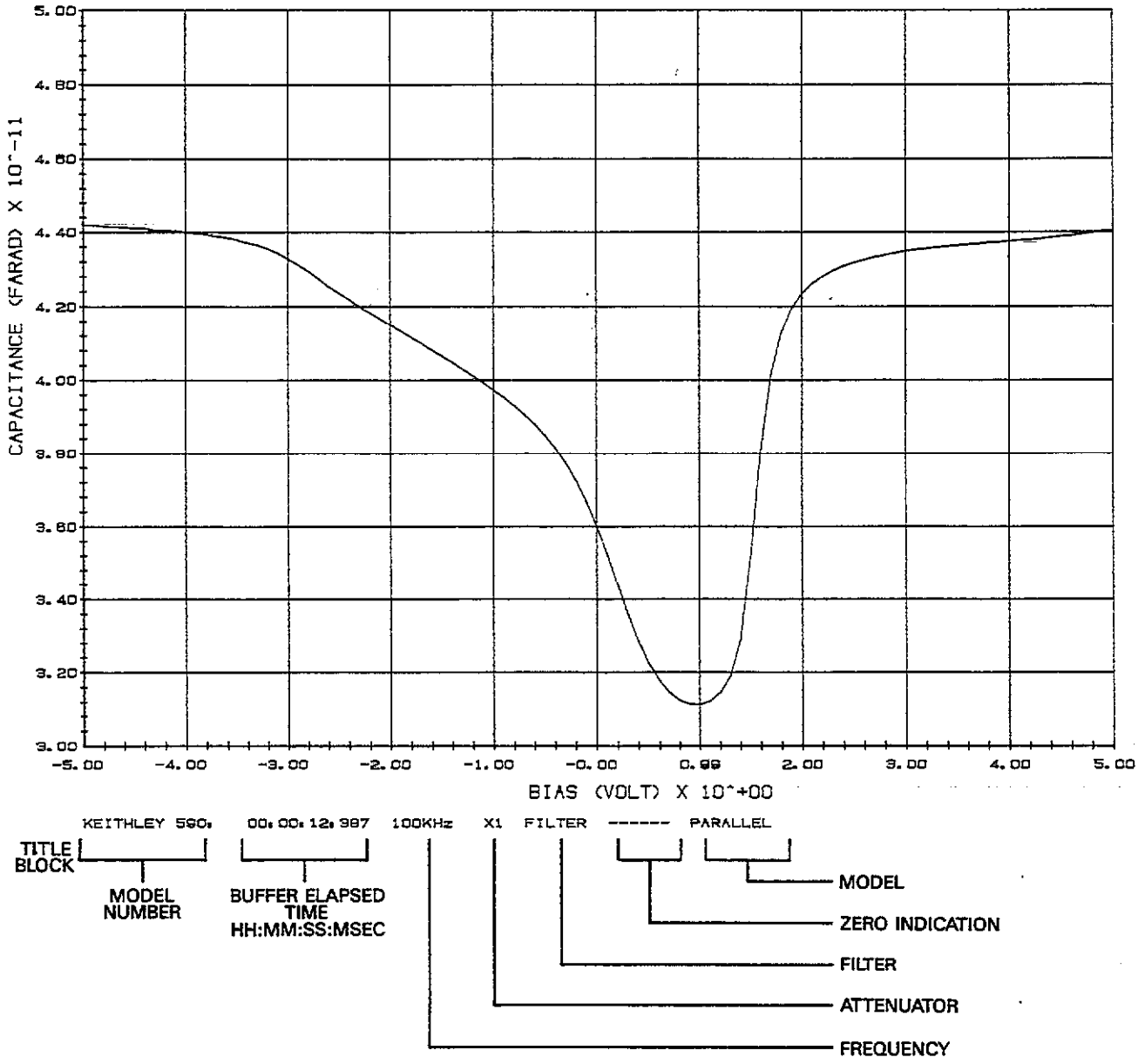
1. Press SETUP and then ▲/▼ repeatedly (or simply hold the key) until the display message for the parameter you wish to program is displayed. For example, the display for grid type is as follows:

   GRID TYPE 0-1

2. Using the numeric keys, enter the number of the parameter to be programmed. For example, for an axis-only grid, press 1.
3. Once all desired parameters have been programmed, press the ENTER key to program the value.
4. If you wish to return to the previously programmed parameter(s), press QUIT instead of ENTER.



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NOTES:

1. DASHES IN TITLE BLOCK INDICATE MODE IS DISABLED OR IRRELEVANT.
2. Y AXIS SHOWS PLOTTED FUNCTION: X AXIS SHOWS BIAS VOLTAGE (TIME INDEX IN C VS. T, CAPACITANCE IN $V_A - V_B$)
3. FULL LABELS AND GRID SHOWN.

**Figure 3-40. Plot Format**



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## 3.16.6 Graph Format

Figure 3-40 shows the general format of a typical plot. Axis type, line type, and title block parameters are indicated on the plot.

Title block parameters include:

1. Keithley Model number.
2. Buffer elapsed time in hours, minutes, seconds, and milliseconds.
3. X10 attenuator status.
4. Filter status.
5. Test frequency.
6. Zero status.
7. Model (series or parallel)

## 3.16.7 Plotting a Grid

To plot a grid on your graph, press the GRID key. The grid along with pertinent labels will then be plotted in accordance with the previously selected setup parameters.

## 3.16.8 Initiating the Plot

Press PLOT to perform the plotting function. The instrument will then send commands and data to the plotter to graph data in accordance with the previously selected SETUP parameters (plot type, pen type, and line type).

## 3.16.9 Aborting a Plot or Grid

If, during the process of generating a plot of grid, you can abort the operation by pressing the ABORT key.

Once a plot or grid has been aborted, press the appropriate key to initiate the required action from the beginning.

## 3.16.10 Plotter Error

Pressing PLOT or GRID while the function is active will cause the instrument to display the following error message:

CONFLICT

## 3.16.11 Plotter Scaling

By selecting appropriate parameters on the setup menu, you can select auto or user-defined scaling, as discussed below.

**Autoscaling**

When autoscaling is selected, the instrument will automatically scale the Y axis between 0 and full range value. For example, if plotting a C vs. V curve with data taken on the 200pF range, the minimum and maximum values will be 0 and 200pF respectively.

The X axis will be scaled in accordance with the minimum and maximum values stored in the buffer being plotted. For example, with the C vs. V plot, if the minimum and maximum stored buffer values are −5 and 5V, the X axis minimum will be −5 and the maximum will be +5.

**User-defined Scaling**

By selecting the appropriate option(s) on the setup menu, you can define the minimum and maximum values for both the X and Y axes. The basic procedure is outlined below.

Selecting Scaling and Programming Scaling Parameters

1. Press SETUP then hold the ▲ key until one of the following messages is displayed. For the X axis, the message is:

   XSCALE N=0 Y=1

   For the Y axis the unit displays the following:

   YSCALE N=0 Y=1

2. To disable scaling, press 0 then ENTER (or select the next parameter to be programmed with the ▲ / ▼ key, then press ENTER after all selections have been made).
3. To enable scaling for the selected axis, press 1 but do not press ENTER at this time.
4. Press ▲ to scroll to the low value for the selected axis. For example, for the low value on the X axis, the display will show:

   +0.0000E+00 XLOW

5. Use the numeric keys to enter the desired scaling factor. Use the → key, as necessary, to place the cursor on the digit(s) to be changed.



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6. Use ▲ to scroll to the remaining scaling parameters, as required. You can program both low and high values for both X and Y axes.
7. Once all scaling factors have been selected, press the ENTER key to program them.

## 3.16.12 Plot Types

By selecting the plot type option on the SETUP menu, you can choose one of the following seven plot types:

| Setup Option | Plot Type | Y Axis | X Axis |
|---|---|---|---|
| 0 | C vs V | Capacitance | Bias voltage |
| 1 | G vs V* | Conductance | Bias voltage |
| 2 | $1/C^2$ vs V | $1/C^2$ | Bias voltage |
| 3 | $C/C_o$ vs V | $C/C_o$ | Bias voltage |
| 4 | C vs t | Capacitance | Buffer location |
| 5 | $C_A$-$C_B$ vs V | $C_A$-$C_B$ | Bias voltage |
| 6 | $[V_A - V_B]C = CONST$ | $V_A - V_B$ | Capacitance |

*R vs V if series model was selected when data was taken.

With all seven plot types, the selected function is plotted along the Y axis. However, the bias voltage is plotted along the X axis only for five plot types. In the case of $V_A$-$V_B$, the capacitance is plotted along the X axis, while buffer location numbers (not actual times) are plotted along the X axis in C vs t.

NOTES:

1. More information on C vs t measurements may be found in paragraph 3.20.
2. The maximum capacitance value stored in the selected buffer is used for Co when plotting $C/C_O$.
3. Series or parallel model affects plotted data.

## 3.16.13 Plot Examples

Examples of typical plots are shown in Figures 3-41 through 3-47. A separate example for each plot type is included.



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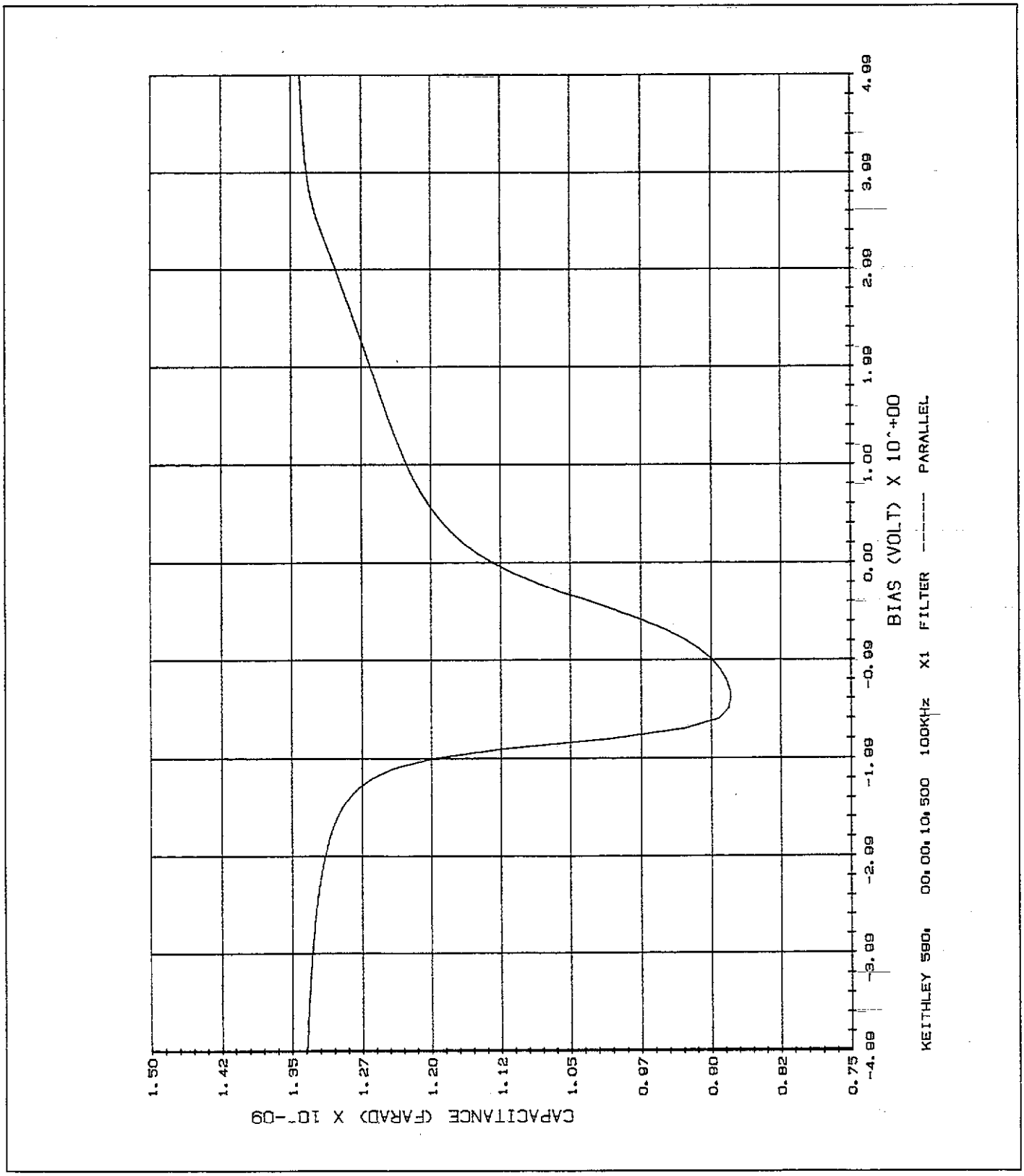



**Figure 3-41. C vs V Example**



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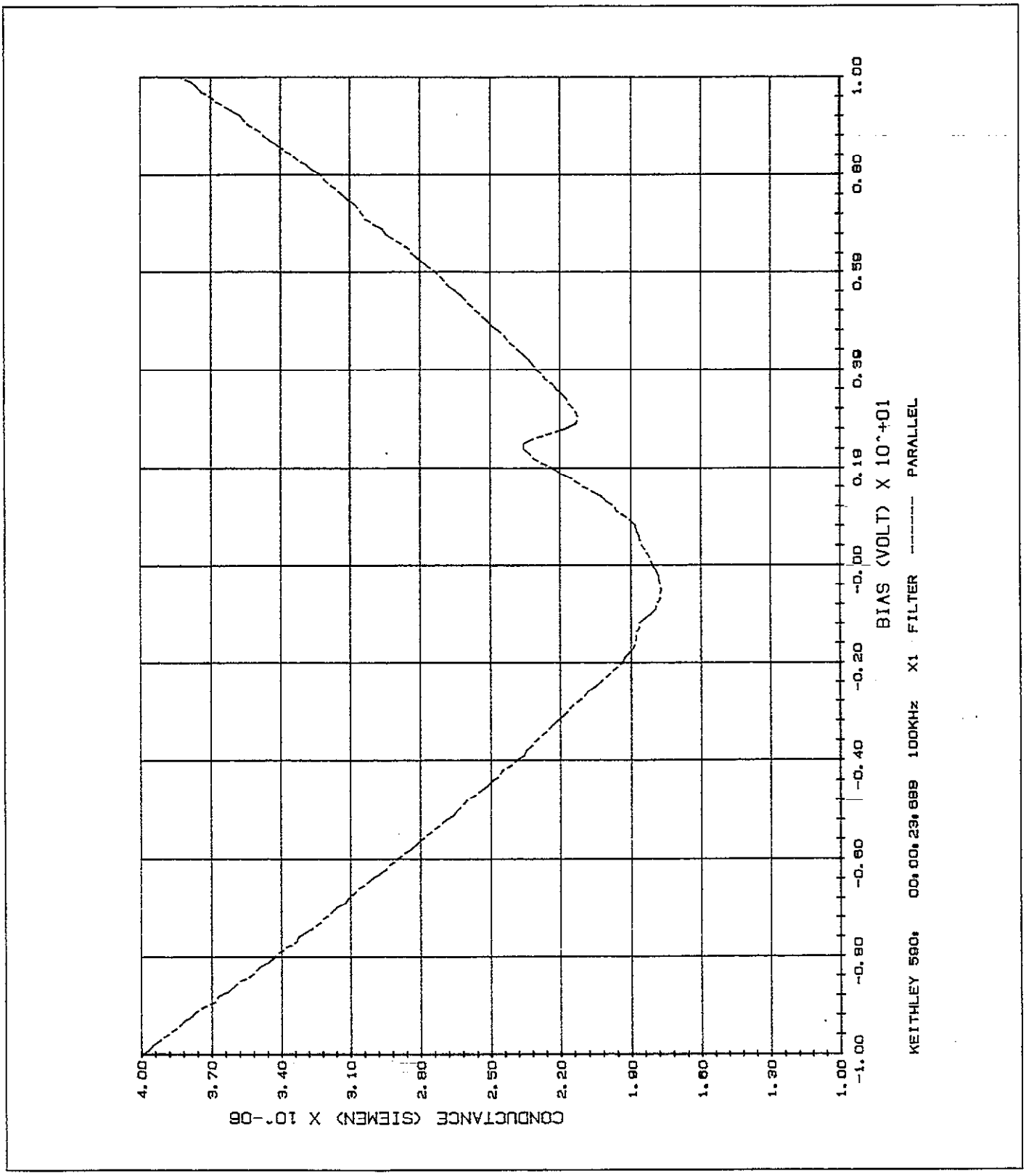



**Figure 3-42. G vs V Example**



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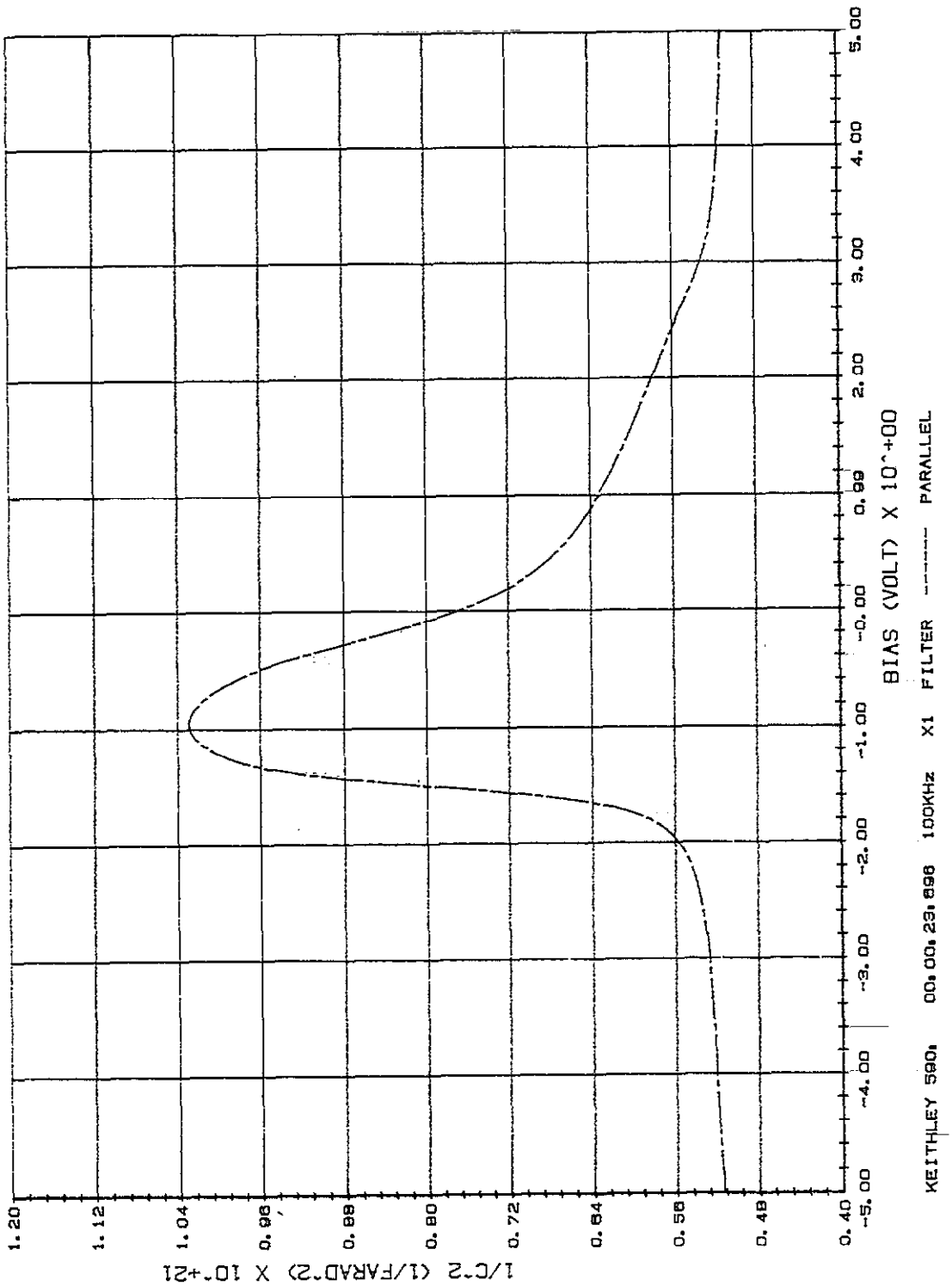



**Figure 3-43. 1/C2 vs V Example**



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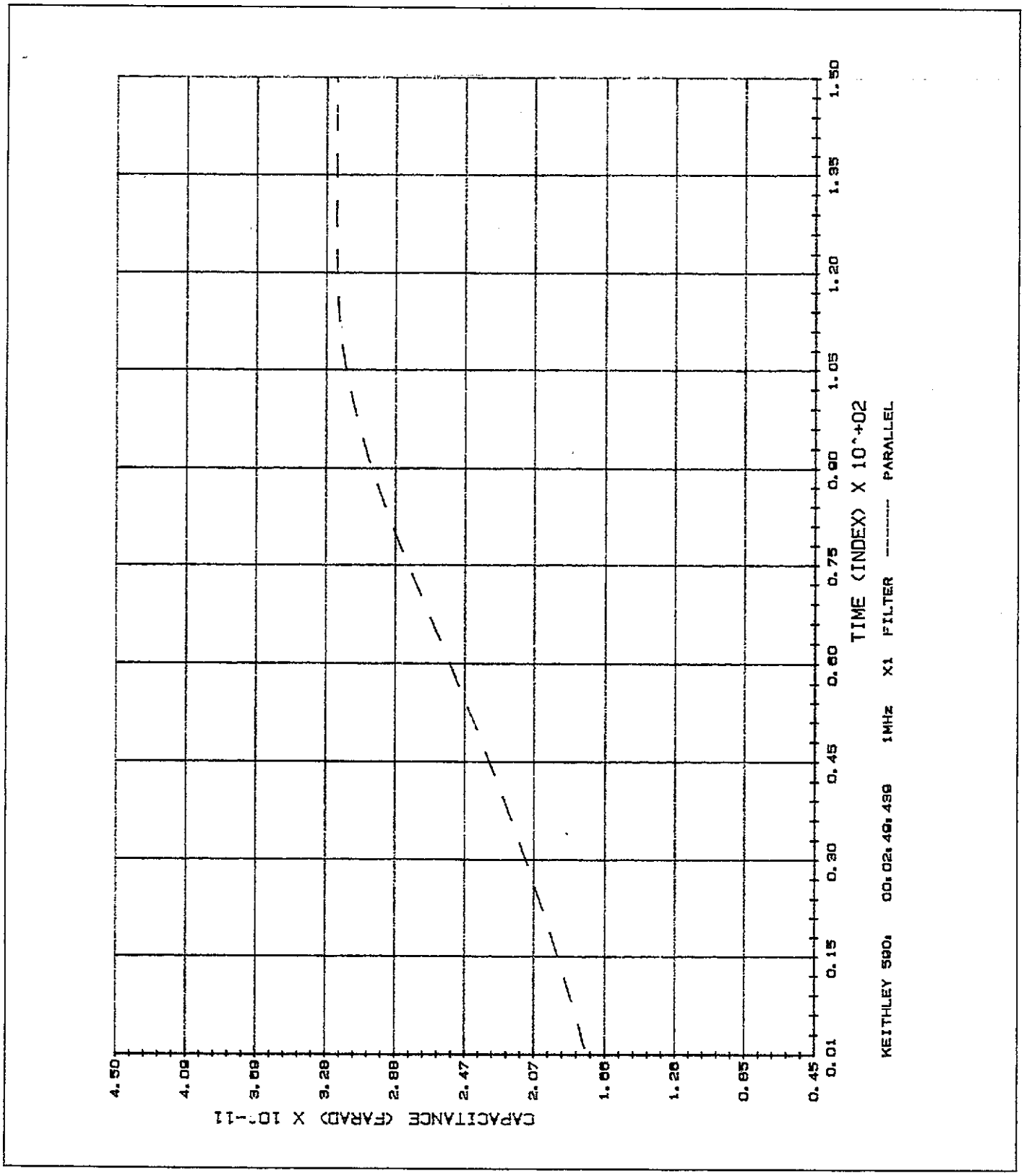



**Figure 3-44. C vs t Example**



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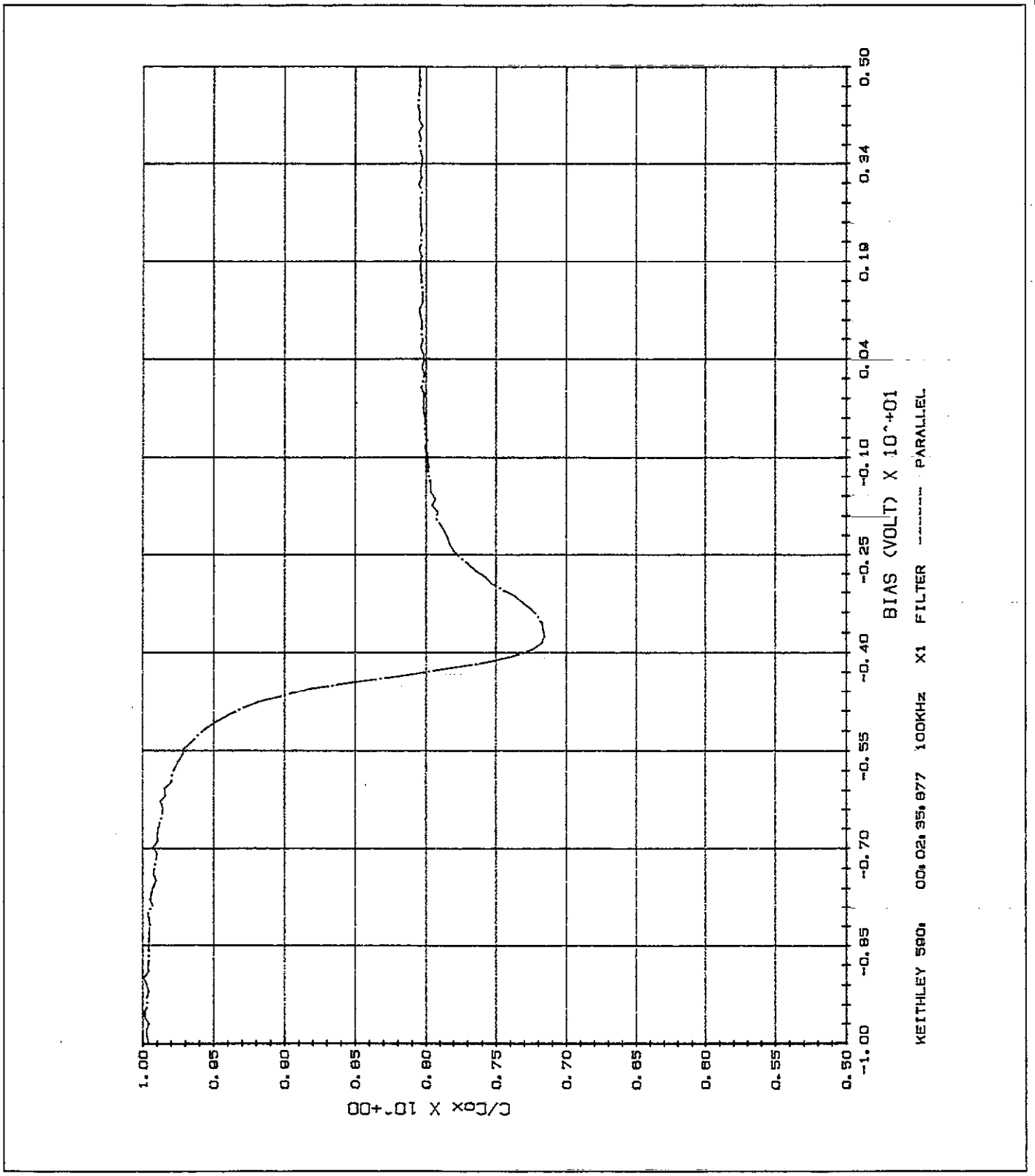



**Figure 3-45. $C/C_O$ vs V Example**



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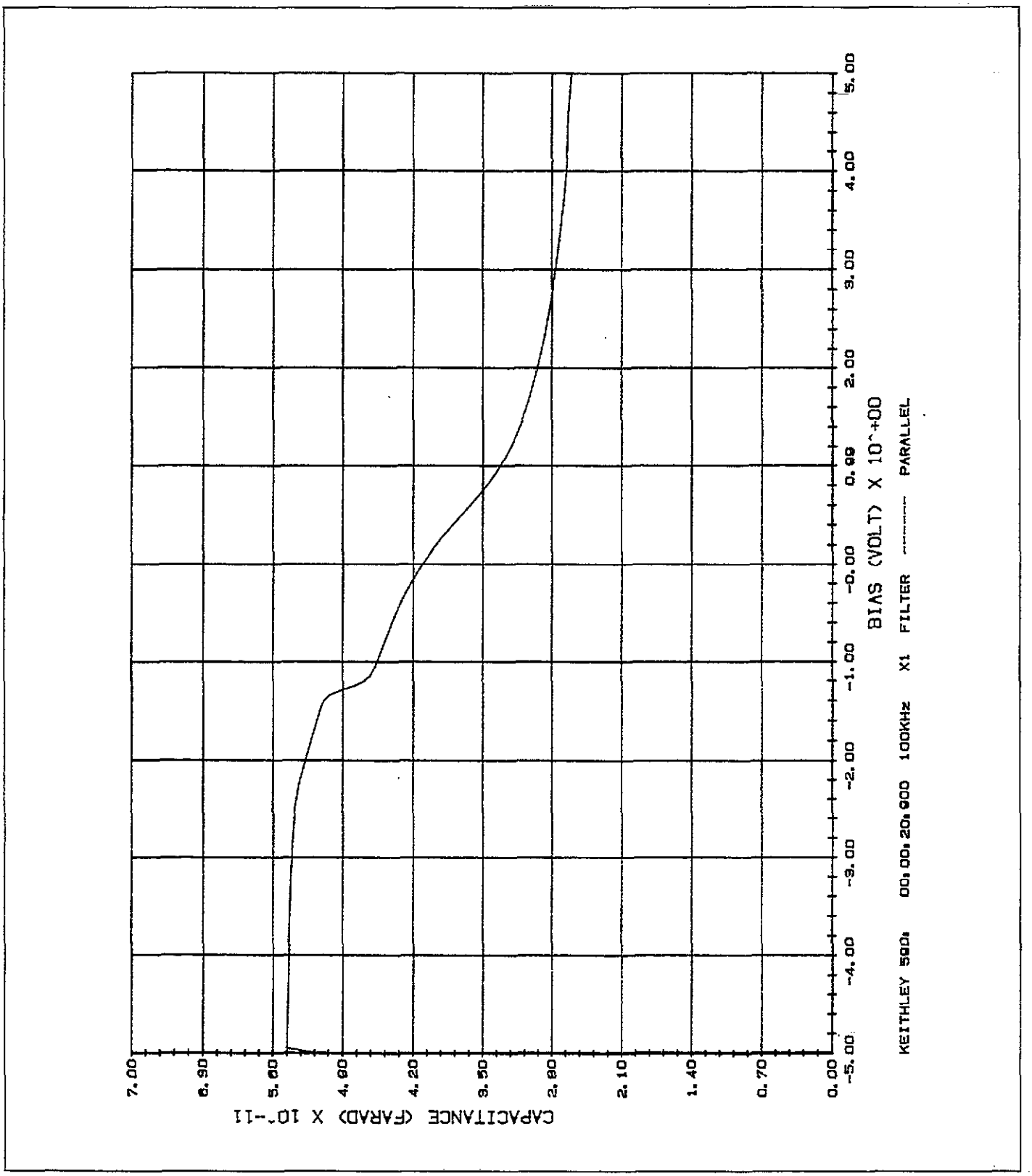



**Figure 3-46. $C_A$ - $C_B$ vs V Example**



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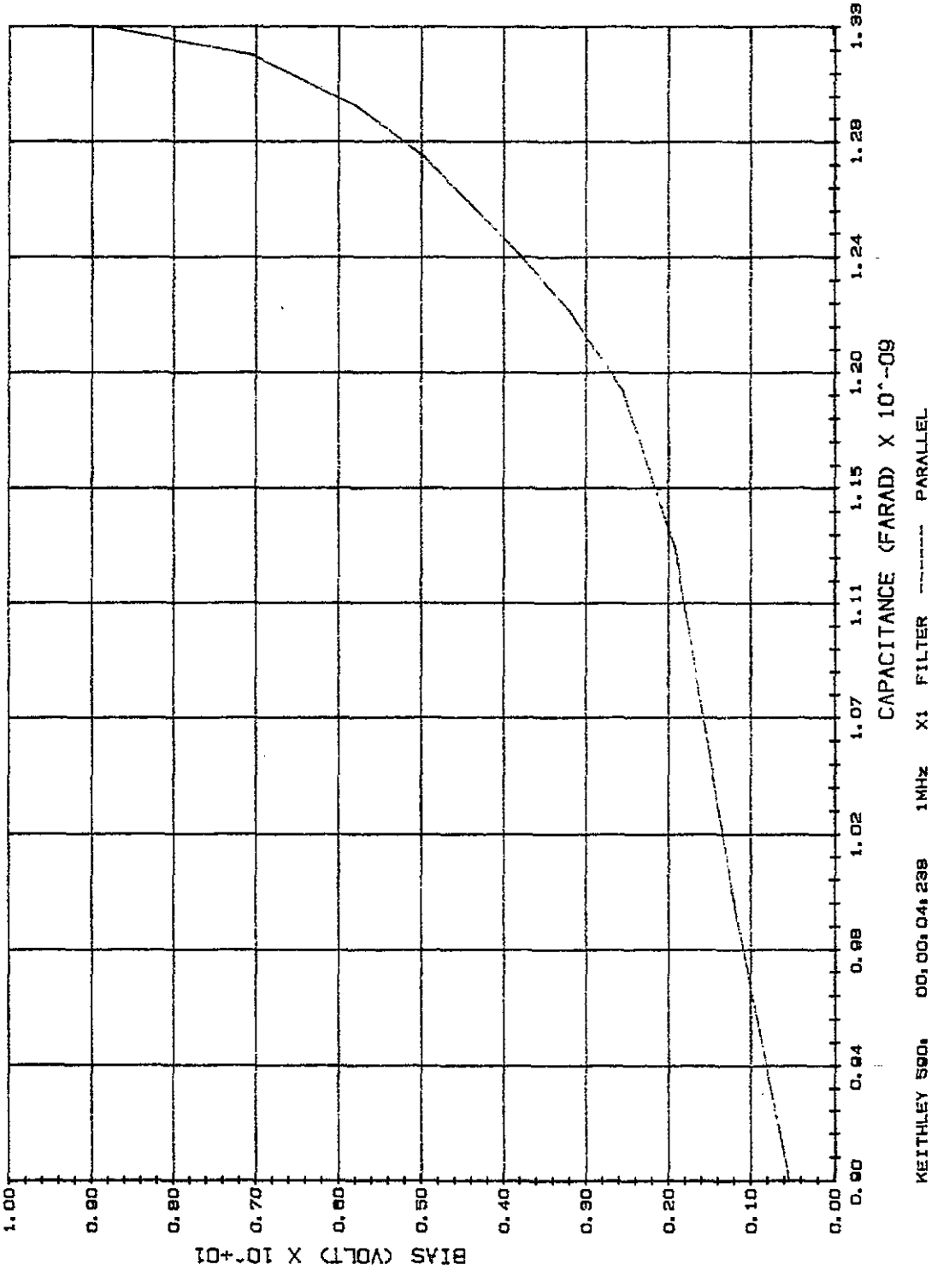
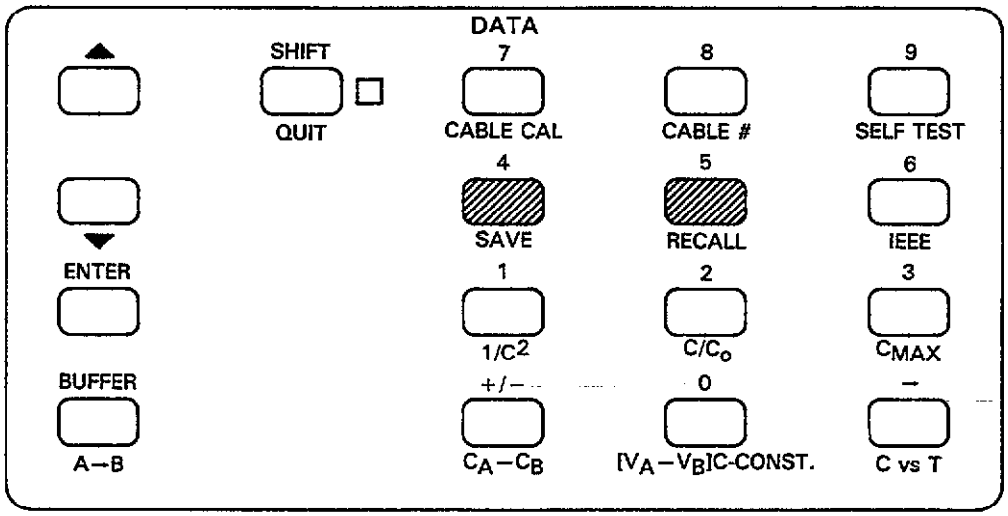



**Figure 3-47. [$V_A - V_B$] C=CONST Example**



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## 3.17 SAVING AND RECALLING INSTRUMENT CONFIGURATIONS

The SAVE and RECALL buttons allow you to store instrument configurations in NVRAM and recall them later at the touch of a button, thus simplifying operation of the instrument with often-used setups.

### 3.17.1 Factory Default Configurations

A maximum of seven user-defined instrument configurations can be stored and retrieved by using this feature. User-defined configurations are numbered 1 through 7. Note that the instrument always assumes the configuration stored in position 1 upon power up, or after the instrument receives the IEEE-488 DCL or SDC command over the bus.

One additional configuration, setup 0, contains factory defaults that are permanently stored in ROM and cannot be altered. Table 3-20 summarizes the factory default configuration for the various front panel operating modes that are affected by save/recall.

NOTES:

1. The IEEE-488 primary address, plotter setup parameters, and model are not affected by save/recall.
2. From the factory, all save/recall positions will be programmed with the same configuration (see Table 3-20).
3. Configuration worksheets to record your setups are located in Appendix F.

**Table 3-20. Factory Default Configurations for Save/Recall**

| Mode | Condition |
|---|---|
| Range | 2nF |
| Frequency* | 100kHz |
| Filter | on |
| Rate | 10 readings/sec |
| Zero | off |
| Trigger mode | Sweep |
| Trigger Source | Front panel (MANUAL) |
| Bias Source | off |
| Bias Waveform | DC |
| Start Time | 1msec |
| Stop Time | 1msec |
| Step Time | 1msec |
| First Bias | 0V |
| Last Bias | 0V |
| Step Bias | 0V |
| Default Bias | 0V |
| Count (Programmed # readings per sweep) | 450 |

*100kHz units

NOTES:

1. Position 0 is permanently stored in ROM and cannot be altered.
2. Position 1 configuration is assumed upon power up.
3. Recall 0 returns all units to 100kHz frequency, including 590/1M models.



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## 3.17.2 SAVEing Configurations

Use the following procedure to save up to seven instrument setups.

1. With the appropriate front panel buttons, select the operating modes to be saved.
2. Press SHIFT SAVE. The instrument will display the following prompt:

SETUP NUMBER ?

3. Press the numeric key (1-7) representing the position you wish to save, but do not press ENTER. Keep in mind that the instrument assumes the position 1 configuration upon power up.
4. The selected configuration will be stored at that position, and the instrument will return to normal operation.

## 3.17.3 RECALLing Configurations

Recall one of eight instrument configurations as follows:

1. Press SHIFT RECALL.
2. The instrument will respond with the following message:

SETUP NUMBER ?

3. Press the number of the position you wish to recall (0-7), but do not use ENTER. Keep in mind that the unit automatically assumes the position 1 configuration upon power up, and that position 0 contains permanently programmed factory defaults.
4. The instrument will then return to normal operation with the various modes programmed in accordance with the selected recall position.

## 3.18 SELF TEST

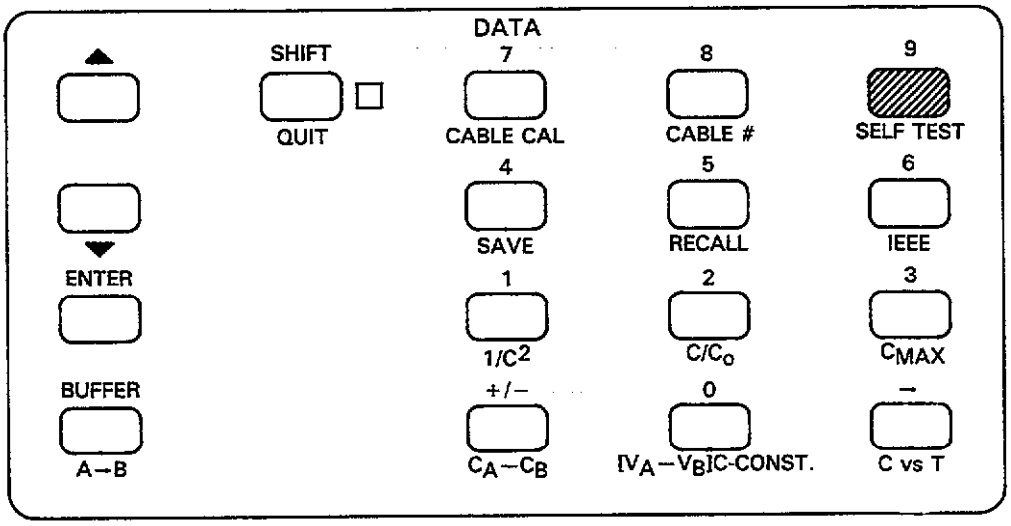
The self test program is intended to check out internal circuitry to make sure that the instrument is operating properly.

The following paragraphs describe circuitry checked out by the self test program and also give the procedure for running the test.

### 3.18.1 Test Sequence

The instrument tests various circuits as follows:

1. The unit tests front panel LEDs and display annunciators by turning them all on at the start of the self test.
2. The hardware multiplier IC is checked for proper operation by performing a mutiplication and checking for proper products.
3. The module inputs are open circuited and then read to check for the presence of abnormal offsets.
4. The internal reference capacitance values are measured and the values compared with those obtained when the unit was last calibrated.






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## 3.18.2 Running the Self Test

Use the following procedure to run the self test.

1. Press SHIFT SELF TEST.
2. The instrument will enter the self test program, at the start of which all front panel display segments and LEDs will turn on to give you an opportunity check for proper operation.
3. During the remaining tests, the instrument will turn on all LED segments.
4. If a problem is found, the instrument will display an appropriate error message as summarized in Table 3-21. Note that the instrument may be operational under these conditions, but improper readings will probably result. In this case, the instrument should be thoroughly checked using the troubleshooting information located in Section 7 of this manual.

**NOTE**

Perform the self test several times if an error occurs to verify that the error is repeatable. If an error occurs, the message will latch into the display. Press a key to return to normal.

**Table 3-21. Self Test Messages**

| Message | Description |
|---|---|
| MULTIPLIER FAIL | Hardware multiplier problem |
| INVALID | Excessive offsets or reference capacitor problem |

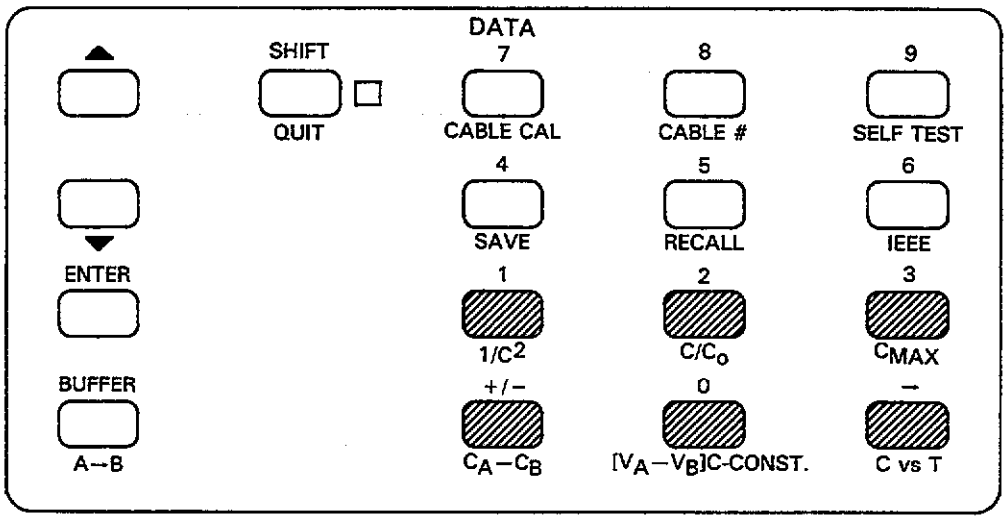
## 3.19 MATHEMATICAL FUNCTIONS

The Model 590 has a number of mathematical functions which can be used to analyze buffer data. The following paragraphs describe the various mathematical functions and how to implement them.

### 3.19.1 Displaying Math Functions

**Math Function Display Formats**

Math function display formats are summarized in Figure 3-48. The display is divided into three basic areas:






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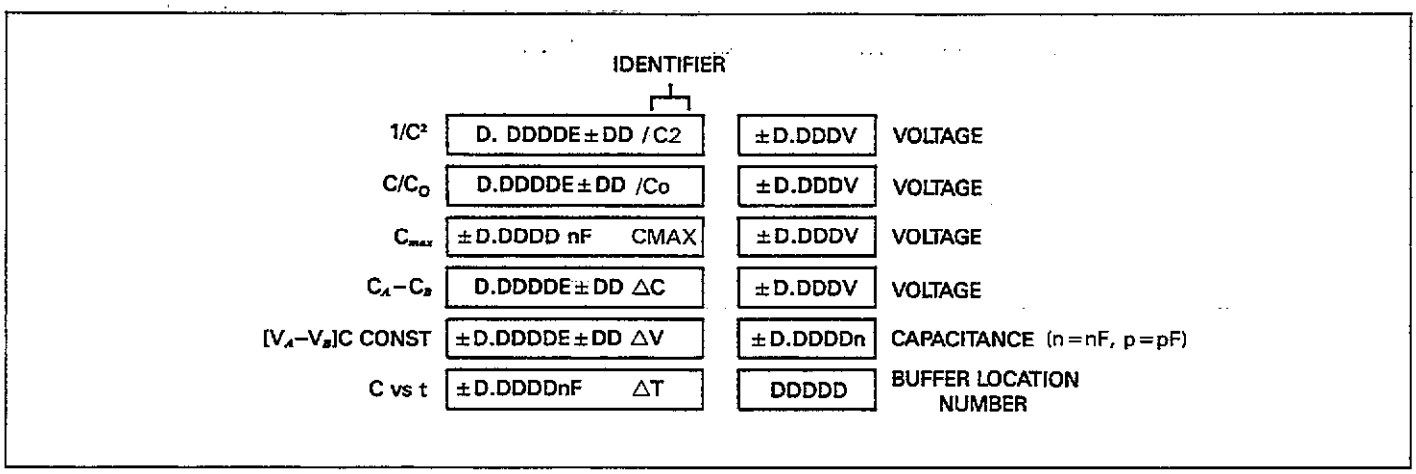



**Figure 3-48. Math Function Display Formats**

1. Floating point result: The result of the selected math function is a floating point number with a 4½-digit signed mantissa and a 2-digit signed exponent.
2. Identifier: An identifier signifies the displayed math function. For example, $C_0$ in this position indicates that a $C/C_0$ value is being displayed.
3. Voltage display: The voltage display area indicates the bias voltage for the following four math functions: $1/C^2$, $C/C_0$, $C_{max}$, and $C_A$-$C_B$. For the $[V_A$-$V_B]$ C CONST function, the display shows the capacitance value. Finally, the voltage display indicates the buffer location being accessed in the C vs t function. Complete information on making C vs t measurements may be found in paragraph 3.20.

**Selection Procedure**

To apply math functions to data located in the buffer and display the result, you must first access the desired buffer and then select the desired math function. The basic procedure is outlined below.

1. Press the BUFFER key. The instrument will prompt you to select the desired buffer:

   BUFFER A=0 B=1 ?

2. Press 0 or 1 to select buffer A or B; at this point, the instrument will automatically enter buffer display at location 1.
3. Once you are displaying buffer data, simply press the desired math button. For example, to display the maximum capacitance value in the selected buffer, press $C_{max}$.
4. For those math functions which operate on individual data points (for example, $1/C^2$ and $C_A$-$C_B$), you can scroll through buffer locations and apply the selected math function by using the ▲ or ▼ keys. Use ENTER or BUFFER to display first and last locations respectively.
5. To cancel the selected math function and select another, simply press the button for another function. Note that you cannot have more than one function operational at any given time.
6. To return to normal buffer display, press RECALL.
7. Press QUIT to return the instrument to normal display, if desired.

## 3.19.2 Using Math Functions with the Plotter

The various math functions can also be used when plotting data by using the basic procedure below. More detailed information on plotting data may be found in paragraph 3.16.

1. Press the plotter SETUP key repeatedly until the following message is displayed:

   PLOT TYPE

2. Press the number of the math function (plot type) you wish to use as indicated below. Note that two of these



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functions (C vs V and G vs V) are an intrinsic part of displaying buffer contents on the front panel.

0= C vs V
1= G vs V
2= $1/C^2$ vs V
3= $C/C_O$ vs V
4= C vs t
5= $C_A$-$C_B$ vs V
6= [$V_A$-$V_B$] at constant C

3. Once the number of the desired plot is displayed, press the ENTER key to select that math function for plotting.
4. As described in paragraph 3.16, select other plotter setup parameters and generate your plot by pressing the PLOT key.

## 3.19.3 Math Function Descriptions

A brief description of each available math function is given below.

**$1/C^2$**

This function inverts and squares each capacitance value in the selected buffer and displays or plots the result. If you are displaying buffer data on the front panel, you can use ▲/▼ to access each data word. The instrument will then calculate $1/C^2$ for each location as it is accessed and display it along with the bias voltage at that location. A typical example is:

+1.1000E+18 /C² −5.000V

When using this function with the plotter, the graph will show $1/C^2$ plotted on the Y axis versus the bias voltage on the X axis of the graph.

**$C/C_O$**

The $C/C_O$ function calculates the ratio between the capacitance value stored at each location and the maximum capacitance value presently stored in the selected buffer.

When displaying $C/C_O$ on the front panel, you can use ▲ or ▼ to scroll through buffer locations. As each location is accessed, the $C/C_O$ value and the bias voltage will be displayed as in this example:

1.2560 E −01 /Co 1.2500 V

When using this function with the plotter, the resulting plot will be a graph of $C/C_O$ vs V, with the Y axis showing $C/C_O$ and the X axis indicating the bias voltage, V.

**$C_{max}$**

The $C_{max}$ function allows you to display the maximum capacitance value presently stored in the selected buffer. Note that this feature is not available for plotting.

To access this value, select the buffer you wish to access with the BUFFER key and then press $C_{max}$. The instrument will then display the maximum capacitance value as in this example:

+ 1.90000E−12 CMAX 5.1000 V

**$C_A$-$C_B$**

This function subtracts each capacitance value in buffer B from the corresponding value in buffer A. For example, the capacitance value in location 10 of buffer B will be subtracted from the capacitance value stored in location 10 of buffer A.

If you are displaying the result of this function on the front panel, you can used ▲ or ▼ to scroll through buffer locations. As you access locations, the result of the subtraction will appear on the display along with the bias voltage from the corresponding location of buffer A. For example, the display might show:

−1.6746 E−12 ΔC 1.000V

When plotting this function, the $C_A$-$C_B$ values will appear on the Y axis while the buffer A bias voltage will be graphed along the X axis.



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### [$V_A$ - $V_B$] C Const

This function displays or plots the difference between bias voltages in buffers A and B at a constant capacitance value. To calculate this function, the instrument searches the two buffers and finds the closest matching capacitance value. It then subtracts the corresponding bias voltage in buffer B from the bias voltage in buffer A.

When displaying this function, the $V_A$-$V_B$ value will appear in the left display, and the constant capacitance value will appear in the right display, as in the example below.

1.2000 E−00 ΔV 1.2300n

Note that the capacitance value not includes the range, by indicating n for nF and p for pF.

When plotting this function, the $V_A$-$V_B$ value will appear along the Y axis and the capacitance value will be plotted along the X axis.

### C vs V and G vs V

During normal buffer access, C, G, and V values are displayed on the front panel as you scroll through buffer locations. When plotting data, the capacitance or conductance value will appear on the Y axis, while bias voltages will be graphed along the X axis. If series model was in effect at the time data was taken, R vs V will be plotted in place of G vs V.

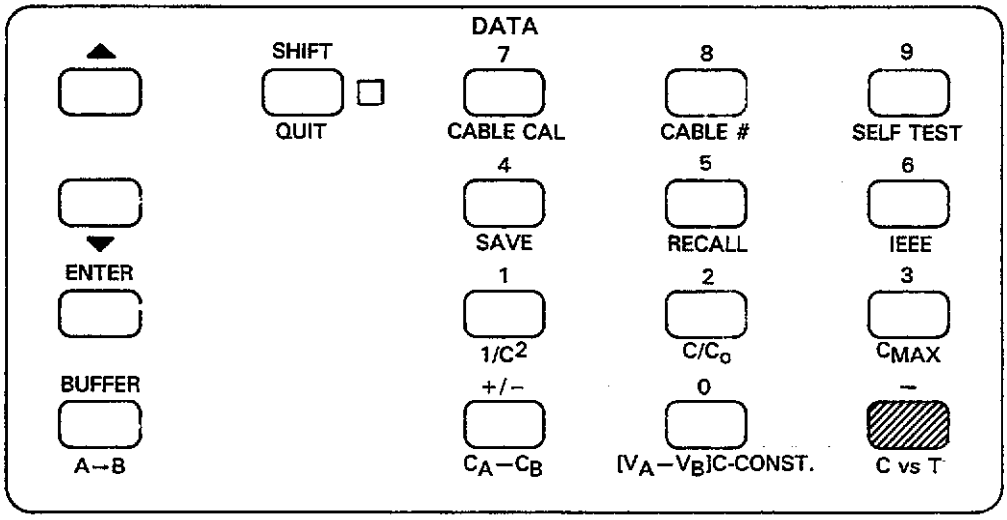
## 3.20 C VS t MEASUREMENTS

The following paragraphs describe the basic principles and procedure behind making C vs t measurements with the Model 590. Both internal and external biasing are covered below.

### 3.20.1 Internal C vs t Measurements

#### C vs t Waveform

A typical C vs t waveform is shown in Figure 3-49. The top waveform shows capacitance variations with time, and the bottom waveform shows the bias voltage.






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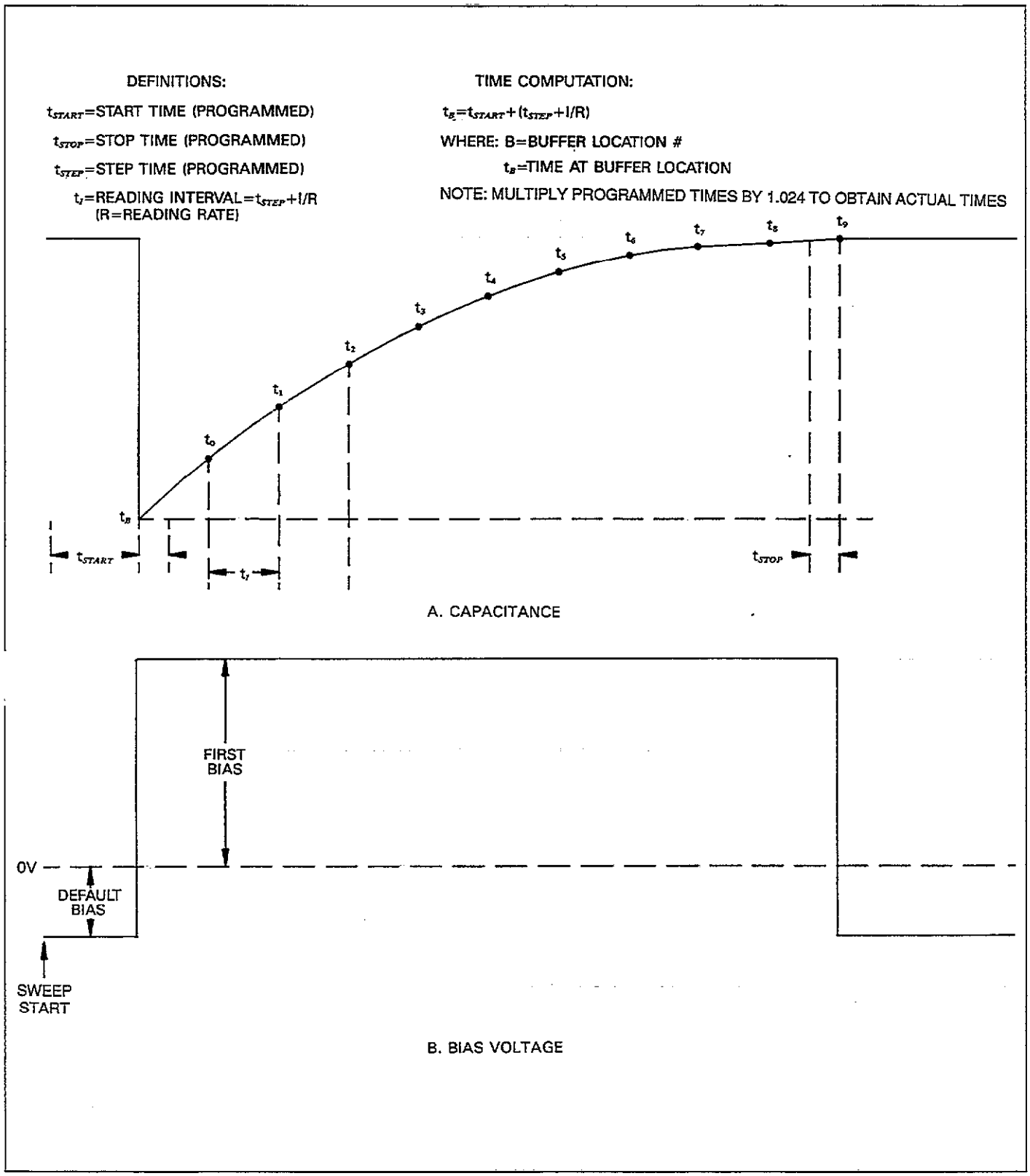



**Figure 3-49. C vs t Waveform**



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## Table 3-22. Internal C vs t Setup Conditions

| Parameter | Description | Comments |
|---|---|---|
| Waveform | DC | |
| Reading Rate | 1, 10, 75 or 1000/sec | Rate determines intervals |
| Start Time | 1msec to 65sec* | |
| Stop Time | 1msec to 65sec* | |
| Step Time | 1msec to 65sec* | Determines interval |
| Default Bias | −20V to +20V | Bias before/after sweep |
| First Bias | −20V to +20V | Bias during sweep |
| Count | #Readings per sweep, 1-450 (1,350 at 1,000/sec) | As required |

*Programmed times must be multiplied by 1.024 to obtain actual times.

### Bias Waveform and Parameters

Parameters necessary for internal C vs t measurements are summarized in Table 3-22. These parameters are further described below.

Waveform Type: A DC bias waveform should be selected for internal C vs t measurements.

Reading Rate: The reading rate and the step time determine the time interval between individual readings.

Default Bias: The bias voltage setting both before and after a reading sweep. Typically, the default bias might be set to 0V, but any other value in the range of −20V to +20V in 5mV steps may be used, as required.

First Bias: The bias voltage setting during a C vs t measurement sweep. The first bias value may be set to any value in the range of −20V to +20V with 5mV resolution.

Step Time: The time interval after one reading before a measurement actually begins. You may program any step time in the range of 1msec to 65sec with 1msec resolution. Although no bias step actually occurs for a DC bias waveform, this time period is considered to be an integral part of the time interval between individual measurements, as described below.

Start Time: The start time is a programmable initial delay period after the sweep is triggered before the instrument begins the first reading interval. That reading interval is the sum of the programmed step time and the reciprocal of the reading rate.

Stop Time: An additional delay period added to the last measurement interval before the instrument returns the bias voltage to the default value.

Count: The number of readings to take during the sweep.

### C vs t Setup

Use the procedure below to set up the instrument for internal C vs t measurements.

1. Select the desired measurement frequency by pressing FREQ. Keep in mind that cable correction should be used at 1MHz.
2. Select the desired model, filter, and zero states with appropriate keys. Note that the filter increases instrument response time to rapidly changing capacitance values.
3. Select the desired reading rate with the RATE key. Remember that the interval between readings is the sum of the programmed step time and the reciprocal of the reading rate.
4. Select the desired range; remember to choose a range that is sufficiently high to measure the maximum expected capacitance value.
5. Using the MODE key, select the sweep trigger mode.
6. Use WAVEFORM to select the DC waveform type necessary to take C vs t measurements.
7. Program the desired start, stop, and step times with the PARAMETER key.
8. In a similar manner, program your desired default and first bias values. As discussed above, the default bias will be applied to the circuit under test before the sweep, and the first bias voltage will be applied to the test circuit during the sweep.



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9. Program the number of readings with the COUNT parameter.

### Taking C vs t Data

Once you have the instrument set up properly, taking data is simply a matter of connecting your test circuit to the instrument and triggering a sweep. Make sure the bias voltage is turned on before initiating the sweep. To trigger a reading, press the MANUAL key (or use the programmed trigger stimulus, if desired). The instrument will cycle through the programmed sweep sequence, taking data at intervals determined by the reading rate and programmed step time.

Once the sweep is complete, transfer the data from buffer A to buffer B for safe keeping by pressing the A → B key. Doing so will prevent your data from being lost should you inadvertently trigger another sweep.

### Displaying and Computing C vs t Information

Once you have taken data, C vs t information can be displayed as follows:

1. Press the BUFFER key and select buffer B at the prompt (assuming you transfered data from buffer A to buffer B).
2. Press the C vs t key and then use ▲ or ▼ to display data at the desired buffer location. Figure 3-50 shows the format for C vs t display.
3. Compute the actual time information at the display location as follows:

$$t_B = 1.024t_{start} + (1.024t_{step} + 1/R)\ (B)$$

Where: $t_B$ = time at a specific buffer location
$t_{start}$ = programmed start time
$t_{step}$ = programmed step time
R = actual reading rate
B = displayed buffer location number
1.024 = multiplying factor to obtain actual times

**NOTE**

Programmed times must be multiplied by 1.024 to obtain actual times.

### C vs t Display Example

Assume the following programmed parameters:

Start time: 50msec
Stop time: 50msec
Step time: 20msec
Reading rate: 75/sec
Buffer location: 100

The cumulative time at buffer location 100 can be calculated as follows:

$$t_B = 1.024t_{start} + (1.024t_{step} + 1/R)\ (B)$$

$$t_{100} = 51.2\text{msec} + (20.48\text{msec} + 1/75)\ (100)$$

$$t_{100} = 2.1\text{sec}$$

### C vs t Plotting

You can plot C vs t information by selection plot type 4 with the SETUP key, then generate your plot in the usual manner (see paragraph 3.16). The Y axis displays capacitance, while the X axis displays buffer location numbers; you can compute time data using the formula in step 3 above.



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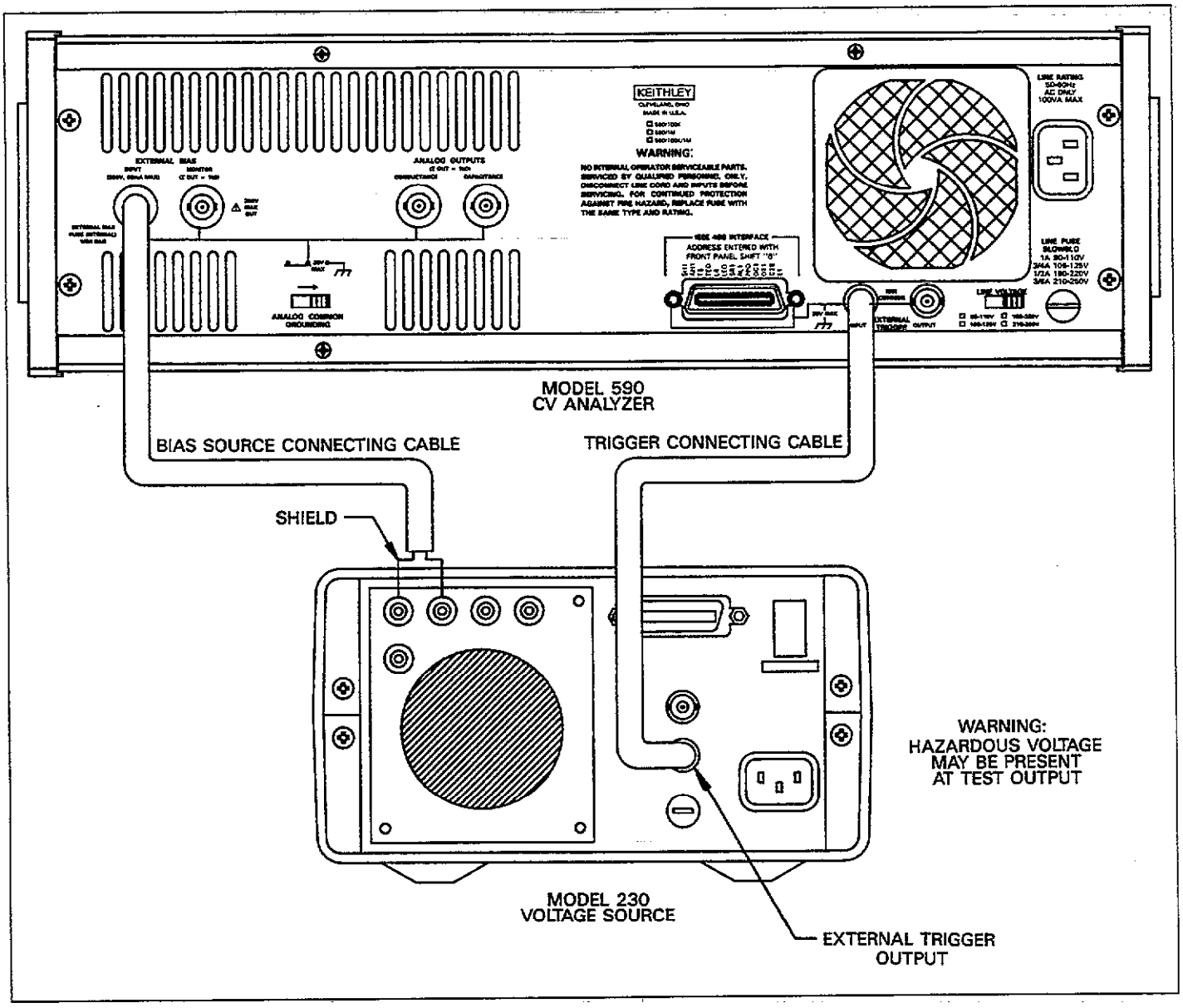



**Figure 3-50. External C vs t Connections**



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**Table 3-23. External C vs t Setup Conditions**

| Parameter | Description | Comments |
|---|---|---|
| Waveform | External | |
| Reading Rate | 1, 10, 75 or 1000/sec | Rate determines intervals |
| Start Time | 1msec to 65sec* | |
| Stop Time | 1msec to 65sec* | |
| Step Time | 1msec to 65sec* | Determines interval |
| Default Bias | As required | Supplied by external source |
| First Bias | As required | Supplied by external source |
| Count | #Readings per sweep 1-450 (1,350 at 1,000/sec) | As required |

*Multiply programmed times by 1.024 to obtain actual times.

## 3.20.2 External C vs t Measurements

External C vs t measurements are performed in a manner similar to that used for internal C vs t measurements, except, of course, for the fact that an external bias source is used. The following paragraphs cover the fundamental principles for making such measurements. The basic waveform and parameters shown on Figure 3-49 still apply, although the bias voltages will be generated externally instead of internally.

### Parameters

Parameters associated with external C vs t measurements are summarized in Table 3-23 and discussed below.

Waveform: An external waveform must be selected in order to use an external bias source.

Reading Rate: The reading rate and step time determine the interval between measurements.

Default and First Bias: These voltages are supplied by an external voltage source instead of being generated internally.

Start, Step, and Stop Times: These times can be programmed for external C vs t measurements. The start time gives an additional delay during the first measurement period, and the stop time provides additional delay at the end of the last measurement period of the sweep. The step time and reading rate determine the interval, $t_i$, between individual readings as follows:

$$t_i = 1.024t_{step} + 1/R$$

Where: $t_i$ = interval between readings
$t_{step}$ = programmed step time
R = selected reading rate

Count: Set the parameter to the desired number of readings.

### Connections

The exact connecting method used for external C vs t measurements will, of course, depend on the type of bias source. Figure 3-51 shows typical connections for using a Keithley Model 230 Voltage Source in conjunction with the 590. Note that all connections should be made with suitable shielded cable.

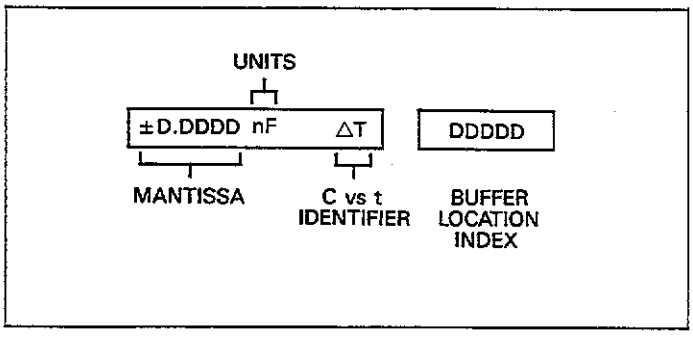



**Figure 3-51. C vs t Display Format**



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Make connections as follows:

1. Connect the 230 TRIGGER OUTPUT to the 590 TRIGGER INPUT.
2. Connect the 230 COMMON and OUTPUT to the 590 VOLTAGE BIAS INPUT. The cable shield should be connected to the 230 COMMON terminal.
3. The circuit under test must be connected to the front panel test INPUT and OUTPUT jacks on the 590 (not shown on diagram).

**WARNING**

**Hazardous voltage may be present at the test OUTPUT jack when using an external bias source.**

### 590 Setup

Program the Model 590 as follows:

1. Select the range, frequency, model, filter, and zero, as required.
2. Using the WAVEFORM key, select the external bias waveform. Also select external-trigger.
3. Program start, stop, step times, number of readings, and reading rate, as required.
4. Turn on the bias voltage by pressing the BIAS ON key.

### 230 Setup

Program the Model 230 voltage source as indicated below. Consult the Model 230 Instruction Manual for details on instrument programming.

1. Program memory location 2 with the desired default voltage value.
2. Program memory location 3 with the first bias voltage value.
3. Program the memory location 2 dwell time for the desired time duration of the default voltage.
4. Program the memory location 3 dwell time for a duration equal to the 590 reading sweep. The duration of that sweep will depend on the selected reading rate and the programmed start, step, and stop times, as well as the programmed number of readings.
5. Program memory location 4 with a dwell time of 0msec.
6. Select the single program mode, then press the RESET button to return the unit to location 1.

### Taking C vs t Data

To take data, turn on the Model 230 output and press the START/STOP button. The Model 230 will then apply the default voltage value for the specified dwell time. At the end of this period, the Model 230 will trigger the Model 590 to begin its measurement sweep and apply the first bias value. The Model 590 will then take the readings at intervals determined by the start, stop, and step times, as well as the selected reading rate.

### Displaying C vs t Information

First transfer data to buffer B for safe keeping, then access buffer B with the BUFFER key. Press C vs t to display the buffer location index, then used ▲ or ▼ to display the desired location. Actual time information at a given location can be computed as discussed in paragraph 3.20.1. Figure 3-51 shows the C vs t format.



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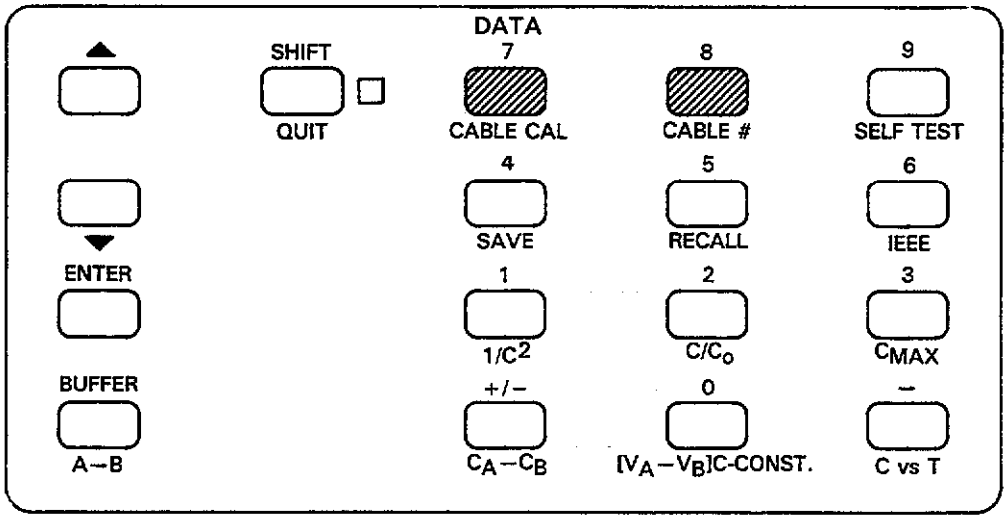



**Table 3-24. Summary of Cable Correction Methods**

| Method | Description | Comments |
|---|---|---|
| Driving point | Measure open ended cable | Front panel or bus |
| Matrix parameters | Program known matrix parameter | IEEE-488 bus only* |
| Calibration capacitor | Measure accurate capacitance sources | IEEE-488 bus only* |

*See paragraph 4.11

## 3.21 CABLE CORRECTION

The following paragraphs describe the procedures and principles behind using cable correction with the Model 590. Cable correction is especially important at 1MHz, and it can also be used for 100kHz tests.

### 3.21.1 Cable Correction Methods

Basically, there are three different methods of correction available in the Model 590, as summarized in Table 3-24. Of these, only the driving point method is available from the front panel; the remaining methods are available only over the IEEE-488 bus, and are discussed in detail in paragraph 4.11.

Available methods of correction include:

**Driving Point Method**

This method involves a driving point admittance measurement of an open-ended cable, from which cable correction terms are calculated and then applied to subsequent measurements.

The disadvantages of this method are that only simple transmission paths can be used for measurement, and that compensation cannot be made for errors due to cable loss or test fixture shunt capacitance.



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### Matrix Parameter Method

With this method, the instrument is programmed with complex values representing the transmission line matrix parameters of the cable. These parameters are determined by measuring certain transmission line characteristics with an LCR meter and a network analyzer. Once parameters are programmed, the instrument automatically calculates the necessary correction constants for use in compensating subsequent measurements.

Unlike the driving point method, the matrix parameter method can be used to compensate for complex transmission paths such as relay switching matrices. Refer to paragraph 4.11 for detailed information on this method of cable correction.

### Calibration Capacitor Method

The calibration capacitor method is performed by connecting precisely known capacitance sources in place of the test fixture. The actual capacitance values are then programmed over the IEEE-488 bus, after which the instrument can perform the necessary correction when making measurements.

Like the matrix parameter method, the calibration capacitor method can compensate for signal paths through a switching matrix or multiple cables and is available only over the IEEE-488 bus (see paragraph 4.11).

## 3.21.2 Front Panel Cable Correction

Use the following procedure to perform cable correction using the driving point procedure described above.

1. Turn on the power and allow the instrument to warm up for at least one hour before performing the cable calibration procedure.
2. Press FREQ to select desired frequency.
3. Using RANGE, select the 2nF range, then press CAL.
4. Connect two identical RG-58 cables of equal length to the front panel of the instrument as shown in Figure 3-52. Note that the opposite end of the cable connected to INPUT must be left open during the cable correction process.
5. Press SHIFT CABLE CAL to initiate cable correction, a process that will take a couple of seconds to complete.
6. Following the correction process, the instrument will prompt you as to whether or not you wish to store the cable correction constants just measured:

   UPDATE N=0 Y=1 ?

7. If you do not wish to store cable calibration, press 0. The unit will then return to normal operation with the new cable constants temporarily in effect. These constants will, however, be lost if the power is turned off.
8. To store cable calibration for future use, press 1 at the update prompt. The unit will then prompt you for a cable position number:

   CABLE NUMBER ?

9. Select the position to save current cable calibration (1-7). The unit will then return to normal operation with the new cable correction constants in effect.
10. Connect your test fixture to the open-end test cables and make your measurements in the normal manner. Cable correction constants measured and calculated using this procedure will be applied to subsequent measurements.

NOTES:

1. To cancel cable correction, select CABLE #0 as discussed in the following paragraph.
2. Cable correction must be performed on the 2nF range, as discussed above.
3. Both cables must be of equal length and of identical construction, or errors in correction will result. Maximum length for each cable is five meters.
4. The driving point method of cable correction discussed here is not intended for use in systems with multiple cables or relay switching matrices. See paragraph 4.11 for methods that can be used with complex setups.
5. Cable correction reduces the dynamic range of capacitance and conductance measurements.



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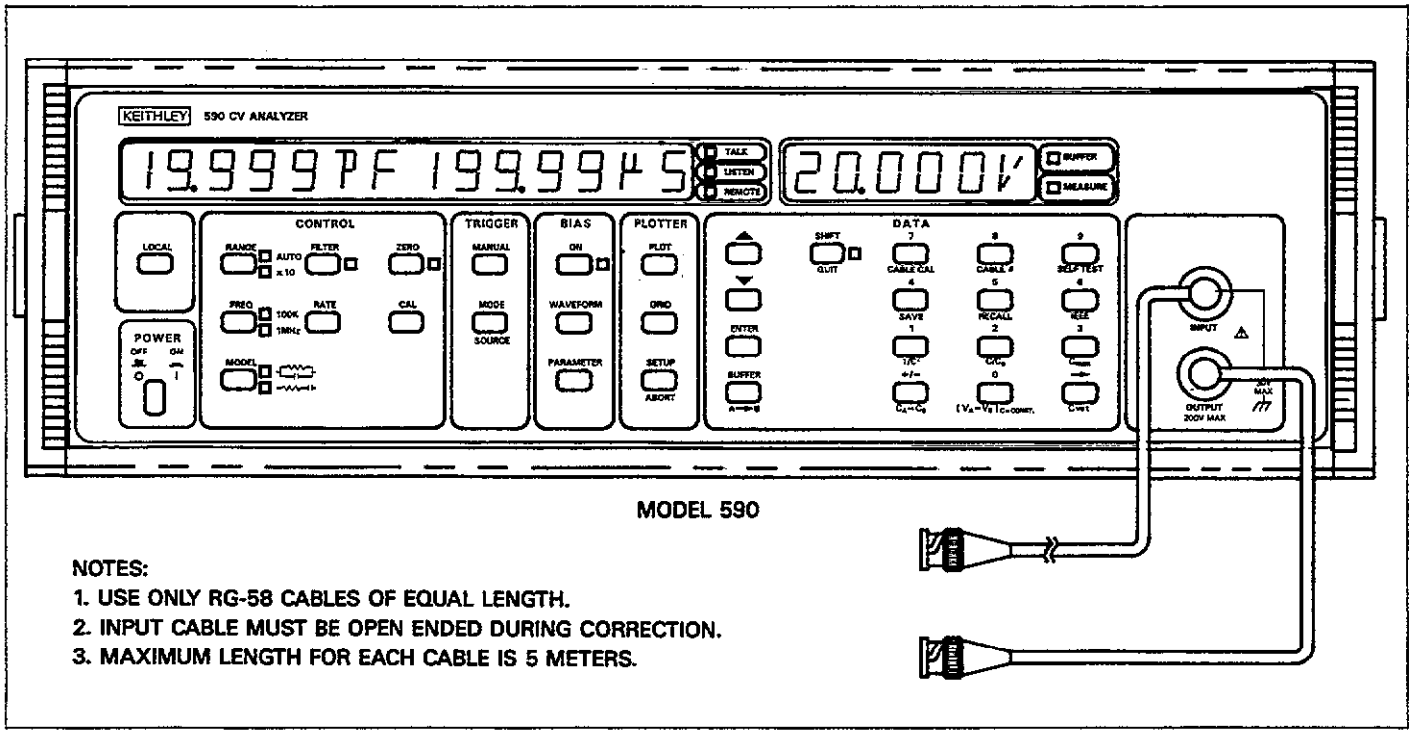



**Figure 3-52. Connections for Cable Correction**

## 3.21.3 Recalling Cable Correction Constants

Cable correction constants can be recalled with the CABLE # key by using the procedure below. This procedure recalls constants stored by all three methods.

1. Select frequency (100kHz or 1MHz).
2. Press SHIFT CABLE #. The Model 590 will prompt for a cable number to recall:

CABLE NUMBER ?

3. Press the cable number you wish to recall (0-7). Note that selecting cable number 0 effectively disables cable correction, while cable numbers 1-7 contain user-defined parameters.
4. After you select the desired cable number, the instrument will return to normal operation with the new correction parameters in effect. These parameters will remain in effect until power is removed, or until cable number 0 is recalled.

## 3.21.4 Cable Correction Considerations

The driving point cable correction algorithm described above makes the following assumptions:

1. The characteristic impedance of both cables connected to the test INPUT and OUTPUT jacks is 50Ω.
2. Cable loss is zero.
3. Both cables are of exactly the same length.

If cable calibration is performed with deviations from the above standards, errors can be expected in readings taken with those constants. In particular, variations in $Z_o$ and cable losses are more detrimental with longer cables. Thus, to minimize errors due to these factors, use the shortest cables possible.

Another factor that can lead to errors is test fixture shunt capacitance. For example, a shunt capacitance of 50pF could add an additional error of up to 0.25%. To minimize errors due to shunt capacitance, use a test fixture of good, low-capacity design. In particular, prober shields should be carried through as close to the wafer as possible.



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## 3.21.5 Fundamentals of Cable Correction

A cable, acting as a transmission line, can be modeled as a two-port network, as shown in Figure 3-53. The transmission or ABCD parameters of such a network are defined as follows:

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

$$= \begin{bmatrix} T_M \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

Where $T_M$ is the transmission matrix.

In the case of a uniformly distributed transmission line, the transmission matrix, $T_M$, becomes:

$$T_M = \begin{bmatrix} \cosh(\gamma\ell) & Z_o\sinh(\gamma\ell) \\ Z_o^{-1}\sinh(\gamma\ell) & \cosh(\gamma\ell) \end{bmatrix}$$

Where the transmission line parameters are:

$Z_O$ = characteristic impedance
$\ell$ = length
$\gamma = \alpha + j\beta$ = the propogation constant
$\alpha$ = the attenuation constant
$\beta$ = the phase constant

If we assume a lossless transmission line, the above matrix reduces to:

$$T_M = \begin{bmatrix} \cos(\beta\ell) & jZ_o\sin(\beta\ell) \\ jZ_o^{-1}\sin(\beta\ell) & \cos(\beta\ell) \end{bmatrix}$$

A further assumption is that the two transmission cables are identical. Thus, the tranmission matrix parameters can be applied to a measurement to compute a corrected measurement as follows:

$$Z_C = \frac{Z_M - K_2}{K_1}$$

Where: $Z_C$ = corrected impedance
$Z_M$ = actual measured impedance
$K_1 = AD$
$K_2 = B(A + D)$

In this case, A, B, and D are the transmission line matrix parameters, as described above.

Once the corrected impedance is known, corrected C and G (or R) values can be easily computed.

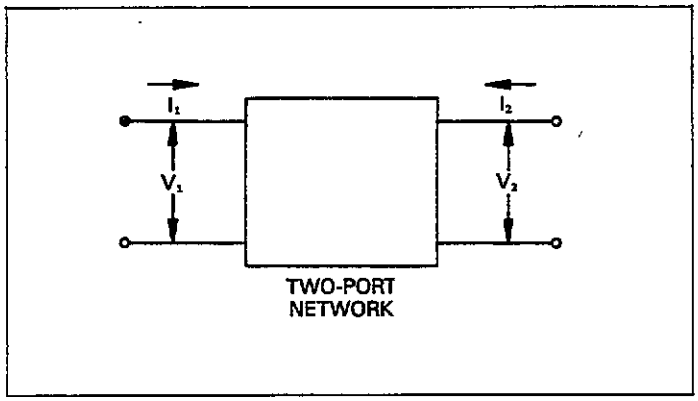



**Figure 3-53. Two-Port Network**

## 3.22 ANALOG OUTPUTS

The Model 590 has analog outputs for the capacitance and conductance readings. Each output provides a scaled voltage that is analogous to the capacitance or conductance reading. Use and characteristics of these two outputs are discussed in the following paragraphs.

### 3.22.1 Analog Output Connections

The analog output BNC connectors are located on the rear panel of the instrument, as shown in Figure 3-54. The CAPACITANCE output provides a scaled 0-2V (0 to 0.2V, 2pF, 100kHz range) for the capacitance reading. In a similar manner, the CONDUCTANCE output provides a scaled 0-2V (0 to 0.2V, 2μS, 100kHz range) for the conductance reading. Figure 3-54 also shows typical connections for the outputs; in this instance, connections to the CAPACITANCE output are shown. Note that the center conductor is high, and the outer ring is low.



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**WARNING**

**Analog output low is connected to analog common which can be floated up to 30V RMS above chassis ground only when the grounding switch is in the floating position. Exceeding 30V RMS may create a shock hazard.**

NOTES:

1. Shielded cable should be used for analog output connections to minimize the possibility of EMI suceptability. Connect the shield to analog output low as well as the low terminal of the measuring device, as shown in Figure 3-54.
2. The output impedance of each analog output is 1kΩ. To minimize errors due to loading, the input impedance of the measuring device should be as high as possible. For example, to keep the error due to loading under 0.1%, the input impedance should be at least 1MΩ.
3. The BIAS VOLTAGE MONITOR output is covered separately in paragraph 3.14.

## 3.22.2 Analog Output Scaling

As mentioned previously, each analog output provides a scaled voltage which is analogous to the capacitance or conductance reading. Table 3-25 summarizes full scale analog output values for various ranges with both measurement frequencies (conductance ranges for the two frequencies differ). Table 3-26 gives some examples of analog output values with specific capacitance and conductance readings.

NOTES:

1. Full scale readings for rated accuracy are limited to 20,000 counts, corresponding to a 2V full scale value at the analog outputs. However, actual full scale readings can be as high as +21,999 counts. The analog outputs will reflect the maximum reading shown on the display, but with typical accuracy above +20,000 counts.
2. An on range analog output voltage may be present if a module overload condition occurs. This value should be considered as erroneous. To verify that an analog output value is valid, check the front panel display for proper readings.

### Table 3-25. Analog Output Full Scale Values

| 100kHz Range | 1MHz Range | Full Scale Output* |
|---|---|---|
| 2pF/2μS | | 200mV |
| 20pF/20μS | 20pF/200μS | 2V |
| 200pF/200μS | 200pF/2mS | 2V |
| 2nF/2mS | 2nF/20mS | 2V |
| 20nF/20mS** | | 2V |

*Value for 20,000 count accuracy limit shown. Actual full scale value is approximately +22,000 counts.

**5904 adapter required.

### Table 3-26. Analog Output Examples

| Range | Display Reading | Analog Output Values (Capacitance/ Conductance) |
|---|---|---|
| 20pF/20μS | 12pF/16μS | 1.2V/1.6V |
| 200pF/200μS | 190pF/50μS | 1.9V/0.5V |
| 2nF/2mS | 1.1nF/1.8mS | 1.1V/1.8V |



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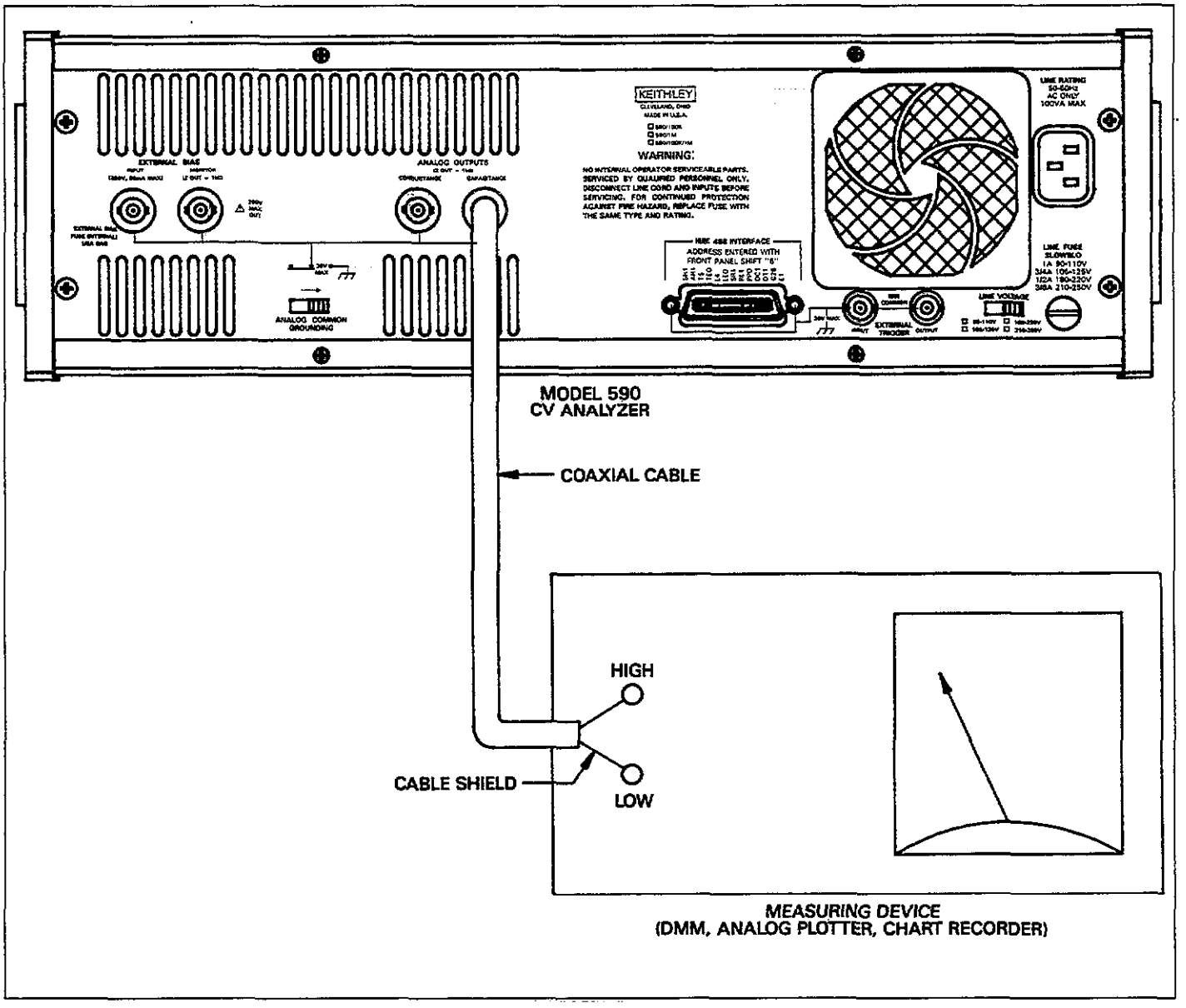



**Figure 3-54. Analog Output Connection Example**



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### 3.22.3 Typical Analog Output Uses

The analog outputs can be used with any measuring device capable of handling the nominal 0-2V output values. Typical examples include a DC voltmeter or DMM to monitor the voltage levels, a chart recorder to graph capacitance or conductance versus time, and an XY plotter to plot C or G versus the bias voltage, V. In the latter instance, the X input of the plotter would be connected to the BIAS MONITOR jack of the 590, while the Y input would be connected to the CAPACITANCE or CONDUCTANCE analog output depending on the desired plot.

**NOTE**

Analog plotting with this method must be done in real time as there is no provision for transmitting buffer data through the analog outputs.

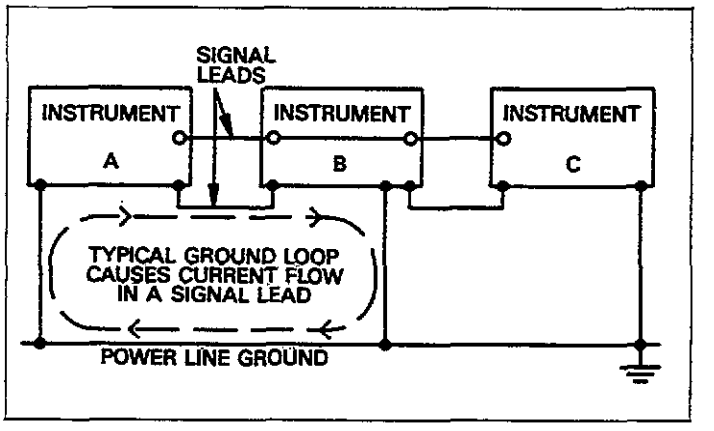



**Figure 3-55. Multiple Ground Points Create a Ground Loop**

## 3.23 MEASUREMENT CONSIDERATIONS

The following paragraphs discuss some measurement considerations to take into account when using the Model 590.

### 3.23.1 Ground Loops

Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or inaccurate measurements. For example, the configuration shown in Figure 3-55 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in one of 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 ground leads can induce sufficient voltages to disturb sensitive measurements.

To prevent ground loops, instruments should be connected to ground only at a single point, as shown in Figure 3-56. Note that only a single instrument is connected directly to power line ground.

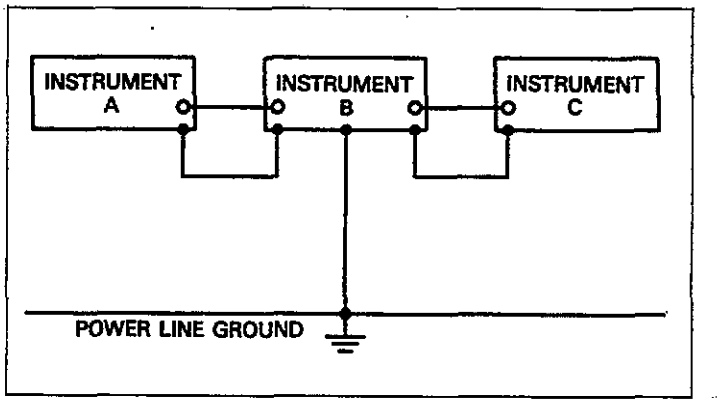



**Figure 3-56. Eliminating Ground Loop**



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Another way to eliminate ground loops with the Model 590 is to operate the instrument with analog common floating. To do so, place the rear panel grounding switch in the floating position. Regardless of the method used, experimentation is the best way to determine an acceptable arrangement. To determine the best method, place the instrument on its lowest range. The configuration that results in the lowest noise signal is the one that should be used.

## 3.23.2 Electromagnetic Interface (EMI)

The electromagnetic interference characteristics of the Model 590 CV Analyzer comply with the electromagnetic compatibility (EMC) requirements of the European Union as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the measurement setup.

Sources of EMI include:

- radio and television broadcast transmitters
- communictions transmitters, including cellular phones and handheld radios
- devices incorporating microprocessors and high speed digital circuits
- impulse sources as in the case of arcing in high-voltage environments

The effect on instrument performance can be considerable if enough of the unwanted signal is present. The effects of EMI can be seen as an unusually large offset, or, in the case of impulse sources, erratic variations in the displayed reading.

The instrument, test leads, and test fixture should be kept as far away as possible from any EMI sources. Additional shielding of the instrument, experiment, and test leads will often reduce EMI to an acceptable level. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate the troublesome signal.

Careful wafer fixture construction and shielding are paramount in the reduction of EMI and noise in general. In many instances, a farady shield that completely surrounds the wafer chuck may be necessary to reduce the effects of EMI. This shield should be insulated from the test fixture ground and must be connected to analog common of the instrument.

Often, the internal filtering of the instrument may sufficiently reduce the effects of EMI. In addition to the analog filter (controlled by the FILTER button), judicious selection of the reading rate will also have positive effects on the measurement. The slowest reading rate has the most digital filtering and thus would be the rate to use when attempting to reduce EMI effects.

## 3.23.3 Parasitic Capacitance

Parasitic or unwanted capacitance appearing in the test cables or fixture can seriously affect the accuracy of measurements made with virtually and instrument. Since the Model 590 measures capacitance, however, measurements made with this instrument can be particularly sensitive to such parasitic capacitance. The way that capacitance is distributed determines the effects of this unwanted capacitance.

### Shunt Capacitance

Shunt capacitance appearing between the high and low terminals of the test INPUT jack can increase noise seen in the readings.

In the equivalent circuit of Figure 3-57, the shunt capacitance is represented by $C_s$. Note that $C_s$ appears between the high and low terminals of the INPUT jack. The primary source of $C_s$ in most situations is the distributed capacitance of the test cables. Thus, the following steps can be taken to minimize shunt capacitance:

1. Keep the cables as short as possible.
2. Use only low-capacitance cbale (RG-58).
3. Keep the number of connectors to a minimum.
4. Use at est fixture with good, low-capacitance design.

### Parallel Capacitance

Parallel capacitance across the device being tested is generally a more serious problem because the two values will combine, leading to erroneous measurements. In the circuit of Figure 3-57, the parallel capacitance is represented by Cp. Careful test fixture design is necessary to minimize any such parallel capacitane that hight upset the measurement.

Two ways to minimize parallel capacitance are:

1. Shield the probes as close to the wafer as possible.
2. Incorporate a farady shield, connected to analog common, around the wafer.



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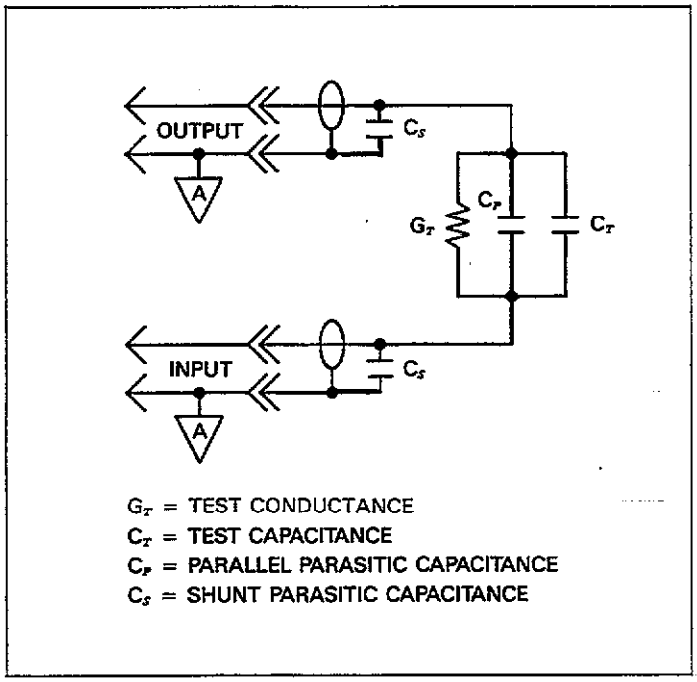



**Figure 3-57. Parasitic Capacitance**

## 3.23.4 Cable Transmission Line Effects

When measuring at 1MHz, the coaxial cable acts like a transmission line, and it can seriously affect measurements unless care is taken to minimize and compensate for these effects. While transmission line theory is beyond the scope of this discussion, there are a number of steps you can take to keep measurement errors due to transmission line effects to a minimum. These precautions include:

1. Use cable correction, especially when measuring at 1MHz (see paragraphs 3.21 and 4.11).
2. Keep the test cables as short as possible. Maximum recommended cable length is five meters per cable.
3. Use only the prescribed cable for test connections (RG-58).
4. Match impedances between the instrument, cables, and connectors as closely as possible. The nominal impedance is 50Ω, and should be matched as closely as possible.
5. Keep the number of discrete connections in the test system to an absolute minimum. No matter how carefully you attempt to match impedances, some small mismatch at each connecting point is almost inevitable. The more connections, the "lumpier" the transmission path becomes. Thus, it would be better to use one continuous length of cable instead of several shorter cables.



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# SECTION 4
# IEEE-488 PROGRAMMING

## 4.1 INTRODUCTION

This section contains information on programming the Model 590 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.

General information on the IEEE-488 bus is located in the Appendix.

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:** Describes an alternate programming method of using easily recognized user-defined words in place of device-dependent commands.

**4.11 Cable Correction:** Describes driving point, matrix parameter, and calibration capacitor methods of cable correction.

**4.12 Programming Examples:** Gives examples for programming the instrument to take one-point measurements, plot data, and generate C vs t information.

**4.13 Bus Data Transmission Times:** Gives 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 590 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 590 to the Controller

With power off, connect the Model 590 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 590 (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 590 is set to 15 at the factory, but you can program other values between 0 and 30 by pressing SHIFT IEEE and then using the numeric keys to change the primary address. Once the desired value is displayed, press ENTER to program the value.



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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 from the instrument. Figure 4-1 shows a basic flow chart that a typical simple program will follow. The programming example below follows this general sequence. This program will allow you to type in command strings to program the instrument and display data on the HP-85 computer CRT.

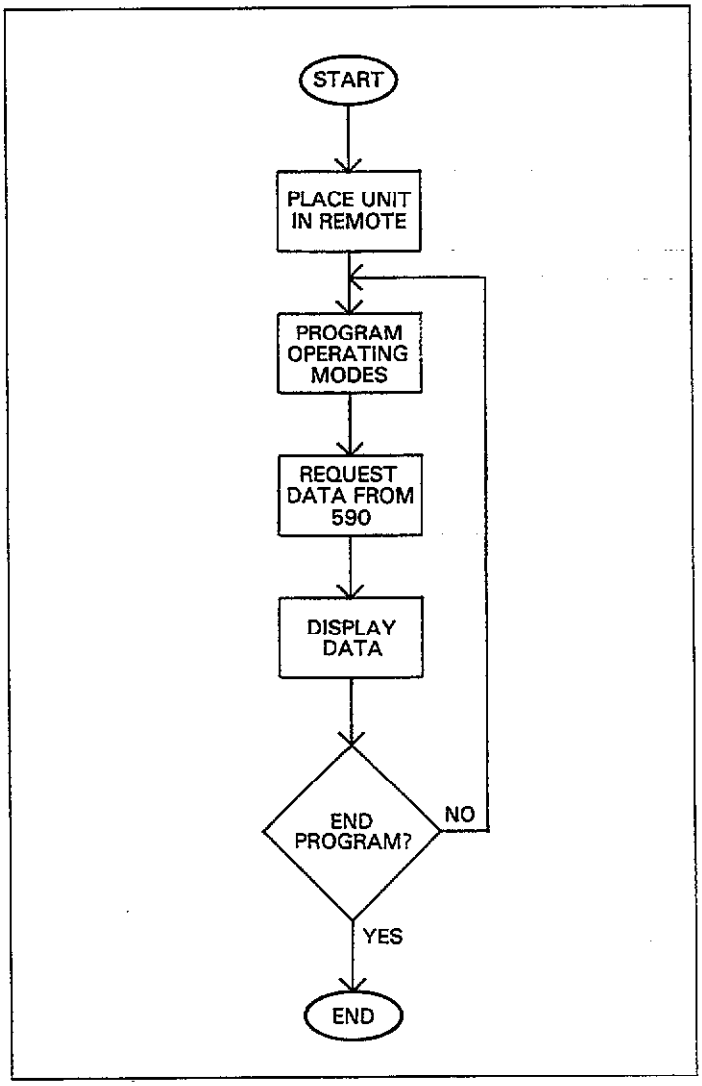



**Figure 4-1. Typical Program Flow Chart**

**Programming Example**—Use the simple HP-85 program below to send programming commands to the Model 590 and display the data string on the computer CRT.

| PROGRAM | COMMENTS |
|---|---|
| `10 REMOTE 715` | Send remote enable. |
| `20 DISP "COMMAND";` | Prompt for command string. |
| `30 INPUT C$` | Input the command string. |
| `40 OUTPUT 715; C$` | Send command string to 590. |
| `50 ENTER 715; A$` | Get a reading from the instrument. |
| `60 DISP A$` | Display the reading. |
| `70 GOTO 20` | Repeat. |
| `80 END` | |

### Step 4: Program Model 590 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 more numbers for the command option(s). Table 4-1 summarizes the most often used Model 590 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 example from Step 3 above, simply type in the command string when prompted to do so. Some example strings are given below.

F0R0X Select 100kHz, autorange.
P0N1X Turn filter off, bias on.
S4R9X Select 1/sec reading rate, turn autorange off.
T0,1X Select sweep on talk trigger mode and source.

**NOTE**

The HP-85 uses a comma to delimit its INPUT statement, the same character used to delimit multiple-option 590 commands. Place quotes around the input string when typing in multiple-option commands.



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**Table 4-1. Summary of Most Often Used IEEE-488 Commands**

| Mode | Command | Description |
|---|---|---|
| Frequency | F0 | 100kHz |
| | F1 | 1MHz |
| | F2 | Disconnect test signal from jacks |
| Range | | **100kHz** **1MHz** |
| | R0 | Autorange on Autorange on |
| | R1 | 2p/2µS 20pF/200µS |
| | R2 | 20pF/20µS 20pF/200µS |
| | R3 | 200pF/200µS 200pF/2mS |
| | R4 | 2nF 2nF/20mS |
| | R5 | R1 × 10 Error |
| | R6 | R2 × 10 Error |
| | R7 | R3 × 10 Error |
| | R8 | R4 × 10 Error |
| | R9 | Autorange off Autorange off |
| Reading Rate | S0 | 1000 readings/sec |
| | S1 | 75 readings/sec |
| | S2 | 18 readings/sec |
| | S3 | 10 readings/sec |
| | S4 | 1 reading/sec |
| Trigger Mode and Source | T0,0 | One-shot talk |
| | T0,1 | Sweep, talk |
| | T1,0 | One-shot, GET |
| | T1,1 | Sweep, GET |
| | T2,0 | One-shot, X |
| | T2,1 | Sweep, X |
| | T3,0 | One-shot, external |
| | T3,1 | Sweep, external |
| | T4,0 | One-shot, front panel |
| | T4,1 | Sweep, front panel |
| Zero | Z0 | Zero off |
| | Z1 | Zero on |
| Filter | P0 | Filter off |
| | P1 | Filter on |
| Bias Voltage | V (first) (,last) (,step) (,default) (,count) | first = first bias; last = last bias; step = step bias; default = default bias; -20.000 ≤ V ≤ +20.000V. 1 ≤ count ≤ 450 (1,350 at 1,000/sec) |
| Waveform and Times | W (waveform) (,start) (,stop) (,step) | 1msec ≤ T ≤ 65sec. Waveform = 0: DC 1: Single staircase 2: Dual staircase 3: Pulse train 4: External bias source |
| Bias Voltage Control | N0 | Bias source off |
| | N1 | Bias source on |

NOTE: See Table 4-9 on page 4-18 for a complete summary of device-dependent commands.



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**Step 5: Trigger a Sweep**

Usually, you will require a complete set of readings: in other words, a sweep. To initiate that sweep, it will be necessary for you to trigger the instrument. The trigger stimulus will depend on the programmed trigger source. For example, you can send the string "T2,1X" to program the sweep on X mode and at the same time trigger a sweep.

**Step 6: Get Readings from the Model 590**

Usually, you will want to obtain one or more readings from the Model 590. 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, wait for a sweep to be completed, and then obtain a whole series of readings.

The basic reading string that the Model 590 sends over the bus is in ASCII characters of the form:

NCSK +1.2345E−09

where:

NCSK is the prefix (N=normal, C=capacitance, S=series, K=100kHz).
+1.2345 is the mantissa of the reading.
E−09 is the exponent.

Note that a variety of data formats are available, as discussed in paragraph 4.9.

## 4.3 BUS CONNECTIONS

### 4.3.1 Bus Connector

The Model 590 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 590, *which is designed for metric threads.*

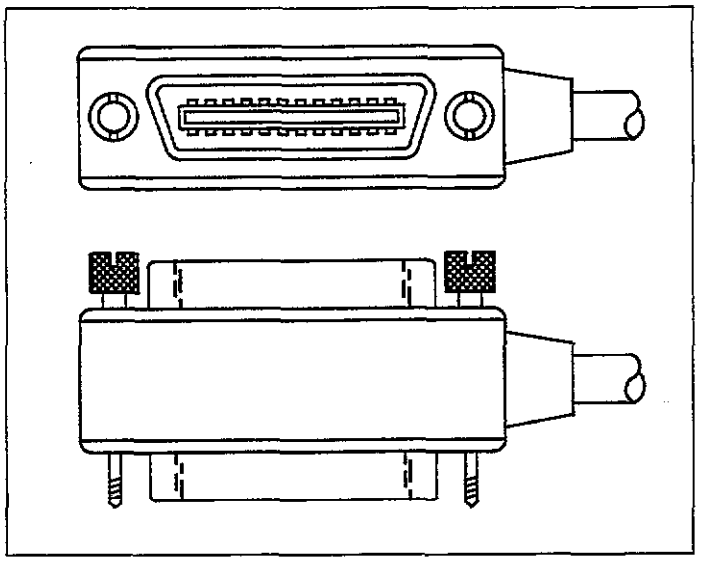


**Figure 4-2. IEEE-488 Connector**

### 4.3.2 Multiple Connections

A typical connecting scheme for a multiple-instrument test setup is shown in Figure 4-3. Although any number of connectors could theoretically be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.

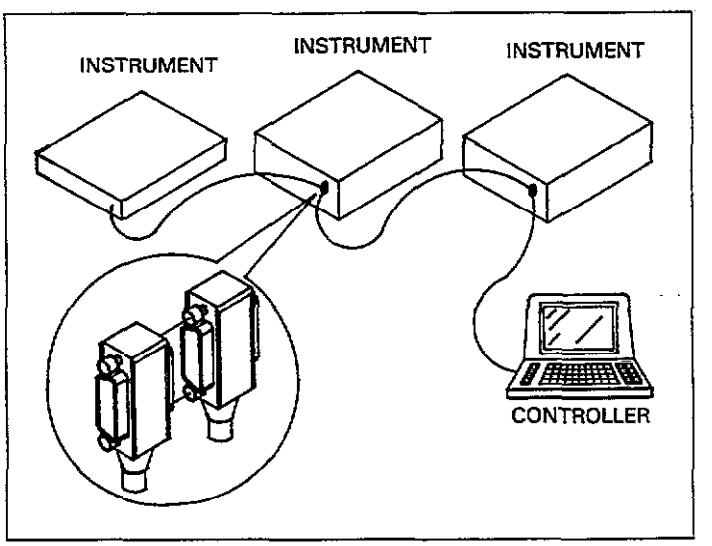



**Figure 4-3. IEEE-488 Connections**



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### 4.3.3 Recommended Cables

In order to minimize interference caused by electromagnetic radiation, it is recommended that only shielded IEEE-488 cables be used. The Models 7007-1 and 7007-2 shielded IEEE-488 cables are available from Keithley Instruments, Inc.

### 4.3.4 Connection Procedure

Connect the Model 590 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.

### 4.3.5 Bus Limitations

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.

### 4.3.6 Contact Assignments

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.

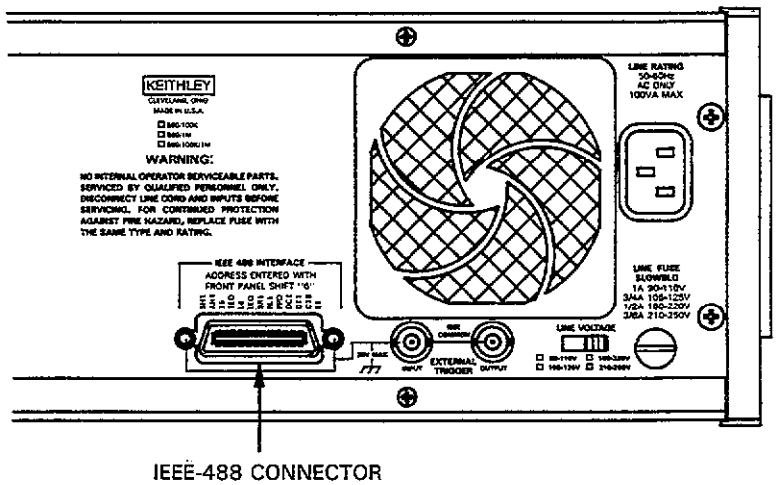



**Figure 4-4. IEEE-488 Connector Location**



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**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 parenthesis refer to signal ground return of referenced contact number. EOI and REN signal lines return on contact 24.

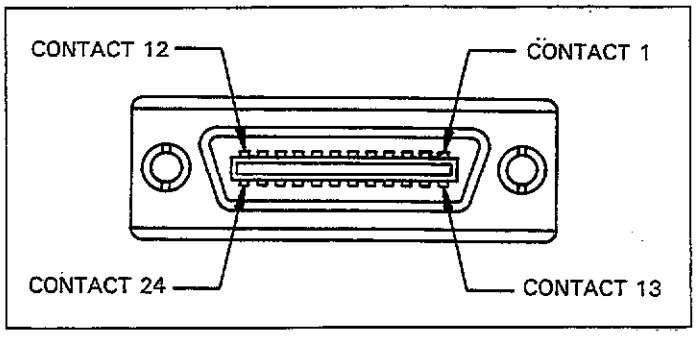



**Figure 4-5. Contact Assignments**

## 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 590 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 590 capabilities as follows:

SH1 (Source Handshake)—SH1 defines the ability of the Model 590 to properly handshake data or command bytes when the unit is acting as a source.

AH1 (Acceptor Handshake)—AH1 defines the ability of the Model 590 to properly handshake the bus when it is acting as an acceptor of data or commands.

T6 (Talker)—The ability of the Model 590 to send data over the bus to other devices is defined by the T6 function. Model 590 talker capabilities exist only after the instrument has been addressed to talk. T6 means that the Model 590 is a basic talker, has serial poll capabilities, and will be unaddressed to talk when it receives its own listen address.

L4 (Listener)—The L4 function defines the ability of the Model 590 to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen. L4 means that the Model 590 is a basic talker and will be unaddressed to listen when addressed to talk.

SR1 (Service Request)—The SR1 function defines the ability of the Model 590 to request service from the controller.

RL1 (Remote Local)—The RL1 function defines the capability of the Model 590 to be placed in the remote or local modes.

PP0 (Parallel Poll)—PP0 means the Model 590 does not have parallel polling capabilities.

DC1 (Device Clear)—The DC1 function defines the ability of the Model 590 to be cleared (initialized).

DT1 (Device Trigger)—The ability for the Model 590 to have its readings triggered is defined by the DT function.

C0 or C28 (Controller)—The Model 590 has limited controller capabilities (C28) only when being used for standalone plotting. When used with a controller, the instrument has no controller capabilities (C0).

TE0 (Extended Talker)—The Model 590 does not have extended talker capabilities.

LE0 (Extended Listener)—The Model 590 does not have extended listener capabilities.

E1 (Bus Driver Type)—The Model 590 has open-collector bus drivers.



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**Table 4-3. Model 590 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 |
| C28 | Limited Controller capability* |
| E1 | Open collector bus drivers |
| TE0 | No Extended Talker capabilities |
| LE0 | No Extended Listener capabilities |

*Stand alone plotting only; C0 (no controller capability) otherwise.

## 4.5 PRIMARY ADDRESS SELECTION

The Model 590 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 15 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.

### 4.5.1 Address Limitations

The primary address can be programmed for any value between 0 and 30. However, each device on the bus must have a unique primary address--a factor that should be kept in mind when setting the primary address of the Model 590. 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, but different than any other device on the bus.

### 4.5.2 Programming the Primary Address

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

1. Press SHIFT IEEE. The instrument will respond with the presently programmed primary address:

   IEEE ADDRESS 15

2. In this example, the default value (15) is being displayed.
3. To exit without changing the address at this point, simply press QUIT.
4. To modify the address, key in a new value with the numeric data keys. Remember that the primary address limits are 0-30 inclusive. If you enter an address above 30, the unit will set the address to 30.
5. Once the desired value is displayed, press the ENTER key.
6. The instrument will then return to normal operation with the new address in effect.

## 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 the programming language for a popular IEEE-488 controller, the Hewlett-Packard HP-85.

### 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.

Some small computers that can be used a IEEE-488 controllers may not support all IEEE-488 functions. With many, 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 in HP-85 BASIC. This com-



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puter was chosen for these examples because of its ease and versatility in controlling the IEEE-488 bus. A partial list of statements for the HP-85 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 590 address (15) 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 715 sends the SDC command to a device with a primary address of 15.

**Table 4-4. HP-85 IEEE-488 BASIC Statements**

| Action | HP-85 Statement |
|---|---|
| Transmit string to device 15. | OUTPUT 715; A$ |
| Obtain string from device 15. | ENTER 715; A$ |
| Send GTL to device 15. | LOCAL 715 |
| Send SDC to device 15. | CLEAR 715 |
| Send DCL to all devices. | CLEAR 7 |
| Send remote enable. | REMOTE 7 |
| Cancel remote enable. | LOCAL 7 |
| Serial poll device 15. | SPOLL (715) |
| Send local lockout. | LOCAL LOCKOUT 7 |
| Send GET to device 15. | TRIGGER 715 |
| Send IFC. | ABORTIO 7 |

## 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 590 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.

The following paragraphs discuss many of these messages in detail. Note that the instrument may be programmed to generate an SRQ and U command status words can be checked for specific error conditions if any of these errors occur. See paragraphs 4.9.15 and 4.9.16.

**Error Message Differences**

There are a few differences between front panel and bus operation regarding the type of message that occurs for specific error conditions. In particular, invalid parameter and mode conflict errors differ somewhat in the type of error message generated for each.

Programming an invalid parameter from the front panel will generate an INVALID error message, as discussed in Section 3. However, attempting to program an invalid parameter over the bus will generate an IDDCO (Illegal Device-Dependent Command Option) error, as discussed below.

Similarly, a front panel mode conflict error situation (for example selecting 1MHz with X10 enabled) results in a CONFLICT error message. In contrast, programming such a mode conflict over the bus generates an IDDCO error.

**No Remote Error**

A no remote error will occur if the instrument is addressed to listen and the REN (Remote Enable) line is false. In this instance, the following error message will be displayed on the front panel.

NO REMOTE ERR

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

**Programming Example**—To demonstrate the NO REMOTE ERR message, type in the following lines:

```
LOCAL 7
OUTPUT 715; ""R1X""
```

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



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## Table 4-5. Front Panel IEEE-488 Messages

| Message | Description | Comments |
|---|---|---|
| NO REMOTE ERR | Unit programmed with REN false. | Set REN true, address unit to listen. |
| IDDC (Illegal Device-Dependent Command) | Illegal command sent. | Send only legal command letters. |
| IDDCO (Illegal Device-Dependent Command Option) | Illegal command option sent. | Send only valid command options. |
| TRIG-OVERRUN | Unit triggered while processing reading or sweep. | Wait for reading or sweep completion before re-triggering. |
| CAL LOCKED | Calibration switch in locked position. | See paragraph 7.3 |
| BUSY | Unit performing calibration | |
| TRANSLATOR-ERR | Translator error | Use only appropriate Translator modes. |
| CONFLICT | Attempt at cable correction at 100kHz | Cable correct at 1MHz only. |
| DISCONECT | Test signal disconnected from jacks | Invoked with F2 command. |

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

An IDDC error occurs when the unit receives an illegal device-dependent command over the bus (the unit does not check command until it detects the "X" character, however). 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.

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

```
REMOTE 715
OUTPUT 715; ''E1X''
```

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

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

Sending the instrument a legal command with an illegal option will result in the following front panel error message:

IDDCO

For example, the command K9X has an illegal option (9) 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. Similarly, the IDDCO error results if an invalid parameter or mode conflict is programmed, or if you attempt to program a frequency for a module not installed. As with the IDDC message, the unit does not check for illegal options until the "X" character is received.

To correct this error condition, use only valid command options, as discussed in paragraph 4.9. Note that an IDDCO error is also flagged in the U1 word, as discussed in paragraph 4.9.15.

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

```
REMOTE 715
OUTPUT 715; ''K9X''
```



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

### Trigger Overrun Error

A trigger overrun message occurs when the instrument is triggered while it is still processing a reading or sweep from a previous trigger. The exact trigger stimulus will depend on the selected trigger mode, as discussed in paragraph 4.9.

Overrun triggers will not affect the instrument except to generate the message below. In other words, the reading or sweep will not be aborted by the overrun trigger stimulus. When such a trigger overrun condition occurs, the instrument will briefly display the following error message:

TRIG-OVERRUN

**Programming Example**—To demonstrate an overrun trigger situation, type in the following statements:

```
REMOTE 715
OUTPUT 715; ''T1,1X''
TRIGGER 715 @ TRIGGER 715
```

Note that the TRIG-OVERRUN message is briefly displayed when the third statement above is executed.

### Calibration Locked Message

Sending a calibration (Q) command (except for Q0, which performs drift correction) with the internal calibration switch in the locked position will result in the following message:

CAL LOCKED

Refer to paragraph 7.3 for calibration information.

**Programming Example**—Demonstrate the calibration locked message by using the statements below.

**CAUTION**

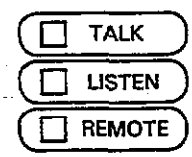
**Do not use the following example unless you are certain that the calibration lock switch is in the disabled position, or miscalibration will result. From the factory, the switch is in the disabled (locked) position.**

```
REMOTE 715
OUTPUT 715; ''Q1X''
```

Note that the CAL LOCKED message is briefly displayed.

## 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.




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 590 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

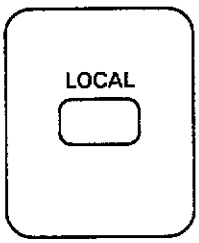


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line, as the instrument must be addressed to listen with REN true before the REMOTE indicator will turn on. When the instrument is in remote, all front panel keys except for the LOCAL key will be locked out. When REMOTE is turned off, the instrument is in the local mode, and front panel operation will be restored (unless LLO is in effect).

### 4.7.3 LOCAL Key

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




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

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

### 4.7.4 Simultaneous Front Panel and Bus Operation

Fundamentally, there is no reason why you cannot control the instrument simultaneously from both the front panel and over the IEEE-488 bus. However, the following points should be kept in mind.

1. All front panel keys except for LOCAL will be inoperative while the Model 590 is in remote (REMOTE on). The unit is placed in remote by addressing it to listen with the REN line true. Thus, to control the unit from the front panel, it will be necessary for you to press LOCAL after programming over the bus. Note that LOCAL is also inoperative if the LLO (Local Lockout) command is in effect.
2. Front panel parameter modification should always be completed before attempting to use bus control. For example, you should not attempt to program bias waveform parameters over the bus while editing them from the front panel, or the unit will hold off the bus. Similarly, attempting to program over the bus while viewing buffer data will also cause a bus hold off.

In any case, you can restore bus operation by using appropriate keys to return to normal display.

## 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 590 are summarized in Table 4-6, which also lists HP-85 statements necessary to send each command. Note that commands requiring a primary address assume that the Model 590 primary address is set to 15 (its factory default address).

**Table 4-6. General Bus Commands and Associated BASIC Statements**

| Command | HP-85 Statement | Effect On Model 590 |
|---|---|---|
| REN | REMOTE 7 | Goes into effect when next addressed. |
| IFC | ABORTIO 7 | Goes into talker and listener idle states. |
| LLO | LOCAL LOCKOUT 7 | LOCAL key locked out. |
| GTL | LOCAL 715 | Cancel remote, restore front panel operation. |
| DCL | CLEAR 7 | Returns to default conditions. |
| SDC | CLEAR 715 | Returns to default conditions. |
| GET | TRIGGER 715 | Triggers measurement with GET source. |



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### 4.8.1 REN (Remote Enable)

REN is a uniline command that must be asserted by the controller to place the Model 590 in remote. 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 before it will actually go into remote.

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. Front panel operation can be restored by pressing the LOCAL key unless LLO (Local Lockout) is in effect.

Note that the instrument need not be in remote to request and obtain data over the bus.

To place the Model 590 in remote, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 590 to listen.

**Programming Example**—Place the Model 590 in remote with the following statement:

```
REMOTE 715
```

When this statement is executed, the Model 590 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 (15).

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.

### 4.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 590 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 states.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

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

```
SEND 7: TALK 15
```

At this point, the TALK indicator 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 this statement is executed.

### 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).

Note that the unit must be in remote (REMOTE on) in order to respond to LLO immediately.



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Operation of the LOCAL key can be restored by setting the REN line false, which will also take the unit out of remote.

In order to send LLO, the controller must perform the following:

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

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

```
REMOTE 715
LOCAL LOCKOUT 7
```

After the second statement is executed, the LOCAL key will be locked out.

To restore front panel operation after asserting LLO, set REN false, as in the following example:

```
LOCAL 7
```

## 4.8.4 GTL (Go To Local)

The GTL command is used to take the instrument out of remote. Operation of the front panel keys will also be restored by GTL unless LLO is in effect. To cancel LLO, you must set REN false.

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

1. Set ATN true.
2. Address the Model 590 to listen.
3. Place the GTL command byte on the data lines.

**Programming Example**—Place the instrument in remote with the following statement:

```
REMOTE 715
```

Verify that the instrument is in remote.

Send GTL as follows:

```
LOCAL 715
```

Note that the instrument goes into the local mode, and that operation of the front panel keys has now been restored (assuming that LLO is not in effect).

## 4.8.5 DCL (Device Clear)

The DCL command may be used to clear the Model 590 and return the unit to default conditions. Table 4-7 lists factory default conditions for the instrument after it receives a DCL. Note that many of these are the same conditions as front panel save/recall position 1, and they may be different if you change that configuration.

**Table 4-7. Power Up, DCL/SDC Default Conditions**

| Mode | Equivalent Command(s) | Description |
|---|---|---|
| Range* | R4 | 2nF |
| Frequency* | F0 | 100kHz |
| Operation | O0,1 | C, G, V data, parallel model |
| Filter* | P1 | Filter on |
| Rate* | S3 | 10/sec |
| Zero* | Z0 | Zero off |
| Trigger* | T4,1 | Sweep, front panel |
| Bias source* | N0 | Off |
| Waveform, times* | W0,IE−3,IE−3, IE−3 | DC, all times 1msec |
| Bias voltages* | V0,0,0,0,450 | All 0V, count=450 |
| Plotter grid | A3,0 | Full grid |
| Plotter pen | A5,1 | Pen #1 |
| Plotter line | A6,7 | Solid line |
| Plotter label | A7,0 | Full labels |
| Plot type | A2,0 | C vs V |
| Buffer to plot | A4,0 | A/D |
| X axis scaling | A8,0 | Auto |
| Y axis scaling | A9,0 | Auto |
| Buffer output | B0 | Current reading |
| Data format | G0 | Prefix on, suffix off, 1rdg |
| EOI and Hold-off | K0 | Both enabled |
| SRQ | M0 | Disabled |
| Terminator | Y0 | <CR><LF> |
| Cable Correction | C0,7 | Correction to front panel. |

NOTE: Sending DCL or SDC cancels drift correction (Q0).
*These modes can be changed by altering setup 1 configuration (L command).



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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.

**NOTE**

DCL does not affect the programmed primary address, but drift correction (Q0) constants will be cancelled by DCL.

**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.

## 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 590 receives the SDC command, it will return to the default configuration shown in Table 4-7. Note that many of these conditions are specified with front panel save/recall position 1 and may be different if altered.

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

1. Set ATN true.
2. Address the Model 590 to listen.
3. Place the SDC command byte on the data bus.

**Programming Example**—Using several front panel controls, alter instrument modes from the factory default configuration. Send SDC with the following statement:

```
CLEAR 715
```

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

## 4.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 590 reading or sweep if the instrument is placed in the appropriate trigger mode. Basically, there are two trigger modes: one-shot and sweep. More information on triggering is located in paragraph 4.9.

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

1. Set ATN low.
2. Address the Model 590 to listen.
3. Place the GET command byte on the data bus.

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

```
REMOTE 715
OUTPUT 715; ''T1,1X''
```

Now trigger the sweep by sending GET with the following statement:

```
TRIGGER 715
```

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

## 4.8.8 Serial Polling (SPE, SPD)

The serial polling sequence in used to obtain the Model 590 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 devices are in the serial poll enabled mode and waiting to be addressed.
3. The Model 590 is then addressed to talk.



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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.

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

```
S=SPOLL(715)
DISP S
```

When the above statements are executed, the Model 590 is serial polled, and the decimal value of the status byte is displayed on the computer CRT.



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## 4.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands concerned with the Model 590 are the most important commands associated with instrument programming because they control most instrument operating modes. All front panel modes (such as rate and range), 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. R4X would be sent to program the 2nF range.

Some commands have two or more parameters that must be separated by commas. For example, the V10,5,1,0X command programs the bias voltage waveform parameters. In this case, V is the command letter, while 10, 5, 1, and 0 are parameters that program the first, last, step, and default voltages respectively.

**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.

**Invalid Commands** If an invalid command is sent as part of the command string, no commands in the string will be executed. Under these conditions, the instrument will 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 4.9.15. Note, however, that 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 commands string.
R1F0S1X Multiple command string.
Z 1X Space is ignored.
W2,3,4X Multiple-parameter command string (parameters separated by commas).

Typical invalid command strings include:

E1X Invalid command, as E is not one of the instrument's valid commands.
K7X Invalid command option because 7 is not an option of the K command.
V30X Invalid parameter (maximum bias voltage is 20V).
W123X Multiple-parameter command without the necessary separating commas.



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**Using Multiple-Option Commands** Some commands have multiple options, allowing you to program several parameters with a single command letter. For example, the W command is used to program the bias waveform, and the start, stop, and step times associated with that waveform, as in the following example:

W1,100E-3,50E-3,10E-3X

In this instance, the first parameter (1) selects single staircase waveform, while the last three parameters program start, stop, and step times of 100msec, 50msec, and 10msec respectively.

The general format for listing multiple-option commands in this manual is shown in the following example:

V(first)(,last)(,step)(,default)

Here, first, last, step, and default are numeric parameters, while the commas indicate the necessary delimiters. The parentheses around a particular parameter indicate that that parameter and the associated delimiter are optional.

**NOTE**
Do not include parenthesis in actual command strings.

When using any multiple-option command, you need not include all parameters in the command string; however, when leaving out preceding parameters, you must include a comma delimiter character for each parameter left out. For example, to program only the default voltage while leaving the first, last, and step bias values unchanged, the following string could be used:

V,,,5X

In this instance, the first three commas mark positions where the first, last, and step bias values are omitted.

If leaving out succeeding characters in the command string, you need not include the parameters or delimiters. For example, the following command could be sent to change only the bias waveform without modifying start, stop, or step times:

W1X

In this instance, only the first parameter (waveform type) is specified, while the start, stop, and step times are not and would be left unchanged.

**Order of Command Execution** Device-dependent commands are not necessarily executed in the order received. Rather, the instrument always executes them in a specific order, as summarized in Table 4-8.

If you wish to force a particular order of command execution, simply include the execute (X) character after each command-option grouping in the command string. For example, the following string would be executed in the received order:

F0XR0XS4X



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### Table 4-8. Order of Command Execution

| Order | Description |
|---|---|
| 1 | A/D programming |
| 2 | I/O programming |
| 3 | Cable correction programming |
| 4 | Global parameter programming |
| 5 | B, C, D, H, I, K, J, L, Q |
| 6 | X |

**Device-dependent Command Summary** All Model 590 device-dependent commands are summarized in Table 4-9, which also lists respective paragraphs where more detailed information on each command may be found. As listed, commands are summarized in most-often-used to least-often-used order. As a convenience, Table 4-10 provides a cross reference in alphabetical order.

Note that you can also use the Translator to simplify programming, as discussed in paragraph 4.10.

### Table 4-9. Device-Dependent Command Summary

| *Mode* | *Command* | *Description* | | Paragraph |
|---|---|---|---|---|
| Execute (X) | X | Execute commands | | 4.9.1 |
| Frequency (F) | F0 | 100kHz | | 4.9.2 |
| | F1 | 1MHz | | |
| | F2 | Disconnect test voltage | | |
| Range (R) | | **100kHZ** | **1MHz** | 4.9.3 |
| | R0 | Autorange on | Autorange on | |
| | R1 | 2pF/2μS | 20pF/200μS | |
| | R2 | 20pF/20μS | 20pF/200μS | |
| | R3 | 200pF/200μS | 200pF/2mS | |
| | R4 | 2nF/2mS | 2nF/20mS | |
| | R5 | R1 x10 on | Error | |
| | R6 | R2 x10 on | Error | |
| | R7 | R3 x10 on | Error | |
| | R8 | R4 x10 on | Error | |
| | R9 | Autorange off, stay on range | | |
| Reading Rate (S)* | S0 | 1000/sec, 3½ digits | | 4.9.4 |
| | S1 | 75 /sec, 3½ digits | | |
| | S2 | 18/sec, 4½ digits | | |
| | S3 | 10/sec, 4½ digits | | |
| | S4 | 1/sec, 4½ digits | | |
| Trigger (T) | T0,0 | One-shot on talk | | 4.9.5 |
| | T0,1 | Sweep on talk | | |
| | T1,0 | One-shot on GET | | |
| | T1,1 | Sweep on GET | | |
| | T2,0 | One-shot on X | | |
| | T2,1 | Sweep on X | | |
| | T3,0 | One-shot on external pulse | | |
| | T3,1 | Sweep on external pulse | | |
| | T4,0 | One-shot on front panel | | |
| | T4,1 | Sweep on front panel | | |

*Rates are nominal.



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## Table 4-9. Device-Dependent Command Summary (Cont.)

| Mode | Command | Description | Paragraph |
|---|---|---|---|
| Bias Voltage (V) | V(first)(,last)(,step)(,default)(,count) | First = first bias; Last = last bias; Step = step bias; Default = default bias; $-20.000 \leq V \leq 20.000$ $1 \leq count \leq 450$ (1,350 at 1,000/sec). | 4.9.6 |
| Waveform (W) | W(waveform)(,start)(,stop)(,step) | Waveform: 0 = DC; 1 = Single stair; 2 = Dual stair; 3 = Pulse; 4 = 200V External bias; 5 = 20V External bias; Start = start time; Stop = stop time; Step = step time; $1msec \leq T \leq 65sec$ | 4.9.7 |
| Bias Control (N) | N0<br>N1 | Bias off<br>Bias on | 4.9.8 |
| Data Format (G0) | G0<br>G1<br>G2<br>G3<br>G4<br>G5 | Prefix on, suffix off, 1 rdg<br>Prefix off, suffix off, 1 rdg<br>Prefix on, suffix on, 1 rdg<br>Prefix on, suffix off, n rdgs<br>Prefix off, suffix off, n rdgs<br>Prefix on, suffix on, n rdgs<br>n rdgs = # readings in buffer | 4.9.9 |
| Operation (O) | Ooutput(,model)(,$C_O$) | Output: 0 = C, G, V (triple); 1 = C only; 2 = G only; 3 = V only; 4 = $1/C^2$; 5 = $C/C_O$; 6 = $C_A - C_B$; 7 = $[V_A - V_B]C_{CONST}$. Model: 0 = Parallel; 1 = Series. $C_O$ (used with $C/C_O$): $0 \leq C_O \leq 20E-9$ | 4.9.10 |
| Buffer (B) | B0<br>B1(,first)(,last)<br>B2(,first)(,last)<br>B3 | Current Reading<br>A/D buffer, first, last limits<br>Plot buffer, first, last limits<br>Transfer A/D buffer to plot buffer | 4.9.11 |
| Plotter (A) | A0<br>A1<br>A2, plot<br><br><br><br>A3, grid<br>A4, buffer<br><br>A5, pen<br><br>A6, line<br><br><br><br><br>A7, label<br><br>A8,n, Xmin, Xmax | Execute plot<br>Execute grid<br>Plot: 0 = C vs V; 1 = G vs V; 2 = $1/C^2$ vs V; 3 = $C/C_O$ vs V; 4 = C vs t; 5 = $[C_A - C_B]$ vs V; 6 = $[V_A - V_B]$ C=CONST<br>Grid: 0 = Full grid; 1 = Axis only<br>Buffer: 0 = A/D buffer (A); 1 = Plot buffer (B)<br>Pen: 0 = No pen; 1 = Pen #1; 2 = Pen #2<br>Line: 0 = Dot at points; 1 = Spaced dots; 2 = Dashes; 3 = Long dash; 4 = Dash dot; 5 = Long dash, short dash; 6 = Long, short, long dash; 7 = Solid line<br>Label: 0 = Full labels; 1 = Label axis and divisions; 2 = Label axis only<br>X axis limits. n=0: Autoscaling (minimum/maximum bias). n=1: Program Xaxis minimum (Xmin) and maximum (Xmax) values. | 4.9.12 |



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## Table 4-9. Device-Dependent Command Summary (Cont.)

| Mode | Command | Description | Paragraph |
|---|---|---|---|
| Plotter (A) (Cont.) | A9,n, Ymin, Ymax | Y axis limits. n=0: Default values, 0 to full scale. n=1: Program Y axis minimum (Ymin) and maximum (Ymax) values | |
| Zero (Z) | Z0<br>Z1 | Disable zero<br>Enable zero | 4.9.13 |
| Filter (P) | P0<br>P1 | Filter off<br>Filter on | 4.9.14 |
| Status (U) | U0<br>U1<br>U2<br>U3<br>U4<br>U5<br>U6<br>U7<br>U8<br>U9<br>U10<br>U11<br>U12<br>U13<br>U14<br>U15<br>U16<br>U17<br>U18<br>U19<br>U20<br>U21<br>U22<br>U23<br>U24<br>U25<br>U26<br>U27<br>U28<br>U29<br>U30<br>U31<br>U32 | Hardware/software revision<br>Error information<br>Buffer A range group<br>Buffer A trigger group<br>Buffer A zero group<br>Buffer A bias group<br>Buffer A bias voltage<br>Buffer A bias time<br>Buffer A position and time<br>Buffer B range group<br>Buffer B trigger group<br>Buffer B zero group<br>Buffer B bias group<br>Buffer B bias voltage<br>Buffer B bias time<br>Buffer B position and times<br>Buffer A maximum/minimum capacitance<br>Buffer A maximum/minimum conductance<br>Buffer A maximum/minimum voltage<br>Buffer B maximum/minimum capacitance<br>Buffer B maximum/minimum conductance<br>Buffer B maximum/minimum voltage<br>Global parameters (series/parallel, $C_O$ value)<br>Plotter parameters (plot, grid, line, etc.)<br>IEEE output parameters (O, G, B, Y, K)<br>IEEE input parameters (L, C, H, K, M)<br>Cable correction parameters<br>Translator user name list<br>Not used<br>Translator reserved word list<br>Translator NEW/OLD state<br>Translator user translation list<br>Not used | 4.9.15 |



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## Table 4-9. Device-Dependent Command Summary (Cont.)

| Mode | Command | Description | Paragraph |
|---|---|---|---|
| SRQ (M) | M0 | Disabled | 4.9.16 |
| | M1 | Reading overflow | |
| | M2 | Module input overload | |
| | M4 | Sweep done | |
| | M8 | Reading done | |
| | M16 | Ready | |
| | M32 | Error | |
| | M128 | IEEE output done | |
| Save/Recall (L) | L0,n | Recall configuration n (0≤n≤7) | 4.9.17 |
| | L1,n | Save configuration n (0≤n≤6) | |
| Cable Parameters (I) | I0 | Measure cable parameters (driving point) | 4.9.18 |
| | I1, n1, n2, n3, n4 | Assign cable parameters K0(n1+jn2), K1(n3+jn4) | |
| | I2, n1, n2, n3, n4, n5, n6, n7, n8 | Assign test OUTPUT cable parameters: A(n1+jn2), B(n3+jn4), C(n5+jn6), D(n7+jn8) | |
| | I3, n1, n2, n3, n4 n5, n6, n7, n8 | Assign test INPUT cable parameters: A(n1+jn2), B(n3+jn4), C(n5+jn6) D(n7+jn8) | |
| | I4 | Zero cable open | |
| | I5, C, G | Measure source parameters, step 1 | |
| | I6, C, G | Measure source parameters, step 2 | |
| Save/Recall Cable Setups (C) | C0,n | Recall cable #n (0≤n≤7) | 4.9.19 |
| | C1,n | Save cable #n (0≤n≤6 | |
| Calibration (Q) | Q0 | Drift correction NORMAL MODE | 4.9.20 |
| | Q1 | Offsets | |
| | Q2, C, G | First capacitance cal point | |
| | Q3, C, G | Second capacitance cal point | |
| | Q4, C, G | Conductance cal point DRIVING POINT MODE | |
| | Q5 | Offsets | |
| | Q6, C, G | First capacitance cal point | |
| | Q7, C, G | Second capacitance cal point | |
| | Q8 | Voltage calibration offsets | |
| | Q9, V | Calibrate voltmeter gain | |
| Terminator (Y) | Y0 | <CR><LF> | 4.9.21 |
| | Y1 | <LF><CR> | |
| | Y2 | <CR> | |
| | Y3 | <LF> | |
| EOI and Hold-off (K) | K0 | EOI and hold-off enabled | 4.9.22 |
| | K1 | EOI disabled, hold-off enabled | |
| | K2 | EOI enabled, hold-off disabled | |
| | K3 | EOI and hold-off disabled | |
| Display (D) | Daaa | Display ASCII characters aa (20 max) | 4.9.23 |
| | DX | Return display to normal | |



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## Table 4-9. Device-Dependent Command Summary (Cont.)

| Mode | Command | Description | Paragraph |
|---|---|---|---|
| Hit Button (H) | | Emulate button press: | 4.9.24 |
| | H12 | SHIFT | |
| | H15 | ENTER | |
| | H16 | (A→B) | |
| | H20 | ON | |
| | H23 | MANUAL | |
| | H25 | ZERO | |
| | H26 | CAL | |
| | H27 | FILTER | |
| | H29 | RANGE | |
| | H30 | FREQ | |
| | H31 | MODEL | |
| Self Test (J) | J1 | Perform self test | 4.9.25 |



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## Table 4-10. Command Cross Reference in Alphabetical Order

| Command Letter | Description | Paragraph |
|---|---|---|
| A | Plotter | 4.9.12 |
| B | Buffer | 4.9.11 |
| C | Cable Parameters | 4.9.19 |
| D | Display | 4.9.23 |
| F | Frequency | 4.9.2 |
| G | Data Format | 4.9.9 |
| H | Hit Button | 4.9.24 |
| I | Input Cable Parameters | 4.9.18 |
| J | Self Test | 4.9.24 |
| K | EOI and Hold-off | 4.9.22 |
| L | Save/Recall Configuration | 4.9.17 |
| M | SRQ | 4.9.16 |
| N | Bias Control | 4.9.8 |
| O | Operation and Model | 4.9.10 |
| P | Filter | 4.9.14 |
| Q | Calibration | 4.9.20 |
| R | Range | 4.9.3 |
| S | Reading Rate | 4.9.4 |
| T | Trigger Mode and Source | 4.9.5 |
| U | Status | 4.9.15 |
| V | Bias Voltages | 4.9.6 |
| W | Waveform and Times | 4.9.7 |
| X | Execute | 4.9.1 |
| Y | Terminator | 4.9.21 |
| Z | Zero | 4.9.13 |



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## 4.9.1 Execute (X)

**Purpose** To execute other device-dependent commands.

**Format** <command>X

**Parameters** None

**Description** The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 590 to execute other device-dependent commands. Generally, the execute character will be the last byte in the command string; however, there may be some cases when it is desirable to send a string of characters at one time and then send the execute character later on.

**Programming Notes**

1. Commands or command strings sent without the X character will not be executed at that time, but they will be stored in an internal command buffer for later execution once the X character is finally received.
2. The command buffer can hold a total of 128 characters. The instrument stores only the last 128 characters received.
3. The X character can also be used to trigger readings or sweeps, as described in paragraph 4.9.5.
4. Commands are not necessarily executed in the order sent (see Table 4-8). In order to force a particular command sequence, the X character should be included after each command in the command string.

**Programming Examples**

```
10 OUTPUT 715; ''R1X''      ! Execute single command.
20 OUTPUT 715; ''F0R2X''    ! Execute multiple command string.
30 OUTPUT 715; ''F0XR0X''   ! Force command sequence.
40 OUTPUT 715; ''G2Y1S2''   ! Send string without execute.
50 OUTPUT 715; ''X''        ! Now execute command string at a later time.
```



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## 4.9.2 Frequency (F)

**Purpose** To program 100kHz or 1MHz test frequency.

**Format** **Fn**

**Parameters**
F0 Select 100kHz test frequency.
F1 Program 1MHz test frequency.
F2 Disconnect test signal from jacks

**Description** The F command performs the functions of the front panel FREQ key by selecting the appropriate CV module, or disconnecting the test and bias voltages from the front panel test jacks.

**Default** Power-up/DCL/SDC Configuration: Determined by save 0 position. Factory default is 100kHz (two module units).

**Programming Notes**
1. The appropriate modules must be installed to select the corresponding frequency. If you send a function command for a module that is not installed, the instrument will display an IDDCO error message. The unit can also be programmed to generate an SRQ under these conditions, as described in paragraph 4.9.16.
2. Cable correction should be used when measuring through cables at 1MHz. See paragraphs 3.21 and 4.11 for detailed information on cable correction methods.
3. The 1MHz test frequency cannot be programmed with the X10 attentuator enabled. The Model 590 will generate an IDDCO error under these conditions.
4. Programming the frequency will abort the sweep and clear the A/D buffer.
5. Cable correction, calibration, or drift correction cannot be performed in disconnect (F2) mode. The unit will generate a CONFLICT error.
6. Data will not be stored or be made available while in disconnect. Also, the first trigger will be ignored, but the subsequent triggers will cause a trigger overrun.

**Programming Examples**

```
10 OUTPUT 715; ''F0X''      ! Select 100kHz test frequency.
20 OUTPUT 715; ''F1X''      ! Select 1MHz test frequency.
30 OUTPUT 715; ''F2X''      ! Diconnect test signal from jacks.
```



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## 4.9.3 Range (R)

**Purpose**

To manually select ranges, control autoranging, or enable the X10 attenuator, depending on the range parameter.

**Format**

**Rn**

**Parameters**

| | 100kHz | 1MHz |
|---|---|---|
| R0 | Autorange on | Autorange on |
| R1 | 2pF/2μS | 20pF/200μS |
| R2 | 20pF/20μS | 20pF/200μS |
| R3 | 200pF/200μS | 200pF/2mS |
| R4 | 2nF/2mS | 2nF/20mS |
| R5 | 20pF/20μS X10 On | Error |
| R6 | 200pF/200μS X10 On | Error |
| R7 | 2nF/2mS X10 On | Error |
| R8 | 20nF/20mS X10 On | Error |
| R9 | Autorange off, stay on range | Autorange off, stay on range |

**Description**

The range (R) command and its parameters give you control over auto and manual ranging, as well as the X10 attenuator. In effect, the various options of the range command perform the same functions as the front panel RANGE button.

**Default**

Power-up/DCL/SDC Configuration: Determined by save 0 position. Factory default is the 2nF (R4) range.

**Programming Notes**

1. For best accuracy and resolution, use the most sensitive range possible without overranging the instrument.
2. The instrument can be programmed to generate an SRQ under module saturation or overflow conditions.
3. Since capacitance and conductance readings are paired together, it may be necessary to measure either capacitance and conductance on a less than optimum range.
4. The Model 5904 Input Adapter must be connected to the instrument in order to properly use a X10 range. A X10 range is available only when measuring at 100kHz, and only the 20nF/20mS range accuracy is specified.
5. Autoranging should not be used when programming rapidly-changing bias waveforms.
6. An IDDCO error will occur if you attempt to enable the X10 attenuator with a test frequency of 1MHz selected.
7. Programming the range will abort a sweep and clear the A/D buffer.
8. Autoranging cannot be used at the 75 and 1,000 per second reading rates. Programming this combination will end in an IDDCO error.

**Programming Examples**

```
10 OUTPUT 715; "R0X" ! Enable autoranging.
20 OUTPUT 715; "R9X" ! Disable autoranging.
30 OUTPUT 715; "R1X" ! Select 2pF range.
40 OUTPUT 715; "R4X" ! Select 2nF range.
50 OUTPUT 715; "R8X" ! Select 20nF range, with X10 attenuator.
```



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## 4.9.4 Reading Rate (S)

**Purpose** To select the reading rate, display resolution, and digital filtering.

**Format** **Sn**

**Parameters**

| | Nominal Rdg/Sec | Digits | Integration Period | Integrations Averaged | Readings | Actual Reading Interval (msec) |
|---|---|---|---|---|---|---|
| S0 | 1000 | 3½ | 120μsec | 1 | C only | 1.024 |
| S1 | 75 | 3½ | 240μsec | 1 | C,G,V | 13.31 |
| S2 | 18 | 4½ | 980μsec | 1 | C,G,V | 55.5 |
| S3 | 10 | 4½ | 2.4msec | 2 | C,G,V | 102.3 |
| S4 | 1 | 4½ | 16.7msec | 4 | C,G,V | 1.024 |

**Description** The reading rate command and its options perform the same functions as the front panel RATE key and allow selection of the desired rate, display resolution, and the amount of digital filtering. The rate command also controls the integration period. Note that the actual rates are some what slower than normal because of the way the instrument generates its time base.

**Default** Power-up/DCL/SDC Configuration: Determined by the save 0 position. Factory default is 10 readings per second (S3).

**Programming Notes**

1. Data will be made available only after a sweep is completed and readings are calculated at the 75 and 1000 reading per second rates. In the one shot trigger mode, the unit must receive sufficient triggers to complete the sweep before the buffer contains relevant data.
2. Only capacitance readings are taken at the 1000 reading per second rate.
3. For minimum reading noise, select the slowest reading rate possible.
4. The 18 reading per second rate is not available from the front panel.
5. The time interval between readings in a sweep is determined both by the reading rate and the programmed step time.
6. Programming the reading rate will abort the sweep and clear the A/D buffer.
7. Autoranging cannot be used at the 75 and 1,000/sec rates.

**Programming Examples**

```
10 OUTPUT 715; ''S0X'' ! Select 1000/second rate.
20 OUTPUT 715; ''S1X'' ! Select  75/second rate.
30 OUTPUT 715; ''S2X'' ! Program 18/second rate.
40 OUTPUT 715; ''S3X'' ! Program 10/second rate.
```



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## 4.9.5 Trigger (T)

**Purpose** To select the trigger source and mode.

**Format** **Tsource,mode**

**Parameters**
T0,0 One-shot on talk
T0,1 Sweep on talk
T1,0 One-shot on GET
T1,1 Sweep on GET
T2,0 One-shot on X
T2,1 Sweep on X
T3,0 One-shot on external trigger pulse
T3,1 Sweep on external trigger pulse
T4,0 One-shot on front panel (MANUAL) trigger
T4,1 Sweep on front panel (MANUAL) trigger

**Description** The trigger mode commands perform similar functions as the front panel MODE/SOURCE key in that both the trigger mode and trigger source are programmed with a single command letter.

Trigger modes include one-shot (take one reading per trigger) and single-sweep (perform one reading sweep per trigger stimulus). Trigger sources include IEEE-488 command triggers (X, GET, or talk commands), as well as an appropriate trigger pulse applied to the rear panel TRIGGER INPUT jack, and the front panel MANUAL button.

**Default** Power-up/DCL/SDC Configuration: Determined by save 0 position. Factory default is sweep on front panel (T4,1).

**Programming Notes**
1. Front panel triggering with the MANUAL button is always enabled regardless of the programmed trigger source; however, all front panel buttons will be locked out if the unit is in remote (REMOTE on). To restore local operation in this case, press the LOCAL key.
2. Re-triggering the unit while it is processing a reading sweep will create a trigger overrun situation, but the present sweep will not be aborted. The instrument will display the following message under a trigger overrun condition:

   TRIG-OVERRUN

   The overrun condition will not occur if the unit is triggered during the stop time.
3. The X character sent when programming a trigger on X mode will trigger the instrument.
4. In order to trigger the instrument when using the trigger on talk mode, you must send the talk command derived from the correct primary address. The factory default primary address is 15.
5. Re-programming the trigger source or mode will abort an active sweep and clear the A/D buffer.
6. In order to ensure rapid response to a new trigger after a sweep, re-program the trigger mode in order to halt the A/D converter.

**Programming Examples**

```
10 OUTPUT 715; "T0,0X" ! Program one-shot on talk mode.
20 SEND 7; TALK 15     ! Trigger one reading.
30 OUTPUT 715; "T1,1X" ! Program sweep on GET mode.
40 TRIGGER 715         ! Trigger reading sweep.
50 OUTPUT 715; "T2,0X" ! Program and trigger reading on X.
```



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## 4.9.6 Bias Voltage Parameters (V)

**Purpose**

To program the first, last, step, and default voltage values and count parameter associated with the bias waveform.

**Format**

**V(first)(,last)(,step)(,default)(,count)**

**Parameters**

first= First bias voltage (−20.000 to +20.000V)
last= Last bias voltage (−20.000 to +20.000V)
step= Bias step voltage (−20.000 to +20.000V)
default= Default bias voltage (−20.000 to +20.000V)
count= Number of readings per sweep for DC and external waveforms.
$1 \leq$ count $\leq$ 450 (1,350 at 1,000/sec rate).

**Description**

The V command and its options program the first and last bias voltages, and the step and default bias voltage values. Thus, this command performs many of the same functions as the front panel PARAMETER key. Four of the parameters are assumed to be in voltage units and may be entered as integer or floating point values. For example, the following parameter values would be equivalent:

12 1.2E1 .12E2

The final (count) parameter allows you to program the number of readings per sweep for the DC and external bias waveforms only. The allowable range for this parameter is 1 to 450 (1,350 at 1,000/sec rate).

**Default**

Power-On/DCL/SDC Configuration: Determined by the save 0 position. Factory default values are:

First bias: 0V
Last bias: 0V
Step bias: 0V
Default bias: 0V
Count = 450

**Programming Notes**

1. Complete definitions for the bias waveform types as well as the various parameters may be found in paragraph 3.14.
2. Note that all parameters are NOT used with every waveform type. Table 4-11 summarizes parameters associated with each waveform.
3. The resolution of all voltage parameters is 5mV.
4. Programming bias voltage parameters will abort a sweep and clear the A/D buffer.
5. Programming invalid parameters will result in an IDDCO error.



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## Table 4-11. Bias Voltage Parameter Summary

| Description | Limits** | Resolution* | DC | Single Staircase | Dual Staircase | Pulse | External |
|---|---|---|---|---|---|---|---|
| Start time | 1msec to 65sec | 1msec | X | X | X | X | X |
| Stop time | 1msec to 65sec | 1msec | X | X | X | X | X |
| Step time | 1msec to 65sec | 1msec | X | X | X | X | X |
| First bias voltage | −20V to +20V | 5mV | X | X | X | X | |
| Last bias voltage | −20V to +20V | 5mV | | X | X | X | |
| Step voltage | −20V to +20V | 5mV | | X | X | X | |
| Default bias voltage | −20V to +20V | 5mV | X | X | X | X | |
| Count | 1 to 450 (1,350 at 1,000/sec rate) | | X | | | | X |

*Voltage parameters can be programmed in 1mV steps, but will be set to 5mV steps.
**Multiply programmed times by 1.024 to obtain actual times.

NOTE: X indicates parameter applies to a particular waveform.

### Programming Examples

```
10 OUTPUT 715; ''V-5,5,0.2,3X'' ! Program −5V first bias, 5V last bias,
                                   0.2 step bias, 3V default bias.
20 OUTPUT 715; ''V-1,2,0.1,1X'' ! −1V first voltage, 2V last voltage, 0.1V
                                   step voltage, 1V default voltage.
```



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## 4.9.7 Waveform Type and Time (W)

**Purpose** To program the bias waveform type, start, stop and step times.

**Format** **W(waveform)(,start)(,stop)(,step)**

**Parameters** Waveform:

| | |
|---|---|
| 0 = DC | 3 = Pulse |
| 1= Single staircase | 4 = External bias source (200V range) |
| 2 = Dual staircase | 5 = External bias source (20V range) |

start= Start time (0.001 to 65.000sec)
stop= Stop time (0.001 to 65.000sec)
step= Step time (0.001 to 65.000sec)

**Default** Power-up/DCL/SDC Configuration: Determined by the save 0 position. Factory default values are:

Waveform type: DC
Start time: 1msec.
Stop time: 1msec.
Step time: 1msec

**Description** The W command and its parameters program the waveform type as well as three aspects of the programmed bias waveform: start time, stop time, and step time. Thus, this command programs the same functions as the WAVEFORM key and the timing aspects of the front panel BIAS PARAMETER key.

**Programming Notes**

1. Note that all parameters are not necessary with every bias waveform type. Table 4-11 summarizes required time parameters for various waveforms.
2. Bias waveforms are defined in detail in paragraph 3.14.
3. An actual waveform unit is 1.024msec because of the way the unit generates its time base. Thus, the actual time units you program should be multiplied by 1.024. For example, if you program a 3sec time period, the actual time will be 3.072sec.
4. Programming a waveform parameter will abort an active sweep and clear the A/D buffer.
5. Programming an invalid parameter will result in an IDDCO error.
6. Up to ±200V may be applied when W4 external bias is selected (±20V is W5 external bias mode.)
7. The minimum stop time with the pulse waveform is 50msec (10/sec rate).

**Programming Examples**

```
10 OUTPUT 715; ''W1,10E-3,50E-3,2X'' ! Program single staircase,
                                       10msec start time, 50msec stop
                                       time, 2sec step time.
20 OUTPUT 715; ''W2,2.5,25E-3,1X''    ! Program dual staircase, 2.5sec
                                       start time, 25msec stop time,
                                       1sec step time.
30 OUTPUT 715; ''W4,0.1,100E-3,5X''   ! Program 200V external bias,
                                       0.1sec start time, 100msec
                                       stop time, 5sec stop time.
```



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## 4.9.8 Bias Source Control (N)

**Purpose** To turn the bias source on or off.

**Format** **Nn**

**Parameters** N0 Bias source off
N1 Bias source on

**Default** Power-up/DCL/SDC Configuration: Determined by the save 0 position. The default configuration is N0 (bias source off).

**Description** The N command performs the functions of the front panel BIAS ON key in that it turns the selected internal or external bias source on or off. The selected and programmed bias values are applied to the circuit under test through the OUTPUT jack on the front panel.

**Programming Notes**

1. Internal or external bias source selection is programmed with the W command, as discussed in paragraph 4.9.7. Bias voltage parameters are programmed with the V command, as discussed in paragraph 4.9.6.
2. Up to 200V may be present at the OUTPUT jack if the external bias source is selected with the bias source on.
3. Turning the bias source on or off will abort a sweep and clear the A/D buffer (buffer A) of any data.

**Programming Examples**

```
10 OUTPUT 715; "N1X" ! Turn bias source on.
20 OUTPUT 715; "N0X" ! Turn bias source off.
```



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## 4.9.9 Data Format (G)

**Purpose** To control data string prefixes and suffixes, and program the number of readings transmitted per data request.

**Format** **Gn**

**Parameters**
G0 Prefix on, suffix off, one reading
G1 Prefix off, suffix off, one reading
G2 Prefix on, suffix on, one reading
G3 Prefix on, suffix off, multiple readings
G4 Prefix off, suffix off, multiple readings
G5 Prefix on, suffix on, multiple readings

**Default** Power-up/DCL/SDC Configuration: The factory default is G0 (prefix on, suffix off, one reading).

**Description** Depending on the programmed format, the ASCII data string the instrument sends will include a prefix (type of data), the reading itself in floating point format, as well as a suffix that indicates the buffer location. In G3 through G5 m readings will be sent, where m indicates the number of readings defined by the B1 or B2 command.

Figure 4-6 shows the general data format, and Table 4-12 lists examples for all six data formats.

**Table 4-12. Examples of Data Formats**

| Command | Typical Data String |
|---|---|
| G0 | NGPK +1.4567E−01 |
| G1 | +1.2446E−09 |
| G2 | ZVSM−1.7500E+01, B0051 |
| G3 | NCPK +1.9000E−12, ..., NCPK +1.8750E−12 |
| G4 | +1.1009pE−01, ..., +1.5040E−01 |
| G5 | NCSM +1.4010E−09, B0001, ..., NCSM +1.5000E−09, B0009 |



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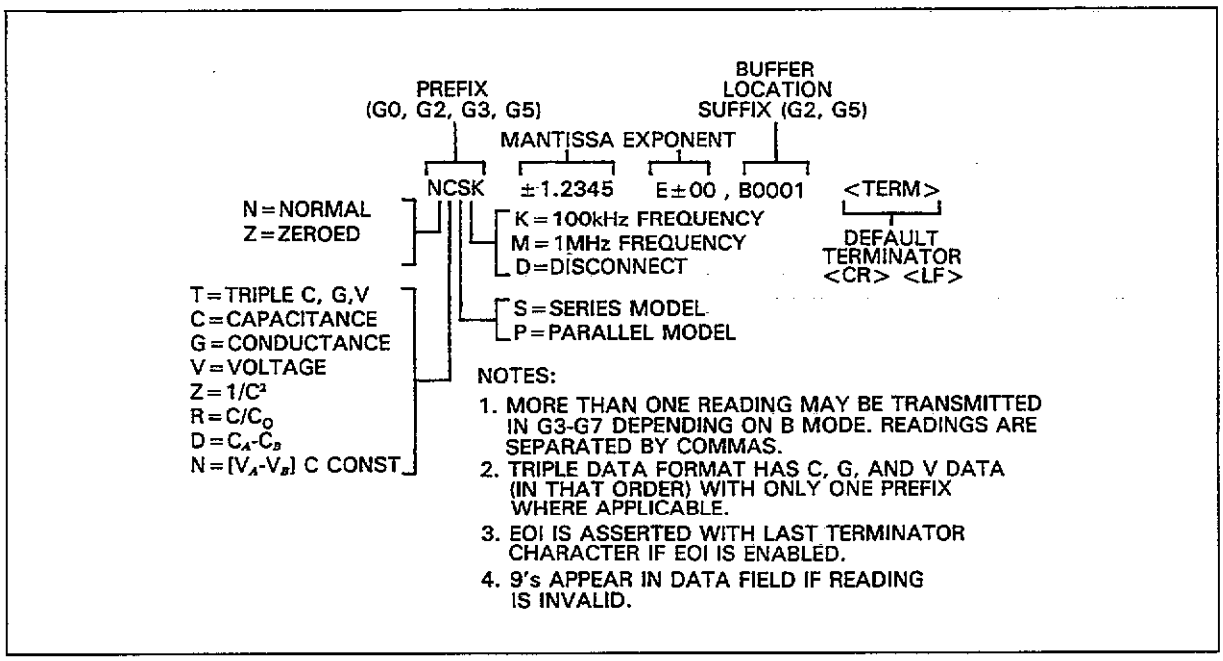



**Figure 4-6. General Data Format**

### 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 590 is addressed to talk by placing the appropriate talk command byte on the data lines.
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. Typically, the input sequence will cease when the CR LF terminator is detected. Some controllers, however, may terminate on EOI.

Generally, data is placed into a string or numeric variable. For example, a typical input sequence for the HP-85 computer is:

```
ENTER 715; A$
```

In this instance, the complete reading string is placed in the A$ variable. In cases where numeric input is required, the instrument can be operated in G1 to eliminate the prefix and suffix, and readings can be placed directly into a numeric variable as in the example below:

```
ENTER 715; A
```



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### Overflow and Invalid Reading Indications

If a particular reading or portion of a reading is overflowed, the data field for that reading will contain all 9s, as in the example below:

+9.9999E+29

Similarly, if a buffer location contains no valid data, the following will be displayed in each data field:

+9.99999999

## Programming Notes

1. EOI will be asserted (if enabled) after each reading in G0-G2, but will be asserted only at the end of the entire buffer transmission in G3-G5.
2. Buffer access must be enabled with the B command in order to obtain more than one reading in G3-G5. The number of readings sent can be controlled by options of the B command. See paragraph 4.9.11.
3. For multiple readings, the individual readings and buffer locations will be separated by commas.
4. The programmed terminator (default CR LF) will be transmitted after each reading in G0-G2, but only at the end of the transmission in G3-G5.
5. When using the 75 and 1000/sec reading rates, no data will be transmitted over the bus until a sweep and the subsequent internal processing has been completed. The instrument will hold off the bus under these conditions.

## Programming Examples

```
10 OUTPUT 715; ''G0X''  ! Program prefix on, suffix off, one reading.
20 ENTER 715; A$        ! Get a reading from the 590.
30 DISP A$              ! Display the reading.
40 OUTPUT 715; ''G1X''  ! Program prefix off, suffix off, one reading.
50 ENTER 715; A$        ! Get a reading from the 590.
60 DISP A$              ! Display the reading.
70 END                  ! End program.
```



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## 4.9.10 Operation and Model (O)

**Purpose** To select the type of capacitance, conductance, and voltage readings or mathematical functions in the data string, parallel or series model, and to program the $C_O$ value used with the $C/C_O$ math function.

**Format** **Ooutput(,model)(,$C_O$)**

**Parameters** Output:

0= Capacitance, conductance, voltage
1= Capacitance only
2= Conductance only
3= Voltage only
4= $1/C^2$
5= $C/C_O$
6= $C_A - C_B$
7= $[V_A - V_B]$ C=const

Model

0= parallel model
1= series model

$C_O$ = capacitance constant ($0 < C_O < 20E-9$)

**Description** The first parameter (output) in the O command allows you to select whether the instrument transmits complete capacitance, conductance, and voltage information or just one selected parameter individually, or allows you to apply specific mathematical operations to the data before being transmitted over the IEEE-488 bus. General data formats for these commands are shown in Figure 4-7.

The second parameter (model) controls selection of series or parallel model in the same manner as the front panel MODEL key. With parallel model, data includes parallel capacitance and conductance. In series model, data is in the form of series capacitance and resistance.

The final parameter of the O command ($C_O$) allows you to program the constant $C_O$ that is used with the $C/C_O$ mathematical function. This function is useful in generating normalized curves. Keep in mind that this programmed $C_O$ value is not used with the front panel and $C/C_O$ plotting functions, as the maximum capacitance value stored in the buffer is automatically used in those cases. A unity value will be used for the O5 command until a $C_O$ value is programmed.



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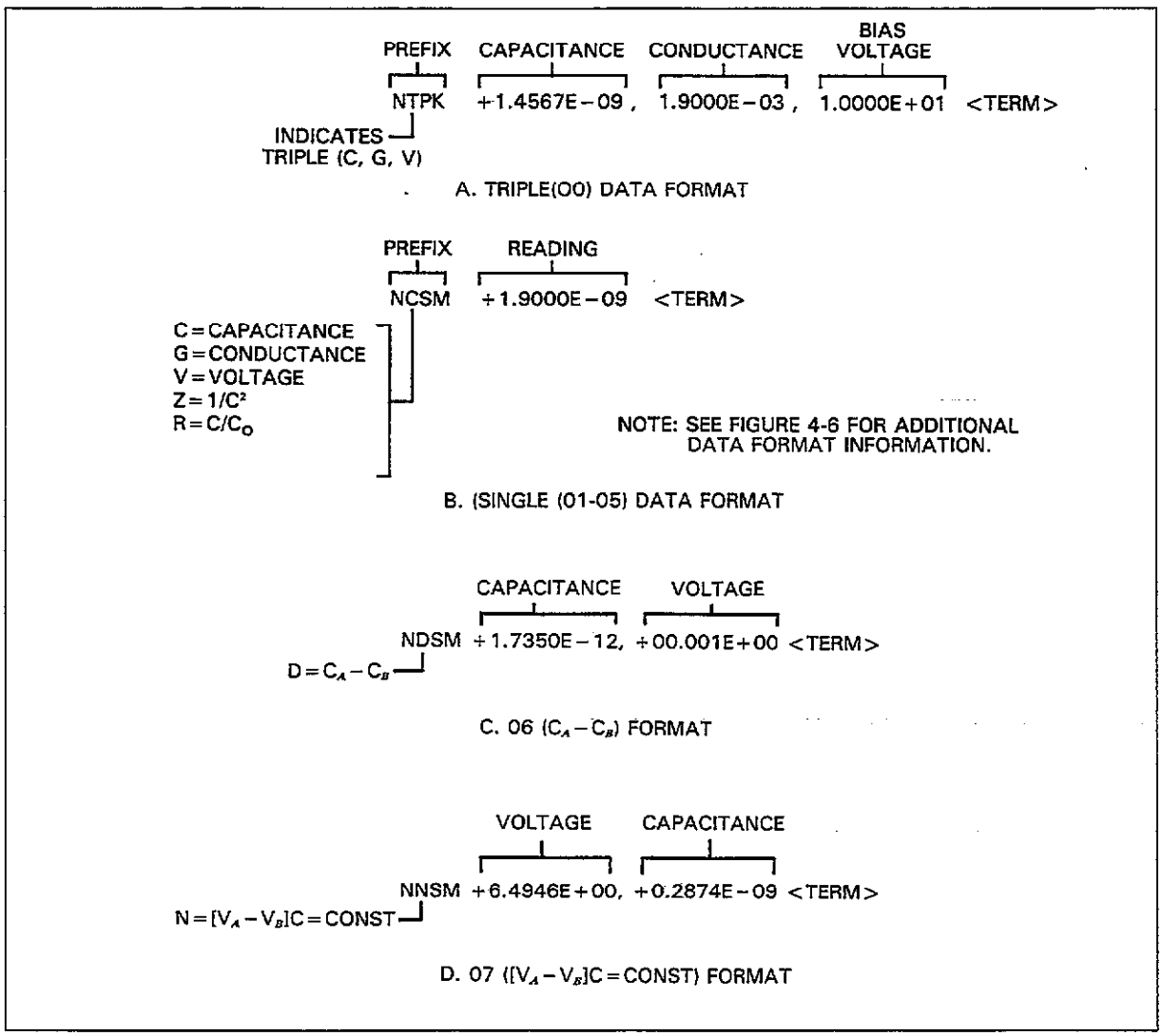



**Figure 4-7. O Command Data Formats**

**Default**

Power-up/DCL/SDC Configuration: The factory default is O0,0,0 (C,G, and V data, parallel model, $C_O$=0).

**Programming Notes**

1. The G command also affects the data format, as described in paragraph 4.9.9. The data string prefix indicates selected output and model parameters, as discussed in that paragraph.
2. The B command controls the data source; see paragraph 4.9.11.
3. Mathematical functions are covered in detail in paragraph 3.19.
4. When the unit is in one-shot, and parallel data has been acquired, it is not possible to convert data to series model by using the O command.

**Programming Examples**

```
10 OUTPUT 715; ''00,0,1.9E-12X''  ! Program C, G, V data, parallel
                                    model, 1.9pF Co value.
20 OUTPUT 715; ''01,1,2.4E-9X''   ! Program C only data, series model,
                                    2.4nF Co value.
30 OUTPUT 715; ''05X''            ! Program C/Co function only.
40 OUTPUT 715; ''03,0X''          ! Program V only, parallel model.
```



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## 4.9.11 Buffer Control (B)

**Purpose**

To select the current reading, A/D buffer, or plotter buffer as IEEE-488 output, and to transfer the contents of buffer A to buffer B.

**Format**

**Bn(,first)(,last)**

**Parameters**

| | |
|---|---|
| B0 | Current reading |
| B1,*first*,*last* | A/D buffer (buffer A), starting at location first ($1 \leq$ first $\leq 450$) ending at location last ($1 \leq$ last $\leq 450$) |
| B2,first,last | Plotter buffer (buffer B), starting at location first ($1 \leq$ first $\leq 450$), ending at location last ($1 \leq$ last $\leq 450$) |
| B3 | Transfer contents of A/D buffer to plotter buffer (A → B) |

**Default**

Power-up/DCL/SDC Configuration: Factory default is B0 (current reading).

**Description**

The B command controls the source of the data sent over the bus. With B0, the data source is the current reading, which is contained in the last reading register. For B1 and B2, two optional parameters (first and last) can be included to specify the first and last buffer locations to be accessed from the A/D and plotter buffers respectively. Finally, B3 allows you to transfer the contents of the A/D buffer (buffer A) to the plotter buffer (buffer B) in a manner similar to the A → B button on the front panel of the instrument.

**Programming Notes**

1. The A/D buffer will be empty until at least one reading sweep is triggered. All 9s will fill in invalid data fields.
2. The plotter buffer contains no relevant data unless deliberately placed there by the B3 command. Again, all 9s will fill in the data fields.
3. If first and last are not specified, buffer access will begin and end with locations 1 and 450 respectively.
4. The maximum buffer value is 1,350 at 1,000/sec rate.

**Programming Examples**

```
10 OUTPUT 715; ''B0X''          ! Select current reading.
20 OUTPUT 715; ''B1,100,200X''  ! Select readings 100 through 200 of
                                  A/D buffer.
30 OUTPUT 715; ''B2,46,99X''    ! Select readings 46 through 99 of
                                  plotter buffer.
40 OUTPUT 715; ''B3X''          ! Transfer contents of A/D buffer to
                                  plotter buffer.
```



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## 4.9.12 Plotter Control (A)

**Purpose** To select plotter parameters, generate a grid, and select the buffer to be plotted.

**Format** **An,parameter**

**Parameters**

A0 Execute plot

A1 Execute grid

A2,plot Select plot type
0= C vs V
1= G vs V (R vs V for series model)
2= $1/C^2$ vs V
3= $C/C_O$ vs V
4= C vs t (Buffer index)
5= $C_A$-$C_B$ vs V
6= $[V_A$-$V_B]C$=CONST

A3,grid Select grid type
0= Full grid
1= Axis only

A4,buffer Select buffer to plot
0= A/D buffer (buffer A)
1= Plot buffer (buffer B)

A5,pen Select pen
0= No pen
1= Pen #1
2= Pen #2

A6,line Program line type
0= Dot at points
1= Spaced dots
2= Dashes
3= Long dash
4= Dash dot
5= long dash, short dash
6= long dash, short dash, short dash
7= solid line

A7,label Select label type
0= Full labels
1= Label axis and divisions (no title block)
2= Label axis only
3= No labels

A8,n,Xmin,Xmax X axis limits
n=0: Autoscaling: Minimum and maximum buffer values
n=1: Program X axis minimum (Xmin) and maximum (Xmax) values.
$-1E29 \leq Xmin \leq 1E29$; $-1E29 \leq Xmax \leq 1E29$.



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A9,n,Ymin,Ymax Y axis limits
n=0: Autoscaling: 0 to full scale
n=1: Programmed Y axis minimum (Ymin) and maximum (Ymax) values.
$-1E29 \leq Ymin \leq 1E29$; $-1E29 \leq Ymax < 1E29$

## Default

The factory default values are indicated in Table 4-13.

**Table 4-13. Plotter Defaults**

| Plotter Parameters | Equivalent Command | Description |
|---|---|---|
| Plot type | A2, 0 | C vs V |
| Grid type | A3, 0 | Full grid |
| Buffer | A4, 0 | Buffer B |
| Pen type | A5, 1 | Pen #1 |
| Line type | A6, 7 | Solid line |
| Label type | A7, 0 | Full labels |
| X Scaling | A8, 0 | Auto scaling |
| Y Scaling | A9, 0 | Auto scaling |

## Description

The first two options of the A command allow you to execute a plot and grid respectively. The remaining options control various aspects of plot and grid generation. Note that you must include the appropriate second parameter when using the A2 through A7 commands, as indicated above.

When programming X and Y axis limits (A8 and A9), you have two options: select autoscaling (n=0), and user-defined the scaling limits (n=1). For the X axis (A8), the limits are −20 to +20 (internal bias) or −200 to +200 (external bias). The programmable Y axis limits are scaled according to the selected plotting function. For example, if plotting C vs V on the 200pF range, the upper limit is 200E−12.

## Programming Notes

1. More complete information on plotting over the bus may be found in paragraph 3.16.
2. The plotter, controller, and Model 590 must each have a different primary address when initiating a plot over the bus.
3. After sending the A0 (execute grid) or A1 (execute plot) commands, you must then address the Model 590 to talk and the plotter to listen. The Model 590 does not address the plotter when performing these functions over the bus because the unit does not implement the TCT (Take Control) command (see paragraph 3.16).
4. For autoscaling, the X axis limits are determined by the minimum and maximum voltages in the buffer. For Y axis autoscaling, the limits are 0 to full scale except for the $C_A - C_B$ function which has limits of ± full scale.
5. Only the C vs t plot type (A2, 4) can be used with data taken at the 1000/sec reading rate.
6. The selected model affects plotted data.



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## Programming Examples

```
 10 OUTPUT 715; ''A2,0X''          ! Select C vs V plot type.
 20 OUTPUT 715; ''A8,1,-10,10X''   ! Program ±10V X axis limits.
 30 OUTPUT 715; ''A9,1,100E-12,    ! Program 100pF to 150pF Y axis
    150E-12X''                       Y axis limits.
 40 OUTPUT 715; ''A5,1X''          ! Select pen #1.
 50 OUTPUT 715; ''A6,2X''          ! Select dashes only line type.
 60 OUTPUT 715; ''A7,0X''          ! Program full label type.
 70 OUTPUT 715; ''A3,1''           ! Select full grid type.
 80 OUTPUT 715; ''M128X''          ! SRQ on plotter done.
 90 OUTPUT 715; ''A0X''            ! Execute plot.
100 SEND 7; UNT UNL TALK           ! Address 590 to talk, plotter to listen.
    15 LISTEN 5
110 RESUME 7                       ! Set ATN false.
120 STATUS 7,2;S                   ! Get bus status.
130 IF NOT BIT(S,5) THEN 120       ! Wait for SRQ.
140 S=SPOLL(715)                   ! Serial poll to clear SRQ.
150 OUTPUT 715; ''A1X''            ! Execute grid.
160 SEND 7; UNT UNL TALK           ! Address 590 to talk, plotter to listen
    15 LISTEN 5
170 RESUME 7                       ! Set ATN false.
180 STATUS 7,2;S                   ! Get bus status.
190 IF NOT BIT (S,5) THEN 180      ! Wait for SRQ.
200 END
```



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## 4.9.13 Zero (Z)

**Purpose** To store a reading as a baseline value and then subtract that value from subsequent readings.

**Format** **Zn**

**Parameters** Z0 Disable zero.
Z1 Enable zero.

**Default** Power-up/DCL/SDC Configuration: Determined by save 0 position. Factory default is Z0 (zero disabled).

**Description** The Z command allows you to store a reading as a baseline value and then subtract that reading from the following readings. The first reading that occurs after zero is enabled becomes the baseline value. Subsequent readings will then be the difference between the actual measured values and the stored baseline.

**Programming Notes**

1. Zero offsets the dynamic range of the reading by the amount of the baseline.
2. The zero value is also stored in the A/D buffer header for use when accessing the buffer. This value will be used instead of the currently stored baseline when accessing buffer data.
3. Any stored baseline will be lost once zero is disabled.
4. The unit must be triggered after zeroing before baseline values are stored.

**Programming Examples**

```
10 OUTPUT 715; ''Z1X'' ! Enable zero.
20 OUTPUT 715; ''Z0X'' ! Disable zero.
```



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## 4.9.14 Filter (P)

**Purpose** To control the analog filter.

**Format** **Pn**

**Parameters** P0 Filter off
P1 Filter on

**Default** Power-up/DCL/SDC Configuration: Determined by the save 0 configuration. The factory default is P1 (filter on).

**Description** The P command controls the analog filter in similar manner as the front panel FILTER key. The filter is of the low-pass variety useful in situations where an excessive amount of noise is noted in the readings.

**Programming Notes**
1. The −3dB point of the filter is approximately 37Hz.
2. The analog filter will increase instrument response time and should not generally be used with rapidly-changing readings.

**Programming Examples**

```
10 OUTPUT 715; ''P1X'' ! Enable analog filter.
20 OUTPUT 715; ''P0X'' ! Disable analog filter.
```



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## 4.9.15 Status (U)

**Purpose** To obtain from the instrument information on errors, as well as programming status for the two buffers, IEEE input and output parameters, and plotter information.

**Format** **Un**

**Parameters**
U0 Hardware and software revision level
U1 Error information
U2 Buffer A range group
U3 Buffer A trigger group
U4 Buffer A zero group
U5 Buffer A bias group
U6 Buffer A bias voltage group
U7 Buffer A bias time group
U8 Buffer A position and time
U9 Buffer B range group
U10 Buffer B trigger group
U11 Buffer B zero group
U12 Buffer B bias group
U13 Buffer B bias voltage group
U14 Buffer B bias time group
U15 Buffer B position and time
U16 Buffer A maximum and minimum capacitance
U17 Buffer A maximum and minimum conductance
U18 Buffer A maximum and minimum voltage
U19 Buffer B maximum and minimum capacitance
U20 Buffer B maximum and minimum conductance
U21 Buffer B maximum and minimum voltage
U22 Global programming parameters (parallel/series, $C_o$ value)
U23 Plotter programming parameters
U24 IEEE output parameters (O, G, B, Y, K modes)
U25 IEEE input parameters (L, C, K, H, M)
U26 Cable correction parameters
U27-U31 Translator status (see paragraph 4.10)

**Description** By sending the appopriate U command and then addressing the instrument to talk as you would with normal data, you can obtain information on machine status, error conditions, as well as a variety of other aspects, as outlined above.

The general format of the status words is

AAA DATA DATA ... DATA <term +EOI>

Where:

AAA is a three letter prefix identifying the type of information.
DATA represents pertinent data
<term> is the programmed terminator (default CR LF)
<EOI> is also asserted if programmed
<spaces> separate the identifier and data fields.



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The specific formats for the U0 through U26 status words are shown in Figures 4-8 through 4-34. Pertinent information is also included, where applicable. Table 4-14 summarizes status word information in more concise form.

## Table 4-14. U Command Format Summary

| Command | Identifier | Mnemonic | #Datum | Datum | Format |
|---|---|---|---|---|---|
| U0 | 590 | | 1 | REV Level | HSS<br>H=hardware<br>SS=software |
| U1 | ERR | ERRor | 20 | TRIG-OVERRUN | 0/1 |
| | | | | NEED100KHz | 0/1 |
| | | | | NEED 1MHz | 0/1 |
| | | | | NOT USED | 0 |
| | | | | CAL LOCKED | 0/1 |
| | | | | CONFLICT | 0/1 |
| | | | | TRANSLATOR-ERR | 0/1 |
| | | | | NO REMOTE ERR | 0/1 |
| | | | | IDDC | 0/1 |
| | | | | IDDCO | 0/1 |
| | | | | INVALID | 0/1 |
| | | | | NOT USED | 0 |
| | | | | NOT USED | 0 |
| | | | | OVERLOAD | 0/1 |
| | | | | NOT USED | 0 |
| | | | | RESERVED | 0000 |
| U2 | ARG | AbufRangeGroup | 6 | RANGE | 0..3 |
| | | | | AUTO | 0/1 |
| | | | | X10 | 0/1 |
| | | | | RATE | 0..4 |
| | | | | FREQ | 0/1 |
| | | | | FILTER | 0/1 |
| U3 | ATG | AbufTrigGroup | 2 | TRIG MODE | 0/1 |
| | | | | TRIG SOURCE | 0..4 |
| U4 | AZG | AbufZeroGroup | 3 | OFF/ON | 0/1 |
| | | | | CONDUCTANCE | SCI-NOTATION |
| | | | | CAPACITANCE | SCI-NOTATION |
| U5 | ABG | AbufBiasGroup | 2 | OFF/ON | 0/1 |
| | | | | WAVEFORM | 0..4 |
| U6 | ABV | AbufBiasVolt | 4 | FIRST BIAS | sdd.ddd |
| | | | | LAST BIAS | sdd.ddd |
| | | | | STEP BIAS | sdd.ddd |
| | | | | DEFAULT BIAS | sdd.ddd |
| | | | | COUNT | dddd |
| U7 | ABT | AbufBiasTime | 3 | START TIME | dd.ddd |
| | | | | STOP TIME | dd.ddd |
| | | | | STEP TIME | dd.ddd |
| U8 | APT | AbufPosTime | 3 | CURRENT COUNT | dddd |
| | | | | FILLING/DONE | 0/1 |
| | | | | ELAPSED TIME | bb:mm:ss:mmm |
| U9 | BRG | BbufRangeGroup | See U2 | | |
| U10 | BTG | BbufTrigGroup | See U3 | | |
| U11 | BZG | BbufZeroGroup | See U4 | | |
| U12 | BBG | BbufBiasGroup | See U5 | | |



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## Table 4-14. U Command Format Summary (Cont.)

| Command | Identifier | Mnemonic | #Datum | Datum | Format |
|---|---|---|---|---|---|
| U13 | BBV | BbufBiasVolt | See U6 | | |
| U14 | BBT | BbufBiasTime | See U7 | | |
| U15 | BPT | BbufPosTime | See U8 | | |
| U16 | ACM | AbufCapMaximum | 2 | MAX FARAD | SCI-NOTATION |
| | | | | MIN FARAD | SCI-NOTATION |
| U17 | AGM | AbufGMaximum | 2 | MAX SIEMENS | SCI-NOTATION |
| | | | | MIN SIEMENS | SCI-NOTATION |
| U18 | AVM | AbufVoltMaximum | 2 | MAX VOLTS | SCI-NOTATION |
| | | | | MIN VOLTS | SCI-NOTATION |
| U19 | BCMG | BbufCapMaximum | See U16 | | |
| U20 | BGM | BbufGMaximum | See U17 | | |
| U21 | BVM | BbufVoltMaximum | See U18 | | |
| U22 | GPP | GlobalProgPar | 2 | PARALLEL/SERIES | 0/1 |
| | | | | Co FARADS | SCI-NOTATION |
| U23 | PPP | PlotProgPar | 6 | PLOT TYPE | 0..7 |
| | | | | GRID TYPE | 0/1 |
| | | | | Bbuf/Abuf | 0/1 |
| | | | | PEN TYPE | 0..2 |
| | | | | LINE TYPE | 0..7 |
| | | | | LABEL TYPE | 0..3 |
| | | | | X SCALE | 0/1 |
| | | | | Y SCALE | 0/1 |
| U24 | IOP | IeeeOutPar | 8 | O MODE | 0..7 |
| | | | | G MODE | 0..5 |
| | | | | B COMMAND | 0..3 |
| | | | | FIRST LOCATION | dddd |
| | | | | LAST LOCATION | dddd |
| | | | | CURRENT LOC | dddd |
| | | | | YMODE | 0..3 |
| | | | | EOI | 0/1 |
| U25 | IIP | IeeeInPar | 7 | RESTORE/SAVE | 0/1 |
| | | | | CABLE-SET# | 0..7 |
| | | | | HIT KEY# | 0 to 31 |
| | | | | HOLD-OFF | 0/1 |
| | | | | RESTORE/SAVE | 0/1 |
| | | | | FRONT-PANEL | 0..7 |
| | | | | SRQ MASK | 0 to 255 |
| U26 | CCP | CableCorrPar | 9 | MEASURE/RECEIVE | 0/1 |
| | | | 8 | CORRECTION COEFFICIENTS | SCI-NOTATION |
| U27 | UNL | UserNameList | varies | User Defined "Alias" Names | |
| U28 | FNL | Not used | | | |
| U29 | RNL | ReservNameList | 7 | LIST; ALIAS FORGET NEW OLD | |
| U30 | NEW | | 0 | | |
| | OLD | the AAA field is the information | | KEITHLEY TRANS-LATOR STATE | |
| U31 | UTL | UserTranslationList | | Send user definitions | |
| U32 | FTL | Not used | | | |



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## Programming Notes

1. The instrument will transmit the appropriate status word only once each time the corresponding U command is transmitted.
2. In order to ensure that correct status is indicated, the status word should be requested immediately after the command is transmitted.
3. The bits in the U1 word will latch and remain in that condition until the U1 word is read.
4. The programmed terminator (default CR LF) will be transmitted at the end of each status word.
5. EOI will be transmitted at the end of the status word unless disabled with the K command.
6. U27 through U31 words, which contain information about the Translator, are covered in paragraph 4.10.
7. For those status words which contain floating point data (for example the U26 word, which details cable correction constants), a positive value is assumed by a leading blank. This blank space will be filled by a minus sign when the corresponding value is negative.
8. The INVALID, CONFLICT, NEED 100kHz, and NEED 1MHz bits in the U1 word will only be set when those error conditions are caused by front panel programming. Similar bus programming errors will generate an IDDCO error (except for the I commands, which will generate a CONFLICT error).
9. An overload condition will not be indicated in those status words containing numeric data. For example, U16-U21, which contain information on maximum and minimum buffer data.

## Programming Examples

```
10  DIM A$[100]          ! Dimension input string.
20  OUTPUT 715; "U0X"    ! Program for revision status.
30  ENTER 715; A$        ! Obtain revision status.
40  DISP A$              ! Display revision status.
50  OUTPUT 715; "U1X"    ! Program for error status.
60  ENTER 715; A$        ! Obtain error status.
70  DISP A$              ! Display error status.
80  OUTPUT 715; "U4X"    ! Program for zero parameters.
90  ENTER 715; A$        ! Obtain zero parameters.
100 DISP A$              ! Display zero parameters.
```



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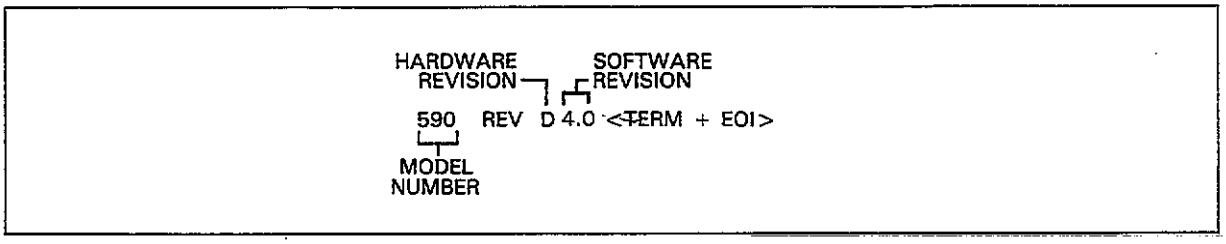



**Figure 4-8. U0 Status Word Format (Hardware/Software Revision)**

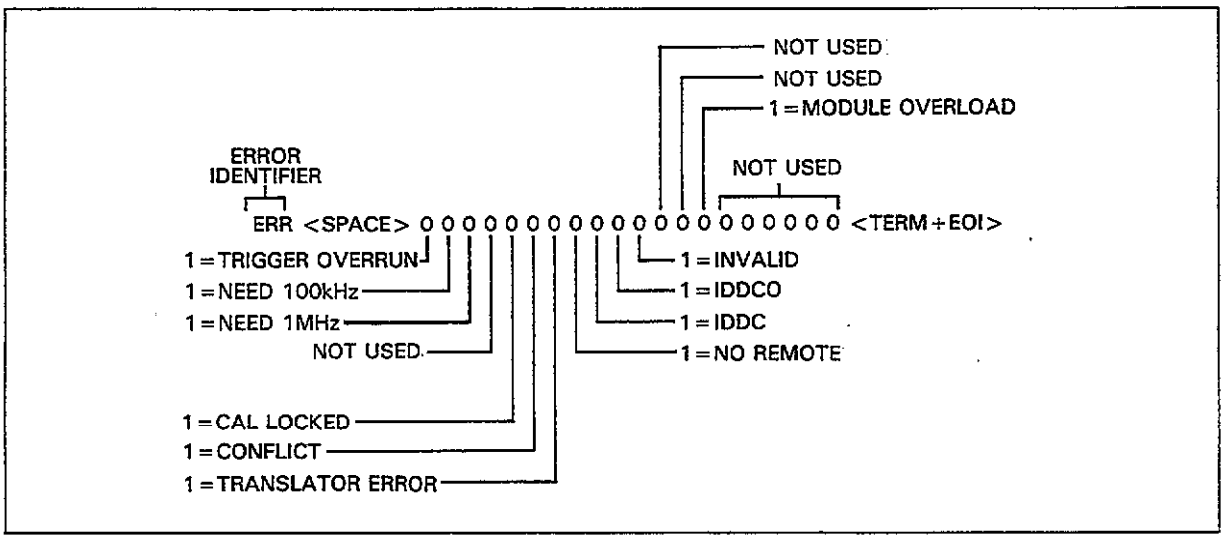



**Figure 4-9. U1 Error Status Word Format**

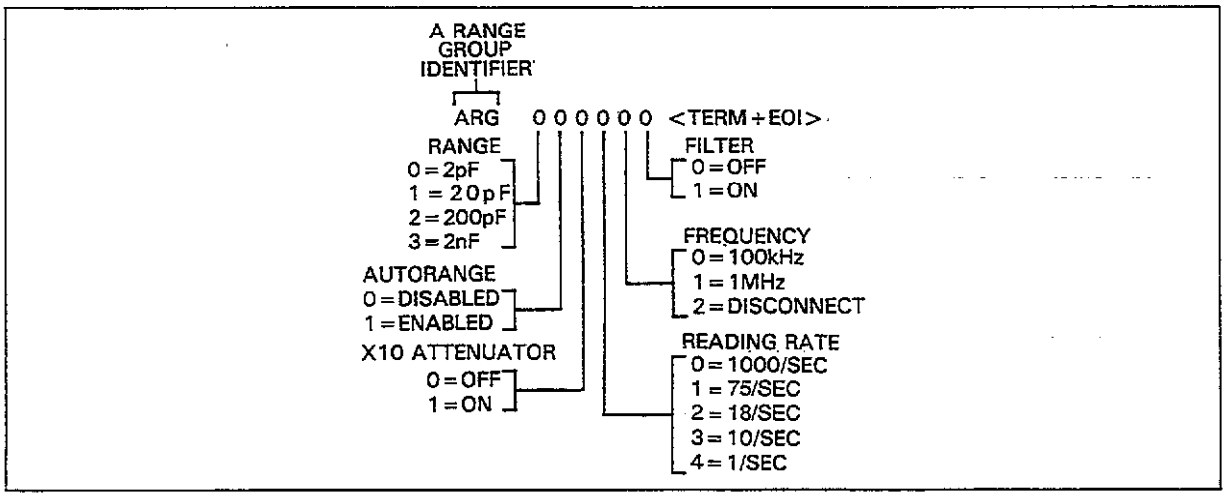



**Figure 4-10. U2 Status Word Format (Buffer A Range Group)**



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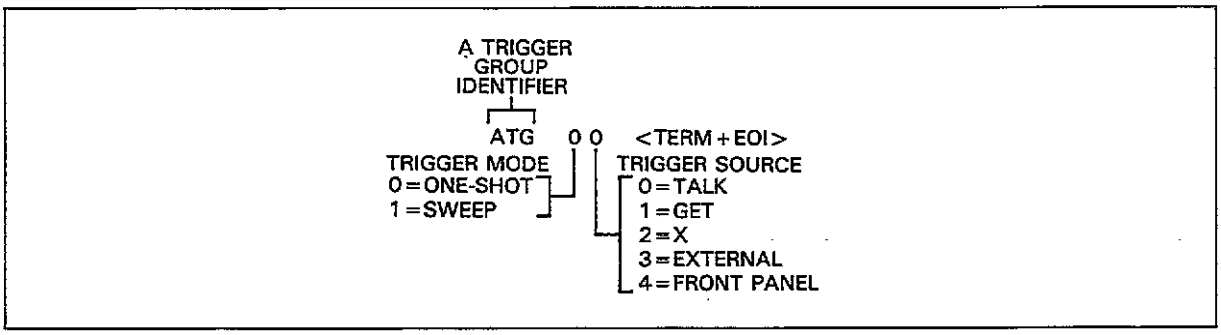



**Figure 4-11. U3 Status Word (Buffer A Trigger Group)**

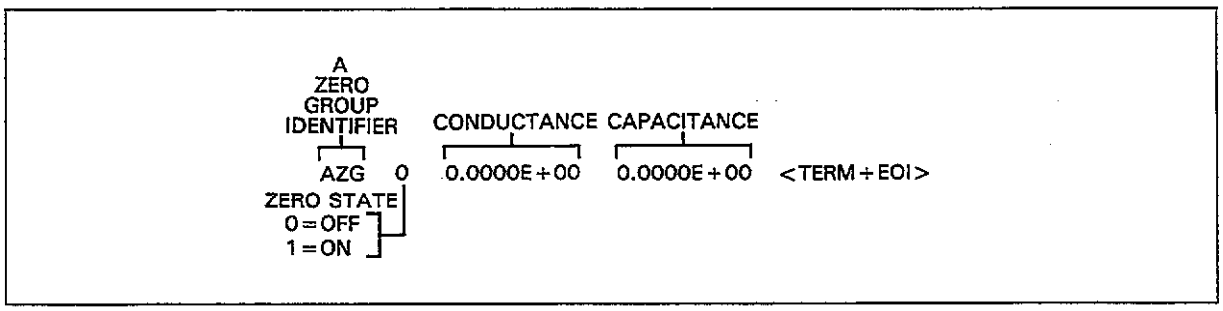



**Figure 4-12. U4 Status Word Format (Buffer A Zero Group)**

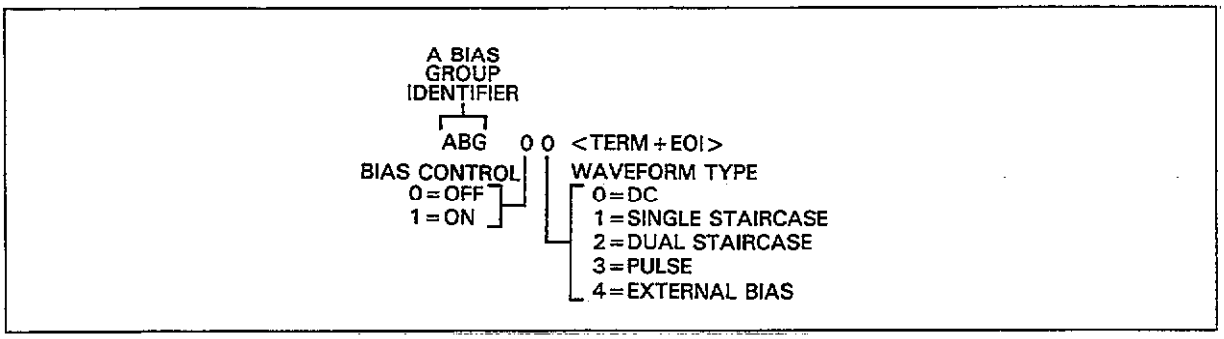



**Figure 4-13. U5 Status Word Format (Buffer A Bias Group)**

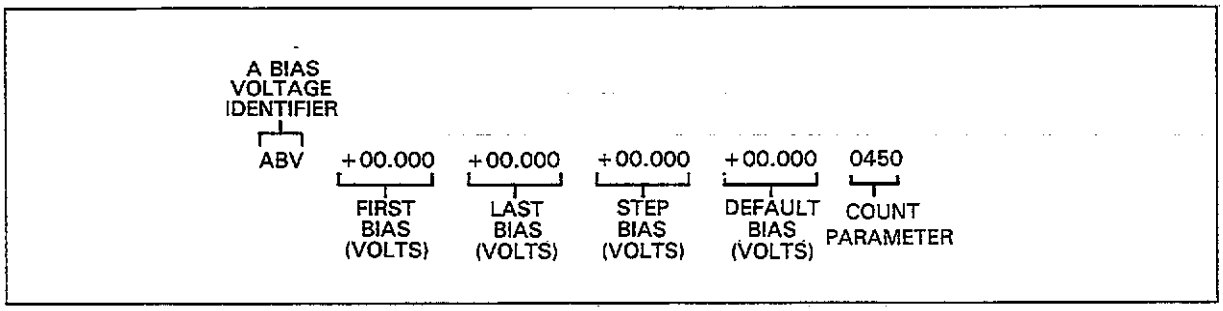



**Figure 4-14. U6 Status Word Format (Buffer A Bias Voltages)**



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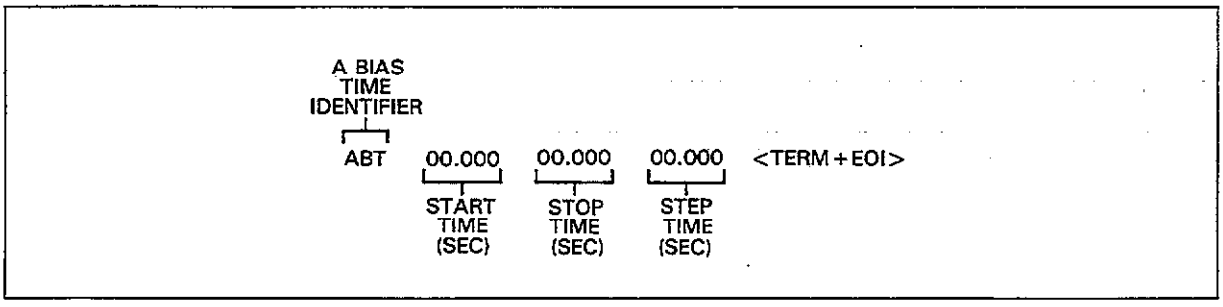



**Figure 4-15. U7 Status Word Format (Buffer A Bias Times)**

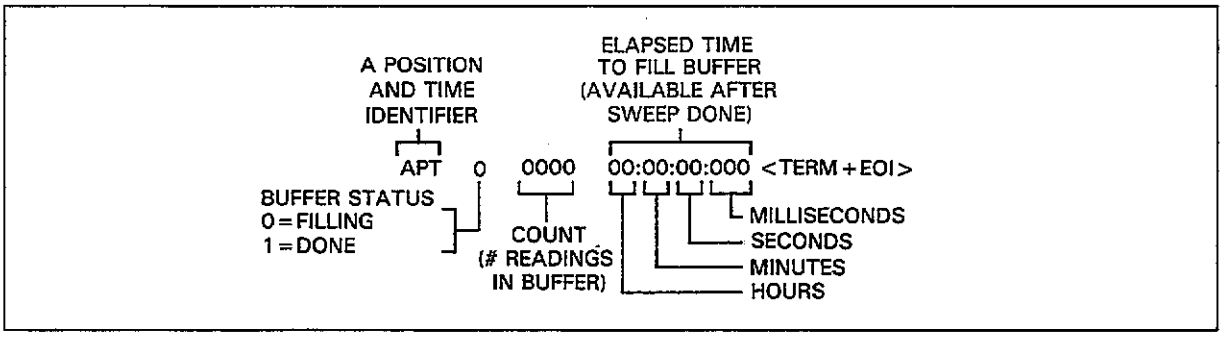



**Figure 4-16. U8 Status Word Format (Buffer A Position and Time)**

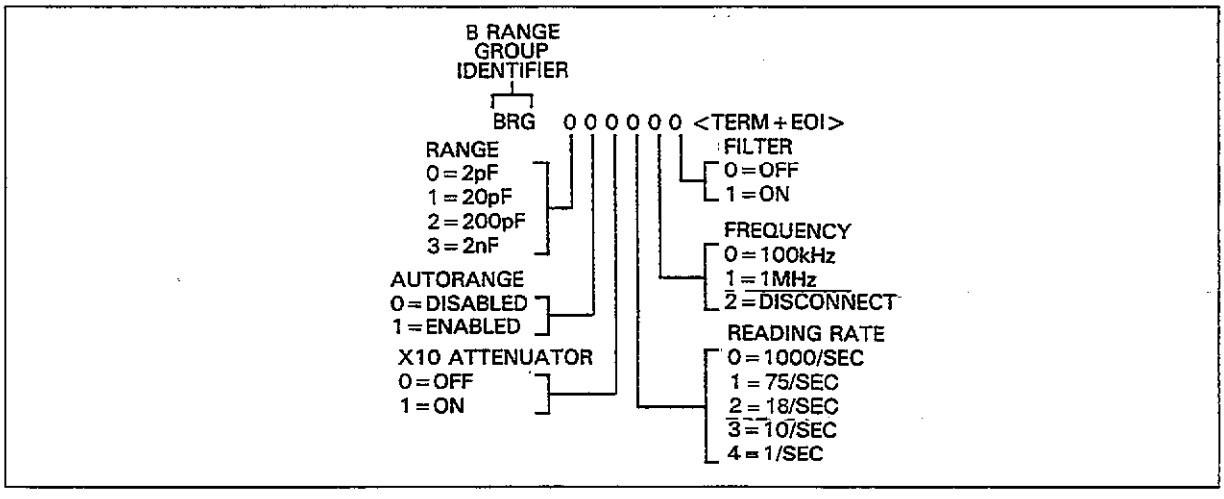



**Figure 4-17. U9 Status Word Format (Buffer B Range Group)**



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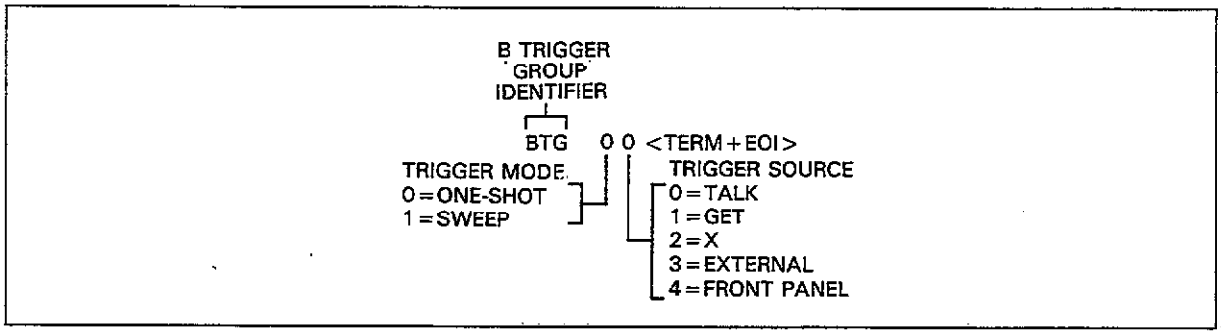



**Figure 4-18. U10 Status Word (Buffer B Trigger Group)**

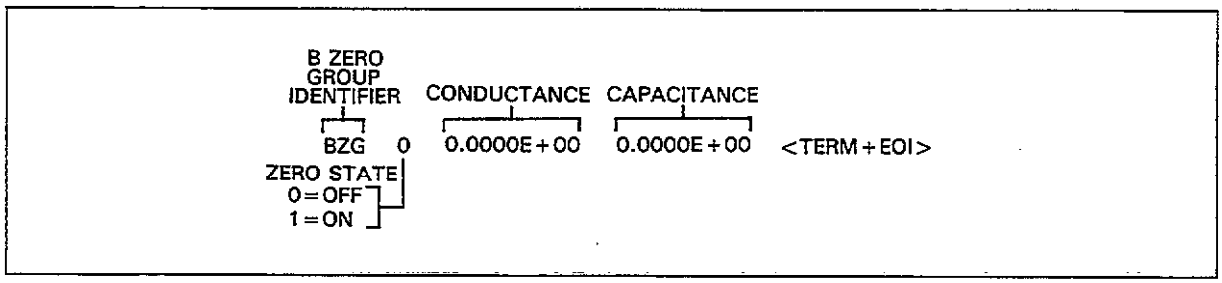



**Figure 4-19. U11 Status Word Format (Buffer B Zero Group)**

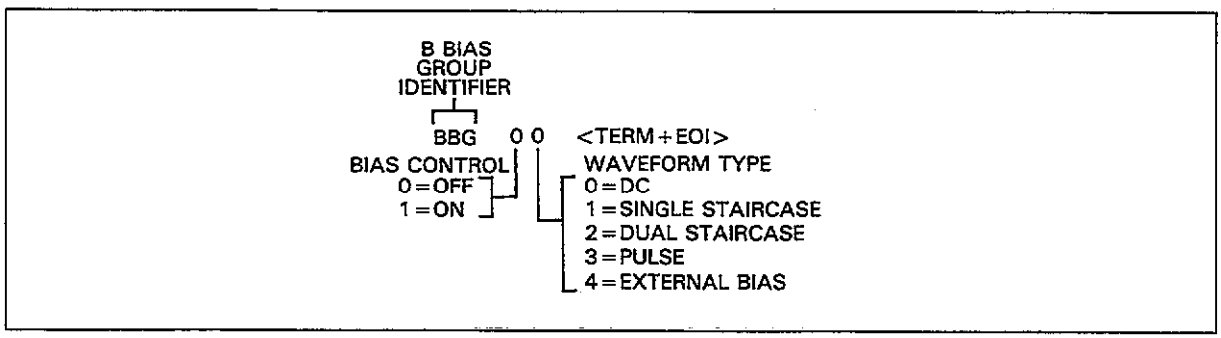



**Figure 4-20. U12 Status Word Format (Buffer B Bias Group)**

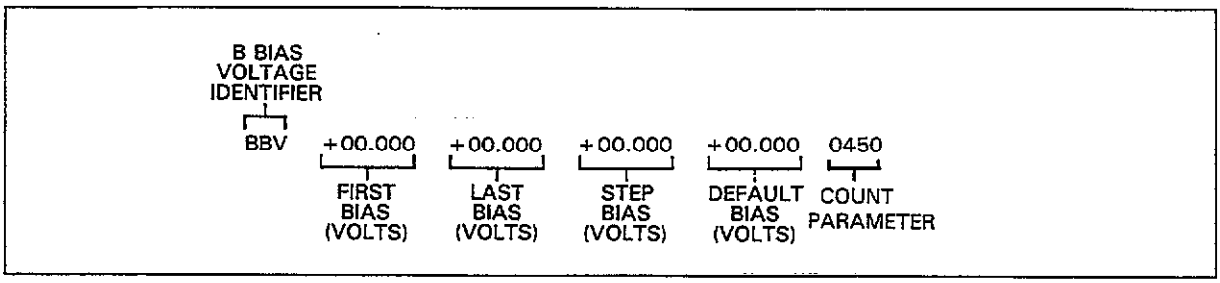



**Figure 4-21. U13 Status Word Format (Buffer B Bias Voltages)**



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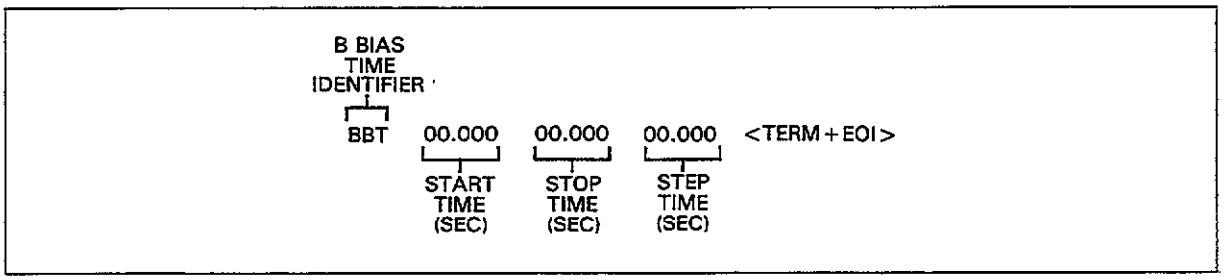



**Figure 4-22. U14 Status Word Format (Buffer B Bias Times)**

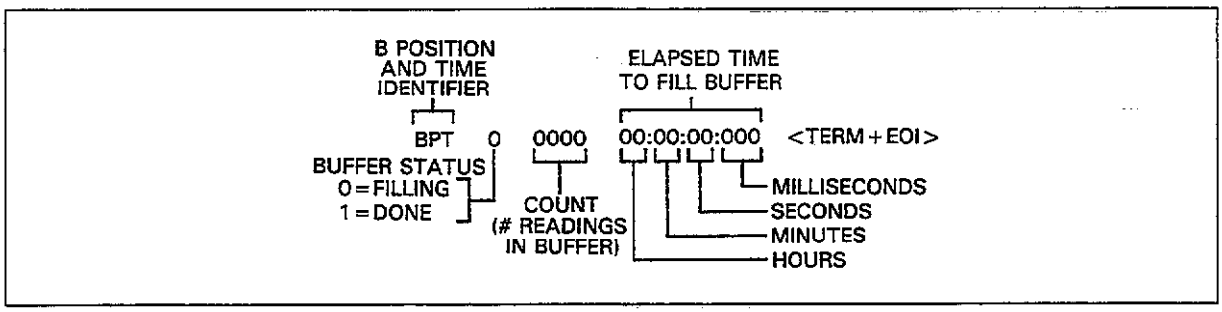



**Figure 4-23. U15 Status Word Format (Buffer B Position and Time)**

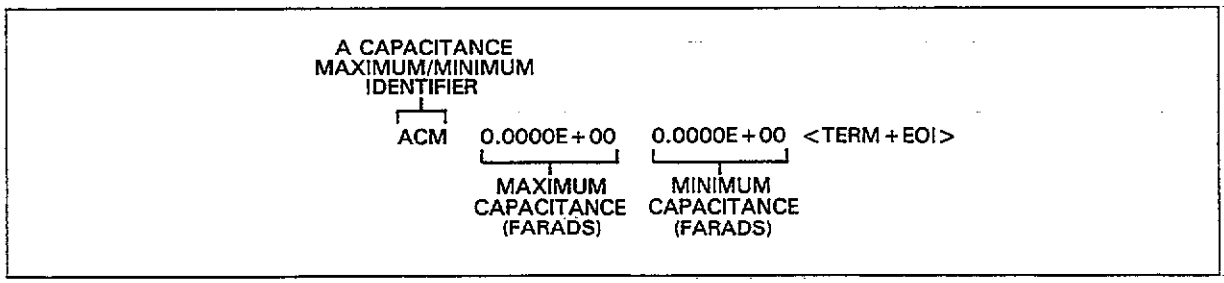



**Figure 4-24. U16 Status Word Format (Buffer A Maximum and Minimum Capacitance)**

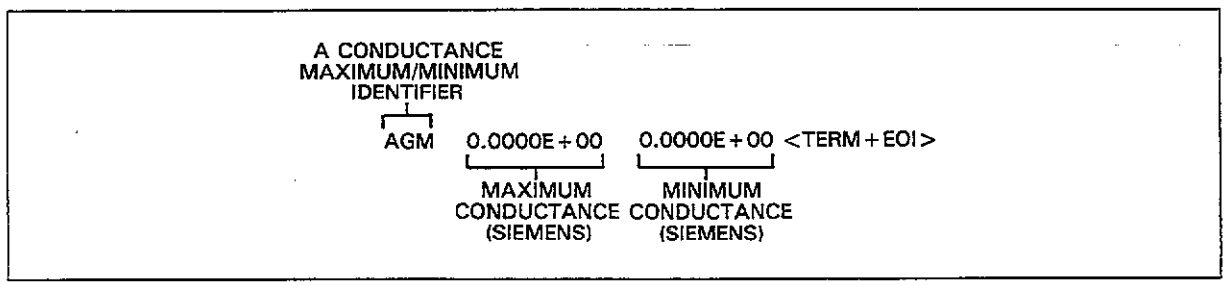



**Figure 4-25. U17 Status Word Format (Buffer A Maximum and Minimum Conductance)**



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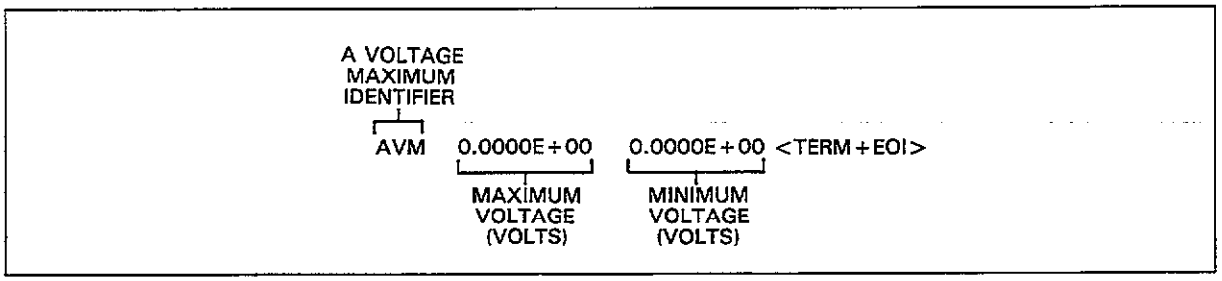



**Figure 4-26. U18 Status Word Format (Buffer A Maximum and Minimum Voltage)**

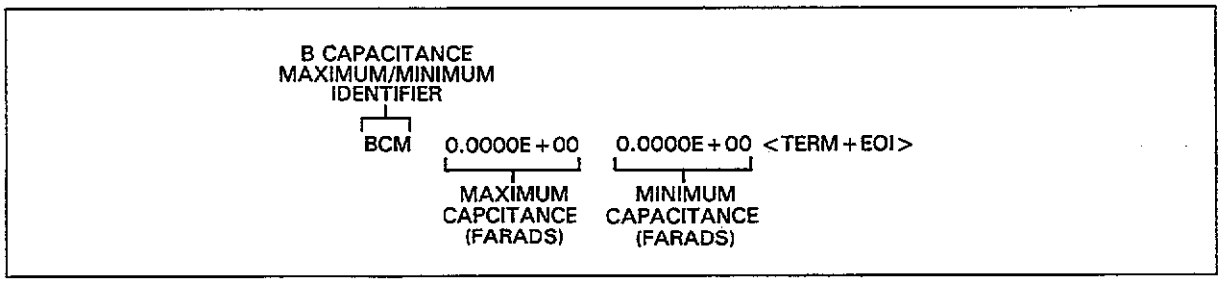



**Figure 4-27. U19 Status Word Format (Buffer B Maximum and Minimum Capacitance)**

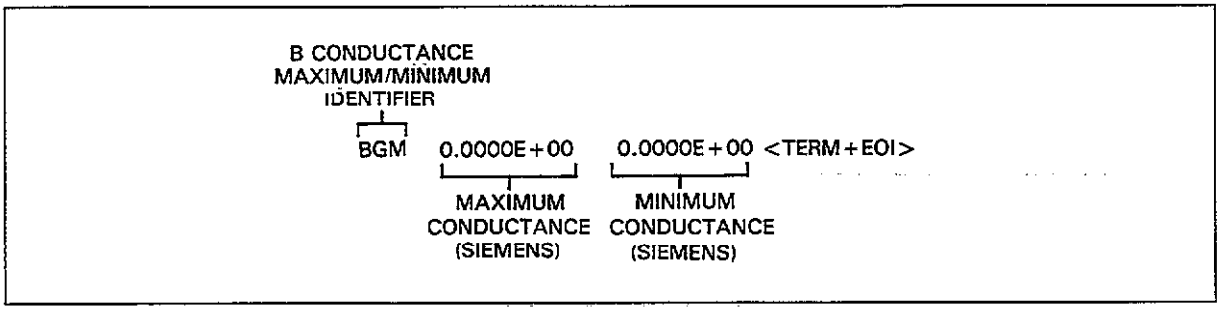



**Figure 4-28. U20 Status Word Format (Buffer B Maximum and Minimum Conductance)**

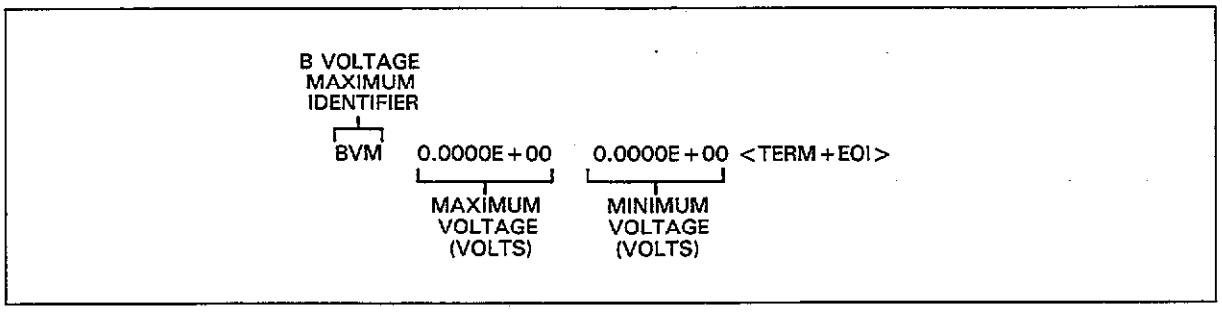



**Figure 4-29. U21 Status Word Format (Buffer B Maximum and Minimum Voltage)**



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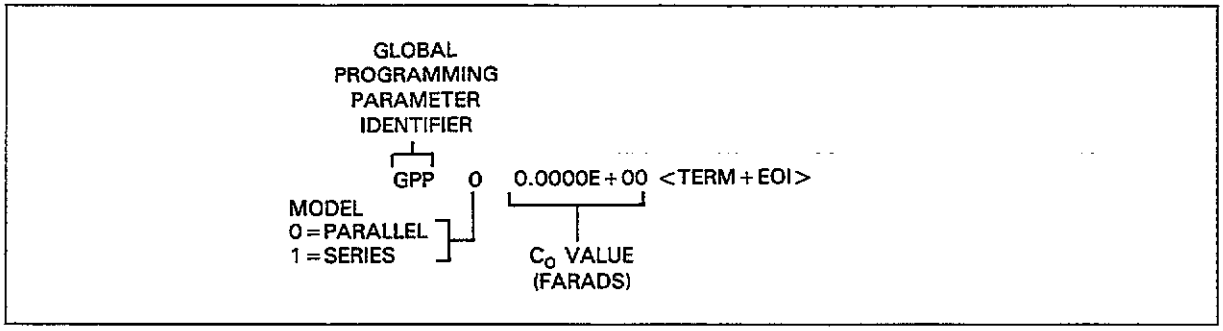



**Figure 4-30. U22 Status Word Format (Global Programming Parameters)**

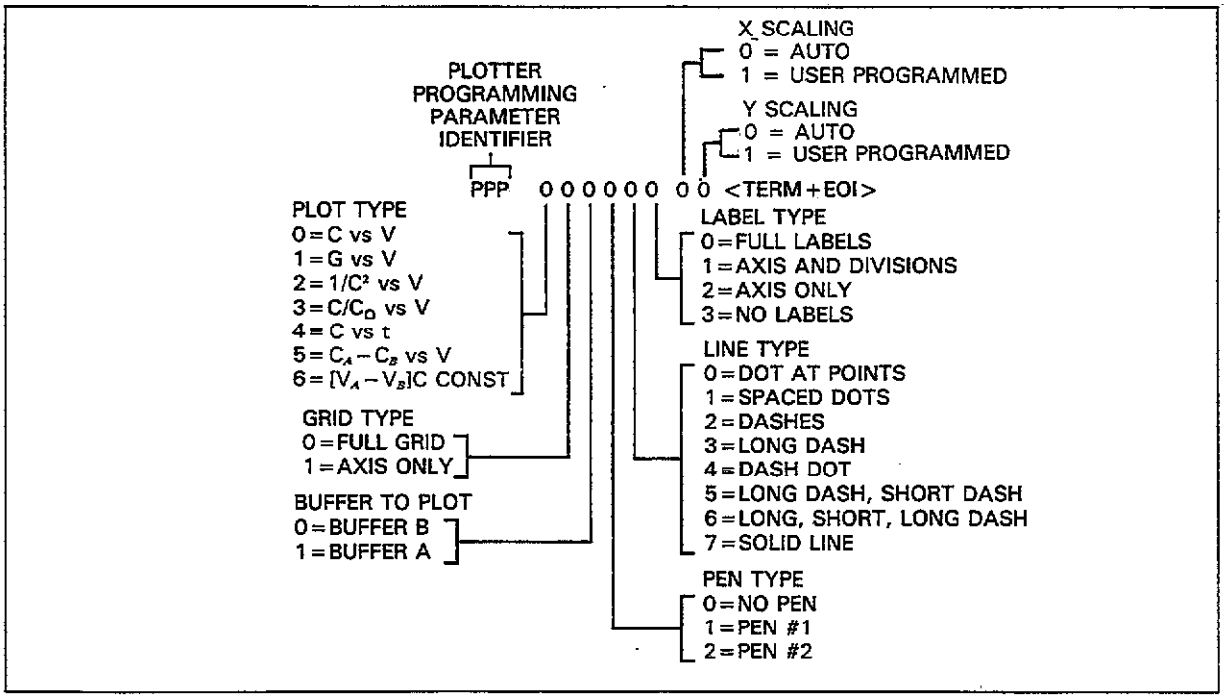



**Figure 4-31. U23 Status Word Format (Plotter Programming Parameters)**



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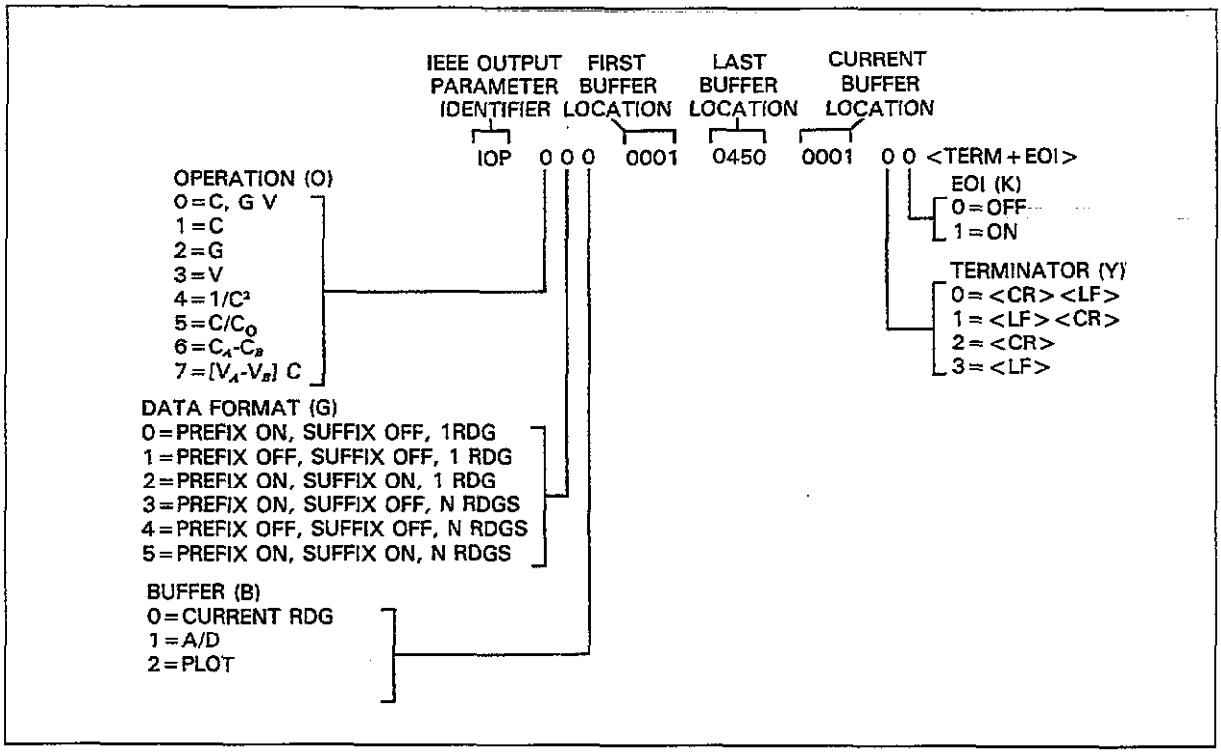



**Figure 4-32. U24 Status Word Format (IEEE Output Parameters)**



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