KEITHLEY

Model 590 CV Analyzer

Instruction Manual

A GREATER MEASURE OF CONFIDENCE

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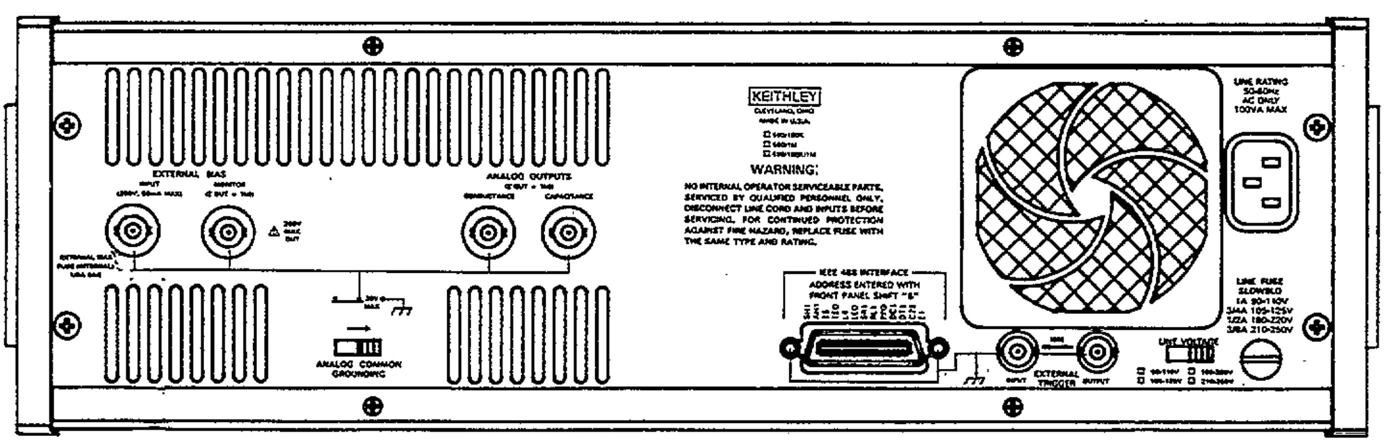
Replace all Model 590 rear panels that appear in this manual with the artwork below.



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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
Revision D (Document Number 590-901-01)....February 1999

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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.

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.

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.

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 fF	0.12% + $(500 \times G/G_{FS} + 200)$	6 fF	0.02% + $(20 \times G/G_{FS})$	0.1 % + $(3 \times G/G_{FS})$
2 µS	0.1 nS	0.12% + $(50 \times C/C_{FS} + 200)$	4 nS	0.02% + $(7 \times C/C_{FS})$	0.1 % + $(3 \times C/C_{FS})$
20 pF	1 fF	0.12% + $(260 \times G/G_{FS} + 10)$	6 fF	0.02% + $(20 \times G/G_{FS})$	0.1 % + $(3 \times G/G_{FS})$
20 µS	1 nS	0.12% + $(22 \times C/C_{FS} + 10)$	4 nS	0.02% + $(7 \times C/C_{FS})$	0.1 % + $(3 \times C/C_{FS})$
200 pF	10 fF	0.12% + $(260 \times G/G_{FS} + 5)$	90 fF	0.02% + $(20 \times G/G_{FS})$	0.1 % + $(3 \times G/G_{FS})$
200 µS	10 nS	0.12% + $(22 \times C/C_{FS} + 5)$	60 nS	0.02% + $(7 \times C/C_{FS})$	0.1 % + $(7 \times C/C_{FS})$
2 nF	100 fF	0.12% + $(260 \times G/G_{FS} + 5)$	900 fF	0.02% + $(20 \times G/G_{FS})$	0.02% + $(2 \times G/G_{FS})$
2 mS	100 nS	0.12% + $(22 \times C/C_{FS} + 5)$	0.6 µS	0.02% + $(7 \times C/C_{FS})$	0.02% + $(3 \times C/C_{FS})$
20 nF*	1 pF	0.25% + $(260 \times G/G_{FS} + 5)$[3]	9 fF	0.1 % + $(30 \times G/G_{FS})$	0.02% + $(2 \times G/G_{FS})$
20 mS	1 µS	0.25% + $(22 \times C/C_{FS} + 5)$	6 µS	0.1 % + $(10 \times C/C_{FS})$	0.02% + $(2 \times C/C_{FS})$

Accuracy is maximum limit for $Q \geq 20$; 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 fF	0.29% + $(300 \times G/G_{FS} + 10)$	6 fF	0.02% + $(20 \times G/G_{FS})$	0.5 % + $(25 \times G/G_{FS})$
200 µS	10 nS	0.29% + $(120 \times C/C_{FS} + 10)$	40 nS	0.02% + $(8 \times C/C_{FS})$	0.5 % + $(10 \times C/C_{FS})$
200 pF	10 fF	0.29% + $(300 \times G/G_{FS} + 5)$	100 fF	0.02% + $(20 \times G/G_{FS})$	0.35% + $(40 \times G/G_{FS})$
2 mS	100 nS	0.29% + $(120 \times C/C_{FS} + 5)$	700 nS	0.02% + $(8 \times C/C_{FS})$	0.35% + $(16 \times C/C_{FS})$
2 nF	100 fF	0.29% + $(300 \times G/G_{FS} + 5)$	200 fF	0.02% + $(20 \times G/G_{FS})$	0.35% + $(40 \times G/G_{FS})$
20 mS	1 µS	0.29% + $(120 \times C/C_{FS} + 5)$	1 µS	0.02% + $(8 \times C/C_{FS})$	0.35% + $(16 \times C/C_{FS})$

Accuracy is maximum limit for $Q \geq 20$; 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.

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. × 17⅝₂ 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

590/100K ANALOG OUTPUT PERFORMANCE

RANGE	ACCURACY (1 Year) 18° -28°C ±(% reading + mV)	P-P NOISE[5] 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 $Q \geq 20$. 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%.

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
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APPENDIX C

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

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/2μS, 20pF/20μS, 200pF/200μS, 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 $\pm$20V bias source that can generate staircase, pulse train, or DC waveforms. Provision to connect an external bias source of up to $\pm$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.

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.

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.

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.

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.

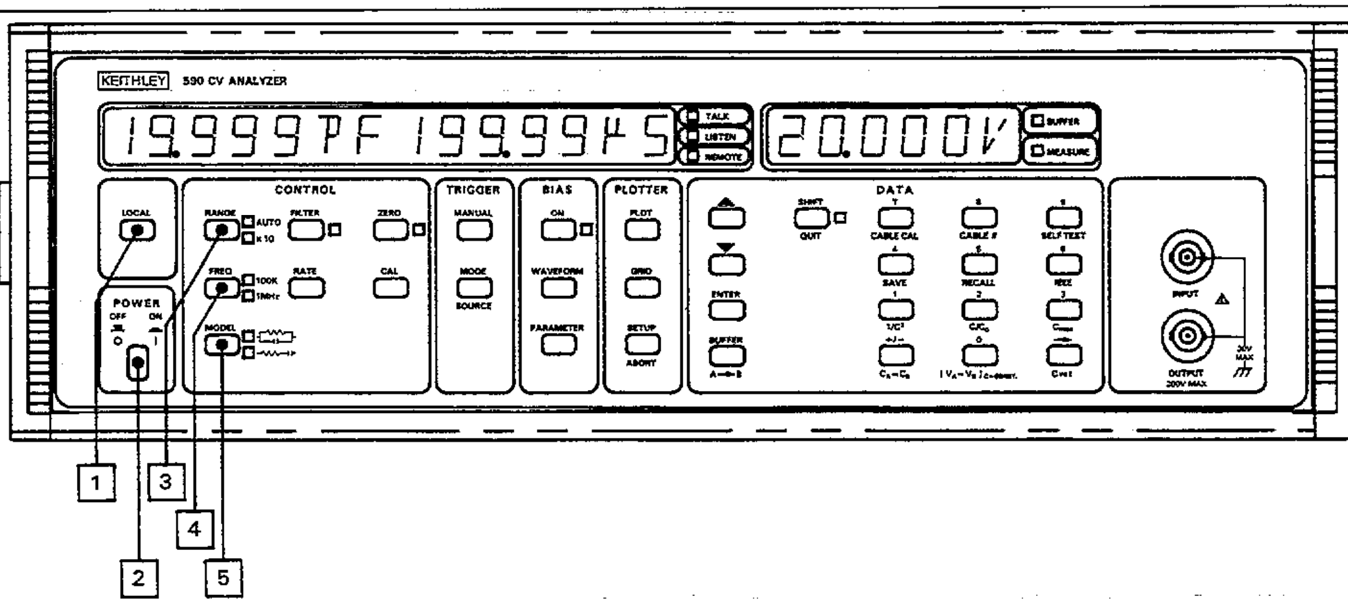
2.2 FRONT PANEL FAMILIARIZATION

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.

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.	3.13
→	Scroll cursor when programming parameters.	
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 ΔV 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.



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:

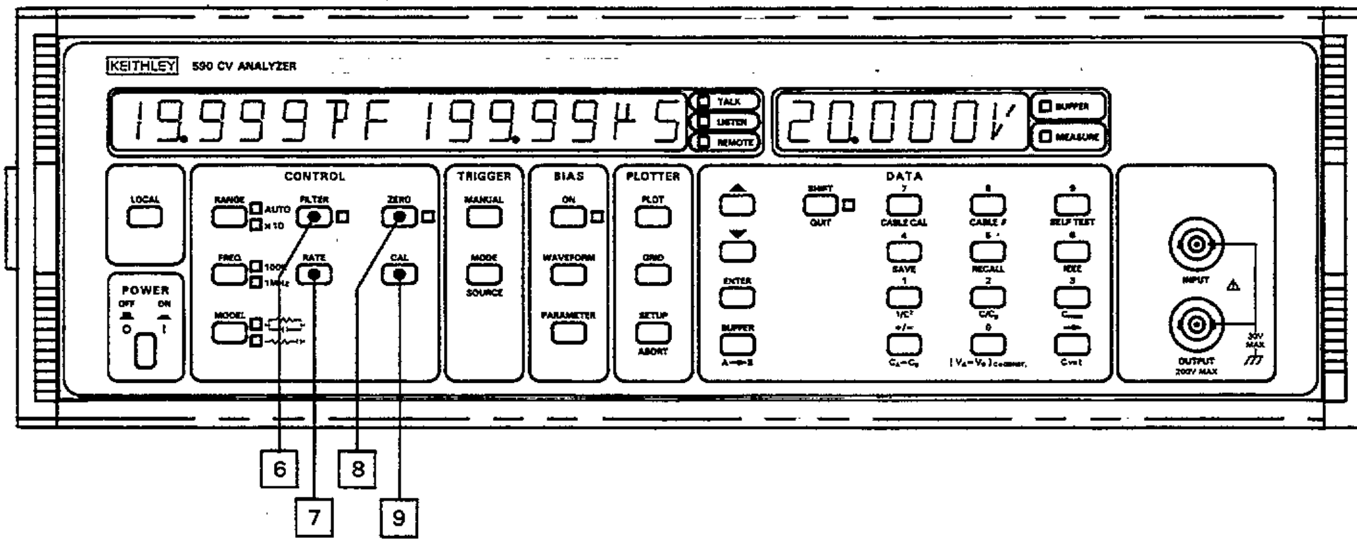
100kHz	1MHz
2pF/2μS	
20pF/20μS	20pF/200μS
200pF/200μS	200pF/2mS
2nF/2mS	2nF/20mS
20nF/20mS*	

*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



Full Scale Conductance/Resistance:

100kHz G	R	1MHz G	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.

NOTE

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

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.

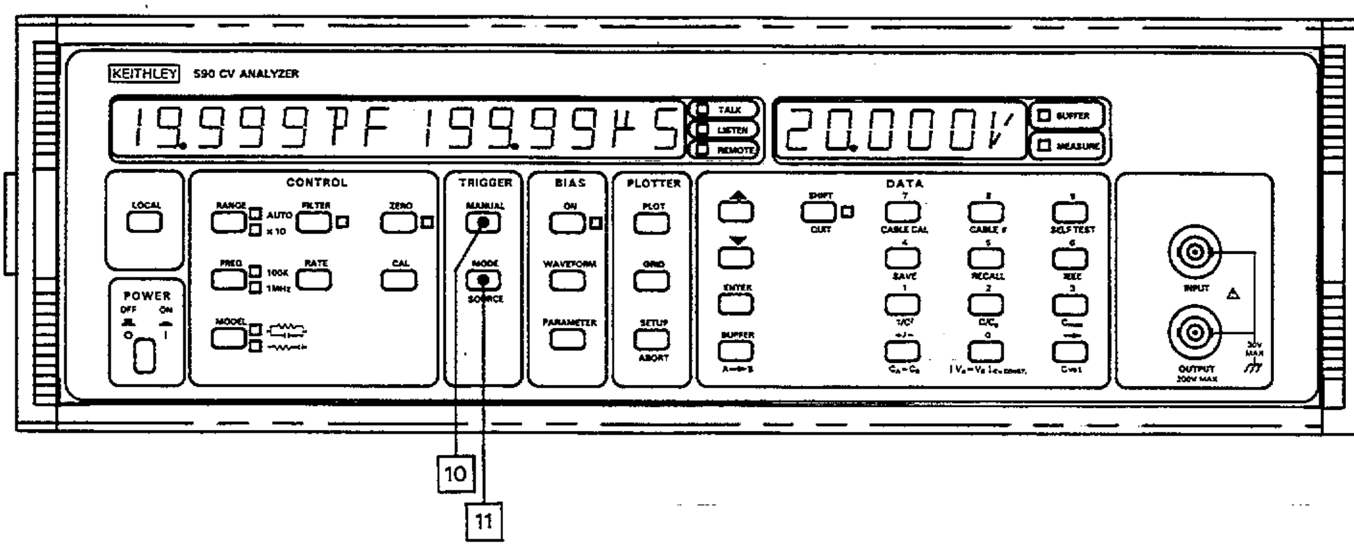
8 **ZERO**—ZERO provides means for supression of a constant value from the readings, or it can be used to cancel internal offsets to maximize accuracy. Enabling ZERO stores the next reading as the baseline value, which is then subtracted from subsequent readings and stored in the buffer header. Note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



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.

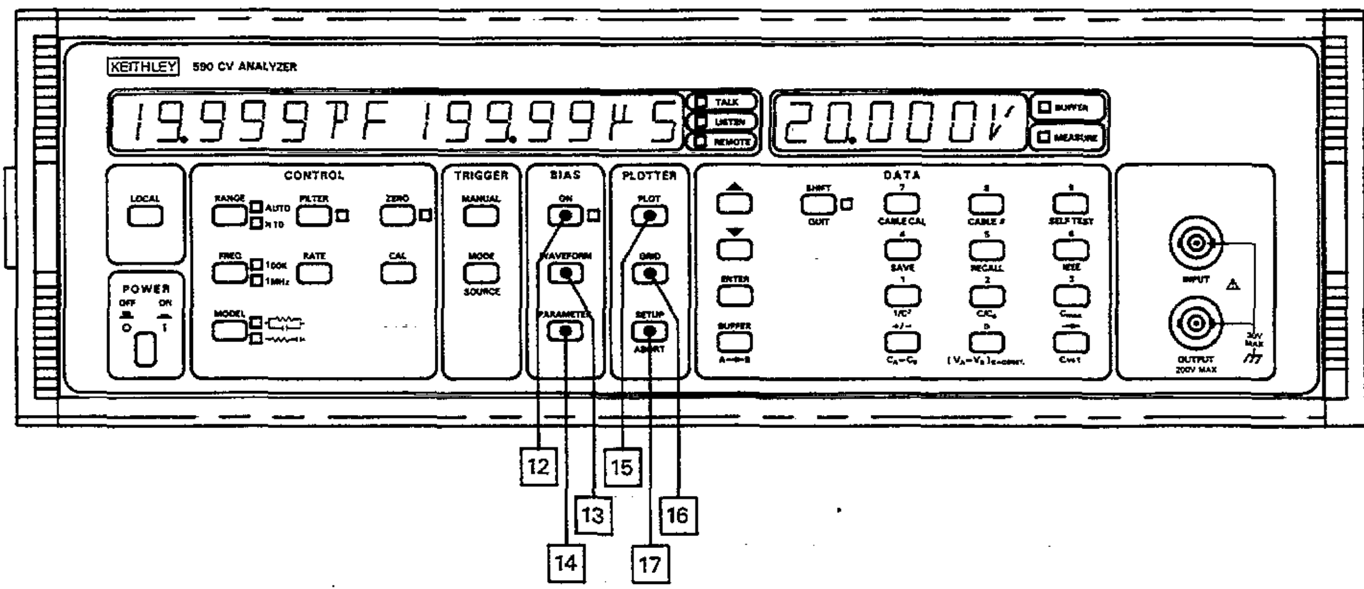
Press SOURCE (SHIFT MODE) then MODE or ▲/▼ to scroll through available trigger sources (or press the appropriate numeric key in the list below). Press ENTER to program displayed source: front panel (MANUAL button), external (a negative-going TTL-compatible pulse applied to the rear panel trigger input 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



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.

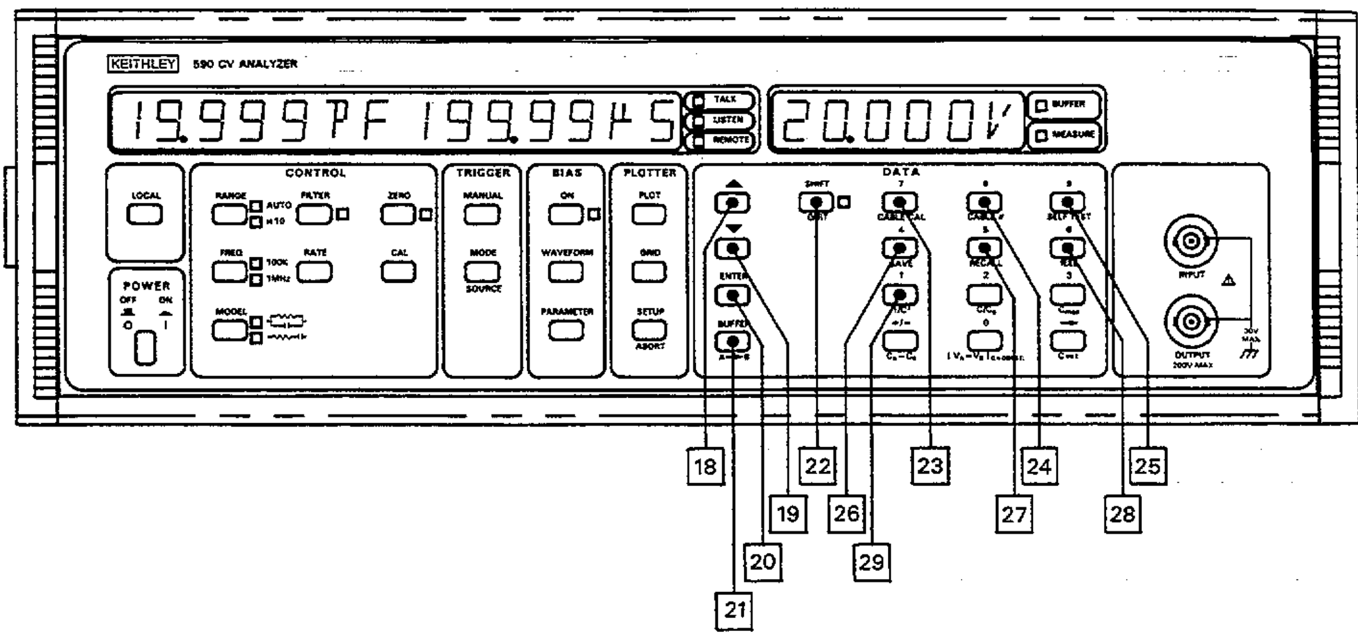
**Plots buffer index.

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.)



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

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.

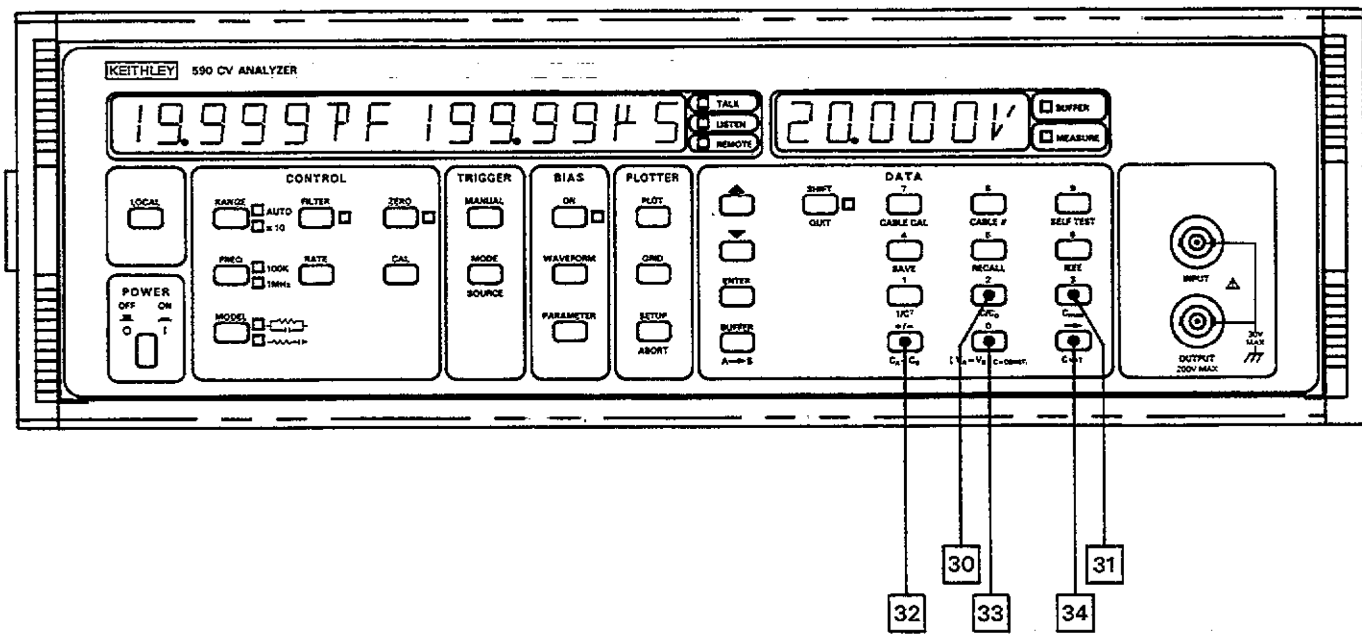
MATHEMATICAL FUNCTIONS

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 **$1/C^2$**—Pressing $1/C^2$ 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.)



[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:

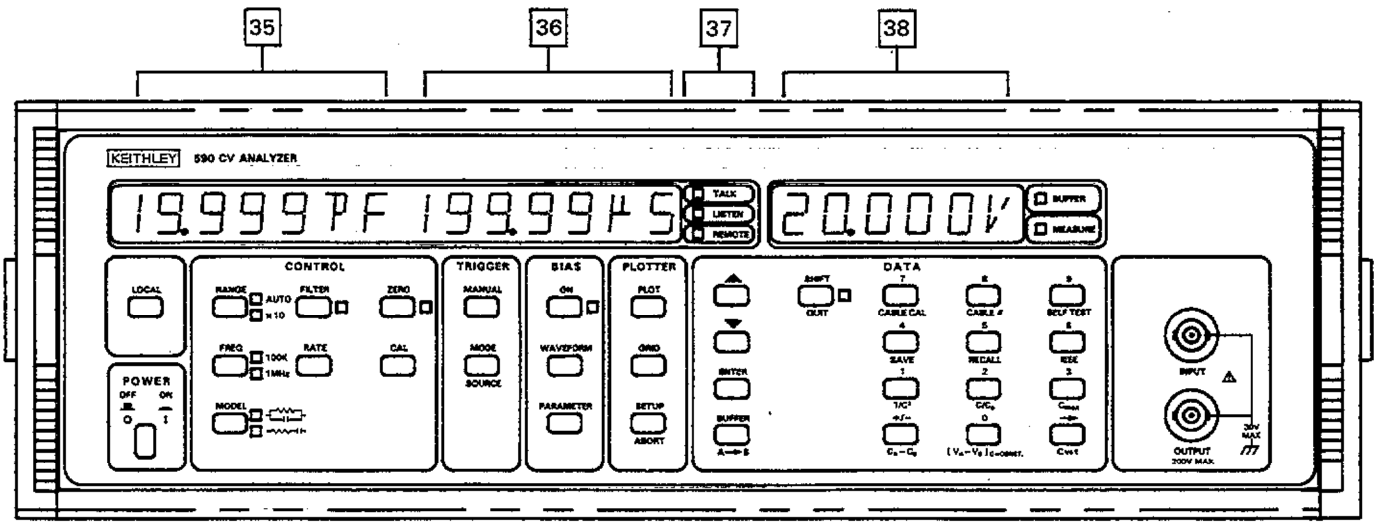
$$t_B = t_{start} + (t_{step} + 1/R)\,(B)$$

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.)



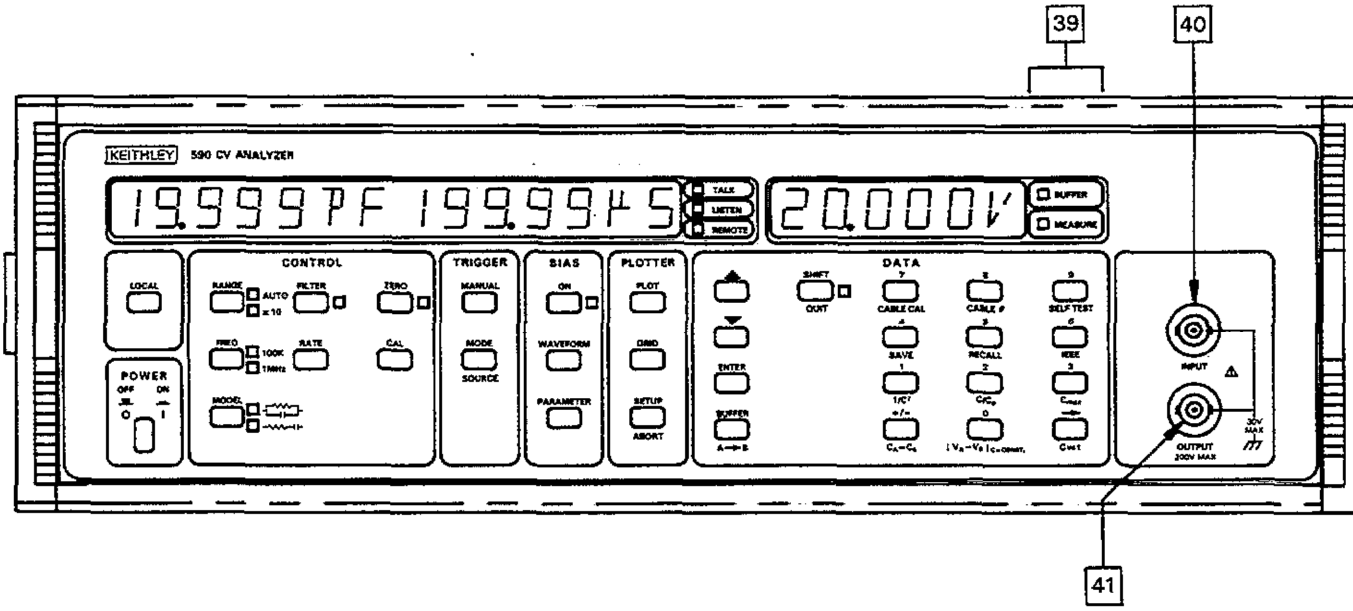
35 **CAPACITANCE DISPLAY**—The normal capacitance display is a 4½-digit 21,999, −19,999 count value. The decimal point along with the associated engineering units indicate the range. The displayed engineering units are pF and nF. The display will show dashes when no valid reading is available (for example, 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



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.

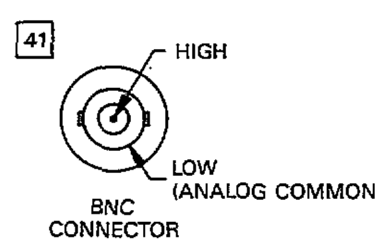


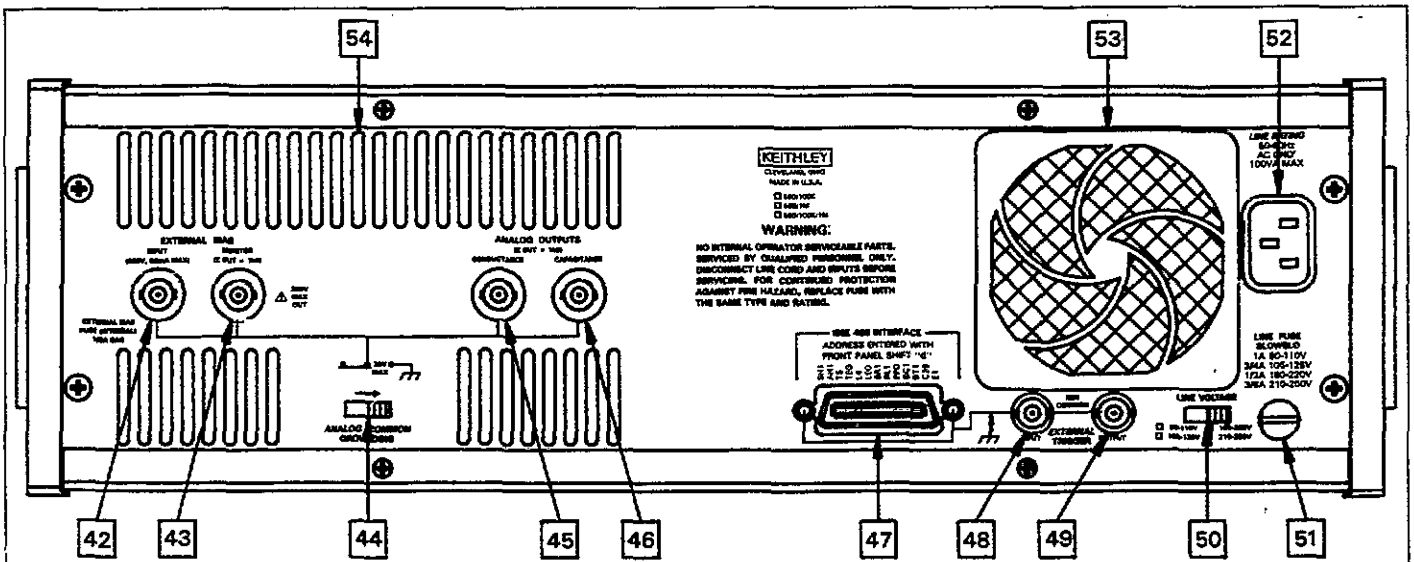
Figure 2-1D. Model 590 Front Panel (Cont.)

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.

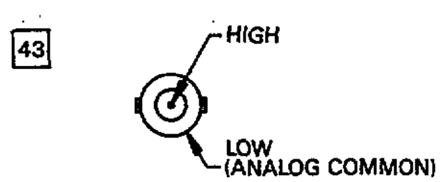
Table 2-2. Model 590 Rear Panel Cross Reference

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



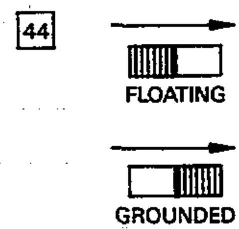
42 **VOLTAGE BIAS INPUT**—This BNC connector is intended to apply external bias voltage up to ±200V DC, 50mA maximum. Note that the input is internally fused to protect the instrument from over current conditions. The voltage applied to BIAS INPUT will be applied to the circuit under test through the 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.

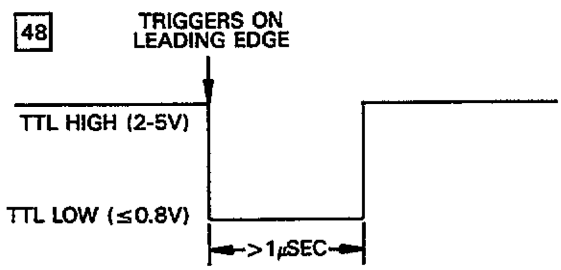
46 **CAPACITANCE ANALOG OUTPUT**—This BNC jack provides a scaled output voltage that is proportional to the capacitance reading. The output range of the CAPACITANCE output is 0-2V full scale. For example, the nominal output voltage with a 140pF reading on the 200pF/200μS range will be 1.4V. Output impedance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

Figure 2-2. Model 590 Rear Panel

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.

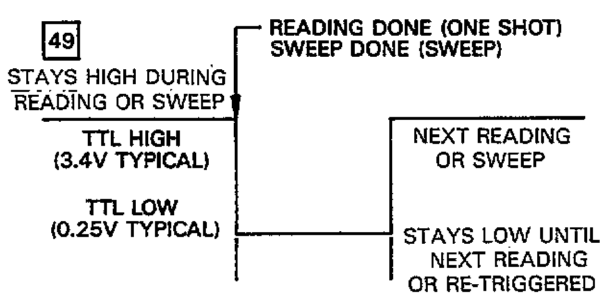
48 **EXTERNAL TRIGGER INPUT**—EXTERNAL TRIGGER INPUT is a BNC jack to be used for applying a trigger pulse to initiate a one-shot or sweep reading, depending on the trigger mode programmed with the TRIGGER MODE key. Note that external trigger must be enabled, also with the MODE key. Inputs to this jack 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.

48

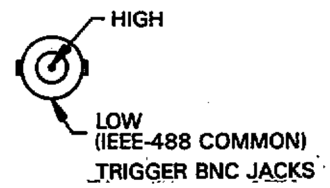


49 This BNC jack provides a TTL-compatible, negative-going pulse when the instrument completes a one-shot reading or reading sweep, depending on the selected trigger mode. The center conductor is high, and the outer ring is low (see above).

49

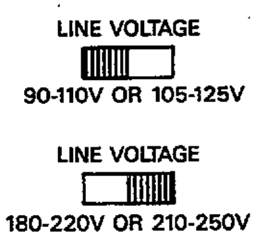


49



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.)

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.

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.

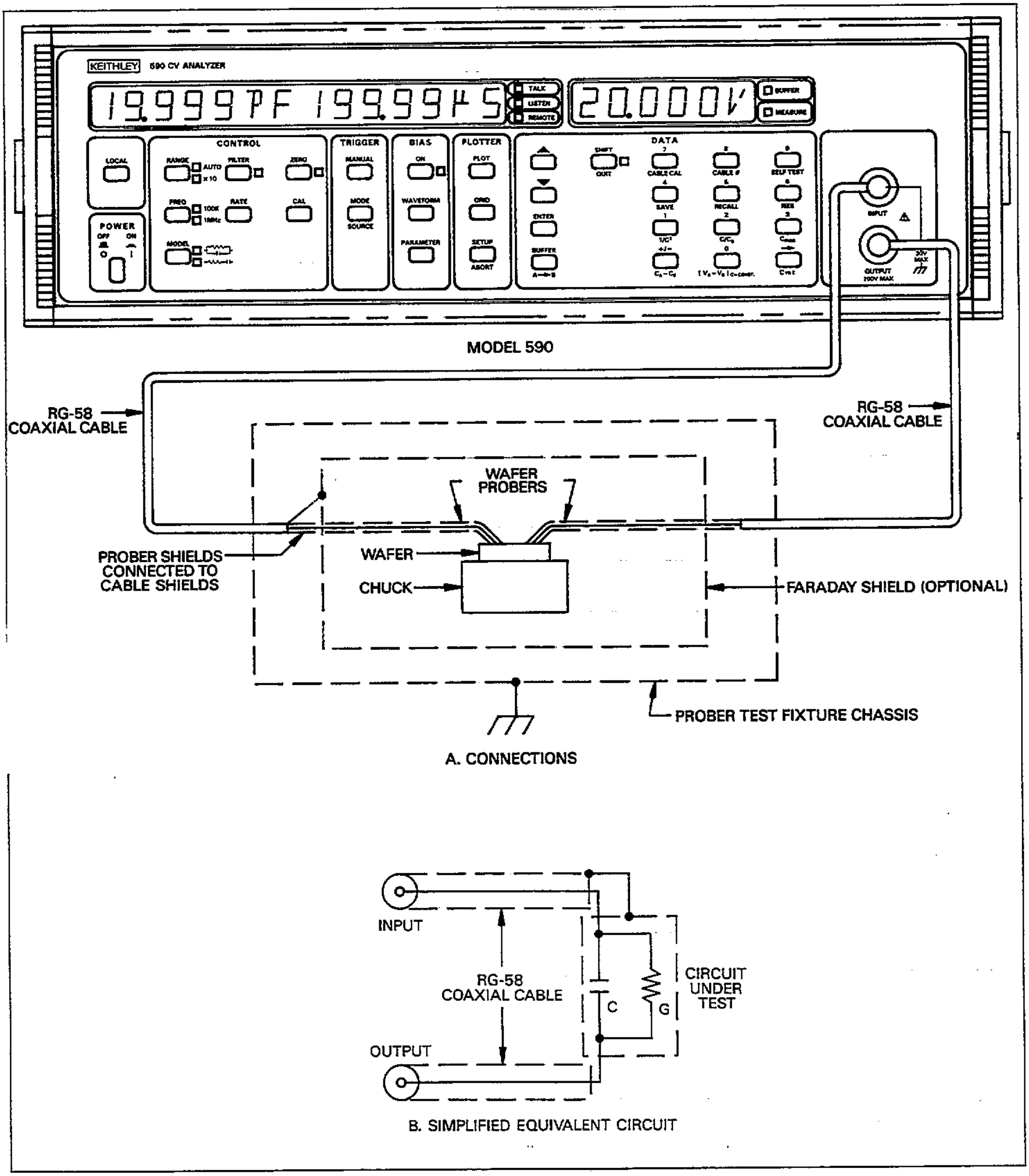


Figure 2-3. Typical Test Connections

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.

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.

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.

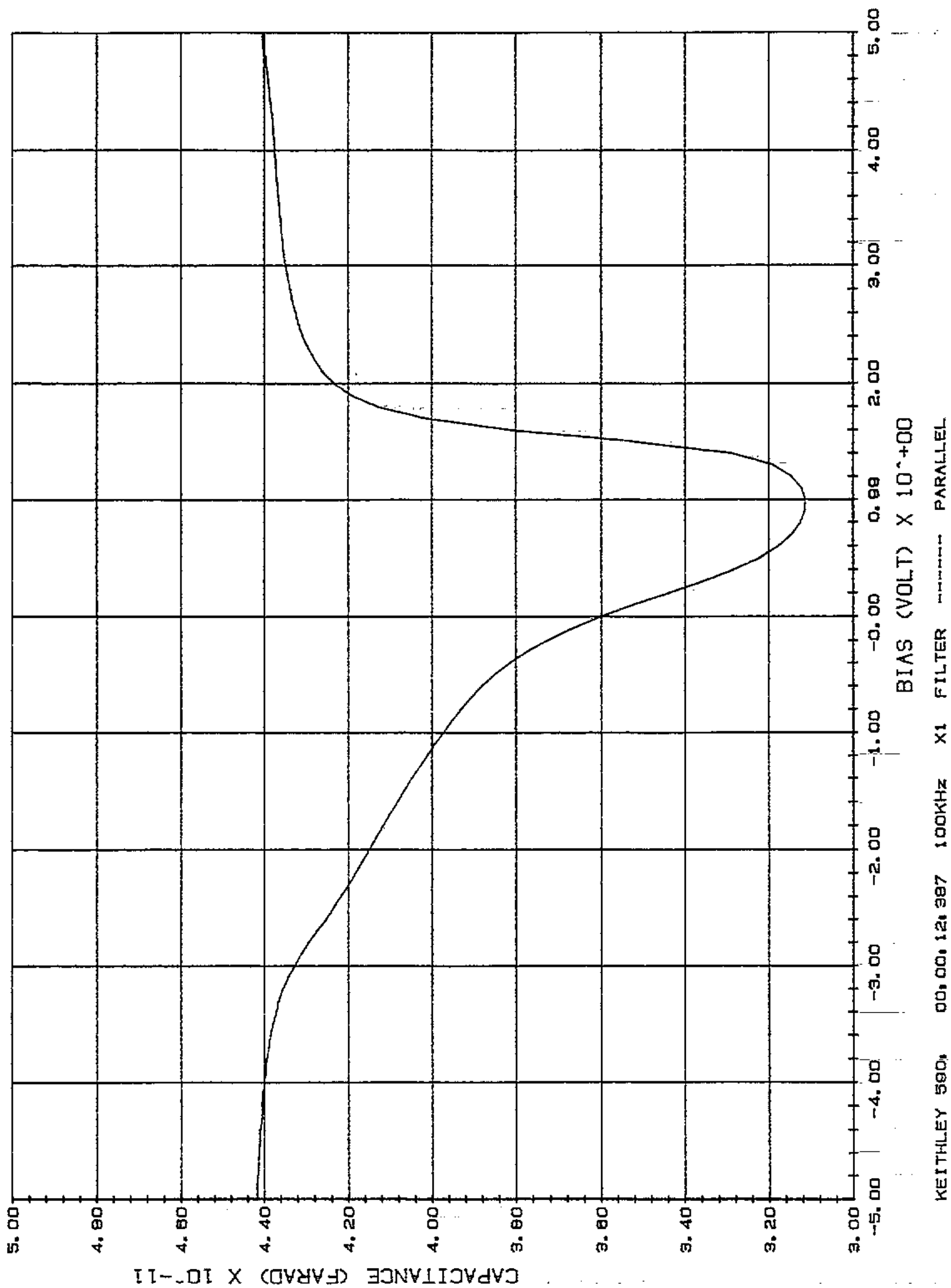


Figure 2-4. Plotting Example

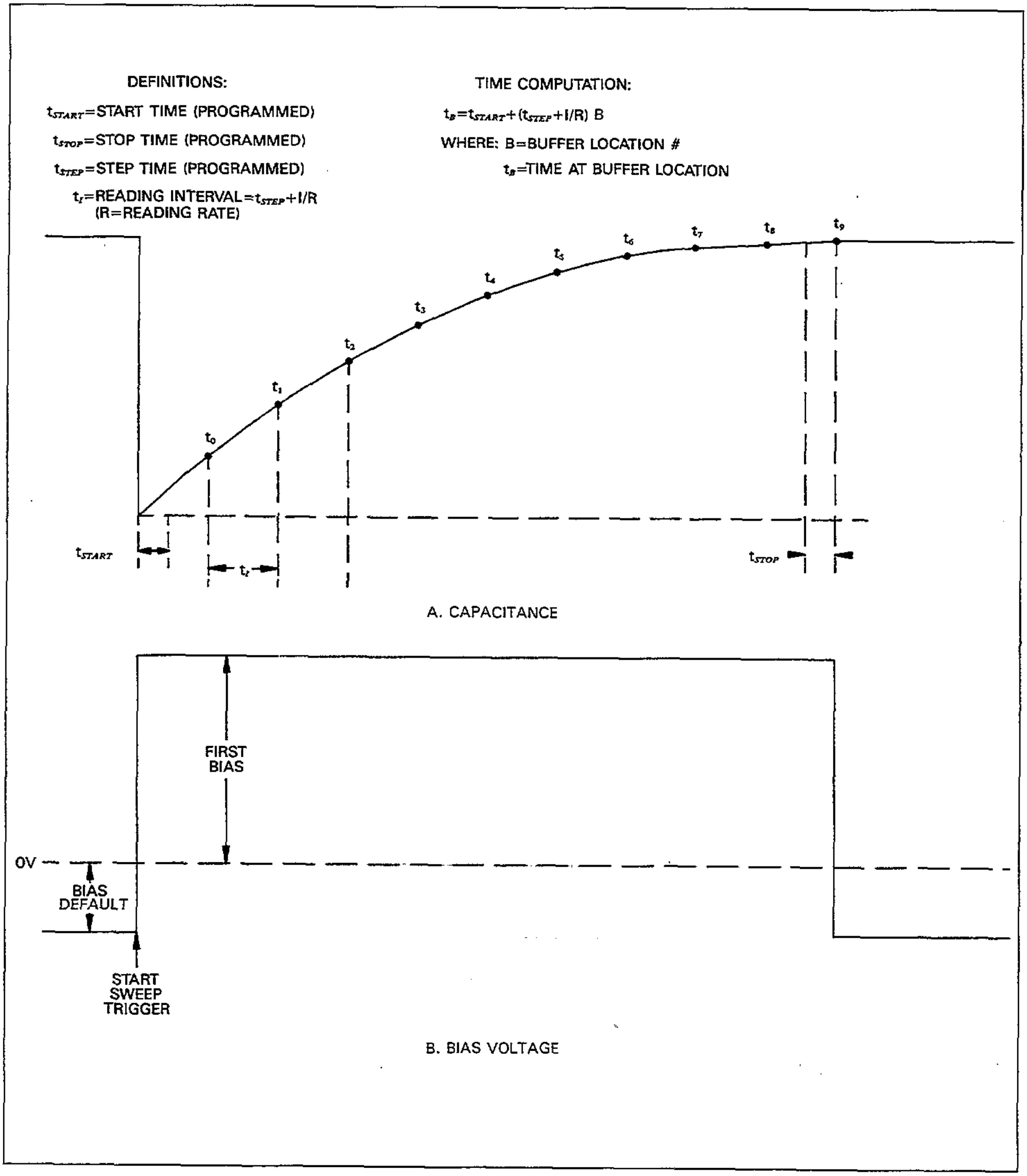


Figure 2-5. C vs t Waveform

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.

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).

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.

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.

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.

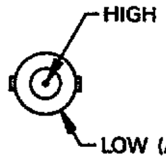


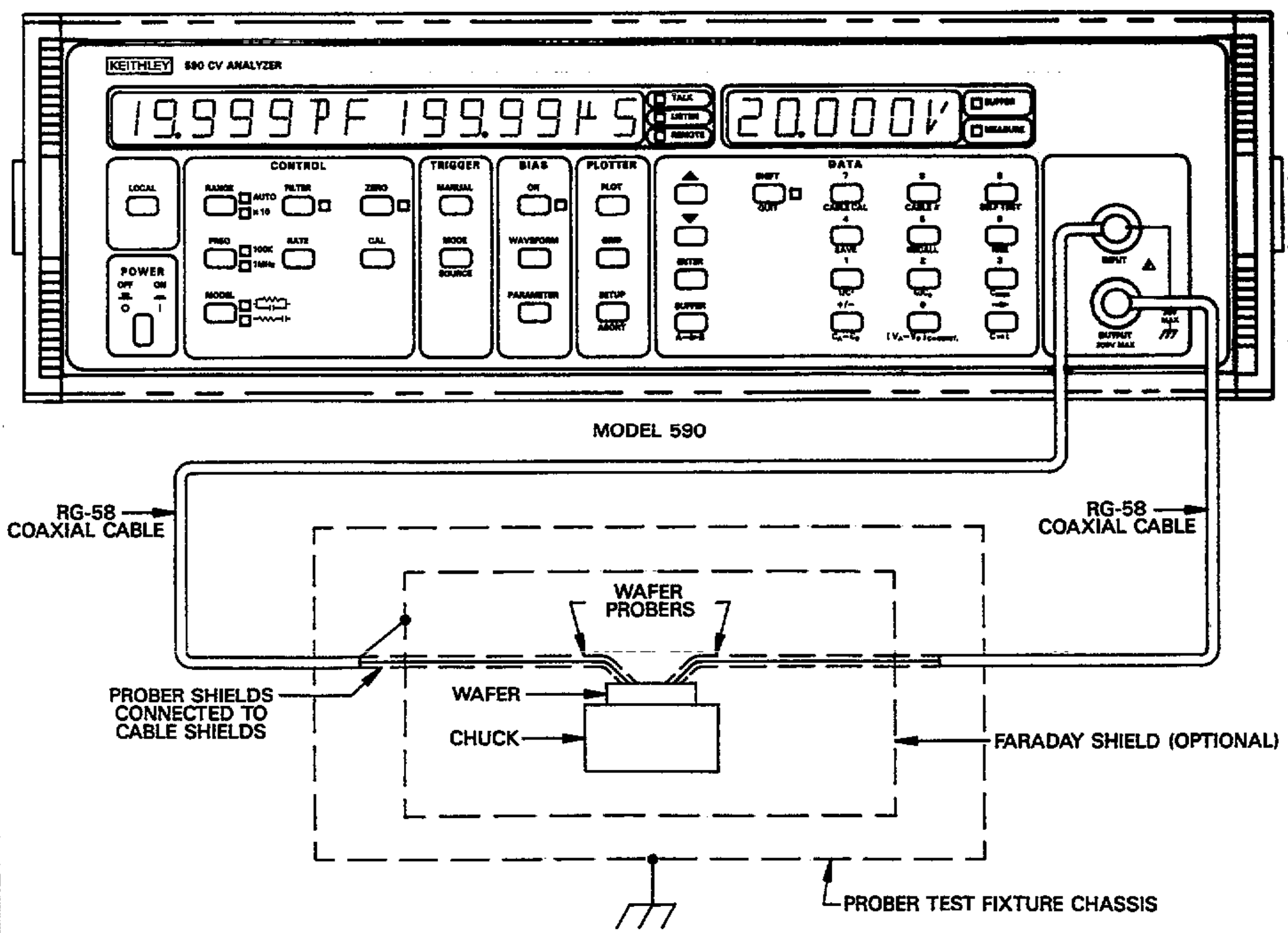
Figure 3-1. Input and Output Jack Configuration

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.



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

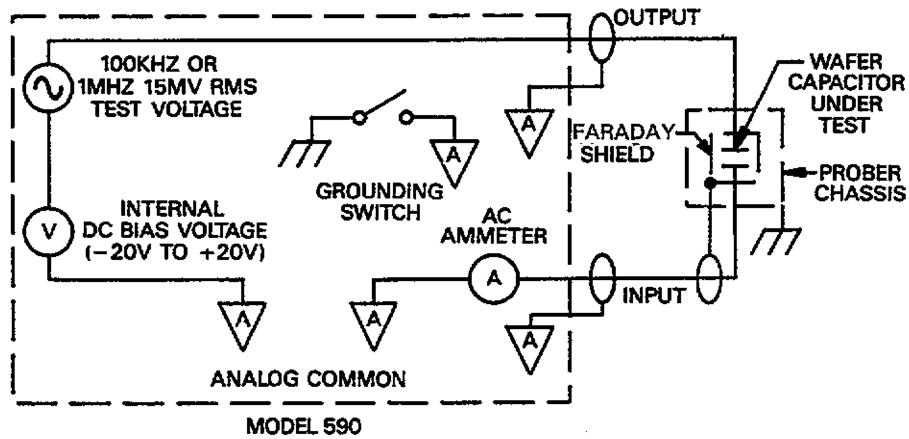


Figure 3-3. Equivalent Circuit of Test Connections

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.

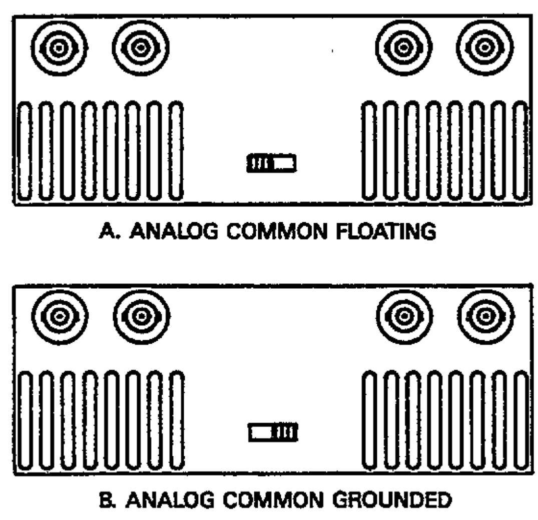


Figure 3-4. Floating/Grounded Operation of Analog Common

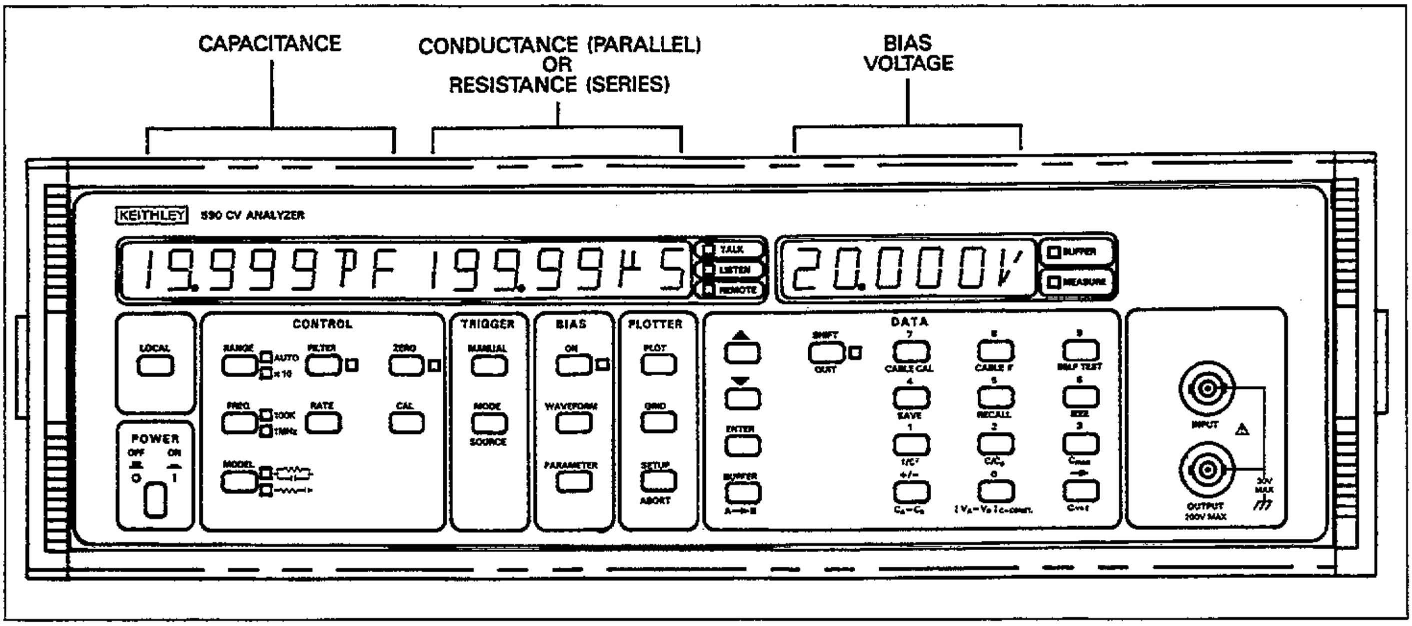


Figure 3-5. Capacitance, Conductance (Resistance), and Bias Voltage Displays

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.

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.

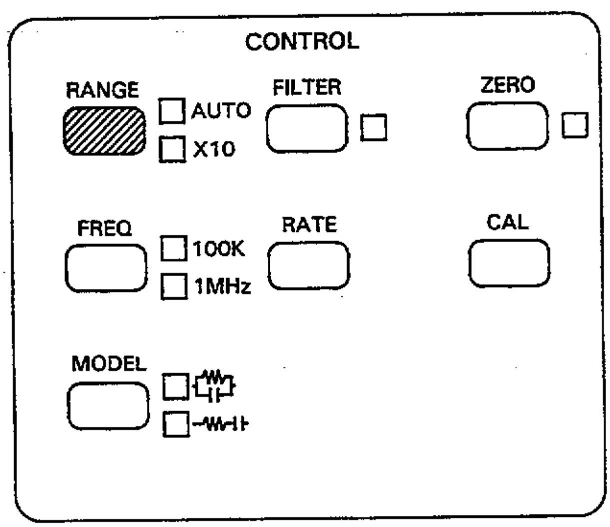
3.4.3 Hardware Control Considerations

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).

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.

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

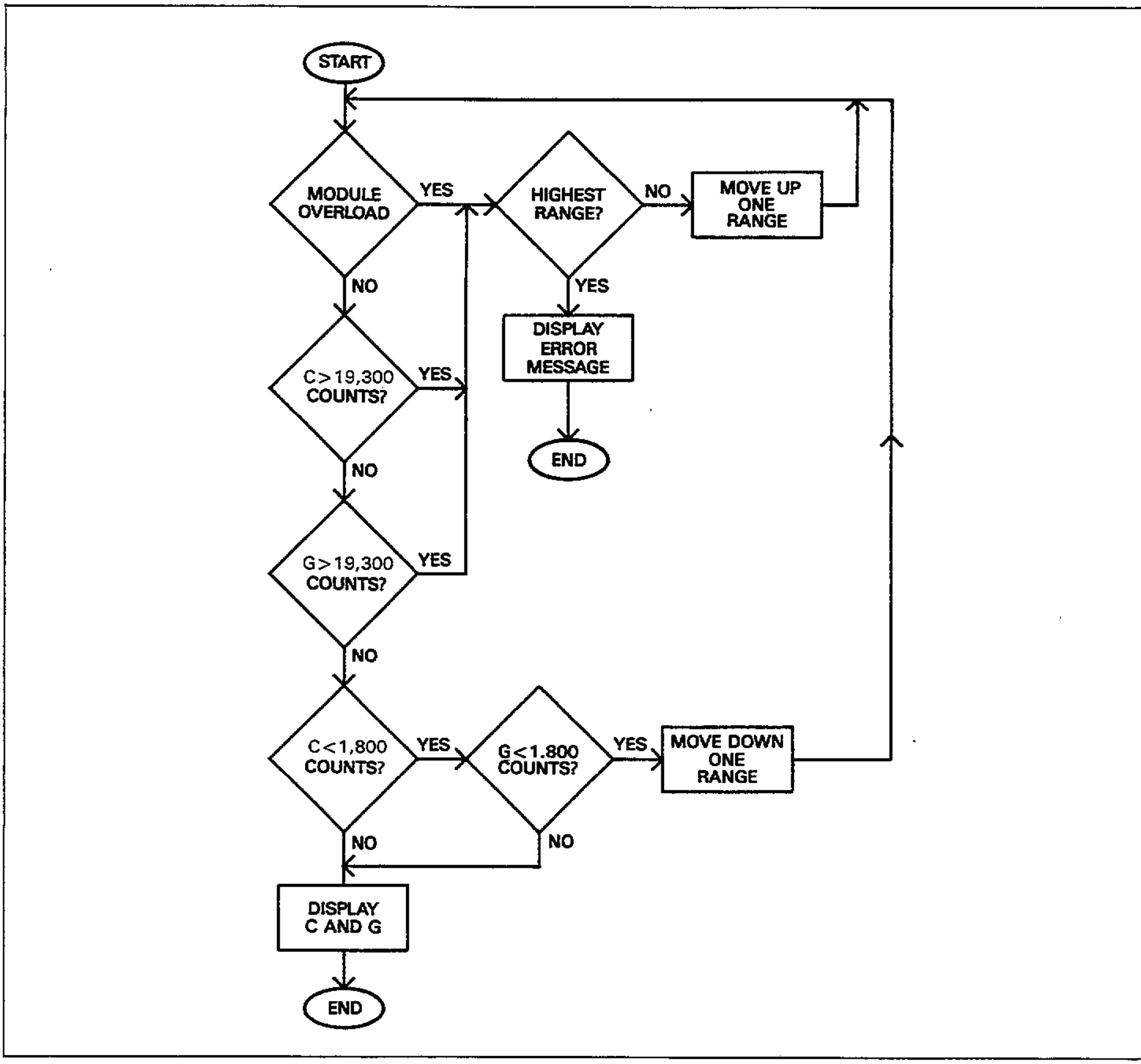


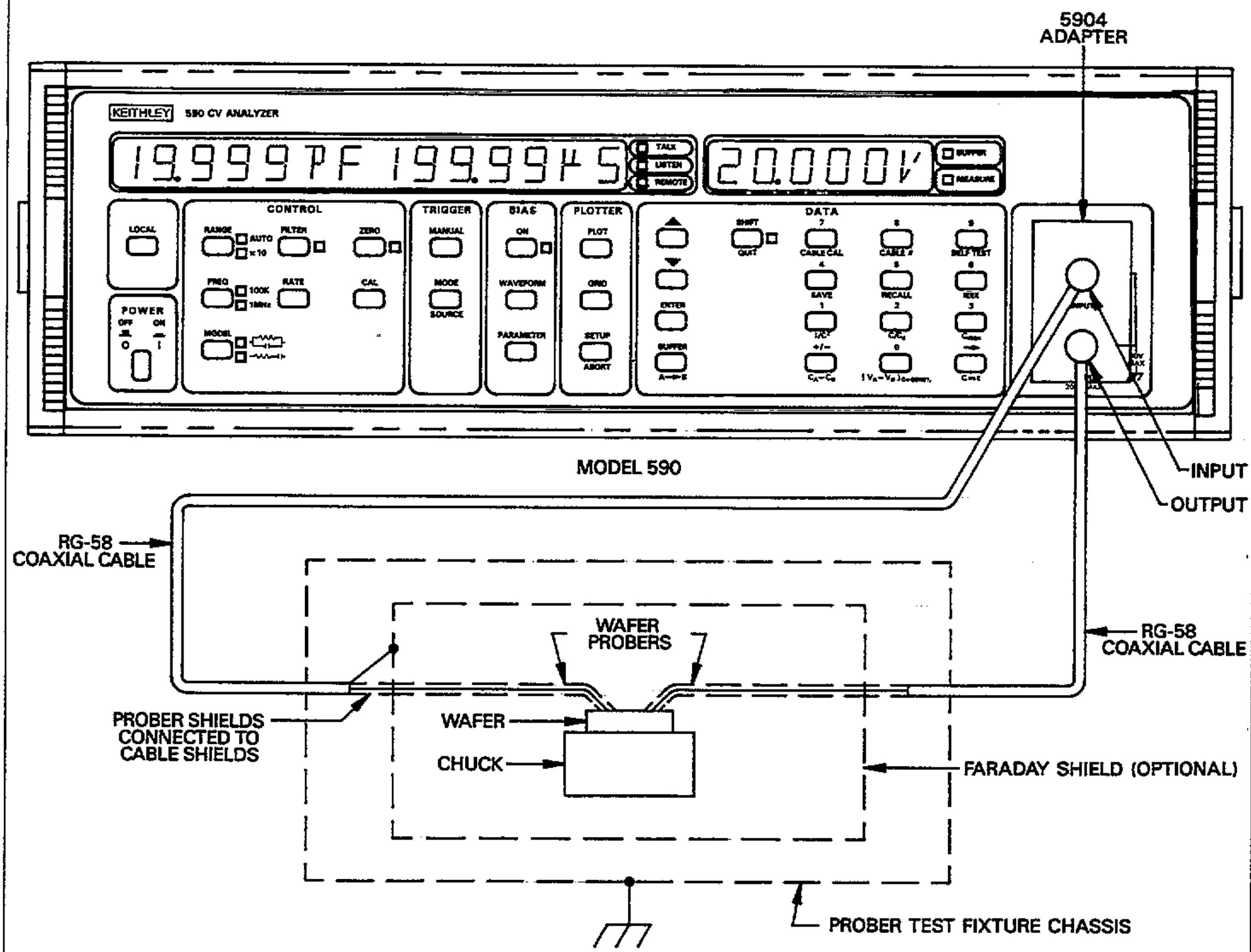
Figure 3-6. Flow Chart of Autoranging Operation

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.



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.

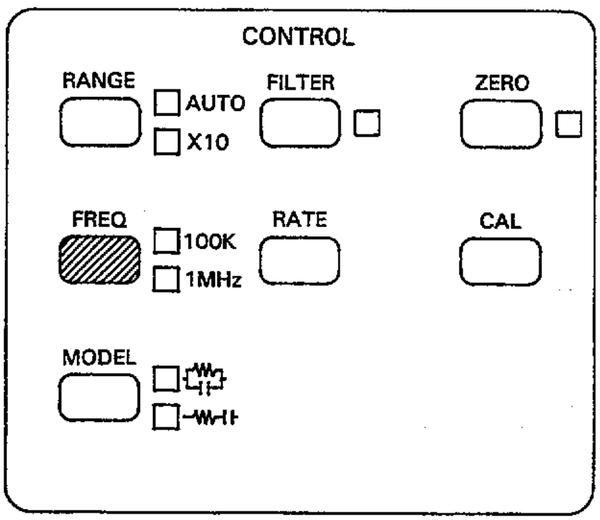
NOTE

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

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.

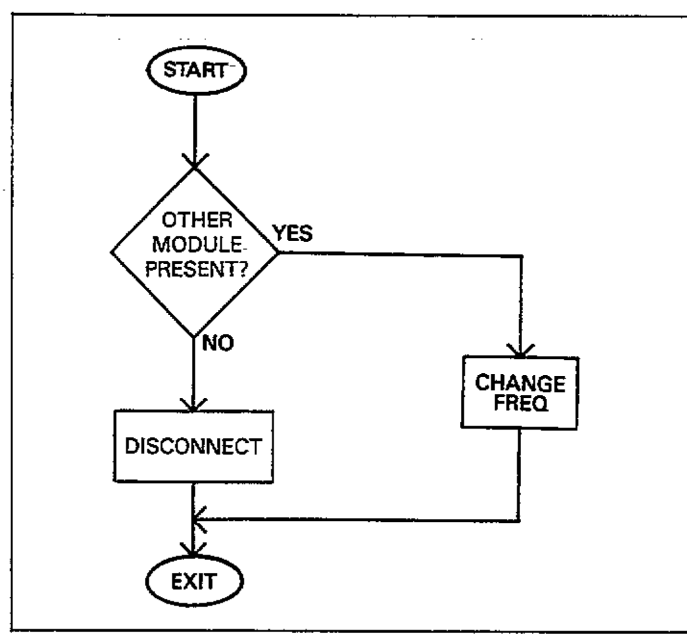


Figure 3-8. Frequency Selection Flow Chart

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

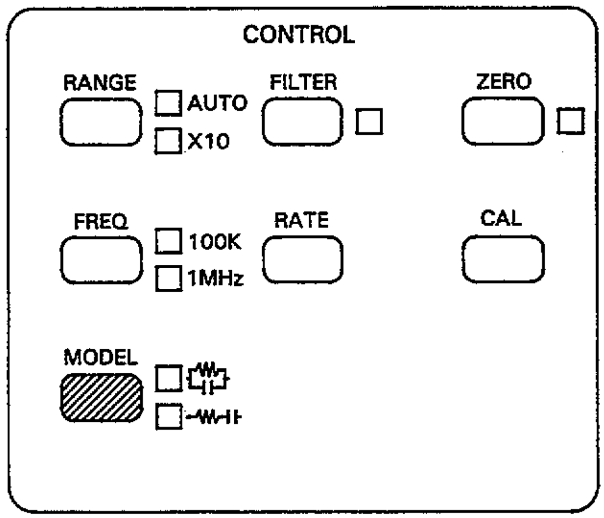
A second feature of the FREQ key allows you to disconnect the test and bias voltages from the device under test without having to remove the connecting cables attached to the test INPUT and OUTPUT jacks. To disconnect the voltages simply press FREQ until the DISCONNECT message is displayed. Internal 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.

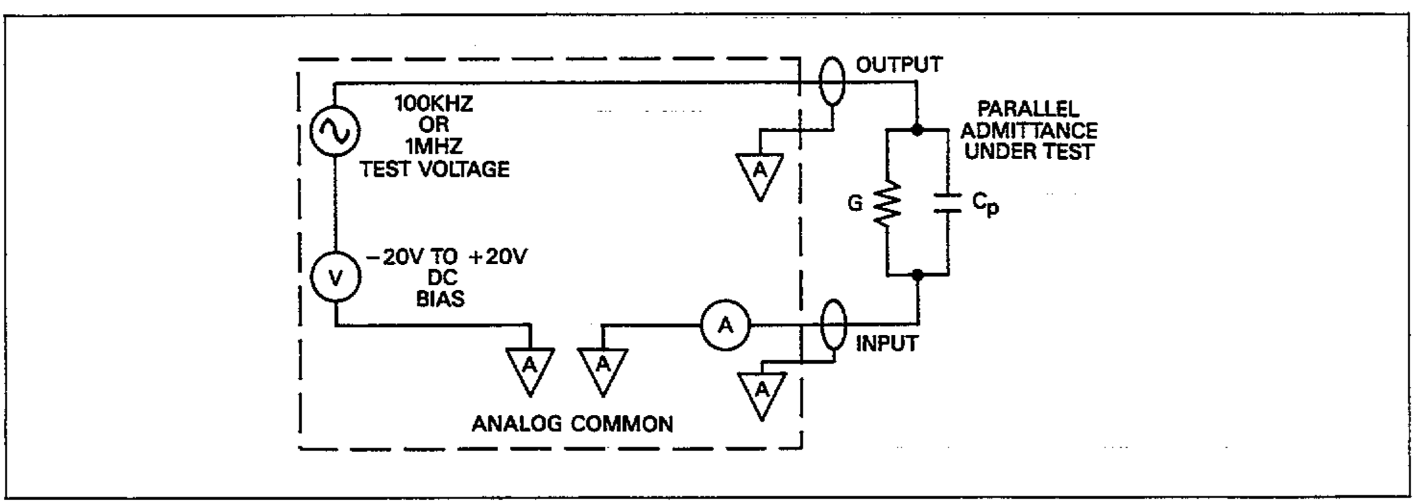


Figure 3-9. Equivalent Circuit of Parallel Capacitance and Conductance

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.

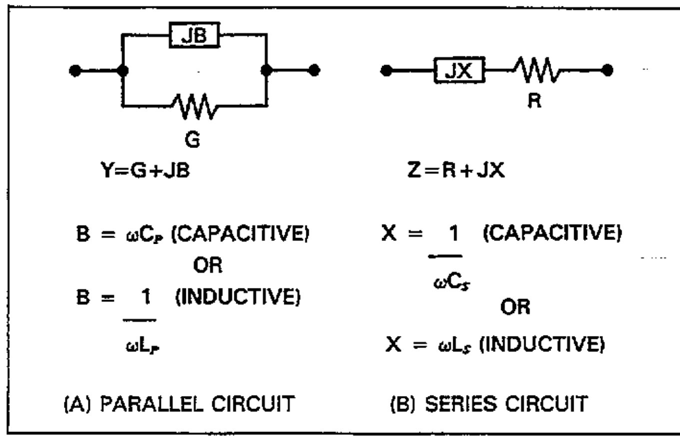


Figure 3-10. Series and Parallel Impedances

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.

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 ωC_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 30µS respectively. From these values, we can calculate the dissipation factor, D, as follows:

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

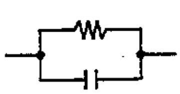
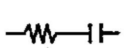
$$D = 0.3$$

The equivalent series capacitance is then calculated as follows:

$$C_s = (1 + 0.09)\ 160\text{pF}$$

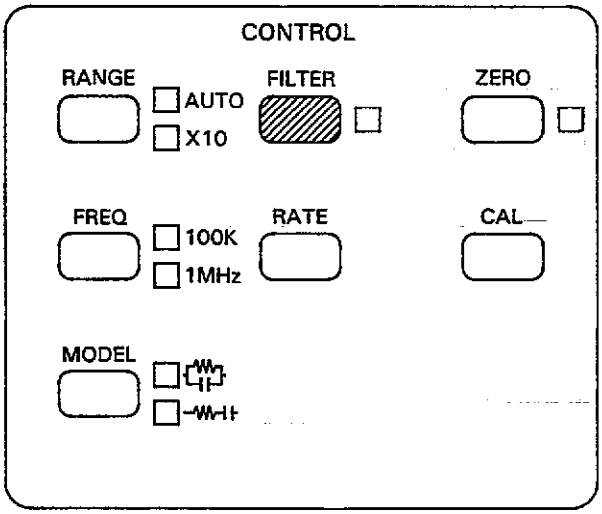
$$C_s = 174.4\text{pF}$$

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	$D = \frac{1}{Q} = \omega C_s R$	$C_p = \frac{C_s}{1 + D^2}$	$G = \frac{D^2}{(1+D^2)R}$

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.



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

3.8.1 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.

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.

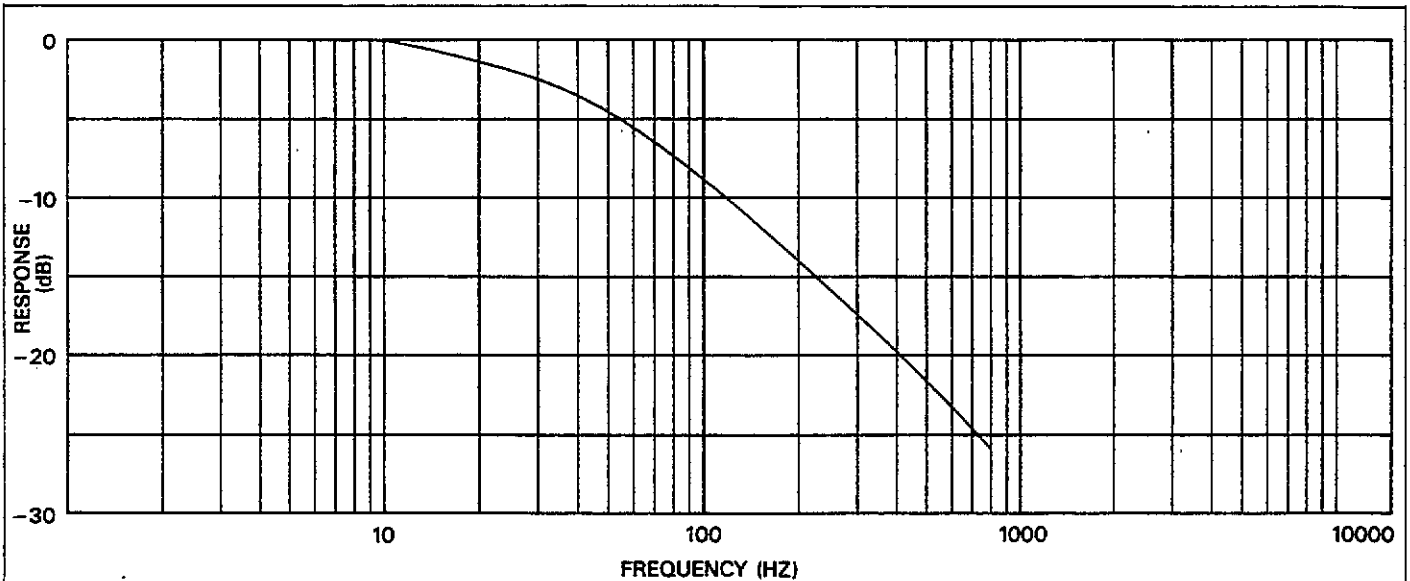


Figure 3-11. Typical Analog Filter Response

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

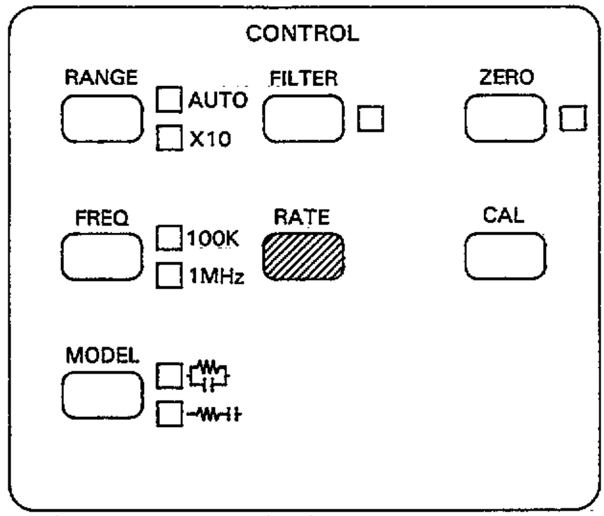
Because of the way the unit generates its time base, the actual reading rates are slightly different than indicated. Table 3-10 lists actual intervals along with other pertinent information.

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.

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

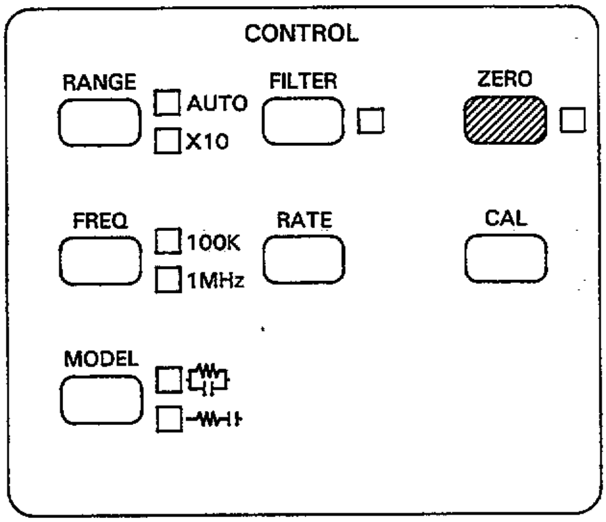
Typical reading rates are summarized below.

	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.

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.

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.

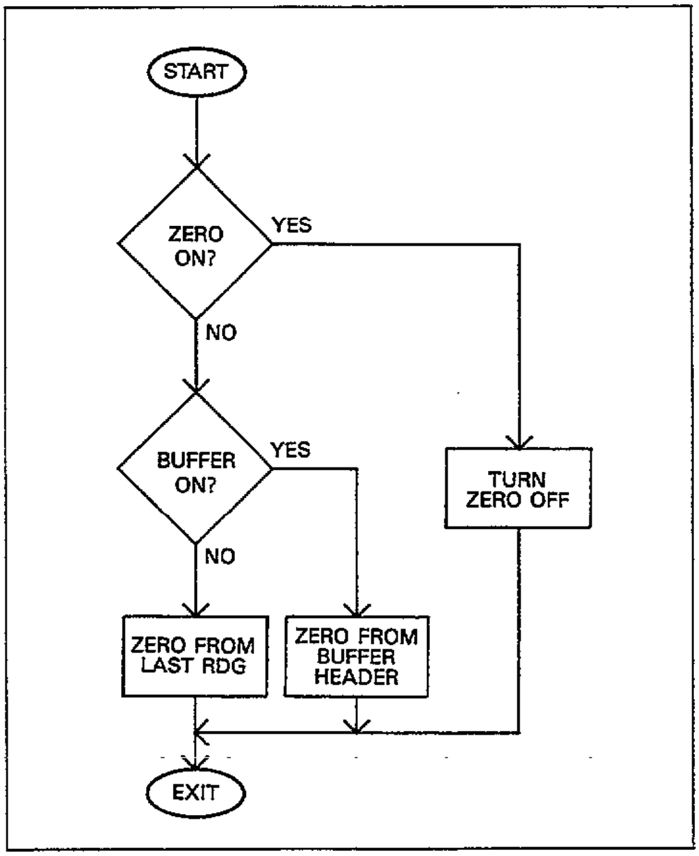


Figure 3-12. Zero Operation Flowchart

3.10.5 Examples of Zero Operation

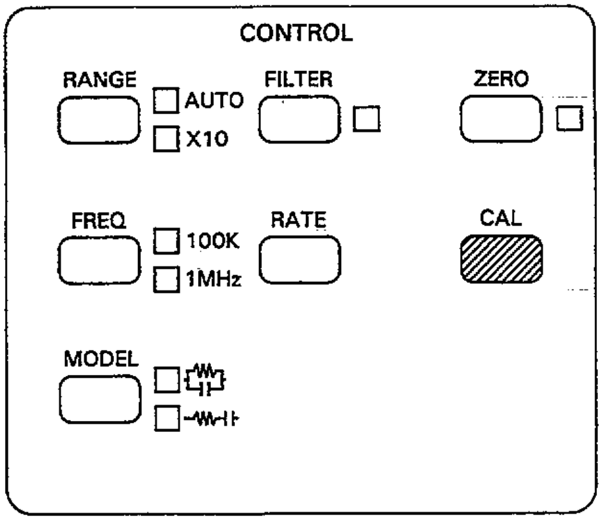
Table 3-11 lists some examples to help clarify zero operation. This table lists stored baseline values, applied signals, and resulting front panel display values for those combinations.

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

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.

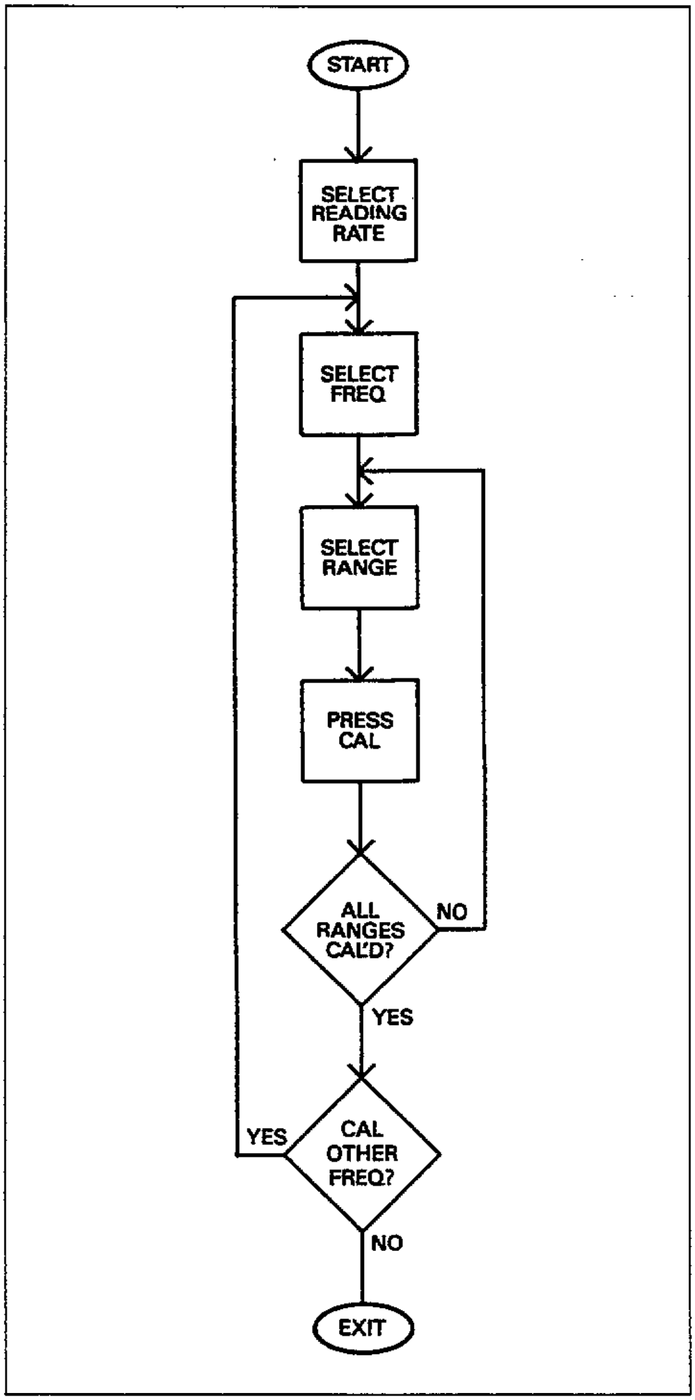


Figure 3-13. Front Panel CAL Sequence

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.

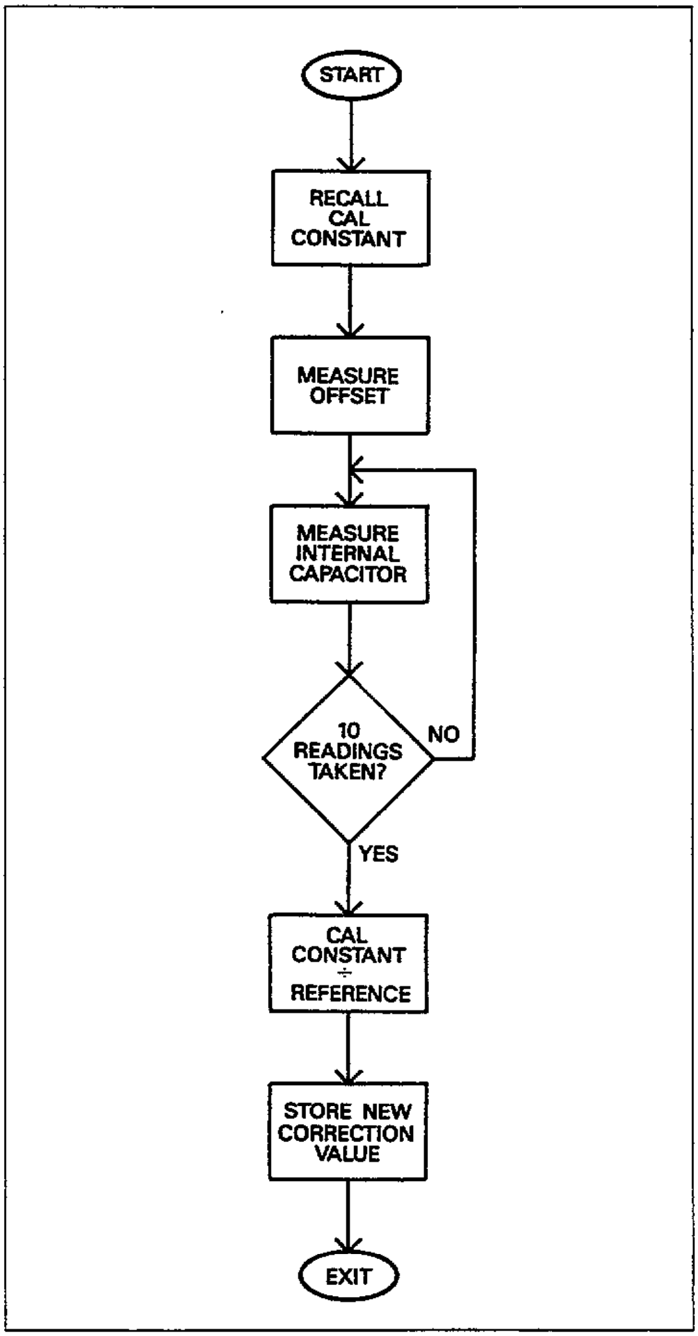
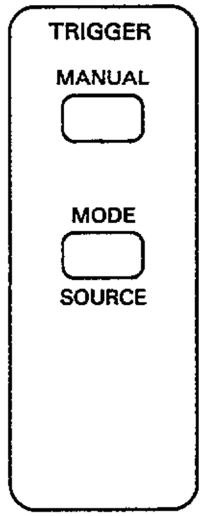


Figure 3-14. Internal Drift Correction Sequence

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.

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)

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.

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.

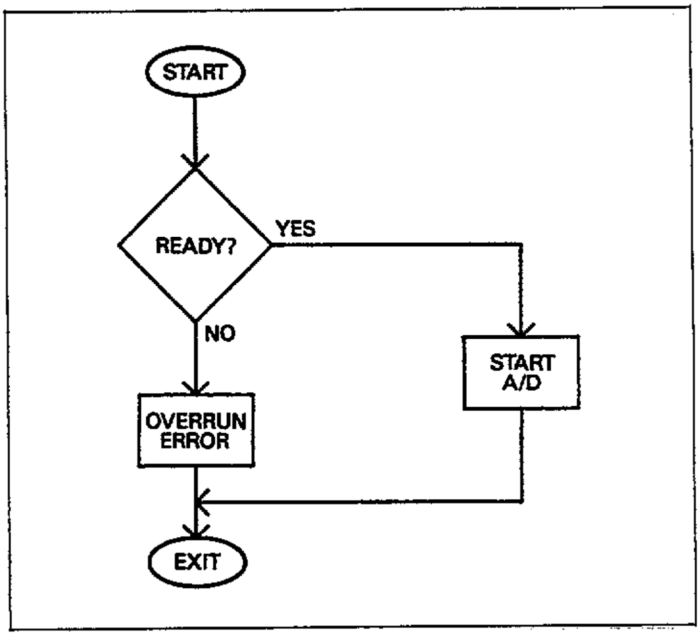


Figure 3-15. Trigger Overrun Operation

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.

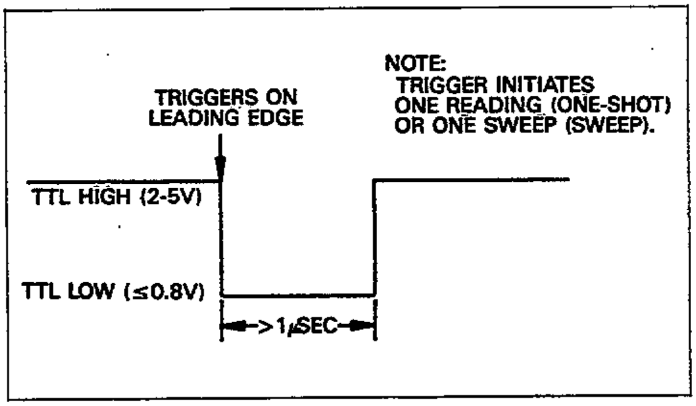


Figure 3-16. External Trigger Input Pulse Specification

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.

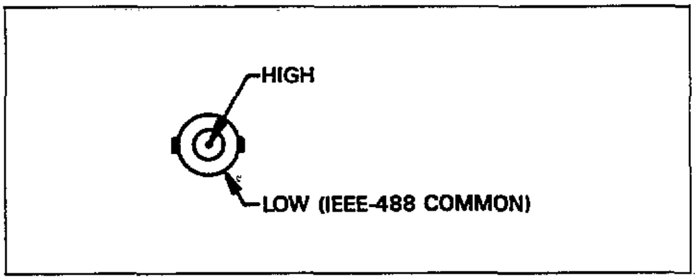


Figure 3-17. Trigger Input and Output Jack Configuration

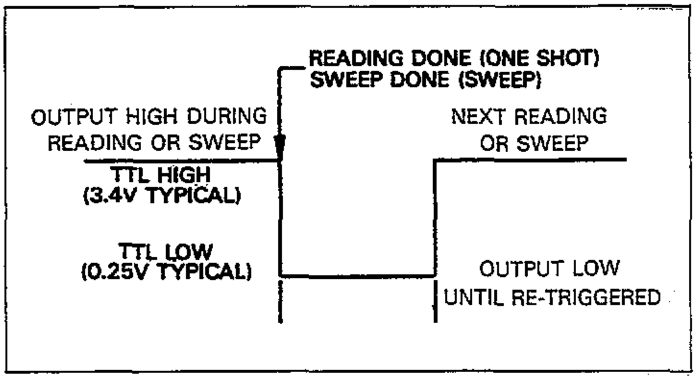


Figure 3-18. External Trigger Output Pulse Specification

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.

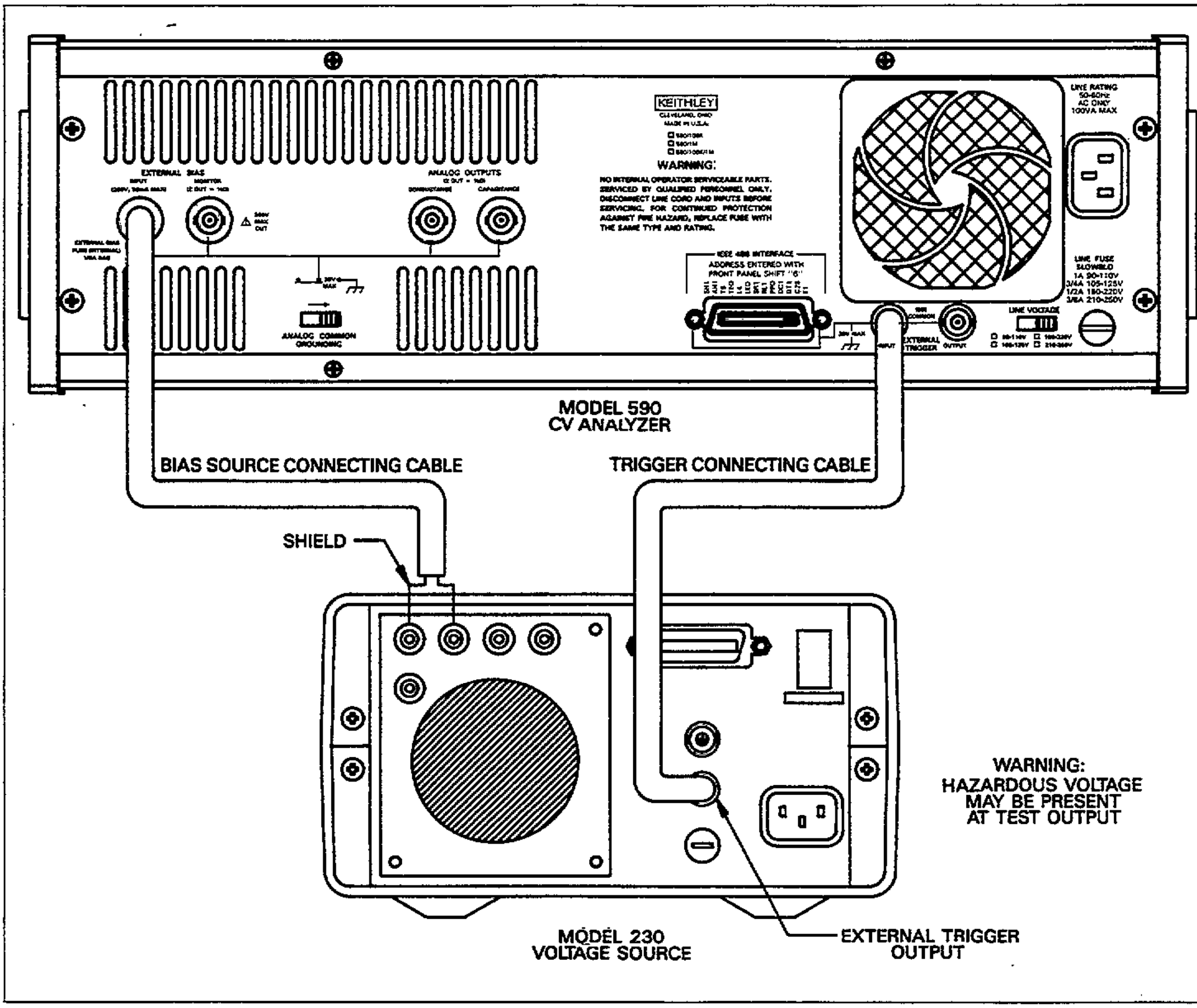
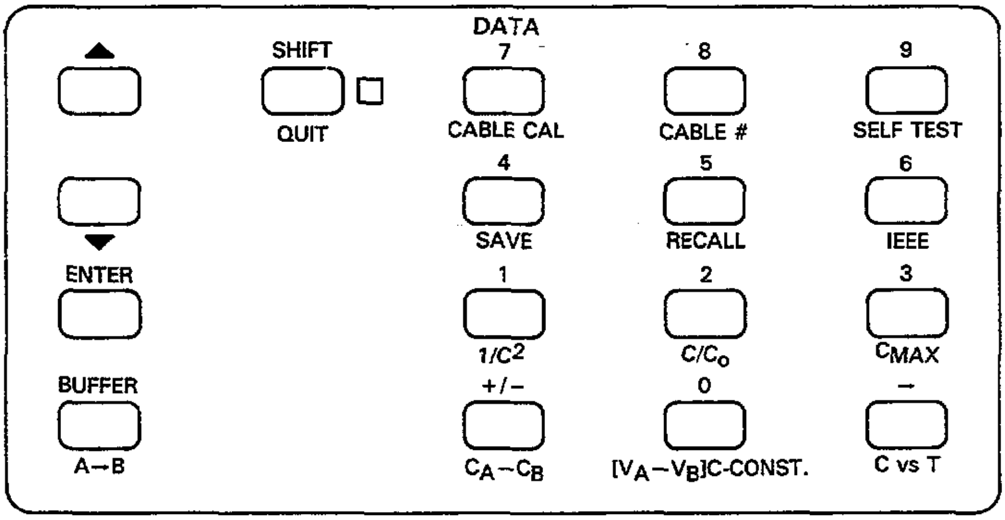


Figure 3-19. External Triggering Connections

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.



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.

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. 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.

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

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.

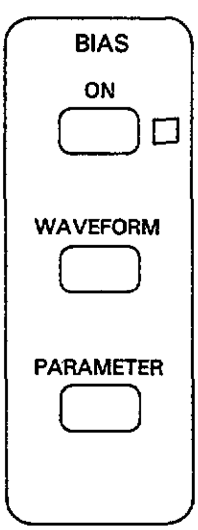
1. Press PARAMETER and note that the instrument displays the start time, as in this example:

   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.

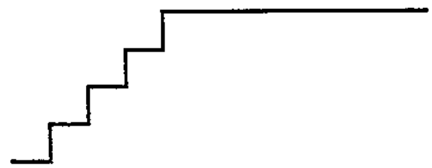
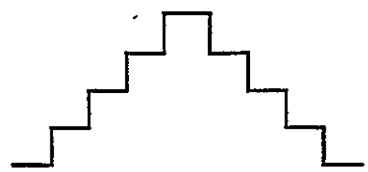
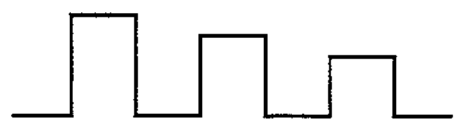
If you wish to return to the previously programmed waveform, press QUIT instead.

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.

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 ≤450 or ≤1,350).
4. Voltage parameters can be programmed to 1mV resolution, but actually have 5mV minimum steps.

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).

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

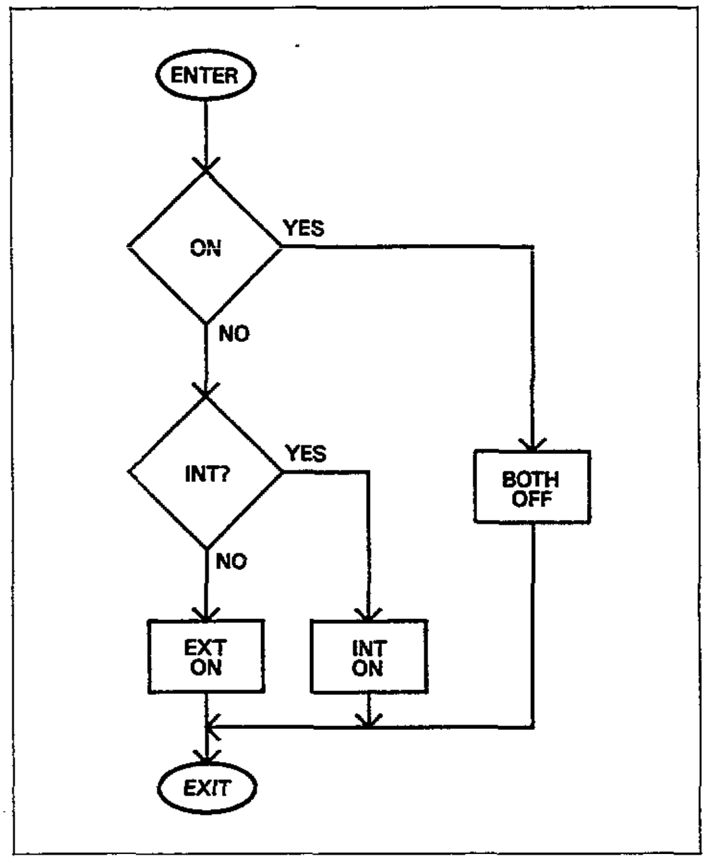


Figure 3-20. Bias ON Key Operation

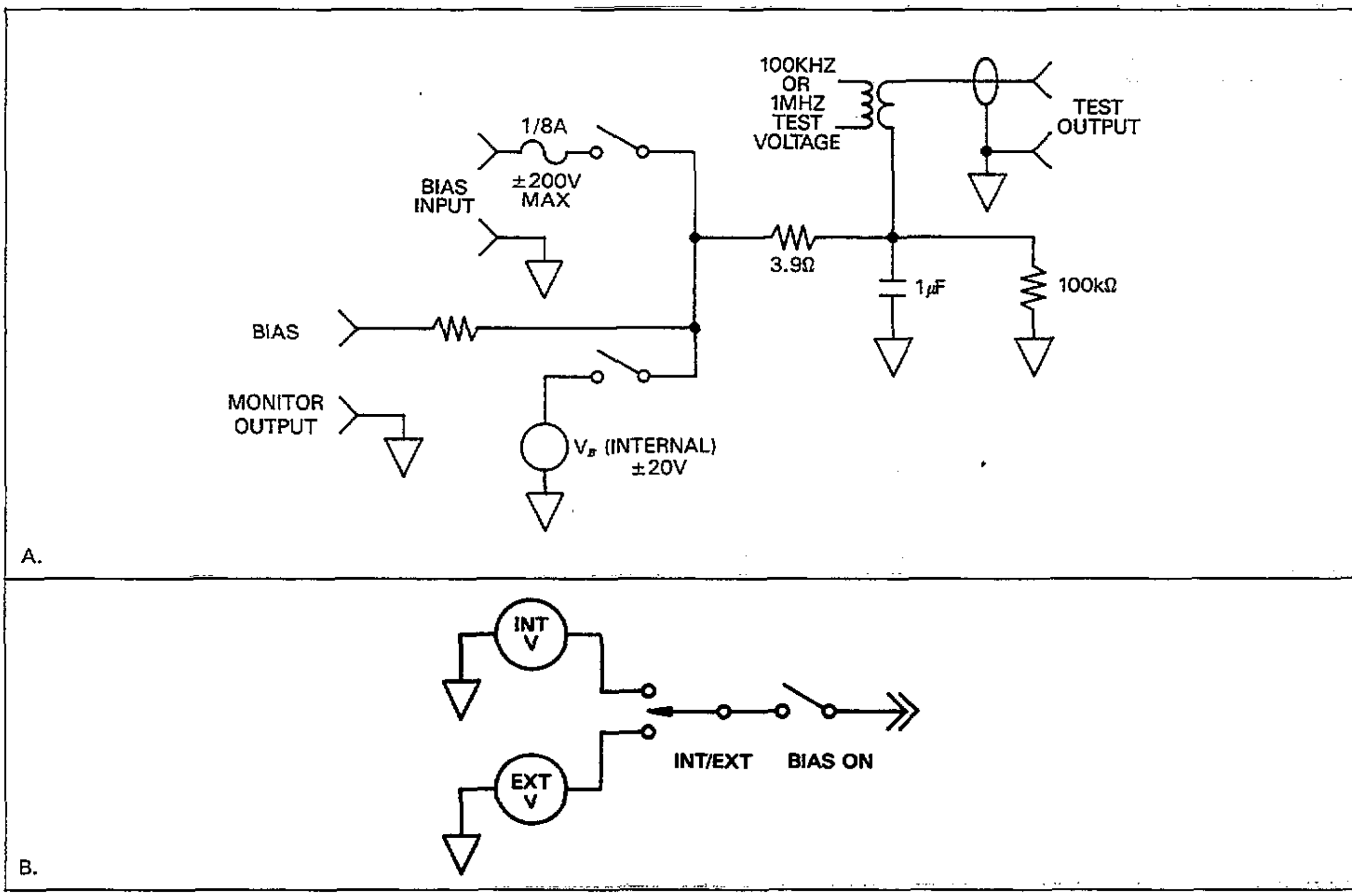


Figure 3-21. Bias Switching Network (a) Software Implementation of Bias ON (b)

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.

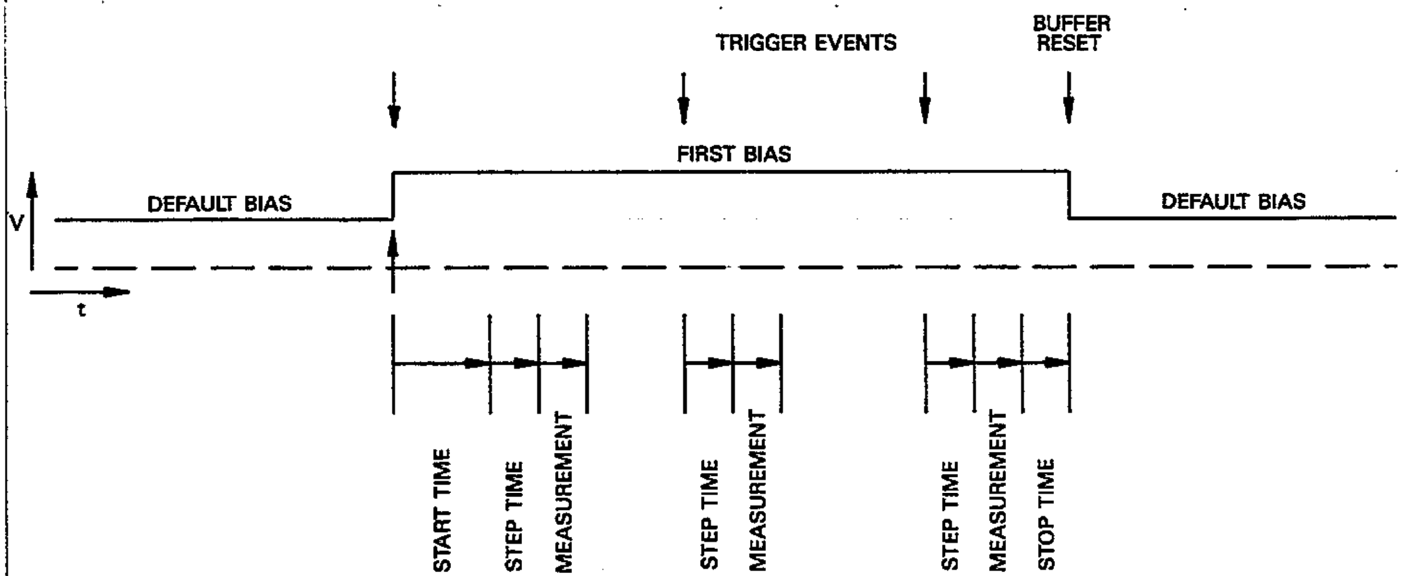
Default Bias: The bias voltage value both before and after a sweep, or between pulses (pulse train only).

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

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.



NOTES:
1. ONE TRIGGER PER READING IS REQUIRED.
2. NUMBER OF READINGS IS DETERMINED BY COUNT PARAMETER.
3. BUFFER IS RESET BY NEXT TRIGGER AFTER COUNT # OF READINGS ARE TAKEN.

Figure 3-22. DC, One-Shot

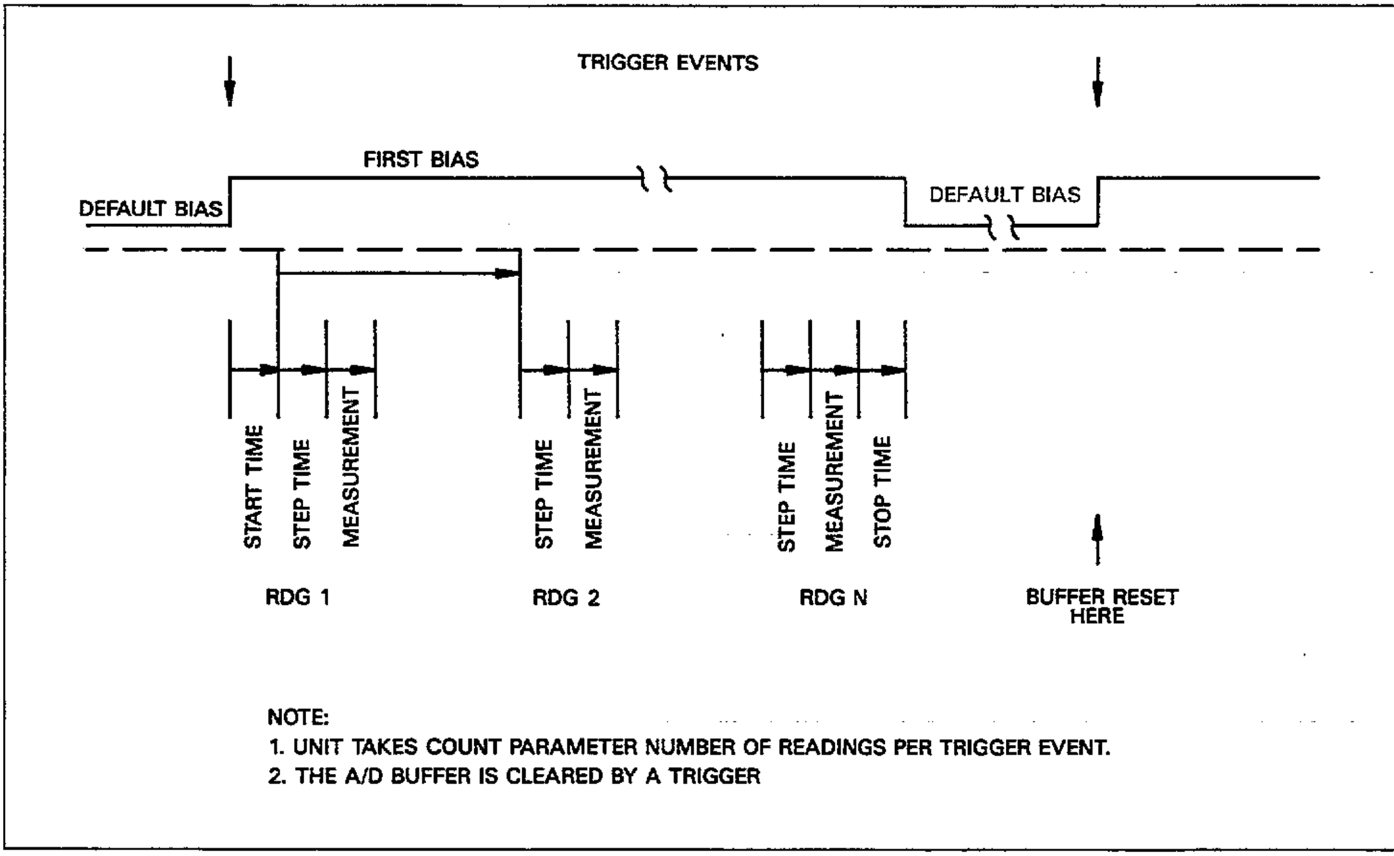


Figure 3-23. DC, Single Sweep

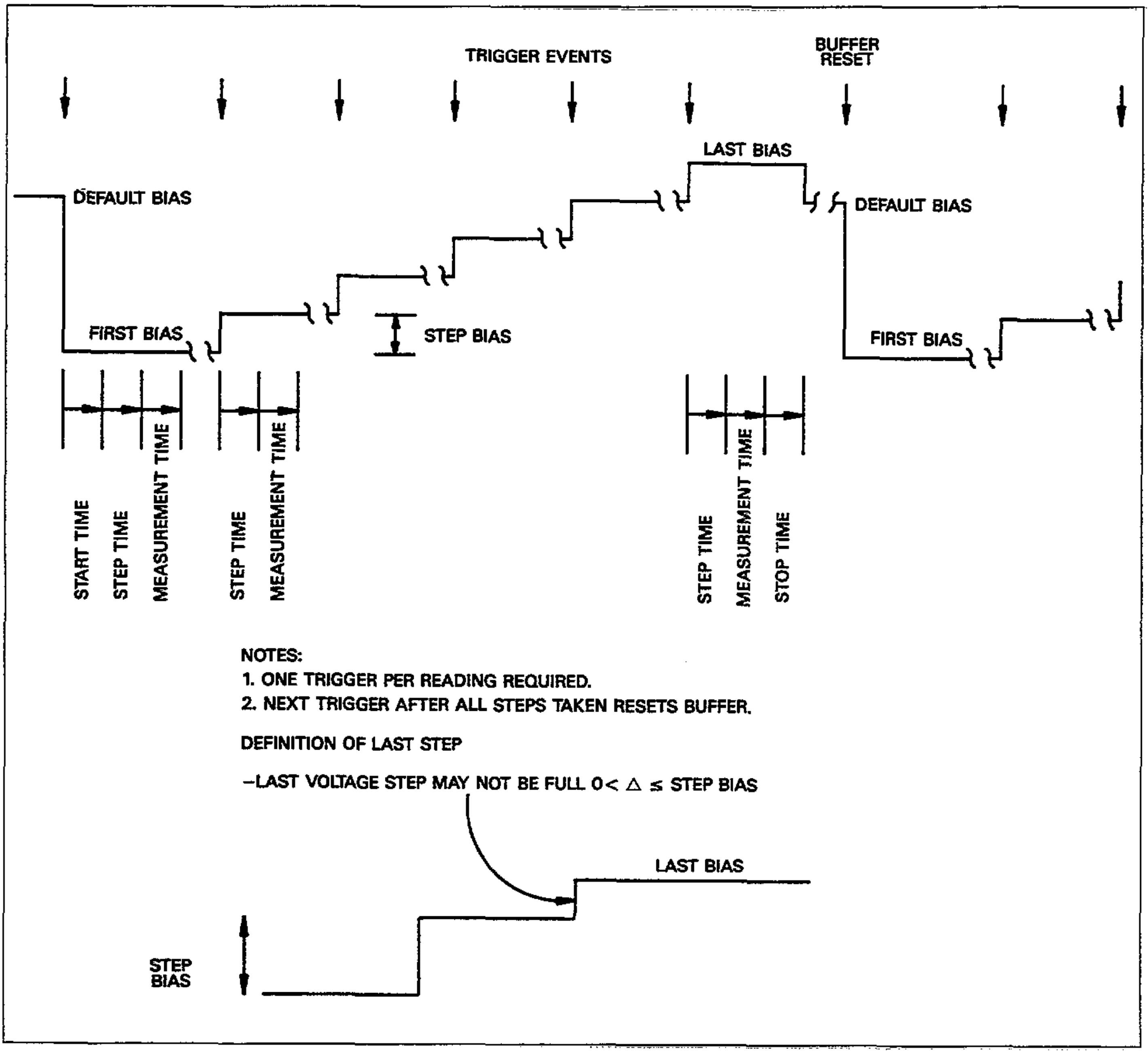


Figure 3-24. Single Staircase, One-Shot

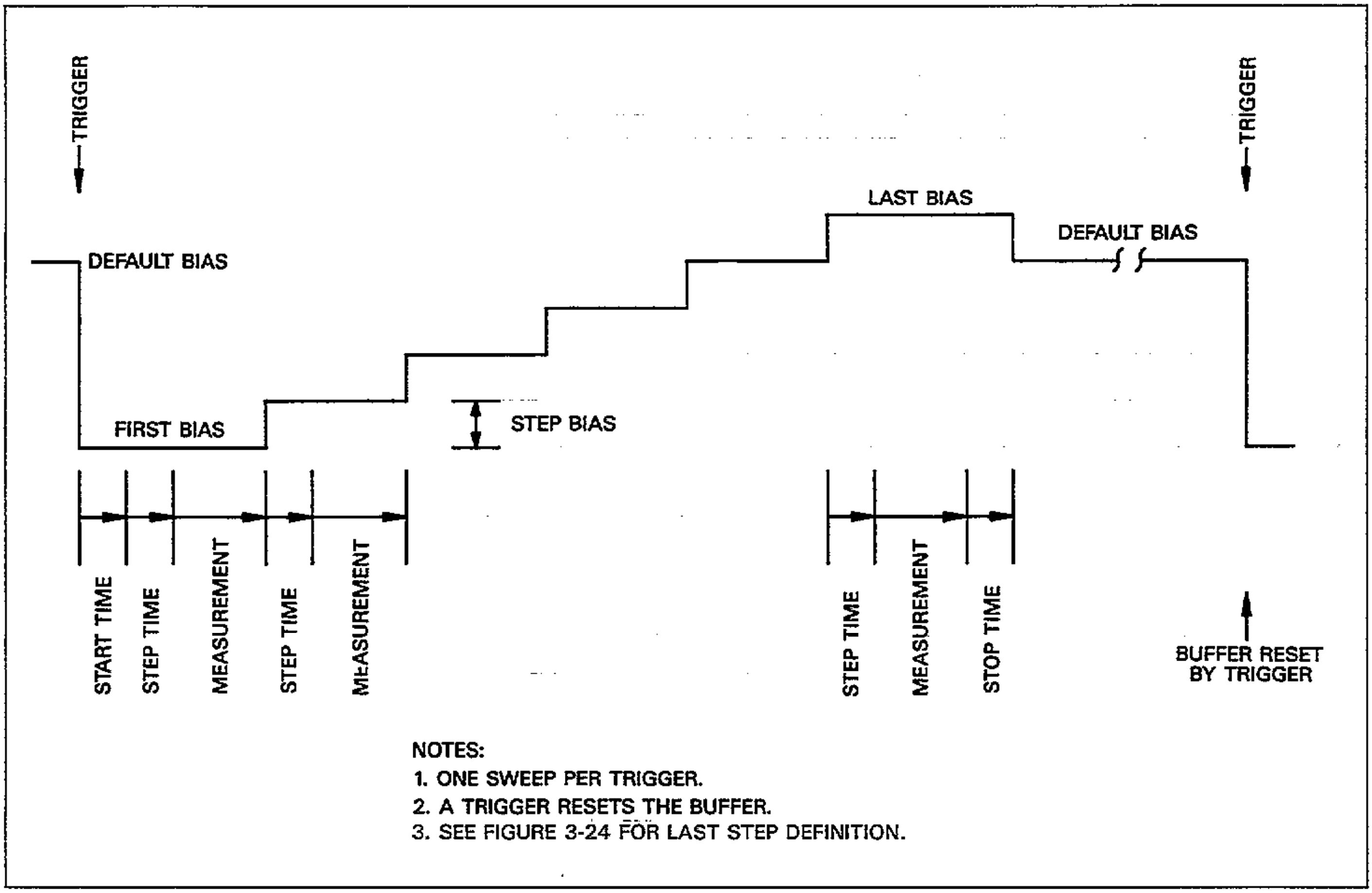


Figure 3-25. Single Staircase, Sweep

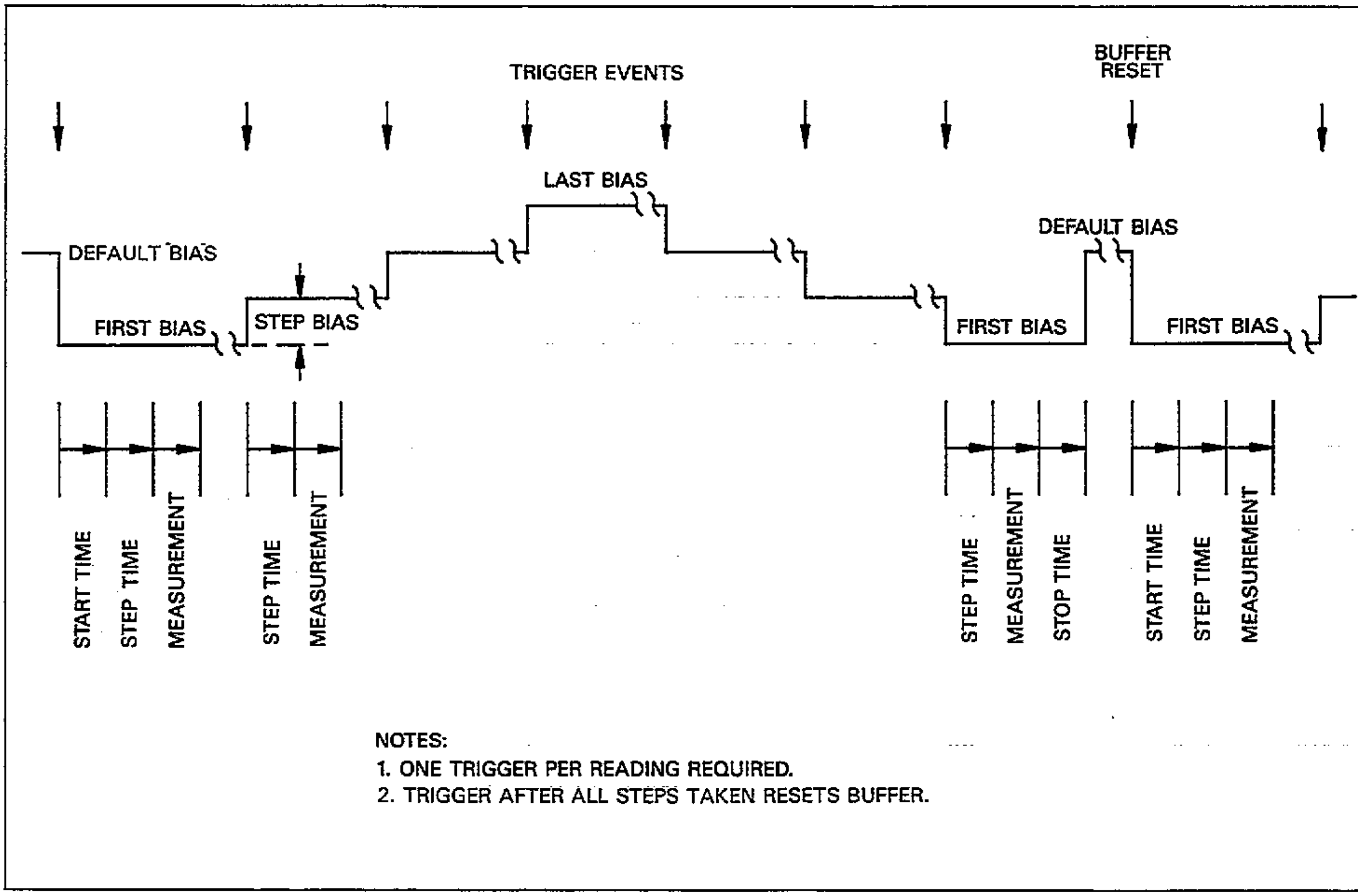


Figure 3-26. Dual Staircase, One-Shot

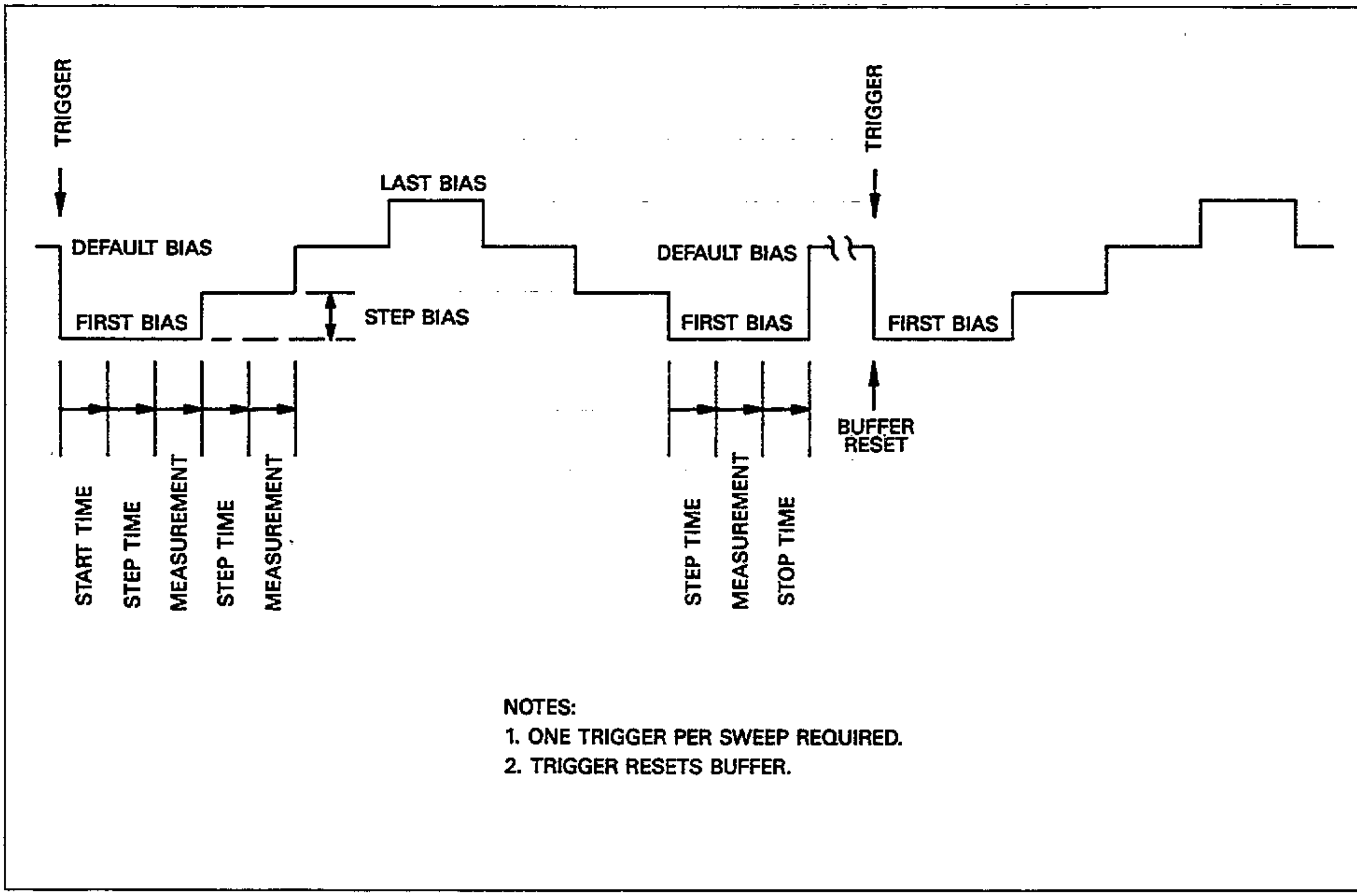


Figure 3-27. Dual Staircase, Single Sweep

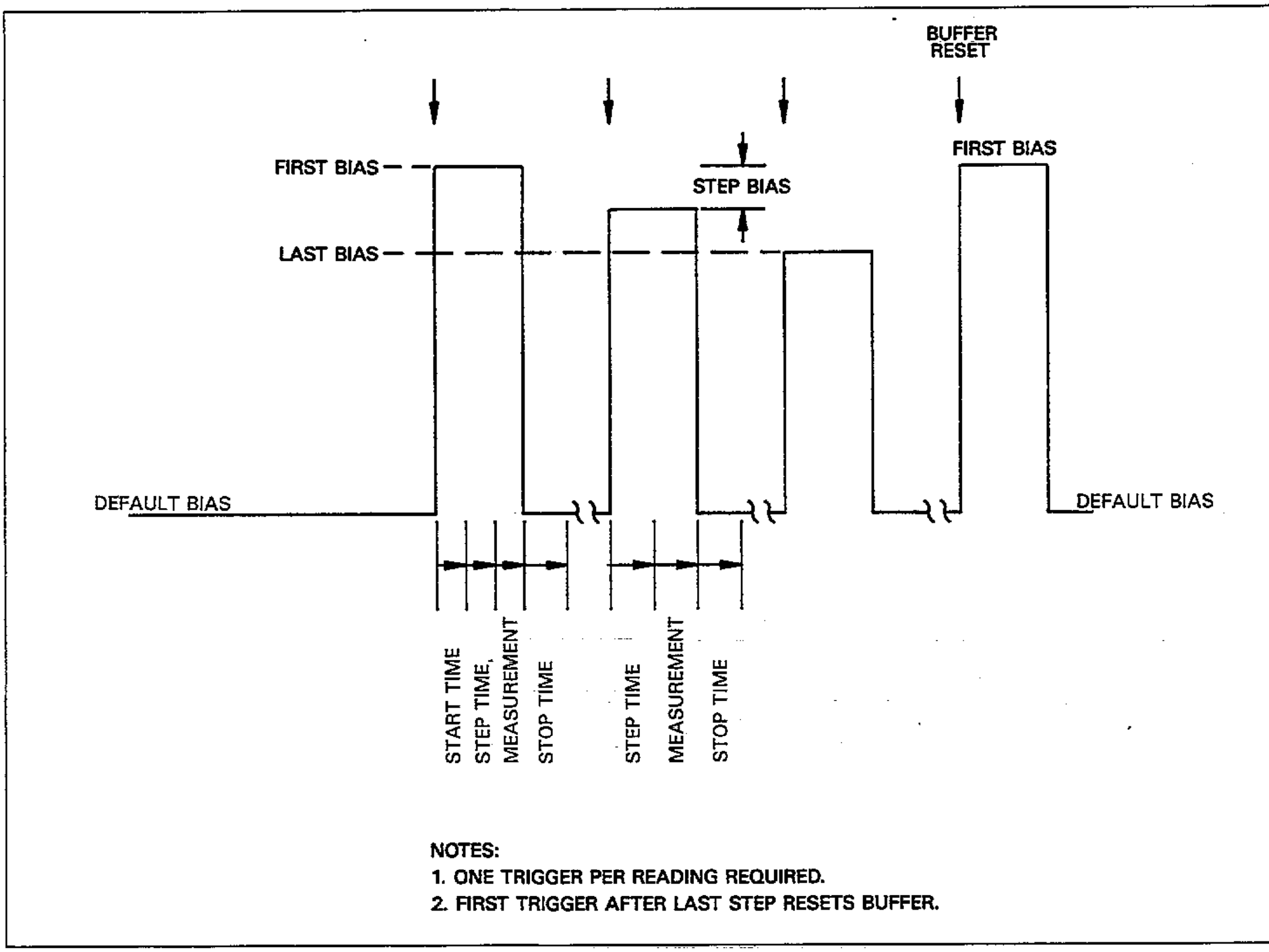


Figure 3-28. Pulse Train, One-Shot

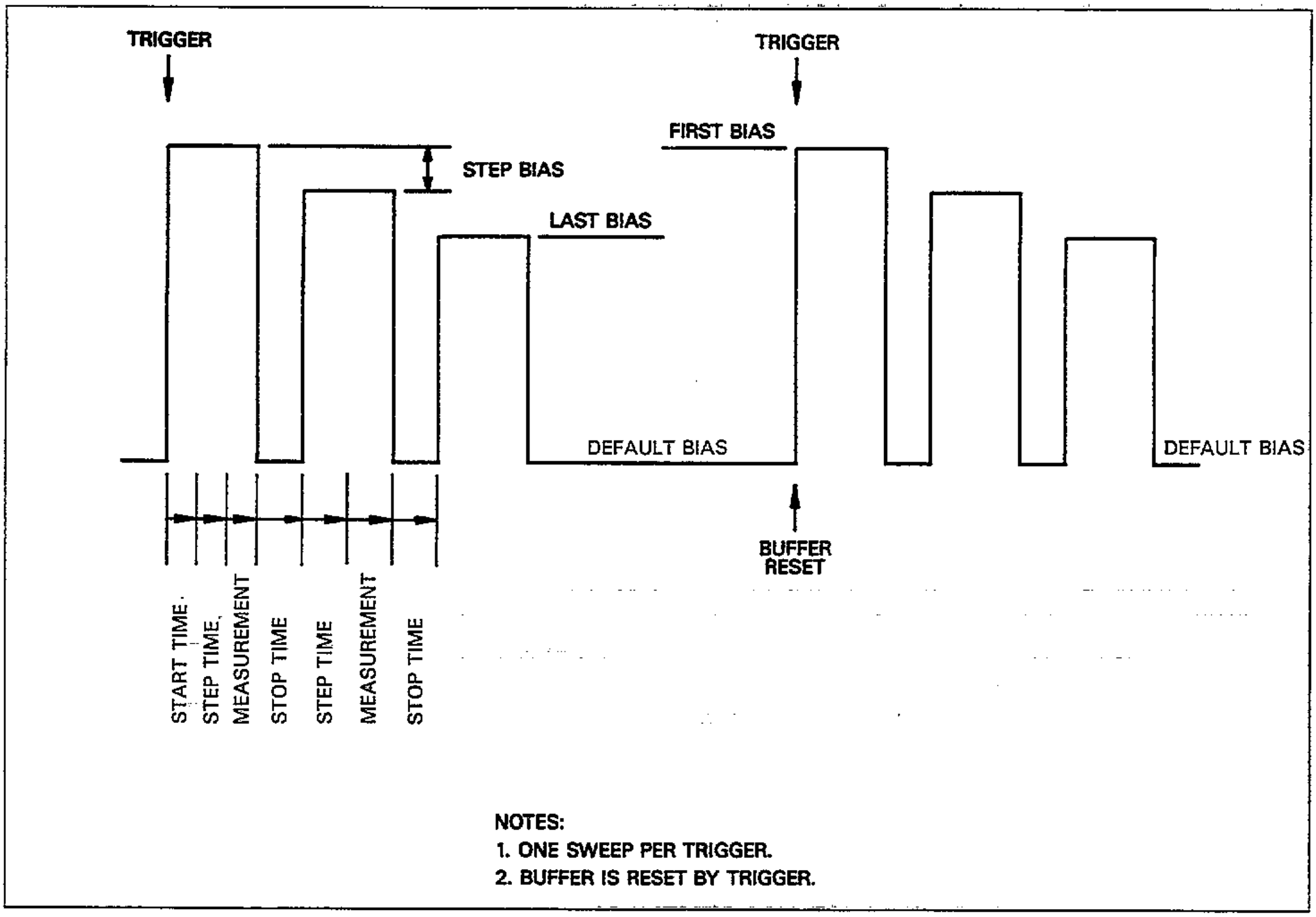
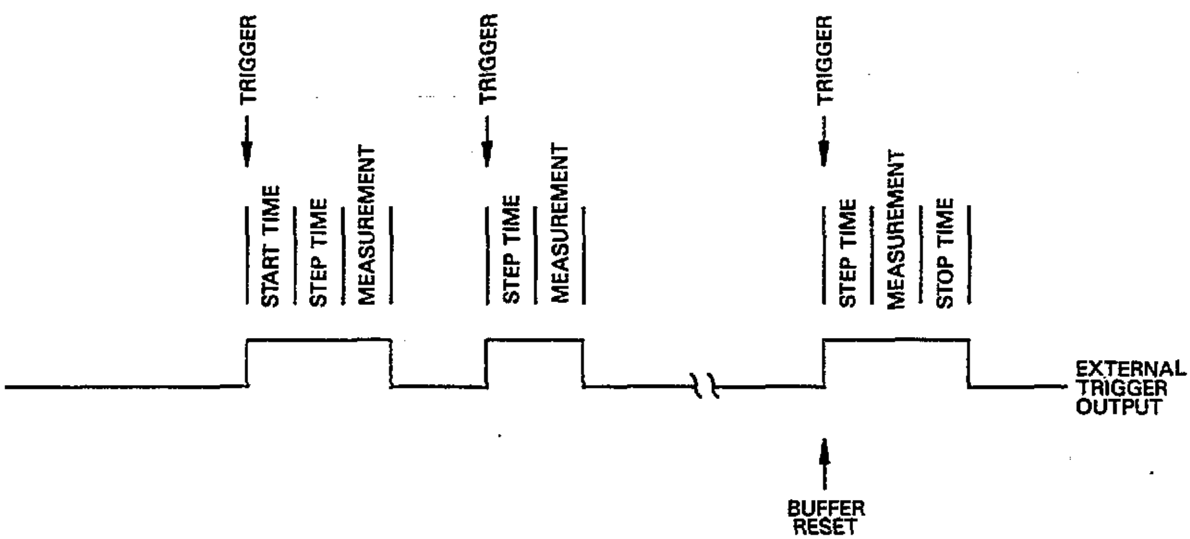
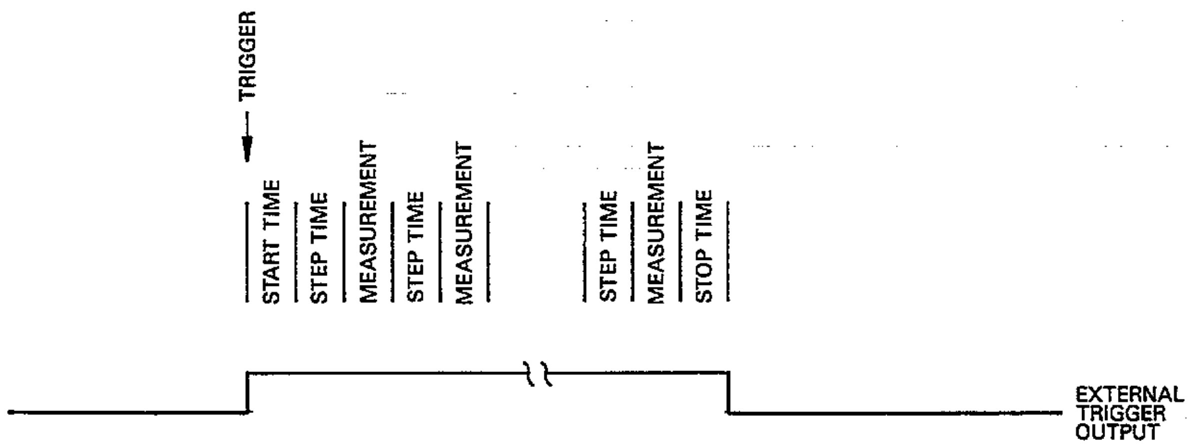


Figure 3-29. Pulse Train, Single Sweep



NOTES:
1. COUNT # OF READINGS ARE STORED IN BUFFER.
2. FIRST CYCLE ONLY INCLUDES START TIME.
3. LAST CYCLE ONLY INCLUDES STOP TIME.
4. FIRST TRIGGER AFTER COUNT # READINGS RESETS THE BUFFER.
5. WAVEFORM SHOWN DEPICTS EXTERNAL TRIGGER OUTPUT -- NOT BIAS WAVEFORM.

Figure 3-30. External, One-Shot



NOTES:
1. ONE TRIGGER PER READING REQUIRED.
2. FIRST TRIGGER AFTER LAST STEP RESETS BUFFER.
3. COUNT READINGS ARE STORED IN BUFFER.
4. WAVEFORM SHOWN DEPICTS EXTERNAL TRIGGER OUTPUT NOT BIAS WAVEFORM.

Figure 3-31. External, Single-Sweep

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.

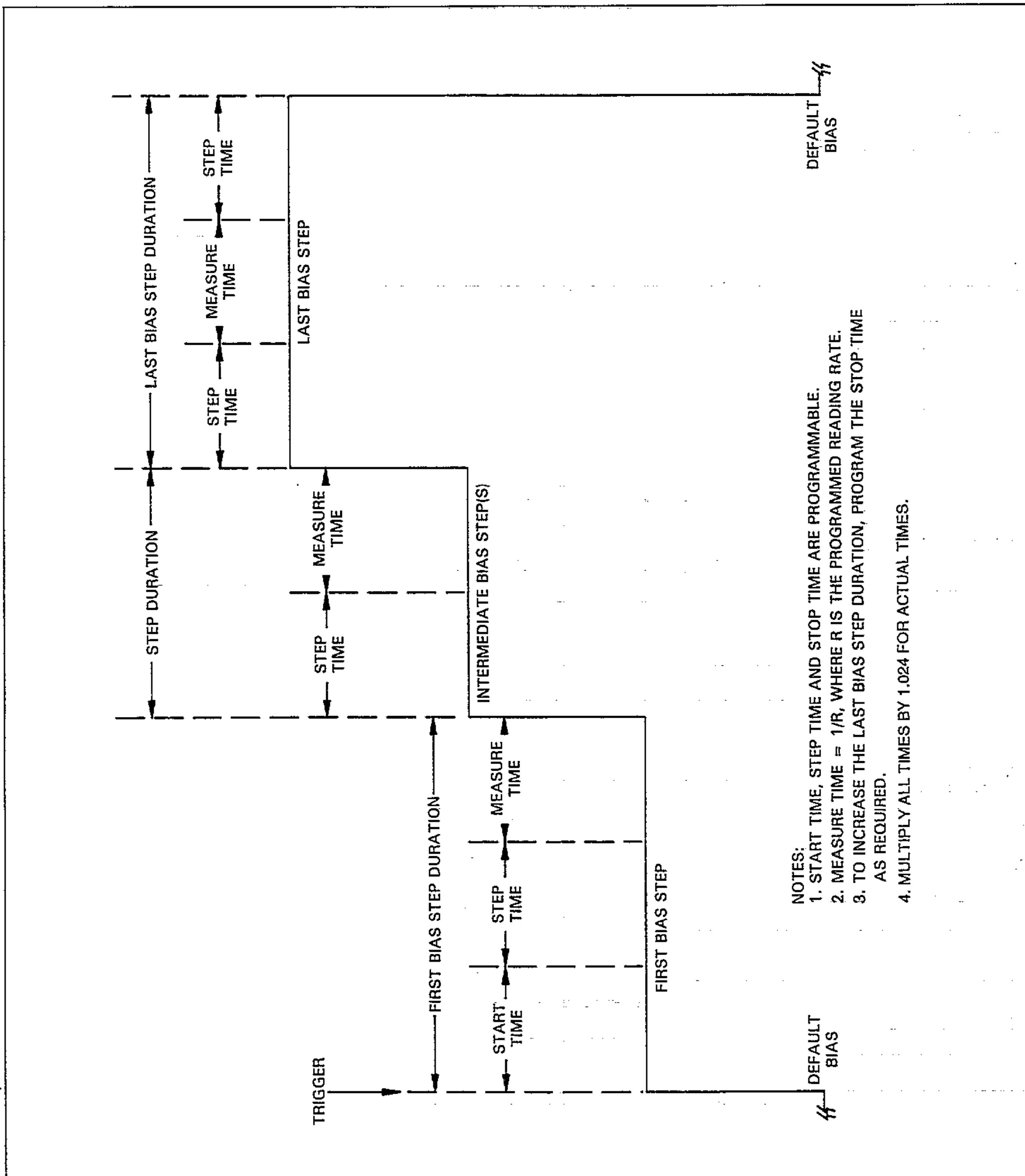


Figure 3-32. Bias Step Durations

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.

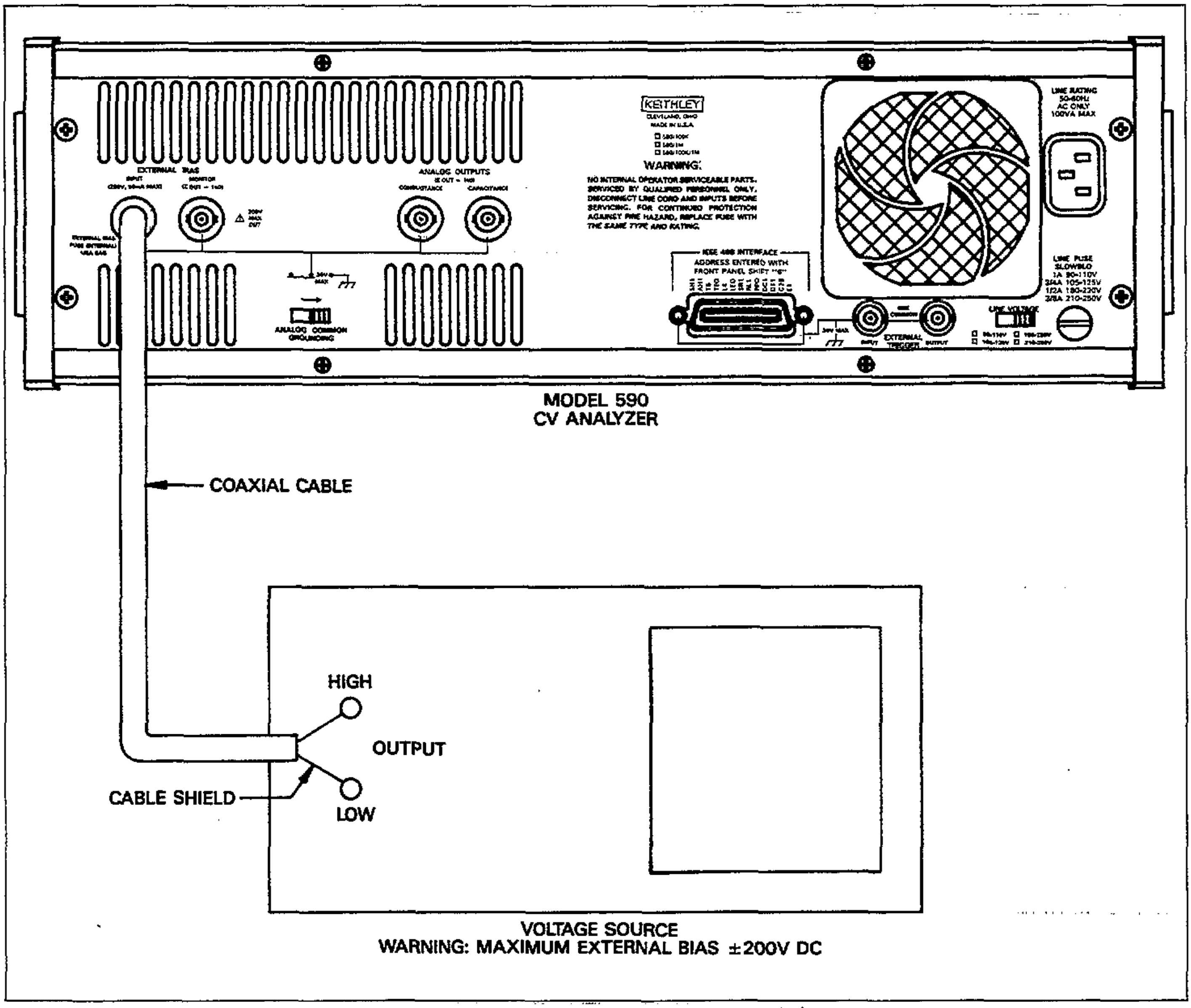


Figure 3-33. External Bias Source Connections

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.

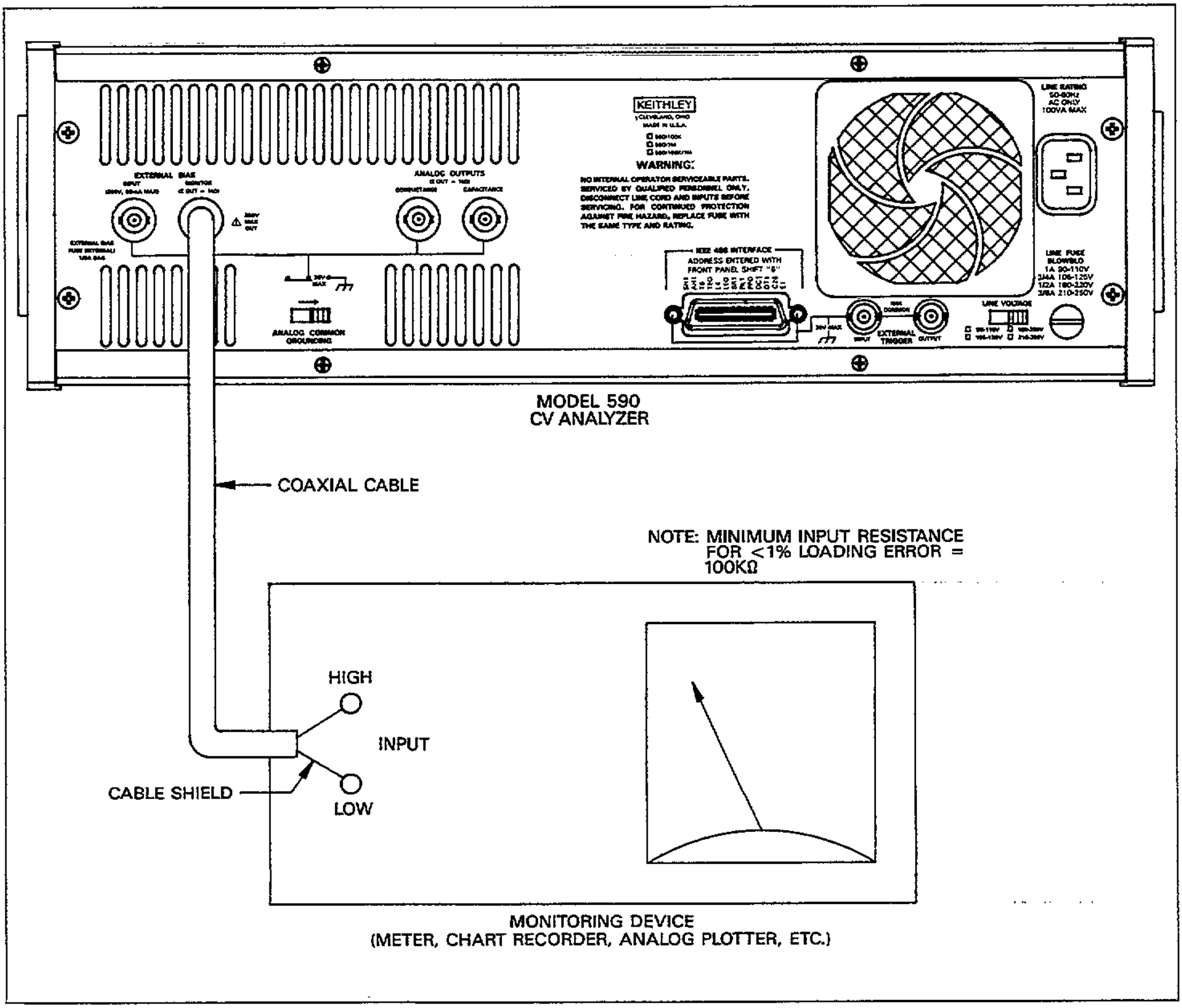
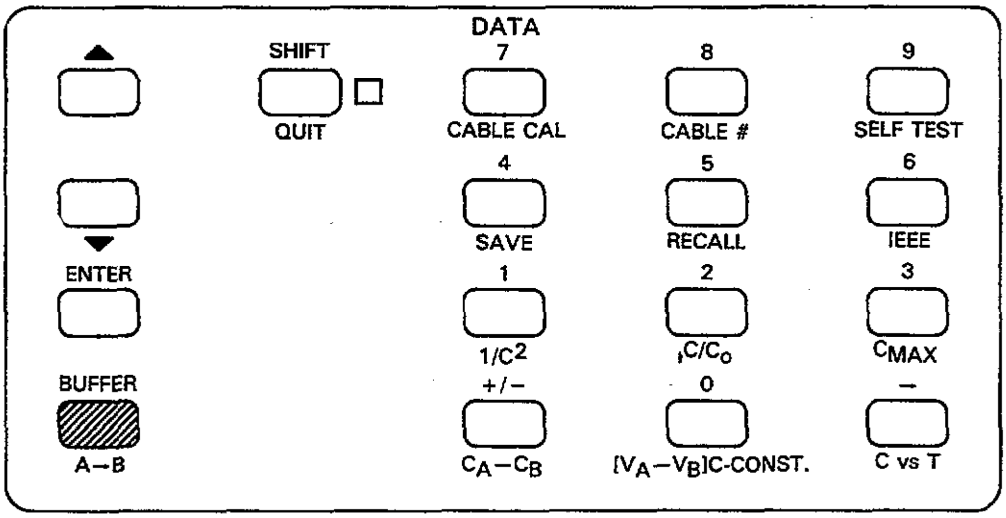


Figure 3-34. Bias Monitor Connections



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.

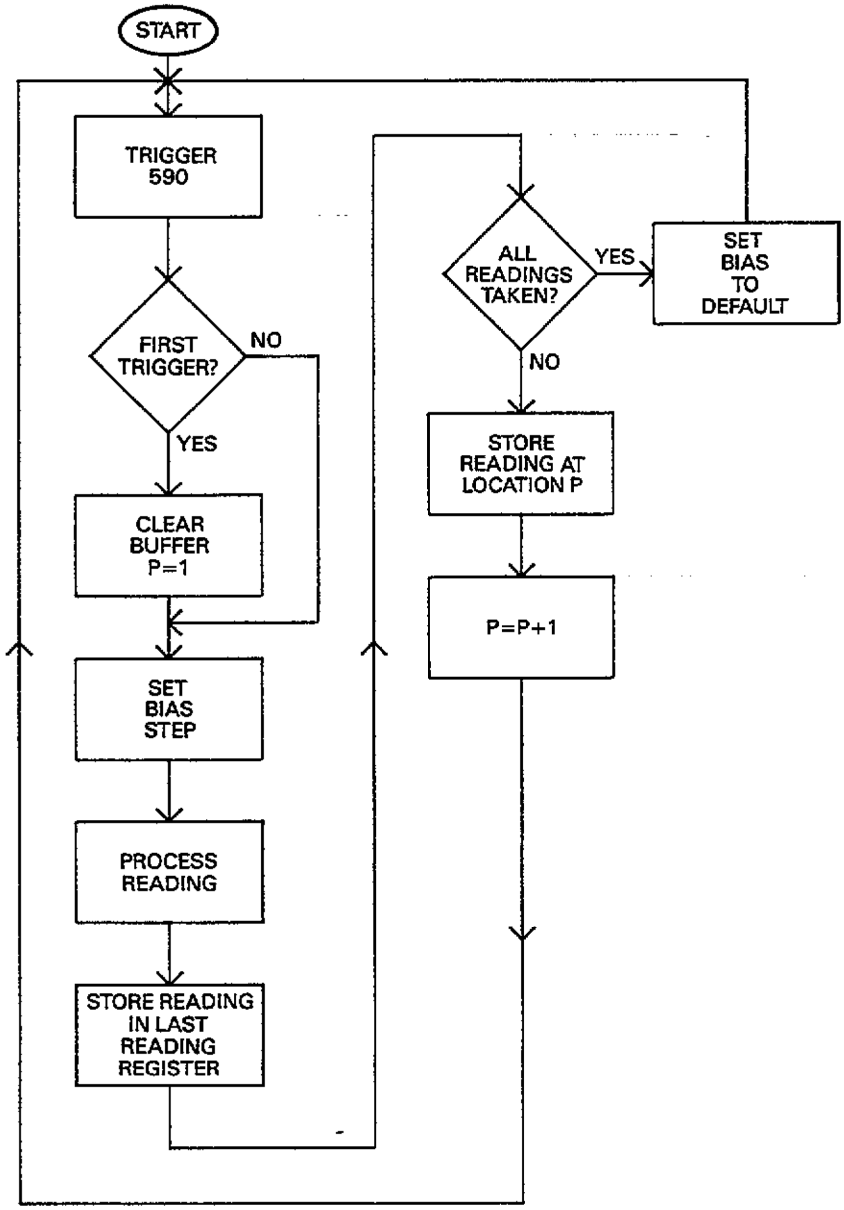
Buffer Location Numbers—Buffer locations are numbered 1 through 450 inclusive, for a total of 450 locations. Each location stores a capacitance, conductance, and bias voltage reading. The unit stores data sequentally in lowest to highest order, beginning at location 1.

NOTE

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

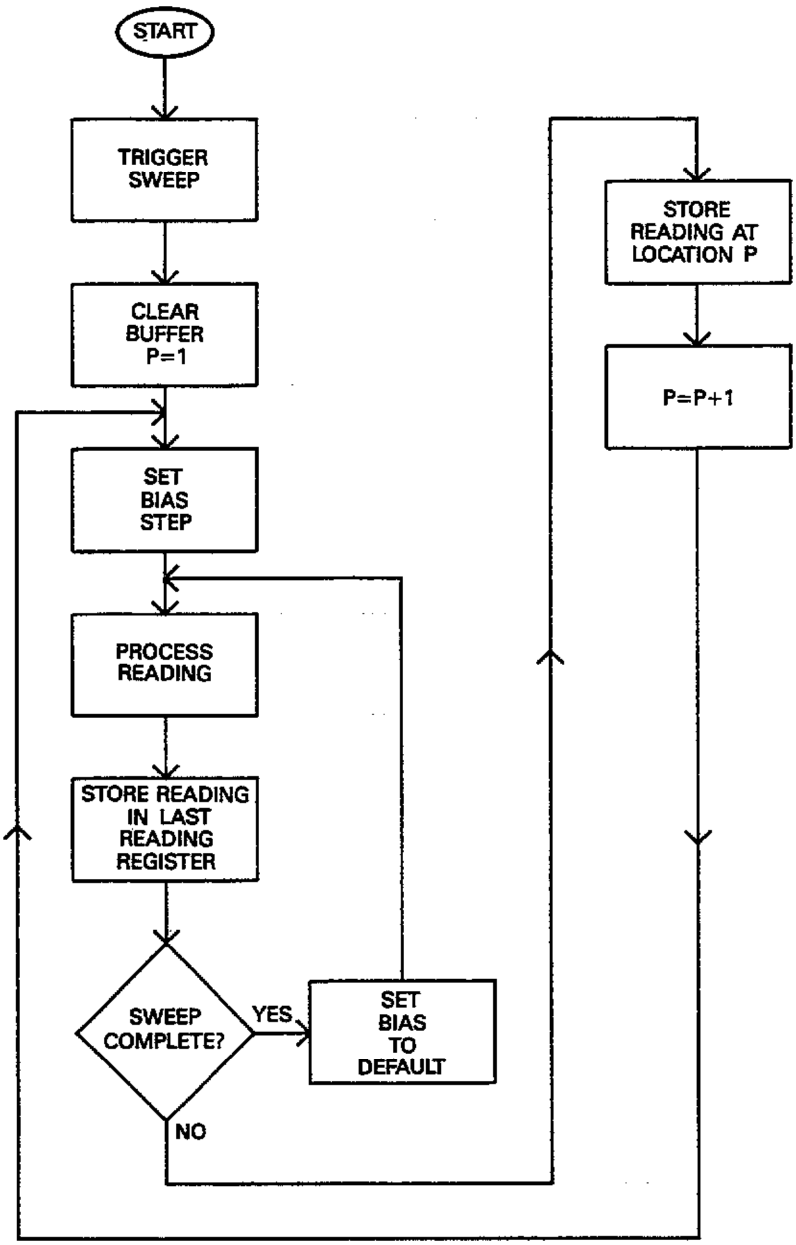
3.15.2 How Trigger Modes Affect the A/D Buffer

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.



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



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

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 sequentally 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

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.

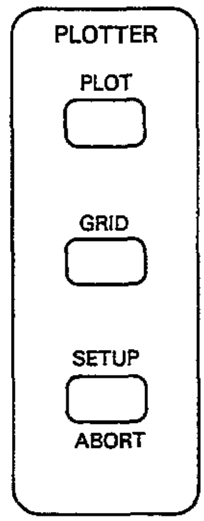
NOTES:

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.

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.

XY PARAMETERS(, OPTIONAL PARAMETERS);

INSTRUCTION MNEMONIC (SEE TABLE)

TERMINATOR

NOTES:
1. NO SEPARATORS IN INSTRUCTION MNEMONIC.
2. COMMA ONLY TO SEPARATE PARAMETERS.
3. PARENTHESIS INDICATE OPTIONAL PARAMETERS AND ARE NOT ACTUALLY SENT.

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.

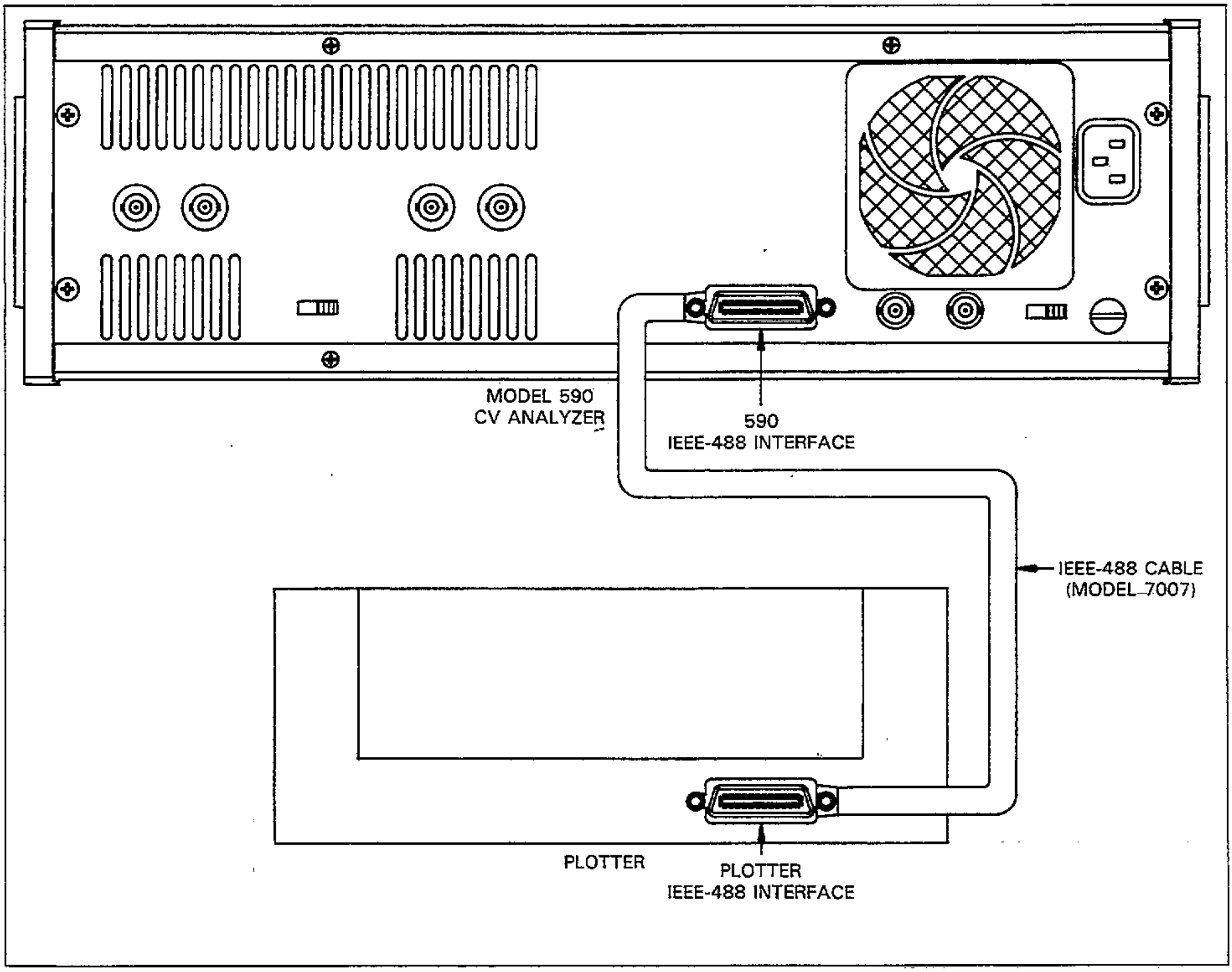


Figure 3-38. IEEE-488 Plotter Connections

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* 1 = G vs V (R vs V, 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
PEN TYPE	0 = No Pen 1 = Pen #1* 2 = Pen #2
LINE TYPE	0 = Dots at plotted 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*
GRID TYPE	0 = Full grid* 1 = Axis only
LABEL TYPE	0 = Full labels* 1 = Label axis and divisions (no title) 2 = Label axis only 3 = No labels
BUFFER	0 = Buffer A (A/D)* 1 = Buffer B (Plot)
X SCALE**	0 = Auto scale* 1 = User-programmed scale
Y SCALE**	0 = Auto Scale* 1 = User-programmed scale

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

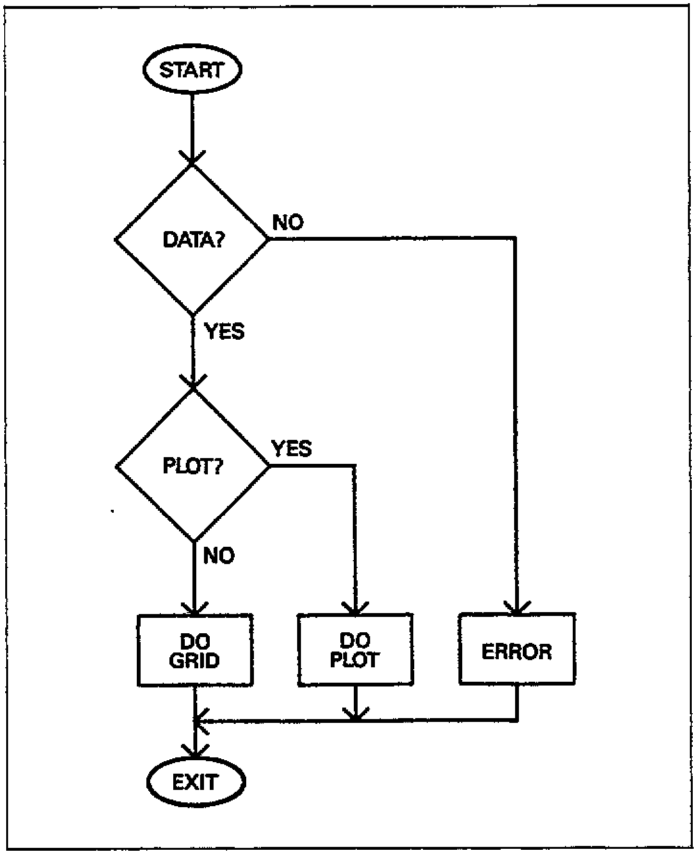


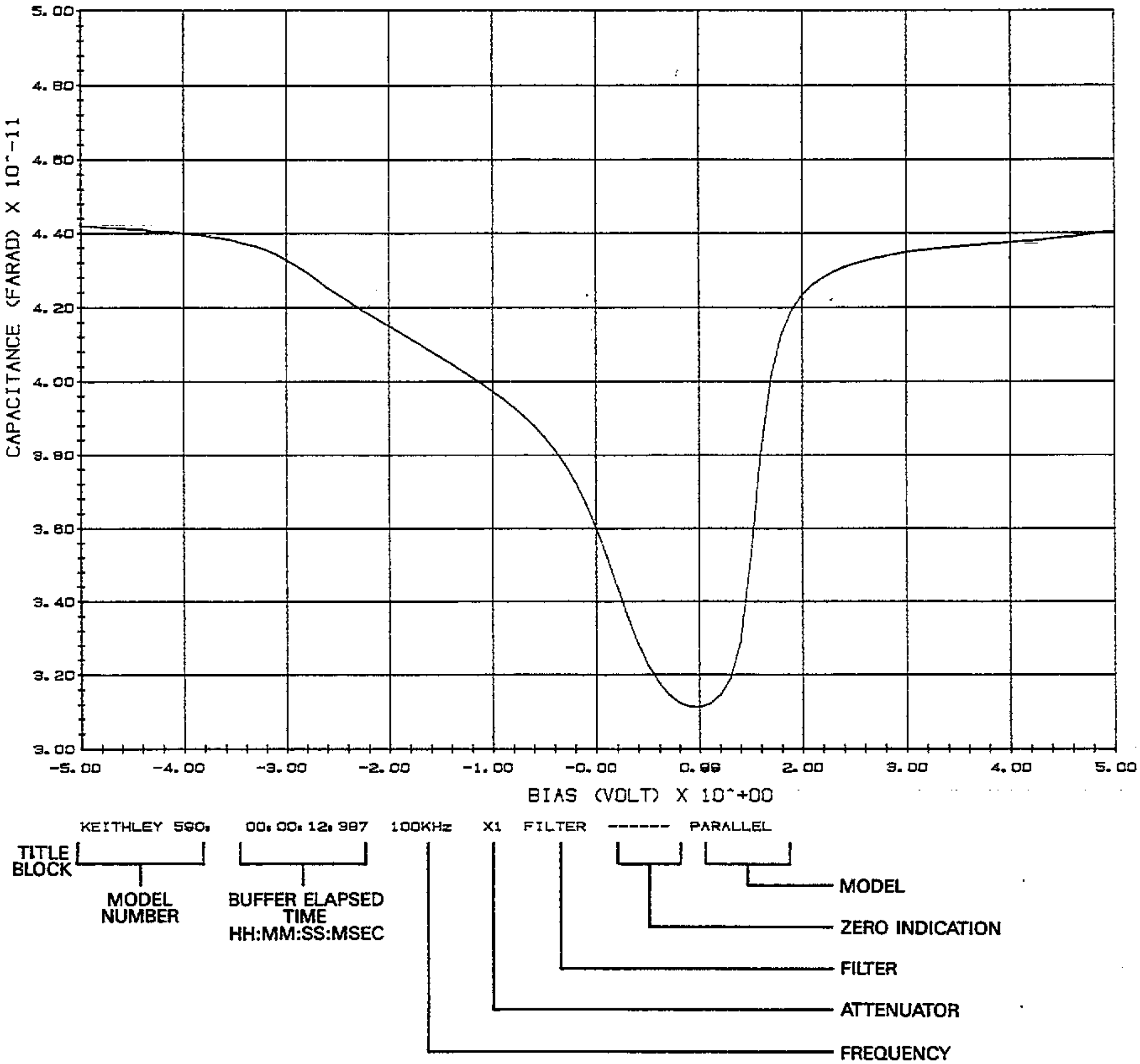
Figure 3-39. Plotting Flowchart

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.



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

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.

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=CO-NST	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.

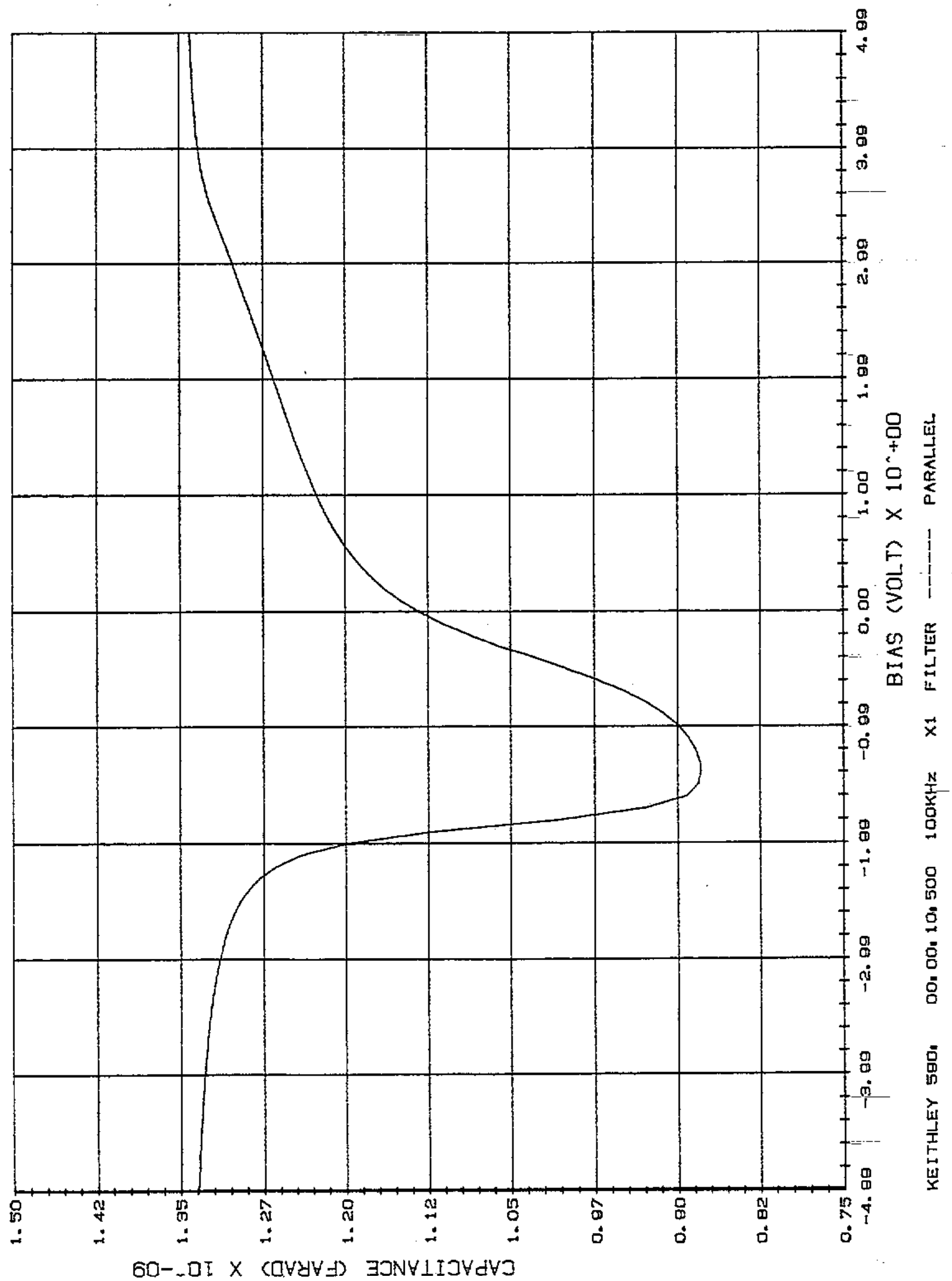


Figure 3-41. C vs V Example

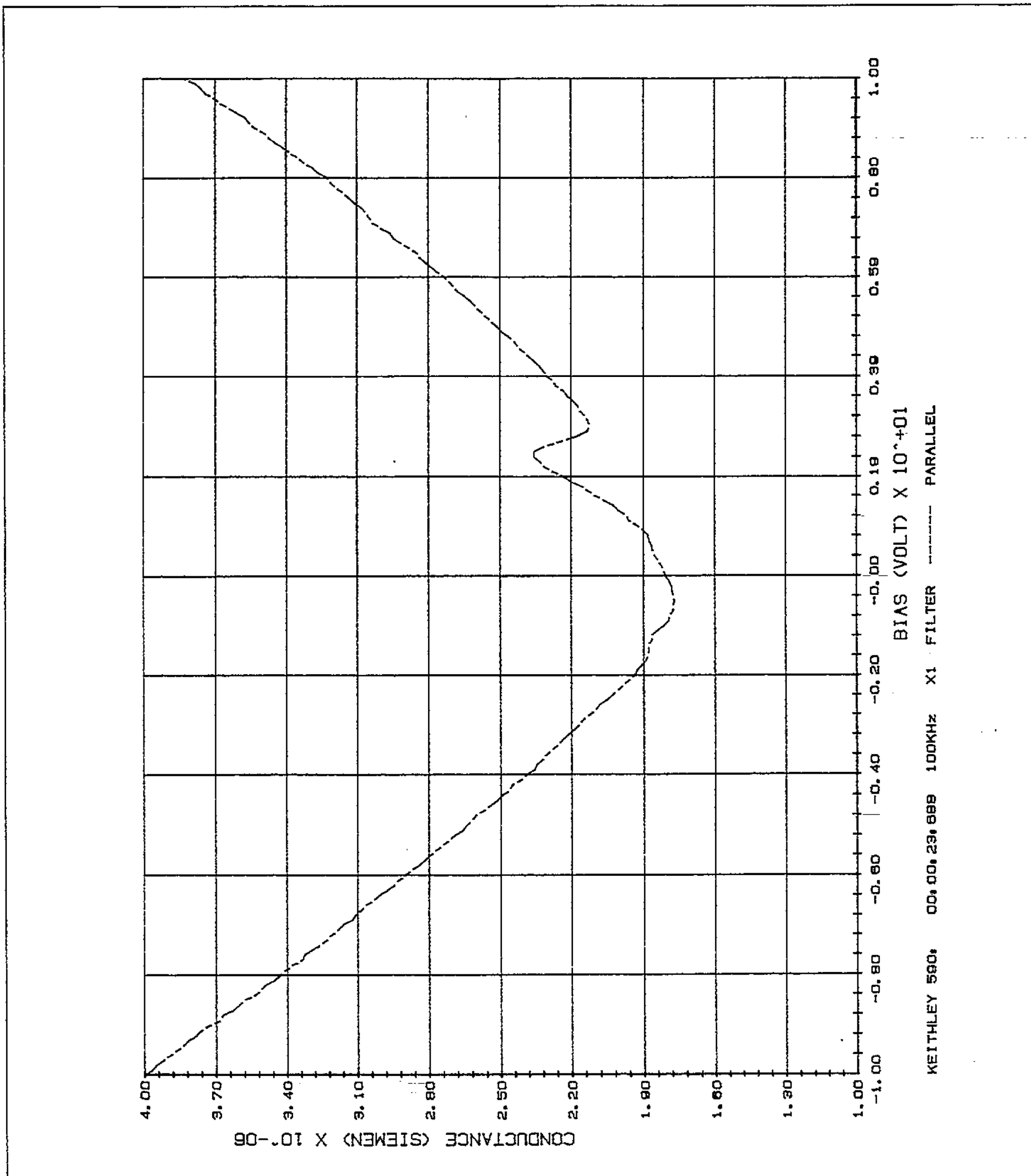


Figure 3-42. G vs V Example

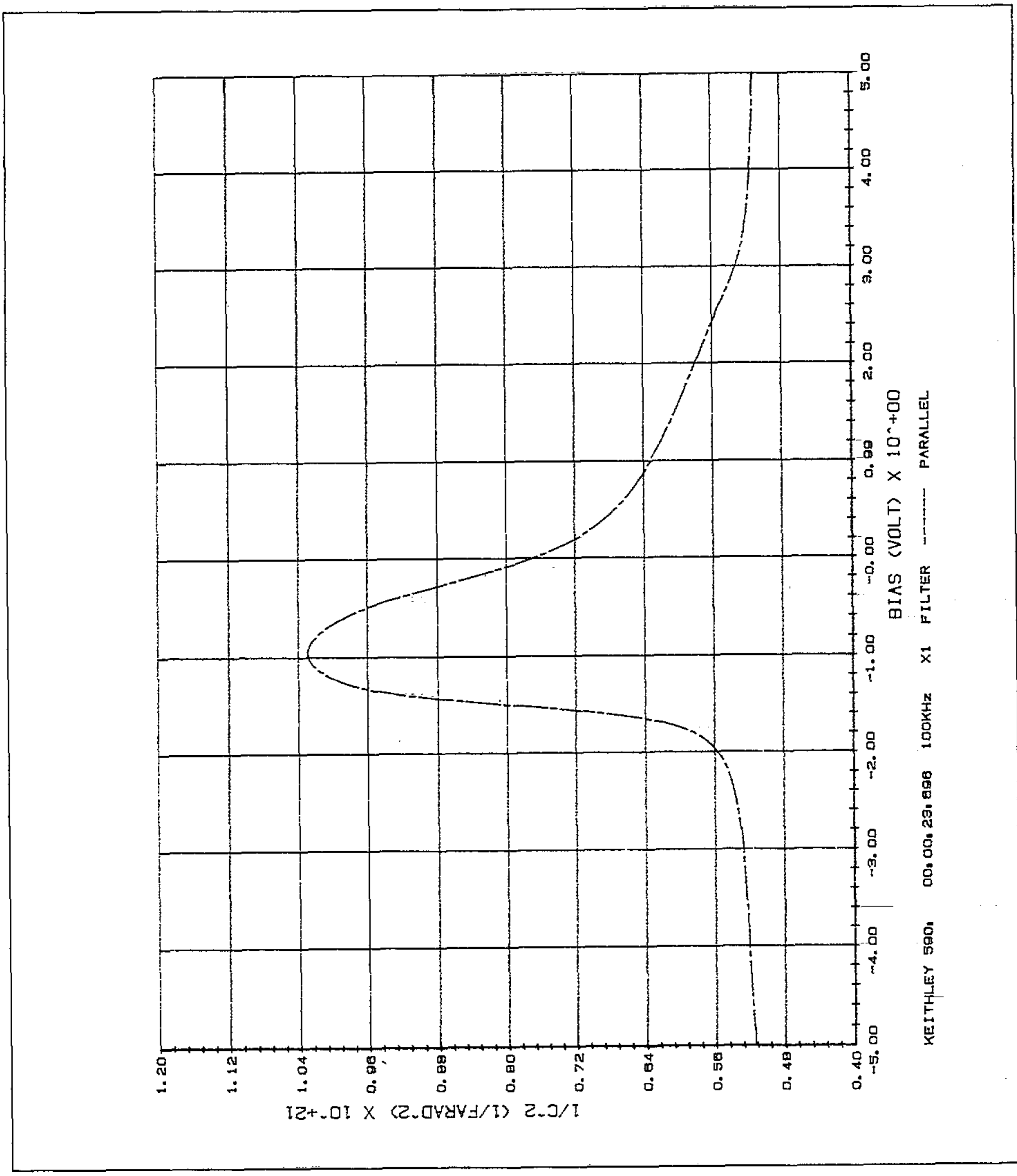


Figure 3-43. 1/C2 vs V Example

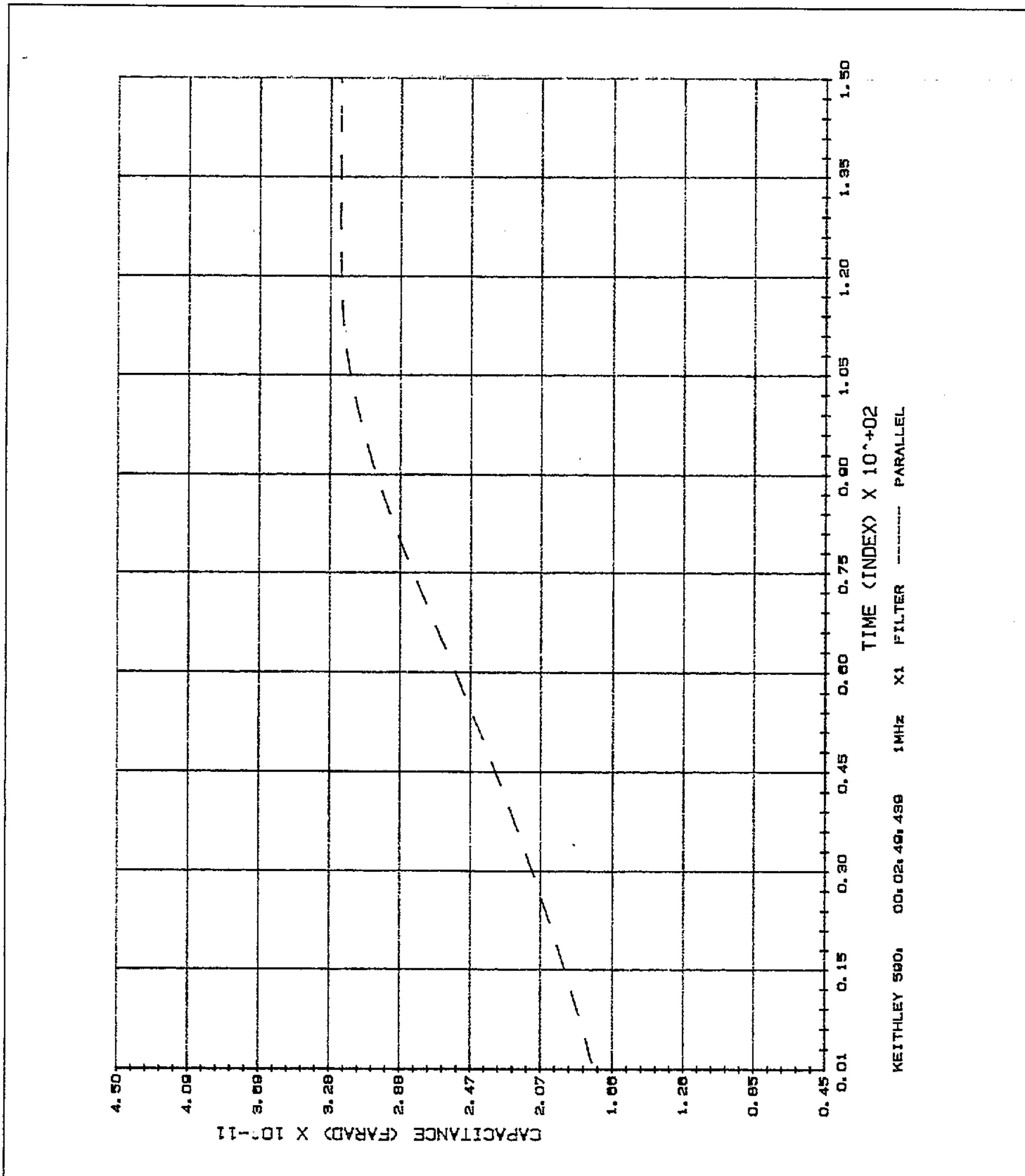


Figure 3-44. C vs t Example

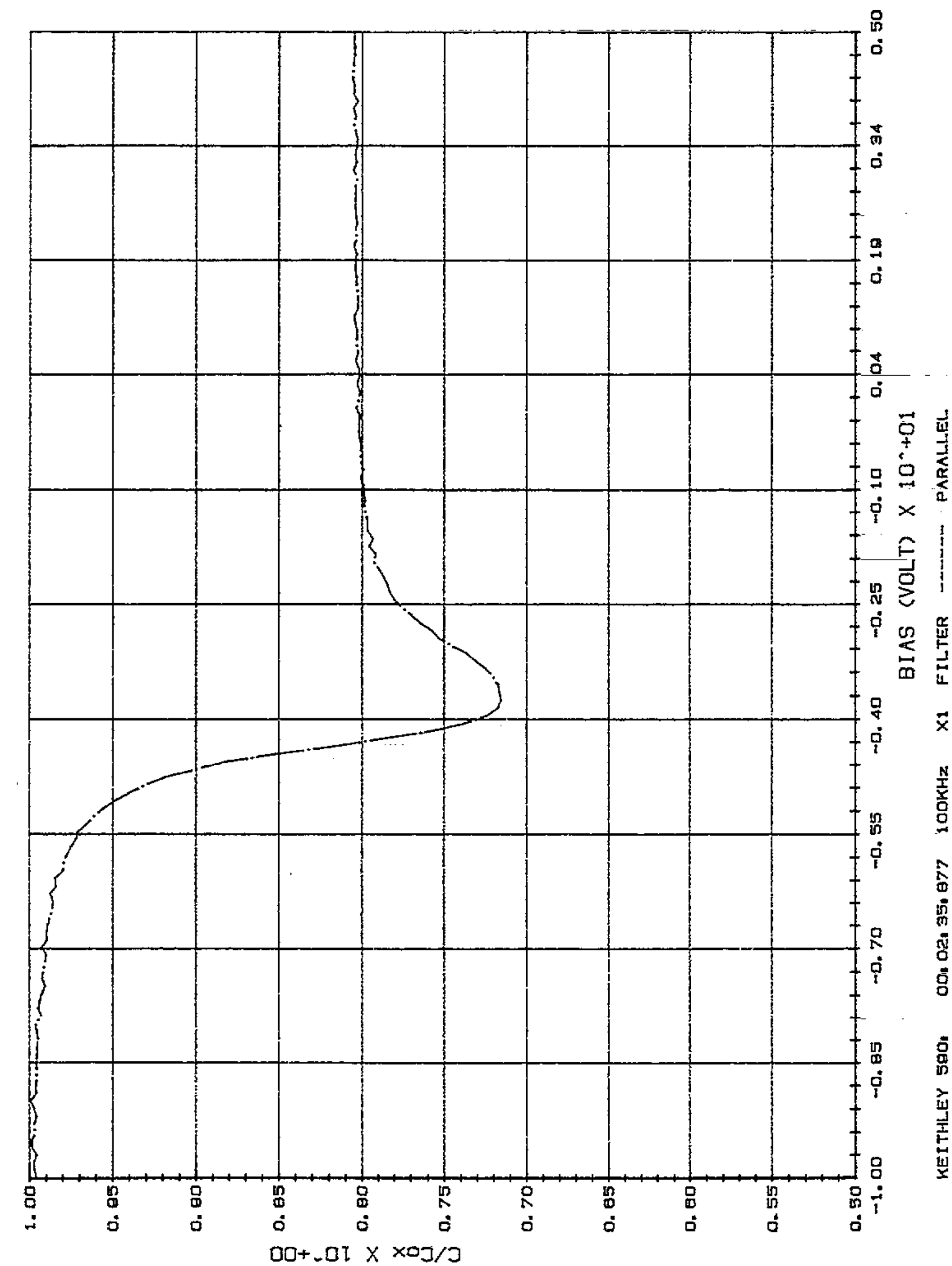


Figure 3-45. C/C$_O$ vs V Example

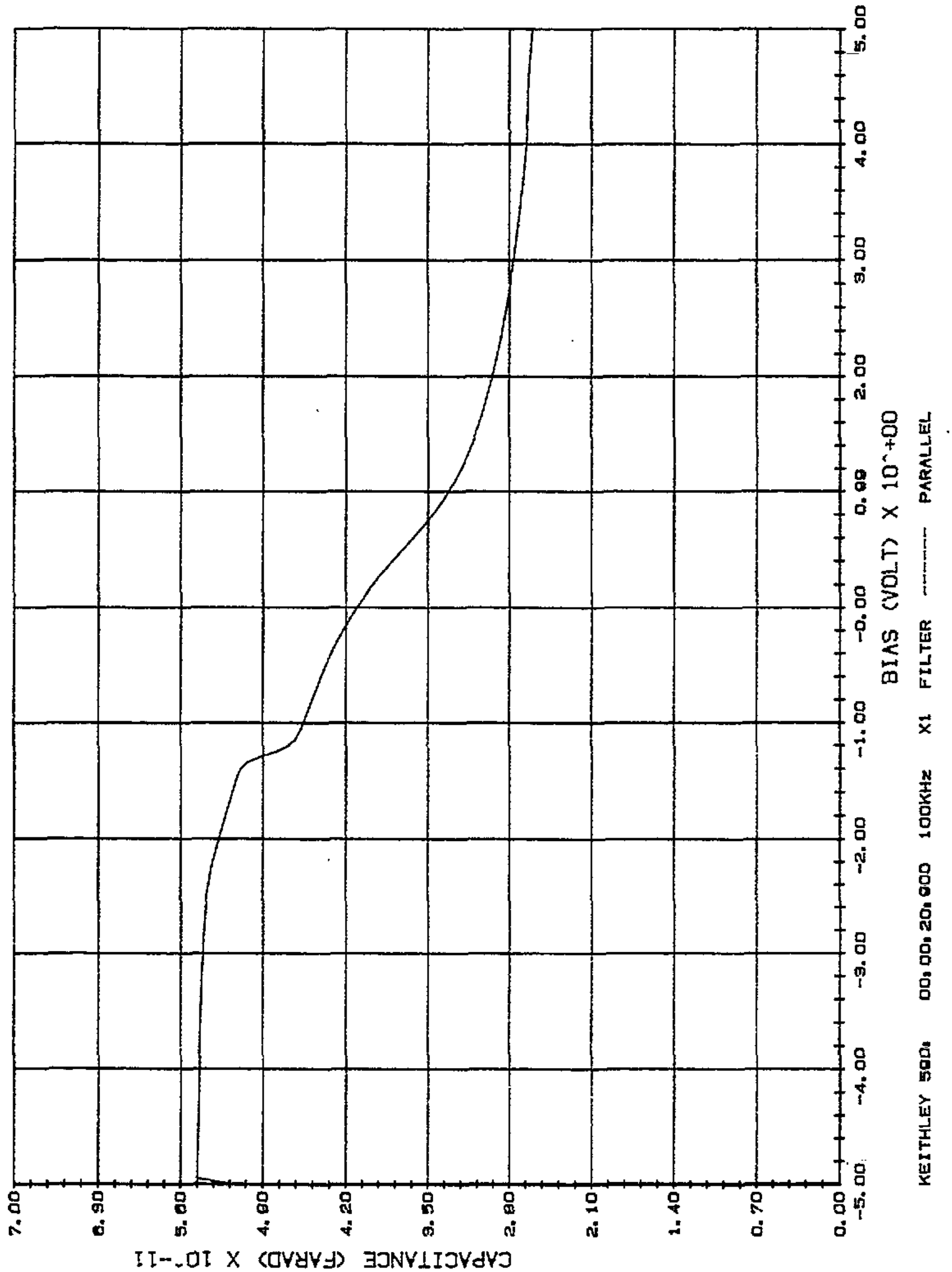


Figure 3-46. C_A - C_B vs V Example

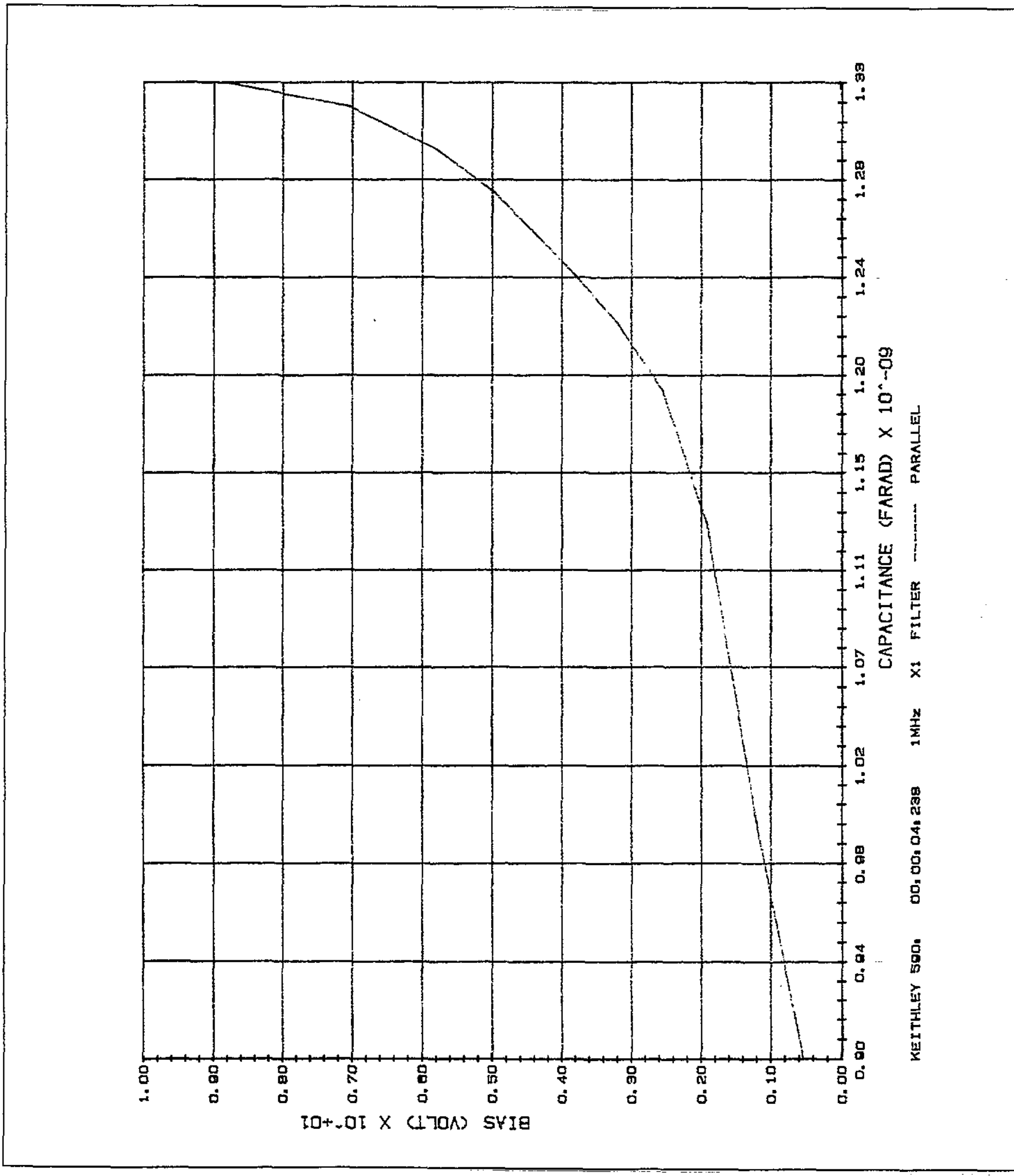
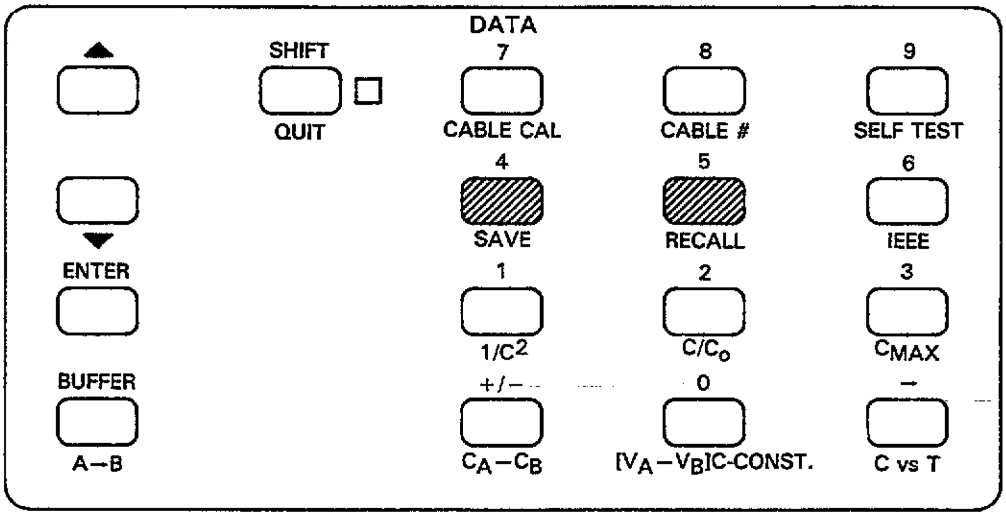


Figure 3-47. [$V_A - V_B$] C=CONST Example



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.

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

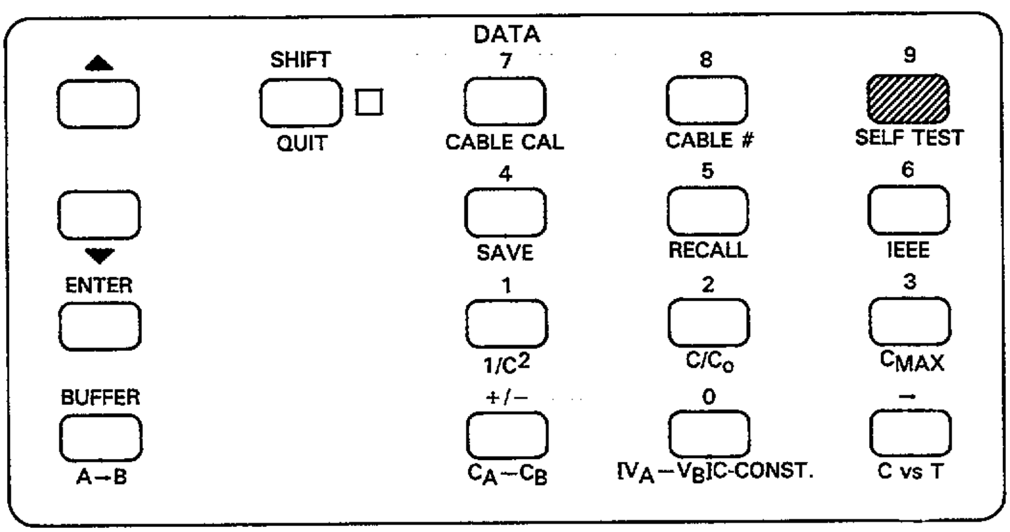
The self test program is intended to check out internal circuitry to make sure that the instrument is operating properly.

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.



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

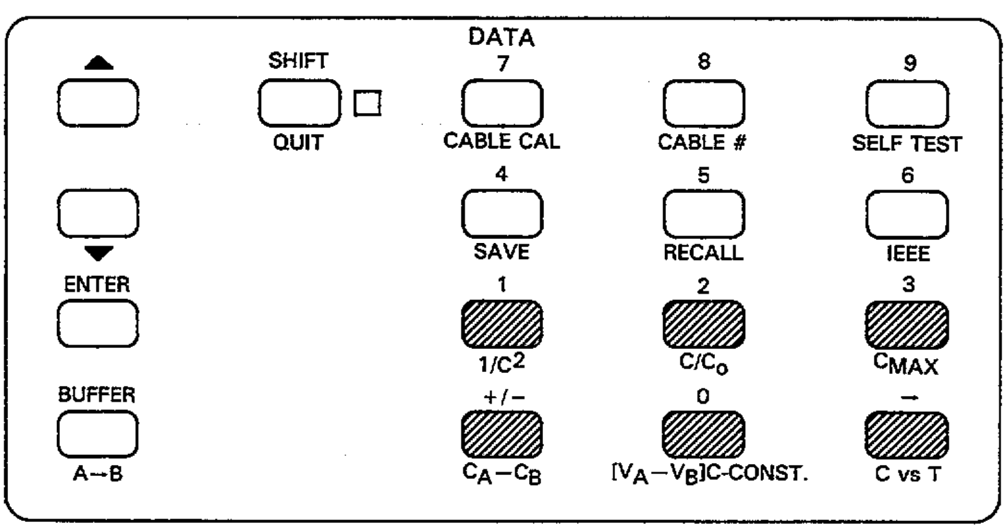
3.19 MATHEMATICAL FUNCTIONS

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:



IDENTIFIER

$1/C^2$	D. DDDDE±DD /C2	±D.DDDV	VOLTAGE
C/C_O	D.DDDDE±DD /Co	±D.DDDV	VOLTAGE
C_{max}	±D.DDDD nF CMAX	±D.DDDV	VOLTAGE
C_A-C_B	D.DDDDE±DD ΔC	±D.DDDV	VOLTAGE
$[V_A-V_B]$C CONST	±D.DDDDE±DD ΔV	±D.DDDDn	CAPACITANCE (n=nF, p=pF)
C vs t	±D.DDDDnF ΔT	DDDDD	BUFFER LOCATION NUMBER

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_O in this position indicates that a C/C_O 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_O, 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

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 $/C^2$ −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.

$[V_A - V_B]$ 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.

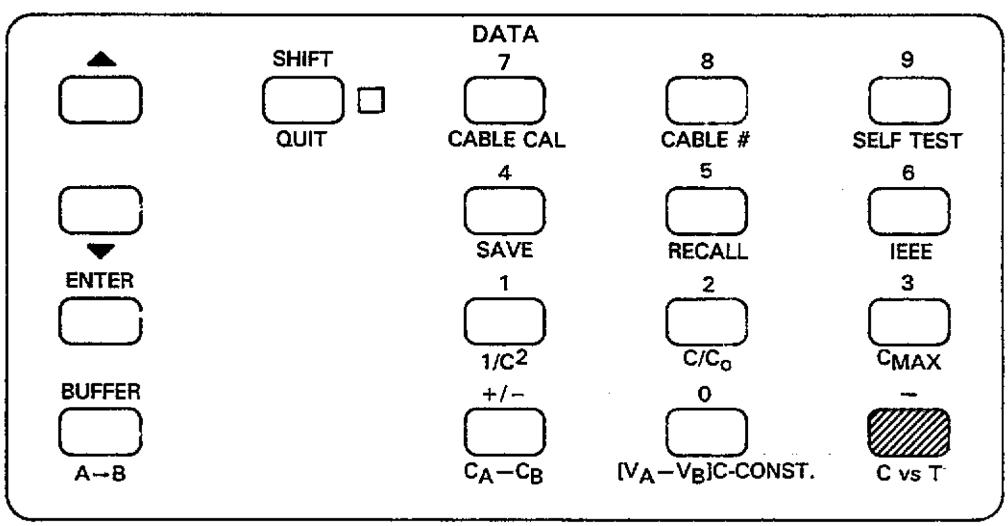
3.20 C VS t MEASUREMENTS

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.



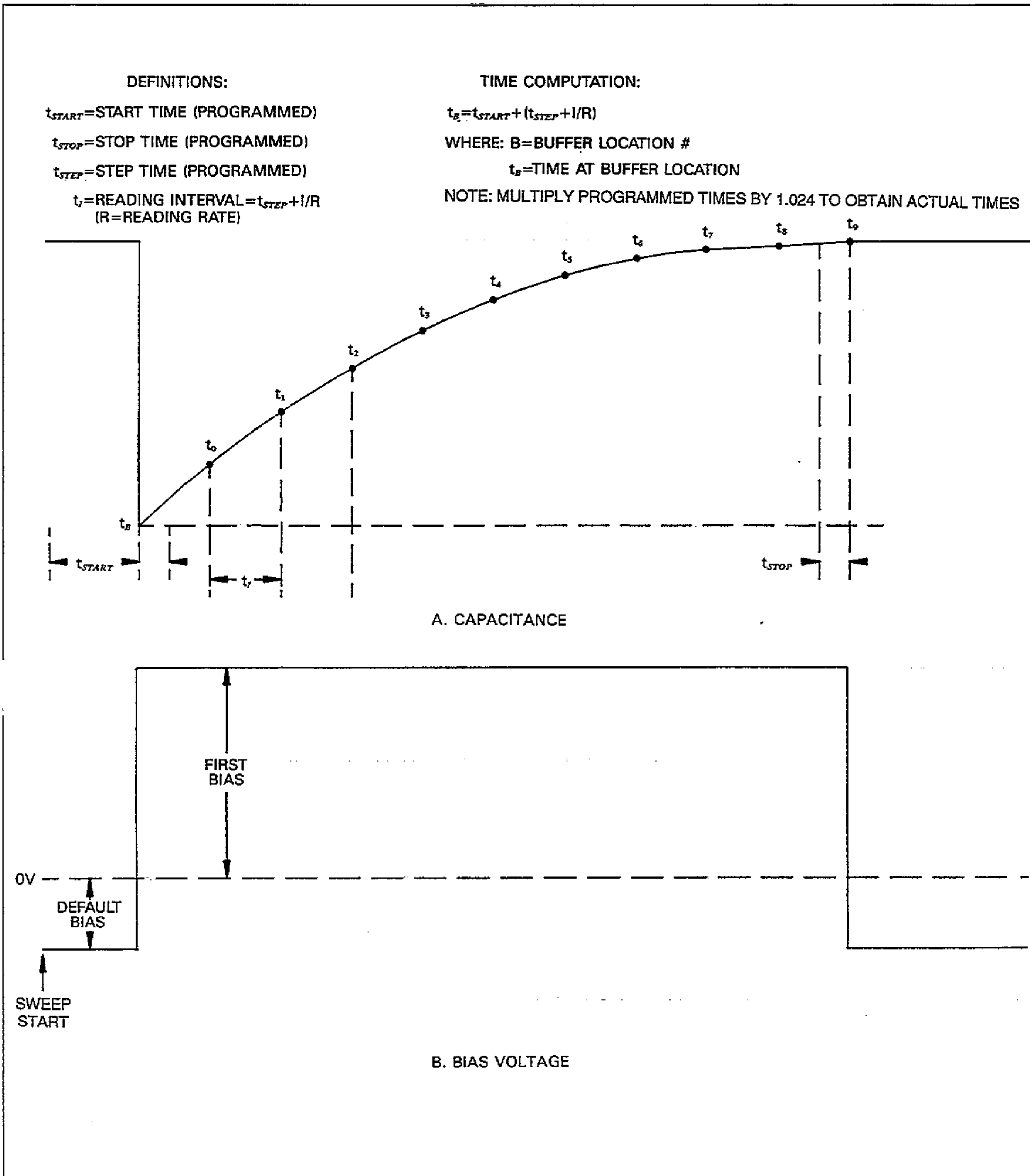


Figure 3-49. C vs t Waveform

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.

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.

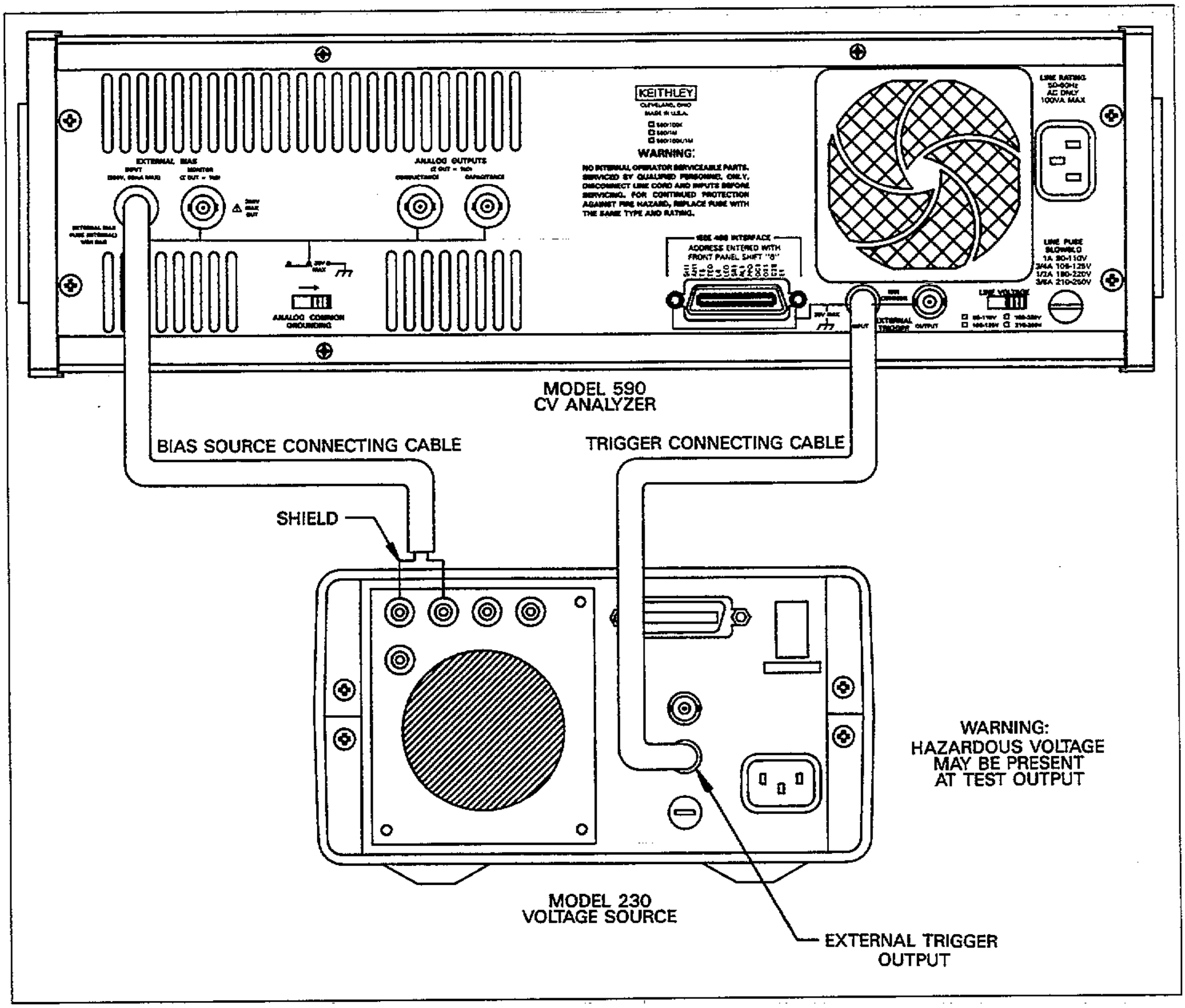


Figure 3-50. External C vs t Connections

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.

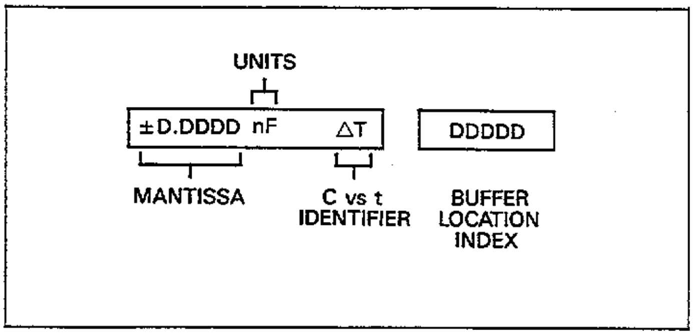


Figure 3-51. C vs t Display Format

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.

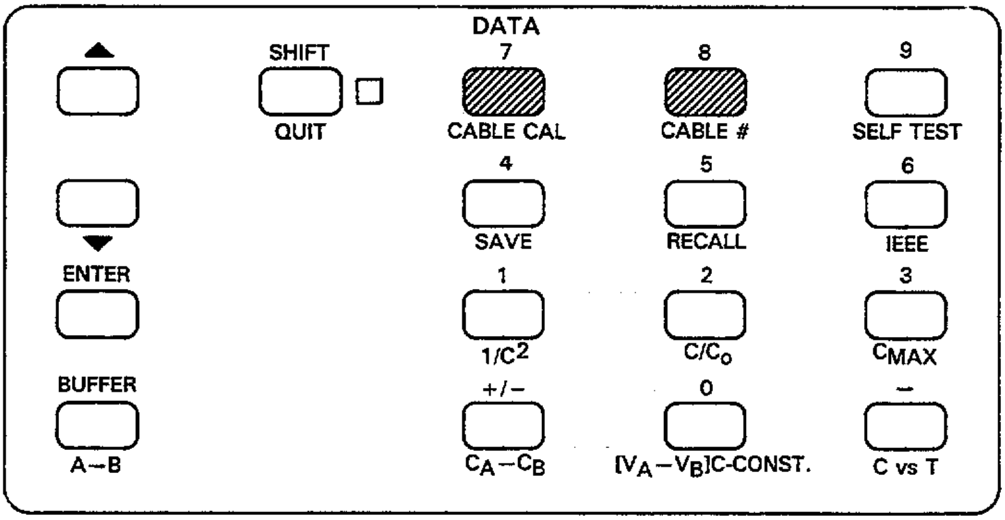


Table 3-24. Summary of Cable Correction Methods

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.

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.

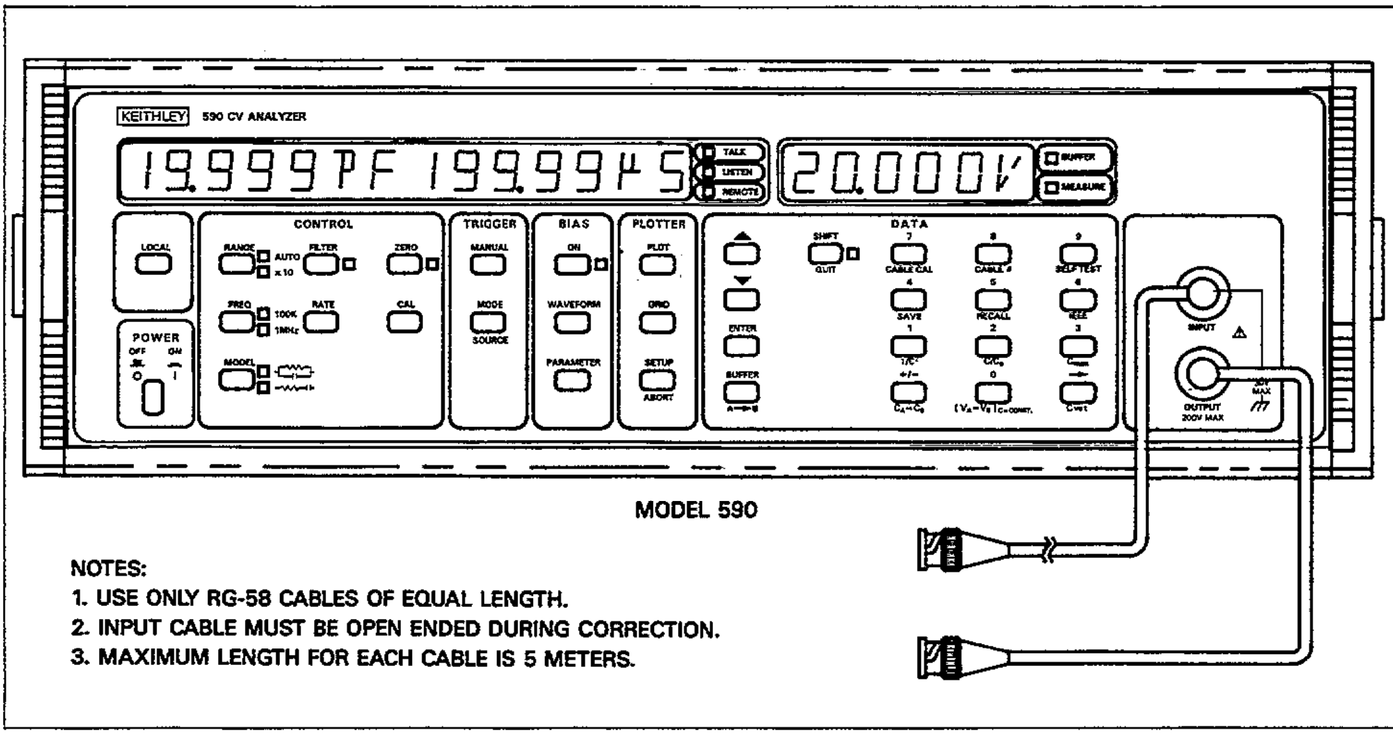


Figure 3-52. Connections for Cable Correction

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.

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
ℓ = length
$\gamma = \alpha+j\beta$ = the propogation constant
α = the attenuation constant
β = 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.

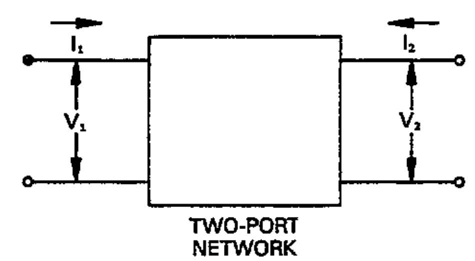


Figure 3-53. Two-Port Network

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.

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

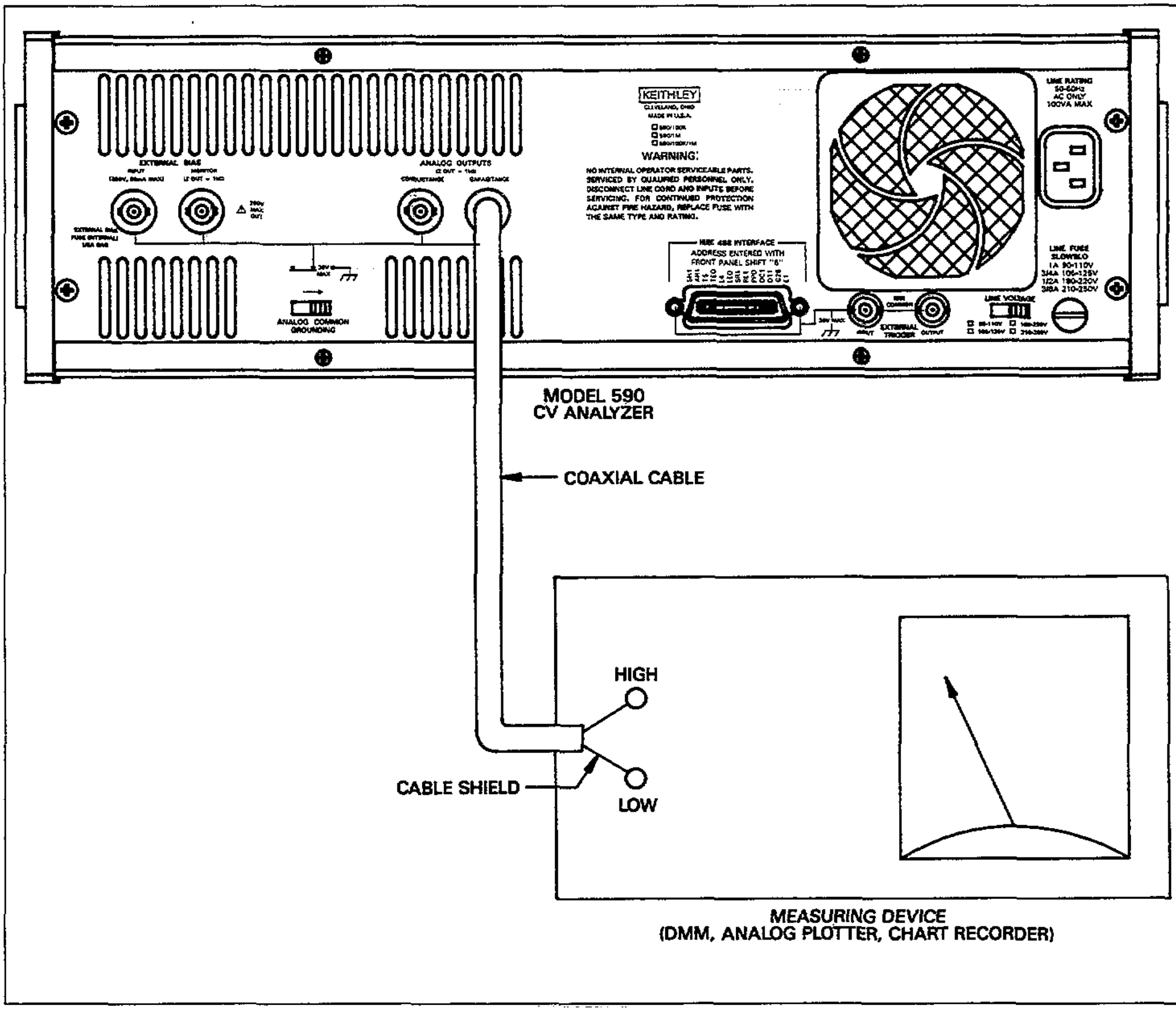


Figure 3-54. Analog Output Connection Example

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.

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.

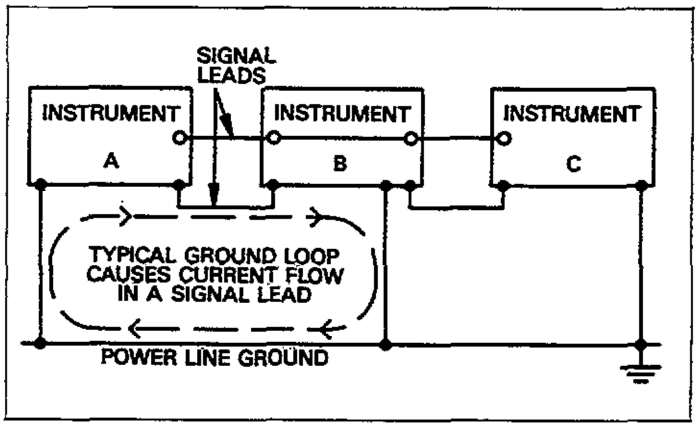


Figure 3-55. Multiple Ground Points Create a Ground Loop

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.

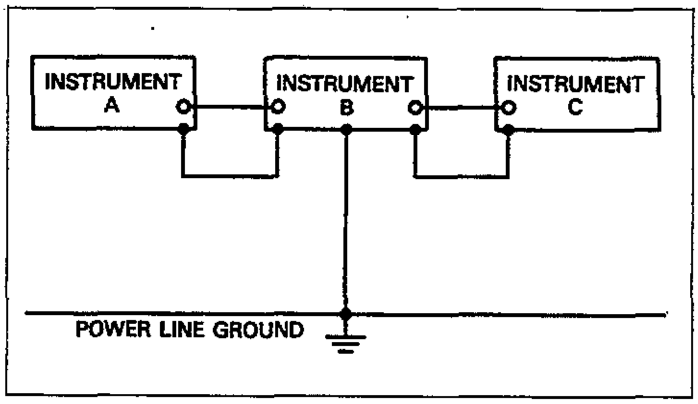


Figure 3-56. Eliminating Ground Loop

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.

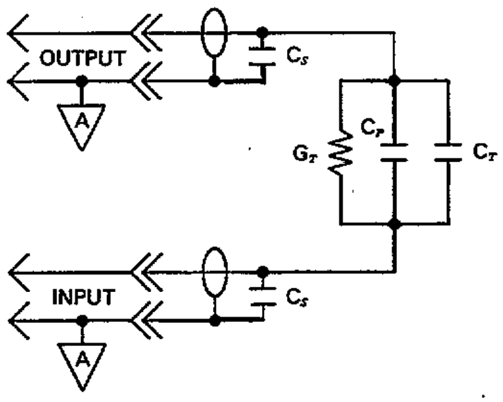


Figure 3-57. Parasitic Capacitance

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.

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.

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.

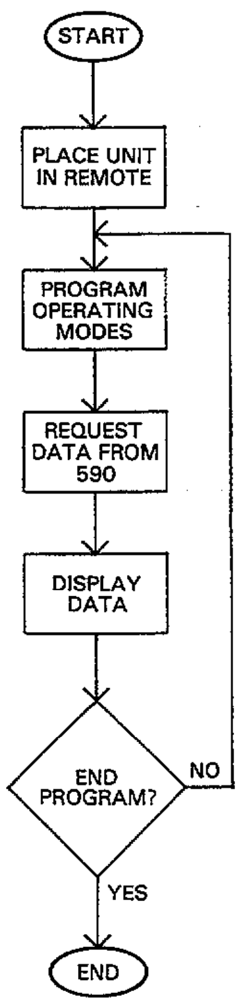


Figure 4-1. Typical Program Flow Chart

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.

Table 4-1. Summary of Most Often Used IEEE-488 Commands

Mode	Command	Description
Frequency	F0 F1 F2	100kHz 1MHz Disconnect test signal from jacks
Range	 R0 R1 R2 R3 R4 R5 R6 R7 R8 R9	**100kHz** — **1MHz** Autorange on — Autorange on 2p/2µS — 20pF/200µS 20pF/20µS — 20pF/200µS 200pF/200µS — 200pF/2mS 2nF — 2nF/20mS R1 × 10 — Error R2 × 10 — Error R3 × 10 — Error R4 × 10 — Error Autorange off — Autorange off
Reading Rate	S0 S1 S2 S3 S4	1000 readings/sec 75 readings/sec 18 readings/sec 10 readings/sec 1 reading/sec
Trigger Mode and Source	T0,0 T0,1 T1,0 T1,1 T2,0 T2,1 T3,0 T3,1 T4,0 T4,1	One-shot talk Sweep, talk One-shot, GET Sweep, GET One-shot, X Sweep, X One-shot, external Sweep, external One-shot, front panel Sweep, front panel
Zero	Z0 Z1	Zero off Zero on
Filter	P0 P1	Filter off 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 N1	Bias source off Bias source on

NOTE: See Table 4-9 on page 4-18 for a complete summary of device-dependent commands.

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.

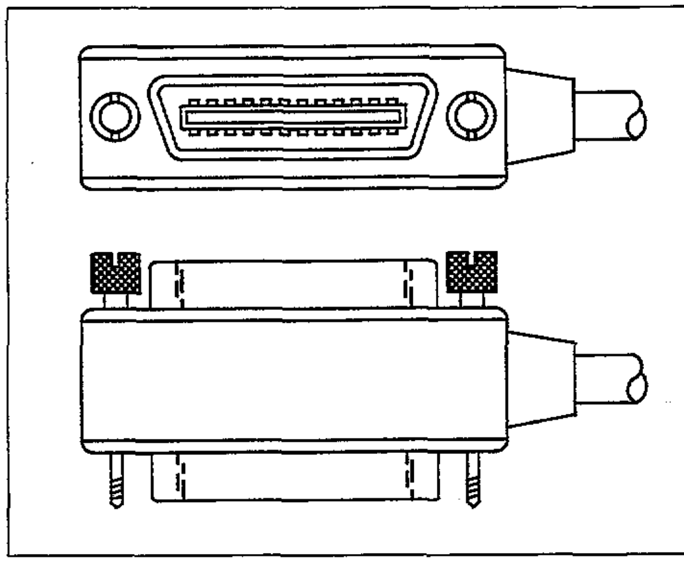


Figure 4-2. IEEE-488 Connector

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.

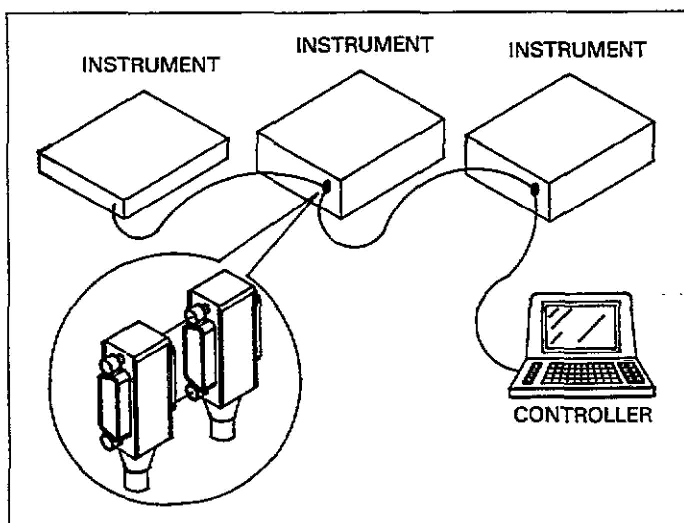


Figure 4-3. IEEE-488 Connections

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.

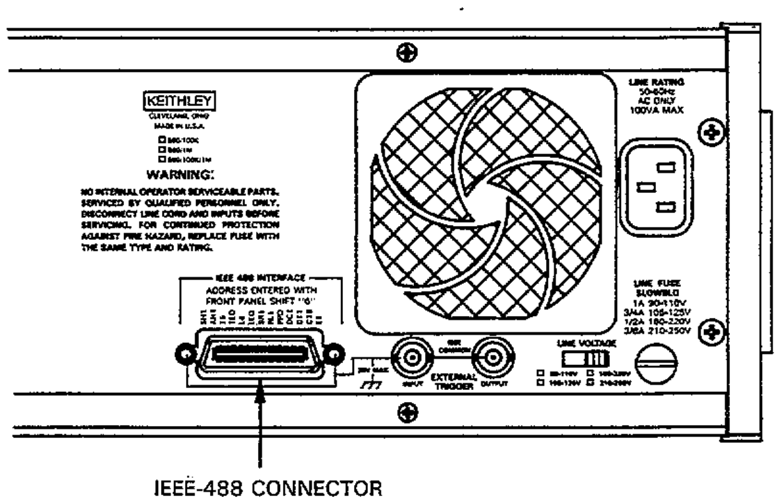


Figure 4-4. IEEE-488 Connector Location

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.

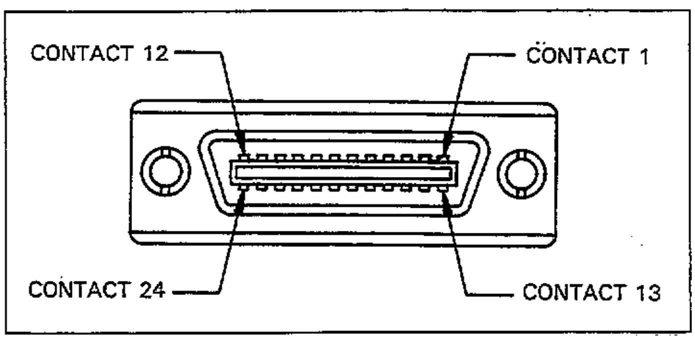


Figure 4-5. Contact Assignments

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 stand-alone 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.

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 computer 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.

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''
```

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.

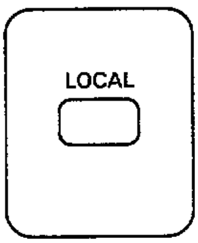
TALK—This indicator will be on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TALK will be off when the unit is in the talker idle state. The instrument is placed in the talker idle state by 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 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.

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.

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).

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.

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.

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.

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

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.

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 N1	Bias off Bias on	4.9.8
Data Format (G0)	G0 G1 G2 G3 G4 G5	Prefix on, suffix off, 1 rdg Prefix off, suffix off, 1 rdg Prefix on, suffix on, 1 rdg Prefix on, suffix off, n rdgs Prefix off, suffix off, n rdgs Prefix on, suffix on, n rdgs 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 B1(,first)(,last) B2(,first)(,last) B3	Current Reading A/D buffer, first, last limits Plot buffer, first, last limits Transfer A/D buffer to plot buffer	4.9.11
Plotter (A)	A0 A1 A2, plot A3, grid A4, buffer A5, pen A6, line A7, label A8,n, Xmin, Xmax	Execute plot Execute grid 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 Grid: 0 = Full grid; 1 = Axis only Buffer: 0 = A/D buffer (A); 1 = Plot buffer (B) Pen: 0 = No pen; 1 = Pen #1; 2 = Pen #2 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 Label: 0 = Full labels; 1 = Label axis and divisions; 2 = Label axis only X axis limits. n=0: Autoscaling (minimum/maximum bias). n=1: Program Xaxis minimum (Xmin) and maximum (Xmax) values.	4.9.12

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	Disable zero	4.9.13
	Z1	Enable zero	
Filter (P)	P0	Filter off	4.9.14
	P1	Filter on	
Status (U)	U0	Hardware/software revision	4.9.15
	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	
	U7	Buffer A bias time	
	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	
	U14	Buffer B bias time	
	U15	Buffer B position and times	
	U16	Buffer A maximum/minimum capacitance	
	U17	Buffer A maximum/minimum conductance	
	U18	Buffer A maximum/minimum voltage	
	U19	Buffer B maximum/minimum capacitance	
	U20	Buffer B maximum/minimum conductance	
	U21	Buffer B maximum/minimum voltage	
	U22	Global parameters (series/parallel, C_O value)	
	U23	Plotter parameters (plot, grid, line, etc.)	
	U24	IEEE output parameters (O, G, B, Y, K)	
	U25	IEEE input parameters (L, C, H, K, M)	
	U26	Cable correction parameters	
	U27	Translator user name list	
	U28	Not used	
	U29	Translator reserved word list	
	U30	Translator NEW/OLD state	
	U31	Translator user translation list	
	U32	Not used	

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	4.9.20
		NORMAL MODE	
	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	

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

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

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.
```

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.
```

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.
```

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.
```

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.
```

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.

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.
```

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.
```

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.
```

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

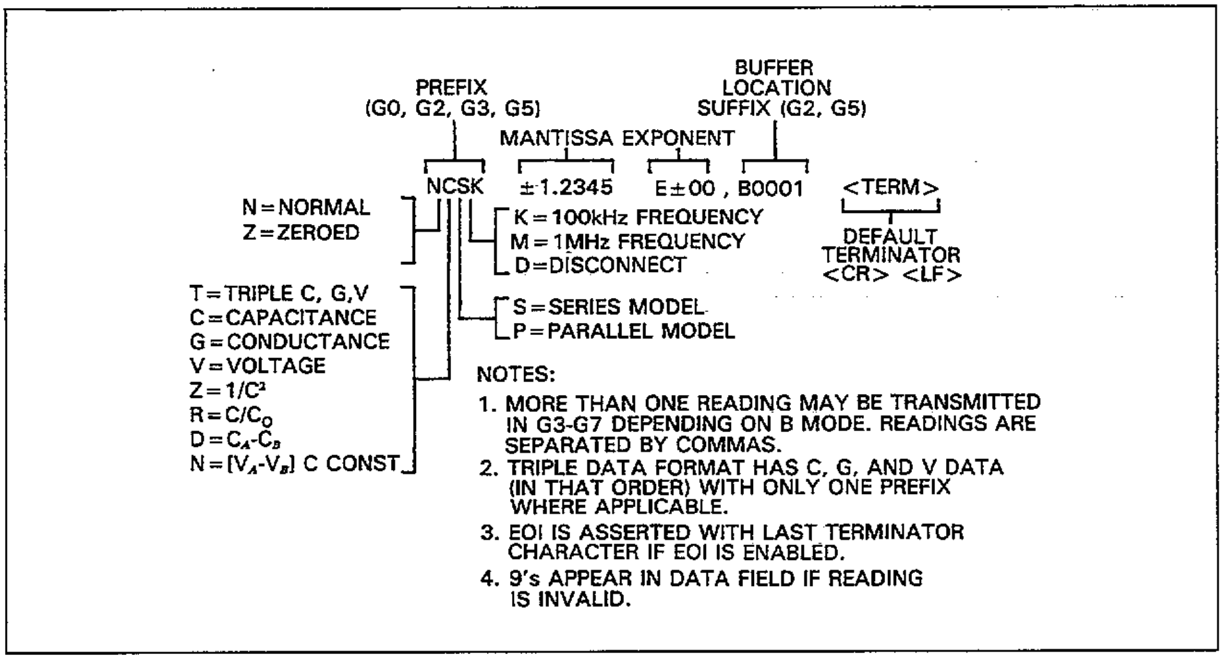


Figure 4-6. General Data Format

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
```

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.
```

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.

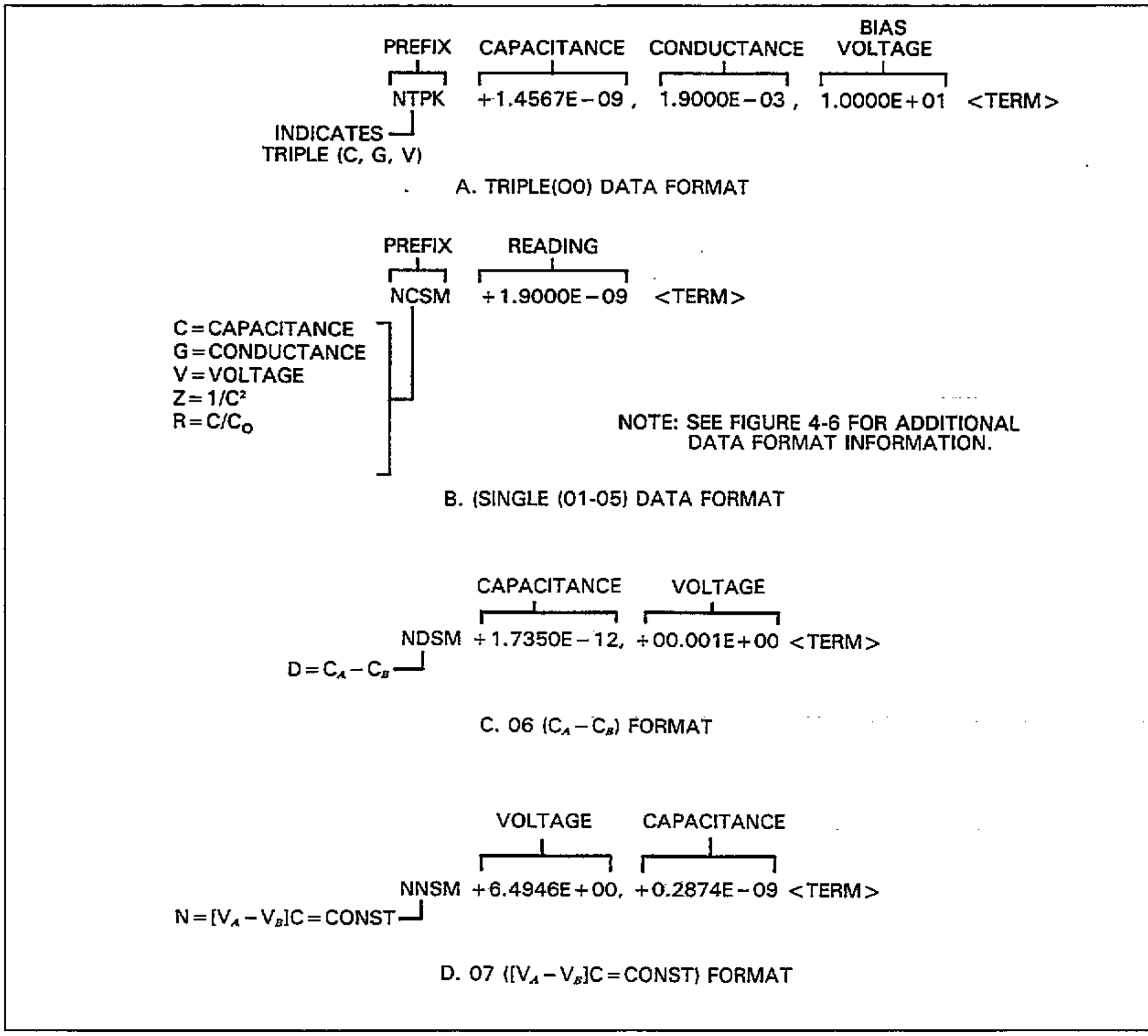


Figure 4-7. O Command Data Formats

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; ''O0,0,1.9E-12X''   ! Program C, G, V data, parallel
                                     model, 1.9pF Co value.
20 OUTPUT 715; ''O1,1,2.4E-9X''    ! Program C only data, series model,
                                     2.4nF Co value.
30 OUTPUT 715; ''O5X''             ! Program C/Co function only.
40 OUTPUT 715; ''O3,0X''           ! Program V only, parallel model.
```

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 ($1 \le$ first ≤ 450) ending at location last ($1 \le$ last ≤ 450)
B2,first,last	Plotter buffer (buffer B), starting at location first ($1 \le$ first ≤ 450), ending at location last ($1 \le$ last ≤ 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.
```

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.
$-1E29 \leq Xmin \leq 1E29$; $-1E29 \leq Xmax \leq 1E29$.

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.

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
```

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.
```

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.
```

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.

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 H=hardware 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		

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 TRANSLATOR STATE	
U31	UTL	UserTranslationList		Send user definitions	
U32	FTL	Not used			

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.
```

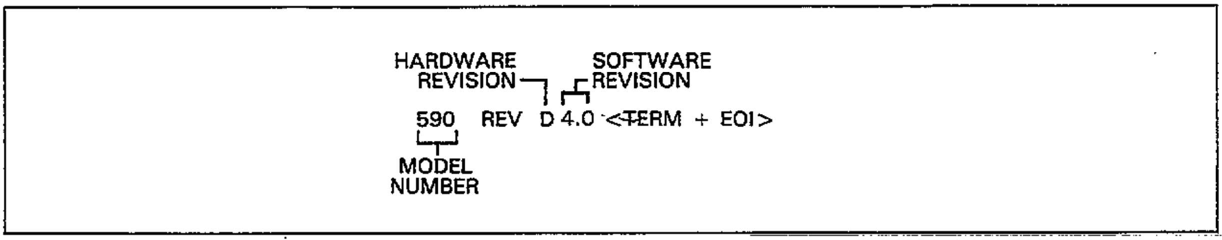


Figure 4-8. U0 Status Word Format (Hardware/Software Revision)

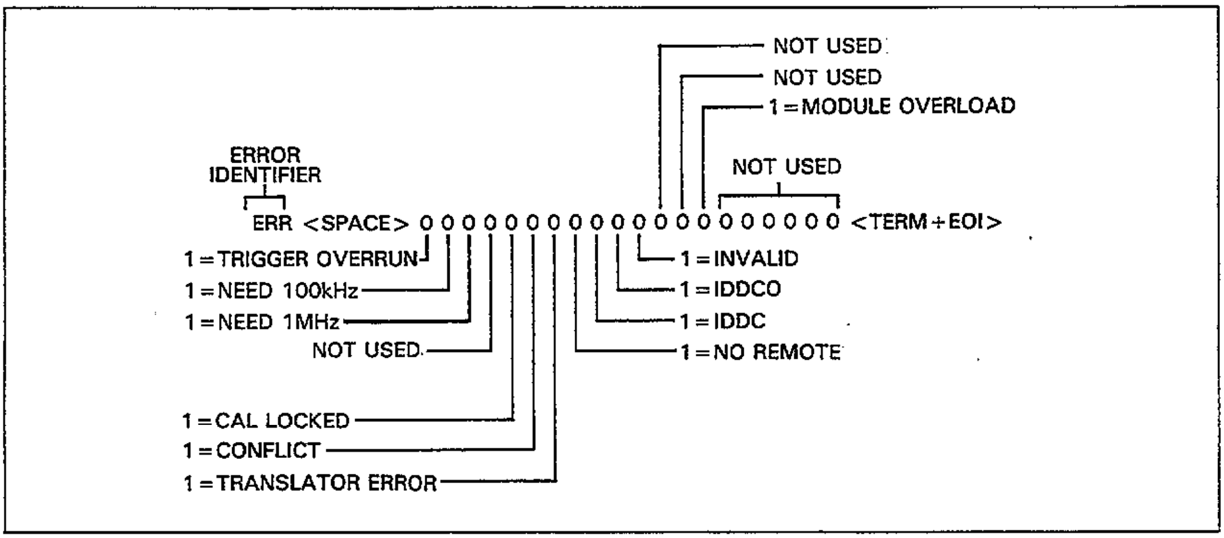


Figure 4-9. U1 Error Status Word Format

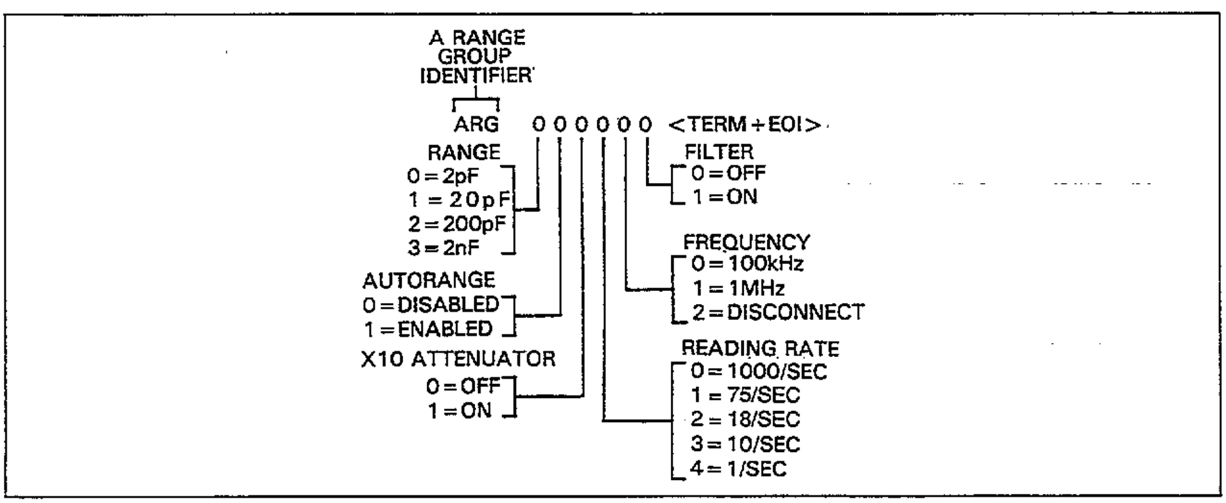


Figure 4-10. U2 Status Word Format (Buffer A Range Group)

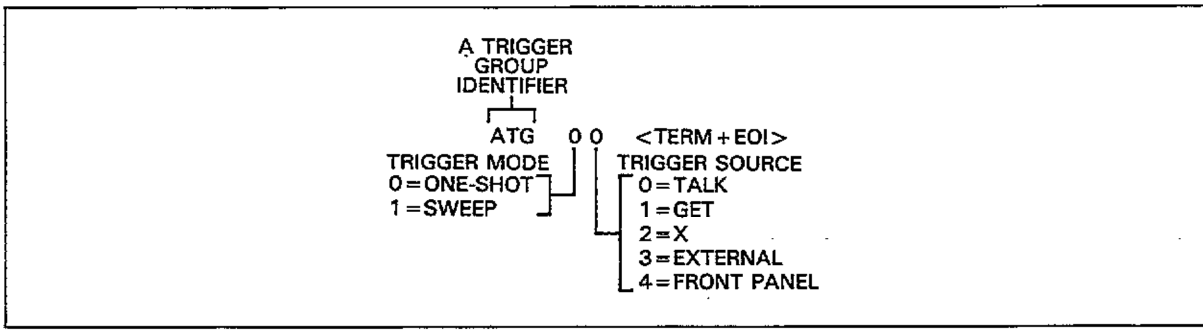


Figure 4-11. U3 Status Word (Buffer A Trigger Group)

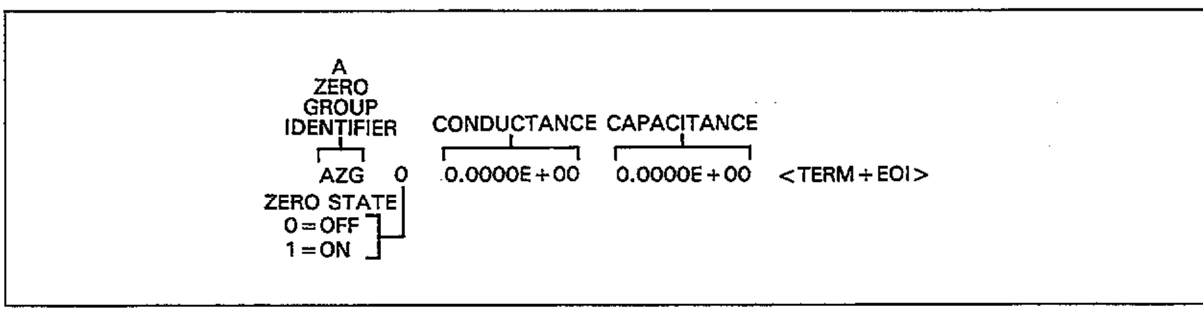


Figure 4-12. U4 Status Word Format (Buffer A Zero Group)

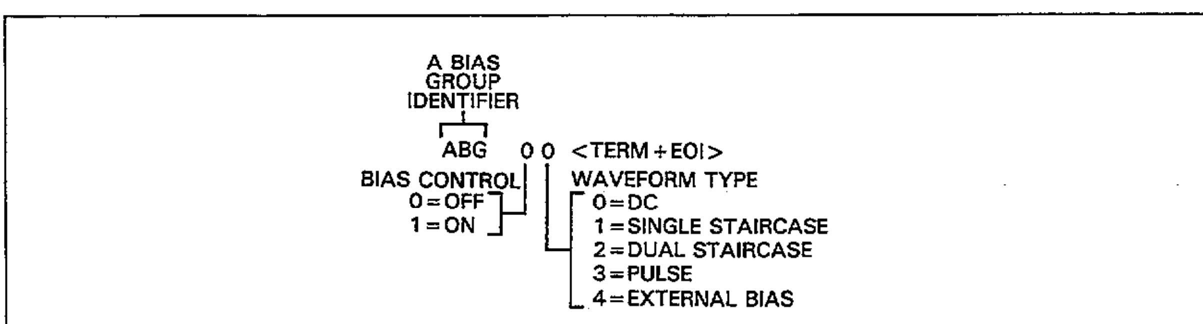


Figure 4-13. U5 Status Word Format (Buffer A Bias Group)

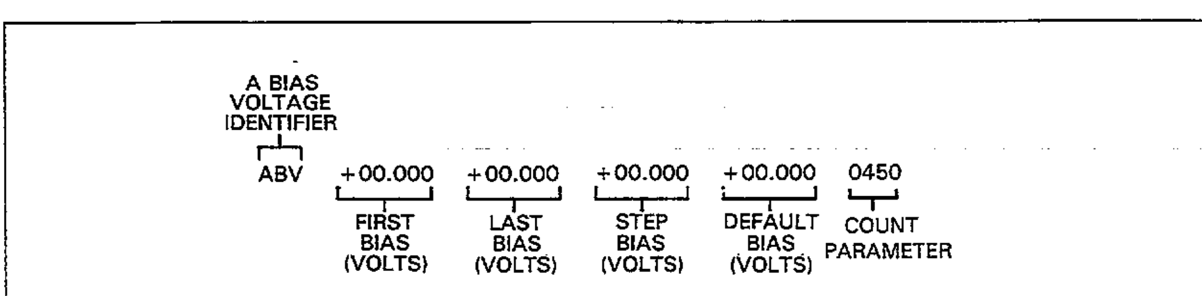


Figure 4-14. U6 Status Word Format (Buffer A Bias Voltages)

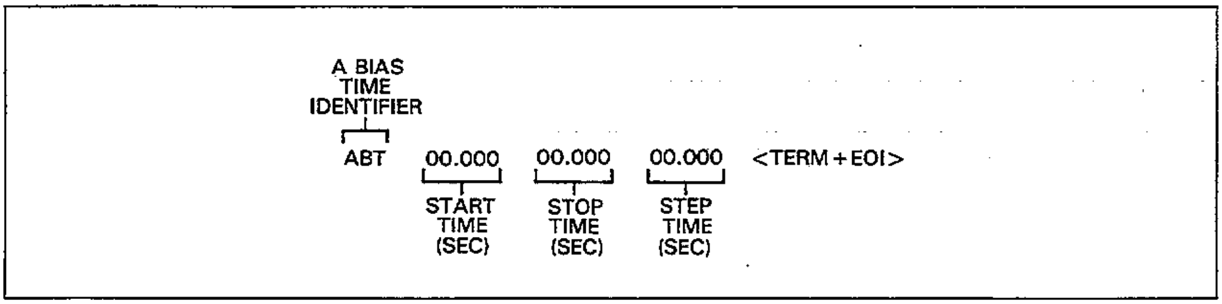


Figure 4-15. U7 Status Word Format (Buffer A Bias Times)

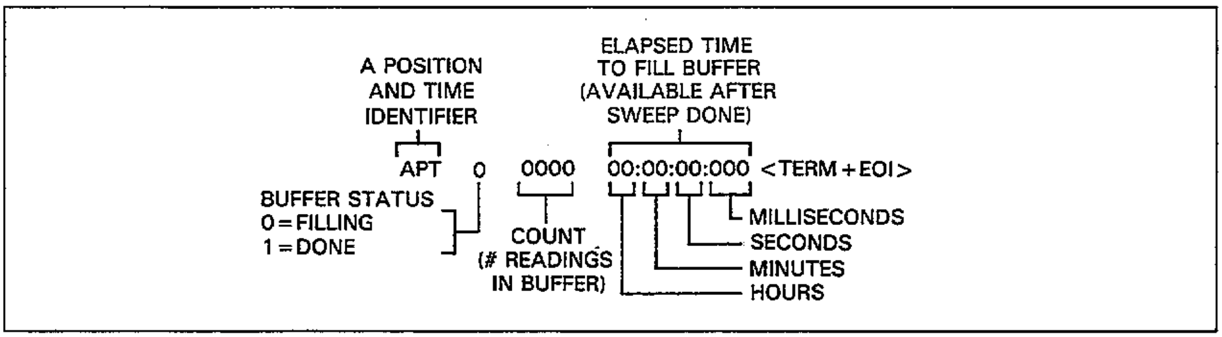


Figure 4-16. U8 Status Word Format (Buffer A Position and Time)

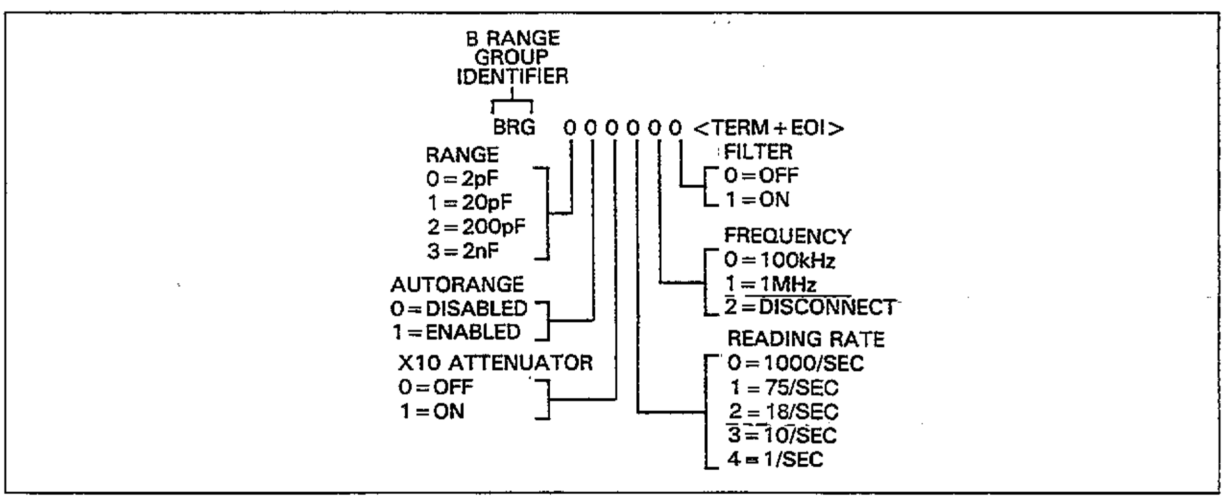


Figure 4-17. U9 Status Word Format (Buffer B Range Group)

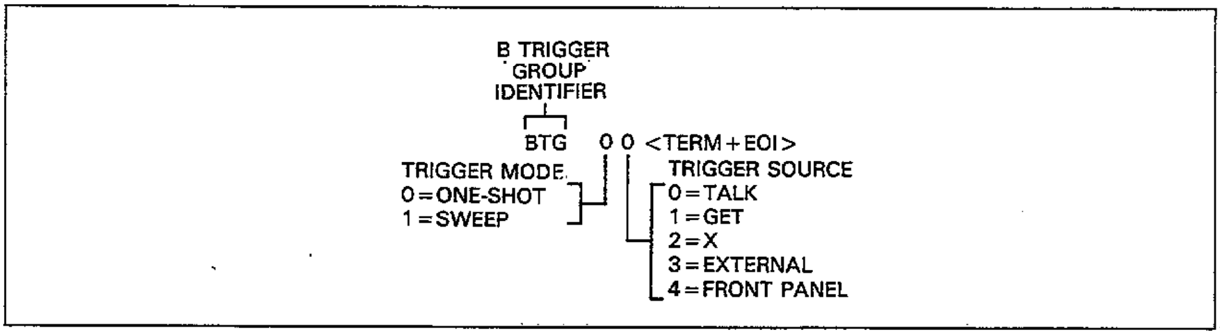


Figure 4-18. U10 Status Word (Buffer B Trigger Group)

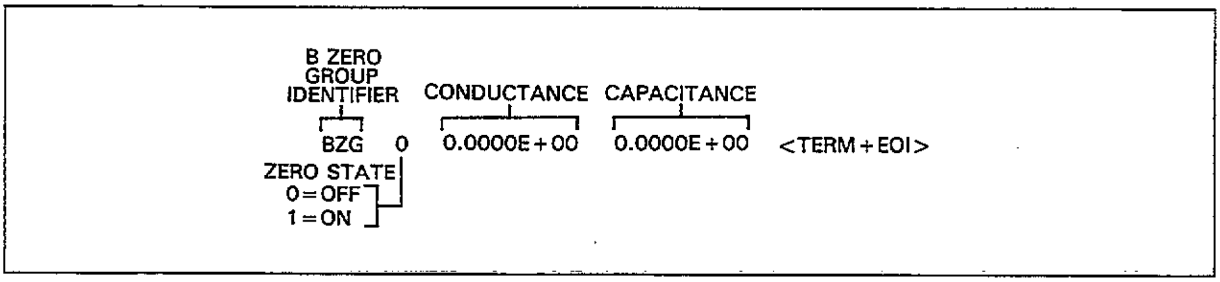


Figure 4-19. U11 Status Word Format (Buffer B Zero Group)

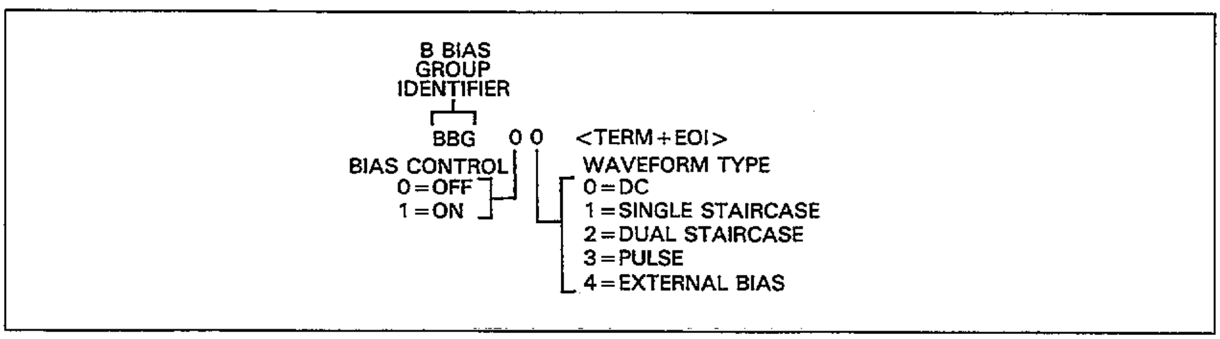


Figure 4-20. U12 Status Word Format (Buffer B Bias Group)

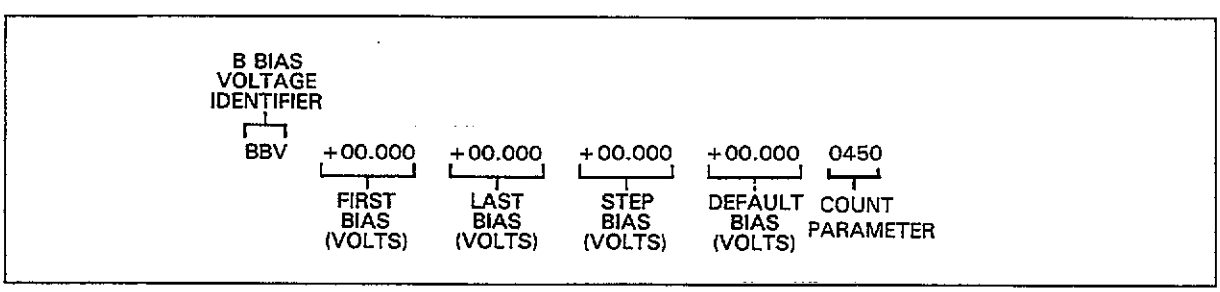


Figure 4-21. U13 Status Word Format (Buffer B Bias Voltages)

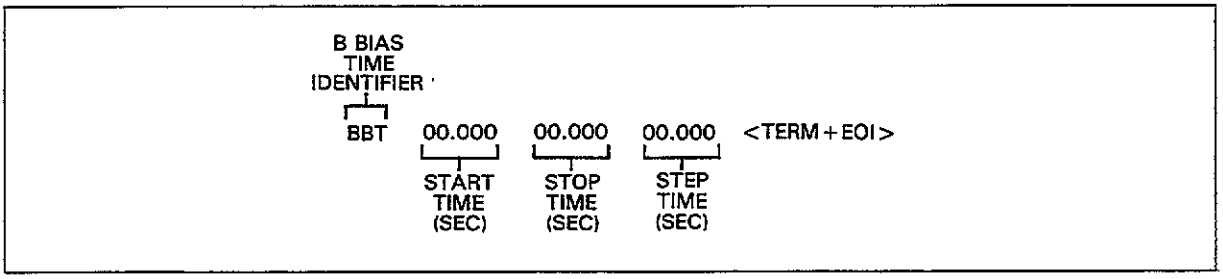


Figure 4-22. U14 Status Word Format (Buffer B Bias Times)

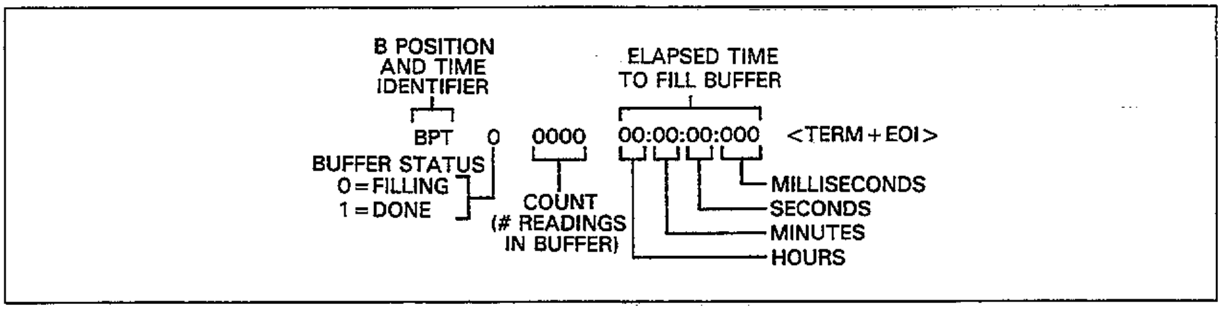


Figure 4-23. U15 Status Word Format (Buffer B Position and Time)

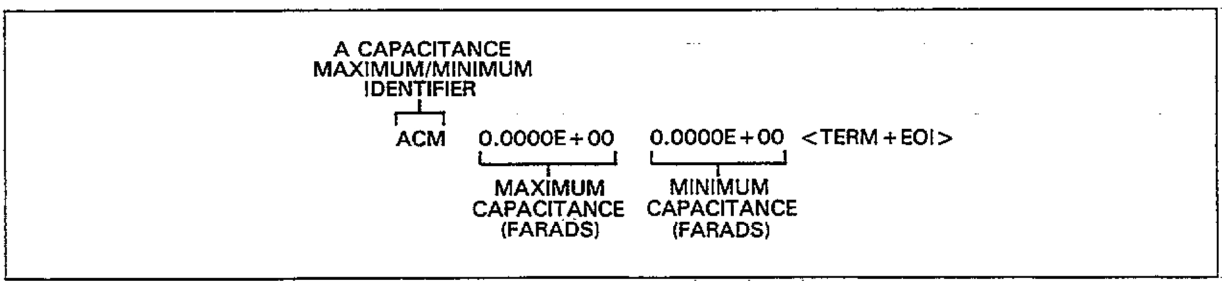


Figure 4-24. U16 Status Word Format (Buffer A Maximum and Minimum Capacitance)

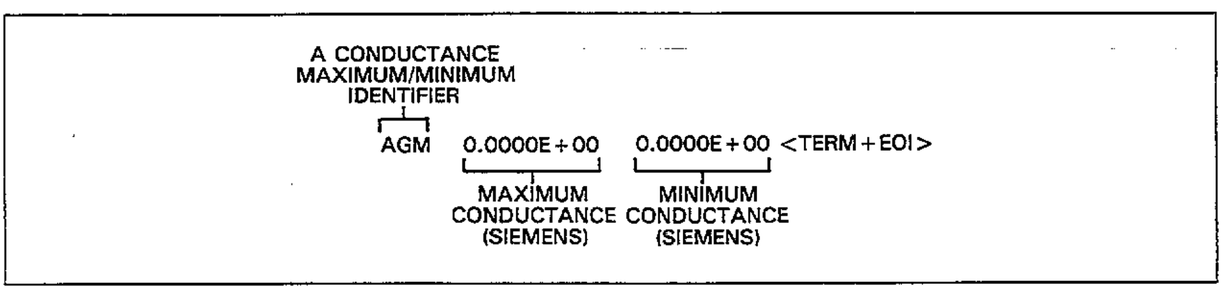


Figure 4-25. U17 Status Word Format (Buffer A Maximum and Minimum Conductance)

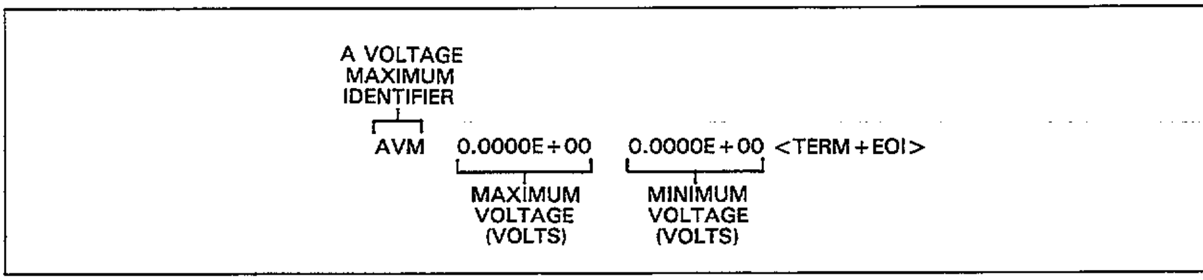


Figure 4-26. U18 Status Word Format (Buffer A Maximum and Minimum Voltage)

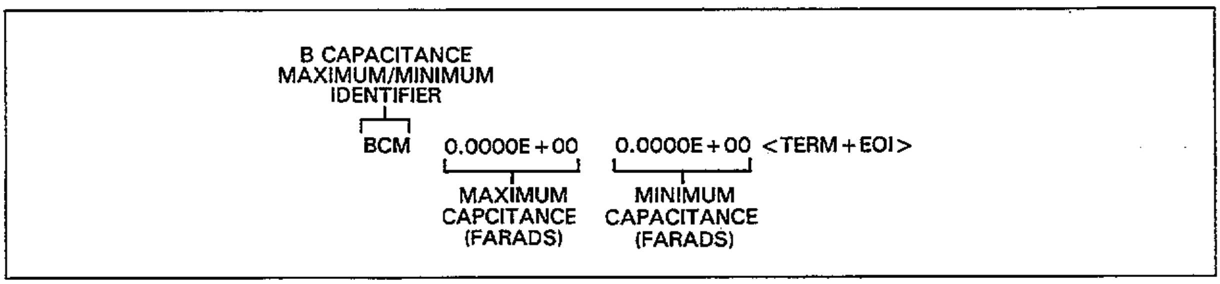


Figure 4-27. U19 Status Word Format (Buffer B Maximum and Minimum Capacitance)

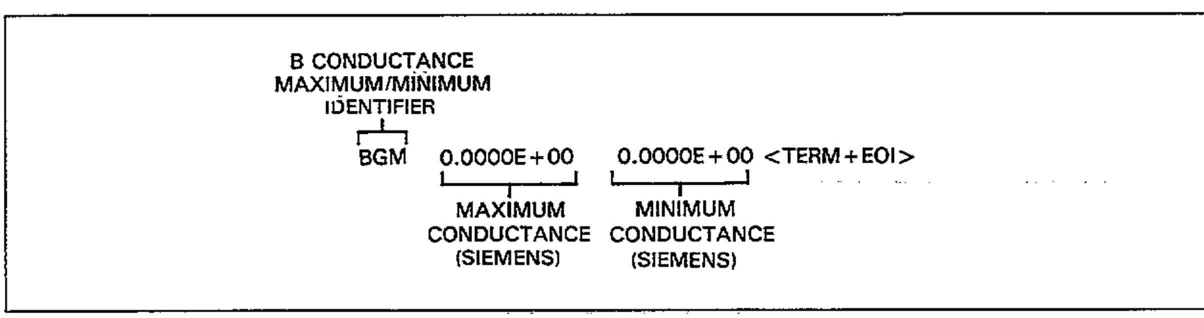


Figure 4-28. U20 Status Word Format (Buffer B Maximum and Minimum Conductance)

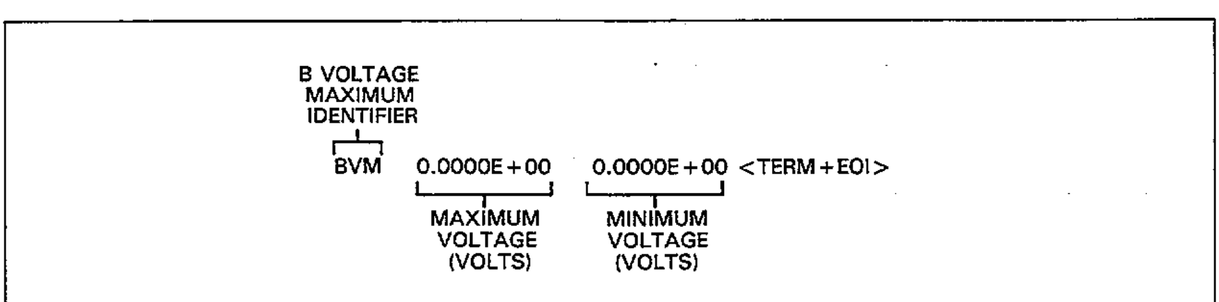


Figure 4-29. U21 Status Word Format (Buffer B Maximum and Minimum Voltage)

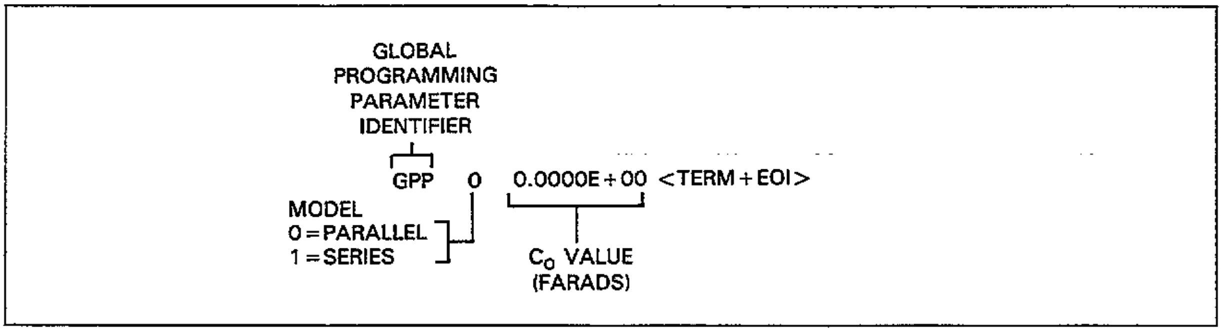


Figure 4-30. U22 Status Word Format (Global Programming Parameters)

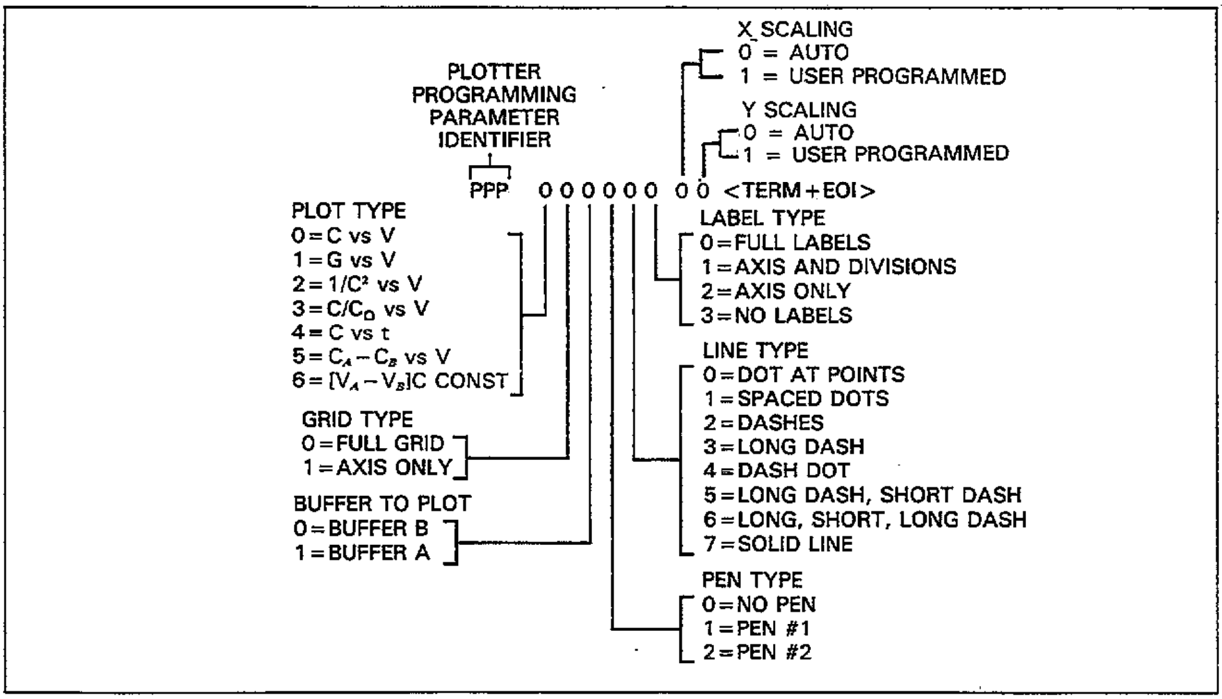


Figure 4-31. U23 Status Word Format (Plotter Programming Parameters)

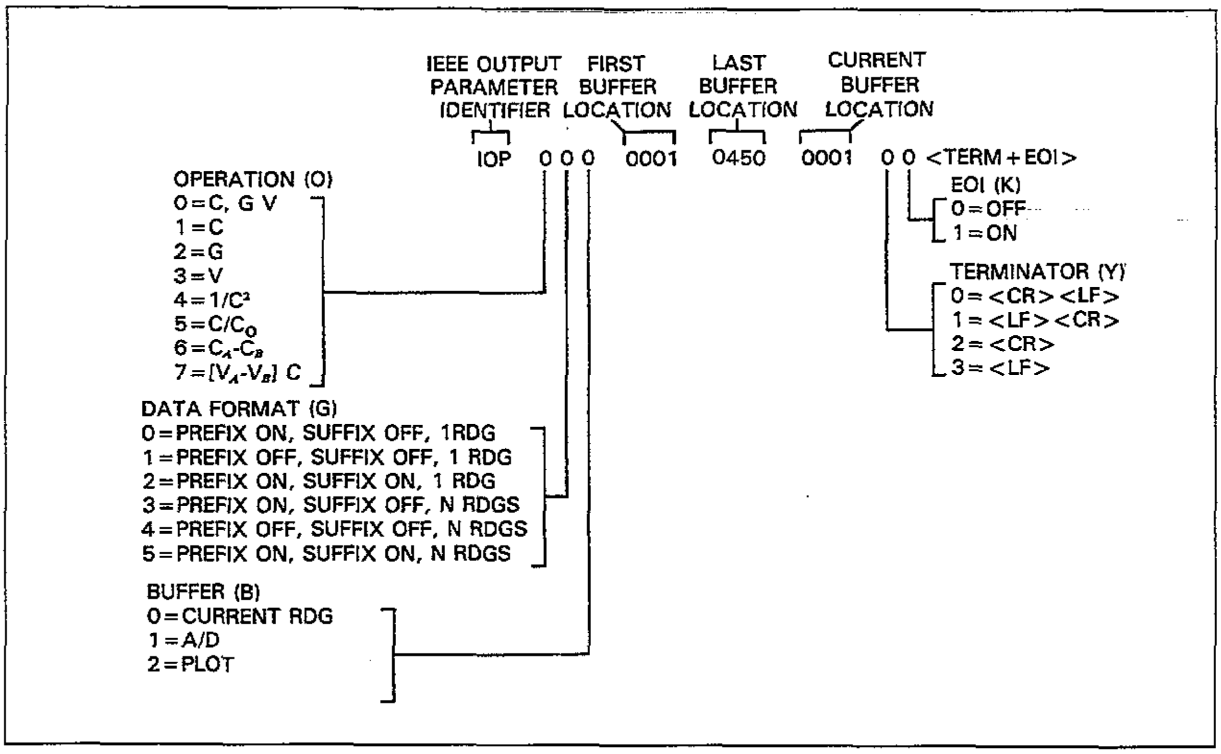


Figure 4-32. U24 Status Word Format (IEEE Output Parameters)

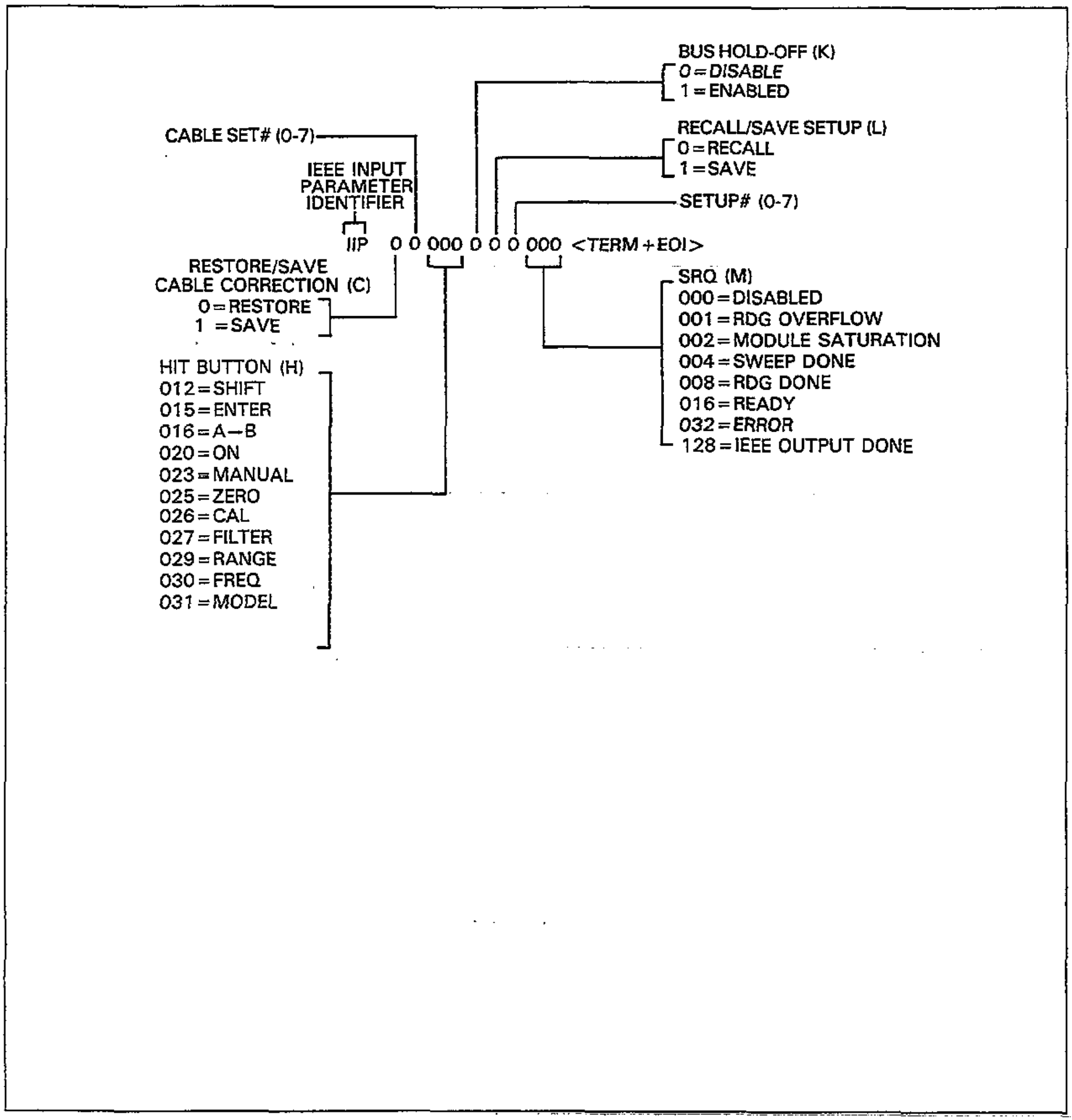
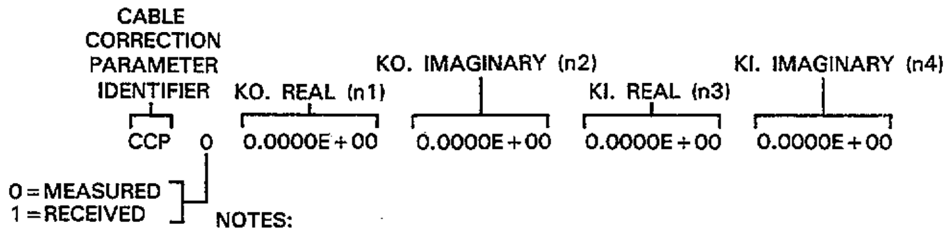


Figure 4-33. U25 Status Word Format (IEEE Input Parameters)



NOTES:
1. SPACES DELIMIT PARAMETERS.
2. PROGRAMMED TERMINATOR AND EOI SENT AT END OF STRING.
3. MEASURED/RECEIVED BIT INDICATES WHETHER PARAMETERS WERE MEASURED (0) USING IO, I2-I5, OR PROGRAMMED (I1)

Figure 4-34. U26 Status Word Format (Cable Correction Parameters)

4.9.16 SRQ (M) and Status Byte Format

Purpose To program which conditions will generate an SRQ (service request).

Format **Mn**

Parameters
M0 SRQ disabled
M1 Reading overflow
M2 Module input overload
M4 Sweep done
M8 Reading done
M16 Ready
M32 Error
M128 IEEE-488 output done

Default Power-up/DCL/SDC Configuration: Factory default configuration is M0 (SRQ disabled).

Description The SRQ command controls which of a number of conditions will cause the Model 590 to generate an SRQ (service request). Once an SRQ has been generated, the status byte can be checked to determine if the Model 590 was the instrument that generated the SRQ, and, if so, what conditions caused it to do so.

The general format of the SRQ mask used to generate SRQs is shown in Figure 4-35. By sending the appropriate M command, you can set the appropriate bit or bits to enable SRQ generation if those particular conditions occur. Possible conditions include:

1. An overflowed reading has occurred (M1).
2. The input stage of the CV module is overloaded (M2).
3. A reading sweep has been completed (M4).
4. A single reading is completed (M8).
5. The instrument has processed a command is ready to accept another (M16).
6. An error has occurred (M32). The nature of the error can then be determined by reading the U1 error word as described in paragraph 4.9.15.
7. Any IEEE-488 output sequence has been completed (M128).

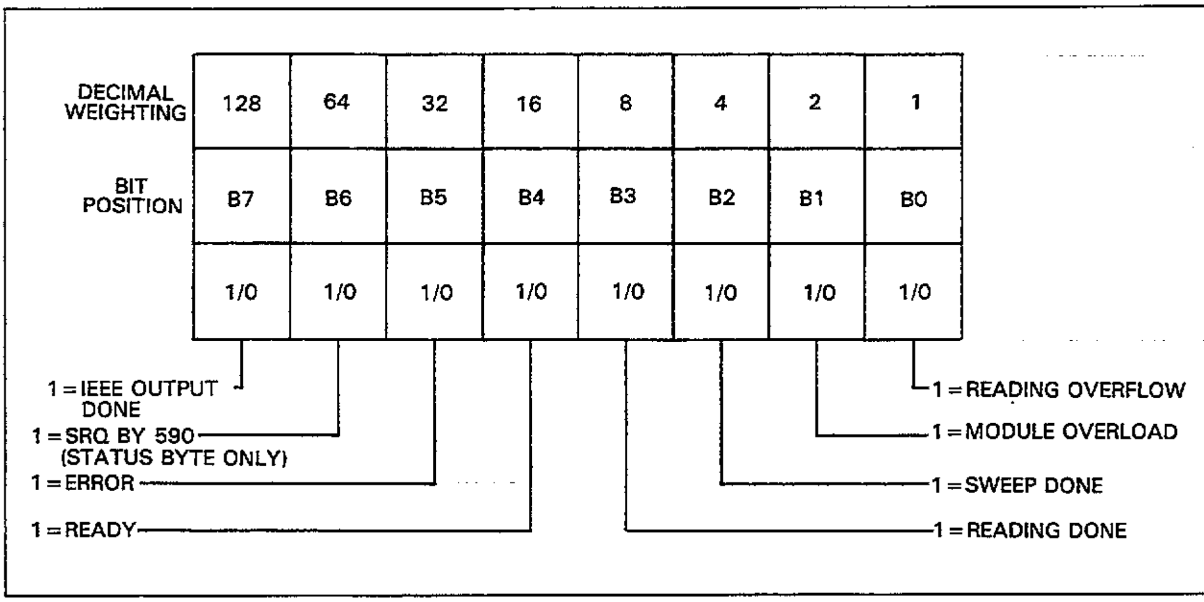


Figure 4-35. SRQ Mask and Status Byte Format

SRQ Timing and Trigger Modes

Timing of SRQ generation depends on the trigger mode and reading rate in effect. Figure 4-36 shows general SRQ timing for the one-shot trigger mode, and Figure 4-37 shows the general timing for the sweep trigger mode. Keep in mind that these figures are not to scale and show only approximate relationships.

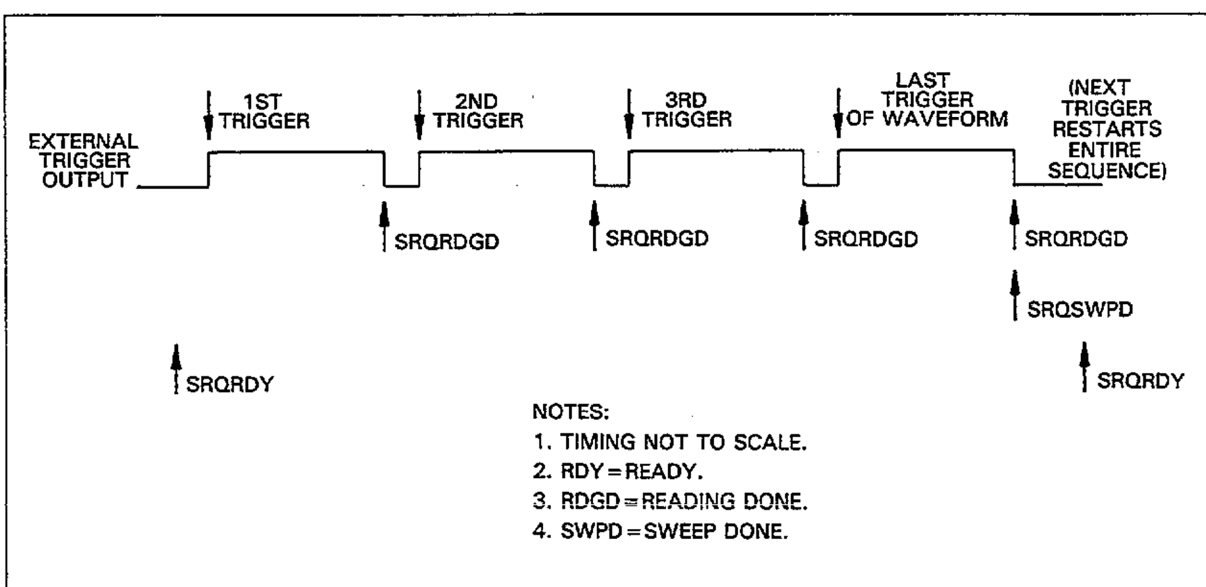


Figure 4-36. SRQ Timing with One-Shot Trigger Mode

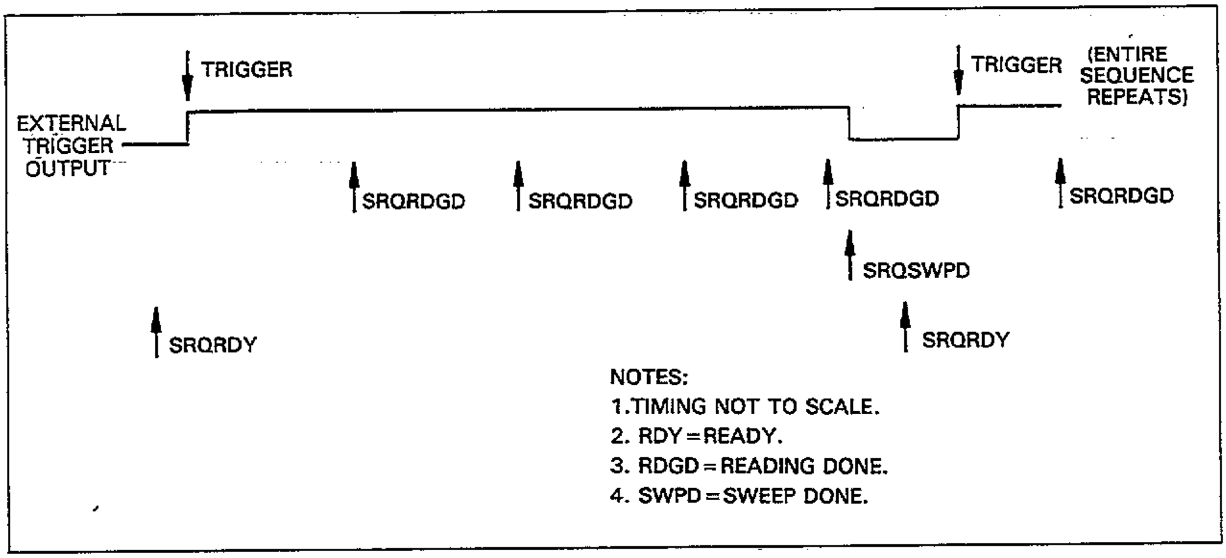


Figure 4-37. SRQ Timing with Sweep Trigger Mode

Status Byte Format

The general format of the status byte is shown in Figure 4-35. Note that all bits except for bit 6 correspond to the bits in the SRQ mask. These bits flag the following conditions.

Reading Overflow (bit 0)—Set when an overflowed reading has been generated. Cleared when an on range reading is available or requested from the instrument.

Module Overload (bit 1)—Set when the input stage of the selected CV module is in saturation (overloaded). Cleared when the overload condition is eliminated.

Sweep Done (bit 2)—Set when a reading sweep has been completed. Cleared when no sweep has been triggerered or if a sweep is in process.

Reading Done (bit 3)—Set when a reading is ready to be sent over the bus. Cleared by requesting a reading over the bus.

Ready (bit 4)—Set when the unit has processed all commands and is ready to accept additional commands over the bus. Cleared while processing commands.

Error (bit 5)—Set if an error condition occurs. Cleared by reading the U1 error word (paragraph 4.9.15).

RQS (Bit 6)—Set if the Model 590 has requested service via the SRQ line; cleared otherwise.

IEEE-488 Output Done (bit 7)—Set after any IEEE-488 output sequence has been completed. Cleared by initiating an output sequence. Typical output sequences include plot generation and sending data strings.

Programming Notes

1. The status byte should be read once the instrument has generated an SRQ in order to clear the SRQ line.
2. All bits in the status byte will latch when the instrument generates an SRQ.
3. If an error occurs, bit 5 (error) in the status byte will latch and remain so until the U1 word is read (paragraph 4.9.15).
4. Multiple error conditions can be programmed by adding up the individual command values. For example, send M12X for SRQ under sweep done and reading done conditions.
5. A sweep done SRQ will occur (and the sweep done bit in the status byte will be set) only after the programmed number of readings are taken. For pulse and staircase waveforms, the number of readings is defined by the first, last, and step bias voltage parameters. For the DC and external waveforms, the number of readings is defined by the count parameter.
6. At the 1000/sec reading rate, a reading done SRQ (and setting of the reading done bit in the status byte) will occur only at the end of the sweep.

Programming Examples

```
10 OUTPUT 715; ''M32X''                 ! Program for SRQ on error.
20 OUTPUT 715; ''E1X''                  ! Attempt to program illegal
                                          command.
30 STATUS 7,2;S                         ! Check interface status.
40 IF NOT BIT(S,5) THEN 30              ! Wait for SRQ to occur.
50 S=SPOLL(715)                         ! Serial poll the instrument.
60 DISP ''B7 B6 B5 B4 B3 B2 B1 B0''     ! Label the bit positions.
70 FOR I=7 TO 0 STEP -1                 ! Loop eight times.
80 DISP BIT(S,I);                       ! Display the bit positions.
90 NEXT I
100 DISP
110 OUTPUT 715; ''U1X''                 ! Program for error status.
120 ENTER 715; A$                       ! Get U1 status to clear error.
130 DISP A$                             ! Display error status.
140 END
```

4.9.17 Save and Recall (L)

Purpose To save and recall instrument setups stored in NVRAM.

Format **Ln,m**

Parameters L0,m Recall configuration #m ($0 \leq m \leq 7$)
L1,m Save configuration #m ($1 \leq m \leq 7$)

Description The L command combines the functions of the front panel SAVE and RECALL keys by allowing the storage or recall of instrument setups. Up to eight instrument configurations can be recalled (0-7) while seven can be saved (1-7).

To save a particular configuration, simply program other operating modes by sending appropriate commands over the bus, then use the L1 command with the number of the position you wish to save. To recall a particular position, send the L0 command along with the number of the position you wish to retrieve.

Programming Notes

1. The instrument assumes save/recall state 1 upon power up or after receiving a DCL or SDC command over the bus.
2. Recall state 0 is permanently stored in ROM and cannot be altered by save.
3. The following modes can be saved and recalled:
   Range (R)
   Frequency (F)
   Filter (P)
   Rate (S)
   Zero (Z)
   Trigger source and mode (T)
   Bias on or off (N)
   Waveform type and times (W)
   Bias voltage parameters (V)
4. Recall state 0 returns all units to 100kHz frequency, including 590/1M models.

4.9.18 Measure and Assign Cable Parameters (I)

Purpose To perform the driving point method of cable correction, and to program parameters associated with the matrix and standards methods of cable correction.

Formats **In(,parameters)**

Parameters

I0 Measure cable parameters (driving point)

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 matrix 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 matrix parameters:
A(n1+jn2),B(n3+jn4),C(n5+jn6),D(n7+jn8)

I4 Perform offset correction

I5,C,G Measure C and G values, step 1

I6,C,G Measure C and G values, step 2

Description The I command allows you to perform the three methods of cable correction over the IEEE-488 bus: driving point, matrix parameter, and calibration capacitor method. Of these three cable correction methods, only the driving point method is available from the front panel, as discussed in paragraph 3.21. All methods are covered in detail in paragraph 4.11 of this section.

Cable correction commands include:

I0: Driving Point Method

This method involves connecting two identical cables to the INPUT and OUTPUT jacks with the opposite ends left open. Cable correction is then performed either by pressing CABLE CAL or by sending I0 over the bus. While this method is the simplest, it cannot be used with complex transmission paths with multiple connecting points.

I1: Assigning Internal Correction Constants

I1 allows you to send the actual internal constants used by the insrument to perform corrections. These constants are derived by the instrument when it performs any form of cable correction, and can be read from the unit by using the U26 command. By combining I1 and U26, the number of correction setups that can be saved can be extended beyond the seven setups that can be stored within the instrument. See paragraph 4.11 for details.

I2 and I3: Matrix Parameter Method

Here, real and imaginary parameters are programmed with the I2 and I3 commands. These parameters are components of the A, B, C, and D matrix parameters.

I4, I5, and I6: Calibration Capacitor Method

With this method, two precisely known capacitance sources are measured. The resulting constants are then used to perform correction with subsequent measurements. I4 is used to perform correction offset, while I5 and I6 are used to send the actual source values over the bus.

Programming Note Use the C command (paragraph 4.9.19) to save and recall cable correction parameters.

Programming Examples

```
10 OUTPUT 715; ''I0X''              ! Perform driving point correction.
20 OUTPUT 715; ''I4X''              ! Zero cable offset.
30 OUTPUT 715; ''I5X,470E-12X''     ! Send first source value.
40 OUTPUT 715; ''I6,180E-12X''      ! Send second source value.
```

4.9.19 Save and Recall Cable Corrections (C)

Purpose To save or recall of cable correction parameters.

Format **Cn,m**

Parameters C0,m Recall cable correction #m ($0 \leq m \leq 7$)
C1,m Save cable correction #m ($1 \leq m \leq 7$)

Default Power-up/DCL/SDC Configuration: Factory default is C0,0 (disable external cable correction)

Description The C command allows you to save and recall up to seven different external sets of cable correction parameters for use when measuring at 100kHz or 1MHz. This process is similar to using the front panel CABLE # key. Before using this command to save corrections you must first perform one of the cable correction processes, as discussed in paragraph 4.9.19.

Programming Notes

1. To disable external cable correction, send a C0,0X command (correction to front panel jacks remains in effect).
2. Saved and recalled corrections at each position must be at the same frequency, or inaccurate readings will result.

Programming Examples

```
10 OUTPUT 715; ''C0,4X''  ! Recall correction #4.
20 OUTPUT 715; ''C1,2X''  ! Save correction #2.
30 OUTPUT 715; ''C0,0X''  ! Disable correction.
```

4.9.20 Calibration (Q)

Purpose To calibrate the instrument to known standards.

Format **Qn(,parameters)**

Parameters
Q0 Thermal drift correction (same as CAL key)
Normal Mode:
Q1 Null offsets
Q2,C,G First capacitance calibration point
Q3,C,G Second capacitance calibration point
Q4,C,G Conductance calibration point
Driving Point Mode:
Q5 Null offsets
Q6,C,G First capacitance calibration point
Q7,C,G Second capacitance calibration point
Voltage Calibration:
Q8 Null offsets
Q9,V Calibrate voltmeter gain

Description The Q0 command performs the same operation as the front panel CAL key by verifying instrument accuracy to internal capacitance standards. This process should be repeated periodically, as discussed in paragraph 3.11.

The remaining Q commands perform complete instrument calibration to precisely known sources. For complete information on using these commands to calibrate the instrument, including required standards, necessary equipment, and detailed calibration procedures, refer to paragraph 7.3 in Section 7 of this manual.

Programming Notes
1. A CAL LOCKED error message will occur if you attempt to use the Q1-Q9 commands with the internal calibration switch in the disabled (locked) position.
2. Calibration should be performed only with precisely known sources, as discussed in paragraph 7.3.
3. Sending DCL or SDC will cancel drift correction (Q0) constants.

Programming Examples

```
10 OUTPUT 715; ''Q0X''  ! Perform internal calibration.
20 OUTPUT 715; ''Q8X''  ! Calibrate voltage offsets.
```

4.9.21 Terminator (Y)

Purpose To program the terminator(s) the instrument sends at the end of its data string.

Format **Yn**

Parameters
Y0 <CR> <LF>
Y1 <LF> <CR>
Y2 <CR>
Y3 <LF>

Default Power-up/DCL/SDC Configuration: Factory default is Y0 (<CR> <LF>).

Description By using the Y command, you can program the number and type of terminator characters the instrument sends at the end of its data string. Available terminator characters are the commonly used CR (carriage return) and LF (line feed) characters. These terminator characters are recognized by most controllers. The ASCII value of the CR character is 13, and the ASCII value of the LF character is 10.

Programming Notes

1. EOI is another method that can be used to terminate the controller input sequence, as discussed in paragraph 4.9.22. EOI is asserted with the last terminator byte when enabled.
2. The programmed terminator will also be transmitted at the end of the status words. Status word programming is covered in paragraph 4.9.15.
3. The programmed terminator is sent only at the end of the complete data transmission sequence regardless of the selected data format.

Programming Examples

```
10 OUTPUT 715; ''Y2X''  ! Program CR only as terminator.
20 OUTPUT 715; ''Y3X''  ! Terminate on LF.
30 OUTPUT 715; ''Y0X''  ! Restore default terminator.
```

4.9.22 EOI and Bus Hold-off on X (K)

Purpose To enable/disable EOI and bus hold-off.

Format **Kn**

Parameters
K0 Both EOI and bus hold-off on X enabled
K1 EOI disabled, bus hold-off on X enabled
K2 EOI enabled, bus hold-off on X disabled
K4 Both EOI and bus hold-off on X disabled

Default Power-up/DCL/SDC Configuration: Factory default is K0 (both EOI and bus hold-off enabled).

Description The EOI line provides one method to positively identify the last byte in the data string sent by the instrument. When enabled, EOI will be asserted with the last byte the instrument sends over the bus.

Bus hold-off allows the instrument to temporarily hold up bus operation via the NRFD line when it receives the X character until all commands are processed. The advantage of using bus hold-off is that no commands will be missed while the instrument is processing previously received commands. Table 4-15 summarizes NRFD hold-off times for various commands.

Programming Notes

1. Some controllers rely on EOI to terminate their input sequences. Suppressing EOI may cause the controller input sequence to hang.
2. When reading a buffer, EOI is asserted only at the end of the entire buffer transmission.
3. When enabled, EOI will be asserted with the last byte in the terminator (if enabled), or with the last byte in the data string if the terminator has been disabled.
4. When bus hold-off is enabled, all bus activity will be held up for the duration of the hold-off period–not just activity associated with the Model 590.

Programming Examples

```
10 OUTPUT 715; ''K1X''  ! Disable EOI, enable hold-off.
20 OUTPUT 715; ''K2X''  ! Enable EOI, disable hold-off.
```

Table 4-15. Typical Bus Hold-off Times

Command	Typical Hold-off Period
Function (F0→F1)	151msec
Range (R1 - R2)	151msec
Rate (S0 → S0)	93msec
(S1 → S1)	110msec
(S3 → S3)	151msec
(S4 → S4)	555msec
Trigger (T0,1 → T1,1)	160msec
Waveform (W1,1,1,1 → W2,2,2,2)	200msec
Bias Voltage (V1,2,3,4 → V2,4,6,8)	200msec
Bias Control (N0 → N0)	150msec
(N1 → N1)	690msec
Data Format (G0 → G1)	61msec
Operation (O0,0,0 → O1,0,0)	88msec
Buffer (B0 → B0)	75msec
(B1 → B1)	87msec
(B2 → B2)	87msec
(B3 → B3)	160msec
Plotter (A0 → A1)	74msec
Zero (Z0 → Z1)	150msec
Filter (P0 → P1)	153msec
Status (U1 → U2)	61msec
SRQ (M1 → M5)	61msec
Save/Recall (L0,1 → L0,2)	176msec
(L1,1 → L1,2)	624msec
Cable Parameters (I0 → I0)	1.96msec
Save/Recall Cable (C0 → C0)	77msec
(C1 → C1)	246msec
Calibration (Q0 → Q0)	3.5sec
(Q8 → Q8)	2sec
Terminator (Y0 → Y1)	61msec
EOI + Hold-off (K0 → K1)	67msec
Self Test (J1)	32sec
Display (DAAAA → DLLLL)	67msec

4.9.23 Display (D)

Purpose To write messages to the front panel display.

Format **Daaa**

Parameters aaa ASCII characters (20 maximum)

Description The D command allows you to display messages on the front panel. To send a message, simply follow the D command with the appropriate ASCII characters. Many displayable ASCII characters can be sent, including upper case characters, and numbers. Characters that can be displayed include: A-Z, 0-9 and + − = / ? ( ).

If a character cannot be displayed (for example !), all segments of that particular character will turn on.

Programming Notes

1. Spaces in the command string are ignored and will not be displayed. However, you can display a <space> by placing the * character in that position.
2. As with other device-dependent commands, the D command string should be terminated with the X.
3. The maximum number of characters is 20; any extra characters in the string will be ignored.
4. To return the display to normal, send DX or press the front panel LOCAL key.

Programming Examples

```
10 OUTPUT 715; ''DPRESS*KEYX''   ! Display PRESS KEY message.
20 OUTPUT 715; ''DMODEL*590X''   ! Display MODEL 590 message.
```

4.9.24 Hit Button (H)

Purpose To allow emulation of front panel key press sequence.

Format **Hn**

Parameters The parameter n represents the number of the front panel button. Table 4-16 lists the numbers of all front panel keys that can be used with the hit command.

Table 4-16. Hit Button (H) Command Summary

Command	Button	Command	Button
H12	SHIFT/QUIT	H25	ZERO
H15	ENTER	H26	CAL
H16	(A−B)	H27	FILTER
H20	ON	H29	RANGE
H23	MANUAL	H30	FREQ
		H31	MODEL

*Shifted modes are shown in parenthesis, send H12X before these commands to implement them.

Description The H command and its options allow you to emulate front panel keystroke sequence. To emulate any such sequence, simply send the appropriate commands in the necessary order.

Programming Notes

1. The instrument may respond to H command options for keys not listed in Table 4-16; however, it is recommended that you not use them because the instrument will hold off the bus in those cases. To restore bus operation, use the appropriate front panel key to return to normal front panel display.
2. The X character must follow each command in a multiple command string.
3. The H command is functional even if LLO (Local Lockout) is in effect.

Programming Examples

```
10 OUTPUT 715; ''H29X''          ! Emulate RANGE button press.
20 OUTPUT 715; ''H30XH31X''      ! Emulate FREQ, MODEL button presses.
30 OUTPUT 715; ''H12XH16X''      ! Emulate SHIFT, A→ presses.
```

4.9.25 Self Test (J)

Purpose To test front panel display and internal circuitry.

Format **Jn**

Parameters J1 Perform self test

Description The self test command allows you to test much of the internal circuitry, including front panel display segments, and internal reference capacitors. If a problem is found, the instrument will display an error message:

MULTIPLIER FAIL: hardware multiplier failure.
INVALID: excessive offsets or reference capacitor problem.

Programming Notes

1. Allow 30 seconds for the instrument to complete the self test.
2. The instrument will hold off bus operation with the NRFD line during self test operation. Thus, no commands can be sent during the self test.

Programming Examples

```
10 OUTPUT 715; ''J1X''   ! Perform self test.
20 WAIT 30000            ! Wait for test completion.
```

4.10 TRANSLATOR

The enhanced Translator software allows you to define your own programming words in place of standard Keithley device-dependent commands or command strings. For example, the word BIAS could be used in place of V1,3,0.1,2X to program bias voltage parameters. In a more complex example, the word SETUP1 could be used in place of R0F1T2G4X.

The Translator can also be used to emulate the command syntax of other manufacturers' products. For example, Hewlett-Packard uses the command RA to place their instruments in autorange, while the Keithley equivalent is R0. By using Translator, a kind-of standard programming language could be developed for a variety of different instruments on the bus.

Translator uses a number of reserved words and character, as summarized in Table 4-17. Note that these words and character are reserved and cannot be used as Translator words. In addition, the X (execute) character cannot be used in a Translator word.

Table 4-17. Translator Reserved Words and Characters

Word or Character	Description
ALIAS	Define words, enable Translator
NEW	Enable Translator, combine words
OLD	Disable Translator
LIST	Get list of Translator words
FORGET	Erase Translator words
;	Terminate Translator definition string
$	Wildcard to define parameter position

One enhanced feature of the 590 Translator is the wildcard method of parameter handling. Wildcard parameter handling allows you to intermix defined Translator words with standard device-dependent command options.

Commands associated with Translator are discussed in the following paragraphs.

4.10.1 Defining Translator Words (ALIAS)

Purpose To define Translator words and associate them with a particular device-dependent command string.

Format **ALIAS WORD COMMAND ;**

Parameters ALIAS: The reserved word used to define Translator words.
WORD: The user-defined Translator word.
COMMAND: A device-dependent command or command string.
; (semicolon): This character is necessary to terminate the Translator definition string.
<space>: Spaces must be included between the words and semicolon.

Description ALIAS is used to define a Translator word and associate that word with a particular device-dependent command string. Once the Translator word has been defined by the ALIAS command, the instrument will be programmed in accordance with the associated device-dependent commands the next time it receives the Translator word over the bus, assuming that the X character was included in the device-dependent command string at the time of definition.

All upper and lower case letters as well as most other displayable ASCII characters can be used in Translator words. Note, however, that the <space> ; or $ characters cannot be used as these characters are reserved for other purposes.

Programming Notes

1. Sending the ALIAS command automatically enables Translator.
2. Spaces must be included in the ALIAS command string as indicated above.
3. Defining a Translator word that already exists will cause the following error message to be displayed:

   TRANSLATOR-ERR

4. A Translator word cannot exceed 31 characters.
5. A device-dependent command string associated with a Translator word cannot be longer than 128 characters.
6. The number of Translator words that can be defined depends on the relative size of the various Translator words and device-dependent command strings. A maximum of 969 bytes (characters) are available for Translator memory. Each word requires a 5-byte overhead plus one byte per letter in the Translator word and device-dependent command string.
7. The X (execute) character cannot be used in the Translator word itself, but it must be included as the last character in the device-dependent command string, if that particular Translator word is to be executed when sent.
8. The DCL and SDC commands will clear Translator words from memory and disable the Translator.

Programming Examples

```
10 OUTPUT 715; ''ALIAS SETUP1 F1R0X ;''     ! Define SETUP1 word for
                                              F1R0X
20 OUTPUT 715; ''ALIAS SETUP2 R2T3S2X ;''   ! Define SETUP2 word for
                                              R2T3S2X
30 OUTPUT 715; ''SETUP1''                   ! Execute SETUP1 word
                                              (F1R0X).
40 OUTPUT 715; ''SETUP2''                   ! Execute SETUP2 word
                                              (R2T3S2X).
```

4.10.2 Enabling the Translator (NEW)

Purpose To enable Translator using previously defined words.

Format **NEW**

Parameters None

Description NEW enables Translator and informs the instrument that the following command strings may contain Translator words. The instrument will then respond both to Translator words as well as the usual device-dependent commands. NEW can also be used to combine Translator words, as described in paragraph 4.10.4.

Programming Notes

1. The ALIAS command, which is used to define Translator words, automatically enables the Translator.
2. Using NEW does not in any way change defined Translator words or the associated command strings.

Programming Example

```
10 OUTPUT 715; ''NEW''
```
! Send NEW to enable Translator.

4.10.3 Disabling the Translator (OLD)

Purpose To disable the Translator without erasing previously-defined words.

Format **OLD**

Parameters None

Description OLD performs the opposite function from NEW in that Translator will be disabled. After OLD is sent, the Model 590 will respond only to device-dependent command strings.

Programming Note Using OLD does not erase previously-defined Translator words from memory. Such words can be used again simply by sending NEW to re-enable the Translator.

Programming Example

```
10 OUTPUT 715; ''OLD'' ! Disable Translator.
```

4.10.4 Combining Translator Words (ALIAS and NEW)

Purpose To combine existing Translator words into a new word with the combined functions of the original words.

Format **ALIAS NEWWORD NEW OLDWORD1 NEW OLDWORD2 ;**

Parameters

ALIAS: Defines the Translator word.

NEWWORD: The new word to be defined.

OLDWORD1 and OLDWORD2: Existing Translator words.

NEW: Reserved word indicating that OLDWORD1 and OLDWORD2 are existing Translator words.

; (semicolon): A terminator that marks the end of the ALIAS sequence.

<space>: A space must be included between each word.

Description ALIAS and NEW can be used together to combine the functions of two or more existing Translator words into a single word. This new word will then include the functions of the device-dependent commands associated with the original words.

Programming Notes

1. Using ALIAS will automatically enable the Translator.
2. The instrument will still recognize any original words even if combined in this manner.
3. Reserved words or the X (execute) character cannot be used in a Translator word.

Programming Examples

```
10 OUTPUT 715; ''ALIAS SETUP1 F1X ;''        ! Define SETUP1 as F1X.
20 OUTPUT 715; ''ALIAS SETUP2 R0X ;''        ! Define SETUP2 as R0X.
30 OUTPUT 715; ''ALIAS SETUP3 NEW            ! Combine SETUP1 and SETUP2
   SETUP1 NEW SETUP2 ;''                       into SETUP3.
40 OUTPUT 715; ''SETUP3''                    ! Execute SETUP3 (F1XR0X).
```

4.10.5 Reading Back Translator Words (LIST)

Purpose To obtain a list of defined Translator words.

Format **LIST**

Parameters None

Description Programmed Translator words can be obtained from the instrument by the controller by using the LIST command. After sending LIST to the instrument, the words can be obtained in the same manner used to access normal instrument data. The various words will be delimited by spaces, and the most recently programmed word will be transmitted first.

Programming Notes

1. If no Translator words exist in memory, none will be transmitted when the word list is requested.
2. Only the Translator words will be sent following the LIST command. The device-dependent commands associated with the commands will not be transmitted.
3. The programmed terminator and EOI command will be transmitted at the end of the complete LIST sequence.

Programming Eamples

```
10 DIM A$[50]                              ! Dimension input string.
20 OUTPUT 715; ''ALIAS SETUP1 R1F1X ;''    ! Define first word.
30 OUTPUT 715; ''ALIAS SETUP2 R0T2X ;''    ! Define second word.
40 OUTPUT 715; ''ALIAS SETUP3 G2S2X ;''    ! Define third word.
50 OUTPUT 715; ''LIST''                    ! Send LIST command.
60 ENTER 715; A$                           ! Get word list.
70 DISP A$                                 ! Display word list.
```

4.10.6 Purging Translator Words (FORGET)

Purpose To erase previously defined user Translator words from memory.

Format **FORGET**

Parameters None

Description Translator words can be purged (erased) from memory by using the reserved word FORGET. Once this command is sent, there is no way to restore them other than by re-programming with the ALIAS command.

Programming Note The DCL and SDC commands will also erase Translator words from memory.

Programming Example `10 OUTPUT 715; ''FORGET''` ! Erase all user Translator words.

4.10.7 Obtaining Translator Status (U27-U31)

Purpose To obtain user and factory Translator word lists, a list of reserved words, and to determine whether or not Translator is enabled.

Format **Un**

Parameters
U27 Send user name list (no DDCs).
U28 Not used
U29 Send list of reserved words.
U30 Indicate Translator state (NEW or OLD).
U31 Send user translation list, including DDCs.

Description The U27 through U31 commands allow you to obtain from the instrument certain information on various aspects of Translator programming. To obtain the desired status, simply send the command, address the instrument to talk, and input the status string as you would with normal data.

U27 will give you the user name list. Information associated with these commands includes the defined Translator words, but the associated device-dependent commands will not be sent. To obtain both the Translator word and the command string associated with it, send U31 for the user list.

U29 will give you a list of the reserved words such as ALIAS and NEW, while U30 will indicate whether the Translator is enabled (NEW) or disabled (OLD).

Table 4-18 summarizes Translator status words, and Figures 4-38 through 4-41 show the general formats for all the Translator status words.

Table 4-18. Translator Status Word Summary

Command	Identifier	Description
U27	UNL	User Name List (No DDCs)
U29	RNL	Reserved Name List
U30	AAA	NEW or OLD in AAA field defines state
U31	UTL	User Translation List (Includes DDCs)

Programming Notes

1. A Translator status word will be sent only once per command.
2. Additional status words which detail other aspects of instrument operation and programming are also available, as discussed in paragraph 4.9.16.
3. The programmed terminator and EOI will be sent at the end of the status word string.
4. The U27 and LIST commands perform the same operation.
5. If no Translator words are defined, nothing except the terminator and EOI (if programmed) will be sent after programming U27.

Programming Examples

```
 10 DIM A$[200]                ! Dimension input string.
 20 OUTPUT 715; ''U27X''       ! Program for user name list.
 30 ENTER 715; A$              ! Get user name list.
 40 DISP A$                    ! Display factory name list.
 50 OUTPUT 715; ''U29X''       ! Program for reserved words.
 60 ENTER 715; A$              ! Get reserved word list.
 70 DISP A$                    ! Display reserved words.
 80 OUTPUT 715; ''U30X''       ! Program for Translator state.
 90 ENTER 715; A$              ! Get Translator state.
100 DISP A$                    ! Display NEW or OLD.
```

```
USER NAME
  LIST
IDENTIFIER
    UNL WORD 1 WORD 2 ... WORD N <TERM+EOI>
```

Figure 4-38. U27 Status Word Format (Translator User Name List)

```
RESERVED NAME
     LIST
  IDENTIFIER
    RNL LIST ;  ALIAS FORGET NEW OLD <TERM+EOI>
```

Figure 4-39. U29 Status Word Format (Reserved Name List)

```
AAA <TERM+EOI>
    NEW=TRANSLATOR ENABLED
    OLD=TRANSLATOR DISABLED
```

Figure 4-40. U30 Status Word Format (New/Old Status)

USER TRANSLATION LIST IDENTIFIER

UTL ALIAS WORD 1 DDC 1; . . . ALIAS WORD N DDC N; <TERM+EOI>

TRANSLATOR WORD

ASSOCIATED DEVICE-DEPENDENT COMMAND STRING

Figure 4-41. U31 Status Word Format (Translator User Translation List)

4.10.8 Translator Parameter Passing ($)

Purpose To allow partial definition of Translator words with parameters later passed in device-dependent command options.

Format **ALIAS WORD Cmd$(,$)(,$) ;**

Parameters

ALIAS: The reserved word that defines Translator words.

Cmd: A device-dependent command letter.

$: A wildcard parameter used to mark a position where command options will later be inserted.

<space>: A space must be included between elements of the string.

;: Semicolon is necessary to terminate the ALIAS string.

Description The $ character is a wildcard that allows you to mark the position in a device-dependent command string where parameters will later be placed. With multiple option commands, you may substitute as few or as many options as desired. For example, to specify voltage parameters, you could define V$,$,$,5X, or simply V$,10,0.5,5X. In the first case, only the default bias (5) is specified when the Translator word is first defined, while the remaining parameters (first, last, and step bias voltages) would be sent when the Translator word is transmitted to the instrument. In the second instance, only the first voltage would be left unspecified, while the remaining parameters would be permanently defined as attributes of the Translator word.

To pass parameters once a word is defined, you need only include the command options immediately following the Translator word in your command string. The word and each option must be separated with a space, and would normally be followed with the usual terminator sequence. For example, assume that you previously defined the word VOLTS as being associated with V$,$,$,5X. Options could then be passed by sending the following string:

VOLTS 1 10 0.5 <TERMINATOR>

In this case, the instrument would perform a command equivalent to V1,10,0.5,5, or first, last, step, and default voltages of 1V, 10V, 0.5V, and 5V, respectively.

Programming Notes

1. With multiple-option commands, each parameter, including wildcards, must be separated by commas.
2. Parameters for all wildcards must be included with the Translator word when sent.
3. The execute character must be included as the device-dependent command string, if those commands are to be executed when that particular string is sent.
4. Parameters are passed in the order they appear in the definition and execution strings.

Programming Examples

```
10 OUTPUT 715; ''ALIAS RANGE R$X ;''    ! Define RANGE with R
                                          command.
20 OUTPUT 715; ''RANGE 0''              ! Program autorange.
30 OUTPUT 715; ''RANGE 9''              ! Turn off autorange.
40 OUTPUT 715; ''RANGE 4''              ! Select 2nF range.
50 OUTPUT 715; ''ALIAS VOLTS V$,        ! Define VOLTS with V command
   $,$,5X ;                               only default voltage specified.
60 OUTPUT 715; ''VOLTS 1 10 2''         ! Send VOLTS with passed para-
                                          meters first, last, and step.
70 OUTPUT 715; ''ALIAS BIAS W1,         ! Define BIAS with W command,
   10E-3,10E-3,$X;''                      all except step time specified.
80 OUTPUT 715; ''BIAS 100E-3''          ! Program BIAS with 100msec step
                                          time.
```

4.10.9 Translator Error Handling

Purpose To flag Translator error conditions.

Format **TRANSLATOR-ERR**

Description If a Translator error occurs, the instrument will briefly display the following message on the front panel:

TRANSLATOR-ERR

In addition, the Translator error bit in the U1 status word will be set when an error condition occurs (paragraph 4.9.15). Since the setting of any bit in the U1 can generate an SRQ (Service Request), the unit can be programmed to request service from the controller should a Translator error occur. Refer to paragraph 4.9.16 for SRQ information.

Conditions that can cause a Translator error include:

1. No more memory available for additional Translator words. A total of 1,450 bytes (characters) are available for Translator words and the associated device-dependent command strings.
2. Use of more than one ALIAS in a definition. ALIAS can be used only once per definition.
3. Translator word exceeds the maximum allowed 31 characters.
4. Use of X in a Translator word.
5. Attempting to define a Translator word that already exists.
6. Using a reserved character or word in a Translator word ($ LIST FORGET ALIAS NEW OLD).

Programming Examples

```
10 OUTPUT 715; ''ALIAS          ! X in word.
   EXTRA F0X;''
20 OUTPUT 715; ''ALIAS
   NEW R1X;''                   ! NEW in word
```

4.11 CABLE CORRECTION

The following paragraphs describe in detail the three available methods of cable correction. Correction methods are:

1. Driving point method (front panel and bus): The driving point admittance of an open-ended cable is measured and correction constants are calculated from the resulting measurements.
2. Matrix parameter method (bus only): Transmission line matrix parameters are sent to the instrument over the bus to derive the necessary correction constants. These matrix parameters are derived from two-port scattering parameters that must be measured with specialized test equipment.
3. Calibration capacitor method (bus only): Here, two precisely known capacitance sources are connected in place of the test fixture, and the Model 590 is programmed with the actual values over the bus.

The three available methods as well as certain facts and limitations are summarized in Table 4-19. Table 4-20 summarizes bus commands associated with cable correction. I0 performs driving point cable correction, while I2 and I3 send the transmission line matrix parameters for the OUTPUT and INPUT paths, respectively. I4, I5, and I6 are used to perform the calibration capacitor method in two steps. I1 is used to send internal cable correction coefficients to the instrument.

Two additional cable correction commands include the C command, which can be used to save and recall cable correction set ups, as well as the U26 command used to obtain cable correction constants from the instrument.

More information on cable correction principles may be found in Section 6 of this manual.

NOTE

The dynamic range of the capacitance and conductance readings is reduced by using cable correction. The amount of reduction will depend on such factors as cable length and capacitance.

Table 4-19. Cable Correction Methods

Method	Description	Typical Accuracy*	Comments
1	Driving point (Front panel or bus)	2%	Single cables only
2	Matrix parameter (Bus only)	1.5%	Can be used with complex paths.
3	Calibration capacitor (bus only)	0.5%	Can be used with complex paths.

*Accuracy figures are only typical and are exclusive of other accuracy figures given at the front of this manual.

NOTE: Cable correction does not affect linearity specifications.

Table 4-20. Cable Correction Commands

Command	Description
C0,n	Recall cable setup n (0≤n≤7)*
C1,n	Save cable setup n (1≤n≤7)
I0	Perform driving point correction
I1,n1,n2,n3,n4	Assign correction constants K0(n1+jn2), K1(n3+jn4)
I2,n1,n2,n3,n4, n5,n6,n7,n8	Assign test OUTPUT matrix 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 matrix parameters: A(n1+jn2), B(n3+jn4), C(5n+jn6), D(n7+jn8)
I4, C, G	Zero cable open
I5, C, G	Program C and G values, step 1
I6, C, G	Program C and G values, step 2
U26	Obtain cable correction constants

*To cancel cable correction, use C0,0

4.11.1 Driving Point Correction

Description

To perform cable correction with this method, you need only connect your test cables to the test INPUT and OUTPUT jacks and send the appropriate command over the bus (cables must be unterminated when the command is sent). Note that this method can be used only with simple transmission paths. To properly correct for multiple-cable or switching matrix paths, you must use either the matrix parameter or standards method described below.

Required Equipment

Other than the two coaxial cables used to connect the test fixture to the Model 590, no additional equipment is required.

Procedure

1. Turn on the Model 590 and allow it to warm up for at least one hour before beginning the correction procedure.
2. Program the Model 590 for the desired frequency and 2nF range. With an HP-85 computer, this command string can be sent with the following statement:

   ```
   OUTPUT 715 ;''F1R4X''
   ```

   In this instance, we have chosen 1MHz.

3. Connect two RG-58 cables of identical length to the test INPUT and OUTPUT jacks of the instrument, but leave the opposite ends disconnected. Keep in mind that the maximum recommended cable length is five meters.
4. Send the command I0X over the bus to perform correction. Again, with an HP-85, this command can be sent as follows:

   ```
   OUTPUT 715 ;''I0X''
   ```

5. The instrument will then perform the correction, a process that will take a few seconds to complete. The new cable correction constants will then be placed into effect immediately.
6. See paragraph 4.11.4 for methods to save the correction constants.
7. Connect the test fixture to the cables and make measurements in the usual manner.

Limitations and Considerations

The driving point cable correction method assumes the following:

1. Only simple, single-cable transmission paths can be used.
2. The characteristic impedance of the cable is 50Ω.
3. Cable loss is zero.
4. Both cables are of exactly the same length.

Any deviations from these ideal conditions will cause errors in the correction constants, resulting in inaccurate readings.

4.11.2 Matrix Parameter Correction

Description

In order to use the matrix parameter method, each pathway must be characterized for its characteristics impedance (Zo) and scattering (S) parameters utilizing specialized test equipment. Once these values are known, the A, B, C and D transmission line parameters must be calculated and then sent to the instrument. Keep in mind, however, that each transmission path must be characterized separately.

Required Equipment

Table 4-21 summarizes the equipment necessary to characterize the transmission paths. The 4275A LCR Meter is used to measure the short-circuit inductance and open-circuit capacitance of the path from which the characteristic impedance is calculated. The 3577A Network Analyzer and 35677A S-Parameter Test Set are used to measure the four scattering parameters of each transmission path.

Table 4-21. Equipment Required for Matrix Parameter Correction

Equipment	Use
Hewlett-Packard 4275A LCR Meter	Determine Z_O of each pathway.
Hewlett-Packard 3577A Network Analyzer	Measure scattering (S) parameters.
Hewlett-Packard 35677A S-Parameter Test Set	Used with 3577A to measure S parameters.

Connections

Figure 4-42 demonstrates the basic connecting methods for normal measurements as well as for the Z_O and S parameter characterization. In (a), a typical test setup using a relay matrix is shown, while (b) and (c) show test configurations for determining Z_O and the S parameter respectively.

As shown, the test setup included a relay switching matrix, a very common situation. When using such a relay setup, you must make certain that the relay contact(s) associated with the transmission path are closed during the characterization. Also, you should characterize as much of each path as possible for most accurate results. Typically, the complete path from the test INPUT and OUTPUT jacks through to the test fixture itself will be included in the path. One final point--each path must be characterized separately unless you are absolutely certain that the paths are identical.

Characteristic Impedance Determination

Characteristic impedance, Z_O, is determined by using the LCR meter to measure the short circuit inductance and open circuit capacitance, from which Z_O can be calculated. In order to complete the following procedure, you must be thoroughly familiar with the operation of the 4275A LCR meter. Consult the operator's manual for complete information.

1. Turn on the 4275A and allow it to warm up for the required period for rated accuracy. Be sure to select the desired frequency (100kHz or 1MHz).
2. Disconnect the test cables from the Model 590 and the test fixture.
3. Connect the end of the cable normally attached to the Model 590 to the LCR meter UNKNOWN terminals, but leave the other end of the cable open at this time.
4. If the transmission path goes through a relay matrix, make sure that any relay contacts are closed.
5. Measure the open-circuit capacitance, C_{OC}, using the LCR meter.
6. Short the open end of the test path cable between the center conductor and shield.
7. Measure the short circuit inductance, L_{SC}, with the LCR meter.
8. Disconnect the cable from the LCR meter and connect the other cable in its place. Again, you should connect the pathway end normally attached to the Model 590.
9. Repeat steps 3 through 8 for the other pathway to determine its L_{SC} and C_{OC} values.
10. Calculate the characteristic impedance for each pathway from the L_{SC} and C_{OC} values as follows:

$$Z_O = \sqrt{\frac{L_{SC}}{C_{OC}}}$$

Where: Z_O = characteristic impedance
L_{SC} = short circuit inductance
C_{OC} = open circuit capacitance

These two characteristic impedance values will be used in calculating transmission line matrix parameters, as described below.

Measuring S (Scattering) Parameters

Four S parameters, as shown in Figure 4-43, can be used to characterize any two-port network including a complex transmission path. Two of these parameters (S_{12} and S_{21}) are concerned with transmission, while the remaining two (S_{11} and S_{22}) are associated with reflection.

Use the following procedure to measure the S parameters for each transmission path. The basic connections for this procedure are outlined in Figure 4-42(C). Refer to the 3577A manual for complete details on connections and operation.

1. Connect the 35677A 50Ω S parameter test set to the network analyzer, as discussed in the manual provided with that equipment.
2. Turn on the 3577A power and allow the unit to warm up for the prescribed period.
3. Disconnect the test cables from the Model 590 and the test fixture.
4. Connect the pathway cable normally connected to the Model 590 to PORT 1 on the S parameter test set.
5. Connect the pathway cable normally connected to the test fixture to PORT 2 on the test set.
6. Select analyzer start and stop frequencies that will cover the frequency of interest (100kHz to 1MHz).
7. If your pathways include one or more relays, make sure any relay contacts are closed while making measurements.
8. Using the network analyzer, determine the real and imaginary components of each of the four S parameters. at the frequency of interest (100kHz or 1MHz).
9. Repeat steps 4 through 8 for the other transmission paths.

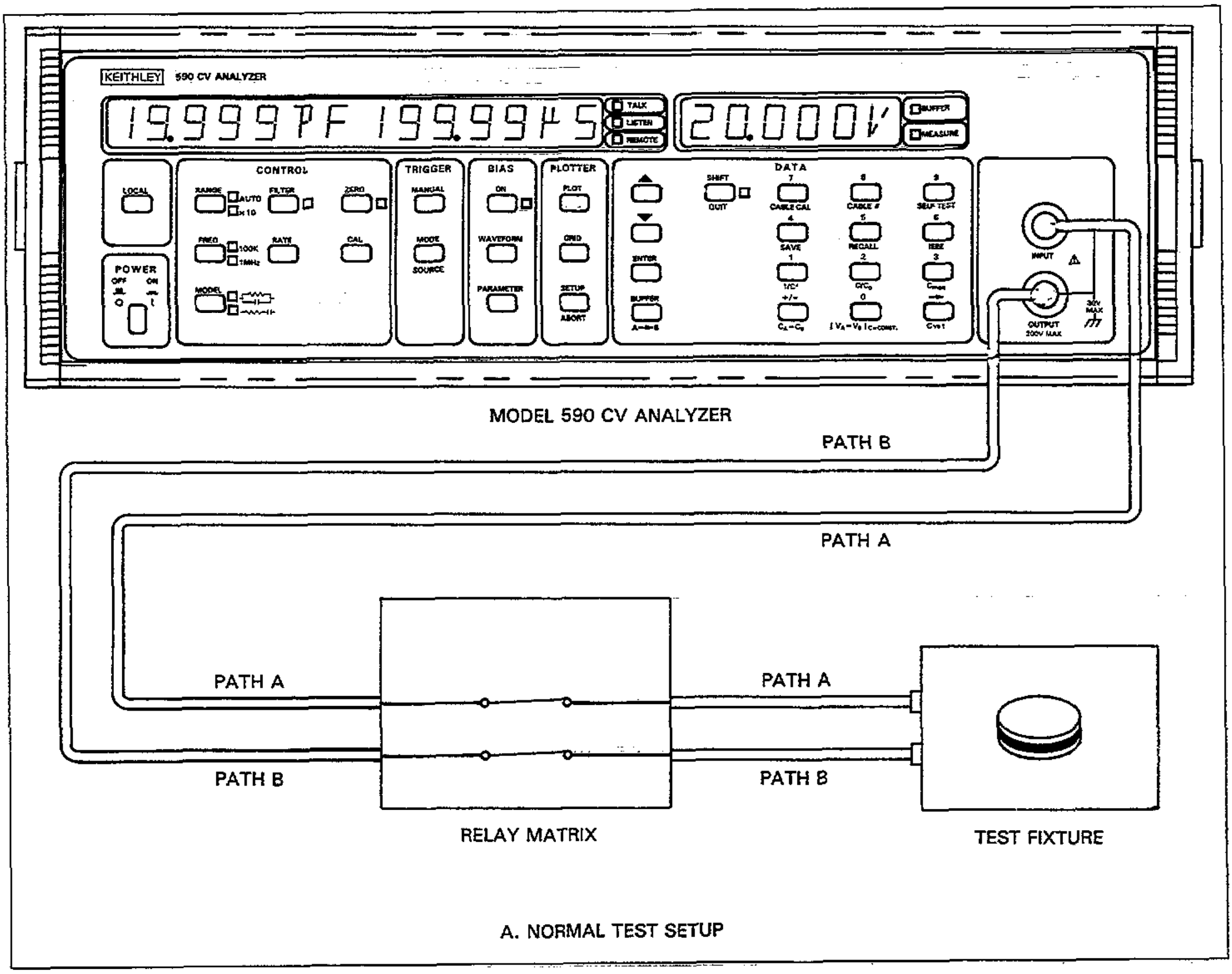


Figure 4-42A. Connecting Methods

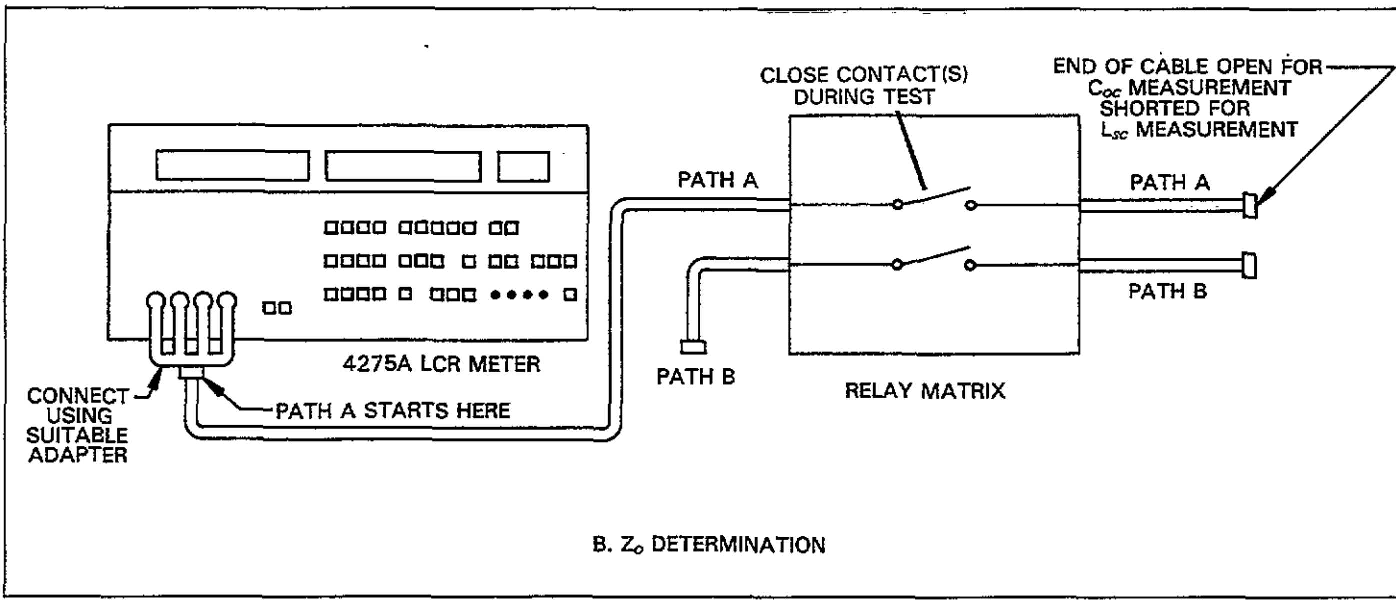


Figure 4-42B. Connecting Methods (Cont.)

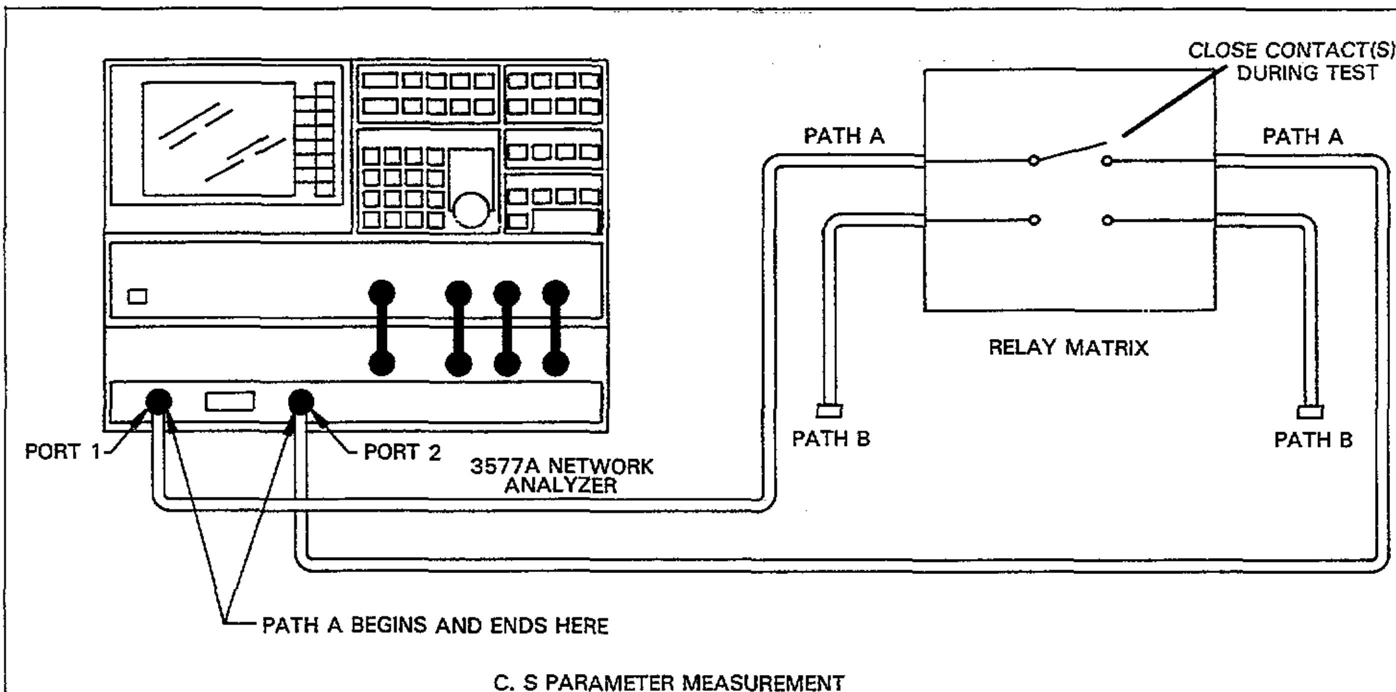
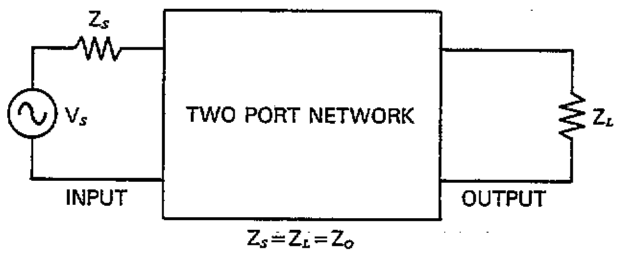


Figure 4-42C. Connecting Methods (Cont.)



S-parameters are simply related to power gain and mismatch loss, quantities which are often of more interest than the corresponding voltage functions:

$$|S_{11}|^2 = \frac{\text{POWER REFLECTED FROM THE NETWORK INPUT}}{\text{POWER INCIDENT ON THE NETWORK INPUT}}$$

$$|S_{22}|^2 = \frac{\text{POWER REFLECTED FROM THE NETWORK OUTPUT}}{\text{POWER INCIDENT ON THE NETWORK OUTPUT}}$$

$$|S_{21}|^2 = \frac{\text{POWER DELIVERED TO A } Z_o \text{ LOAD}}{\text{POWER AVAILABLE FROM } Z_o \text{ SOURCE}}$$

= TRANSDUCER POWER GAIN WITH Z_o LOAD AND SOURCE

$|S_{12}|^2$ = REVERSE TRANSDUCER POWER GAIN WITH Z_o LOAD AND SOURCE.

Figure 4-43. Simplified Parameter Definition

Calculating Matrix Parameters

Once the Z_O and S parameter values are known, the A, B, C, and D transmission line matrix parameters can be calculated by using the appropriate formula, as summarized in Table 4-22. Each matrix parameter result will be a complex number of the form:

$$a + jb$$

Where: a is the real component
b is the imaginary component

Note that, although it is possible to derive phase and magnitude equivalents, it is best to leave the results in rectangular form as the Model 590 requires that they be programmed in that manner.

Programming Matrix Parameters

To program matrix parameters use the appropriate I command to send the eight parameters representing the real and imaginary components of the transmission matrix. For example, the command to program test OUTPUT pathway parameters is of the form:

I2,n1,n2,n3,n4,n5,n6,n7,n8

Where: n1= A parameter, real component
n2= A parameter, imaginary component
n3= B parameter, real component
n4= B parameter, imaginary component
n5= C parameter, real component
n6= C parameter, imaginary component
n7= D parameter, real component
n8= D parameter, imaginary component

The basic command structure and parameter set for the INPUT cable is the same, except, of course, for the fact that I3 is used in place of I2. In either case, the programmed correction values will be placed into effect immediately. If you wish to save the correction, use the C command, as described below.

The simple program below will allow you to program these parameters using an HP-85 computer.

Table 4-22. Matrix Parameter Calculation

Matrix Parameter	I2 or I3 Command Parameters	Calculation
A	n1(real), n2(imaginary)	$A = \dfrac{(1+S_{11})(1-S_{22})+S_{12}\,S_{21}}{2S_{21}}$
C	n5(real), n6(imaginary)	$C = \dfrac{(1-S_{11})(1-S_{22})-S_{12}\,S_{21}}{2S_{21}\,Z_O}$
D	n7(real), n8(imaginary)	$D = \dfrac{(1+S_{22})(1-S_{11})+S_{12}\,S_{21}}{2S_{21}}$
B	n3(real), n4(imaginary)	$B = \dfrac{AD - \dfrac{S_{12}}{S_{21}}}{C}$

```
PROGRAM                              COMMENTS

10 REMOTE 715                        ! Place unit in
                                       remote.
20 CLEAR 7                           ! Send device clear.
25 OUTPUT 715; ""F1X""               ! Program 1MHz.
30 CLEAR                             ! Clear CRT.
40 DISP ""PROGRAM TEST               ! Prompt for path-
   INPUT OR OUTPUT""                   way.
50 DISP
60 DISP ""1= TEST OUTPUT""
70 DISP ""2= TEST INPUT""
80 INPUT A                           ! Input selection.
90 IF A=1 THEN C$=""I2,""            ! Define program-
   ELSE C$=""I3,""                     ming command.
100 DISP""A PARAMETER,               ! Prompt and input
    REAL""
110 INPUT N1                         ! real and imaginary
120 DISP""A PARAMETER,               ! components for all
    IMGINARY""                       ! four matrix para-
                                       meters.
130 INPUT N2
140 DISP""B PARAMETER,
    REAL""
150 INPUT N3
160 DISP""B PARAMETER,
    IMAGINARY""
170 INPUT N4
180 DISP""C PARAMETER,
    REAL""
190 INPUT N5
200 DISP""C PARAMETER,
    IMAGINARY""
210 INPUT N6
220 DISP ""D PARAMETER
    REAL""
230 INPUT N7
240 DISP""D PARAMETER,
    IMAGINARY""
250 INPUT N8
260 OUTPUT 715; C$;N1;               ! Program 590 with
    ",";N2;",";N3;                     matrix para-
    ",";N4;",";N5;                     meters.
    ",";N6;",";N7;
    ",";N8;"X"
270 DISP""REPEAT (YES OR             ! Prompt to repeat
    NO)""                              program.
280 INPUT A$
290 IF A$[1,1]=""Y"" THEN
    30
300 END
```

A Practical Example

As a practical example, assume that the Model 590 is to be used in conjunction with a Keithley Model 705 Scanner equipped with a Model 7062 RF Switch Card, as shown in Figure 4-44. This arrangement would allow the Model 590 to automatically test up to five wafers without operator intervention.

To demonstrate typical S parameters, one pathway for the setup in Figure 4-44 was tested for the four S parameters in the frequency range of 100kHz to 1MHz. The resulting real and imaginary values were plotted using autoscaling; the results are shown in Figures 4-45 through 4-52.

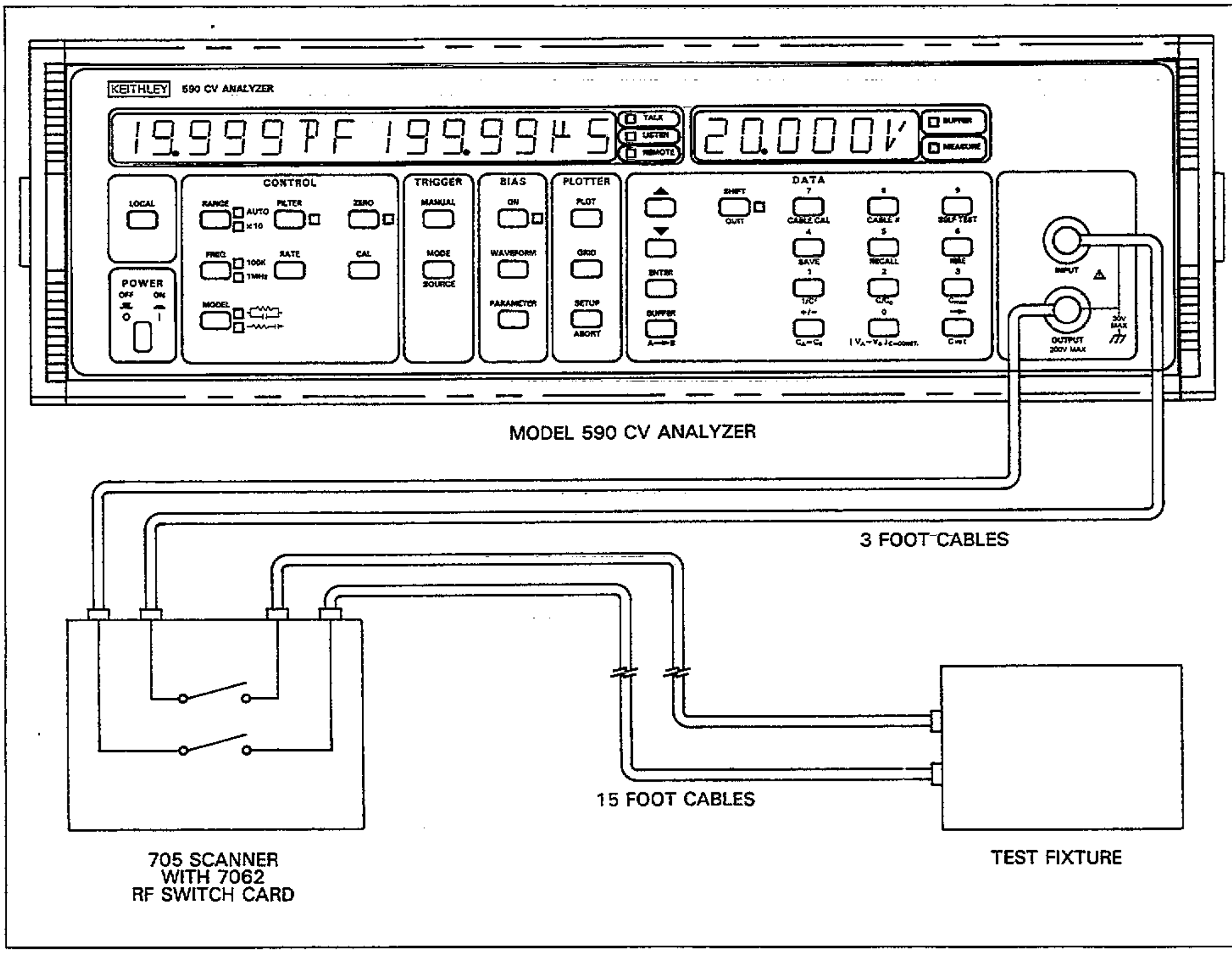


Figure 4-44. Test Configuration for S Parameter Examples

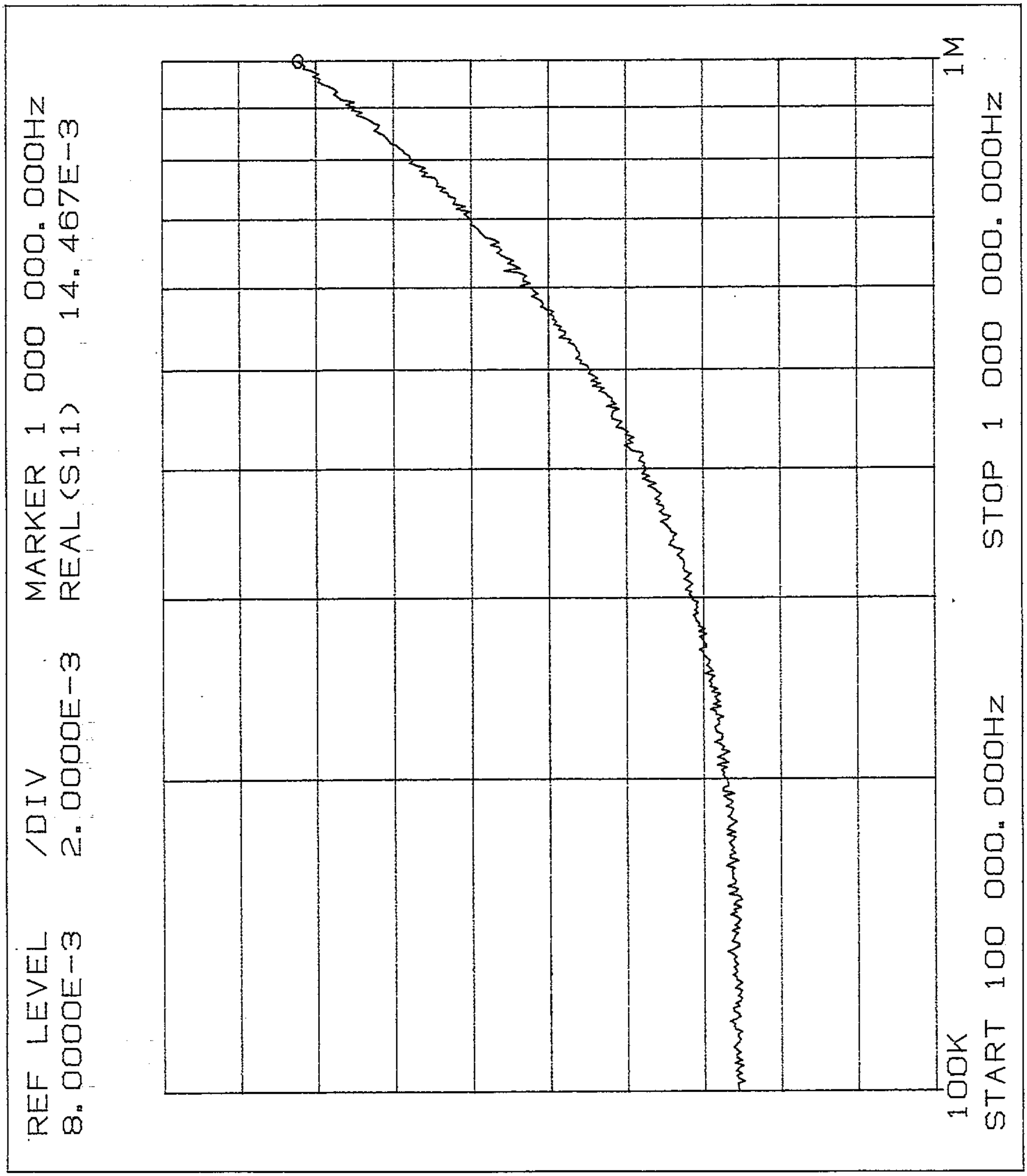


Figure 4-45. S_{11} Real Component

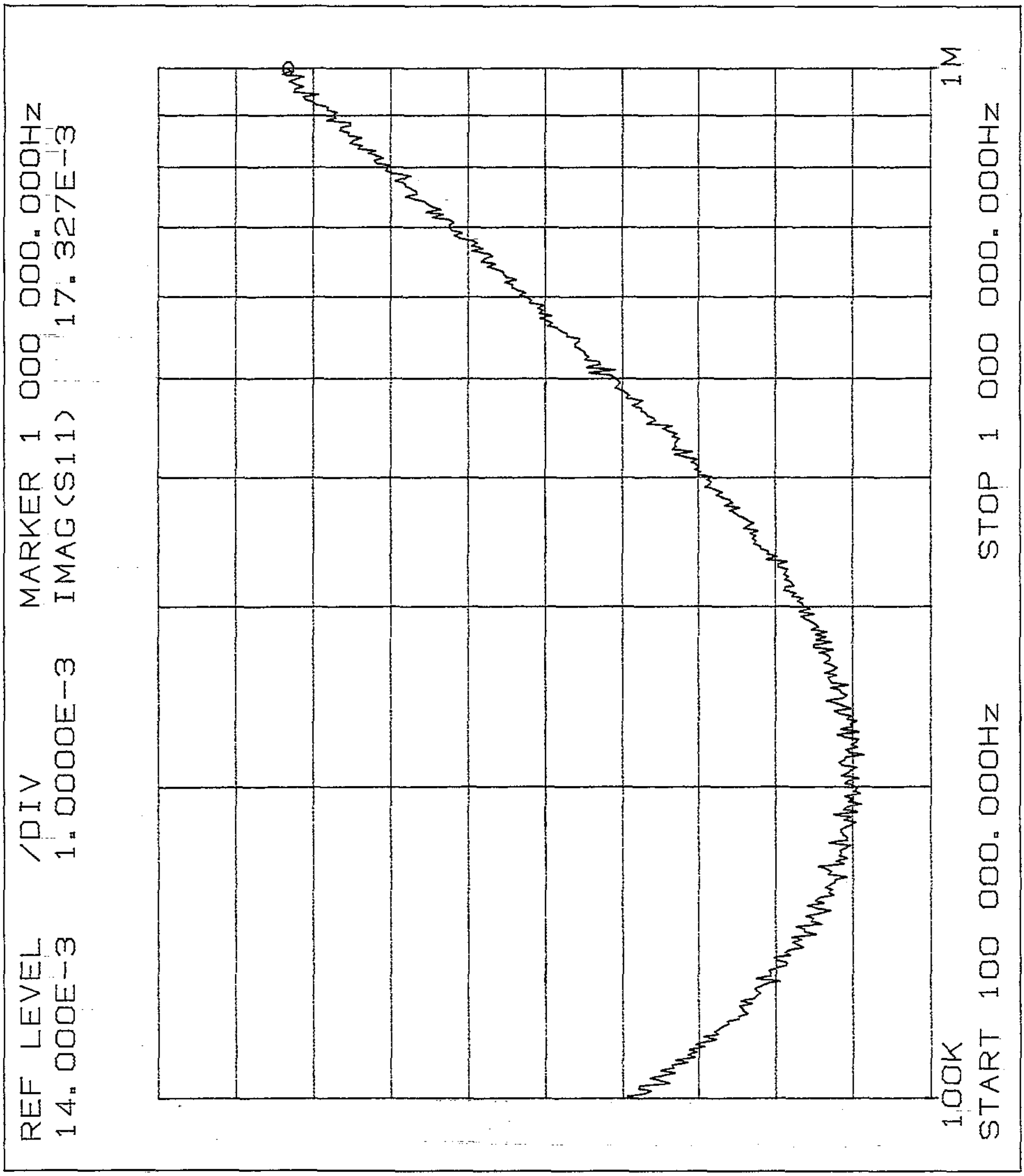


Figure 4-46. S_{11} Imaginary Component

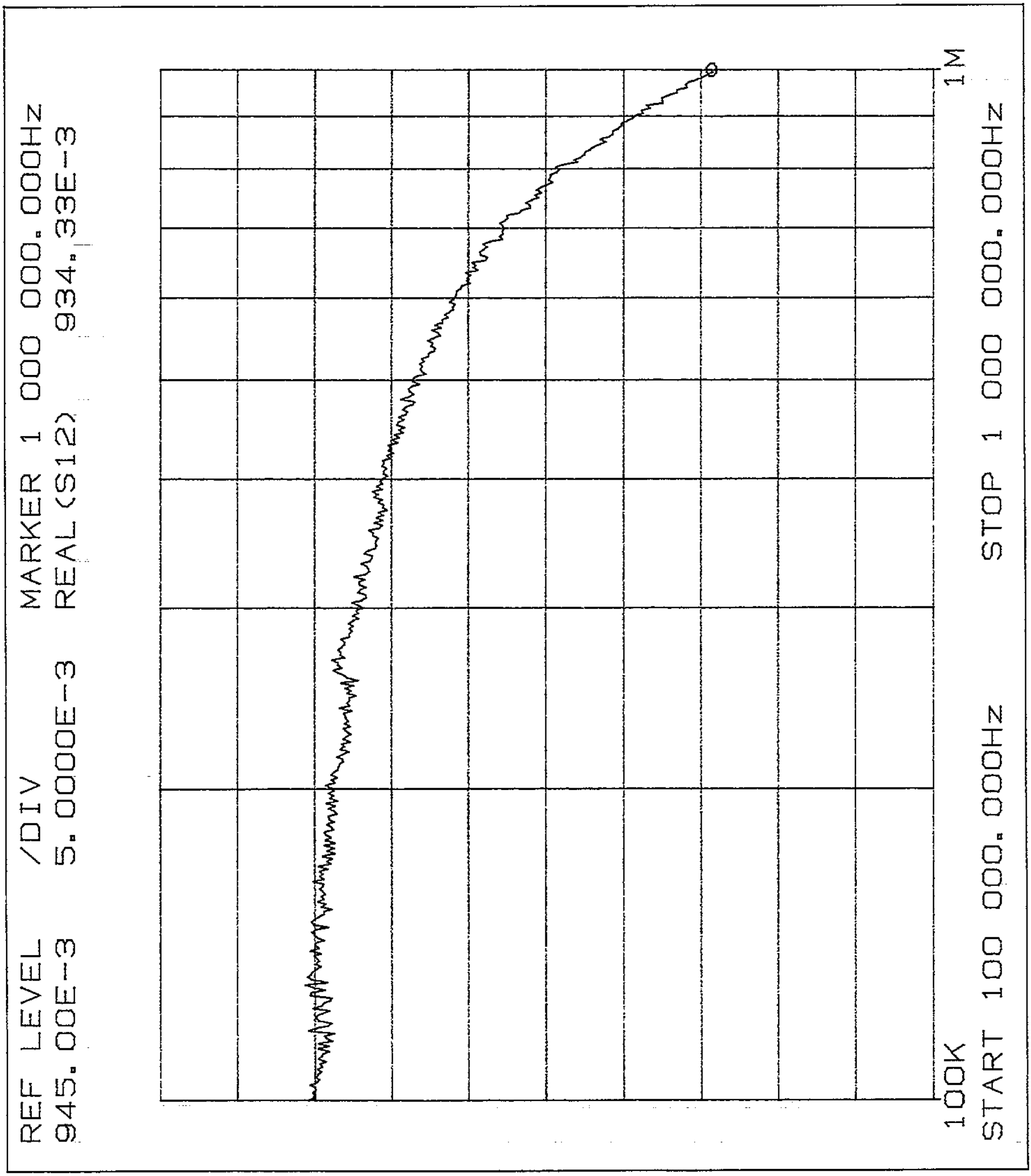


Figure 4-47. S_{12} Real Component

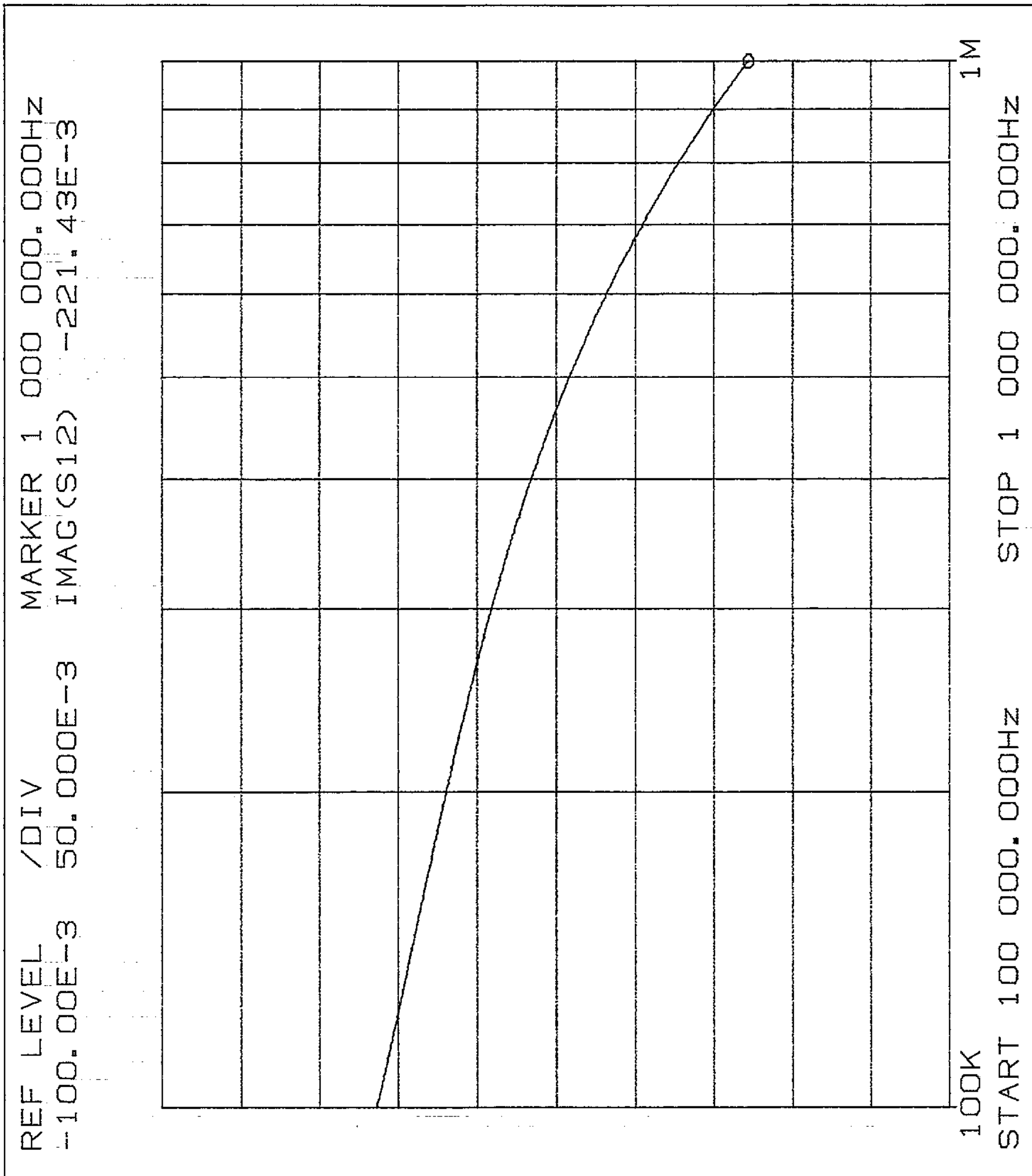


Figure 4-48. S_{12} Imaginary Component

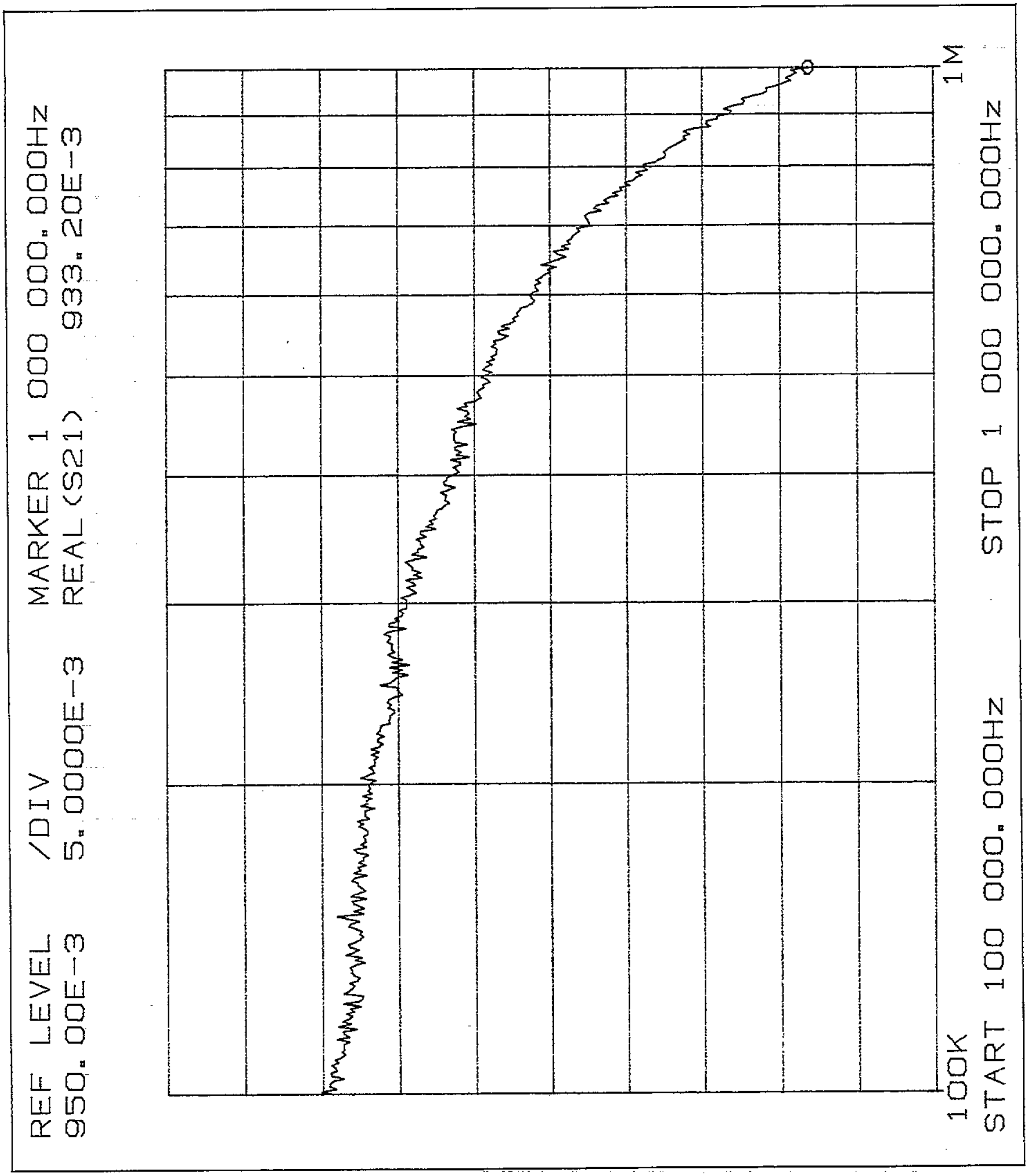


Figure 4-49. S_{21} Real Component

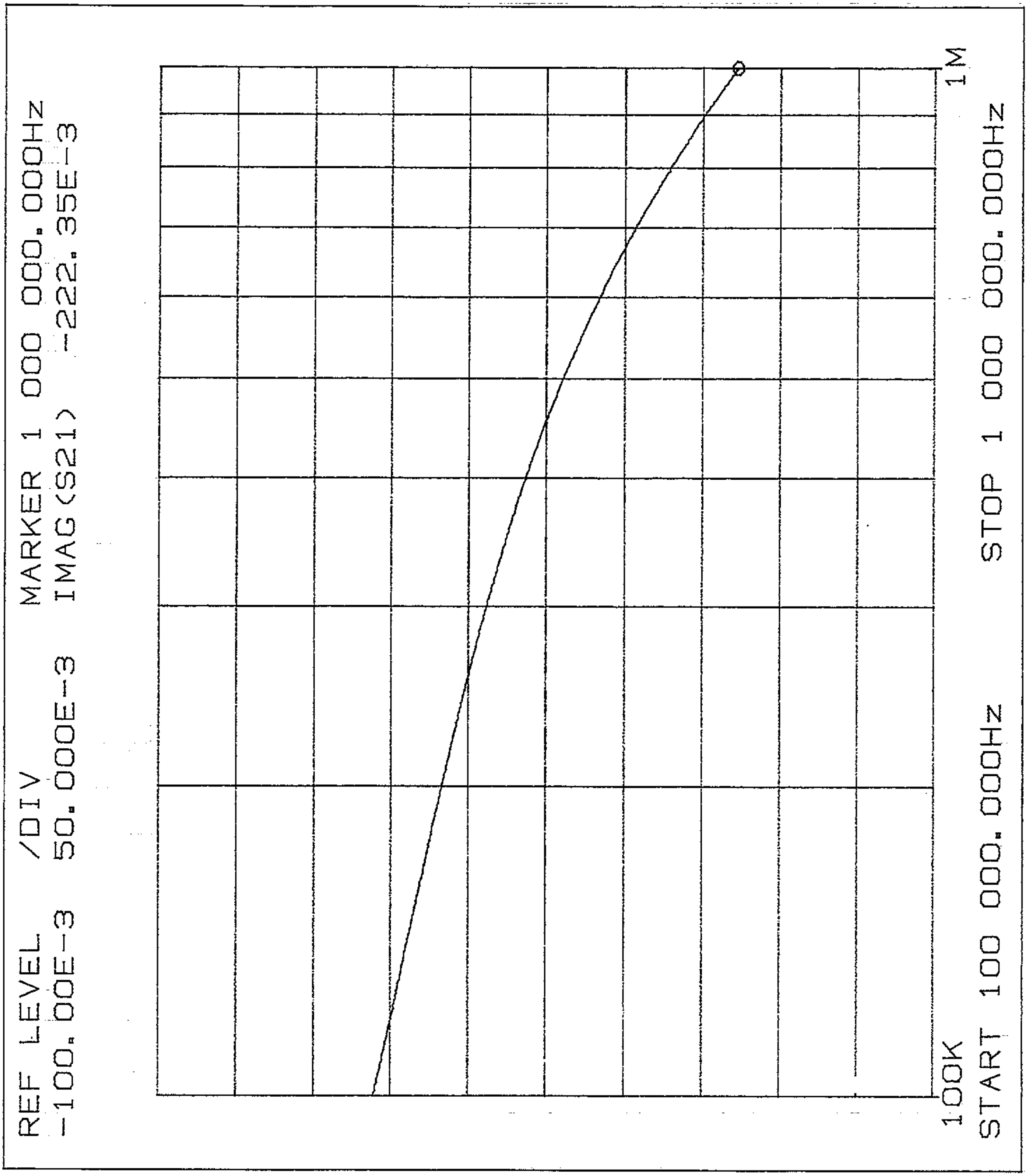


Figure 4-50. S_{21} Imaginary Component

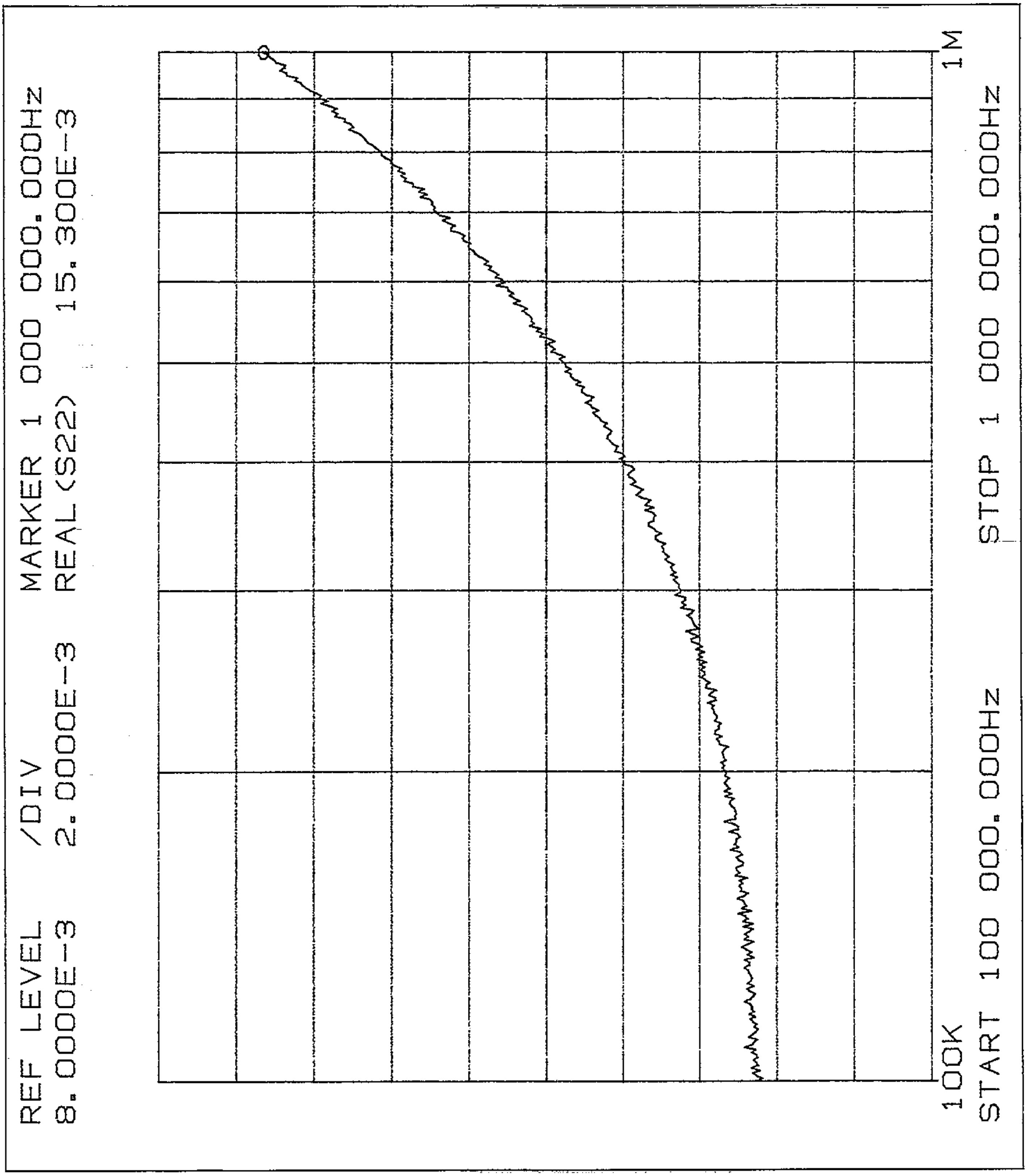


Figure 4-51. S_{22} Real Component

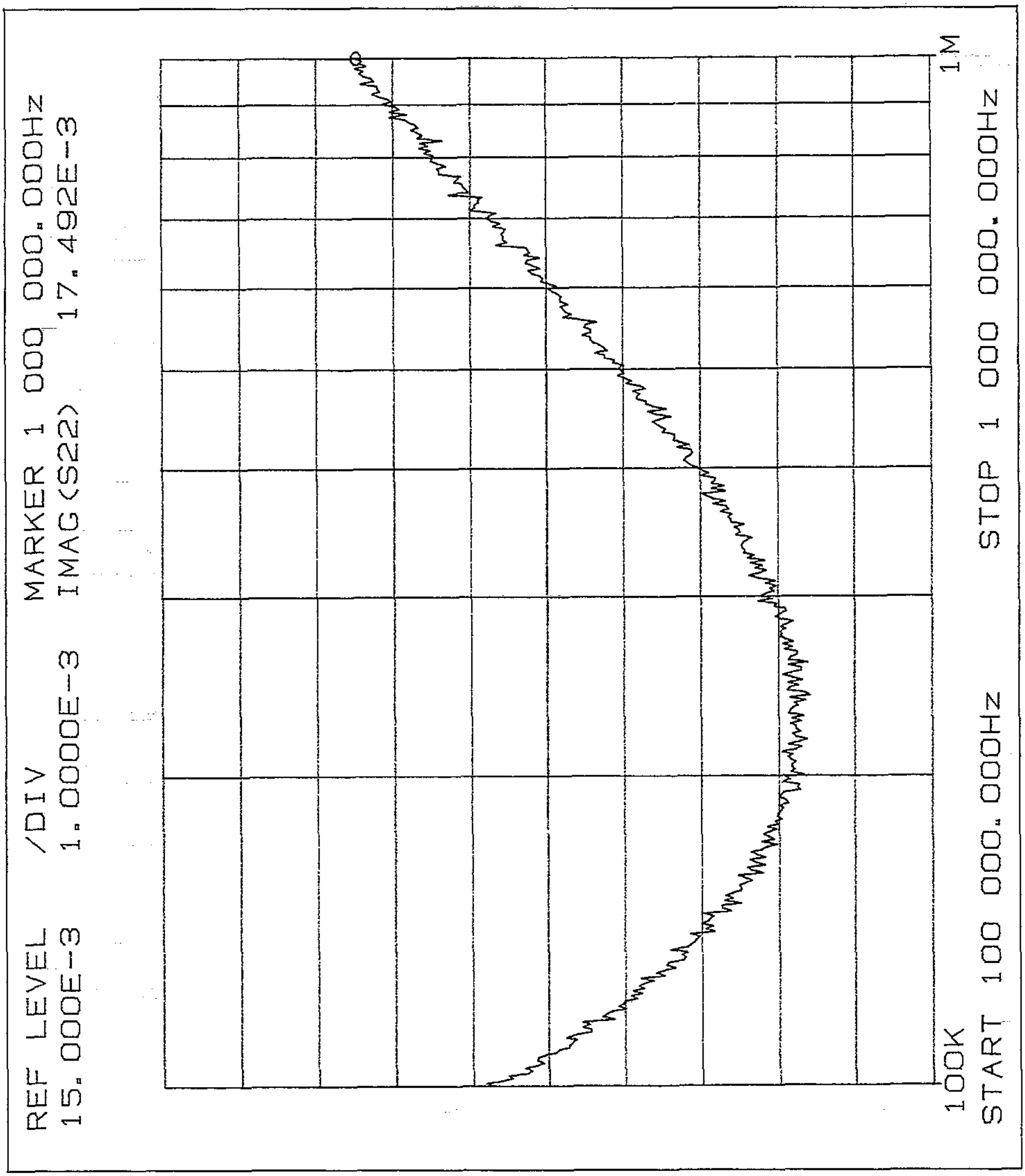


Figure 4-52. S_{22} Imaginary Component

4.11.3 Calibration Capacitor Correction

Description

The calibration capacitor method is a two-step process involving connecting two precisely known capacitors to the instrument in place of the DUT (device under test) and then programming the actual capacitance values over the bus. Of the three methods, this one is the most accurate, assuming that capacitance source used have been precisely characterized for both capacitance and conductance.

NOTE

The method outlined here uses the Model 5907 and is performed on the 2nF range, yielding very good accuracy on all three ranges. The other ranges can be corrected (and stored) separately if appropriate sources are available.

Recommended Sources

Table 4-23 lists the recommended capacitance sources for cable correction. Note that the values listed are nominal, and you should use the actual 100kHz or 1MHz values marked on the sources when programming them over the bus.

If different capacitors are used, they must be of high-quality stable design and properly characterized at the frequency of interest with suitable laboratory standards equipment. Also, each capacitor should be mounted in a shielded enclosure to minimize noise effects.

Table 4-23. Capacitance Sources Required for Cable Correction

Value*	Keithley Model Number
470pF	5907**
1.8nF	5907

*Nominal values shown. 100kHz or 1MHz value marked on source should be used.
**Model 5907 includes adapters to connect source to cables.

Connections

Figure 4-53 shows typical connections for this method of cable correction. Again, we have assumed that a relay matrix will be included in the test path. Of course, your particular test configuration will probably be different. In any case, you should include as much of the actual test path in the test pathways. Typically, the test fixture will be disconnected from the cables and the source capacitor connected in its place. A better solution would be to connect the source capacitor directly to the test fixture, if possible, since doing so would allow for correction of fixture capacitance.

Procedure

1. Turn on the Model 590 and allow the instrument to warm up for at least one hour.
2. Select the 2nF range by sending the command S3R4T2X over the bus.
3. Program the frequency (100kHz or 1MHz).
4. Perform drift correction by sending the command Q0X.
5. Disconnect the cables normally connected to the test fixtures and leave the cable ends open. The opposite ends should remain connected to the test INPUT and OUTPUT jacks. Close any relays in the test paths.
6. Send the correction offset command, I4X. A typical HP-85 statement is:

```
OUTPUT 715; ''I4X''
```

7. Connect the 1.8nF capacitance source listed in Table 4-23 in place of your test fixture as shown in Figure 4-53.
8. Program the capacitance value by using the I5 command. A typical HP-85 statement is:

```
OUTPUT 715; ''I5,1.8E-9,0X''
```

   Here, we have assumed a capacitance of 1.8nF.
9. Disconnect the 1.8nF source and connect the 470pF source in its place (Table 4-23).
10. Program the actual source C value with the I6 command, as in this HP-85 example:

```
OUTPUT 715; ''I6,470E-12,0X''
```

11. After the last command is sent, the programmed cable correction factors will go into effect immediately. If desired, you can store the correction by using the save command discussed in the following paragraph.
12. Disconnect the source from the test cables and connect the test fixture in its place. Measurements may now be taken as usual.

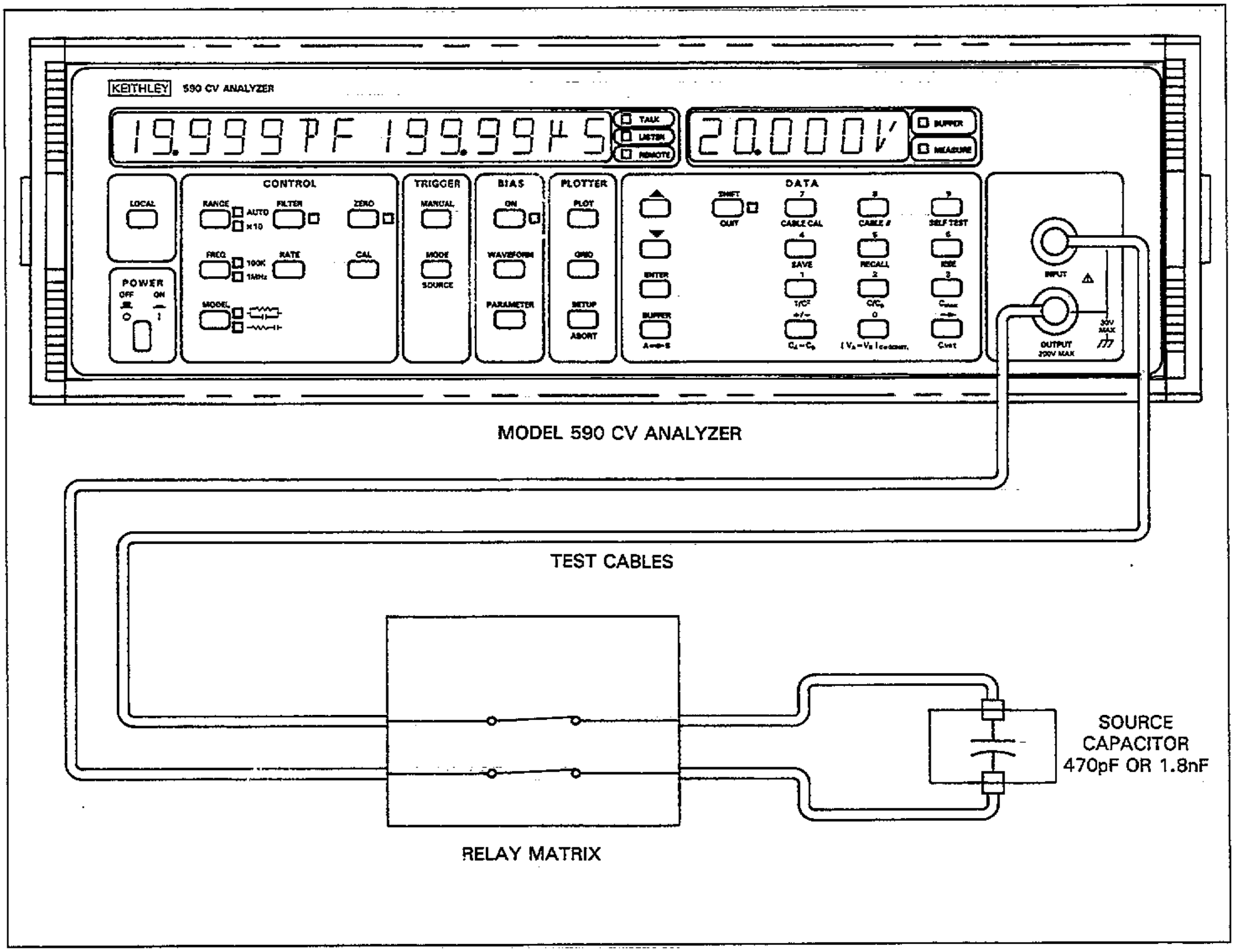


Figure 4-53. Connections for Calibration Capacitor Correction

4.11.4 Saving and Recalling Cable Setups

By using the C command, you can save and recall up to seven cable setups in NVRAM. Cables setups stored in this manner will be retained for future use even if power is removed from the instrument.

Saving Cable Setups

To save a cable setup, first perform the correction procedure with the desired method (see above) and then send the command C1,n over the bus. Here n represents the position number to save (1-7). For example, to save setup #4, the following command would be sent:

```
OUTPUT 715; ''C1,4X''
```

Recalling Cable Setups

The C0,n command allows you to reverse the above procedure by allowing the recall of previously stored cable setups. To recall setups, simply include the appropriate cable position number in the command option. Note that numbers 1 through 7 are stored setups, while a parameter of 0 will disable user cable correction and restore factory defaults necessary to correct for internal cabling to the front panel test jacks. Note that the recalled position will go into effect immediately.

For example, to recall position 6, the following command would be sent:

```
OUTPUT 715; ''C0,6X''
```

Similarly, the following command would be used to disable user cable correction constants:

```
OUTPUT 715; ''C0,0X''
```

NOTES:

1. Sending a DCL or SDC command will also disable user correction and restore correction to the front panel only.
2. Corrections saved and recalled at each given position must be at the same frequency, or inaccurate readings will result.

4.11.5 Internal Correction Constants

Description

With all three cable correction methods, the instrument internally processes the resulting data into two correction constants, K0 and K1. Each of these constants is a complex number of the form:

$$a + jb$$

where a is the real component, and b is the imaginary component.

By sending appropriate commands to the instrument, you can request the K0 and K1 constants in effect at that particular time. A different command allows you to later send them back to the instrument. Thus, these two commands would allow you to save a virtually unlimited number of cable setups, instead of being restricted to the seven user setups that can be saved and recalled with the C command.

Requesting Correction Constants

The U26 command can be used to request correction constants K0 and K1. The basic procedure below outlines this operation.

1. First make certain that the cable correction constants you wish to access are in effect. If you have just completed a correction and the resulting constants are now operational, you need do nothing further. However, if you are accessing a particular cable setup number, first use the C0,n command with n representing the position number of the cable setup to be accessed.
2. Now send the command string U26X over the bus. For example, the correct HP-85 statement is:

   ```
   OUTPUT 715; ''U26X''
   ```

3. Request data from the instrument as you would normal data, placing instrument status (see Figure 4-54) in a string variable. For example, a typical HP-85 statement would be:

   ```
   ENTER 715; A$
   ```

   In this instance, the U26 status word, which contains the four cable correction parameters, would be placed in the A$ variable (A$ must be previously dimensioned, by the way, because the data string is longer than 18 characters).
4. The data string can be parsed and broken up into four discrete numeric variables, placed in computer memory, or placed on a mass storage medium, as desired. The example program on the next page demonstrates this process.

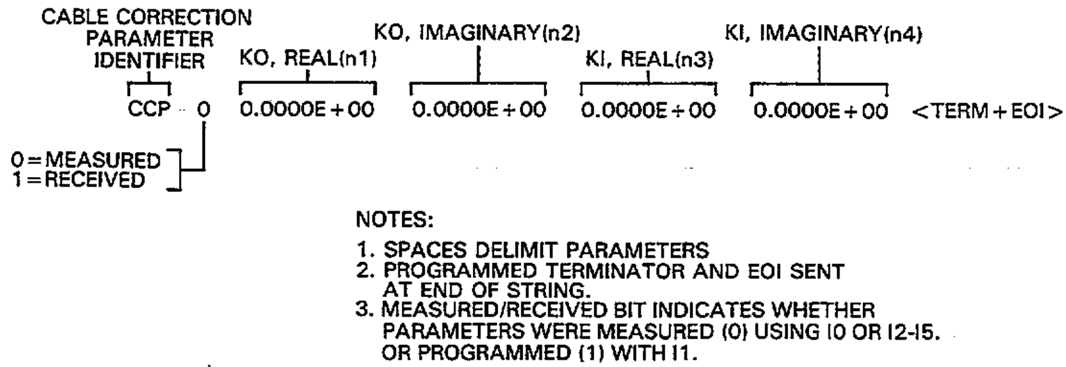


Figure 4-54. Status Word Showing K0, K1 Real and Imaginary Parameters

Sending Correction Constants to the Instrument

Correction constants can be sent from the computer by using the I1 command, which is of the form:

I1,n1,n2,n3,n4

Where: n1= K0, real component
n2= K0, imaginary component
n3= K1, real component
n4= K1, imaginary component

To send these parameters, simply include them in the command string in the order indicated above. As always, the string must be terminated by the X character in order for the instrument to execute the string. Once executed, the constants will be placed into effect immediately. You can then save them in NVRAM by using the C1 command, if desired.

Programming Example

The program below demonstrates the basic principles for reading or writing all seven cable setups stored in the instrument. The parameters are then stored on or retrieved from tape.

NOTE
Selecting the write option in the following program will overwrite any presently stored cable setups.

Program	Comments
10 DIM A$[100]	! Dimension input string.
20 REMOTE 715	! Place 590 in remote.
30 CLEAR	! Clear computer CRT.
35 OUTPUT 715; ''F1X''	! Program 1MHz.
40 DISP''1= READ CONSTANTS FROM 590''	! Prompt for read or write of instrument parameters.
50 DISP''2= WRITE CONSTANTS TO 590''	
60 DISP	
70 DISP''SELECT 1 OR 2''	
80 INPUT A	
90 IF A=2 THEN 290	
100 DISP''FILENAME''	! Assign filename for storage.
110 INPUT F$	
120 CREATE F$,5	! Create file for storage.
130 ASSIGN#1 TO F$	! Open file to tape.
140 FOR N= 1 TO 7	! Loop for all seven setups.
150 OUTPUT 715;''C0,'';N;''X''	! Recall cable #N.
160 OUTPUT 715; ''U26X''	! Request cable parameters.
170 ENTER 715; A$	! Input parameter string.
180 N1=VAL(A$[7,17])	! Parse string for parameters.
190 N2=VAL(A$[19,29])	
200 N3=VAL(A$[31,41])	

Program	Comments
210 N4=VAL(A$[42,52])	
220 PRINT#1;N1,N2,N3,N4	! Write parameters to tape.
230 NEXT I	! Loop back for next cable setup.
240 ASSIGN#1 TO *	! Close file.
250 DISP''REPEAT (Y/N)''	! Prompt to repeat.
260 INPUT B$	
270 IF B$[1,1]=''Y'' THEN 30	
280 GOTO 430	
290 DISP''WARNING-CABLE SETUPS	! Display warning message.
300 DISP''WILL BE OVER-WRITTEN	
310 DISP''CONTINUE (Y/N)''	
320 INPUT B$	
330 IF B$[1,1]=''N'' THEN 30	
340 DISP''FILENAME''	! Input filename.
350 INPUT F$	
360 ASSIGN#1 TO F$	! Open file.
370 FOR N=0 TO 6	! Loop for all seven cable setups.
380 READ#1; N1,N2,N3,N4	! Read parameters from tape.
390 OUTPUT 715; ''I1,''; N1;'',''; N2;'',''; N3;'',''; N4;''X''	! Send parameters to 590.
400 OUTPUT 715; ''C1,''; N;''X''	! Save cable setup N.
410 NEXT N	! Loop for next setup.
420 GOTO 240	
430 END	

4.12 PROGRAMMING EXAMPLES

The following paragraphs give some examples of how to program the instrument for typical measurements. As listed, the programs are not necessarily in the most efficient form, but instead are written for maximum clarity in understanding program flow.

4.12.1 Programming for One-Point Measurements

Use the program below to take single-point measurements and display the results on the computer CRT. The program assumes that the instrument will be operated at 100kHz, with autoranging, and at the 1 reading per second rate. Appropriate changes can be made for other parameters, if desired.

Figure 4-55 shows a general flowchart of the program below.

Program	Comments
10 DIM A$[100]	! Dimension data input string.
20 REMOTE 715	! Place unit in remote.
30 CLEAR 7	! Send device clear.
40 OUTPUT 715; ''F0R0X''	! Program 100kHz, autorange.
50 OUTPUT 715; ''S4B0X''	! Select 1/sec rate, current reading output.
60 OUTPUT 715; ''T1,0X''	! Program GET, one-shot trigger.
70 OUTPUT 715; ''M8X''	! Program for SRQ on reading done.
80 DISP ''PRESS 'CONT' TO GET READING''	! Display prompt.
90 PAUSE	! Pause for operator input.
100 TRIGGER 715	! Trigger a single reading.
110 STATUS 7,2;S	! Get interface status.
120 IF NOT BIT(S,5) THEN 110	! Wait for SRQ to occur.
130 S = SPOLL(715)	! Serial poll unit to clear SRQ.
140 ENTER 715; A$	! Get reading string from 590.
150 DISP A$	! Display reading string.
160 GOTO 80	! Repeat.
170 END	

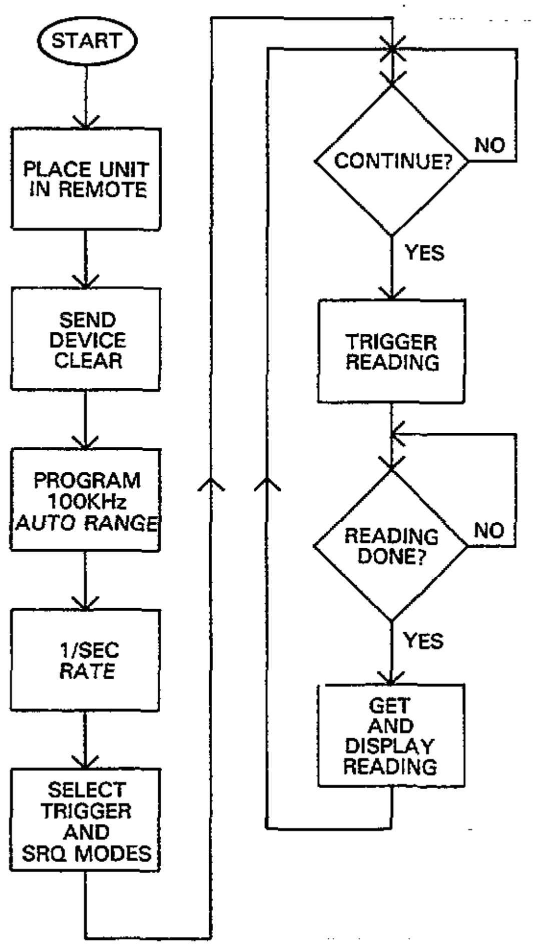


Figure 4-55. Flowchart of One-Point Program

4.12.2 CV Plotter Programming

The program below will allow you to take a reading sweep and then graph the data on an intelligent plotter connected to the instrument through the IEEE-488 bus. This program assumes that the plotter primary address is 5.

A flowchart of the program is shown in Figure 4-56.

```
Program                          Comments

 10 REMOTE 715                   ! Place 590 in remote.
 20 CLEAR 7                      ! Send device clear.
 30 OUTPUT 715; ''F0R4X''        ! Select 100kHz, 2nF
                                   range.
 40 OUTPUT 715; ''S1P0X''        ! Program 100/sec rate,
                                   filter off.
 50 OUTPUT 715; ''T1,1X''        ! Select sweep on GET
                                   mode.
 60 OUTPUT 715; ''W1X''          ! Select single stair-
                                   case.
 70 OUTPUT 715;                  ! Program -5V first V,
    ''V-5,5,0.1,0X''               +5V last V,0.1V
                                   step V, 0V default
                                   V.
 80 OUTPUT 715; ''M4X''          ! Program for SRQ on
                                   sweep done.
 90 DISP''PRESS 'CONT' TO        ! Prompt for measure-
    MEASURE''                      ment.
100 PAUSE                        ! Pause for operator
                                   input.
110 OUTPUT 715; ''N1X''          ! Turn on bias output.
120 TRIGGER 715                  ! Trigger reading
                                   sweep.
130 DISP''SWEEP IN               ! Display sweep mes-
    PROGRESS''                     sage.
140 STATUS 7,2;S                 ! Check interface
                                   status.
150 IF NOT BIT(S,5) THEN         ! Wait for SRQ.
    140
160 S = SPOLL(715)               ! Serial poll to clear
                                   SRQ.
170 OUTPUT 715; ''B3X''          ! Transfer data to plot
                                   buffer.
180 DISP''SWEEP DONE--           ! Prompt for plotting.
    LOAD PLOTTER WITH
    PAPER, PRESS 'CONT'''
190 OUTPUT 715; ''N0X''          ! Turn off bias source.
200 PAUSE                        ! Wait for operator
                                   input.
210 OUTPUT 715; ''M128X''        ! SRQ when plotter
                                   done.
220 OUTPUT 715; ''A5,1X''        ! Select pen #1.
230 OUTPUT 715; ''A6,7X''        ! Program solid line
                                   type.
240 OUTPUT 715; ''A7,0X''        ! Select full labels.
250 OUTPUT 715; ''A2,0X''        ! Select C vs V plot
                                   type.
260 OUTPUT 715; ''A3,0X''        ! Select full grid type.
270 OUTPUT 715; ''A4,1X''        ! Plot from plot
                                   buffer.
280 OUTPUT 715; ''A0X''          ! Execute plot.
290 SEND 7; UNT UNL TALK         ! Address 590 to talk,
    15 LISTEN 5                    plotter to listen.
300 RESUME 7                     ! Set ATN false.
310 STATUS 7,2;S                 ! Get bus status.
320 IF NOT BIT(S,5) THEN         ! Wait for plot to
    310                            finish.
330 SEND 7; UNT UNL              ! Untalk and unlisten
                                   the bus.
340 S=SPOLL(715)                 ! Serial poll to clear
                                   SRQ.
350 OUTPUT 715; ''A1X''          ! Execute grid.
360 SEND 7; UNT UNL TALK         ! Address 590 to talk,
    15 LISTEN 5                    plotter to listen.
370 RESUME 7                     ! Set ATN false.
380 STATUS 7,2;S                 ! Get bus status.
390 IF NOT BIT(S,5) THEN         ! Wait for grid to
    380                            finish.
400 SEND 7; UNT UNL              ! Untalk and unlisten
                                   the bus.
410 S=SPOLL(715)                 ! Serial poll to clear
                                   SRQ.
420 END
```

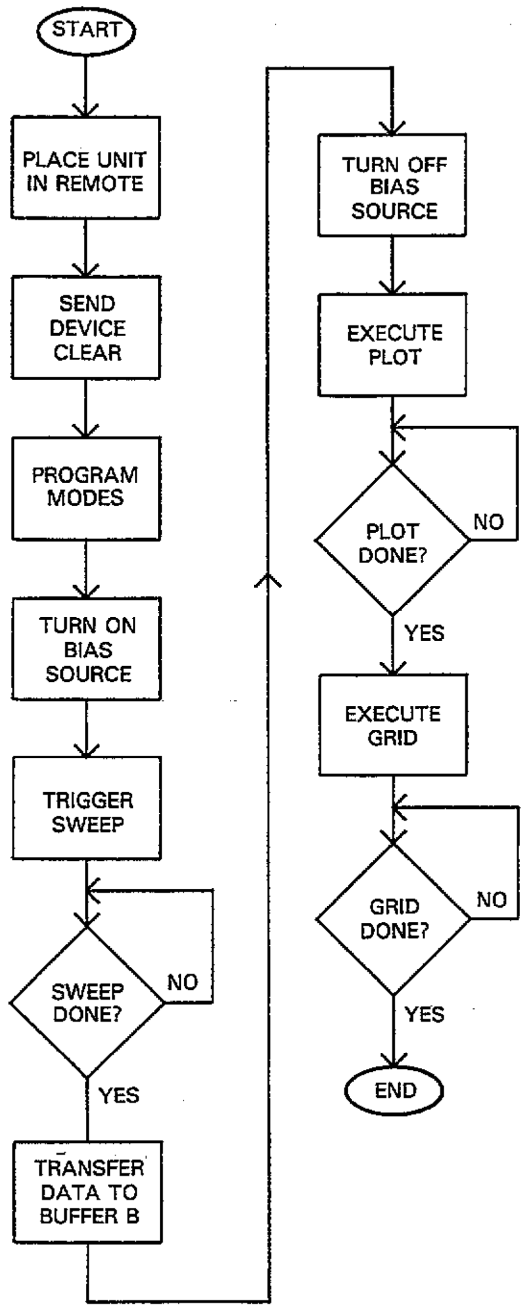


Figure 4-56. Flowchart of C vs V Plotting Example Program

4.12.3 C vs t Programming

The program below demonstrates the basic procedure for programming C vs t measurements over the bus. The program will prompt you to access information located at a specific location after the reading sweep has been completed.

As written, the program uses the 1000/sec rate, but other rates can be used as well. The computed time information assumes the 1000/sec rate and start, stop, and step times of 1msec.

Figure 4-57 shows a flowchart of the program.

Program	Comments
`10 DIM A$[100]`	! Dimension input string.
`20 REMOTE 715`	! Place 590 in remote.
`30 CLEAR 7`	! Send device clear.
`40 OUTPUT 715; "F0R4X"`	! Select 100kHz, 2nF range.
`50 OUTPUT 715; "S0P0X"`	! Select 1000/sec rate, filter off.
`60 OUTPUT 715; "T1,1X"`	! Program sweep on GET mode.
`70 OUTPUT 715; "W0,1E-3, 1E-3,1E-3X"`	! Select DC bias waveform, start, stop, and step times of 1msec.
`80 OUTPUT 715; "V5,,,,100"`	! Program 5V first—V, 100 count.
`90 OUTPUT 715; "M4X"`	! SRQ on sweep done.
`100 DISP "PRESS 'CONT' TO MEASURE"`	! Display prompt for measurement.
`110 PAUSE`	! Pause for operator input.
`120 OUTPUT 715; "N1X"`	! Turn on bias source.
`130 TRIGGER 715`	! Trigger reading sweep.
`140 STATUS 7,2;S`	! Check bus status.
`150 IF NOT BIT (S,5) THEN 140`	! Wait for SRQ to occur.
`160 S = SPOLL(715)`	! Serial poll to clear SRQ.
`170 OUTPUT 715; "B3X"`	! Transfer data to plot buffer.
`180 OUTPUT 715; "N0X"`	! Turn off bias source.
`190 DISP "BUFFER LOCATION TO ACCESS (1-100)"`	! Prompt for buffer location.
`200 INPUT B`	! Input buffer location #.
`210 IF B <1 OR B > 100 THEN 190`	! Check for buffer limits.
`220 OUTPUT 715; "B2,";B; "X"`	! Select access from location B.
`230 OUTPUT 715; "01X"`	! Capacitance only.
`240 ENTER 715; A$`	! Input data.
`250 T = .001 +.002*B`	! Compute time.
`260 DISP "CAPACITANCE:"; A$`	! Display data.
`270 DISP "TIME:"; T`	! Display time.
`280 END`	

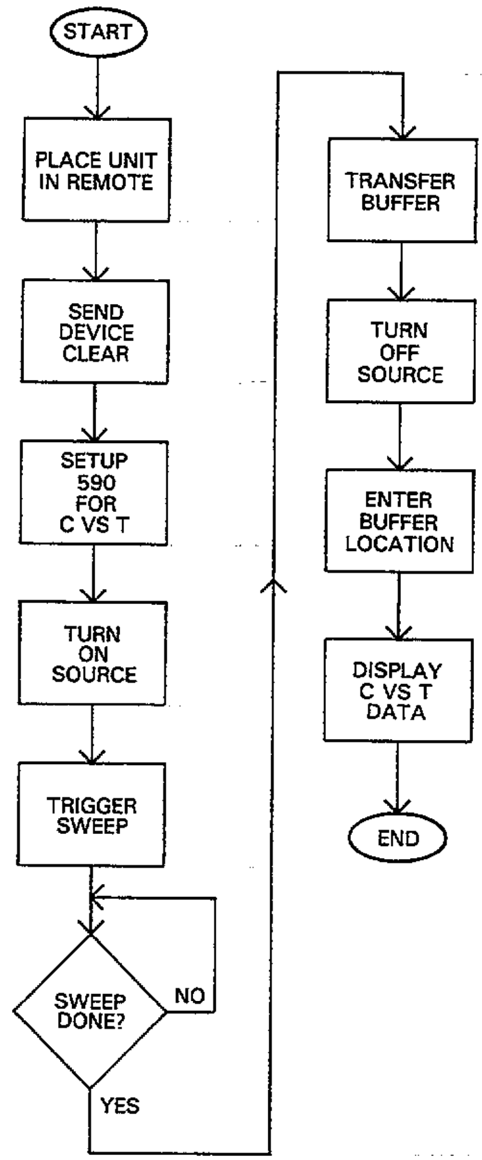


Figure 4-57. Flowchart of C vs t Program

4.12.4 Accessing Buffer Information

Very often, you will want to read out data from one of the buffers and place that information within a computer array for further analysis. The program below demonstrates the basic method for accessing buffer data and storing the information in a numeric array within the computer. In general, it's a good idea to transfer data to the plotter buffer immediately after the sweep is finished because sending many commands will automatically clear the A/D buffer of any relevant data.

In this instance, data is read into the computer in single reading units for convenience. An alternate method would be to operate the Model 590 in the G4 or G5 data format and output the entire buffer in one long string. Paragraph 4.13 discusses that method in more detail.

A general flowchart of the program is shown in Figure 4-58.

Program	Comments
10 OPTION BASE 1	! Set array lower bound to 1.
20 DIM A(101)	! Dimension input array.
30 REMOTE 715	! Place unit in remote.
40 CLEAR 7	! Send device clear.
50 OUTPUT 715; ''F0R4X''	! 100kHz, 2nF range.
60 OUTPUT 715; ''S2P0X''	! 18/sec reading rate, filter off.
70 OUTPUT 715; ''W1X''	! Single staircase waveform.
80 OUTPUT 715; ''T1,1X''	! Sweep on GET mode.
90 OUTPUT 715; ''V-5, 5,0.1,0X''	! First V, last V, step V, default V.
100 OUTPUT 715; ''M4X''	! SRQ on sweep done.
110 DISP''PRESS 'CONT' TO MEASURE''	! Prompt to start measurement.
120 PAUSE	
130 OUTPUT 715; ''N1X''	! Turn on bias source.
140 TRIGGER 715	! Trigger a reading sweep.
150 DISP''SWEEP IN PROGRESS''	! Sweep is now active.
160 STATUS 7,2;S	! Get bus status.
170 IF NOT BIT(S,5) THEN 160	! Wait for SRQ.
180 DISP''SWEEP DONE-READING BUFFER''	! Sweep is over.
190 S=SPOLL(715)	! Serial poll to clear SRQ.
200 OUTPUT 715; ''B3X''	! Transfer data to buffer B.
210 OUTPUT 715; ''N0X''	! Turn off bias source.
220 OUTPUT 715; ''G1X''	! No prefix on data format.
230 OUTPUT 715; ''O1,0X''	! C only, parallel model.
240 OUTPUT 715; ''B2,1, 101X''	! Plotter buffer output, all points.
250 FOR I=1 TO 101	! Loop for all points.
260 ENTER 715; A(I)	! Put data point into array.
270 NEXT I	! Next data point.
280 DISP''DATA POINT TO DISPLAY''	! Prompt for data point.
290 DISP''(1-101)''	
300 INPUT P	! Input point number.
310 IF P <1 OR P > 101 THEN 280	! Check point limits.
320 DISP A(P)	! Display the point.
330 GOTO 280	! Repeat.
340 END	

The above program can easily be modified to manipulate the data in just about any way you desire. For example, assume that you wish to take a simple average of all points in the data base. To do so, delete lines 280 through 340 above and add the lines below.

280 A=0	! Sum variable =0.
290 FOR I = 1 TO 101	! Loop for 101 points.
300 A=A+ A(I)	! Sum the data points.
310 NEXT I	! Loop back for next point.
320 DISP A/101	! Display average of points.
330 END	

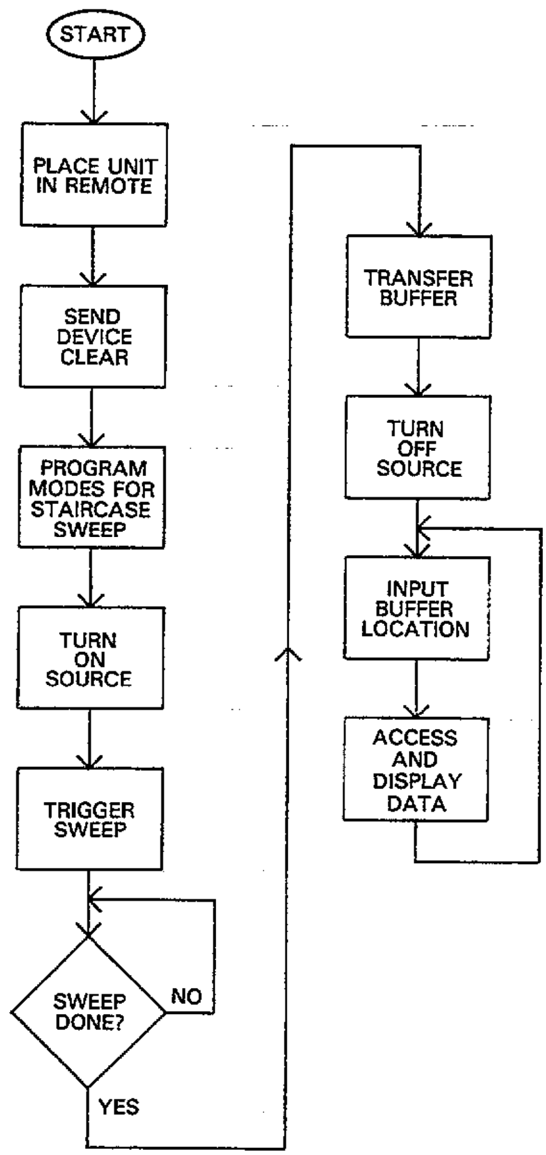


Figure 4-58. Flowchart of Buffer Program

4.12.5 Obtaining Complete Instrument Status

Use the program below to obtain and display all status words associated with instrument operation. Status words are discussed in detail in paragraphs 4.9.15 and 4.10.

Figure 4-59 shows a program flowchart.

Program	Comments
10 REMOTE 715	! Place 590 in remote.
20 DIM A$[200]	! Dimension input string.
30 FOR I = 0 TO 31	! Loop for all words.
40 OUTPUT 715;''U'';I;''X''	! Program for status.
50 ENTER 715; A$	! Get status word.
60 DISP A$	! Display status word.
70 NEXT I	! Loop back and get next word.
80 END	

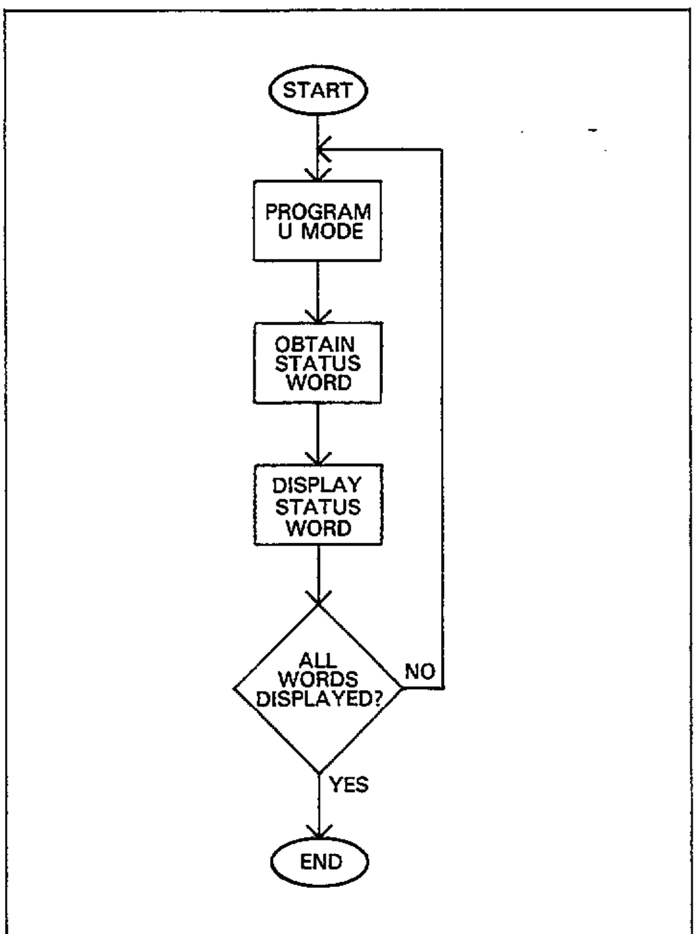


Figure 4-59. Flowchart of Status Word Program

4.12.6 Using the Translator

The program below will demonstrate the basic process for defining Translator words and programming the instrument using the defined words. As written, the program will prompt the operator to select such operating modes as range, frequency, reading rate, as well as voltages and times associated with the bias waveform.

The program also demonstrates methods for using end-of-line branching to process a service request when an error condition occurs. An appropriate error message will be displayed on the computer CRT should such an error occur.

Figure 4-60 shows a programming flowchart.

Program	Comments
10 DIM A$[100]	! Dimension input string.
15 ON INTR 7 GOTO 780	! Point where to jump on SRQ.
20 P=715	! Primary address is 15.
25 ENABLE INTR 7;8	! Enable bus interrupt on SRQ.
30 REMOTE P	! Put 590 in remote.
40 CLEAR 7	! Send device clear.
50 OUTPUT P; ''ALIAS RANGE R$X ;''	! Define range Translator word.
60 OUTPUT P; ''ALIAS FREQ F$X ;''	! Define frequency word.
70 OUTPUT P; ''ALIAS RATE S$X ;''	! Define rate Translator word.
80 OUTPUT P; ''ALIAS TRIGGER T1,1X ;''	! Define trigger Translator word (sweep, GET).
90 OUTPUT P; ''ALIAS SRC_ ON N1X ;''	! Define source on word.
100 OUTPUT P; ''ALIAS SRC_ OFF N0X ;''	! Define source off word.
110 OUTPUT P; ''ALIAS VOLTS V$,$,$,$X ;''	! Define bias voltage Translator word.
120 OUTPUT P; ''ALIAS TIME W1,$,$,$X ;''	! Define waveform (staircase) and times Translator word.
130 OUTPUT P; ''ALIAS TRANSFER B3X ;''	! Define A > B buffer transfer word.
140 OUTPUT P; ''ALIAS BUFFER B2,$,$X ;''	! Setup buffer location word.
150 OUTPUT P; ''ALIAS SERVICE M36X ;''	! SRQ on sweep done or error.
160 CLEAR	! Clear CRT.

Program	Comments
170 OUTPUT P;''TRIGGER	! Program trigger source and mode.
180 OUTPUT P;''SERVICE	! Program SRQ mode.
190 DISP''RANGE''	! Prompt for range.
200 DISP''0=AUTO:''	
210 DISP''1=2PF''	
220 DISP''2=20PF''	
230 DISP''3=200PF''	
240 DISP''4=2NF''	
250 INPUT R	! Input range selection.
260 OUTPUT P;''RANGE'';R	! Program range.
270 CLEAR	! Clear CRT.
280 DISP''FREQUENCY:''	! Prompt for frequency.
290 DISP''0=100KHZ''	
300 DISP''1=1MHZ''	
310 INPUT F	! Input frequency selection.
320 OUTPUT P;''FREQ'';F	! Program frequency.
330 CLEAR	
340 DISP''READING RATE:''	! Prompt for reading rate.
350 DISP''0=1000/SEC''	
360 DISP''1=100/SEC''	
370 DISP''2=20/SEC''	
380 DISP''3=10/SEC''	
390 DISP''4=1/SEC''	
400 INPUT S	! Input reading rate selection.
410 OUTPUT P;''RATE'';S	! Program reading rate.
420 CLEAR	
430 DISP''FIRST BIAS (-20V TO 20V)''	! Prompt for and input bias parameters.
440 INPUT V1	
450 DISP''LAST BIAS (-20 TO 20V)''	
460 INPUT V2	
470 DISP''STEP BIAS (-20 TO 20V)''	
480 INPUT V3	
490 DISP''DEFAULT BIAS (-20 TO 20V)''	
500 INPUT V4	
510 OUTPUT P;''VOLTS'';V1;'' '';V2;'' '';V3;'' '';V4	! Program bias voltage tage parameters (spaces to delimit parameters).
520 CLEAR	
530 DISP''START TIME (1MS TO 65S)''	! Prompt for and input waveform
540 INPUT T1	! times.
550 DISP''STOP TIME (1MS TO 65S)''	
560 INPUT T2	
570 DISP''STEP TIME (1MS TO 65S)''	
580 INPUT T3	
590 OUTPUT P;''TIME'';T1;T2;T3	! Program waveform times.
600 OUTPUT P;''SRC_ON''	! Turn on bias source.
610 TRIGGER 715	! Trigger sweep.
615 CONTROL 7,1;0	! Turn off SRQ interrupt.
620 STATUS 7,2;S	! Get bus status.
630 IF NOT BIT(S,5) THEN 620	! Wait for SRQ on sweep done.
640 CLEAR	
650 OUTPUT P;''TRANSFER''	! Transfer buffer A to B
660 OUTPUT P;''SRC_OFF''	! Turn off bias source.
670 DISP''FIRST BUFFER LOCATION''	! Get first location to access.
680 INPUT F	
690 DISP''LAST BUFFER LOCATION''	! Get last location to access.
700 INPUT L	
710 OUTPUT P;''BUFFER'';F;L	! Program buffer locations.
720 N=L-F+1	! Compute number of locations.
730 FOR I=1 TO N	! Loop for desired locations.
740 ENTER P;A$	! Input a reading.
750 DISP A$	! Display the reading.
760 NEXT I	! Loop for next reading.
770 GOTO 980	! End program.
780 STATUS 7,1;S1	! Subroutine to process SRQ.
790 S2=SPOLL(P)	! Serial poll 590.
800 IF NOT BIT(S2,5) THEN 900	! If no error, forget it.
810 OUTPUT P;''U1X''	! Program for error status.
820 ENTER P;A$	! Get error status.
830 RESTORE	! Restore data pointer.
840 FOR I=5 TO 19	! Loop to test status bits.
850 READ B$	! Read error message.
860 IF A$[I,I]=''1'' THEN DISP B$;'' ERROR'' @ BEEP	! Display the error.
870 NEXT I	! Loop for next error bit.
880 DISP''PRESS 'CONT'''	
890 PAUSE	

```
900 ENABLE INTR 7;8 @       ! Re-enable SRQ
    GOTO 40                   interrupt.
910 DATA ''TRIGGER          ! Data statements con-
    OVERRUN'', ''NEED         taining error mes-
    100K''                    sages.
920 DATA ''NEED 1M'',
    ''NOT USED''
930 DATA ''CAL LOCKED''
    ,''CONFLICT''
940 DATA ''TRANSLATOR''
    ,''NO REMOTE''
950 DATA ''IDDC'',
    'IDDCO'',
    ''INVALID''
960 DATA ''NOT INSTALL-
    ED'', ''NOT USED''
970 DATA ''MODULE OVER-
    LOAD'', ''NOT
    USED''
980 END
```

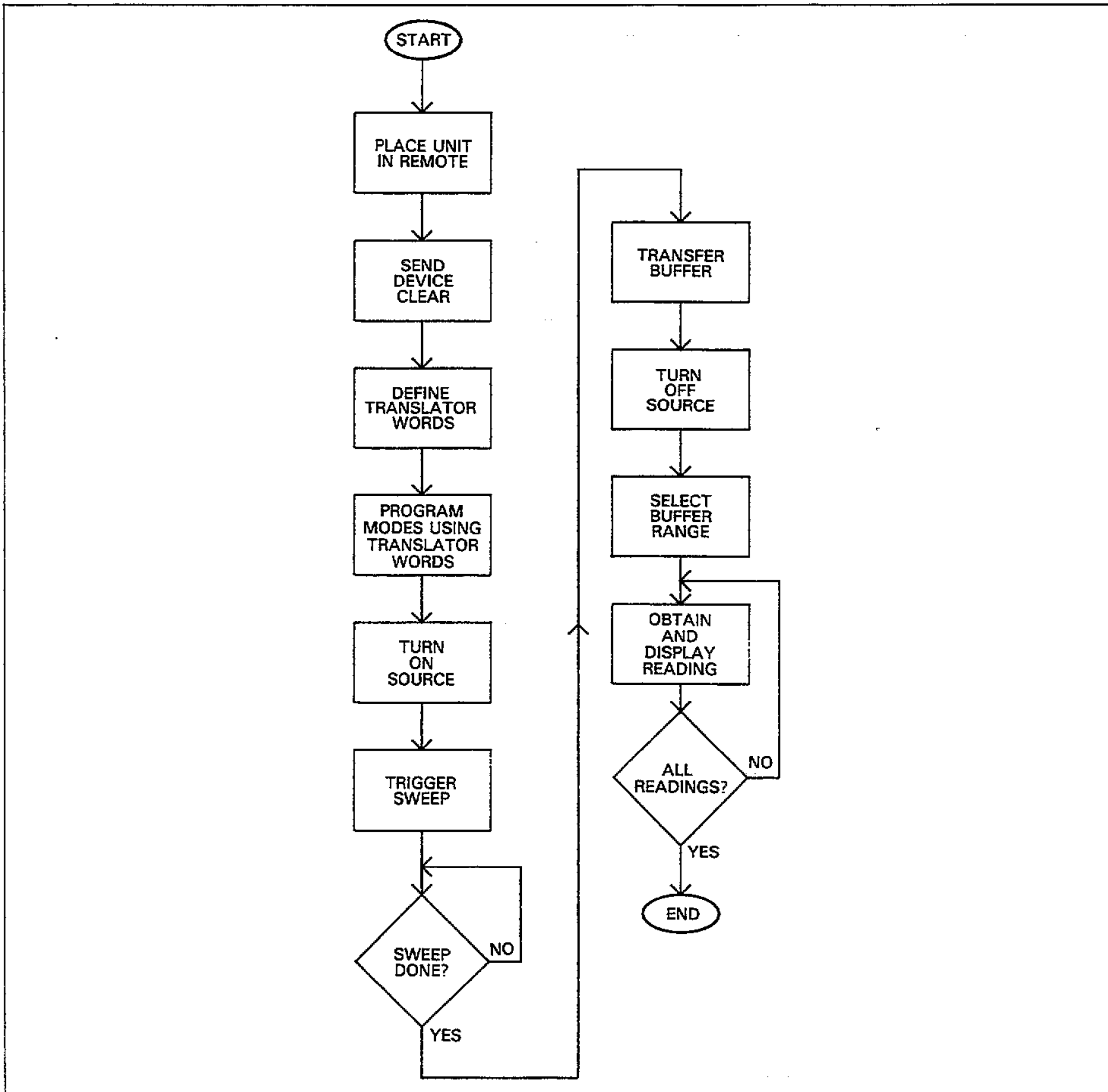


Figure 4-60. Translator Program Flow Chart

4.12.7 Using an External Bias Source

Some devices may require bias voltages greater than the nominal ±20V that the Model 590 can supply. The Keithley Model 230 Programmable Voltage source can be used with the Model 590 to supply bias voltages up to ±101V DC. The following paragraphs discuss equipment connections and programming notes for using the Model 230 in conjunction with the Model 590 to supply higher bias voltages.

A sample program is also included to help clarify programming techniques. This program will allow you to setup the Model 230 for the desired voltage parameters, generate a sweep, and then plot the data on a digital plotter.

Instrument Connections

In order to use the program below, instrument connections must be made as outlined below. Figure 3-19 in Section 3 details 230/590 connections, while Figure 3-2 shows device connections in detail. Use suitable coaxial cable for all connections.

1. Connect the Model 230 EXTERNAL TRIGGER OUTPUT to the Model 590 EXTERNAL TRIGGER INPUT.
2. Connect the Model 230 source output to the Model 590 BIAS VOLTAGE INPUT jack.
3. Connect the device being measured to the Model 590 front panel test jacks in the usual manner.
4. The instruments and plotter must be connected to the controller using suitable IEEE-488 cables. See paragraph 3.16 for more information on the types of plotters that can be used.

Programming Considerations

At the start of the program, you will be prompted to enter first, last, and step bias voltages, which are used to program the Model 230. These voltages are analogous to those used when programming the Model 590 voltage source, except, of course, for the fact that the Model 230 is programmed instead of the Model 590.

The Model 230 dwell time is used as a step duration and can be considered as the time duration for the individual steps in the bias waveform. Care must be taken not to select too short a dwell time or you will cause a Model 590 trigger overrun condition. For example, with a 75/sec rate, you should be able to use dwell times as short as 30msec.

In order to synchronize the two instruments, the Model 590 is set up for the one-shot, external trigger mode. With this arrangement, the Model 230 trigger pulse (which occurs at the end of each dwell time) is used to trigger each model 590 reading.

It is important that each reading be allowed sufficient settling time after the Model 590 is triggered. For that reason, the CV analyzer is programmed for a step time equal to 40% of the entered Model 230 dwell time. In some cases, it may be necessary to change this value for best results.

The Model 230 advances to memory location 2 when first triggered by the controller. Also, since the trigger output pulse does not occur until after the second memory location dwell time, memory location 3 is the first one used.

Other aspects of the program include user-defined frequency, reading rate, and a choice between C vs V and C vs t plot types. Keep in mind that C vs t indicates the buffer index along the X axis, from which you can compute the actual time at each location.

Program	Comments
`10 P1=713`	! 230 primary address is 13.
`20 P2=715`	! 590 primary address is 15
`30 DIM A$[100]`	! Dimension input string.
`40 CLEAR`	! Clear CRT.
`50 REMOTE P1,P2`	! Put instruments in remote.
`60 CLEAR 7`	! Send device clear.
`70 DISP ''THIS PROGRAM CONTROLS A''`	
`80 DISP ''230 VOLTAGE SOURCE AND''`	
`90 DISP ''590 CV ANALYZER.''`	
`100 DISP`	
`110 DISP ''PRESS 'CONT'''`	
`120 PAUSE`	
`130 OUTPUT P1; ''P0T2X''`	! 230 step, start on GET.
`140 OUTPUT P2; ''T3,0X''`	! One-shot external trigger.
`150 CLEAR`	! Clear CRT.

```
Program                                         Comments

160 DISP ‘‘SELECT FREQUENCY’’                   ! Prompt for test frequency.
170 DISP
180 DISP ‘‘0 = 100KHZ’’
190 DISP ‘‘1 = 1MHZ’’
200 INPUT F                                     ! Input test frequency.
210 IF F<0 OR F>1 THEN 160
220 OUTPUT P2; ‘‘F’’;F;‘‘X’’                    ! Program frequency.
230 CLEAR
240 DISP ‘‘SELECT 590 RANGE’’                   ! Range prompt.
250 DISP
260 DISP ‘‘0 = AUTORANGE’’
270 DISP ‘‘1 = 2PF’’
280 DISP ‘‘2 = 20PF’’
290 DISP ‘‘3 = 200PF’’
300 DISP ‘‘4 = 2NF’’
310 INPUT R                                     ! Input range selection.
320 IF R < 0 OR R > 4 THEN 170                  ! Check range limits.
330 OUTPUT P2; ‘‘R’’;R;‘‘X’’                    ! Program 590 range.
340 CLEAR
350 DISP ‘‘SELECT READING RATE’’                ! Prompt for rate.
360 DISP
380 DISP ‘‘1 =  75/SEC’’
390 DISP ‘‘2 = 18/SEC’’
400 DISP ‘‘3 = 10/SEC’’
410 DISP ‘‘4 = 1/SEC’’
420 INPUT S                                     ! Input rate selection.
430 IF S<1 OR S>4 THEN 350
435 IF S=1 THEN OUTPUT PS; "P0X"                ! If 75/sec rate, turn off filter.
440 OUTPUT P2; ‘‘S’’;S;‘‘X’’                    ! Program reading rate.
450 DISP ‘‘FIRST BIAS’’                         ! Get first bias.
460 INPUT F
470 DISP ‘‘LAST BIAS’’                          ! Get last bias.
480 INPUT L
490 DISP ‘‘STEP BIAS’’                          ! Get step bias.
500 INPUT S1
510 N = ABS((L-F)/S1+1)                         ! Compute number readings in sweep.
520 IF N > 98 THEN DISP ‘‘230 MEMORY LOCATION   ! Check for 230 memory limits.
    LIMIT EXCEEDED’’ @ GOTO 270
530 DISP ‘‘230 DWELL TIME’’                     ! Get bias step duration.
540 INPUT W
550 W1 = 0.4*W                                  ! Compute step delay time.
560 CLEAR
570 DISP ‘‘SELECT PLOT TYPE’’                   ! Choose C vs V or C vs t.
580 DISP
590 DISP ‘‘1 = C VS V’’
600 DISP ‘‘2 = C VS T’’
610 INPUT P
620 IF P<1 OR P>2 THEN 570
630 IF P=1 THEN P=0 ELSE P=4                    ! Convert to plot type parameter.
640 DISP ‘‘PROGRAMMING INSTRUMENTS’’
645 OUTPUT P2; ‘‘V,,,,’’;N;‘‘X’’                ! Program COUNT.
650 OUTPUT P2; ‘‘W4,,,’’;W1;‘‘X’’               ! 590 external waveform, delay time
                                                  after step change.
660 FOR I = 1 TO N+2                            ! Loop for all voltage bias points.
670 OUTPUT P1; ‘‘B’’;I;‘‘X’’                    ! Select 230 buffer location.
680 OUTPUT P1; ‘‘W’’;W;‘‘X’’                    ! Program 230 dwell time.
690 IF I<3 THEN 720                             ! First two 230 locations not used.
700 OUTPUT P1; ‘‘V’’;F;‘‘X’’                    ! Program 230 voltage.
710 F = F + S1                                  ! Compute next bias voltage.
720 NEXT I                                      ! Loop for next voltage.
730 CLEAR                                       ! Clear CRT.
740 DISP ‘‘CHECK CONNECTIONS THEN’’
750 DISP ‘‘PRESS ‘CONT’ TO BEGIN’’
760 OUTPUT P1; ‘‘M4X’’                          ! Program 230 to SRQ when sweep done.
770 S1 = SPOLL(P1)                              ! Serial poll 230 to make sure SRQ
                                                  is cleared.
780 PAUSE                                       ! Wait for operator input.
790 OUTPUT P2; ‘‘N1X’’                          ! Turn on 590 bias.
800 OUTPUT P1; ‘‘F1X’’                          ! Turn on 230 output.
810 TRIGGER P1                                  ! Trigger 230 to start sweep.
820 STATUS 7,2;S                                ! Check interface status.
830 IF NOT BIT(S,5) THEN 820                    ! Wait for SRQ to occur when sweep
                                                  is done.
840 S1=SPOLL(P1)                                ! Serial poll 230 to clear SRQ.
```

Program	Comments
850 OUTPUT P1; ''F0X''	! Turn off 230 output.
860 OUTPUT P2; ''B3X''	! Transfer 590 data to buffer B.
870 OUTPUT P1; ''M0X''	! Turn off 230 SRQ.
880 OUTPUT P2; ''M128X''	! 590 SRQ on plotter done.
890 OUTPUT P2; ''A2,'';P; ''X''	! Program plot type.
900 OUTPUT P2; ''A4,1X''	! Plot buffer B.
910 OUTPUT P2; ''A0X''	! Tell 590 to plot.
920 SEND 7; UNT UNL TALK 15 LISTEN 5	! Address 590 to talk, plotter to listen.
930 RESUME 7	! Set ATN false.
940 STATUS 7,2;S	! Get bus status.
950 IF NOT BIT(S,5) THEN 940	! Wait for SRQ on plotter done.
960 S=SPOLL(P2)	! Serial poll 590 to clear SRQ.
970 SEND 7; UNT UNL	! Untalk and unlisten the bus.
980 OUTPUT P2; ''A1X''	! Generate the grid.
990 SEND 7; UNT UNL TALK 15 LISTEN 15	! Address 590 to talk, plotter to listen.
1000 RESUME 7	! Set ATN false.
1010 STATUS 7,2;S	! Get bus status.
1020 IF NOT BIT(S,5) THEN 1010	! Wait for SRQ on plotter done.
1030 SEND 7; UNT UNL	! Untalk and unlisten the bus.
1040 S=SPOLL(P2)	! Serial poll 590 to clear SRQ.
1050 END	

4.13 BUS TRANSMISSION TIMES

How rapidly the instrument transmits data over the bus is a function of a variety of factors, including selected reading rate and the number of programmed bias steps. The following paragraphs discuss the factors that affect transmission times and give a typical example for a 200 step measurement.

4.13.1 Factors Affecting Bus Times

Basically, there are four phases to programming the instrument, performing a sweep, and transmitting the data over the bus as follows:

1. Programming phase: Here, all the necessary operating modes are programmed by sending appropriate commands over the bus. Typically, you will select the range, frequency, reading rate, trigger mode and source, and bias waveform.
2. Trigger phase: In order to perform a sweep, the unit must be triggered in some fashion; that trigger will, of course, depend on the programmed trigger source. If the instrument is to be synchronized with external equipment, an external trigger source should be selected. If you intend to trigger the unit from a controller, use one of the IEEE trigger sources (X, GET, or talk). The best one to use in many situations may be GET for two reasons: (1) with trigger on X, the unit will be re-triggered when sending commands, and (2) with trigger on talk, the instrument will be re-triggered when requesting data. In either case, a trigger overrun situation will occur.
3. Sweep phase: During this phase, the instrument cycles through the steps of the bias waveform and takes readings. For the staircase and pulse waveforms, the number of readings depends on the first, last, and step bias voltage values. The number of readings for the DC and external waveforms can be separately programmed, by the count parameter.
4. Data transmission phase: Once the sweep is completed and data is stored in the Model 590 buffer, data must be transmitted to the computer. Basically, there are two general method that can be used: complete sweep data transmission and single point transmission. If your computer can handle a long string of bytes, program the Model 590 to dump its entire buffer in one block. Alternately, a single point-at-a time can be transmitted, if desired.

Keeping these points in mind, the total transmission time from trigger is the sum of the following:

1. Trigger response time: This time period is the interval from the time the unit receives a trigger to the time that is begins the sweep. In most situations, this interval is so small that it can be ignored.
2. Sweep interval: The length of time it takes to complete a sweep depends on the number of data points, reading rate, and programmed start, stop, and step times.
3. Transmission time: The length of time for transmission depends on such factors as the number of bytes of data, as well as the speed of the controller.

4.13.2 Optimizing Measurement Speed

The exact steps necessary to optimize measurement speed will depend somewhat on your particular test configuration and requirements. However, there are a few simple rules that will apply in most cases, including:

1. Select the fastest reading rate possible. If you require only capacitance data and can use a DC or external waveform, use the 1000/sec reading rate. However, if you require C, G, and V data, or must use a staircase or pulse waveform, the fastest rate available is 100 readings per second. In either case, some compromises such as display resolution and reading noise must be taken into account.
2. Program the minimum possible start, stop, and step times for the particular test configuration. Here, some experimentation may be required to determine optimum times based on such factors as settling time of the device under test. Also, you should turn off the analog filter when using short intervals because of the 25msec settling time of that filter.
3. Use SRQ to detect end of sweep. Generally, the Model 590 can be "untouched" over the bus while it is processing a sweep. Thus, the best way to detect the end of a sweep is to program an SRQ on sweep done condition (M4) and then use the controller to detect when the SRQ occurs. For simpler control situations, a polling method can be used. In other cases, it may be necessary to use interrupt processing to detect the SRQ.
4. Transfer buffer data and turn off the A/D converter when the sweep is finished. The first thing that should be done once the sweep is completed is to transfer the data to buffer B for safekeeping (sending many commands will clear buffer A, destroying your data). Next, send a command that will turn off the A/D converter (for example, N0) to maximize transmission speed.
5. Select the most compact data format. If your computer can handle long strings in one continuous block, use the G4 data format, which will eliminate reading prefixes and suffixes and dump the entire buffer in one long block. Also, if you are interested only in one type of data (for example only capacitance or conductance), use the O command to select the type of data output (for example, send O1 for capacitance only). Both these steps will minimize the number of bytes that must be transmitted over the bus.
6. Use the fastest controller data transmission mode. Some controllers have more than one transmission mode such as DMA or fast handshake methods. Use the fastest mode to minimize transmission time.

4.13.3 Programming Example

The program below was used to determine the time period from the initial trigger until all data is transferred to the computer. In order to minimize the total time necessary for the complete process, the instrument and computer are set up as follows:

1. The instrument is programmed for the 1000/sec rate using a DC bias waveform and is externally triggered. A total of 200 points are taken at the minimum start, stop, and step times possible (1msec).
2. The instrument data format is programmed to eliminate prefixes and suffixes and to allow a complete buffer dump (G4). This arrangement minimizes the number of bytes requiring transfer and maximizes efficiency.
3. The HP-85 computer is operated in the fast handshake mode for most rapid data transfer.

Using the program below to take 200 points of capacitance only information, a total interval of 14 seconds from trigger was achieved.

Program	**Comments**
10 DIM A$[4000], B$[4000]	! Dimension strings.
20 IOBUFFER B$	! Define I/O buffer.
30 REMOTE 715	! Place unit in remote.
40 OUTPUT 715; ''W0, .001, .001, .001X''	! DC waveform, 1msec start stop, step times.
50 OUTPUT 715; ''V10,,,,200X''	! 10V bias, 200 count.
60 OUTPUT 715; ''T3,1X''	! Sweep on external trigger mode.
70 OUTPUT 715; ''M4X''	! SRQ on sweep done.
80 OUTPUT 715; ''S0X''	! 1000/sec reading rate.
90 OUTPUT 715; ''O1G4X''	! C only, no prefix or suffix.
100 OUTPUT 715; ''P0X''	! Turn off filter.
110 OUTPUT 715; ''N1X''	! Turn on bias source.
120 DISP''APPLY TRIGGER TO EXTERNAL JACK''	! Prompt for trigger.
130 STATUS 7,2;S	! Get bus status.
140 IF NOT BIT(S,5) THEN 130	! Wait for SRQ.
150 OUTPUT 715; ''B3X''	! Transfer data to buffer B.
160 OUTPUT 715; ''N0X''	! Turn off bias source.
170 OUTPUT 715; ''B2,1, 200X''	! Access buffer B readings 1-200.
180 TRANSFER 715 TO B$ FHS ; EOI	! Get buffer data from 590.
190 ENTER B$; A$	! Transfer it to usable string.
200 DISP A$	! Display data.
210 END	

SECTION 5
PERFORMANCE VERIFICATION

5.1 INTRODUCTION

The procedures outlined in this section may be used to verify that Model 590 accuracy is within the limits stated in the specifications at the front of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment, or following calibration, if desired.

If the instrument is found to be in need of calibration, refer to Section 7 of this manual for the correct calibration procedures.

NOTE

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

Information in this section is arranged as follows:

5.2 Environmental Conditions: Gives the temperature and humidity limits for the verification procedure.

5.3 Initial Conditions: Details the warm-up procedure and what to do if the instrument has been stored in environmental extremes.

5.4 Recommended Test Equipment and Sources: Lists equipment necessary for capacitance, conductance, and bias source accuracy verification.

5.5 Verification Limit Calculations: Discusses how to calculate allowed reading limits for the various verification procedures.

5.6 Verification Procedures: Details procedures for verifying both 100kHz and 1MHz conductance and capacitance accuracy of the complete instrument, as well as the analog outputs separately. Accuracy checks for the voltage display and internal bias source are also included.

5.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at an ambient temperature between 18-28°C (65-82°F) and at less than 70% relative humidity unless otherwise noted.

NOTE

The ambient temperature must not change more than ±2°C from the time the CAL button is pressed until each reading is made.

5.3 INITIAL CONDITIONS

Before beginning the verification procedure, turn the Model 590 on and allow it to warm up for at least one hour. If the instrument has been subjected to temperatures outside the range given in paragraph 5.2, additional time must be allowed for internal temperatures to stabilize. Typically, it takes one additional hour to stabilize an instrument that is 10°C (18°F) outside the normal temperature range.

5.4 RECOMMENDED TEST EQUIPMENT AND SOURCES

Table 5-1 lists all test equipment and sources required for the verification procedures. Alternate equipment may be used as long as that equipment has specifications at least as good as those listed in the table.

NOTE

Accuracy of conductance and capacitance sources used for the verification procedures must be traceable to recognized standards. For that reason, it is recommended that only the sources listed in Table 5-1 be used for the verification procedures. Accuracy of the procedures with different sources cannot be guaranteed.

Table 5-1. Equipment and Sources Required for Verification

Description	Specifications	Manufacturer and Model	Use
1.5pF, 18pF, 180pF, 1.8nF, 18nF Source capacitors	*	Keithley 5905, 5906	Check capacitance accuracy.
1.8μS, 18μS, 180μS,1.8mS, 18mS Conductance sources	*	Keithley 5905, 5906	Check conductance accuracy.
DC Calibrator	0 to ±200V, ±0.002%	Fluke 343A	Check voltage read-back accuracy.
DMM	0 to ±20V, ±0.009% ≥10MΩ Input resistance	Keithley 196	Check analog outputs and bias source.

*These values must be characterized and traceable to recognize standards.

5.5 VERIFICATION LIMIT CALCULATIONS

Each capacitance source has actual characterized values for the frequencies of interest marked on it. This value will probably differ somewhat from the nominal value. For that reason, it is not possible to provide actual verification limits in this manual. Instead, it will be necessary for you to calculate the limits based on instrument accuracy specifications and the displayed reading.

Calculations for conductance verification limits are not necessary as these limits have been provided in this section.

5.5.1 Specification Format

Instrument accuracy is generally specified as a percent of reading value plus so many counts, including a spillover component in counts. For example, the capacitance accuracy of the 2nF range might be specified as:

0.25% of reading + (200G/GFS + 5) counts

Here, the 0.25% value is a percent of reading specification, while the G/GFS term computes the deviation from accuracy due to spillover of conductance into the capacitance reading. The final count value (5) is a fixed number that must also be taken into account when calculating verfication limits.

5.5.2 Full Scale Accuracy

For full scale accuracy checks, the limits can be computed from the percent of reading and fixed count specifications alone. For example, assume the 0.25% specification applies to the 2nF range with an actual reading of 1.802nF. The allowed increment of the reading, ΔR, would be simply:

$$\Delta R = 1.802 \times 0.0025 + 5/10{,}000$$
$$\Delta R = 0.0045 + 0.0005 = 0.005$$

Note that it is necessary in this case to divide the count value by 10,000 to properly scale units. This scaling factor will, of course, depend on the range.

The reading limits can then be calculated simply by adding and subtracting this value from the actual displayed value. If the lower and higher limits are R_L and R_H, we have:

$$R_L = 1.802 - 0.005 = 1.797\text{nF}$$

and,

$$R_H = 1.802 + 0.005 = 1.807\text{nF}$$

Thus, the allowable reading range for rated accuracy would be between 1.797nF and 1.807nF.

5.5.3 Spillover Calculations

The spillover calculations use the actual marked values along with the spillover component in the specifications. For capacitance sources, you can assume a conductance of zero, and the spillover into the conductance reading can be calculated from the spillover factor alone. For example, assume that you are verifying the 2nF range with an actual capacitance source value of 1.8nF. The conductance reading limits on the 2mS range can be calculated as follows:

$$R = 0 \pm (22 \times C/CFS + 5)/10,000$$

Where: R = conductance reading limits
C = capacitance source value
CFS = full scale capacitance for selected range
10,000 = factor to convert from counts to reading units (depends on range)

In our current example, the conductance reading limits would be:

$$R = 0 \pm (22 \times 1.8/2 + 5)/10,000$$
$$R = 0 \pm 0.0025\mu S$$

Since 0.1% tolerance resistors are used for the conductance sources, conductance spillover limits have been provided. Table 5-2 summarizes nominal conductance source values, actual resistances used, along with stray capacitances for each conductances source. Note that these stray capacitance values are factored into the verification limits given in this section.

5.5.4 Conductance Specification Considerations

Model 590 accuracy for a Q of less than 20 is specified as typical. Because the conductance verification procedures in this section are performed with a conductance of approximately 90% of full scale, all the conductance limits calculated in this section are based on typical specifications.

5.5.5 Analog Output Calculations

Calculations for the analog output tests are done in a similar manner, except that values are in volts and millivolts instead of capacitance, conductance, or counts.

5.5.6 Absolute Values

In some cases, the connected source may yield a negative reading on the display. For example, stray inductance for a high value conductance source might result in a negative capacitance display value. In all cases, the absolute value of the displayed reading should be used for the calculations.

Table 5-2. Model 5905 and 5906 Conductance Source Parameters

Nominal Conductance	DC Resistance*	Actual Conductance*	Stray Capacitance**
1.8μS	562kΩ	1.7794μS	+0.16pF
18μS	56.2kΩ	17.794μS	+0.16pF
180μS	5.62kΩ	177.94μS	+0.158pF
1.8mS	562Ω	1.7794mS	+0.004pF
18mS	56.2Ω	17.794mS	−15.42pF

*±0.1% tolerance.
**±(10% + 0.02pF) tolerance

5.6 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying capacitance and conductance accuracy. In addition, a procedure to verify accuracy of the internal bias source is also included.

The procedures in this section are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications, refer to Section 7 for calibration procedures.

WARNING

The maximum common-mode voltage (voltage between analog common and chassis ground) is 30V RMS. Exceeding this value may create a shock hazard. Some of the procedures in this section may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

5.6.1 Front Panel Verification

The procedures below outline verification of front panel capacitance and conductance accuracy. For separate verification of the analog outputs, refer to paragraph 5.7.2. Keep in mind that conductance accuracy specifications for Q<20 are typical.

To verify each range, you will be required to connect the capacitance or conductance sources to the instrument. In all cases the source must be connected to the instrument directly at the front panel test INPUT and OUTPUT jacks as shown in Figure 5-1. Under no circumstances are cables to be used, as these will affect the accuracy of the procedures. Figure 5-2 is a general flowchart for the verification procedures.

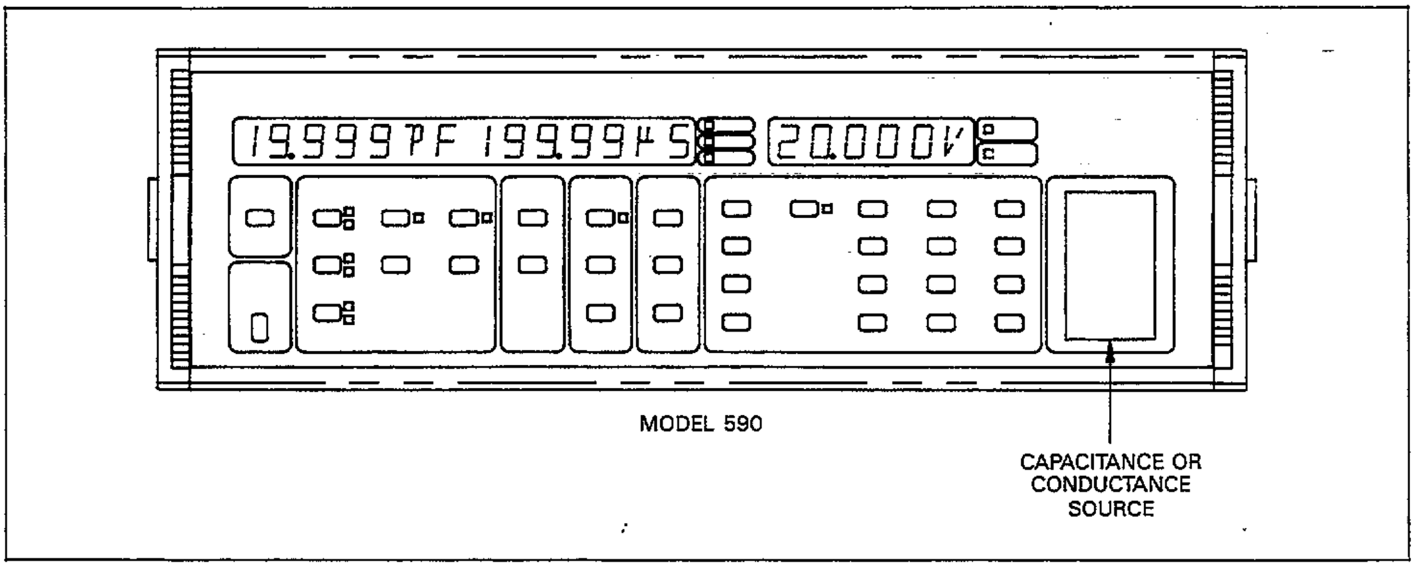


Figure 5-1. Mounting Source on Instrument

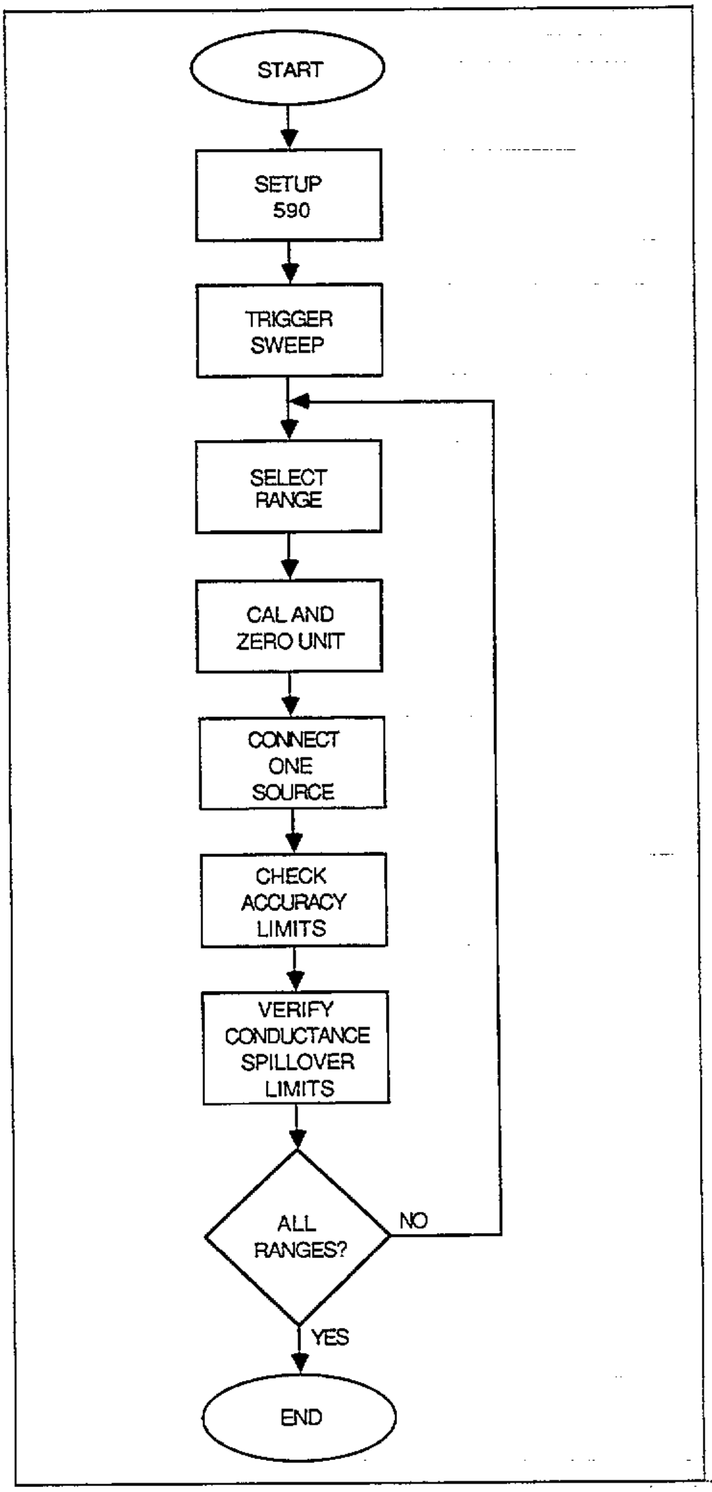


Figure 5-2. General Flowchart of Instrument Verification

100kHz Capacitance Verification

1. Turn on instrument power and allow it to warm up for at least one hour.
2. Initially set up the instrument as follows:
   Frequency: 100kHz
   Model : parallel
   Filter: on
   Reading rate: 10 per second
   Zero: off
   Trigger mode: sweep
   Trigger source: front panel
   Bias: off
3. Select the 2pF range with the RANGE key.
4. Press the CAL button and allow sufficient time for the instrument to complete the calibration cycle. During the cycle, the unit will display the BUSY message.
5. With nothing connected to the test INPUT and OUTPUT jacks press ZERO to enable that mode. Leave zero enabled while taking measurements.
6. Trigger the instrument by pressing the MANUAL button.
7. Connect the 1.5pF capacitance source to the test INPUT and OUTPUT jacks.
8. Compute the allowed reading limits from instrument specifications (see front of manual) and the displayed capacitance value by using the appropriate formula at the bottom of Table 5-3. Space has been provided for you to record the limits in the capacitance only column. After computation, verify that the displayed reading is within calculated limits.
9. Calculate the allowed spillover limits by using the formula including the spillover component at the bottom of Table 5-3. Record the reading limits in the table, if desired.
10. Verify that the displayed conductance reading is within the limits calculated above.
11. Repeat steps 4 through 10 for the 20pF through 2nF ranges by using the appropriate capacitance sources listed in Table 5-3. Be sure to calibrate and zero the instrument properly for each range as outlined in the appropriate steps above.
12. If you normally use a 5904 input adapter, and wish to verify its performance, connect the 5904 to the 590 test INPUT and OUTPUT jacks and repeat steps 4 through 10 using the correct sources. The range of interest here is 20nF. Be sure to place the instrument on the proper range by enabling the X10 attenuator (press SHIFT RANGE).

Table 5-3. Instrument 100kHz Capacitance Verification

Range	Nominal Capacitance	Capacitance Accuracy Limits*	Conductance Spillover Limits**
2pF/2μS	1.5pF	___ to ___ pF	___ to ___ μS
20pF/20μS	18 pF	___ to ___ pF	___ to ___ μS
200pF/200μS	180 pF	___ to ___ pF	___ to ___ μS
2nF/2mS	1.8nF	___ to ___ nF	___ to ___ mS
20nF/20mS†	18 nF	___ to ___ nF	___ to ___ mS

*Calculated as follows:

$$R = C \pm [(P \times C)/100 + C0/D]$$

where: R = Reading limits (pF or nF)
C = Capacitance source value (pF or nF)
P = Percent of reading value from specifications (percent)
C0 = Fixed count value from specifications
D = Divisor to adjust count units: D=10,000 (2pF, 2nF); 1,000 (20pF, 20nF); 100 (200pF)

**Calculated as follows:

$$R = 0 \pm (M(C/CFS)+G0)/D$$

where: R = Reading limits (μS or mS)
G = Displayed conductance (μS or mS)
G0 = Fixed count value from specifications
C = Capacitance source value (pF or nF)
CFS = Full scale capacitance for selected range (pF or nF)
M = C/CFS multiplier from specifications
D = Divisor (see above).

†This range applicable only to Model 5904 Input Adapter.

NOTE: Use absolute C and G values.

100kHz Conductance Verification

1. Turn on instrument power and allow the unit to warm up for at least one hour.
2. Initially set up the Model 590 as follows.
   Frequency: 100kHz
   Model: parallel
   Filter: on
   Reading rate: 10 per second
   Zero: off
   Trigger mode: sweep
   Trigger source: front panel
   Bias: off
3. Select the 2μS range with the RANGE key.
4. Press the CAL button and allow sufficient time for the instrument to complete calibration. BUSY will be displayed while correction is being performed.
5. With nothing connected to the test INPUT and OUTPUT jacks, enable zero. Leave zero enabled while making measurements.
6. Press MANUAL to trigger the unit.
7. Connect the 1.8μS source to the test INPUT and OUTPUT jacks.
8. Verify that the conductance and capacitance readings are within the limits shown in Table 5-4.
9. Repeat steps 4 through 8 to verify the 20pF through 2nF ranges by using the appropriate sources. Be sure to calibrate and zero the instrument properly after selecting each range.
10. If using a 5904 input adapter, connect the 5904 to the instrument test INPUT and OUTPUT terminals and repeat steps 4 through 13. The range of interest is 20mS. To place the instrument on the proper range, select the X10 attenuator by pressing SHIFT RANGE.

Table 5-4. Instrument 100kHz Conductance Verification

Range	Nominal Conductance	Conductance Reading Limits**
2pF/2μS	1.8 μS	1.7569 to 1.8021μS
20pF/20μS	18 μS	17.784 to 17.804μS
200pF/200μS	180 μS	177.68 to 178.20μS
2nF/2mS	1.8mS	1.7768 to 1.7820μS
20nF/20mS*	18 mS	17.745 to 17.843μS

*This range applicable only to Model 5904 Input Adapter.
**Using Keithley Model 5905 or 5906 conductance sources.

1MHz Capacitance Verification

1. Turn on the Model 590 and allow it to warm up for one hour.
2. Set up the instrument as follows.
   Frequency: 1MHz
   Model: parallel
   Filter: on
   Reading rate: 10 per second
   Zero: off
   Trigger mode: sweep
   Trigger source: front panel
   Bias: off
3. Select the 20pF range with the RANGE button.
4. Press the CAL key and allow sufficient time for the instrument to perform internal calibration. The Model 590 will display the BUSY message during correction.
5. With nothing connected to the test INPUT and OUTPUT jacks, enable zero. Leave zero enabled while taking measurements.
6. Press MANUAL to trigger the unit.
7. Connect the 18pF capacitor directly to the test INPUT and OUTPUT jacks.
8. Calculate the allowed accuracy reading limits for the selected range from instrument specifications and the displayed capacitance value. Use the correct formula from the bottom of Table 5-5. Record the limits in Table 5-5, if desired.
9. Verify that the instrument reading is within the limits calculated in step 8 above.
10. Compute the allowed reading limits for conductance spillover with the appropriate formula from Table 5-5. Record the limits, if desired.
11. Verify that the displayed reading is within the limits calculated in step 11.
12. Repeat steps 4 through 11 for the 200pF and 2nF ranges by using the appropriate source values. Be sure to properly calibrate and zero the unit after selecting each range.

1MHz Conductance Verification

1. Turn on the instrument and allow it to warm up for one hour.
2. Intitially configure the instrument as follows:
   Frequency: 1MHz
   Model: parallel
   Filter: on
   Reading rate: 10 per second
   Zero: off
   Trigger mode: sweep
   Trigger source: front panel
   Bias: off
3. Select the 200μS range with the RANGE key.
4. Press MANUAL to trigger the sweep.
5. Press CAL and allow sufficient time for the instrument to complete the calibration cycle. BUSY will be displayed during correction.
6. With nothing connected to the test INPUT and OUTPUT jacks, enable zero. Leave zero enabled while making measurements. Press MANUAL.
7. Connect the 180μS source to the instrument.
8. Verify that the displayed capacitance and conductance readings are within limits (see Table 5-6).
9. Repeat steps 3 through 8 for the 2mS and 20mS ranges by using the appropriate sources, as listed in the table. Be sure to properly calibrate and zero the instrument after selecting each range.

Table 5-5. Instrument 1MHz Capacitance Verification

Range	Nominal Capacitance	Capacitance Reading Limits*	Conductance Spillover Limits**
20pF/200µS	18 pF	___ to___ pF	___ to___ µS
200pF/2mS	180 pF	___ to___ pF	___ to___ mS
2nF/20mS	1.8nF	___ to___ nF	___ to___ mS

*Calculated as follows:

$$R = C \pm [(P \times C)/100 + C0/D]$$

where: R = Reading limits (pF or nF)
C = Capacitance source value (pF or nF)
P = Percent of reading value from specifications (percent)
C0 = Fixed count value from specifications
D = Divisor to adjust count units: D=1,000 (20pF); 100 (200pF); 10,000 (2nF)

**Calculated as follows:

$$R = 0 \pm (M(C/CFS) + G0)/D$$

where: R = Reading limits (pF or nF)
G0 = Fixed count value from specifications
C = Capacitance source value (pF or nF)
CFS = Full scale capacitance for selected range (pF or nF)
M = C/CFS multiplier from specifications
D = Divisor: D = 100 (200µS); 10,000 (2mS); 1,000 (20mS)

NOTE: Use absolute C and G values.

Table 5-6. Instrument 1MHz Conductance Verification

Range	Nominal Conductance	Conductance Reading Limits*
20pF/200μS	180 μS	177.31 to 178.57 μS
200pF/2mS	1.8mS	1.7737 to 1.7851mS
2nF/20mS	18 mS	17.736 to 17.852mS

*Using Keithley Model 5905 or 5906 sources.

5.6.2 Analog Output Verification

Analog output verification procedures are very similar to those used for normal reading verification. The main difference is that you will be measuring an analog output voltage on the rear panel using a DMM. Instead of a capacitance reading, the signal will be a scaled 0-2V value. Also, since software accuracy compensation is not applied to these signals, the allowable tolerances are substantially larger than for front panel readings.

The same sources are to be used for these tests; refer to Figure 5-1 for connections. Figure 5-3 shows a general flowchart of the analog output verification procedures.

100kHz Capacitance Verification

1. Turn on instrument power and allow it to warm up for at least one hour.
2. Initially set up the instrument as follows:
   Frequency: 100kHz
   Filter: on
   Bias: off
3. Connect the DMM to the CAPACITANCE ANALOG OUTPUT jack on the rear panel, as shown in Figure 5-4. The DMM high terminal should be connected to the center conductor, and the low terminal should be connected to the cable shield. Select the DCV function and autoranging.
4. Select the 20pF range with the RANGE key, then zero the DMM.
5. Connect the 18pF capacitance source to the test INPUT and OUTPUT jacks.
6. Compute the allowed voltage limits from instrument specifications (see front of manual) and the DMM reading by using the appropriate formula at the bottom of Table 5-7. Space has been provided for you to record the limits in the capacitance only column. After computation, verify that the measured voltage is within calculated limits.
7. Calculate the allowed limits by using the formula including the spillover component at the bottom of Table 5-7. Record the voltage limits in the table, if desired.
8. Verify that the measured voltage is within the limits calculated above.
9. Repeat steps 4 through 8 for the 200pF and 2nF ranges by using the appropriate capacitance and conductance sources listed in Table 5-7.
10. If you normally use a 5904 input adapter, and wish to verify 20nF range performance, connect the 5904 to the 590 test INPUT and OUTPUT jacks and repeat steps 4 through 8 using the correct sources. Be sure to place the instrument on the proper range by enabling the X10 attenuator (press SHIFT RANGE).

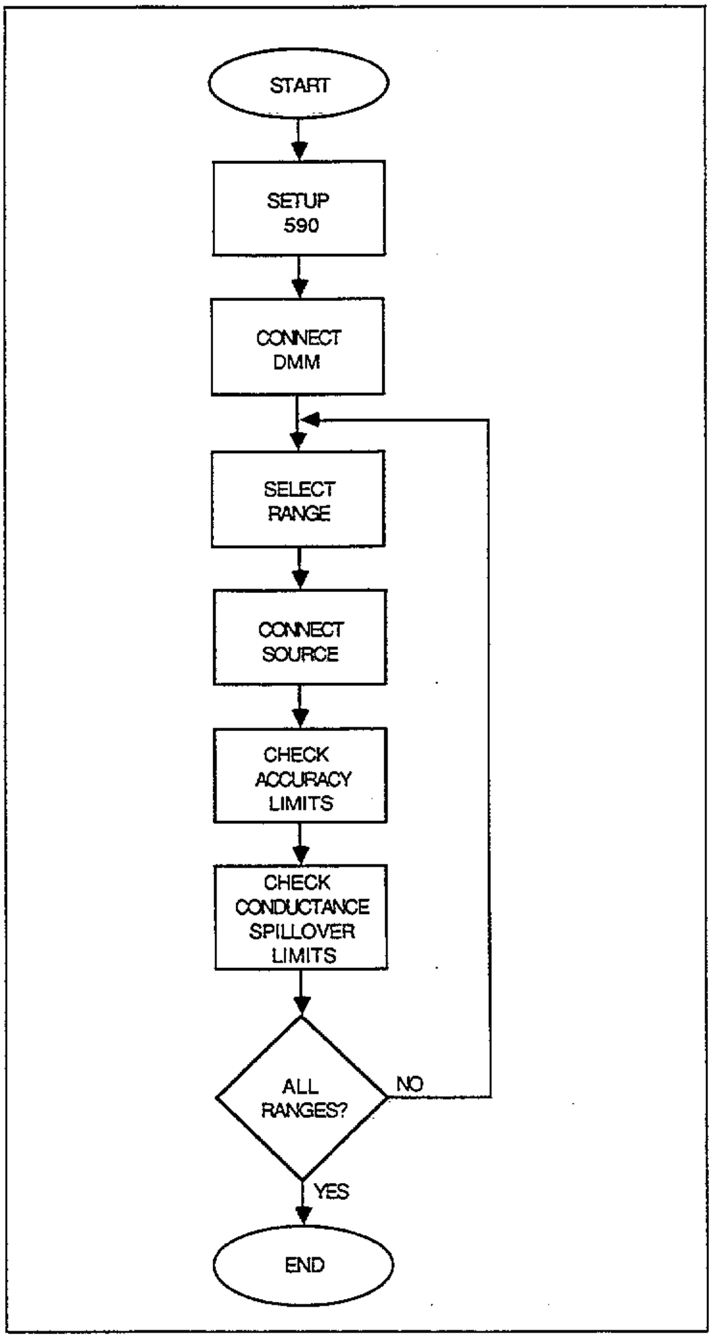


Figure 5-3. General Flowchart of Analog Output Verification

Table 5-7. Analog Output 100kHz Capacitance Verification

Range	Nominal Capacitance	Nominal Output	Capacitance Output Limits*	Conductance Output Spillover Limits**
20pF/20μS	18 pF	1.8V	___ to ___ V	___ to ___ V
200pF/200μS	180 pF	1.8V	___ to ___ V	___ to ___ V
2nF/2mS	1.8nF	1.8V	___ to ___ V	___ to ___ V
20nF/20mS†	18 nF	1.8V	___ to ___ V	___ to ___ V

*Calculated as follows:

$$O = C \pm [(P \times C)/100 + V/1{,}000]$$

where: O = Analog output voltage limits in volts
C = Displayed capacitance (converted to volts)
P = Percent of reading value from specifications (percent)
V = Fixed offset value from specifications (mV)

**Calculated as follows:

$$O = 0 \pm [(M(C/CFS) + V)/1{,}000]$$

where: O = Conductance analog output voltage limits in volts
M = C/CFS multiplier
C = Capacitance source
CFS = Full scale capacitance
V = Fixed offset value (mV)

†This range applicable only to Model 5904 Input Adapter.

NOTE: Use absolute values for C and G readings.

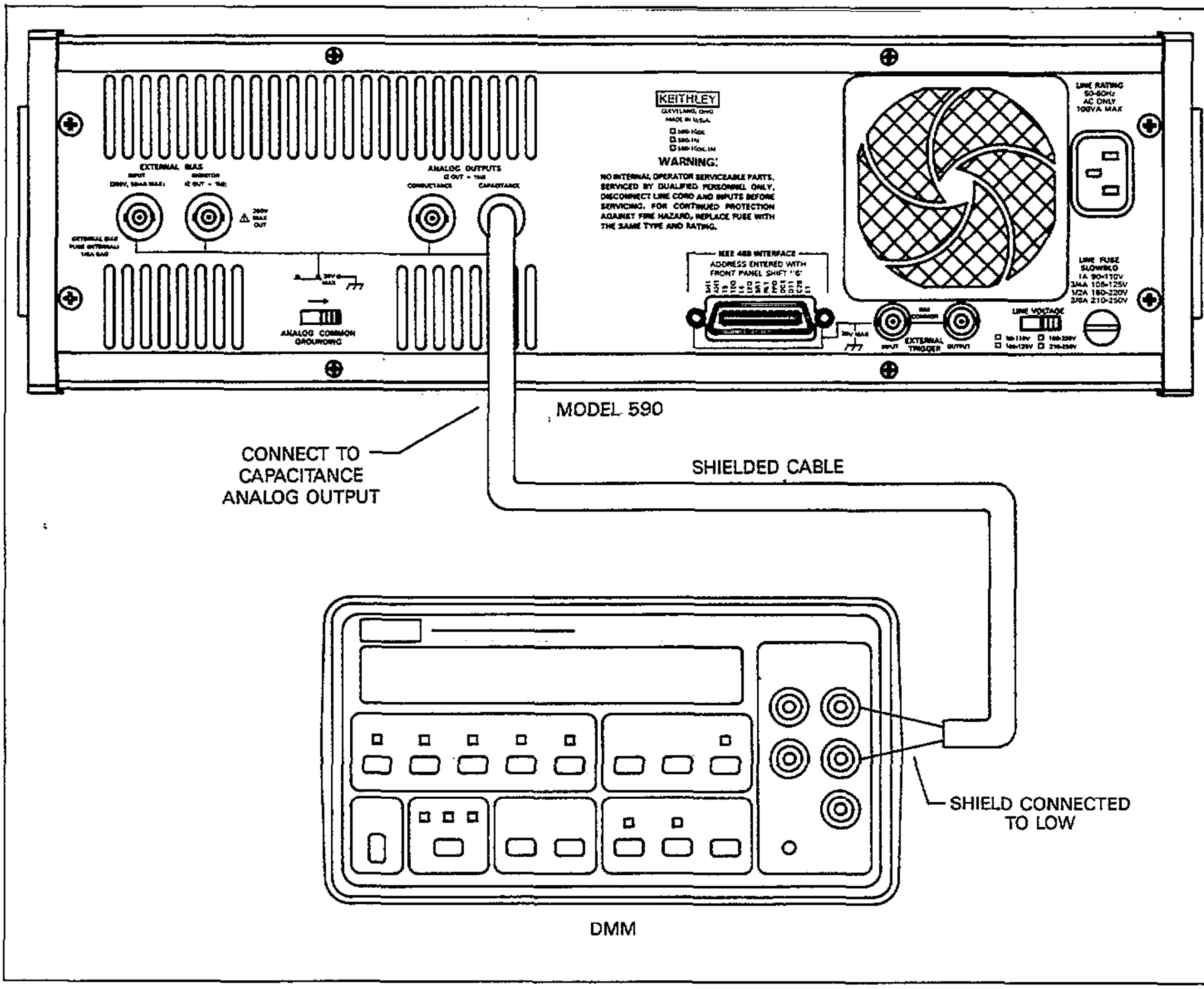


Figure 5-4. Connecting for Analog Output Capacitance Verification

100kHz Conductance Verification

1. Turn on instrument power and allow the unit to warm up for at least one hour.
2. Initially set up the instrument as follows:
   Frequency: 100kHz
   Filter: on
   Bias: off
3. Connect the DMM to the CONDUCTANCE ANALOG OUTPUT jack on the rear panel, as shown in Figure 5-5. The DMM high terminal should be connected to the center conductor, and the low terminal should be connected to the cable shield. Select the DCV function and autoranging.
4. Select the 20μS range with the RANGE key, then zero the DMM.
5. Connect the 18μS source to the test INPUT and OUTPUT jacks.
6. Verify that the measured voltages are within the limits shown in Table 5-8.
7. Repeat steps 4 through 6 to verify the 200μS and 2mS ranges by using the appropriate sources.
8. If using a 5904 input adapter, verify the 20mS range. To do so, connect the 5904 to the instrument test INPUT and OUTPUT terminals and repeat steps 4 through 6. To place the instrument on the proper range, enable the X10 attenuator by pressing SHIFT RANGE.

1MHz Capacitance Verification

1. Turn on instrument power and allow it to warm up for at least one hour.
2. Initially set up the instrument as follows:
   Frequency: 1MHz
   Filter: on
   Bias: off
3. Connect the DMM to the CAPACITANCE ANALOG OUTPUT jack on the rear panel, as shown in Figure 5-4. The DMM high terminal should be connected to the center conductor, and the low terminal should be connected to the cable shield. Select the DCV function and autoranging
4. Select the 20pF range with the RANGE key, then zero the DMM.
5. Connect the 18pF capacitance source to the test INPUT and OUTPUT jacks.
6. Compute the allowed voltage limits from instrument specifications (see front of manual) and the displayed DMM reading by using the appropriate formula at the bottom of Table 5-9. Space has been provided for you to record the limits in the capacitance only column. After computation, verify that the measured voltage is within calculated limits.
7. Calculate the allowed voltage limits by using the formula including the spillover component at the bottom of Table 5-9. Record the voltage limits in the table, if desired.
8. Verify that the measured voltage is within the limits calculated above.
9. Repeat steps 4 through 8 for the 200pF and 2nF ranges by using the appropriate capacitance and conductance sources listed in Table 5-9.

Table 5-8. Analog Output 100kHz Conductance Verification

Range	Nominal Conductance	Nominal Output	Conductance Output Limits*
20pF/20μS	18 μS	1.8V	1.7616 to 1.797V
200pF/200μS	180 μS	1.8V	1.7616 to 1.797V
2nF/2mS	1.8mS	1.8V	1.7438 to 1.815V
20nF/20mS†	18 mS	1.8V	1.726 to 1.833V

†This range applicable only to Model 5904 Input Adapter

*Using Keithley Model 5905 or 5906 sources.

1MHz Conductance Verification

1. Turn on instrument power and allow the unit to warm up for at least one hour.
2. Initially set up the instrument as follows:
   Frequency: 1MHz
   Filter: on
   Bias: off
3. Connect the DMM to the CONDUCTANCE ANALOG OUTPUT jack on the rear panel, as shown in Figure 5-5. The DMM high terminal should be connected to the center conductor, and the low terminal should be connected to the cable shield. Select the DCV function and autoranging.
4. Select the 200μS range with the RANGE key and zero the DMM.
5. Connect the 180μS source to the test INPUT and OUTPUT jacks.
6. Verify that the measured voltages are within the limits shown in Table 5-10.
7. Repeat steps 4 through 6 to verify the 2mS and 20mS ranges by using the appropriate sources.

Table 5-9. Analog Output 1MHz Capacitance Verification

Range	Nominal Capacitance	Nominal Output	Capacitance Output Limits*	Conductance Output Spillover Limits**
20pF/200μS	18 pF	1.8V	____ to ____ V	____ to ____ V
200pF/2mS	180 pF	1.8V	____ to ____ V	____ to ____ V
2nF/20mS	1.8nF	1.8V	____ to ____ V	____ to ____ V

*Calculated as follows:

$$O = C \pm [(P \times C)/100 + V/1{,}000]$$

where: O = Analog output voltage limits in volts
C = Displayed capacitance (volts)
P = Percent of reading value from specifications (percent)
V = Fixed offset value from specifications (mV)

**Calculated as follows:

$$O = 0 \pm [(M(C/CFS) + V)/1{,}000]$$

where: O = Analog output voltage limits in volts
C = Capacitance source value
M = C/CFS multiplier
CFS = Full scale capacitance
V = Fixed offset value (mV)

NOTE: Use absolute values for C and G readings.

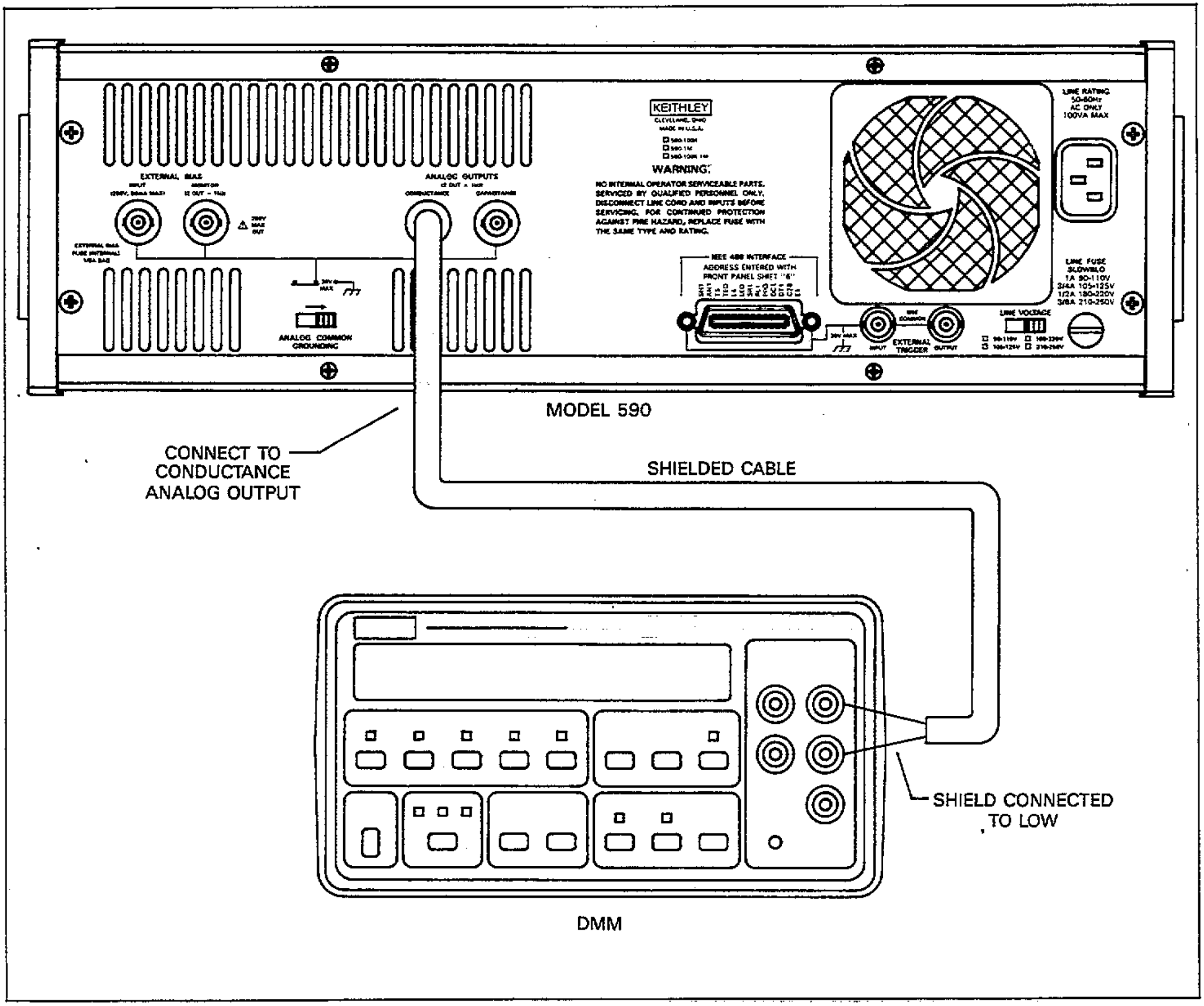


Figure 5-5. Connections for Analog Output Conductance Verification

Table 5-10. Analog Output 1MHz Conductance Verification

Range	Nominal Conductance	Nominal Output	Conductance Output Limits*	Capacitance Output Spillover Limits*
20pF/20μS	180 μS	1.8V	1.744 to 1.815V	−0.068 to +0.068V
200pF/2mS	1.8mS	1.8V	1.725 to 1.833V	−0.067 to +0.067V
2nF/20mS	18 mS	1.8V	1.654 to 1.904V	−0.268 to −0.268V

*Using Keithley Model 5905 or 5906 sources.

5.6.3 Complete Model 5904 Verification

From the factory, the Model 590 is calibrated to use the 5904 input adapter only on the 20nF/20mS range. However, if you have field calibrated the instrument for use with the 20pF through 2nF ranges (see paragraph 7.3), you can verify accuracy of that calibration by repeating the procedures from paragraph 5.7.1 and 5.7.2 using the appropriate sources, as indicated below:

20pF/20μS: 18pF/18μS
200pF/200μS: 180pF/180μS
2nF/2mS: 1.8nF/1.8mS

5.6.4 Voltage Verification

The following procedures are intended to verify the accuracy of the internal bias source as well as the read-back accuracy of the voltage display. Figure 5-6 shows a general flowchart of the voltage verification procedures.

Internal Bias Source and 20V Range Read-Back Accuracy

1. Turn on the Model 590 and allow it to warm up for one hour.
2. Connect the DMM to the VOLTAGE BIAS MONITOR jack, as shown in Figure 5-7. Select the DCV function and autoranging on the DMM.
3. Set up the instrument as follows:
   Waveform: DC
   Trigger source: front panel
   Trigger mode: one-shot
   Bias: on
4. Use the PARAMETER key to program a first bias voltage value of exactly 19.000V.
5. Press the MANUAL key to trigger a reading.
6. Note the reading on the DMM and record its value (the actual measured values will be required for the 20V range read back check outlined below). Check to see that the reading is within the limits stated in Table 5-11.
7. Calculate the allowable range of the Model 590 voltage display reading using the measured value obtained in step 6 and the formula at the bottom of Table 5-11.
8. Note the reading on the Model 590 voltage display. Check to see that displayed reading is within the limits calculated in step 7.
9. Repeat steps 4 through 8 for the remaining voltages listed in Table 5-11. For each programmed step, measure the voltage and verify that the value is within prescribed limits. Then use the measured voltage value to calculate the allowed limits of the Model 590 voltage display, and compare the actual display to calculated limits.

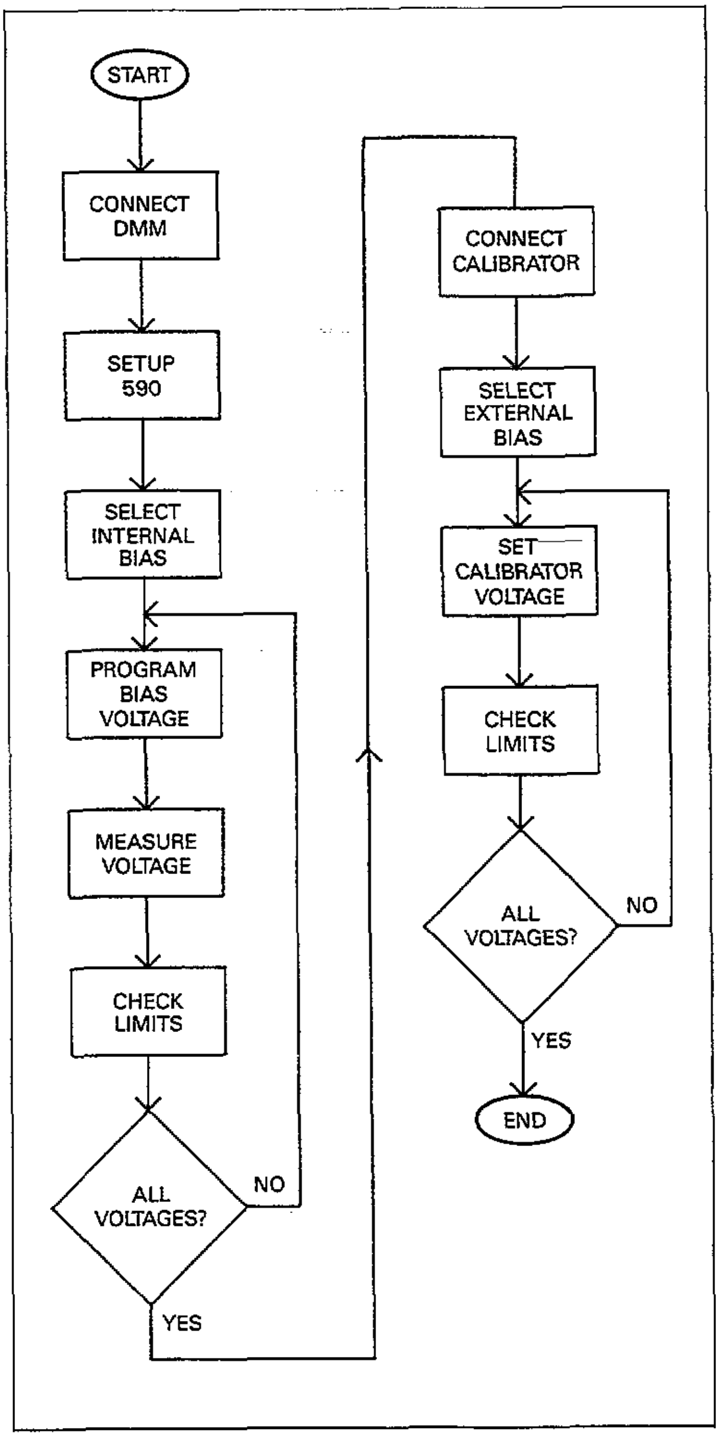


Figure 5-6. Voltage Verification Flowchart

Table 5-11. Internal Bias Source and 20V Range Read-Back Accuracy

Programmed Voltage	Measured Internal Bias Source Limits	20V Read-Back Accuracy Limits*
−19.000V	−19.02 to −18.98 V	___ to ___ V
−15.000V	−15.0175 to −14.9825V	___ to ___ V
−10.000V	−10.015 to − 9.985 V	___ to ___ V
− 5.000V	− 5.0125 to − 4.9875V	___ to ___ V
0.000V	− 0.01 to + 0.01 V	___ to ___ V
+ 5.000V	+ 4.9875 to +-5.0125V	___ to ___ V
+10.000V	+ 9.985 to +10.015 V	___ to ___ V
+15.000V	+14.9825 to +15.0175V	___ to ___ V
+19.000V	+18.98 to +19.02 V	___ to ___ V

*Calculated as follows:

$$V = M \pm (0.0005M + 0.005)$$

where: V = Read-back voltage limits
M = Actual measured internal bias source value

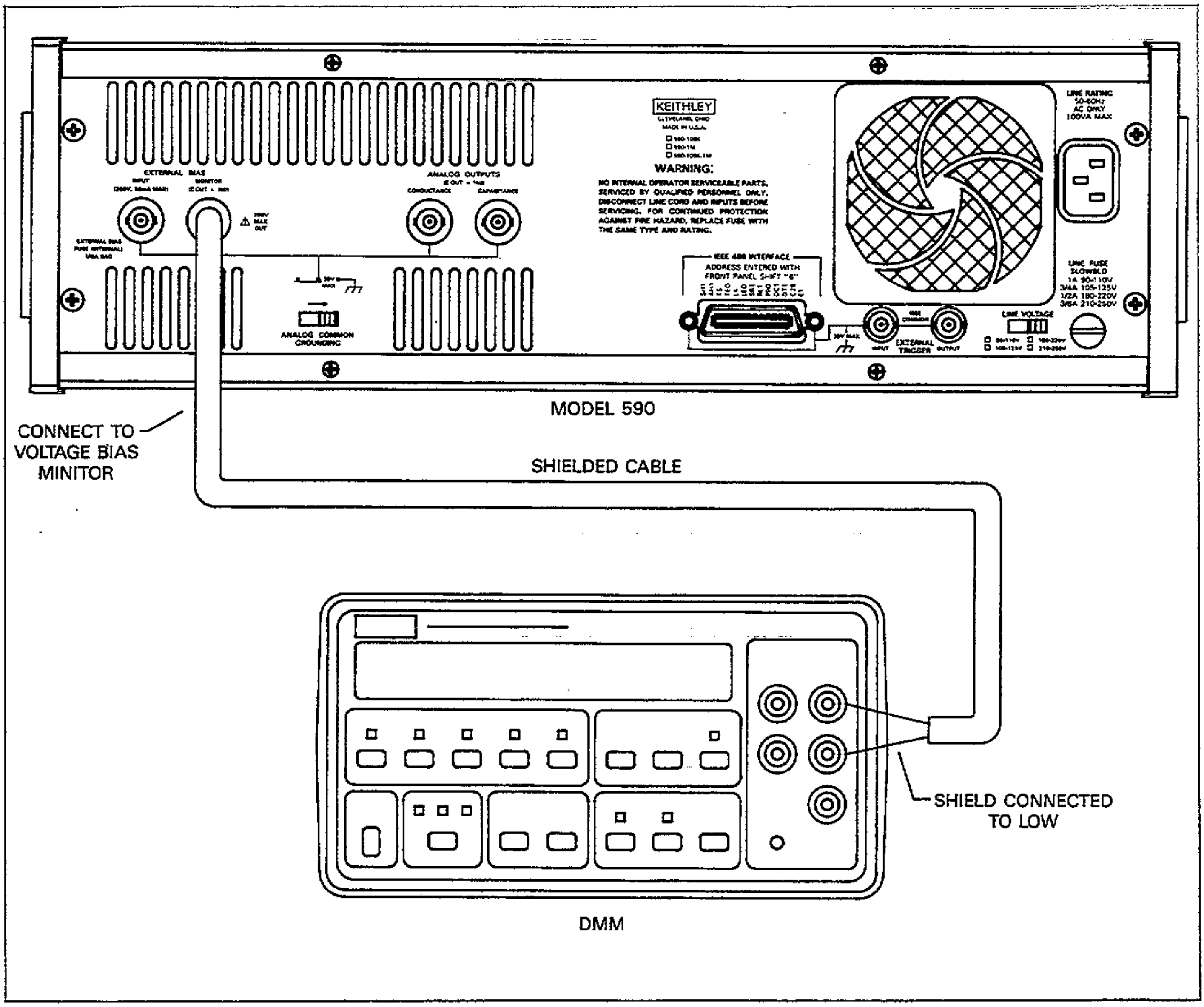


Figure 5-7. Connections for Voltage Verification

200V Range Read-Back Accuracy Check

The internal bias voltage read back circuits are set to the 200V range whenever the external bias source is selected. The procedure below will allow you to check the accuracy of the voltage display when reading external bias source.

WARNING
Hazardous voltages are used in many of the following steps. Take care not to contact these voltages, which could cause personal injury or death.

CAUTION
Do not place the DC calibrator used in this procedure to standby with the Model 590 bias on. Doing so may blow the bias fuse. Always turn off the Model 590 bias before placing the calibrator in standby.

1. Connect the external DC calibrator to the VOLTAGE BIAS INPUT jack, as shown in Figure 5-8. Initially set the calibrator to 0.0000V and place the unit in operate.
2. Turn on the Model 590 and allow it to warm up for one hour.
3. Turn on the DC calibrator and allow it to warm up for the prescribed period.
4. Set up the Model 590 as follows:
   Waveform: external
   Trigger source: front panel
   Trigger mode: one-shot
   Bias: on
5. Set the DC calibrator to exactly −190.000V.
6. Trigger a reading by pressing MANUAL.
7. Note the reading on the Model 590 voltage display, and compare it to the limits in the first line of Table 5-12.
8. Repeat steps 5 through 7 for each voltage listed in Table 5-12. At each voltage step, compare the displayed Model 590 reading with the limits listed in the table.
9. Turn off the Model 590 bias source (BIAS ON LED off) and then place the DC calibrator in standby.

Table 5-12. Limits for 200V Read-Back Range

Applied Voltage	Read-Back Limits
−190.000V	−190.15 to −189.85V
−175.000V	−175.14 to −174.86V
−150.000V	−150.13 to −149.87V
−125.000V	−125.11 to −124.89V
−100.000V	−100.10 to − 99.90V
− 75.000V	− 75.09 to − 74.91V
− 50.000V	− 50.08 to − 49.92V
− 25.000V	− 25.06 to − 24.94V
0.000V	− 0.05 to + 0.05V
+ 25.000V	+ 24.94 to + 25.06V
+ 50.000V	+ 49.92 to + 50.08V
+ 75.000V	+ 74.91 to + 75.09V
+100.000V	+ 99.90 to +100.10V
+125.000V	+124.89 to +125.11V
+150.000V	+149.87 to +150.13V
+175.000V	+174.86 to +175.14V
+190.000V	+189.85 to +190.15V

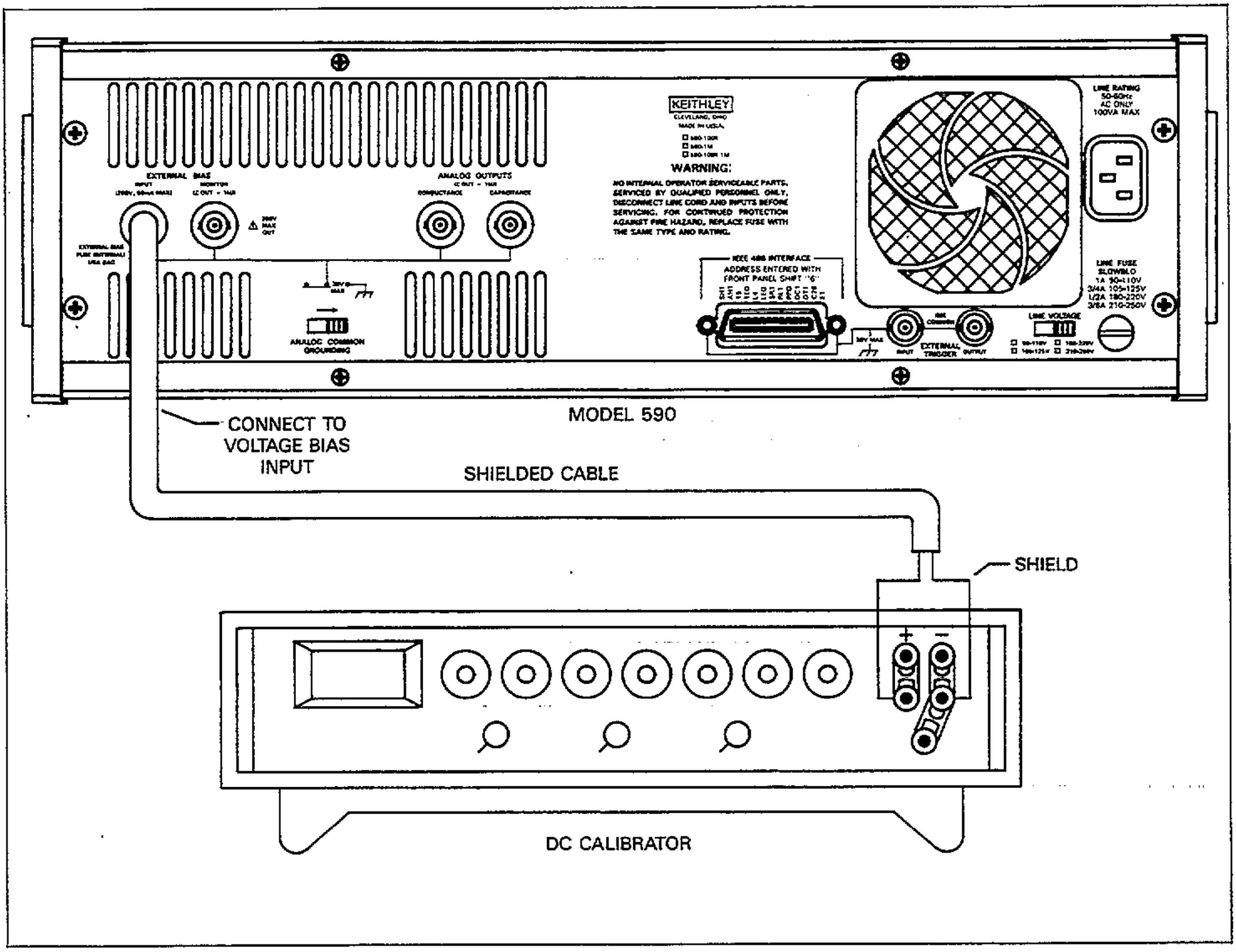


Figure 5-8. Connections for 200V Read-Back Verification

SECTION 6
PRINCIPLES OF OPERATION

6.1 INTRODUCTION

This section contains an overall functional description of the Model 590 as well as detailed operating principles for various circuits within the instrument. Some descriptions include simplified block diagrams or schematics as an aid to understanding. Detailed schematic diagrams and component layout drawings for the various circuit boards are located in Section 8.

Section 6 is arranged as follows:

6.2 Functional Description: Presents Model 590 circuitry in block diagram form and gives an overview of circuit operation.

6.3 Digital Circuits: Outlines the operation of digital circuits such as the hardware multiplier and microcomputer.

6.4 Analog Circuitry: Describes operation of the analog circuitry including the A/D converter.

6.5 100kHz Capacitance Module: Details operation of the 100kHz capacitance module including measurement principles.

6.6 1MHz Capacitance Module: Gives a detailed description of the 1MHz capacitance module and its operating principles.

6.7 Power Supplies: Discusses the power supplies that feed the various circuits within the instrument.

6.8 Display Board: Covers operation of the display and keyboard circuits.

6.9 Cable Correction: Outlines the basic principles of cable correction used by the instrument to compensate for transmission line effects.

6.2 FUNCTIONAL DESCRIPTION

A simplified block diagram of the instrument is shown in Figure 6-1. The unit is essentially divided into two sections, analog and digital. These two sections are electrically isolated to allow analog common to be floated while maintaining digital common at chassis ground potential.

Key analog circuits include switching and control circuits, the 100kHz and 1MHz capacitance modules, the A/D converter, and the internal bias voltage source. Important digital circuits include the microcomputer, keyboard, display, and IEEE-488 interface circuits. Separate power supplies are included for the analog and digital sections in order to maintain isolation.

The device under test is connected to the selected 100kHz or 1MHz module. The module applies a composite of the nominal 15mV test frequency (100kHz and 1MHz) and the programmed bias voltage to the device under test, and it then measures the resulting 100kHz or 1MHz current through that device. The module then converts the resulting capacitance and conductance signals into a scaled 0-2V signal usable by the A/D converter.

The A/D converter digitizes the capacitance, conductance, and bias voltage signals for transmission to the microcomputer. The transmission process is done in serial form via an opto-isolator in order to maintain the necessary electrical isolation mentioned previously.

An internal voltage source supplies up to ±20V of bias that can be applied to the circuit under test. Like the remaining analog circuits, this supply is controlled by signals from the microcomputer.

The clock circuits generate the necessary signals to synchronize both analog and digital circuits. An 8MHz signal is used both for the 1MHz module (if present) and the microcomputer. In this case, isolation is maintained by sending the clock signal through a pulse transformer instead of an opto-isolator because of the high frequency involved. The 8MHz signal is divided down to 4MHz for the A/D converter and 800kHz for the 100kHz capacitance module.

The 6809-based microcomputer supervises virtually all operating aspects of the instrument, including control of the A/D converter, voltage source, and capacitance modules. Control information from the microcomputer to these circuits is transmitted in isolated form through opto-isolators. Additional circuits controlled by the microcomputer include the display, keyboard, and the IEEE-488 interface.

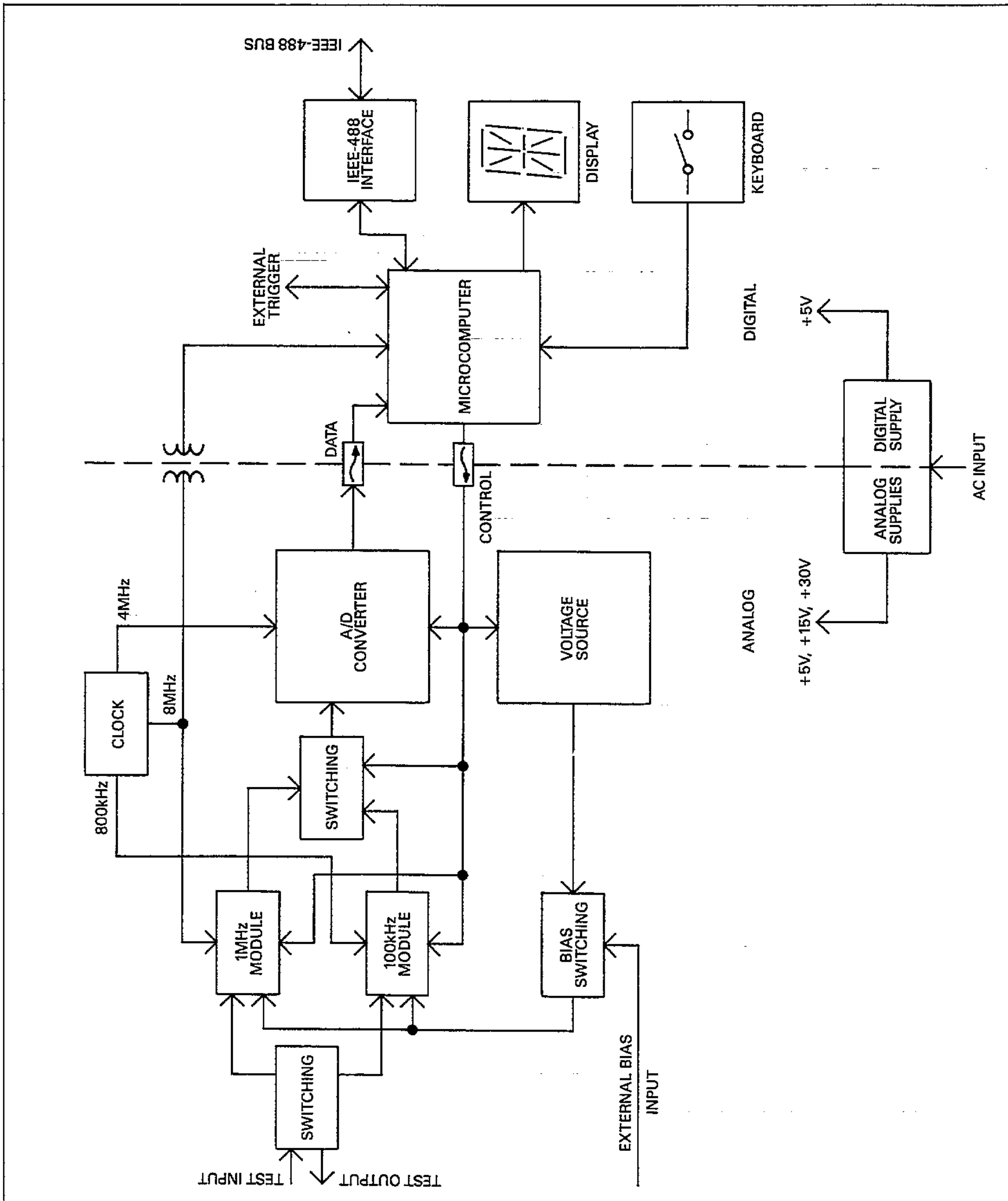


Figure 6-1. Block Diagram

The power supply circuits convert the applied AC power line voltage into various DC voltages used by the instrument. Fundamentally, the power supply is divided into analog and digital sections. Analog supplies include ±5, ±15, and ±30V sections, while a single +5V supply powers the digital circuits.

6.3 DIGITAL CIRCUITRY

The paragraphs below discuss the various digital circuits used in the Model 590. Figure 6-2 shows a simplified block diagram of the digital circuits, and a complete schematic is located on drawing number 590-126 located at the end of Section 8.

6.3.1 Microprocessor

The 68B09 processor provides the intelligence to control the instrument. The B designation indicates that the processor is a 2MHz unit, which is the frequency of operation for the MPU bus. As shown in the programming model of Figure 6-3, the 6809 has two 16-bit index registers (X and Y), two 16-bit stack pointers (U and S), a 16-bit program counter, and two eight-bit accumulators, A and B. The direct page and condition code registers round out the register complement.

Key 6809 signal lines include:

Data lines (D7-D0): The MPU has an eight-bit data bus use to read and write information to external devices.

Address lines (A15-A0): The sixteen address lines give the 6809 a 64K byte addressing capability.

Read/write (R/$\overline{\mathrm{W}}$): The state of the read/write line determines whether data is being read from or transferred to external devices. A read occurs when this line is high, while a write takes place when the line is low.

Bus clock (E and Q): Quadrature 2MHz bus clock signals are provided by these two lines.

Reset ($\overline{\mathrm{RESET}}$). This terminal is held low for 690msec upon power up to generate a system reset. The reset signal is generated by U302 and associated components.

Interrupt request ($\overline{\mathrm{IRQ}}$): The 1.024msec system clock is connected to this terminal to cause system interrupt timing at that interval. This interrupt-generated timing controls such operating aspects as A/D conversion. The interrupt signal is derived by dividing the 2MHz E clock by 2048, a function performed by U342.

Fast interrupt request ($\overline{\mathrm{FIRQ}}$): Pulling this line low causes a fast interrupt sequence, in which case the 6809 stacks only the condition code register and program counter, in contrast to a full interrupt, which causes all registers to be stacked. In the Model 590, $\overline{\mathrm{FIRQ}}$ is connected to the IEEE-488 GPIA chip $\overline{\mathrm{IRQ}}$ terminal, which means that IEEE bus interrupts are processed on a fast interrupt basis.

Non-maskable interrupt ($\overline{\mathrm{NMI}}$): As the name implies, a low signal on this terminal causes an interrupt that cannot be disabled (masked) by setting the IRQ flag in the condition code register. This terminal is connected to the VIA $\overline{\mathrm{IRQ}}$ pin, meaning that interrupts associated with I/O operations are processed on an NMI basis.

MPU clock (EXTAL): An 8MHz clock, which originates on the mother board, is applied to this terminal. The clock passes through T301 for isolation and is re-shaped by U331A before being applied to the MPU. The 6809 internally divides this signal by four to generate the 2MHz E and Q bus clock signals.

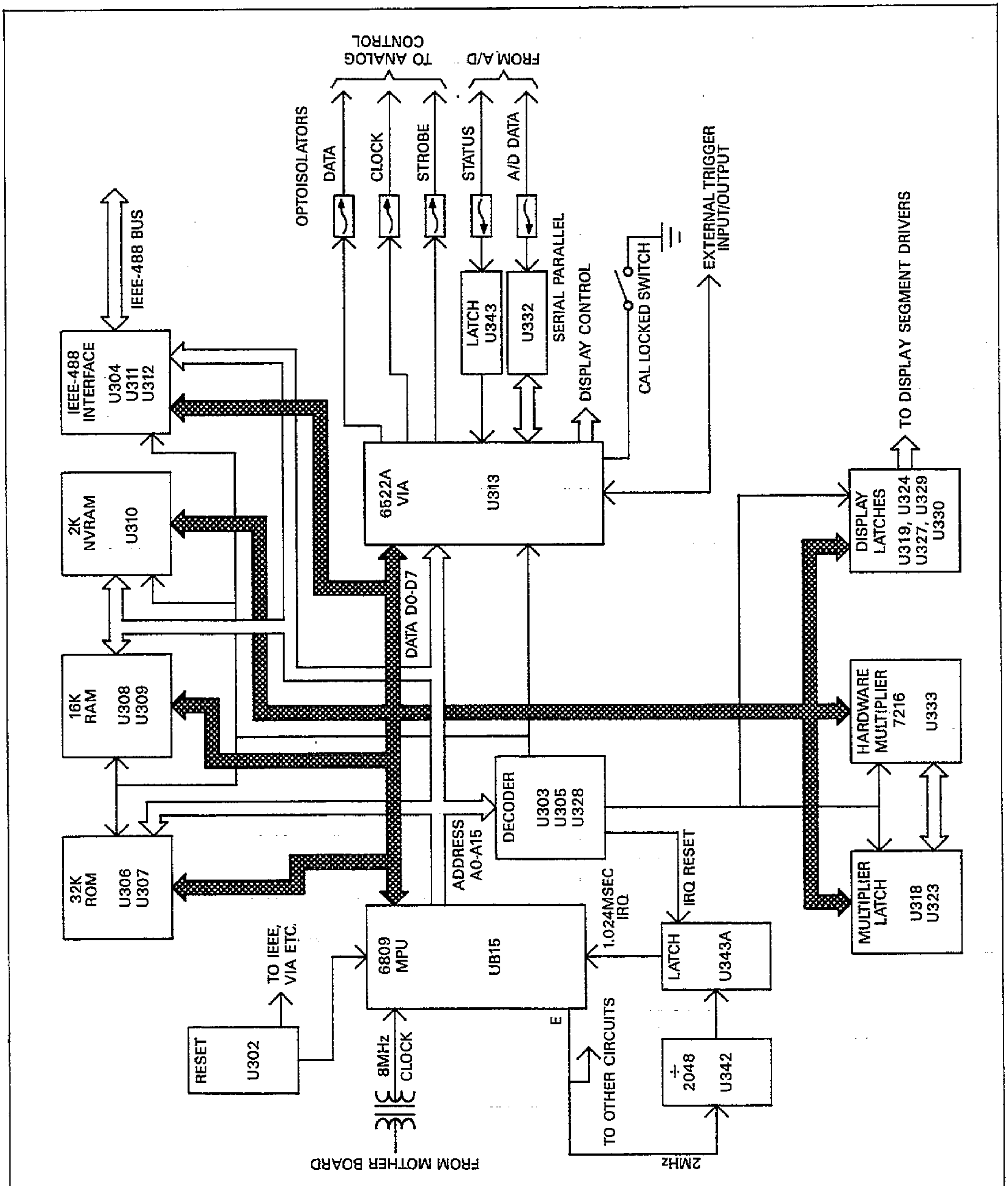


Figure 6-2. Digital Circuit Block Diagram

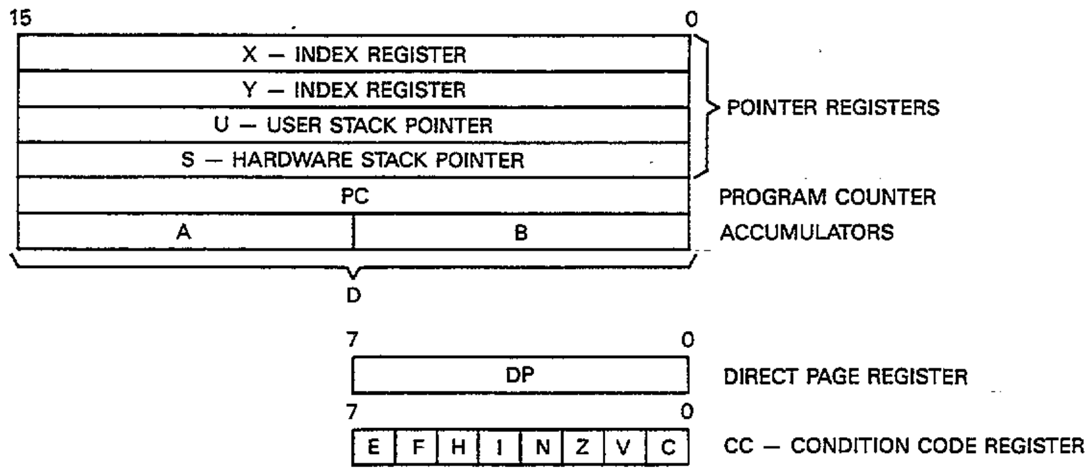


Figure 6-3. 6809 Microprocessor Programming Mode

6.3.2 Memory Circuits

ROM Memory

A total of 32K bytes of program coding is stored in two ROMS, U306 and U307. Each of these devices is a 27128 ROM IC capable of storing 16K bytes.

RAM Memory

U308 and U309 provide 16K bytes of working storage for the operating system. Each device is an 8K byte static RAM (6264), which, unlike dynamic RAM, requires no refreshing circuitry. Among other things, the RAM ICs are used to store data taken as part of a reading sweep. This form of RAM storage is volatile, meaning that data is lost when power is removed.

NVRAM

Non-volatile memory storage is provided by U310, which is a 2K byte storage device. This IC stores such data as calibration and setup configuration constants that must be retained when power is removed.

Address Decoding

Because none of the memory ICs is capable of completely decoding the entire 64K address space, additional decoding is necessary. U303 decodes for the memory circuits, as well as for the VIA and IEEE chips. U305 decodes for the display latches and hardware multiplier, while U328 provides additional decoding for the hardware multiplier and associated latches.

Memory Mapping

Table 6-1 summarizes the address locations for the various memory ICs. In addition, locations for various chips such as the VIA and GPIA are also included.

Table 6-1. Memory Map

Address		
Hexadecimal	Decimal	Description
$0000	0	Write X register, read high-order multiplier
$0002	2	Write Y register, read low-order multiplier
$1000 - $1001	4,096-4,097	Display latches
$1040 - $1041	4,160-4,161	Display latches
$1080	4,224	Register C, multiplier
$1081	4,225	IRQ counter clear
$1100 - $1107	4,352-4,359	9914A GPIA
$1200 - $120F	4,608-4,623	6522A VIA
$1400 - $17FF	5,120-6,143	NVRAM
$2000 - $3FFF	8,192-16,383	RAM #1
$4000 - $5FFF	16,384-24,575	RAM #2
$6000 - $FFFF	24,576-65,535	Program ROMs

6.3.3 Hardware Multiplier

U333 is the hardware multiplier (7216) used in the Model 590 in order to achieve fast, real-time digital processing at speeds that would otherwise be impossible using software. This versatile IC can multiply two 16-bit numbers and provide a 32-bit, double-precision product in only 75nsec. This speed and versatility allow the Model 590 to perform array processing on buffer data with greater efficiency.

Multiplier IC Connections

Multiplicand data inputs (X15-X0): These terminals provide 16-bit input for the multiplicand.

Multiplier data inputs (Y15-Y0): The 16-bit value of the multiplier is applied to these inputs.

Product outputs (P15-P0): The most significant or least significant word of the product are made available at this port, depending on the state of $\overline{\text{MSPSEL}}$ (see below).

Product select ($\overline{\text{MSPSEL}}$): The state of this line determines whether the product port assumes the value of the low or high-ordered bits of the 32-bit product. When set low, the most significant product (MSP) will be selected, while the least significant product (LSP) will appear on the lines when MSPSEL is high.

Output port enable ($\overline{\text{OEP}}$): A low logic level on this terminal is necessary to enable the product port, which has tri-state outputs.

Clock terminals (CLKX, CLKY, CLKM, CLKL): Clock signals for the X, Y, MSP, and LSP registers are applied to these terminals.

Multiplier/MPU Interfacing

Since the multiplier operates on 16-bits words and the MPU has an eight-bit data bus, additional support ICs are necessary to interface the multiplier to the MPU. U318 acts as a data latch for the low ordered eight bits of the product, while U323 performs a similar function when writing to the highest ordered eight bits of the X or Y registers. Additional decoding is provided by U328, which generates the necessary clock or enable signals for the data latches and hardware multiplier itself.

Typical Calculation Sequence

A typical multiplication sequence is as follows:

1. The high-ordered byte (X15-X8) of the multiplicand is written to the input data latch (U323).
2. The low-ordered byte (X7-X0) is then written to the multiplier. This action automatically latches the complete 16-bit multiplicand into the X register.
3. The process is then repeated for the multiplier, with the 16-bit word latched into the Y register, using the two-step process above.
4. The CLKM and CLKL terminals are then toggled to perform the multiplication process.
5. The product is then read through the product port (P15-P0). During this process, $\overline{\text{OEP}}$ is set low to enable the port.

6.3.4 Input/Output

Much of the interfacing between the MPU and other circuits in the Model 590 is performed by U313, a 6522A VIA (versatile interface adapter). This peripheral IC has two eight-bit bidirectional ports, two 16-bit timers, and includes automatic handshaking capabilities.

The input/output functions performed by U313 include:

1. Control word transmission: The 32-bit control word, which supervises the analog circuits, is sent over opto-isolators U317, U322, and U326 via the CLK, DATA, and STB lines.
2. A/D data input: A/D data, in serial form is transmitted through opto-isolators U325 to U332, which converts the serial data into nibble form, is then read by the VIA through the C0-C3 lines.
3. Analog status information: Status bits, coming from the A/D converter, voltage source, and C modules, are transmitted through U320 and then read by the VIA.
4. External trigger input/output: The VIA reads the status of the external trigger input through its CA2 line, and it controls the external trigger output with the CA1 pin.
5. Display digit select and keyboard read: Control of display digits and keyboard matrix row select is performed through the DATA' and CLK' lines. Keyboard matrix reading is done through S0-S3.
6. Calibration lock switch read: The status of the calibration lock switch is read through the PA2 terminal of the VIA.

6.3.5 IEEE-488 Interface

ICs associated with the IEEE-488 interface include U304, U311, and U313. U304 and U312 are bus drivers needed to supply the drive capability for up to 15 devices. U311 is a 9914A GPIA (general purpose interface adapter), which is designed to perform many bus functions automatically, thus freeing the MPU for more important tasks. For example, the GPIA can perform input/output handshaking automatically.

MPU Interfacing

Terminals on the MPU side of the GPIA include:

Data lines (D7-D0): These lines are connected to the D7-D0 lines of the MPU data bus.

Register select lines (RS2-RS0): The register select lines are connect to the A2-A0 lines of the address bus, and they are used to select among the 14 internal registers (seven read, seven write).

Clock (E): The 2MHz E clock is applied to this terminal.

Read/write (R/$\overline{W}$): The state of this line determines whether a read or write action to a specific GPIA register is to occur.

Interrupt ($\overline{IRQ}$): The $\overline{IRQ}$ line is connected to the 6809 $\overline{FIRQ}$ terminal, allowing fast interrupt processing of IEEE-488 interrupts.

Reset ($\overline{RST}$): This terminal is held low for approximately 690msec upon power up to reset the GPIA.

Chip enable ($\overline{CE}$): The GPIB is enabled for a read or write action by placing $\overline{CE}$ low.

Bus Interfacing

Bus lines are grouped into three general catagories: data, handshake, and bus management. All lines are active low with a true condition represented by approximately 0V.

Data lines: The data lines are DIO8 through DIO1. DIO8 is the most significant bit, and DIO1 is the least significant bit.

Handshake lines: These lines, which include NRFD (Not Ready For Data), NDAC (Not Data Accepted), and DAV (Data Valid) are used to ensure proper transfer of each data byte.

Bus management lines: The following lines are used to send the appropriate uniline commands: REN (Remote Enable), IFC (Interface Clear), SRQ (Service Request), ATN (Attention), and EOI (End or Identify).

6.3.6 Data Segment Latches and Drivers

The Model 590 uses a multiplexed display, meaning that each display digit is actually on for only a brief period of time. This arrangement does minimize the amount of hardware necessary to drive the display, but at the expense of MPU overhead.

As a compromise between hardware and software requirements, data latches are incorporated to store display segment information. U319, U324, U327, and U329 are the latches used to store segment data, while U334-U341 provide the drive capabilities necessary to power the various segments in the display.

6.4 ANALOG CIRCUITRY

The following paragraphs discuss the various analog circuits, including the A/D converter, internal bias source, as well as the circuits necessary to control the converter, voltage source, and the capacitance modules.

Figure 6-4 shows a block diagram of the analog circuits, and a detailed schematic may be found on drawing number 590-106 (two sheets) located at the end of Section 8.

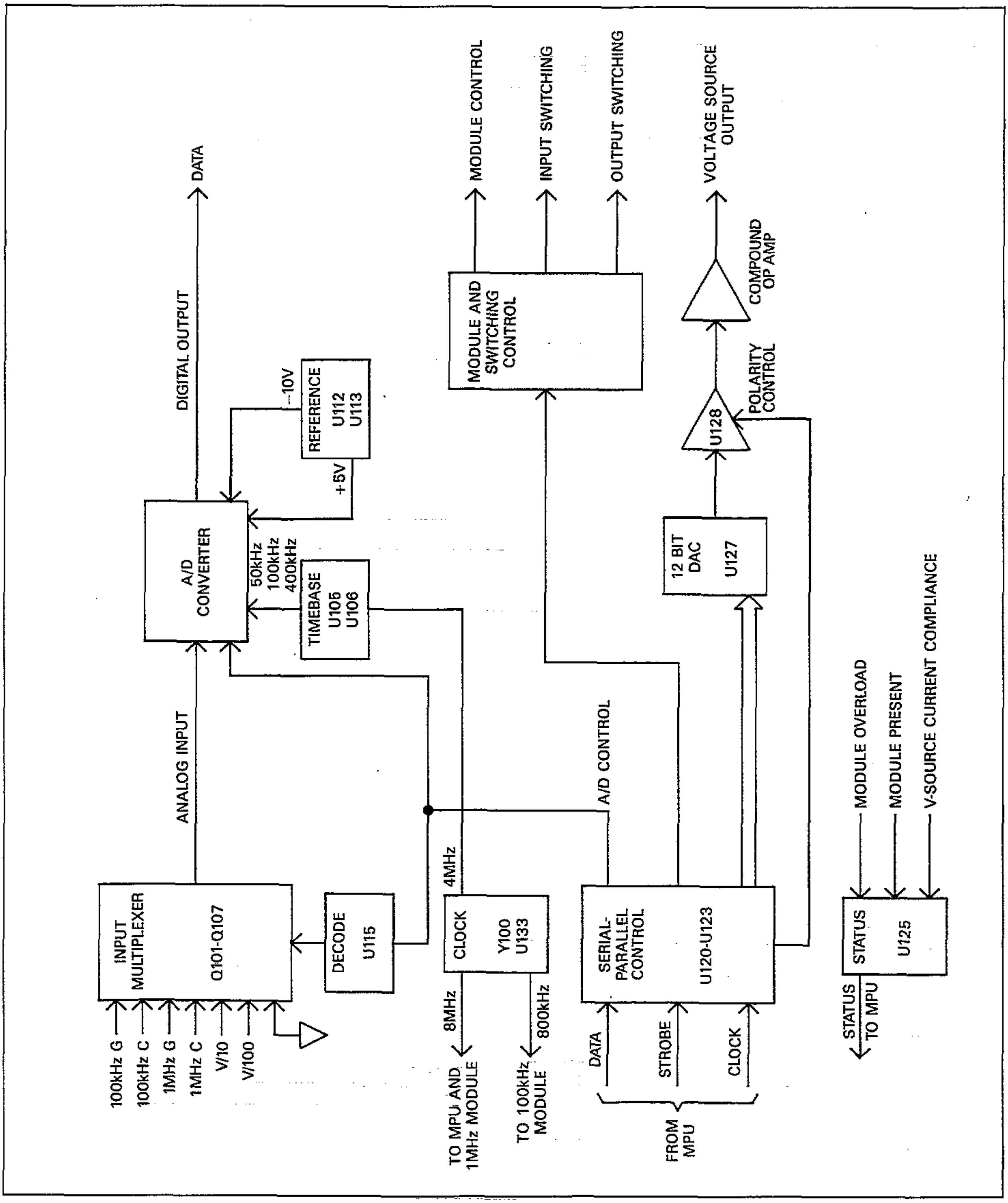


Figure 6-4. Analog Circuitry Block Diagram

6.4.1 Clock Signals

Y100 generates a stable 8MHz clock that is used directly by the 6809 MPU (on the digital board) as well as the 1MHz capacitance module (if present). The 8MHz signal is further divided down by U133 to 4MHz to act as a time base for the A/D converter, and to 800kHz for the 100kHz capacitance module.

6.4.2 Serial Control

A 32-bit control word is shifted into four shift register ICs, U120-U123 via the DATA line. The shift-in process is controlled by the CLOCK signal; after all 32 bits are shifted in (long-shift), the STROBE line is brought low to latch the bits into the outputs of the shift registers.

Control Bit Configuration

A simplified diagram of the shift register control section is shown Figure 6-5. As indicated, the bits control the following functions:

1. A/D converter control (U120, Q1 through Q7): These bits control various aspects of the A/D converter including final slope (Q1), X1/X10 gain (Q2), initialize (Q3), the A/D sync signal (Q4), and input multiplexer switching (Q5 through Q7).
2. Short/long shift selection (U120, Q8): Basically, there are two shift-in modes. A long-shift sequence utilizes all 32 bits, and would be used when the configuration of the modules or voltage source is to be changed. A short-shift sequence, which places only the first eight bits into U120, would be used where only A/D converter configuration must be changed. This arrangement minimizes MPU overhead and speeds up processing.
3. Module and input/output switching control (U121, Q1 through Q8): These bits control various C module or switching functions: Q1, driving point cable correction (ICCT); Q2, 2nF range control; Q3, 200pF range control; Q4, filter on or off; Q5, 20pF reference capacitor select; Q6, 200pF reference capacitor select; Q7, 1MHz C module select; and Q8, cal zero enable.
4. Voltage source control (U122 and U123): Q5 through Q8 of U122 and all eight bits of U123 provide 12-bit voltage programming data for the voltage source. Q4 of U122 selects voltage source polarity, while Q1 and Q2 of U122 select external or internal bias.

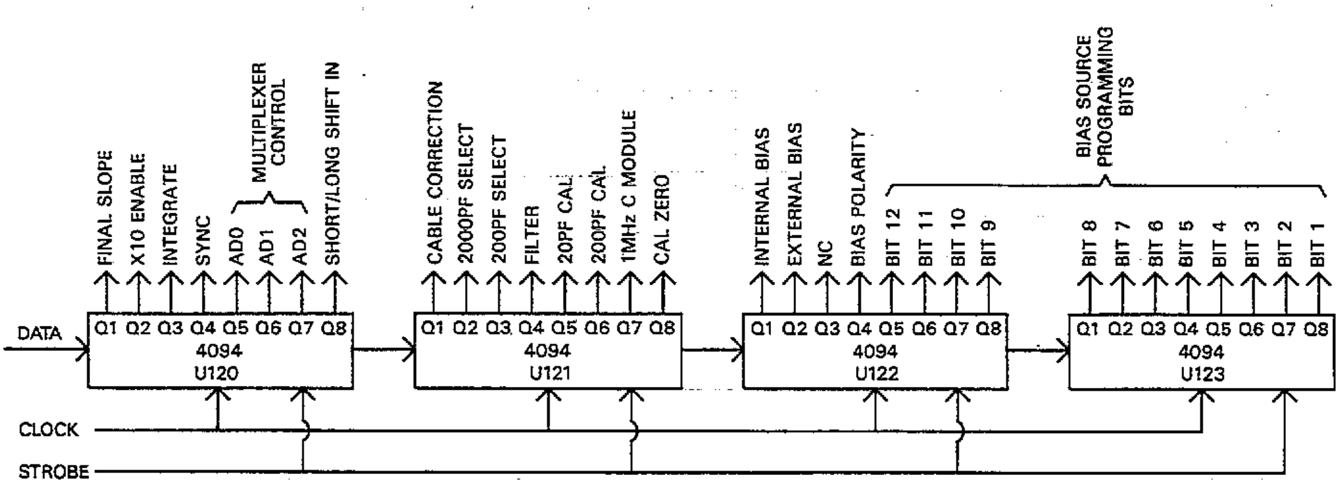


Figure 6-5. Serial Control Bit Format

Relay Drive and Relays

In many cases, the outputs of the shift registers cannot directly drive the circuits they are to control. In those cases, additional drivers and relays are incorporated. For example, elements of U107 and U114 are necessary to drive relays located in the 5901 or 5902 modules. In a similar manner, sections of U112 and U124 drive relays K100 through K108, which are located on the mother board itself. These relays control various functions, as summarized in Table 6-2.

Table 6-2. Relay Functions

Relay	Function	Comments
K100, K103	CAL zero	Disconnect input/ output during calibration
K101, K104	200pF calibration	Connect 200pF reference capacitor to module input
K102, K105	20pF calibration	Connect 20pF reference capacitor to module input
K106, K107	Select 1MHz module	
K108	Select external bias source	

Power-on Safeguard

In order to prevent random circuit operation during the power up cycle, the outputs of the shift registers are tri-stated until they can be loaded with correct control information. U118 and U119 perform the safeguard function for the unit.

U118A and U118B form what is essentially an R-S flip-flop, which is reset upon power-up or power-down by signal derived from a 60Hz signal from the power transformer. With the flip-flop reset, the output enable (OEN) pins of U120-U123 are held low, tri-stating the outputs. When the first STROBE pulse comes along, however, the flip-flop is set, and the shift register outputs are turned on. The control bits will then be applied to the various circuits to perform their assigned control functions.

6.4.3 Status Circuits

In order to keep tabs on the capacitance modules and the voltage source, the MPU must be able to obtain certain information status about these circuits. U125, which is a parallel-to-serial converter, provides this important information to the MPU.

The following status bits are applied to the parallel-to-serial converter:

1. Module present status: P4 and P7 indicate the presence of the 100kHz and 1MHz modules, respectively. This bit is held low by a jumper in the module when that module is present.
2. Module overload status: P5 and P6 indicate a module overload condition for the 1MHz and 100kHz modules respectively.
3. Voltage source current compliance: The voltage source status bit is applied to P8. This signal is generated by sections of U126, and is intended to flag an overcurrent condition in the voltage source.

To read the status, U125 is strobed to latch status information bits into that IC. The status information is then shifted serially out the Q8 line to the MPU using the same clock signal that sequences the control word shift registers.

6.4.4 Input Multiplexer

An input multiplexer is used to select among eight different signals that can be applied to the A/D converter during the measurement cycle. Key aspects of the multiplexer include the control section and switching FETs, as discussed below.

Multiplexer Control

Multiplexer control signals are derived by decoding the AD2-AD0 bits from the serial control section. This function is performed by U115, which is a one-of-eight decoder. The TTL logic levels are converted to appropriate signals by sections of U116 and U117 in order to drive the multiplexer FETs.

The signal routed through the multiplexer depends on the the logic levels applied to the A2-A0 lines. Table 6-3 summarizes signals applied for each combination of logic levels.

Table 6-3. Multiplexer Control Signals

AD2	AD1	AD0	Control	FET On
0	0	0	100kHz Conductance	Q105
0	0	1	100kHz Capacitance	Q106
0	1	0	1MHz Conductance	Q102
0	1	1	1MHz Capacitance	Q103
1	0	0	Analog common	Q104
1	0	1	V/10	Q100
1	1	0	V/100	Q101
1	1	1	1V Reference	Q107

Multiplexer Operation

A simplified schematic of the input multiplexer is shown in Figure 6-6. Each FET is essentially an analog switch that is controlled by the logic levels discussed above. Signals controlled by the multiplexer FETs include:

1. 100kHz module signals: Q105 and Q106 control 100kHz conductance and capacitance, respectively.
2. 1MHz module signals: Q102 and Q103 switch 1MHz conductance and capacitance signals.
3. Zero reference: The zero reference signal is controlled by Q104.
4. Bias voltage signals: The V/10 and V/100 signals are controlled by Q100 and Q101.
5. Reference voltage: Q107 switches the 1V reference.

Meausurement Phases

Figure 6-7 shows the measurement phases for a typical measurement cycle. During each phase, the appropriate FET is turned on in order to apply that particular signal to the A/D converter. Note that the zero reference (analog common) phase is performed twice, once with X1 gain on the A/D input amplifier, and the second time with X10 gain on that amplifier.

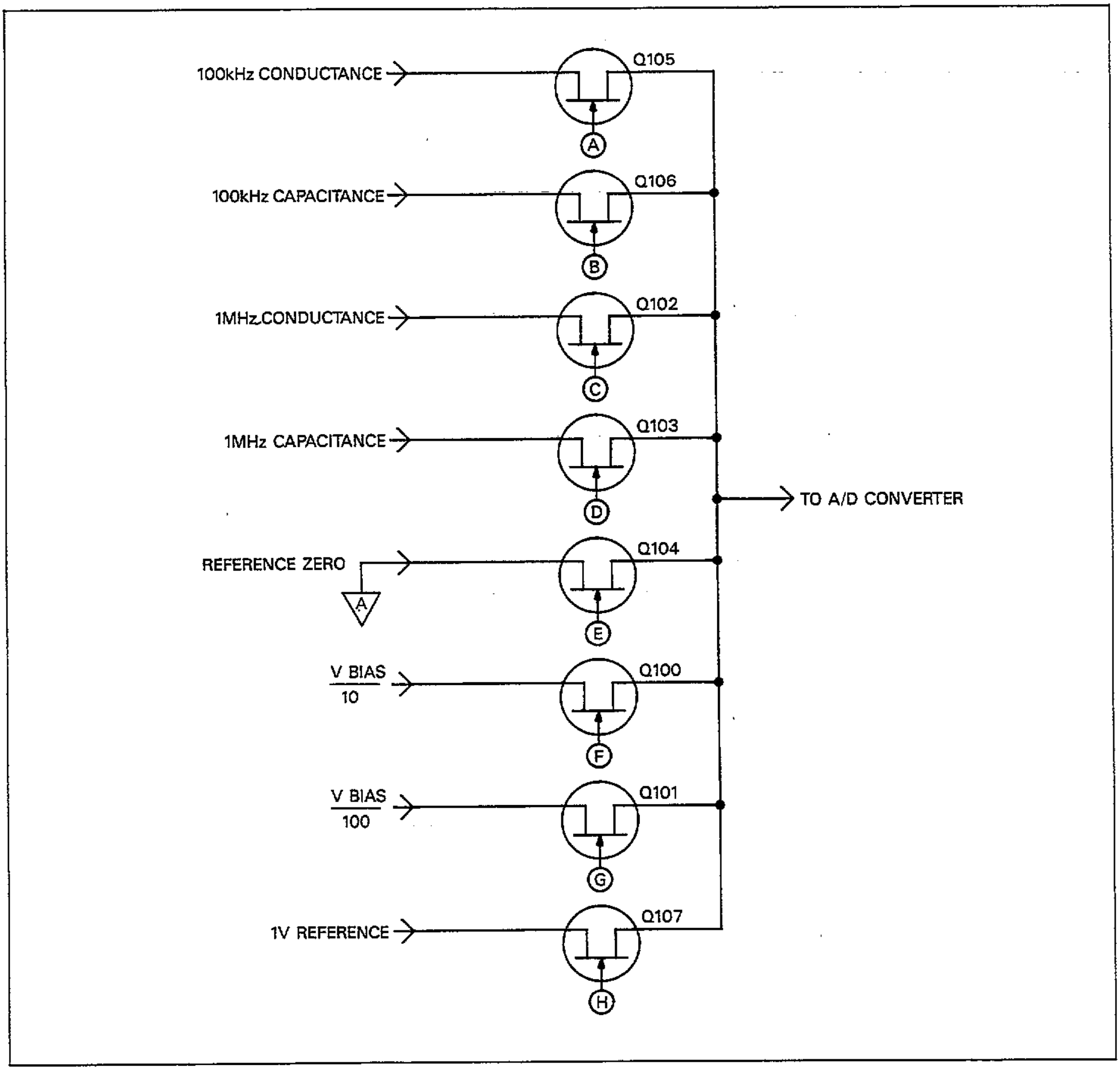


Figure 6-6. Simplified Schematic of Input Multiplexer

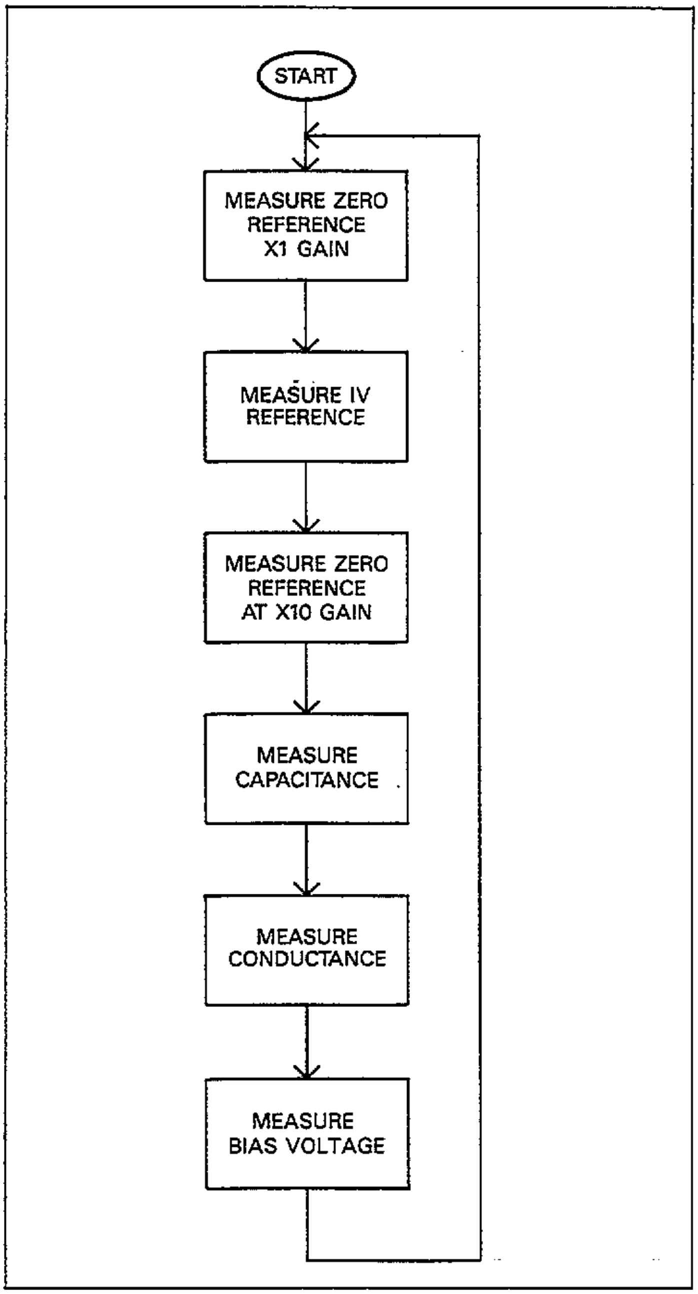


Figure 6-7. Measurement Phase

6.4.5 A/D Converter

Instrument capacitance, conductance, and bias voltage information must be converted into digital form before it can be used and processed by the microcomputer. The following paragraphs described the basic operation of the converter and its associcated circuits. A simplified schematic diagram of A/D converter circuits is shown in Figure 6-8.

Time Base Circuits

Various elements of the converter must be carefully synchronized-- a job performed by the converter time base circuits. U105 and U106 are counter ICs which divide down the 4MHz signal generated by the clock circuits to 50kHz, 100kHz, and 400kHz clock signals. One additional signal provided by the time base circuits is the SYNC signal, which is used to control integrator discharge.

Reference Voltages

Two separate reference voltages of −10 and +5V are used by the A/D converter. The basic voltage reference for both supplies is VR100, a nominal 6.33V zener diode. The reference voltage is inverted by U112 and buffered by U113A to provide the −10V reference source.

The nominal 6.33V zener reference voltage is divided down to 5V and 1V by a voltage divider made up of R122, R123, and R124. The 5V supply is further buffered by U113B and Q110, while the 1V reference is fed to the multiplexer to be read as part of the measurement cycle.

X1/X10 Gain Amplifier

The X1/X10 gain amplifier (U100A) is an operational amplifier configured with a switchable feedback network. U101C, which is an analog switch, controls the gain switching by either connecting the U100A output to its inverting input (X1 gain) or selecting the feedback network made up of R100 and R106 (X10 gain).

The gain of this amplifier is set to X10 when the instrument is measuring capacitance or conductance on the 2pF/2μS range, and during the X10 reference portion of the measurement phase (see Figure 6-7). At all other times, amplifier gain is X1.

In addition to controlling gain, the amplifier also acts as a buffer between the multiplexer and the A/D converter.

A/D Converter Operation

The Model 590 uses a combination frequency, variable pulse width analog converter for good resolution and fast conversion times. The discussion below covers integrator discharge, conversion phases, and the integrator itself.

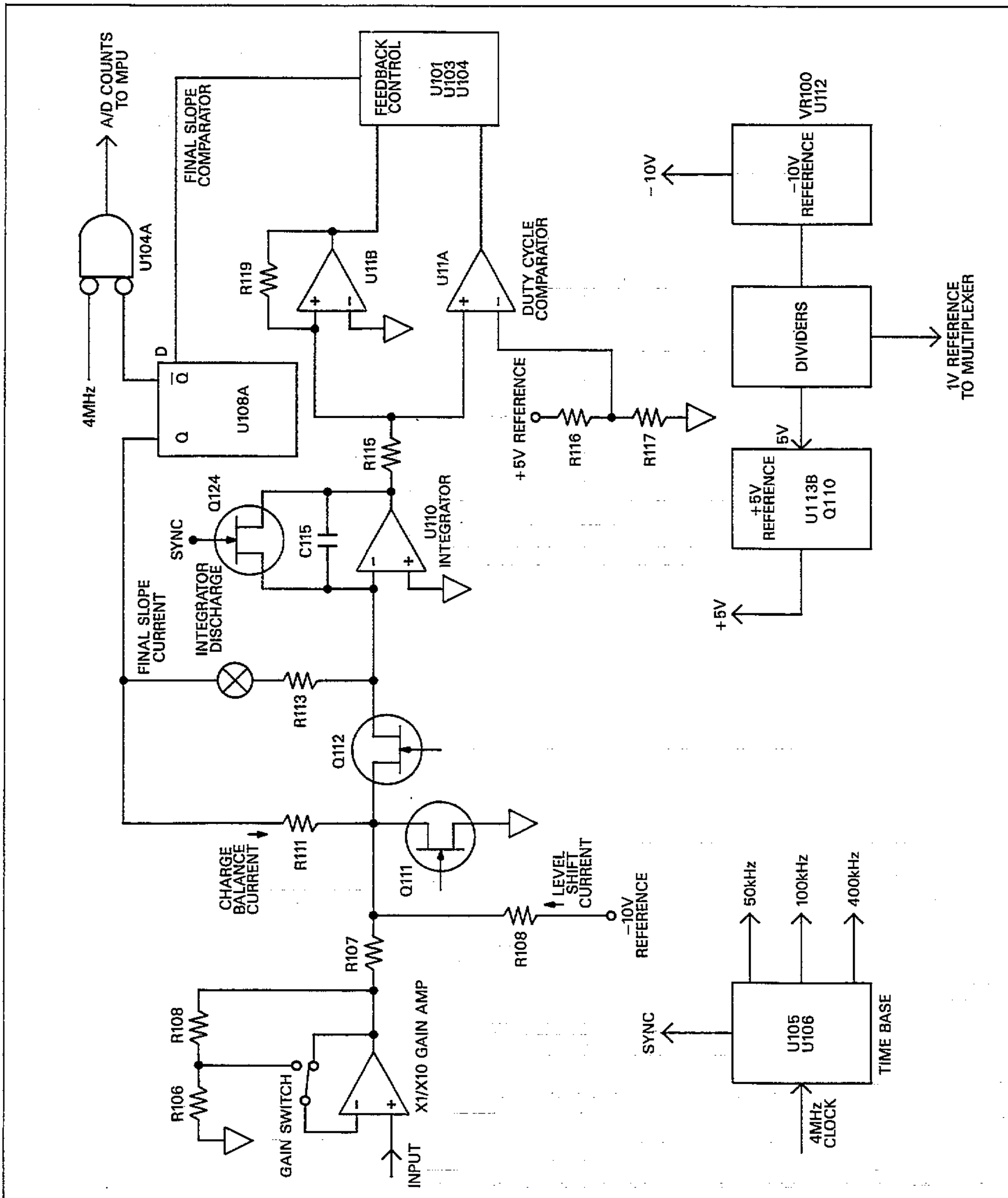


Figure 6-8. Simplified Schematic of A/D Converter

Before integration is begun, the SYNC signal is applied to the gate of Q124, which turns that device on to discharge the integrator capacitor, C115. This step is necessary to minimize integrator offset that could affect measurement accuracy.

The converter has two basic phases of operation, charge balance and final slope. The charge balance phase begins when the input enable/disable line is set high. This action occurs at the end of a software-generated delay period that allows the the signal to settle after the appropriate multiplexer FET is turned on. Once the input is enabled, the signal from the X1/X10 amplifier is added to the level shift current applied through R108. In this manner, the nominal ±2V bipolar signal from the X1/X10 amplifier is converted into a unipolar signal that can be integrated.

The integrator itself is made up U110 and C115. When the input to the integrator is applied, the integrator output ramps up until its voltage is slightly more positive than the reference voltage applied to the inverting input of the duty cycle comparator (U111A). The charge balance current, which is proportional to the input, is fed back to the integrator input through R111 and Q112. Since the charge balance current is much larger than the sum of the input and level shift currents, the integrator output now ramps in the negative direction until the Q output of U108A goes low. During this phase, the MPU counts the total number of pulses that occur.

At the end of the charge balance phase, the integrator output is resting at some positive voltage. Since the integrator output is connected to the non-inverting input of the final-slope comparator (U111B), the final-slope comparator output remains high until the integrator output ramps in the negative direction. During the final-slope phase, Q112 is turned off, and the feedback current is now fed through R113 to the integrator input. The final-slope comparator output is then gated with the 4MHz clock by U104A, and the number of cycles of the 4MHz clock that occur are then counted. Once the comparator output goes low, no further clock pulses are counted, and the measurement can then be computed by the MPU.

6.4.6 Voltage Source

A simplified schematic diagram of the internal bias voltage source is shown in Figure 6-9. Major sections of the source include the D/A converter, polarity switching, gain and output amplifier, and current compliance detection circuits.

Digital-to-Analog Converter

12-bit programming information is applied to the digital inputs of U127, as 12-bit DAC (digital-to-analog converter). The nominal output range of the DAC is in the range of 0 to 10V, with a 0 count input (all 0s) resulting in a 10V output, and a 4095 count input (all 1s) giving a 0V output. Actually, the maximum count input is limited to 4000 counts in order to achieve a minimum resolution value of 5mV. Thus the actual maximum output voltage will be 9.768V.

Gain and offset for the DAC IC are set with R156 and R157.

Polarity Switching

Since the DAC output is unipolar, and the voltage source output must be bipolar, some form of polarity switching must be incorporated to allow positive and negative outputs. U128 and associated components perform the polarity switching function for the voltage source.

U128 is an operational amplifier configured for unity gain by feed back elements R149, R150, and R151. U131, an analog switch IC performs polarity switching by routing the DAC output to either the inverting or non-inverting input of U128. The POLARITY control signal is generated by the Q4 output of U122 as part of the serial control information. If the output of the voltage source is to be positive, U128 is operated as an inverting amplifier (since the output stage also inverts the signal). Conversely, U128 is operated as a non-inverting amplifier if the voltage source output is to be negative.

Output Stage

The output stage provides the necessary gain and drive for the voltage source, and is actually a compound operational amplifier. U130 provides the gain while a complementary output stage made up of transistors Q116-Q119 provide the voltage and current output capabilities. The feedback network made up of R161 and R162 sets the gain of the stage. Since the output stage is essentially a compound operational amplifier, the gain of the stage is:

$A = -R162/161$

$A = -20k/9.76k$

$A = -2.049$

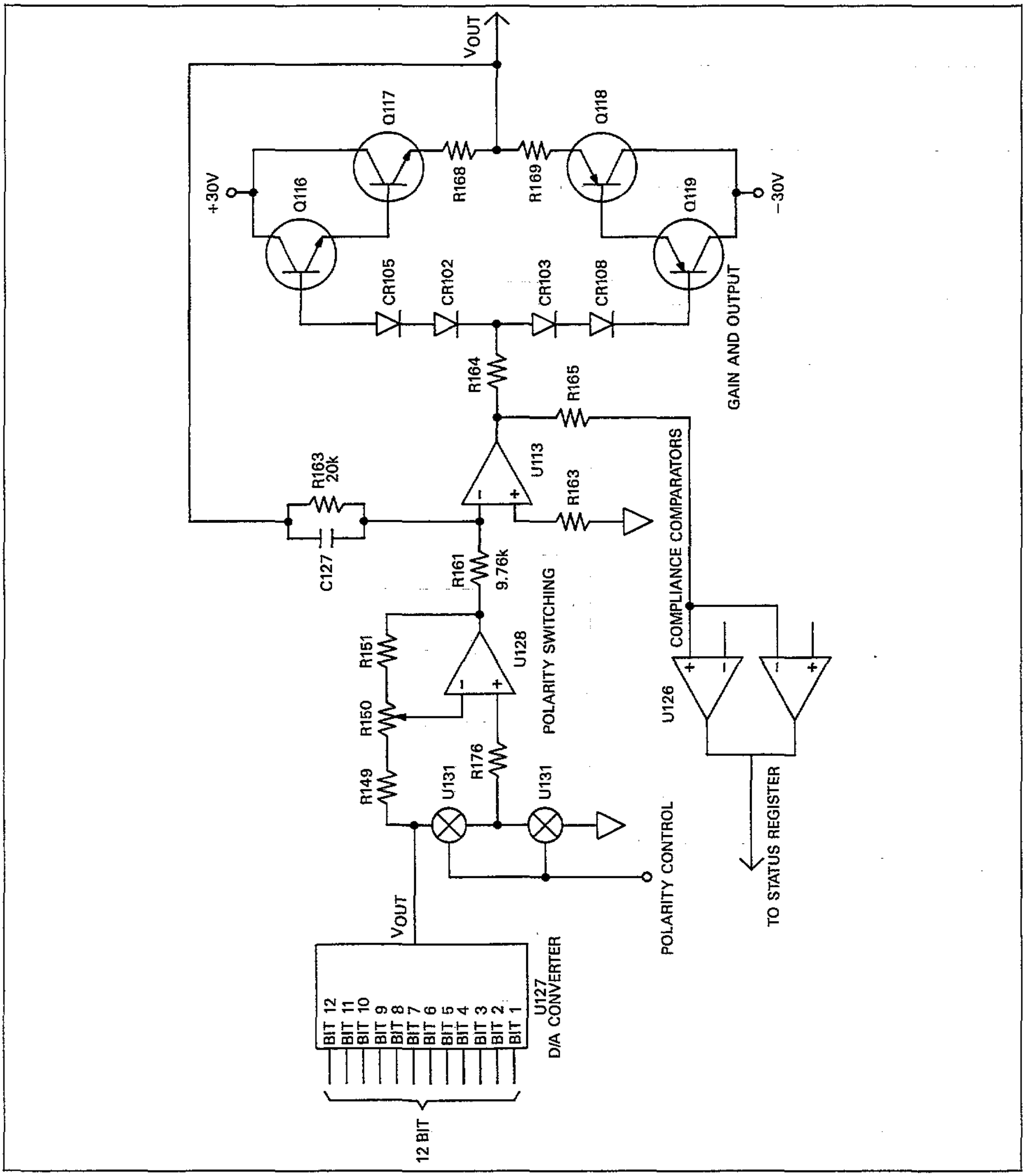


Figure 6-9. Simplified Schematic of Voltage Source

This seemingly strange gain factor is used to compensate for the fact that only 4000 of the possible 4095 input counts are used with the DAC. Since the maximum DAC output is 9.768V, the maximum voltage source output is:

$$V = (9.768)(20.49)$$
$$V = 20V$$

The resolution of the voltage source is simply 20/4000 = 5mV.

Compliance Detection

A compliance bit in the status information tells the MPU if the voltage source has exceeded its current limit. That compliance information is generated by a detection circuit made up of elements of U126.

U126A and U126B are window comparators that monitor the output of U130 for excessive deviations in output voltage–a condition that would flag excessive current. Two comparators are required, one each for positive and negative outputs. Normally, the output of U130 is approximately the same as the output voltage. However, if an over current condition occurs, Q123 or Q122 will turn on (depending on output polarity), causing the output voltage of U130 to increase in amplitude. The over-voltage condition is then detected by the comparators.

The compliance signal is inverted by U126C and then buffered by U126D before being applied to the status parallel-to-serial converter, U125. C130 provides a time delay of approximately 1msec to prevent premature compliance detection with capacitive loads.

6.5 100kHz CAPACITANCE MODULE

A block diagram of the 100kHz (5901) capacitance module is shown in Figure 6-10. Refer to drawing number 5901-106, located at the end of Section 8, for a schematic diagram of the module.

6.5.1 Circuit Overview

The key sections of the module, which are shown in the block diagram of Figure 6-10, include:

1. Waveform synthesizer: This section generates the 10μsec reference waveform which ultimately becomes the test signal, as well as the timing waveforms for the synchronous detector.
2. Output amplifier: The output amplifier provides gain, bandwidth limiting via a tuned circuit, and also shapes the test signal into a low-distortion sine wave.
3. AGC: The automatic gain control circuits keep the amplitude of the test signal at a constant level.
4. Output coupling: A transformer couples the test signal to the output and also provides a 23.5:1 step-down ratio, which reduces the test signal amplitude to a nominal 15mV RMS. Also, the DC bias voltage is applied at this point.
5. Trans-impedance amplifier: The primary purpose of this amplifier is to convert the test signal from the device under test from a current to a voltage. Range switching is also included in this amplifier.
6. Tuned amplifier: Provides X4 gain for the input signal and some bandwidth limiting.
7. Gain amplifiers: These amplifiers provide X36 gain to provide sufficient drive for the detector circuits.
8. Synchronous detector: Multiplies the incoming signal by the quadrature reference signals from the waveform synthesizer.
9. Buffers: The buffers isolate the detector from the A/D converter and from devices connected to the analog outputs.

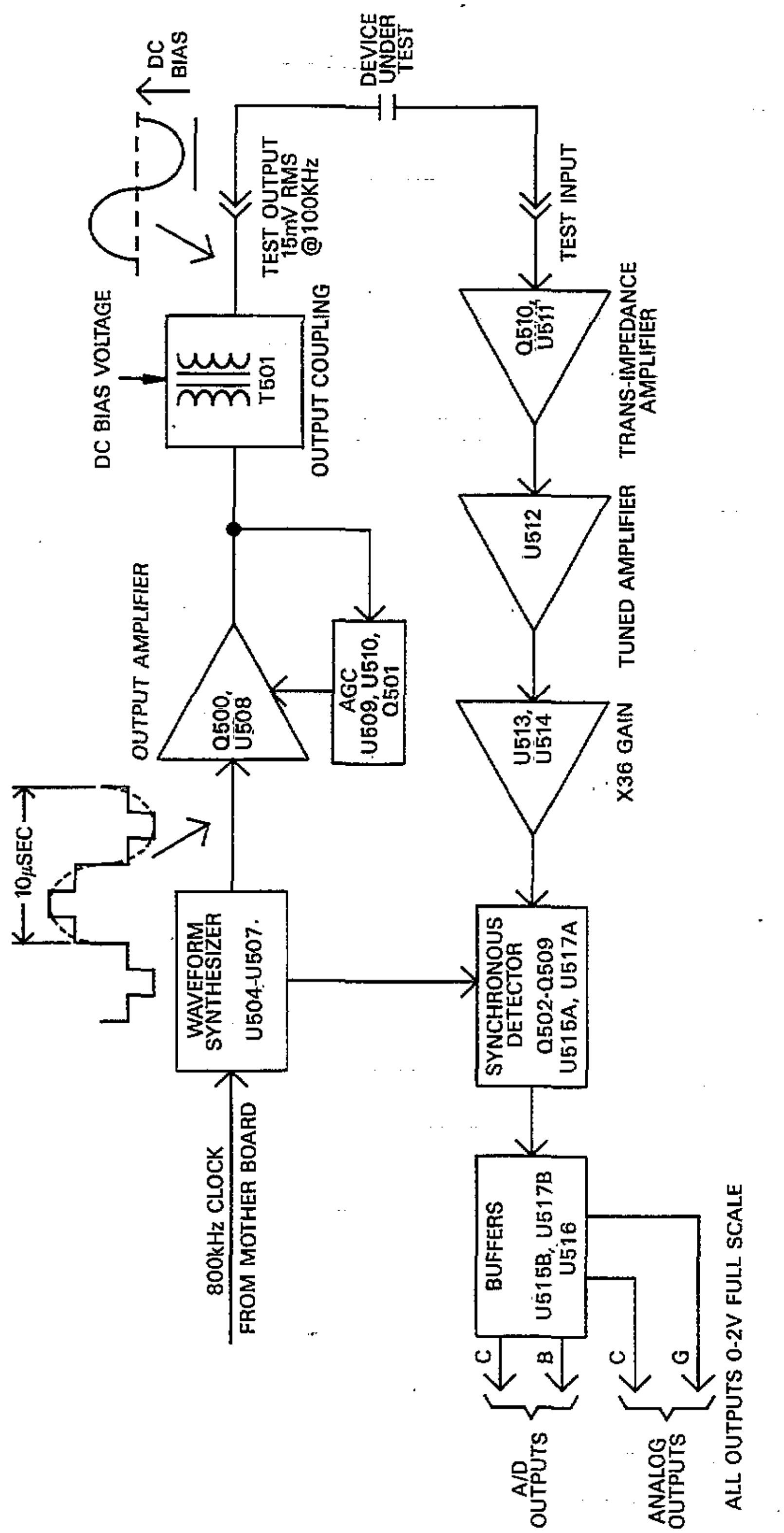


Figure 6-10. Block Diagram of 100kHz Capacitance Module

6.5.2 Waveform Synthesizer

The waveform synthesizer is made up of U502, U504, U505, and U507. The 800kHz clock signal from the mother board is applied through buffer U502C to the clock input of U504A, which is first in a chain of four D-type flip-flops. These flip-flops make up a four-stage counter with feedback necessary to generate the waveform. The flip-flop outputs are gated by elements of U507 and summed at the junction of R504, R505, and R564 in order to synthesize the waveform.

Additional signals produced by the synthesizer include the A, B, C, and D waveforms for the synchronous detector. These signals are first buffered and inverted by elements of U506 before being applied to the detector.

6.5.3 Output Amplifier

The synthesized waveform is applied to the base of Q500, which is a gain-controlled, tuned amplifier. Gain of this stage is controlled by varying the emitter resistance with opto-coupling, as discussed below. The collector circuit of Q500 is tuned to approximately 100kHz by C502 and T500. This tuned amplifier configuration increases the gain and restricts the bandwidth, such that the output signal is essentially a 100kHz sine wave.

From the tuned amplifier, the reference signal is coupled through the 10:1 step-down transformer, T500, which also provides a coarse phase adjustment for the 20pF range. Fine phase adjustment for the 20pF range is performed by R513.

From the transformer, the signal is applied to the non-inverting input of operational amplifier, U508, which acts as a buffer. The gain of this amplifier is set to unity by connecting the output directly to the inverting input.

The amplitude of the signal at this point is approximately 1V p-p. The amplified signal is then coupled from the output of U508, through C507 to the primary of transformer T501, which provides a 23.5:1 step-down ratio. The signal has now been attenuated down to its final 15mV RMS value, and it is then applied to the test OUTPUT jack.

The DC bias voltage (external or internal) is also applied at this point in the circuit. The high side of the bias voltage is applied through R570 at the junction of C508, C567 and R569. The low side is connected directly to the low terminal of the test OUTPUT jack.

6.5.4 Automatic Gain Control

In order to assure accurate measurements, the amplitude of the test signal must be kept constant-- a function performed by the automatic gain control circuits. Key components in the AGC circuits include U509, CR500, CR501, U510, Q501, and AT500.

The test signal is coupled from the output of U508 to the DC rectifier made up of U509, CR500, and CR501, which forms a DC error voltage. Filtering for the rectifier is performed by C510.

At this point, the DC signal, which is directly proportional to the 100kHz test signal amplitude, is applied to the inverting input of U510, which is a combination comparator/integrator. The reference voltage for the comparator is provided by VR500, and the integrator time constant is set by the values of C514 and R517.

The output of the integrator/comparator is used to drive Q501, which controls the current through AT500. The signal is then optically coupled to the resistive element of AT500, which controls the gain of Q500 by controlling the total resistance in the emitter circuit.

To briefly discuss how the AGC circuit controls gain, let us assume that the test signal amplitude begins to rise slightly. This increase in amplitude will be reflected at the output of U508 and coupled to the DC rectifier. Thus, the output of the rectifier will go more positive with the increase in signal amplitude, resulting in a decrease in the output voltage of U510. The reduced output will decrease the current through the emitter circuit of Q501, which also decreases the current through the LED located in AT500. With the decrease in current, the LED light output will decrease, causing an increased Q500 emitter resistance. This increased resistance will decrease the gain of Q500 slightly to compensate for the increased amplitude.

6.5.5 Input Amplifiers

Key elements of the input amplifiers include the transimpedance, tuned stage, and X36 amplifiers, as discussed in the following paragraphs.

Trans-impedance Amplifier

The input signal, which is a phase and magnitude varying current, is applied through the test INPUT jack to the input of the trans-impedance amplifier, Q510 and U511. At the input of this amplifier CR507 and CR508 are used for spike suppression, while C526 provides input coupling. The DC bias component is eliminated by L500, while L500 and C525 resonate at 100kHz to provide maximum sensitivity.

The purpose of the trans-impedance amplifier, which includes Q510 and U511, is to convert the input signal current into a voltage that can be further amplified and ultimately used by the synchronous detector. Q510 forms a differential amplifier that is used to improve noise performance of the 20pF range only, and is switched by contacts on K503. The approximate gain of this stage is X6.

Gain control of the input stage is performed by switching various feedback elements in or out of the circuit. K501 controls the 2nF range, and K500 switches in the necessary elements for the 200pF range. Various adjustable elements allow control of gain or phase. For example, R521 controls 200pF range gain, while C529 adjusts 200pF phase.

Note that the nominal output of the trans-impedance amplifier is approximately 15mV RMS with a full scale capacitance applied.

Tuned Stage Amplifier

U512 and associated components form the tune stage amplifier. Tuning is done by the parallel resonant circuit made up of C539 and L501, located in the feedback network of U512. The circuit is tuned to the 100kHz frequency of interest, and the Q of the circuit is approximately 3, giving the amplifier somewhat broad band characteristics for a tuned amplifier.

The maximum gain of the tuned amplifier is approximately 4.12, as set by the relative values of R531 and R530.

X36 Amplifier

One final degree of input signal amplification is performed by two identical amplifier stages, U513 and U514. Each stage has a voltage gain of 6, as determined by the feedback networks: R532 and R533 set the gain of U513, and R534 and R535 control the gain of U514.

From the output of the amplifier at pin 6 of U514, the signal is coupled through transformed T502 to the synchronous detector.

6.5.6 Synchronous Detector

The synchronous detector circuits are designed to extract magnitude and phase information from the input signal and provide voltage outputs that are analogous to the capacitance and conductance being measured. Basically, there are two virtually identical sections to the synchronous detector: Q502, Q503, Q506, Q507, and U515A form the detector for capacitance information, while Q504, Q505, Q508, Q509, and U517A detect the conductance signal.

Basically, each group of FETs acts as an RF mixer with two input signals: the local oscillator, and the measured signal itself. The local oscillator signals are supplied by the waveform synthesizer; the A and B signals control Q502, Q503, Q506, and Q507, and the C and D signals, which are 90 degrees out of phase with A and B, switch Q504, Q505, Q508, and Q509. The output of each detector is buffered by an operational amplifier (U515A, capacitance; U517A, conductance), and filtering is incorporated into the feedback networks in order to limit bandwidth to about 720Hz. U517A has an adjustable feedback element (R547) that allows the gain of the conductance detector output to be set controlled. R545 and R546 provide offset adjustment for capacitance and gain circuits, respectively.

After filtering and buffering, the full scale output is a nominal 2V. Thus the nominal output with zero scale input will be 0V.

6.5.7 Buffers

In order minimize detector loading, additional buffering is used. U515B and U517B buffer the capacitance and conductance signals respectively, while still more buffering (U516A and U516B) is provided for the two analog outputs. R549 and R550 protect the buffer amplifiers should the analog outputs become shorted. Over voltage protection for the analog outputs is provided by CR509.

Low-pass analog filtering is controlled by K502, which switches filter capacitors C557 and C556. Filter roll-off point is determined by the relative values of C557 and R544 (capacitance), and C556 and R548 (conductance). The nominal −3dB point is 37Hz.

6.6 1MHz CAPACITANCE MODULE

A block diagram of the 1MHz (5902) capacitance module is shown in Figure 6-11. Refer to drawing number 5902-106, located at the end of Section 8, for a schematic diagram of the module.

6.6.1 Circuit Overview

The key sections of the module, which are shown in the block diagram of Figure 6-11, include:

1. Waveform synthesizer: This section generates the 1μsec reference waveform which ultimately becomes the test signal, as well as the timing waveforms for the synchronous detector.
2. Output amplifier: The output amplifier provides gain, bandwidth limiting via a tuned circuit, and also shapes the test signal into a low-distortion sine wave.
3. AGC: The automatic gain control circuits keep the amplitude of the test signal at a constant level.
4. Output coupling and attenuation: A transformer couples the test signal to the output and also provides a step-down ratio, which, combined with the attenuator, reduces the test signal amplitude to a nominal 15mV RMS. Also,the DC bias voltage is applied at this point.
5. Trans-impedance amplifier: The purpose of this amplifier is to convert the test signal from the device under test from a current to a voltage. Some range switching is also included in this amplifier.
6. Differential amplifier: Provides gain for the input signal and some range switching. The differential configuration is used to minimize crosstalk from other circuits.
7. Synchronous detector: Demodulates the phase and amplitude of the input signal.
8. Buffers: The buffers isolate the detector from the A/D converter and from devices connected to the analog outputs.

6.6.2 Waveform Synthesizer

The waveform synthesizer is made up of U602, U603, U604, and U605. The 8MHz clock signal from the mother board is applied through buffers U602C and and U602D to the clock input of U603A, which is first in a chain of four D-type flip-flops. These flip-flops make up a four-stage counter with feedback necessary to generate the waveform.

The flip-flop outputs are gated by elements of U605 and summed at the junction of R606, R608, and R609 in order to synthesize the waveform.

Additional signals produced by the synthesizer include the A, B, C, and D waveforms for the synchronous detector. These signals are first buffered and inverted by elements of U601 before being applied to the detector.

6.6.3 Output Amplifier

The synthesized waveform is applied to the base of Q601, which is a gain-controlled, tuned amplifier. Gain of this stage is controlled by varying the emitter resistance with opto-coupling, as discussed below. The collector circuit of Q601 is tuned to approximately 1MHz by L601 and C601. This tuned amplifier configuration restricts the bandwidth, such that the output signal is essentially a 1MHz sine wave.

From the tuned amplifier, the reference signal is applied to the base of Q602, which is used to shift the phase of the signal by 90 degrees. R681 and R619 provide phase adjustment for the 20pF and 2nF ranges respectively (other phase adjustments are incorporated into the input stages, as discussed in paragraphs below). These adjustments are selected by contacts on K607, depending on selected range.

From the phase-shift amplifier, the signal is applied to the non-inverting input of operational amplifier, U606. The gain of this amplifier is set to approximately +5 by resistors R622 and R621. The amplitude of the signal at this point is approximately 4.5V p-p.

The amplified signal is then coupled from the output of U606, through C604 to the primary of transformer T601, which provides a 23.5:1 step-down ratio. The signal is further attenuated down to its final 15mV RMS value by a voltage divider made up of R624, R625, and R626. In addition to attenuation, this divider network also results in a very low output impedance.

The DC bias voltage (external or internal) is also applied at this point in the circuit. The high side of the bias voltage is applied through R623 at the junction of C607, C608 and R626. The low side is connected directly to the low terminal of the test OUTPUT jack.

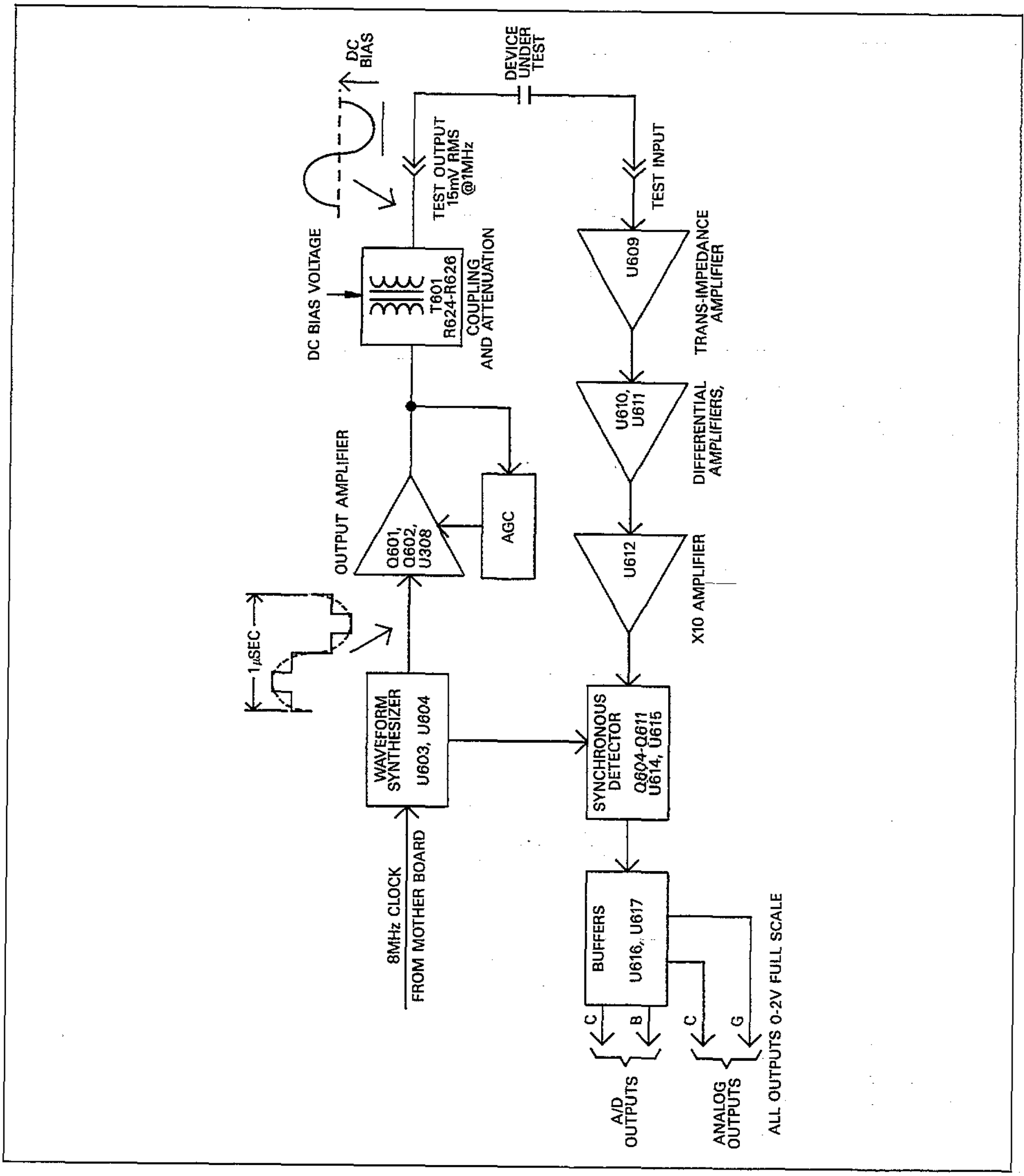


Figure 6-11. Block Diagram of 1MHz Capacitance Module

6.6.4 Automatic Gain Control

In order to assure accurate measurements, the amplitude of the test signal must be kept constant-- a function performed by the automatic gain control circuits. Key components in the AGC circuits include U607, CR602, CR601, U600, Q603, and AT601.

The test signal is coupled from the output of U606 to the inverting input of operational amplifier U607. The purpose of this amplifier is to provide gain, which is slightly less than −2, with the gain determined by R633, R634, and R629. Note that R634 provides some adjustment in the gain of the circuit.

From U607, the signal is coupled through T602 to CR602, which rectifies the signal to form a DC error voltage. RF bypassing for the rectifier is performed by C619.

At this point, the DC signal, which is directly proportional to the 1MHz test signal amplitude, is applied to the inverting input of U600, which is a combination comparator/integrator. The reference voltage for the comparator is provided by VR601, and the integrator time constant is set by the values of C611 and R631.

The output of the integrator/comparator is used to drive Q603, which controls the current through AT601. The signal is then optically coupled to the resistive element of AT601, which controls the gain of Q601 by controlling the total resistance in the emitter circuit.

To briefly discuss how the AGC circuit controls gain, let us assume that the test signal amplitude begins to rise slightly. This increase in amplitude will be reflected at the output of U607 and coupled through T602. Thus, the output of CR602 will go more positive with the increase in signal amplitude, resulting in a decrease in the output voltage of U600. The reduced output will decrease the current through the emitter circuit of Q603, which also decreases the current through the LED located in AT601. With the decrease in current, the LED light output will decrease, causing an increased Q601 emitter resistance. This increased resistance will decrease the gain of Q601 slightly to compensate for the increased amplitude.

6.6.5 Input Amplifiers

Key elements of the input amplifiers include the trans-impedance, differential, and X10 amplifiers, as discussed in the following paragraphs.

Trans-impedance Amplifier

The input signal, which is a phase and magnitude varying current, is applied through the test INPUT jack to the input of the trans-impedance amplifier, U609. At the input of this amplifier CR605 and CR606 are used for spike suppression, while C667 provides input coupling and blocks any DC bias component.

The purpose of the trans-impedance amplifier is to convert the input signal current into a voltage that can be further amplified and ultimately used by the synchronous detector. Because of the high (1MHz) frequency involved, a special 600MHz operational amplifier is used. Because of the wide bandwidth, however, special compensation is required in the feed back circuit for stabilization. Key components here include: R674, R676, R677, R678, C668, R682, C669, and C670. The purpose of these feedback networks is to maintain approximately unity gain at 1MHz while increasing the gain to X10 at higher frequencies in order to maintain stability. Feedback network switching is done by K602 and depends on the range.

Note that the nominal full scale output of the trans-impedance amplifier is approximately 10mV RMS.

Differential Amplifiers

Two differential amplifiers, U610 and U611, are used to provide additional voltage gain. Note that only U610 is used for the 2nF range, while U611 is added to increase gain for the 20pF and 200pF ranges. The differential configuration is used to minimize crosstalk and noise pick up from other circuits.

The amplified voltage signal is coupled through T605 to the input of U610, which is operated in the differential configuration. The input of this amplifier is tuned to approximately 1MHz by C664 and L617. The Q of this circuit is about 3, which is low enough to prevent excessive temperature drift, but high enough to remove interfering signals that may overload succeeding stages. Gain of U610 is set to approximately 15 by U669 and R670, with some adjustment provided by R669.

A second differential amplifier, U611, is used only for the 20pF and 200pF ranges. Amplifier gain is set nominally to X10 by R663 and R664, with adjustment provided by R663. The input is tuned by L613 and C661 (Q=1), which are used to adjust the phase shift of U611 to zero. Gain switching is provided by K601 and K603, which select either the output of U610 or U611 depending on the range.

X10 Amplifier

One final stage of input signal amplification is performed by U612, another 600MHz bandwidth operational amplifier. The gain of this stage is fixed at X10 by the relative values of R659 and R662. The amplifier output is coupled through C642 to the primary to T603, which coupled the signal to the synchronous detector.

6.6.6 Synchronous Detector

The synchronous detector circuits are designed to extract phase and amplitude information from the input signal and provide voltage outputs that are analogous to the capacitance and conductance being measured. Basically, there are two virtually identical sections to the synchronous detector: Q604 through Q607 and U614 form the detector for capacitance information, while Q608-Q611 and U615 detect the conductance signal.

Basically, each group of FETs acts as an RF mixer with two input signals: the local oscillator, and the measured signal itself. The output of each RF mixer is a function of both the phase and magnitude of the measured signal. The local oscillator signals are supplied by the waveform synthesizer; the A and B signals control Q604-Q607, and the C and D signals, which are 90 degrees out of phase with A and B, switch Q608-Q611. The output of each detector is buffered by an operational amplifier (U614, capacitance; U615, conductance), and filtering is incorporated into the feedback networks in order to limit bandwidth to less than 1kHz. U615 has an adjustable feedback element (R651) that allows the gain of the conductance detector output to be set controlled. R646 and R648 provide offset adjustment for capacitance and gain circuits, respectively.

The detector outputs for full scale inputs are pulsating DC. After filtering and buffering, the full scale output is a nominal 2V. Conversely, the detector waveform for zero scale inputs will be symmetrical, with an average value of zero. Thus the nominal output with zero scale input will be 0V.

6.6.7 Buffers

In order minimize detector loading, additional buffering is used. U617A and U617B buffer the capacitance and conductance signals respectively, while still more buffering (U616A and U616B) is provided for the two analog outputs. R642 and R643 protect the buffer amplifiers should the analog outputs become shorted. Over voltage protection for the analog outputs is provided by CR603.

Low-pass analog filtering is controlled by K606, which switches filter capacitors C631 and C696. Filter roll-off point is determined by the relative values of C631 and R644 (capacitance), and C696 and R650 (conductance). The nominal −3dB point is 37Hz.

6.7 POWER SUPPLIES

A block diagram of the power supplies is shown in Figure 6-12, and the power supply schematic may be found on drawing number 590-126, sheet 1, located at the end of Section 8.

6.7.1 AC Line Input

AC power is applied to the line filter (J1010), through fuse F300 and the power switch S300 to the primary of the power transformer, T300. Note that both sides of the line input are switched by S300.

Power line voltage is selected by line voltage selection switch (S302) which places the transformer windings in parallel or series depending on whether the instrument is to be set up for nominal 115V or 230V operation.

From the primary, power is magnetically coupled to various secondary windings used by the analog and digital supplies discussed below. Secondary windings for the analog supplies are shielded to minimize noise coupling that could affect sensitive analog circuits.

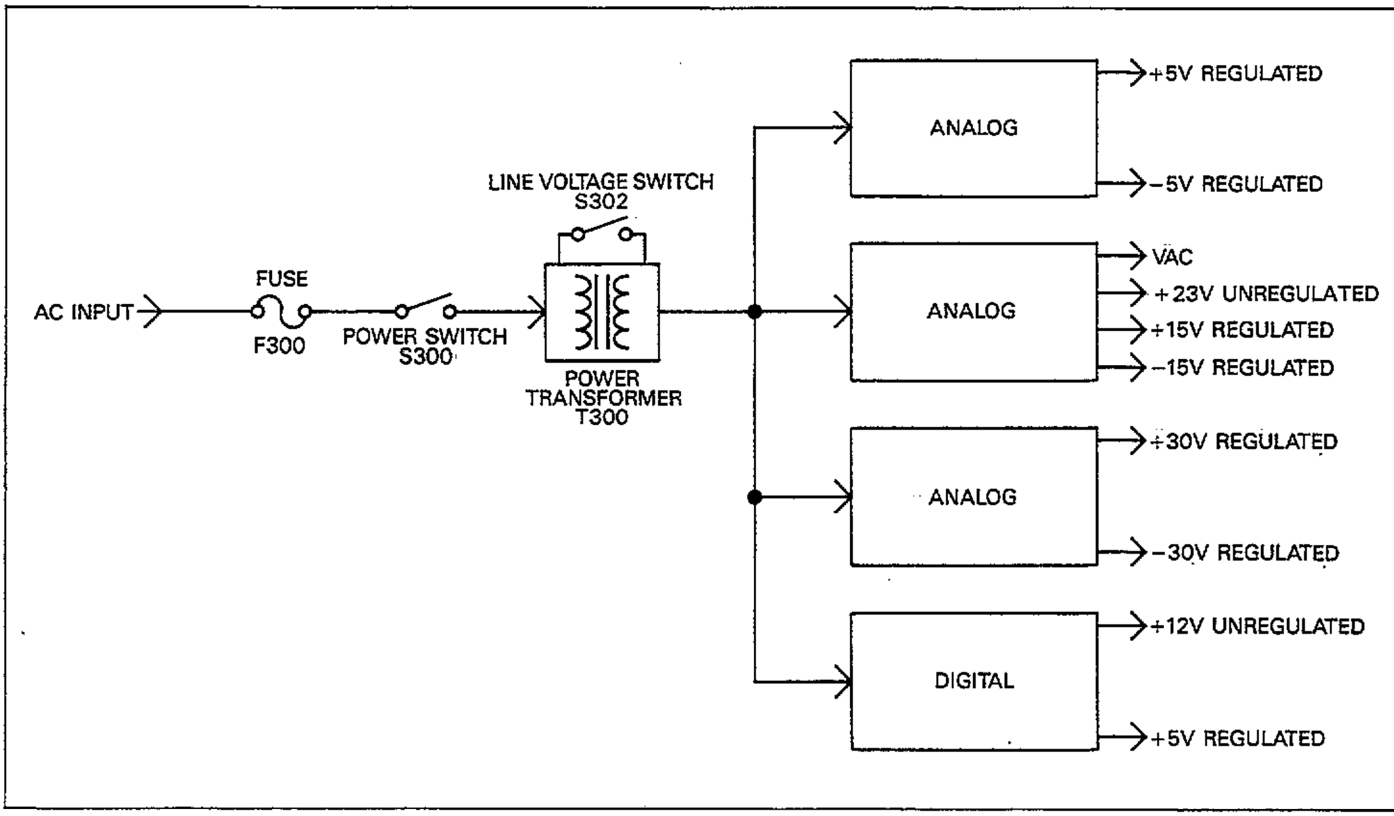


Figure 6-12. Block Diagram of Power Supply

6.7.2 Analog Supplies

Supply voltages for the analog circuits include ±5, ±15, and ±30V regulated supplies, as well as 23V unregulated and pulsed DC (VAC) circuits.

±5V Supplies

CR306 provides the rectification for the ±5V supplies, while C346 and C345 provide input filtering. VR300 and VR301 are IC regulators, while output filtering is provided by C347 and C348.

±15V Supplies

These supplies are essentially the same as the ±5V supplies, except, of course, for the fact that their output voltages are ±15V. CR307 rectifies the AC input voltage, while C343 and C344 provide input filtering. VR302 and VR303 are the IC regulators, and C349 and C350 filter the outputs.

Diode CR309 is included in the circuit in order to isolate the VAC signal from the input filter of the +15V supply. This signal is actually a pulsed DC waveform used by the safeguard circuit in the serial control section. See paragraph 6.4.2.

One final voltage supplied by these components is the 23V DC supply. Since this voltage is taken directly from the input filter, this supply voltage is unregulated.

±30V Supplies

Rectification for the ±30V supplies is done by CR308, and C341 and C342 provide input filtering. Unlike the remaining supplies, an IC regulator is not used due to the higher voltage involved. Instead, each regulator is made up of a resistor, zener diode, and transistor. Each side of the supply operates essentially the same (except, of course, for polarity). For example, CR305 provides the reference voltage for the positive supply, while R393 limits zener current to a safe value. Q300 is the series pass transistor which regulates the output voltage.

6.7.3 Digital Supplies

In order to maintain complete electrical isolation between digital and analog sections, a separate digital supply is used. CR305 rectifies the AC voltage from a separate secondary winding of the power transformer, and C340 provides input filtering. Regulation is performed by VR304, and C351 filters the output.

A separate +12V unregulated source used by the power up reset circuit (U302) in the digital section is tapped off at the input of the voltage regulator. See paragraph 6.3.1.

6.8 DISPLAY AND KEYBOARD CIRCUITS

A block diagram of the display and keyboard circuits is shown in Figure 6-13, and drawing number 590-116 shows a schematic diagram of most of these circuits. Segment latches may be found on drawing number 590-126, sheet 2, while segment drivers are located on drawing number 590-126, sheet 3.

6.8.1 Display

DS201-DS210 are the 14-segment display LEDs, while DS211 through DS224 are the LED annunciators. U319, U324, U327, and U329 are the segment latches, while U334-U341 are the segment drivers. R362 through R385 limit segment current to the correct value.

Digit drivers for the displays and LEDs include elements of U201-U203. These drivers are controlled by data from U206 and U207.

Turning on a particular display segment is a two-step process. First, the display segment latches are loaded with the information necessary to turn on the desired segments. These segments are paired into two groups, with the a0-a6 and b0-b6 information controlling segments in DS201-DS205, and c0-c6 and d0-d6 concerned with DS206-DS210.

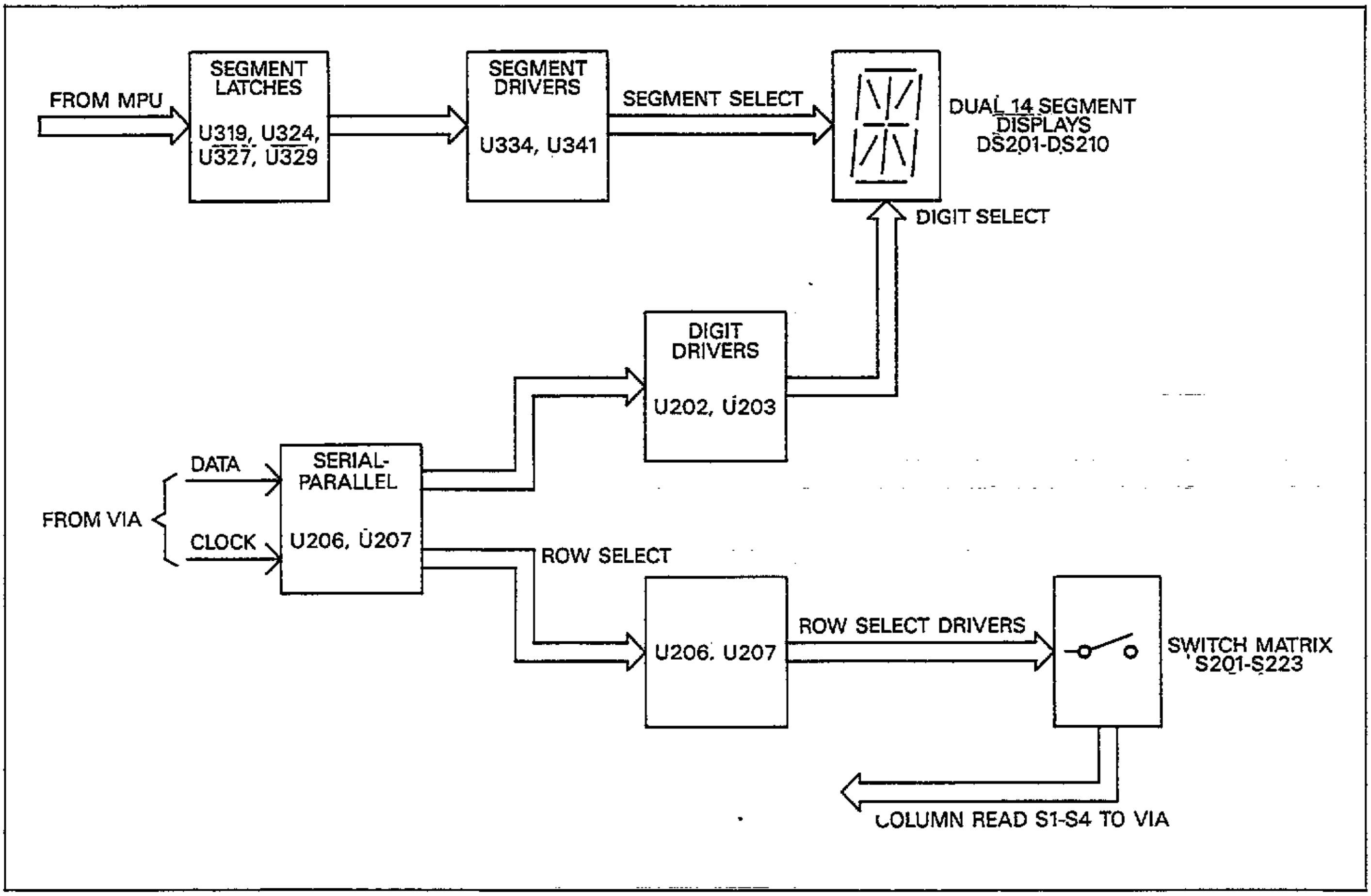


Figure 6-13. Block Diagram of Display and Keyboard

Once the segment latches have been loaded, the appropriate display digit pair is selected with data shifted into U206 and U207 via the DATA line. The shift-in process is controlled a 1kHz signal applied to the CLOCK line. The selection process begins with the A select line, which selects one-half of both DS201 and DS206. The process sequences through all digits, until all have been selected and is then repeated. As with the A select line, each signal (B-J) controls a pair of digits.

Each digit will be on for approximately 950μsec when selected. Since there are 10 selection steps (for the 20 digits), the display refresh rate is approximately 100/sec in order to minimize display flicker.

The selection process is similar for the discrete annunciator LEDs. For example, the b7 segment select and G digit select lines are used to control DS211.

6.8.2 Keyboard

The keyboard switches, S201-233, are organized into a four column by eight row matrix (except for column 1, which has nine rows). The switches are read by sequencing through the various rows with select signals shifted into U206 and U207 via the DATA and CLOCK lines. These select signals are first buffered by sections of U204 and U205 before being applied to the switch matrix.

Once a particular row is selected, the column lines (S1-S4) are then read through the VIA on the digital board to determine which, if any, keys in that row are pressed. The process repeats for all rows, with a column read operation performed after each row is selected.

6.9 CABLE CORRECTION PRINCIPLES

The following paragraphs discuss cable correction principles as implemented in the Model 590. First an error model for internal and external correction is presented, followed by a discussion of correction algorithms.

6.9.1 Error Models

The error model for cable correction paths is shown in Figure 6-14. Figure 6-15 shows the error model for the internal electronics of the instrument.

The model for internal error correction includes the input/output and transmission section, but excludes the external and device under test sections. Internal corrections are necessary to compensate for the three feet of internal cable between the 5902 module and the front panel test jacks.

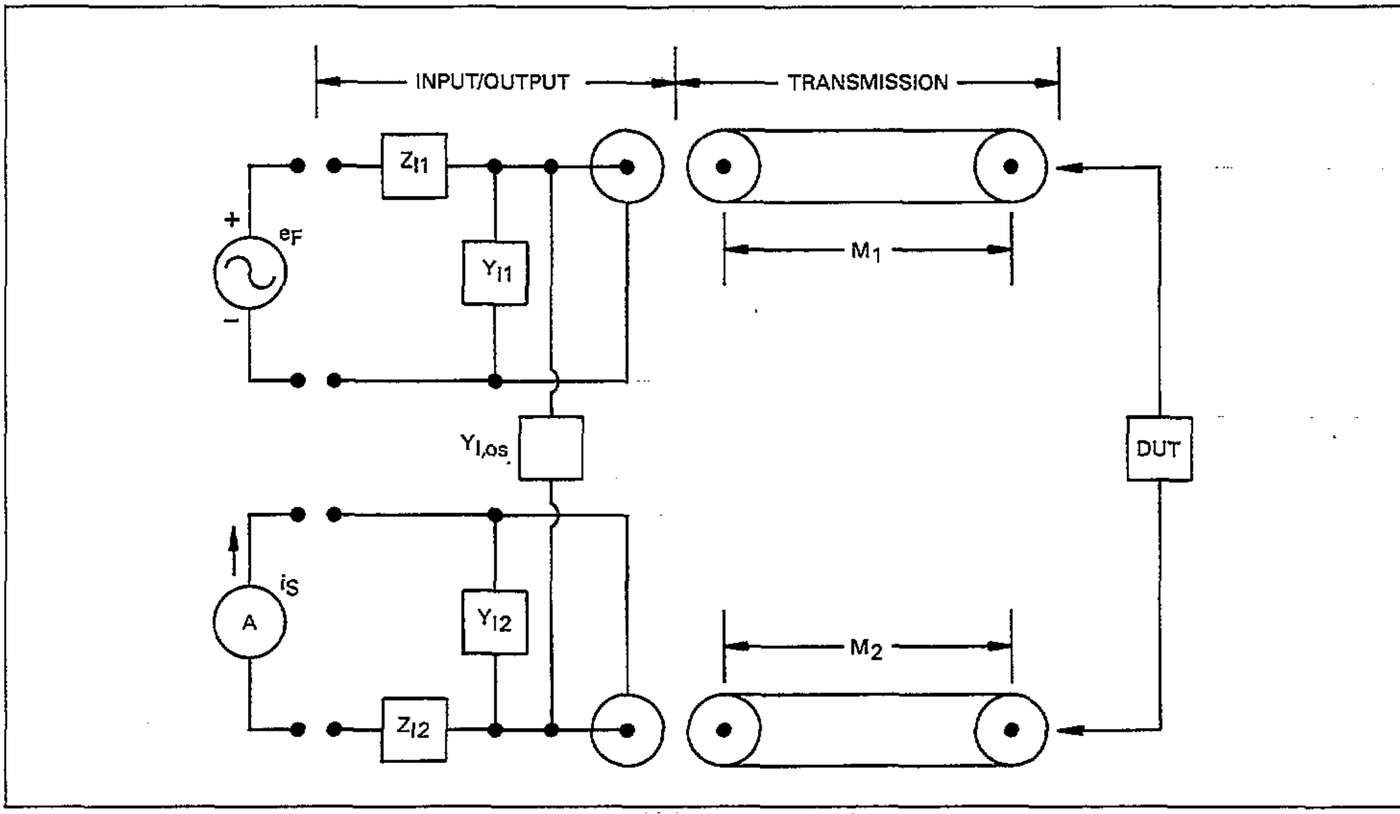


Figure 6-14. Transmission Path Error Model

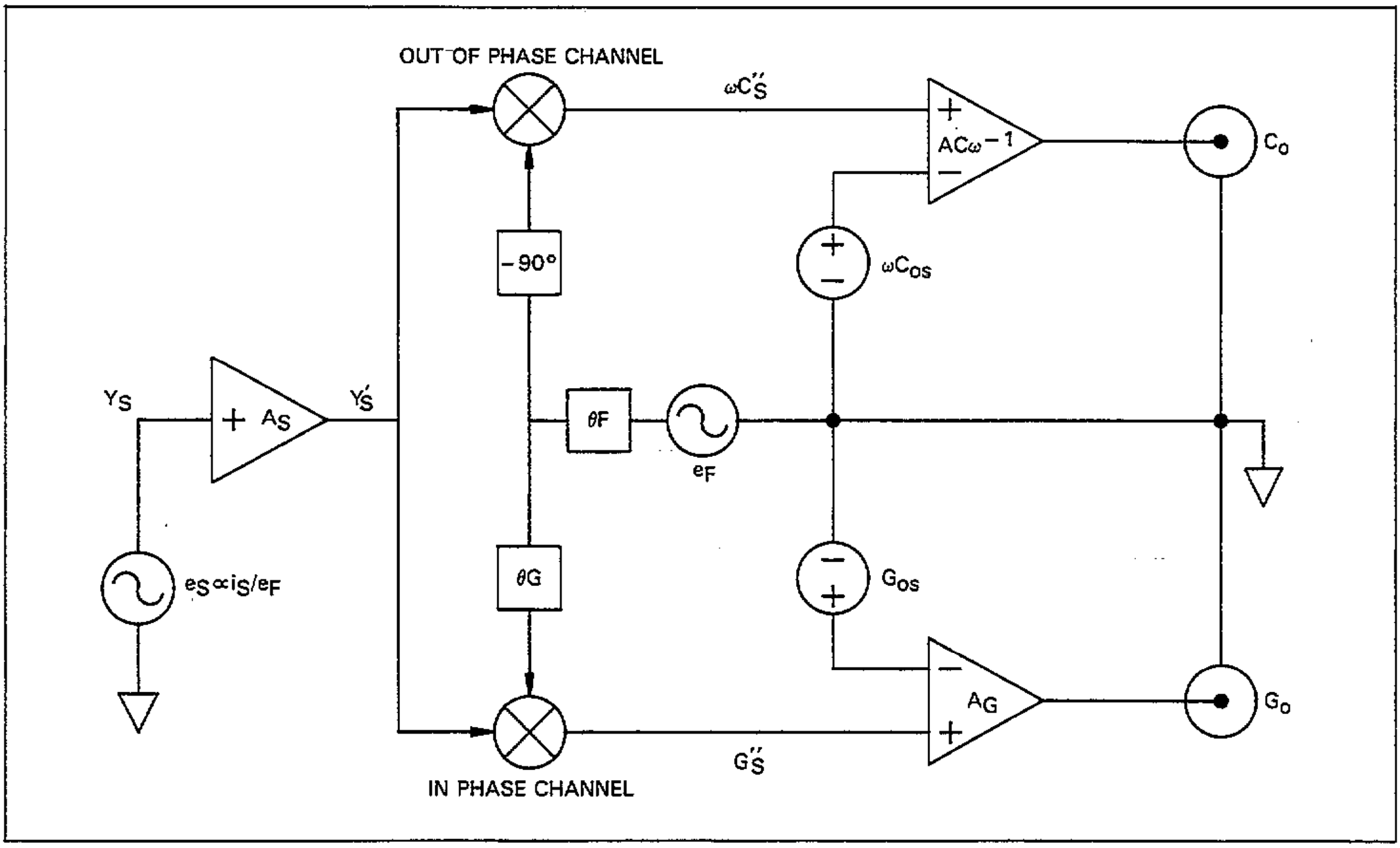


Figure 6-15. Electronics Error Model

6.9.2 Internal Model Corrections

The A/D gain and offset errors are combined with the capacitance and conductance gain and offset errors. The phase error, θ F and the sense amplifier gain error, A_s, are combined by treating the C and G readings as complex numbers. The correction factor for these terms is the result of one complex multiplication to perform both phase and gain correction in a single operation.

Keeping these points in mind, the steps necessary for internal error correction are as follows:

1. Subtract the C and G channel offset errors from the C and G channel readings.
2. Multiply the C and G readings by the scaling factors required to put them into the correct units (farads and siemens).
3. Treat the C and G readings as a complex number, then multiply that number by the inverse value of the complex number representing gain and phase errors.

The process defined in step 3 is later combined into the I/O and transmission correction algorithm to avoid two successive complex products where one will perform both corrections.

6.9.3 I/O and Transmission Model Corrections

In order to correct the readings for the tranmission path to the front panel, the error terms Z_{l1}, Y_{l1}, Z_{l2}, Y_{l2}, M_1, and M_2 must be taken into account. These factors are included by considering the measurement signal path as a series of two-port networks.

Each two port network accounts for one of the error terms (Z_{l1} → [T_{Z1}], etc.).

The total transmission matrix is then the product of the individual transmission matrices.

$[T_{EX}]$ = Total transmission matrix

$$= [T_{Z1}] \times [T_{Y1}] \times [T_{M1}] \times [T_{DUT}] \times [T_{MZ}] \times [T_{Y2}] \times [T_{Z2}]$$

$$= \begin{bmatrix} A_{EX} & B_{EX} \\ C_{EX} & D_{EX} \end{bmatrix}$$

Where A_{EX}, B_{EX}, C_{EX}, and D_{EX} are the respective elements of the resulting transmission matrix.

Since,

$$T_{DUT} = \begin{bmatrix} 1 & Z_E \\ 0 & 1 \end{bmatrix}$$

Where Z_E is equivalent (complex) impedance of the device under test.

Evaluation $[T_{EX}]$ will result in matrix elements each of which will be a linear function of Z_E.

That is;

$$[T_{EX}] = \begin{bmatrix} A_1 \times Z_E + B_1 & A_2 \times Z_E + B_2 \\ A_3 \times Z_E + B_3 & A_4 \times Z_E + B_4 \end{bmatrix}$$

with A_N and B_N all complex numbers.

The Model 590 in making a measurement of $[T_{EX}]$, forces an input voltage and measures a short-circuit output current. In effect, the transfer short-circuit admittance of $[T_{EX}]$ is being measured.

Converting a transmission matrix to an admittance matrix is as follows:

if

$$[T] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

$$[Y] = \begin{bmatrix} \frac{D}{B} & \frac{-1}{B} \\ \frac{-1}{B} & \frac{A}{B} \end{bmatrix}$$

where $-1/B$ is the transfer short-circuit admittance.

$$= -Y_{XFER}$$

Then;

$$Y_{XFER} = 1/(A_2 Z_E + B_2)$$

Replacing A_2 and B_2 with K_1 and K_2 respectively and solving for $1/_{ZE}$;

$$1/_{ZE} = Y_{DUT} = K1/(1/Y_{XFER} - K2)$$

or

$$Z_E = 1/Y_{DUT} = (Z_{XFER} - K2)/K1$$

The complex constants K1 and K2 are determined through calibration of the Model 590 against known sources.

6.9.4 Cable Correction Algorithm

The correction algorithm used to correct the data for cable and other external effects is fundamentally the same for all three forms of correction: Driving Point Admittance, Calibration Source, and S-Parameter Methods. The fundamental difference in the correction modes is in the method used to calculate the coefficients for the correction algorithm.

6.9.5 Driving Point Correction

The following discussion shows how the correction terms are derived for the driving point mode. The driving point correction mode is the easiest to implement, but of the three methods, is the one that must make the most assumptions about the transmission paths.

Basic Assumptions

When using the driving point mode, the following assumptions apply:

1. The correction coefficients are based on measurements made on only the cable connected to the test INPUT jack. The two cables are assumed to be identical.
2. The cables are assumed to be lossless.
3. The driving point measurements are taken with the opposite end of the cable open. This measurement assumes that shunt and offset capacitances present during the driving point measurement are the same as in actual use, and that the shunt capacitance at the end of the cable has the same value for each cable.
4. The cables are assumed to be RG-58 A/U with an impedance of 50Ω and a propagation velocity of 66% of the speed of light.
5. Only cables can be accommodated; no switch matrices or other unusual configurations can be used.

In making the driving point corrections two additional matrices are inserted into the previous model to account for the input and output cables. By measuring the shunt capacitance of the open ended input cable the length of that cable can be determined. Using the cable length, transmission matrices are constructed and used to modify the total transmission matrix described in 6.9.3

6.9.5 Calibration Source Correction

Using this method the calibration point for the Model 590 is moved from the front panel to the end of a measurement pathway. The process is equivalent to that described in paragraph 6.9.3.

6.9.7 S-Parameter Correction

Here the Model 590 accepts measurement pathway descriptions based on measured S-parameters and characteristic impedance. These are then converted to transmission matrix parameters and used according to the procedure in paragraph 6.9.3

SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 590 CV Analyzer. Fuse replacement and fan filter cleaning procedures are also included.

WARNING
The procedures in this section are intended only for qualified electronics service personnel. Do not attempt to perform these procedures unless you are qualified to do so. Some of the procedures may expose you to potentially lethal voltages (>30V RMS) that could result in personal injury or death if normal safety precautions are not observed.

This section is outlined as follows:

7.2 Fuse Replacement: Gives the procedures for replacing the line fuse located on the rear panel, and the external bias voltage input fuse located internally.

7.3 Calibration: Details the procedures necessary for calibrating the Model 590 including recommended calibrating equipment and sources.

7.4 Special Handling of Static-Sensitive Devices: Covers precautions necessary when handling static-sensitive parts within the instrument.

7.5 Disassembly/Re-assembly: Covers the procedures for disassembling and re-assembling the instrument, including the case and all circuit boards.

7.6 Troubleshooting: Outlines troubleshooting procedures for the various circuit boards within the Model 590 and the 100kHz and 1MHz modules.

7.7 Fan Filter Cleaning/Replacement: Gives the procedure for fan filter removal, cleaning, and replacement, if necessary.

7.2 FUSE REPLACEMENT

The paragraphs below give the basic procedures for replacing the line fuse located on the rear panel and the external bias input fuse located internally.

WARNING
Disconnect the instrument from the power line and all other equipment before removing the top cover or replacing fuses.

7.2.1 Line Fuse Replacement

The line fuse, located on the rear panel (Figure 7-1), protects the power line input of the instrument. Use the following procedure to replace the fuse, if necessary.

1. With the power off, place the end of a flat-bladed screwdriver into the slot in the rear panel fuse holder. Press in gently and rotate the fuse holder approximately one quarter turn counterclockwise. Release pressure on the holder and allow the internal spring to push the carrier and fuse out of the holder.
2. Separate the fuse from the carrier by carefully pulling the two apart.
3. Using an ohmmeter, check the fuse for continuity. A good fuse will show low resistance, while a blown fuse will read high (essentially infinite) resistance.
4. If the old fuse is defective, replace it with the type recommended in Table 7-1.

CAUTION
Do not use a fuse with a higher rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the problem before resuming operation of the unit.

5. Install the new fuse, located in the fuse carrier, by reversing the above procedure.

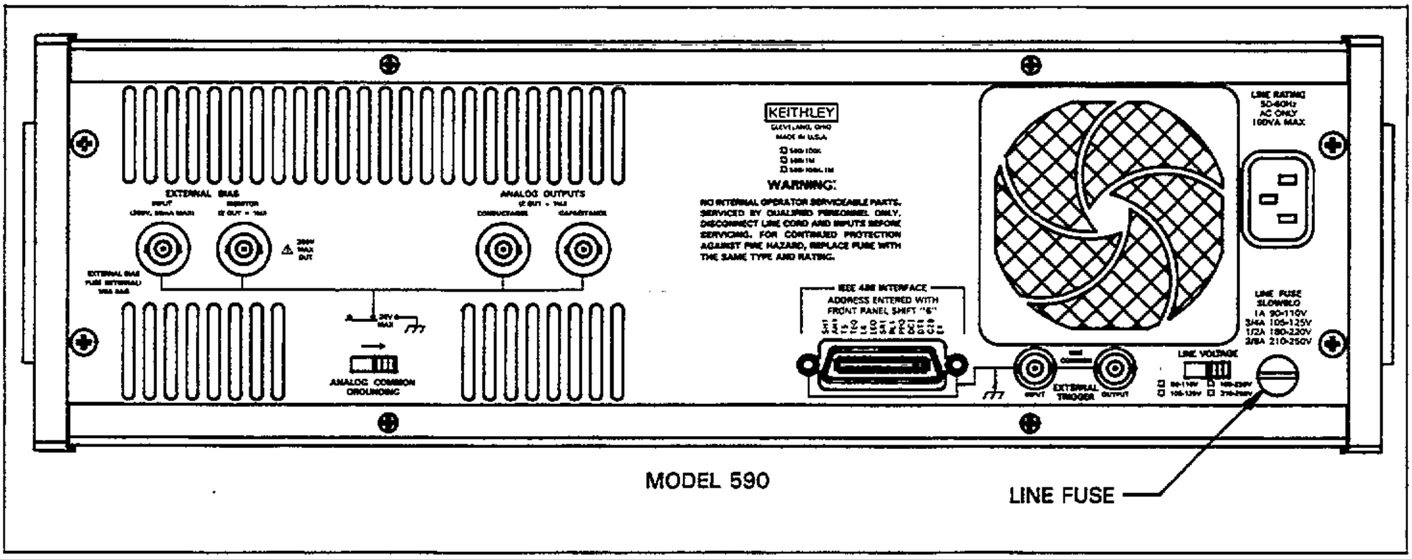


Figure 7-1. Line Fuse Location

Table 7-1. Line Fuse Values

Line Voltage Range	Fuse Rating	Keithley Part No.
90-110V	1A, slow blow, 250V, 3AG	FU-10
105-125V	¾A, slow blow, 250V, 3AG	FU-19
180-220V	½A, slow blow, 250V, 3AG	FU-4
210V-250V	$^{3}/_{8}$A, slow blow, 250V, 3AG	FU-18
105-125V	0.8A, slow blow, 5mm	FU-71*
210-250V	0.4A, slow blow, 5mm	FU-80*

*Use of 5mm fuse types requires different fuse carrier; order part number FH-26.

7.2.2 External Bias Input Fuse

An internal $^{1}/_{8}$ A fuse protects the instrument from excessive currents applied to the VOLTAGE BIAS INPUT jack on the rear panel. Use the procedure below to test and replace this fuse, if necessary.

CAUTION
The external bias fuse may blow if your external bias source or DC calibrator shorts its output terminals when it is placed in standby. To avoid blowing fuses in this situation, press the 590 BIAS ON key to turn off the bias voltage (BIAS ON LED off) before placing the external bias source or DC calibrator in standby.

1. Remove the two screws that secure the top cover to the rear panel, and slide the cover off to the rear of the instrument.
2. Refer to Figure 7-2 for the location of the external bias fuse. Using a fuse puller, remove the fuse from the fuse clips.
3. Check the fuse for continuity with an ohmmeter. A good fuse will show low resistance, while a blown fuse will give a very high (infinite) resistance reading.
4. If necessary, replace the fuse with the following type:

   $^{1}/_{8}$ A, 250V, 8AG, Fast Blow, Keithley Part Number FU-5

CAUTION
Do not use a fuse with a higher current rating than specified above, or instrument damage may occur.

5. After replacing the fuse, replace the top cover and secure it properly before resuming normal operation.

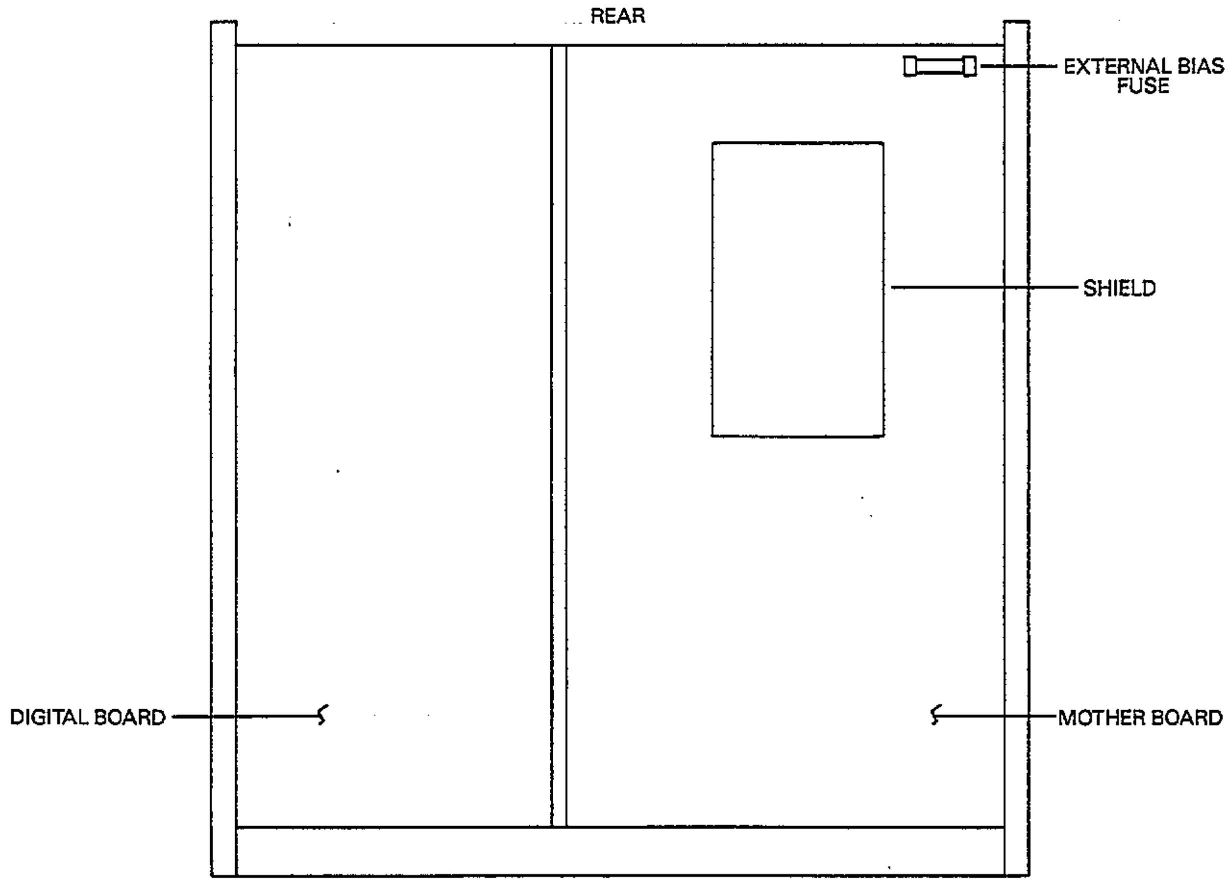


Figure 7-2. External Bias Fuse Location

7.3 CALIBRATION

The following paragraphs discuss various aspects of instrument calibration including recommended calibration equipment and standards, environmental conditions, as well as the basic calibration procedures for instruments equipped with 100kHz and 1MHz modules.

WARNING
Certain steps in the calibration procedures require the use of hazardous voltage. Be careful not to contact these voltages to ensure personal safety.

NOTE
These calibration procedures are intended for those who are familiar with electronics test equipment and calibration procedures in general. Do not carry out these procedures unless you are thoroughly qualified to so. Unless the procedures are carefully performed, serious accuracy degradation of the instrument may occur.

7.3.1 Factory Calibration

Because of the difficulty in obtaining accurate capacitance and conductance sources and the complexity of the procedures, it is recommended that the instrument be returned to the factory for calibration. Consult your Keithley representative or the factory for details on obtaining factory calibration.

7.3.2 Calibration Cycle

Calibration should be performed every 12 months, or if the performance verification procedures discussed in Section 5 show that the instrument is operating outside its stated specifications (detailed Model 590 specifications may be found at the front of this manual). If any of the calibration procedures cannot be properly performed, refer to the troubleshooting information in this section.

7.3.3 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23 ±2°C and a relative humidity of less than 70%. If the instrument has been subjected to temperatures outside this range, or to higher humidity allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

NOTE

The calibration procedure should be done as quickly as possible to avoid the effects of temperature changes during calibration.

7.3.4 Recommended Calibration Equipment and Sources

Table 7-2 summarizes the equipment and sources necessary to perform the various calibration procedures. Other equipment may be substituted as long as accuracy is at least as good as those values given in the table.

NOTE

Capacitance and conductance sources must be traceable to recognized standards and must have minimal internal shunt capacitance. For that reason, it is recommended that only the sources listed in Table 7-2 be used for calibration.

7.3.5 Calibration Switch

An internal switch, located on the mother board (see Figure 7-3), must be set to the enabled position before the instrument will accept calibration commands. Sending calibration commands with the switch in the disabled position will result in the following front panel error message:

CAL LOCKED

Calibration will not take place under these conditions. The CAL LOCKED bit in the U1 status word will also be set (paragraph 4.9.15), and the Model 590 can be programmed to generate an SRQ under these conditions (paragraph 4.9.16).

Once calibration has been completed, it is recommended that the switch be placed in the disabled position to avoid the possibility of miscalibration during normal operation.

Table 7-2. Recommended Calibration Equipment and Sources

Description	Specifications	Manufacturer and Model
0.5pF, 1.5pF, 4.7pF, 18pF 47pF, 180pF, 470pF, 1.8nF, 4.7nF, 18nF, capacitance sources	*	Keithley Models 5905, 5906
1.8μS, 18μS, 180μS, 1.8mS, 18mS conductance sources	*	Keithley Models 5905, 5906
DC calibrator	20V, 200V DC ±0.002%	Fluke 343A
DMM (2)**	2V, ±0.06%	Keithley Model 196 or 197.

*Capacitance and conductance values must be characterized and traceable to known standards. To maintain capacitance linearity specifications, use of Model 5905 and 5906 sources is recommended.

**Although two DMMs are preferred, procedure may be performed with only one.

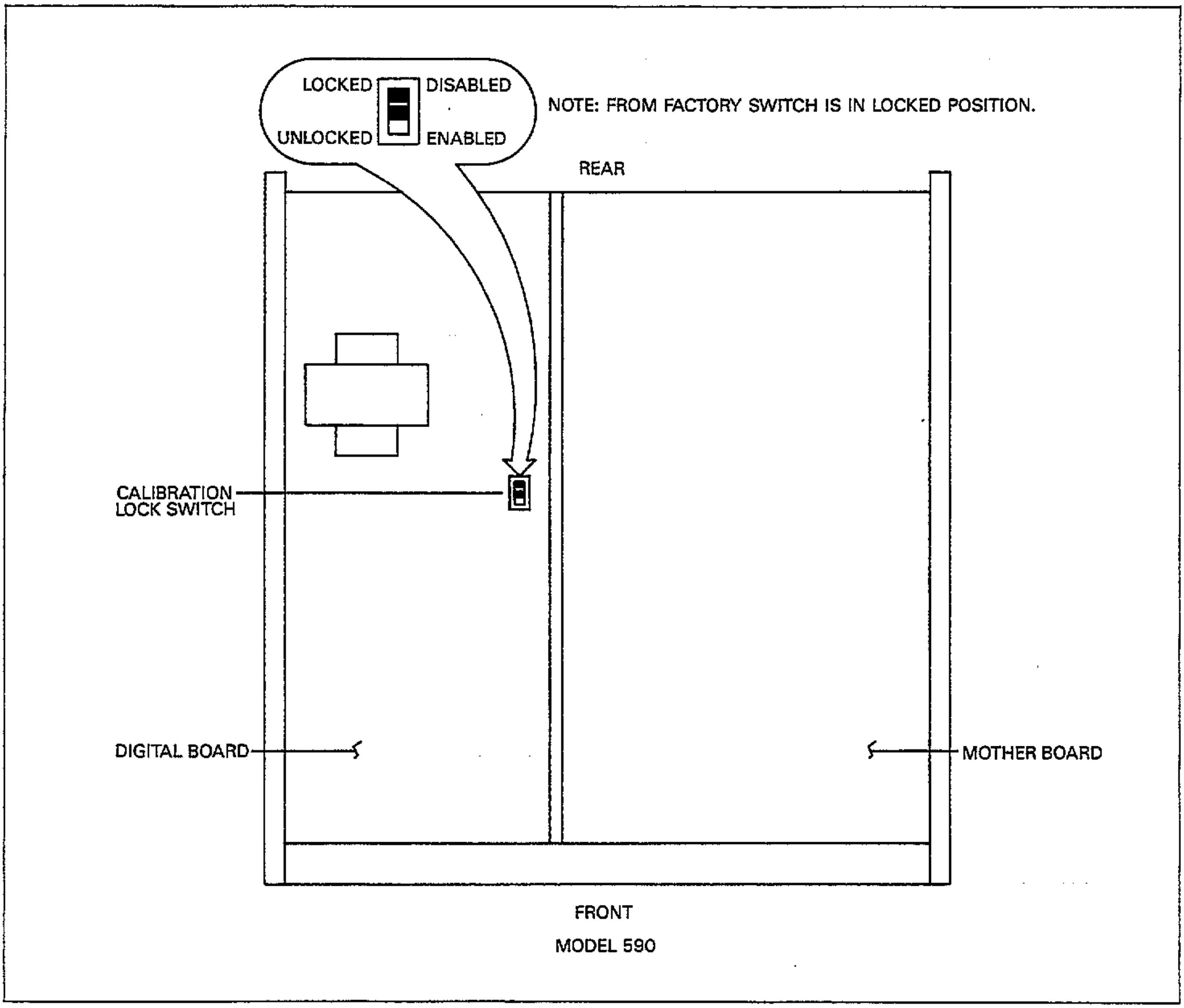


Figure 7-3. Calibration Lock Switch Location

7.3.6 Calibration Commands

Table 7-3 summarizes calibration commands for the Model 590. These commands include:

1. Phase drift calibration (Q0): This command performs the same function as pressing the front panel CAL key. This command is not used as part of this calibration procedure, but is intended merely to optimize accuracy during normal use. Note that this command can be used even if the calibration switch is in the disabled position.
2. Normal mode calibration (Q1, Q2, Q3, and Q4): These four commands perform calibration of the normal C and G measurement ranges.
3. Driving point calibration (Q5, Q6, and Q7): Calibration of the driving point mode of cable correction is performed by these commands.
4. Voltage calibration (Q8 and Q9): Calibration of the voltage read back circuits is performed with these two commands.

Table 7-3. Calibration Command Summary

Command	Description	Comments
Q0	Phase drift calibration	Same as pressing CAL
Q1	Normal mode offset cal	
Q2, C, 0	Normal mode 1st C cal point	Use actual C value
Q3, C, 0	Normal mode 2nd C cal point	Use actual C value
Q4, 0, G	Normal mode G cal point	Use actual C value
Q5	Driving point offset cal	
Q6, C, 0	Driving point 1st cal point	Use actual C value
Q7, C, 0	Driving point 2nd cal point	Use actual C value
Q8	Voltage offset calibration	
Q9, V	Voltmeter gain calibration	

7.3.7 Calibration Program

You can use the program below to send the calibration commands to the instrument. As written, the program is in HP-85 BASIC but can be modified for other controllers. Some error checking is included in the program to notify the operator of possible programming errors.

```
Program                           Comments

10 REMOTE 715                     ! Put 590 in remote.
20 CLEAR
30 DIM A$[100]                    ! Dimension input
                                    string.
40 DISP''COMMAND''                ! Prompt for com-
                                    mand string.
50 INPUT A$                       ! Input command
                                    string.
60 OUTPUT 715; A$                 ! Output command
                                    string to 590.
70 S=SPOLL(715)                   ! Check status.
80 IF BIT(S,5) THEN GOSUB         ! Bit set indicates an
   100                              error.
90 GOTO 40                        ! Repeat.
100 RESTORE                       ! Clear data pointer.
110 OUTPUT 715; ''U1X''           ! Find out which
                                    error.
120 ENTER 715; A$                 ! Get error status
                                    from 590.
130 FOR I= 5 TO 15                ! Parse error word.
140 READ B$                       ! Read error message.
150 IF A$[I,I]=''1'' THEN         ! Display error
    DISP B$; '' ERROR''             message.
160 NEXT I                        ! Loop for next
                                    message.
170 RETURN
180 DATA ''TRIGGER OVER-
    RUN'', ''NEED 100K''
190 DATA ''NEED 1M'',
    ''STRING OVERFLOW''
200 DATA ''CAL LOCKED'',
    ''CONFLICT''
210 DATA ''TRANSLATOR'',
    ''NO REMOTE''
220 DATA ''IDDC'',
    ''IDDCO'',
    ''INVALID''
230 END
```

7.3.8 Module Calibration

The calibration procedures for the 100kHz (5901) and 1MHz (5902) capacitance modules are covered below.

NOTE

The modules should be calibrated before attempting digital calibration, which is covered in paragraph 7.3.9.

DMM Connections

In order to calibrate the modules, a DMM is used to measure the voltages at the analog outputs of the instrument. The two DMMs should be connected to the CONDUCTANCE and CAPACITANCE ANALOG OUTPUT jacks; Figure 7-4 shows the connecting method for one of the DMMs. A single DMM can be used by switching connections during the procedure, if desired.

Since the DMM reading will be in volts, it will be necessary to convert the applied standard value to voltage. For example, a nominal 180pF standard value will yield a nominal 1.8V DMM reading with the Model 590 on the 200pF range.

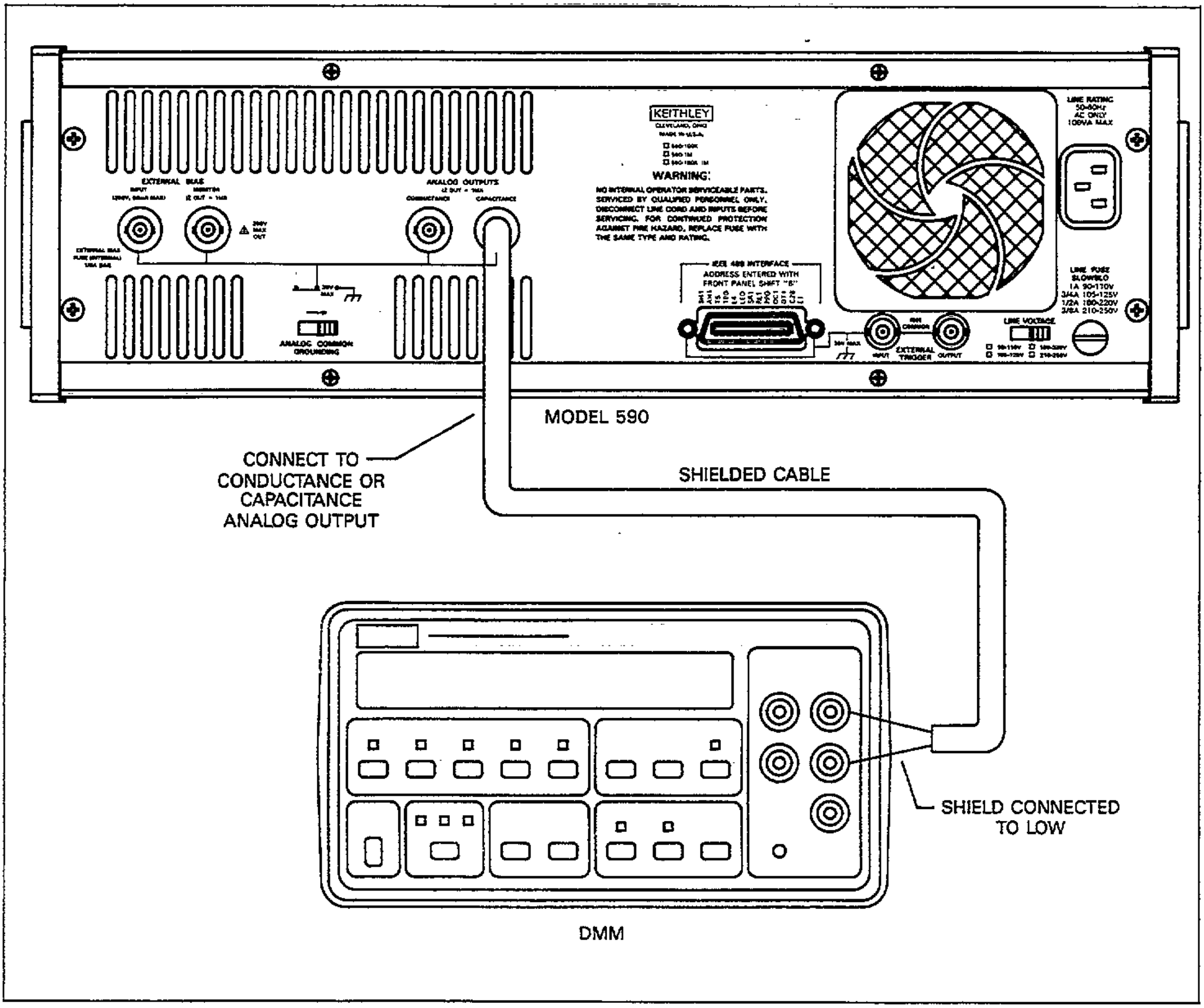


Figure 7-4. Module Calibration Connections

Source Connections

In all cases, the sources are to be connected directly to the front panel test INPUT and OUTPUT jacks. Cables should not be used, as these will degrade calibration accuracy.

Calibration Adjustment Locations

The calibration adjustments and jumpers are shown in Figure 7-5. Be sure to carry out the procedures in the order given here.

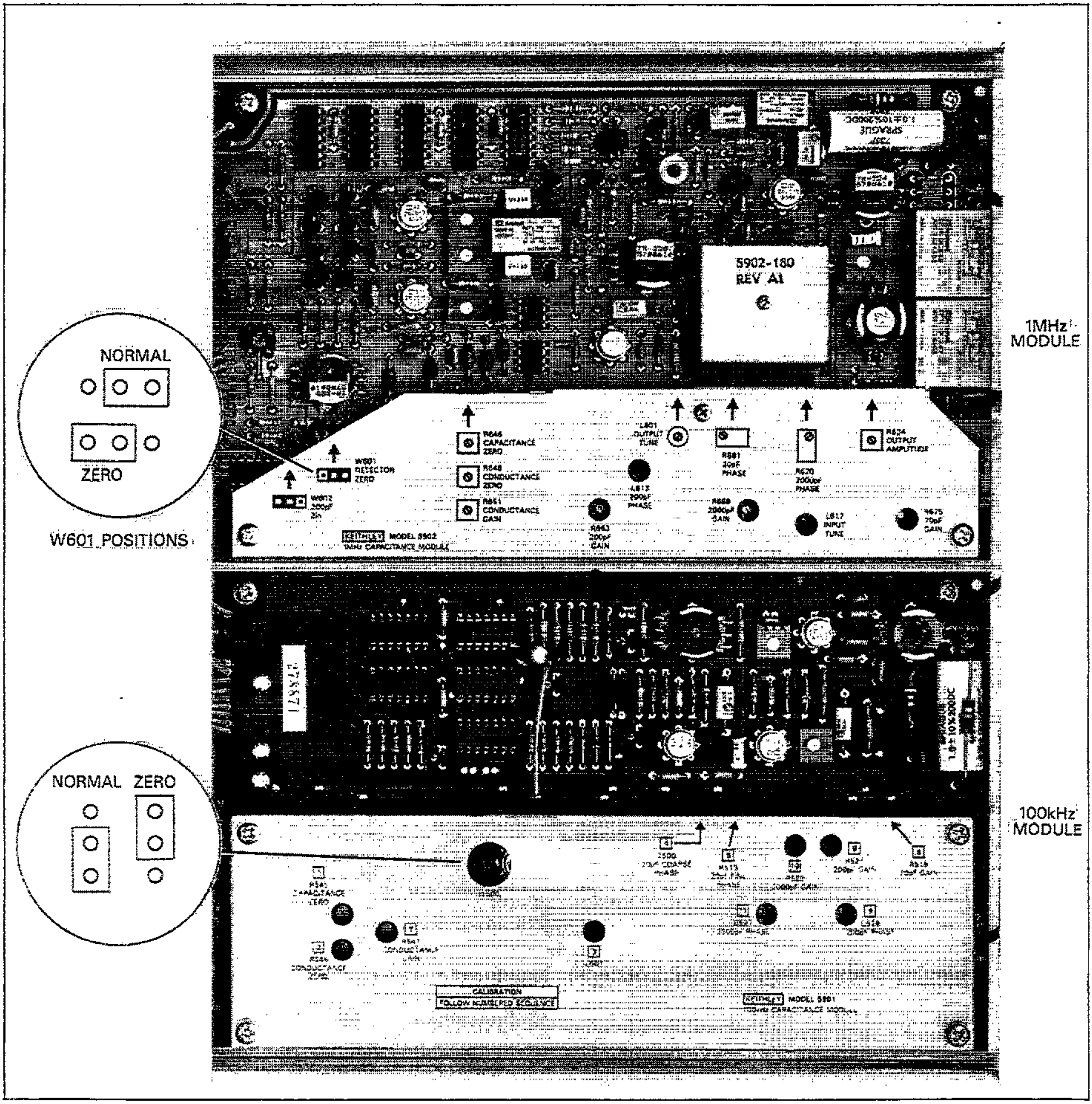


Figure 7-5. Module Calibration Adjustments

100kHz (5901) Module Calibration

Calibrate the 100kHz module as follows:

1. Turn on the Model 590 and allow it to warm up for at least one hour before beginning calibration. Also allow the DMMs to warm up for the period stated in their instruction manuals.
2. Select the following operating modes on the Model 590:
   Frequency: 100kHz
   Filter: ON
   Range: 2nF
3. Select the 2V DC range on both DMMs. Temporarily short the ends of the DMM connecting cables, and then enable zero on both DMMs. Make sure the DMMs are connected to the analog outputs after zeroing them.
4. Change the position of jumper W500 to the ZERO position, as shown in Figure 7-5.
5. Adjust R545 (CAPACITANCE ZERO) for a reading of 0V $\pm 100\mu V$ as measured on the DMM connected to the CAPACITANCE OUTPUT.
6. Adjust R546 (CONDUCTANCE ZERO) for a reading of 0V $\pm 100\mu V$, as measured on the DMM connected to the CONDUCTANCE OUTPUT.
7. Return jumper W500 to its normal position, as shown in Figure 7-5.
8. Select the 20pF range on the Model 590 and re-zero the DMMs with nothing connected to the front panel test jacks.
9. Connect the 18pF nominal capacitance source to the front panel test INPUT and OUTPUT jacks.
10. Adjust R513 (20pF FINE PHASE) for a reading of 0V $\pm 100\mu V$ as measured on the conductance DMM.
11. Adjust R515 (20pF GAIN) for a voltage reading analogous to the 100kHz capacitance value marked on the standard, $\pm$1mV. For example, if the marked 100kHz standard value is 18.05pF, adjust for a DMM reading of 1.805V $\pm$1mV.
12. Disconnect the 18pF source and make sure the Model 590 is on the $20\mu S$ range.
13. Re-zero the DMMs connected to the analog outputs.
14. Connect the $18\mu S$ conductance source to the front panel test jacks and adjust R547 (CONDUCTANCE GAIN) for a conductance DMM reading analogous to the conductance value marked on the source, $\pm$1mV. For example, if the marked value is $18.1\mu S$, adjust for a voltage reading of 1.81V $\pm$1mV.
15. Remove the $18\mu S$ source from the instrument.
16. Select the 200pF range on the Model 590 and re-zero the DMMs.
17. Connect the 180pF source to the front panel test INPUT and OUTPUT jacks of the Model 590.
18. Adjust R521 (200pF GAIN) for a voltage reading analogous to the marked 100kHz source value, $\pm$1mV on the capacitance DMM. For example, if the source value is 180.6pF, adjust for a DMM reading of 1.806 $\pm$1mV.
19. Adjust C529 (200pF PHASE) for a reading of 0V $\pm$1mV on the conductance DMM.
20. Remove the 180pF source from the instrument.
21. Select the 2nF range on the Model 590 and re-zero the DMMs.
22. Connect the 1.8nF source to the front panel test INPUT and OUTPUT jacks.
23. Adjust R523 (2000pF GAIN) for a voltage reading analogous to the marked 1.8nF source value, $\pm$1mV on the capacitance DMM. For example, if the marked source value is 1.795nF, adjust for a voltage reading of 1.795V $\pm$1mV.
24. Adjust C527 (2000pF PHASE) for a reading of 0V $\pm$1mV on the conductance DMM.
25. Remove the 1.8nF capacitance source from the unit.

This concludes calibration of the 100kHz module. If the Model 590 has a 1MHz module installed, calibrate that unit using the procedure below. Otherwise, proceed to paragraph 7.3.9 for digital calibration procedures.

1MHz (5902) Module Calibration

Use the following procedure to calibrate the 1MHz module. Note that the procedure must be repeated several times until no adjustment is required at any point in order for the module to be properly calibrated.

1. Turn on the Model 590 and allow it to warm up for at least one hour before beginning calibration. Also allow the DMMs to warm up for the period stated in their instruction manuals.
2. Select the 2V DC range on the DMMs. Temporarily short the ends of the DMM test leads, then enable zero on both DMMs. Connect the DMMs to the CAPACITANCE and CONDUCTANCE ANALOG OUTPUTS.
3. Select the following operating modes on the Model 590:
   Frequency: 1MHz
   Filter: On
   Range: 2nF

   Initially, nothing should be connected to the front panel test jacks.
4. Move jumper W601 to the ZERO position (see Figure 7-5).
5. Adjust R646 (CAPACITANCE ZERO) for a reading of 0V $\pm 100\mu V$ on the capacitance DMM (the DMM connected to the CAPACITANCE OUTPUT).
6. Adjust R648 (CONDUCTANCE ZERO) for a reading of 0V $\pm 100\mu V$ on the conductance DMM (the DMM connected to the CONDUCTANCE OUTPUT).
7. Re-zero both DMMs.
8. Return jumper W601 to the normal position (see Figure 7-5).

9. Verify that the voltage readings on both DMMs are less than $\pm$15mV. If higher offset values are noted, check to see that all module shields are properly secured.
10. Check to see that the Model 590 is on the 2nF range and re-zero the conductance and capacitance DMMS.
11. Connect the 1.8nF Model 5905 capacitance source to the test INPUT and OUTPUT jacks of the instrument.
12. Adjust R620 (2000pF PHASE) for a value of 0V $\pm$3mV, as indicated on the conductance DMM.
13. Adjust R669 (2000pF GAIN) for a voltage reading analogous to the 1MHz capacitance value marked on the source, $\pm$2mV. For example, if the 1MHz value is 1.7996nF, adjust for a DMM reading of 1.7996V $\pm$2mV.
14. Remove the 1.8nF source from the instrument.
15. Select the 200pF range on the Model 590 and re-zero both DMMs.
16. Connect the 180pF capacitance source to the front panel test INPUT and OUTPUT jacks.
17. Adjust L613 (200pF PHASE) for a reading on 0V $\pm$1mV on the conductance DMM.
18. Adjust R663 (200pF GAIN) for a DMM reading analogous to the 1MHz capacitance value marked on the 180pF source to within 1mV. For example, if the marked 1MHz value is 181.4pF, adjust R663 for a reading of 1.814V $\pm$1mV.
19. Remove the 180pF source from the instrument.
20. Place the Model 590 on the 20pF range and re-zero both the capacitance and conductance DMMs.
21. Connect the 18pF source to the front panel test INPUT and OUTPUT jacks.
22. Adjust R681 (20pF PHASE) for a reading of 0V $\pm$1mV on the conductance DMM.
23. Adjust R675 (20pF PHASE) for a DMM reading analogous to the 1MHz value marked on the capacitance source to within 1mV. For example, if the marked 1MHz value is 18.13pF, adjust R675 for a DMM reading of 1.813V $\pm$1mV.
24. Remove the 18pF source from the instrument.
25. Repeat steps 11 through 24 until no further adjustment is required.
26. Select the 2mS range an re-zero the DMMs.
27. Connect the 1.8mS source to the front panel test INPUT and OUTPUT jacks.
28. Adjust R651 (CONDUCTANCE GAIN) for a conductance DMM reading analogous to the marked conductance source value to within 14mV. For example, if the marked value is 1.802mS, adjust R651 for a DMM reading of 1.802V $\pm$14mV.
29. Remove the 1.8mS source from the instrument.

This concludes 1MHz module calibration. Proceed to paragraph 7.3.9 for digital calibration procedures.

7.3.9 Digital Calibration

Initial Instrument Setup

Before each calibration procedure, send the command "S3T2X" to select the 10/sec reading rate and correct trigger mode.

Voltage Read-Back Calibration

WARNING
Hazardous voltages will be used in some of the following steps. Take care not to contact these voltages.

Use the following procedure to calibrate the read-back accuracy of the voltage display. Table 7-4 summarizes the procedure.

1. Connect the DC voltage calibrator to the rear panel VOLTAGE BIAS INPUT jack, as shown in Figure 7-6.
2. Initially set the calibrator to 0.0000VDC.
3. Turn on the Model 590 and allow it to warm up for one hour. Send the command "S3T2X" to initialize the instrument.
4. Turn on the calibrator and allow it to warm up for the period recommended by the manufacturer.
5. Set the calibrator to operate.
6. Send the command "W4N1X" to select external bias and turn the bias on.
7. Send "Q8X" to calibrate voltage offsets on the 200V read-back range.
8. Set the DC calibrator t +200.000VDC.
9. Send the command "Q9,200X" to calibrate full scale.
10. Set the DC calibrator to 0.0000VDC and send the command string "W0XQ8X" to calibrate voltage offsets on the 20V read back range.
11. Set the calibrator to +20.0000V and send the command "Q9,20X" to calibrate full scale.
12. Set the DC calibrator to 0.0000V and disconnect it from the Model 590.

Table 7-4. Voltage Read-Back Calibration Summary

Step	DC Calibrator Voltage	Command	Comments
1	—	S3T2X	Initialize unit
2	0.000VDC	W4N1X	Select external bias
3	0.000VDC	Q8X	Calibrate offsets
4	+200.0000VDC	Q9,200X	Calibrate full scale
5	0.000VDC	W0XQ8X	Select DC, cal offset
6	+20.0000VDC	Q9,20X	Calibrate full scale

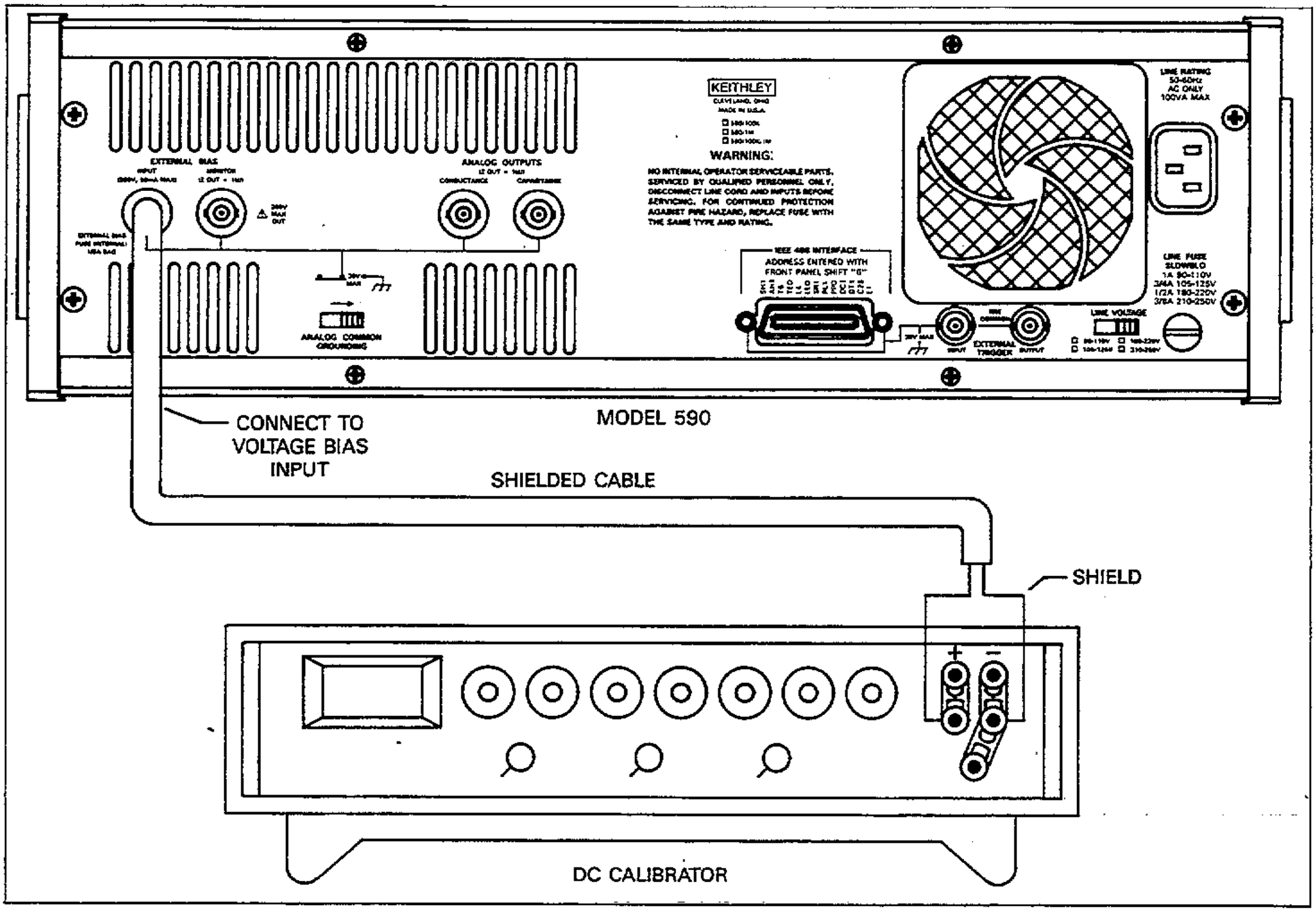


Figure 7-6. Connections for 200V Read-Back Calibration

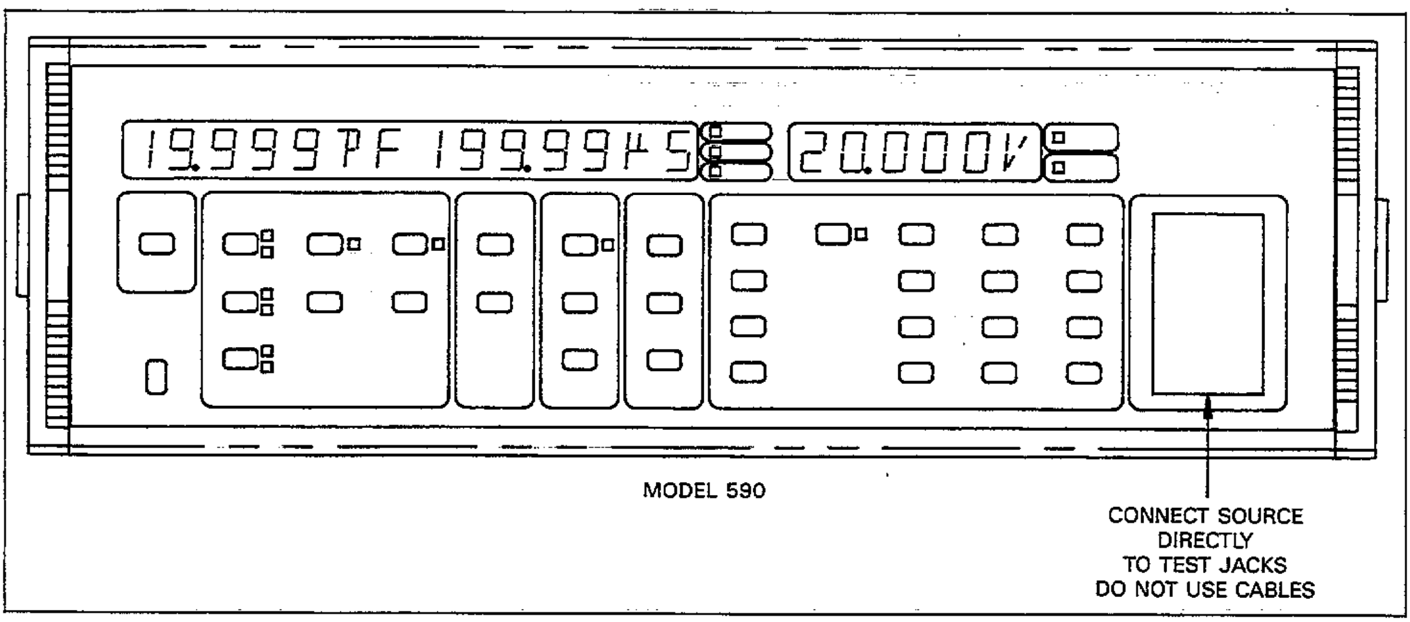


Figure 7-7. Source Connections

Internal Bias Voltage Source Calibration

Perform the following procedure to calibrate the internal bias source. Calibration adjustments are shown in Figure 7-8. Table 7-5 summarizes the procedure.

NOTE
Read-back calibration must be performed before attempting voltage source calibration.

1. With the power off, remove the two screws that secure the top cover and slide the top cover off to the rear of the instrument.
2. Turn on the power and allow the Model 590 to warm up for one hour. Send the command "S3T2X" to initialize the unit.
3. Send the command "W0X" to select a DC waveform type.
4. Send the command "V0.001N1X" and note the reading on the voltage display. Record this value as reading A.
5. Send "V-0.001X" and note and record reading B.
6. Compute the average of the two readings from steps 4 and 5: (A-B)/2.
7. Adjust R152 to display the average computed in step 5.
8. Adjust R157 for a reading of 00.000V on the voltage display.
9. Send the command "V-19X" and then adjust R156 for a reading of exactly −19.000V on the voltage display.
10. Send "V19X" and then adjust R150 for a reading of +19.000V on the voltage display.
11. Turn off the power, mount the module support tray, and replace the top cover. Paragraph 7.5 covers assembly in more detail.

Table 7-5. Voltage Source Calibration Summary

Step	Command	Adjustment	Comments
1	S3T2X		Initialize 590
2	W0X		DC waveform
3	V0.001N1X		Record reading A
4	V−0.001X		Record reading B
5			Take average: (A−B)/2
6		R152	Adjust to display average computed in Step 5
7		R157	Adjust for display of 00.000V
8	V−19X	R156	Adjust to display −19.000V
9	V19X	R150	Adjust to display +19.000V

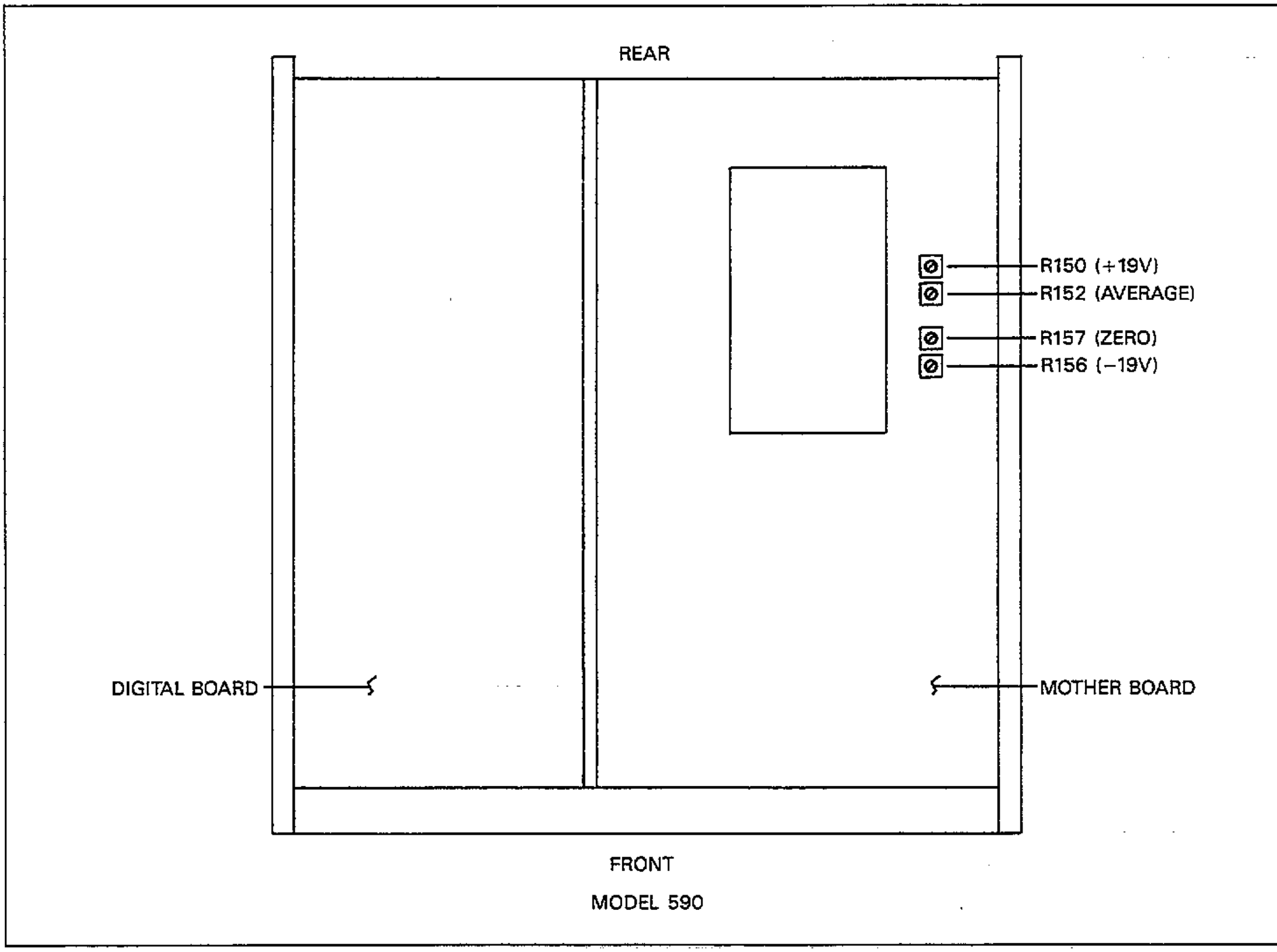


Figure 7-8. Voltage Source Calibration Adjustment Locations

100kHz Calibration

Follow the steps below in the order shown to calibrate the unit at 100kHz. Table 7-6 summarizes the procedure, commands, and necessary sources.

1. Turn on the power and allow the unit to warm up for one hour. Send the command "S3T2X" to initialize the unit.
2. Send the command string "F0R1X" to select 100kHz and place the unit on the 2pF range.
3. With nothing connected to the test INPUT and OUTPUT jacks, send the command "Q1X" to calibrate offsets.
4. Connect the 1.5pF source to the instrument and send the command "Q2,C,0X" where C is the actual 100kHz value marked on the capacitor.
5. Connect the 0.5pF source and send the command "Q3,C,0X" where C is the actual 100kHz capacitance value.
6. Connect the 1.8μS source and send the command "Q4,0,GX", using the actual 100kHz value G.
7. Send the command "R2X" to place the unit on the 20pF range.
8. With nothing connected to the test INPUT and OUTPUT jacks, send "Q1X" to calibrate offsets.
9. Connect the 18pF source to the instrument and send the command "Q2,C,0X" where C represents the actual 100kHz C value.
10. Connect the 4.7pF source to the Model 590 and send the command "Q3,C,0X", using actual C value.
11. Connect the 18μS source to the instrument and send "Q4,0,GX" where G is the actual value.
12. Repeat steps 7 through 11 for the 200pF and 2nF ranges by using the appropriate sources and the R3 and R4 commands, as summarized in Table 7-6

Table 7-6. 100kHz Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	Initialize 590
2		F0R1X	Select 100kHz, 2pF range
3	None*	Q1X	Calibrate offsets
4	1.5pF	Q2, C, 0X	Use actual C value
5	0.5pF	Q3, C, 0X	Use actual C value
6	1.8μS	Q4, 0, GX	Use actual G value
7		R2X	Select 20pF range
8	None*	Q1X	Calibrate offsets
9	18pF	Q2, C, 0X	Use actual C value
10	4.7pF	Q3, C, 0X	Use actual C value
11	18μS	Q4, 0, GX	Use actual G value
12		R3X	Select 200pF range
13	None*	Q1X	Calibrate offsets
14	180pF	Q2, C, 0X	Use actual C value
15	47pF	Q3, C, 0X	Use actual C value
16	180μS	Q4, 0, GX	Use actual G value
17		R4X	Select 2nF range
18	None*	Q1X	Calibrate offsets
19	1.8nF	Q2, C, 0X	Use actual C value
20	470pF	Q3, C, 0X	Use actual C value
21	1.8mS	Q4, 0, GX	Use actual G value

*Test jacks must be left open when performing these tests.

20nF/20mS Range Model 5904 Input Adapter Calibration

Use the procedure below to calibrate the Model 590/5904 for use on the 20nF/20mS range (see below for complete calibration procedure.

1. Turn on the power and allow the unit to warm up for one hour. Send the command "S3T2X".
2. Connect the Model 5904 to the test INPUT and OUTPUT jacks of the Model 590.
3. Send the command string "F0R8X" to select 100kHz and place the unit on the 20nF range.
4. With nothing connected to the Model 5904 jacks, send the command "Q1X" to calibrate offsets.
5. Connect the 18nF source to the Model 5904 and send the command "Q2,C,0X" where C is the actual 100kHz value marked on the capacitor.
6. Connect the 4.7nF source and send the command "Q3,C,0X" where C is the actual 100kHz capacitance value.
7. Connect the 18mS conductance source to the instrument and send the command "Q4,0,GX" using the actual 100kHz value.

Complete Model 5904 Input Adapter Calibration

Use the following procedure to calibrate the unit for use with the Model 5904 Input Transformer on the 20pF through 20nF ranges. Table 7-7 summarizes the Model 5904 calibration procedure.

NOTE

The procedure below assumes that the Model 5904 is to be calibrated for the 20pF-20nF ranges. Since calibration constants for the attenuated 20pF-2nF ranges are shared with unattenuated 20pF-2nF ranges, complete calibration using the procedure below will miscalibrate the unit for unattenuated use on the 20pF through 2nF ranges. Use the 20nF only calibration procedure above for cases where the instrument is to be used without the Model 5904 adapter on the 20pF-2nF ranges.

1. Turn on the power and allow the unit to warm up for one hour. Send the command "S3T2X".
2. Connect the Model 5904 to the test INPUT and OUTPUT jacks of the Model 590.
3. Send the command string "F0R5X" to select 100kHz and place the unit on the 20pF range.
4. With nothing connected to the Model 5904 jacks, send the command "Q1X" to calibrate offsets.
5. Connect the 18pF source to the Model 5904 and send the command "Q2,C,0X" where C is the actual 100kHz value marked on the capacitor.
6. Connect the 4.7pF source and send the command "Q3,C,0X" where C is the actual 100kHz capacitance value.
7. Connect the 18μS source and send the command "Q4,0,GX", using the actual 100kHz value for G.
8. Send the command "R6X" to place the unit on the 200pF range.
9. With nothing connected to the Model 5904 jacks, send "Q1X" to calibrate offsets.
10. Connect the 180pF source capacitor to the Model 5904 jacks and send the command "Q2,C,0X" where C represents the actual C value.
11. Connect the 47pF source to the Model 5904 and send the command "Q3,C,0X", using the actual C value.
12. Connect the 180μS source to the Model 5904 and send "Q4,0,GX" where G is the actual value at 100kHz.
13. Repeat steps 8 through 12 for the 2nF and 20nF ranges by using the appropriate sources and the R7 and R8 commands, as summarized in Table 7-7.

Table 7-7. Model 5904 Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	Initialize 590
2		F0R5X	Select 100kHz, 20pF range
3	None	Q1X	Calibrate offsets
4	18pF	Q2, C, 0X	Use actual C value
5	4.7pF	Q3, C, 0X	Use actual C value
6	18μS	Q4, 0, GX	Use actual G value
7		R6X	Select 200pF range
8	None	Q1X	Calibrate offsets
9	180pF	Q2, C, 0X	Use actual C value
10	47pF	Q3, C, 0X	Use actual C value
11	180μS	Q4, 0, GX	Use actual G value
12		R7X	Select 2nF range
13	None	Q1X	Calibrate offsets
14	1.8pF	Q2, C, 0X	Use actual C value
15	470pF	Q3, C, 0X	Use actual C value
16	1.8mS	Q4, 0, GX	Use actual value
17		R8X	Select 20nF range
18	None	Q1X	Calibrate offsets
19	18nF	Q2, C, 0X	Use actual C value
20	4.7nF	Q3, C, 0X	Use actual C value
21	18mS	Q4, 0, GX	Use actual G value

NOTE: Using this procedure will miscalibrate the unit for unattenuated use on 20pF/20μS through 2nF/2mS range.

1MHz Calibration

Follow the steps below in the order shown to calibrate the unit at 1MHz. Table 7-8 summarizes the procedure, commands, and necessary sources

1. Turn on the power and allow the unit to warm up for one hour. Send the command "S3T2X" to initialize the unit.
2. Send the command string "F1R2X" to select 1MHz and place the unit on the 20pF range.
3. With nothing connected to the test INPUT and OUTPUT jacks, send the command "Q1X" to calibrate offsets.
4. Connect the 18pF source to the instrument and send the command "Q2,C,0X" where C represents the actual C value at 1MHz.
5. Connect the 4.7pF source to the Model 590 and send the command "Q3,C,0X", using the actual C value at 1MHz.
6. Connect the 180μS source to the instrument and send "Q4,0,GX" where G is the actual value at 1MHz.
7. Repeat steps 7 through 11 for the 200pF and 2nF ranges by using the appropriate sources and the R3 and R4 commands, as summarized in Table 7-8.

Table 7-8. 1MHz Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	Initialize 590
2		F1R2X	Select 1MHz, 20pF range
3	None	Q1X	Calibrate offsets
4	18pF	Q2, C, 0X	Use actual C value
5	4.7pF	Q3, C, 0X	Use actual C value
6	180μS	Q4, 0, GX	Use actual G value
7		R3X	Select 200pF range
8	None	Q1X	Calibrate offsets
9	180pF	Q2, C, 0X	Use actual C value
10	47pF	Q3, C, 0X	Use actual C value
11	1.8mS	Q4, 0, GX	Use actual G value
12		R4X	Select 2nF range
13	None	Q1X	Calibrate offsets
14	1.8nF	Q2, C, 0X	Use actual C value
15	470pF	Q3, C, 0X	Use actual C value
16	18mS	Q4, 0, GX	Use actual G value

Cable Correction Calibration

Use the procedure below to calibrate the driving point cable correction mode of the Model 590.

NOTE

If your Model 590 is equipped only with a 100kHz CV module, perform this procedure at 100kHz instead of 1MHz as indicated.

Perform the steps below in the indicated order. Table 7-9 summarizes the procedure, commands, and required sources.

1. Turn on the power and allow the Model 590 to warm up for at least one hour.
2. Send the command string "F1R4S3T2Z0X" to select 1MHz and place the unit on the 2nF range.
3. With nothing connected to the test INPUT and OUTPUT jacks, send the command "Q5X" to calibrate offsets.
4. Connect the 470pF capacitor to the test INPUT jack only using the right angle adapter supplied with the Model 5905. Short the source jack normally connected to the test OUTPUT using the supplied shorting plug.
5. Send the command "Q6,C,0X", using the actual 1MHz C value marked on the source.
6. Connect the 180pF source to the instrument (see step 4 for connections) and send the command "Q7,C,0X" where C represents the actual 1MHz C value.

Table 7-9. Driving Point Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2Z0X	Initialize 590
2		F1R4X	1MHz, 2nF range*
3	None	Q5X	Calibrate offsets
4	470pF	Q6, C, 0X	Use actual C value
5	180pF	Q7, C, 0X	Use actual C value

*Use F0R4X for 100kHz.

7.4 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices are designed to operate at high impedance levels for lower power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. In general, it should be assumed that all devices are static sensitive.

Use the precautions below when handling static-sensitive devices.

1. Transport such devices only in containers designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Always leave the devices in question in their orignal containers until ready for installation.
2. Remove the devices from their protective containers only at a properly-grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must also be properly grounded to the bench or table.
5. Use only anti-static type de-soldering tools.
6. Use only soldering irons with properly-grounded tips.
7. Once the device is installed on the PC board, it is usually adequately protected, and normal handling can resume.

7.5 DISASSEMBLY

The following paragraphs contain disassembly procedures for the Model 590 and modules. In general, disassembly should be carried out in the order presented here unless otherwise noted. The various sections can be re-assembled by reversing the corresponding disassembly procedure.

WARNING
Disconnect the line cord and all other equipment from the instrument before beginning the disassembly procedure.

7.5.1 Top and Bottom Cover Removal

Refer to Figure 7-9 and remove the top or bottom cover using the corresponding procedure below.

Top Cover Removal

1. Remove the two screws that secure the top cover to the rear panel.
2. Carefully slide the top cover to the rear of the instrument until it is completely clear of the case sides then remove it.

Bottom Cover Removal

1. Place the Model 590 upside down on a soft cloth to avoid scratching the case.
2. Remove the two screws that secure the cover to the rear panel.
3. Remove the four feet located on the bottom cover.
4. Slide the bottom cover to the rear of the instrument until it is free of the case and remove it completely.

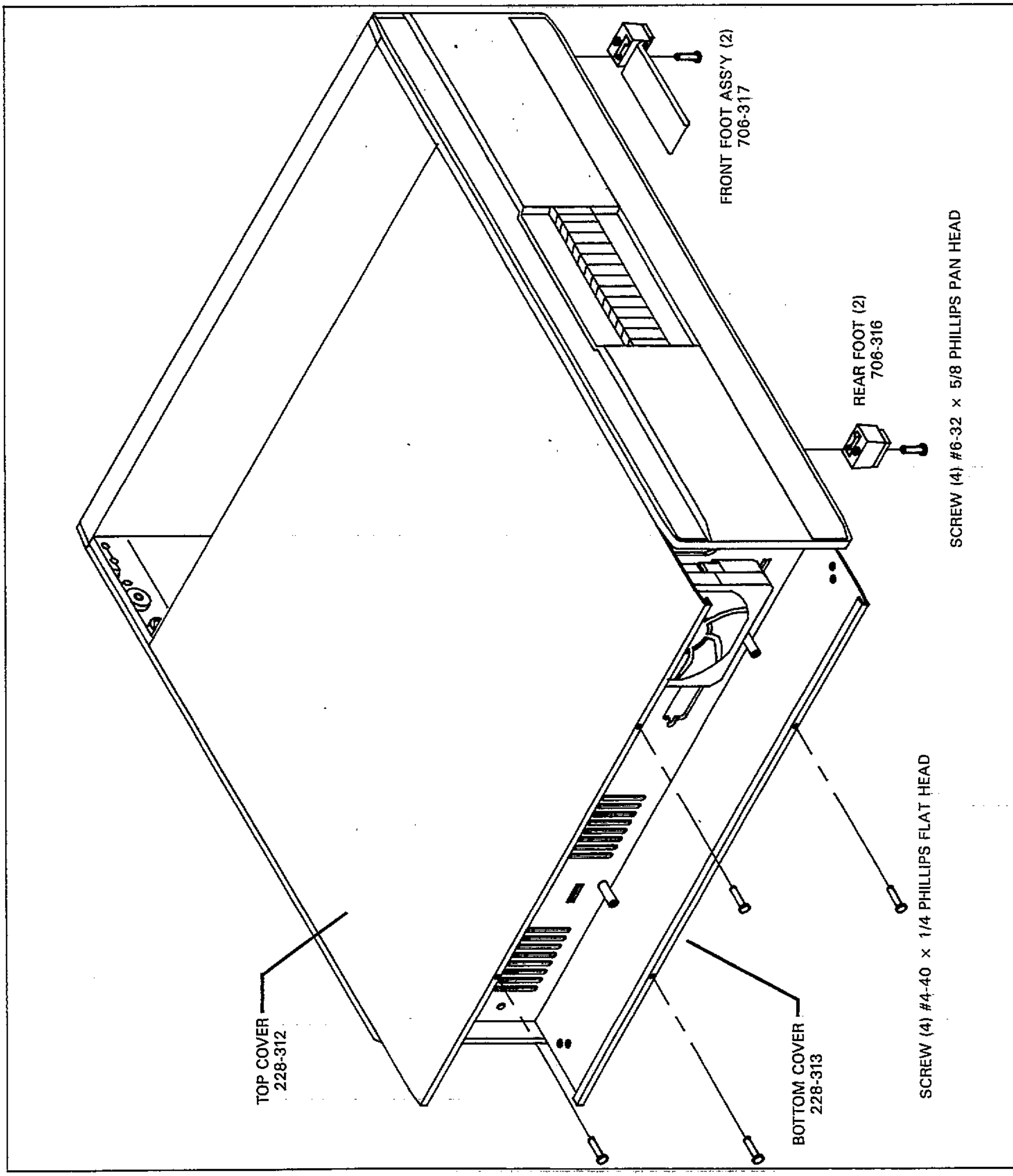


Figure 7-9. Top and Bottom Cover Removal

7.5.2 Module and Circuit Board Removal and Replacement

Removal and replacement of the modules and circuit boards is covered below. These items should be removed in the order shown and replaced in reverse order. General module and circuit board configuration is shown in Figure 7-10, while cable connections are shown in Figure 7-11.

Removal

1. Remove the rear panel in the following manner:
   A. Remove the two screws that secure the IEEE-488 connector to the rear panel.
   B. Remove the four screws that secure the rear panel to the case sides (two screws on each side).
   C. Pull the rear panel an inch or so away from the instrument to allow access to the various connectors. Be careful not to excessively strain the wires.
   D. Disconnect the four coaxial connectors going to the rear panel at the A/D board end.
   E. Disconnect the line and fan wiring connectors from the digital board.
   F. Disconnect the grounding strap.
   G. Remove the rear panel completely.
2. Remove the module support tray and modules as follows:
   A. Disconnect all cables going to the 5901 (100kHz) or 5902 (1MHz) modules.
   B. To remove a module from the support tray, take out the screws that secure the module to the tray, then remove the module.
   C. Remove the screws that attach the support tray to the top case rails and then remove the tray with modules still attached from the unit.
3. The mother board can be removed as follows:
   A. If the rear panel has been removed, go on to step B. Otherwise use a small screwdriver to pry out the upper trim strip from each case side, then remove the screws that attach the upper support rails. Remove the support rails from the unit.
   B. Disconnect the two cables connected to the digital board.
   C. Disconnect the two coaxial cables going to the front panel test jacks.
   D. Turn the instrument upside down, and remove the six screws that secure the mother board to the bottom support rails.
   E. Place the unit right side up, and remove the A/D board.
4. Remove the digital board using the procedure below:
   A. Disconnect the display board ribbon cable at the front of the board.
   B. Turn the instrument upside down, and remove the six screws that attach the board to the bottom support rails.
   C. Turn the instrument right side up, slide the board to the rear to clear the power switch, and remove the board.

Circuit Board and Module Installation

In general, the boards and modules can be installed by reversing the above procedure. However, the following points should be noted when installing these items:

1. Make sure that all screws are properly installed.
2. Make sure the all connectors are properly replaced, using Figure 7-11 as a guide. In particular check to see that module connections are not interchanged (5901, 100kHz and 5902, 1MHz connections are marked on the mother board.
3. Pay particular attention to the installation of ribbon cables, as it is possible to improperly position these cables so that the connector is one or more pins off.
4. Make sure that the rear panel is properly attached to the case, and that the IEEE-488 connector screws are securely tightened.

7.5.3 Case Disassembly

At this point in the disassembly process, the top support rails and rear panel should have already been removed. Use the procedure below to complete case disassembly, using Figure 7-12 as a guide.

1. Using a small screwdriver, pry the bottom trim strips from the case sides.
2. Remove the four screws that secure the front panel to the case sides and then remove the front panel.
3. Remove the two screws that attach each of the three bottom rails to the case sides and remove the three rails.
4. If desired, remove the two screws that attach each handle to the case sides. Compress the handle and guide it through the slots to remove it.
5. When re-assembling the case, make sure that the top and bottom rails are installed in the correct positions, or it will not be possible to properly secure the module support tray and circuit boards that attach to the rails.

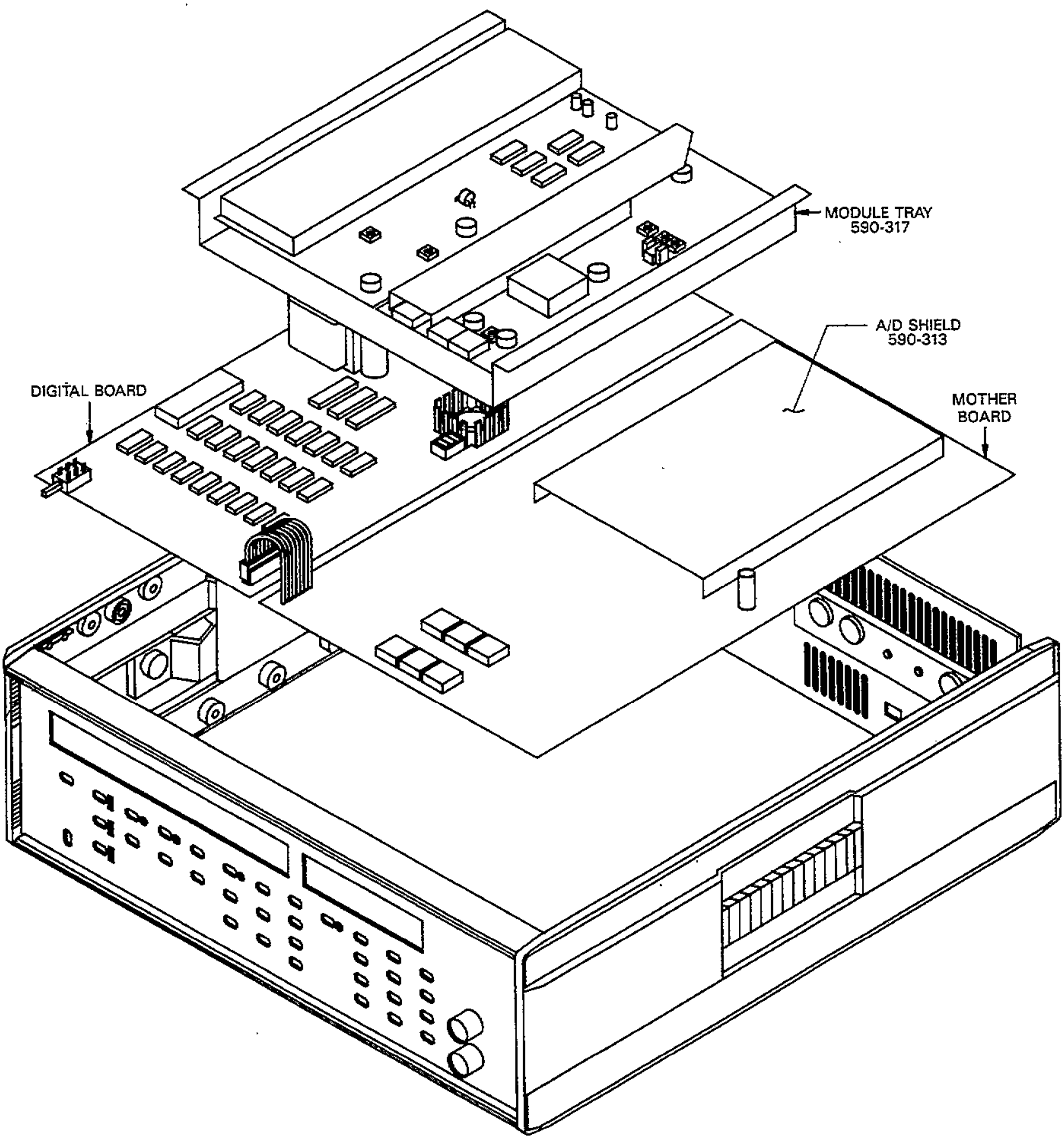


Figure 7-10. Circuit Board Removal and Replacement

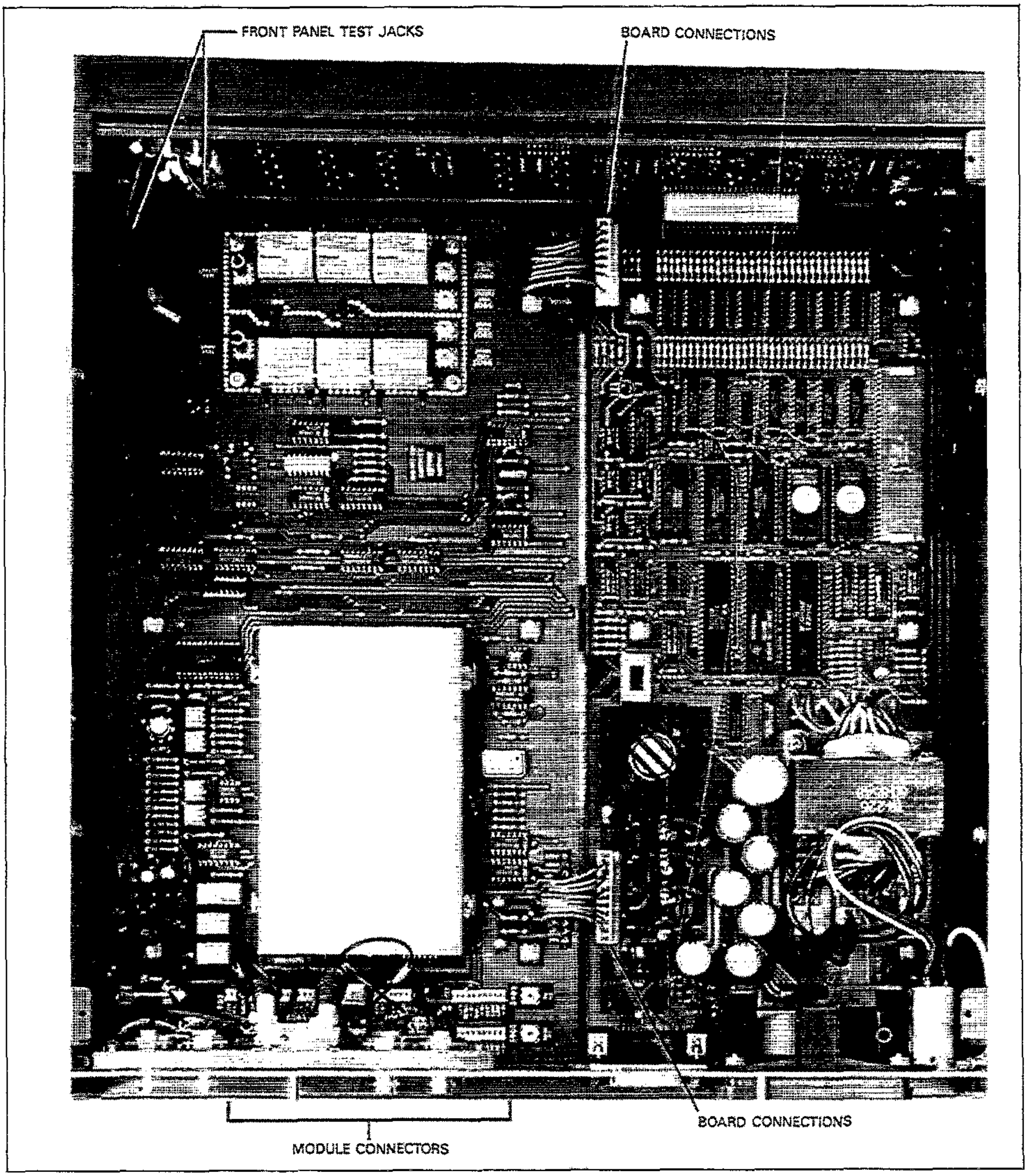


Figure 7-11. Cable Connections

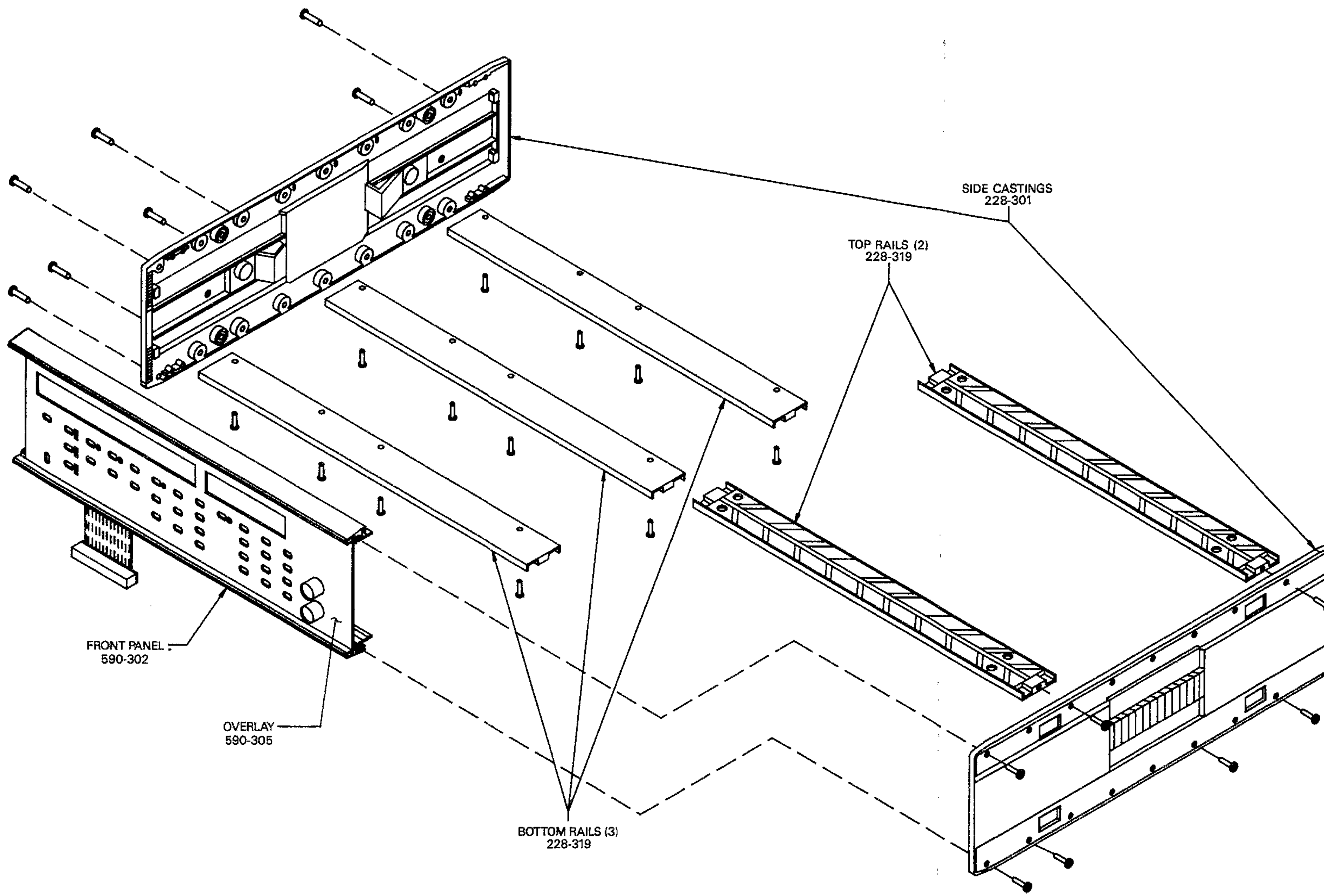


Figure 7-12. Case Disassembly

7.5.4 Rear Panel Disassembly

Refer to Figure 7-13 and remove parts from the rear panel as follows:

1. Remove the four screws that secure the fan and fan guard and remove them.
2. Remove the nut that holds the green ground wire to the rear panel and disconnect the wire.
3. Remove the two nuts that secure the line receptacle/filter and remove it.
4. To remove the four BNC jacks, remove the screws that secure the bracket to the rear panel, and remove the bracket.
5. When installing these parts, make certain all screws and nuts are tight, and that the ground wires and capacitor solder lugs are properly secured.

WARNING
The ground wires must be properly installed to ensure continued protection against possible shock hazards.

7.5.5 Front Panel Disassembly

An exploded view of the front panel assemble is shown in Figure 7-14. Use the following procedure to disassemble the front panel.

1. Remove the screws that attach the test jack bracket to the front panel and remove the bracket.
2. Using an allen wrench, loosen the two allen screws that secure each front panel rail, and remove each rail.
3. Remove the remaining screw that secures the display board to the front panel, and remove the board.
4. Re-assemble the front panel as follows:
   A. Insert the display board between the top and bottom rails, but do not tighten the screws at this time.
   B. Attach the rail and board assembly to the case sides with four screws (two on each side).
   C. Align the buttons in the holes, making sure that no buttons are sticking. Now tighten the rail set screws to secure the display board.
   D. Tighten the screw holding the display board to the front panel.

7.6 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for qualified personnel who have a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment, as well as ordinary troubleshooting procedures.

This information has been written to assist in isolating a defective circuit or circuit section. Isolation of a specific component is left to the technician.

Schematic diagrams, component layout drawings, and parts lists for the various circuit boards within the instrument are located at the end of Section 8.

7.6.1 Recommended Test Equipment

Success in troubleshooting complex electronic equipment such as the Model 590 relies both on the skill of the technician and the use of accurate, reliable test equipment. Table 7-10 lists recommended equipment for troubleshooting the Model 590.

Table 7-10. Recommended Troubleshooting Equipment

Description	Manufacturer and Model	Use
5½ Digit DMM	Keithley; 196	DCV, ACV, resistance checks
Dual-trace 100MHz oscilloscope	Tektronix; 2235	Digital waveform checks
DC Calibrator	Fluke; 343	Accurate DC signal source

7.6.2 Self Test

The instrument has a built-in self-test program which can be used to locate some problems. To run the test, simply press the front panel SELF TEST button, or send the command J1X over the IEEE-488 bus. If a problem is found, the unit will display an appropriate message, as summarized in Table 7-11. To return the display to normal, press any key.

Table 7-11. Self Test Display Messages

Message	Description
MULTIPLIER FAIL	Hardware multiplier failure
INVALID	Test failure*
00000	ROM Error
AAAAA	RAM Error

*Indicates excessive offsets or possible range calibration problem.

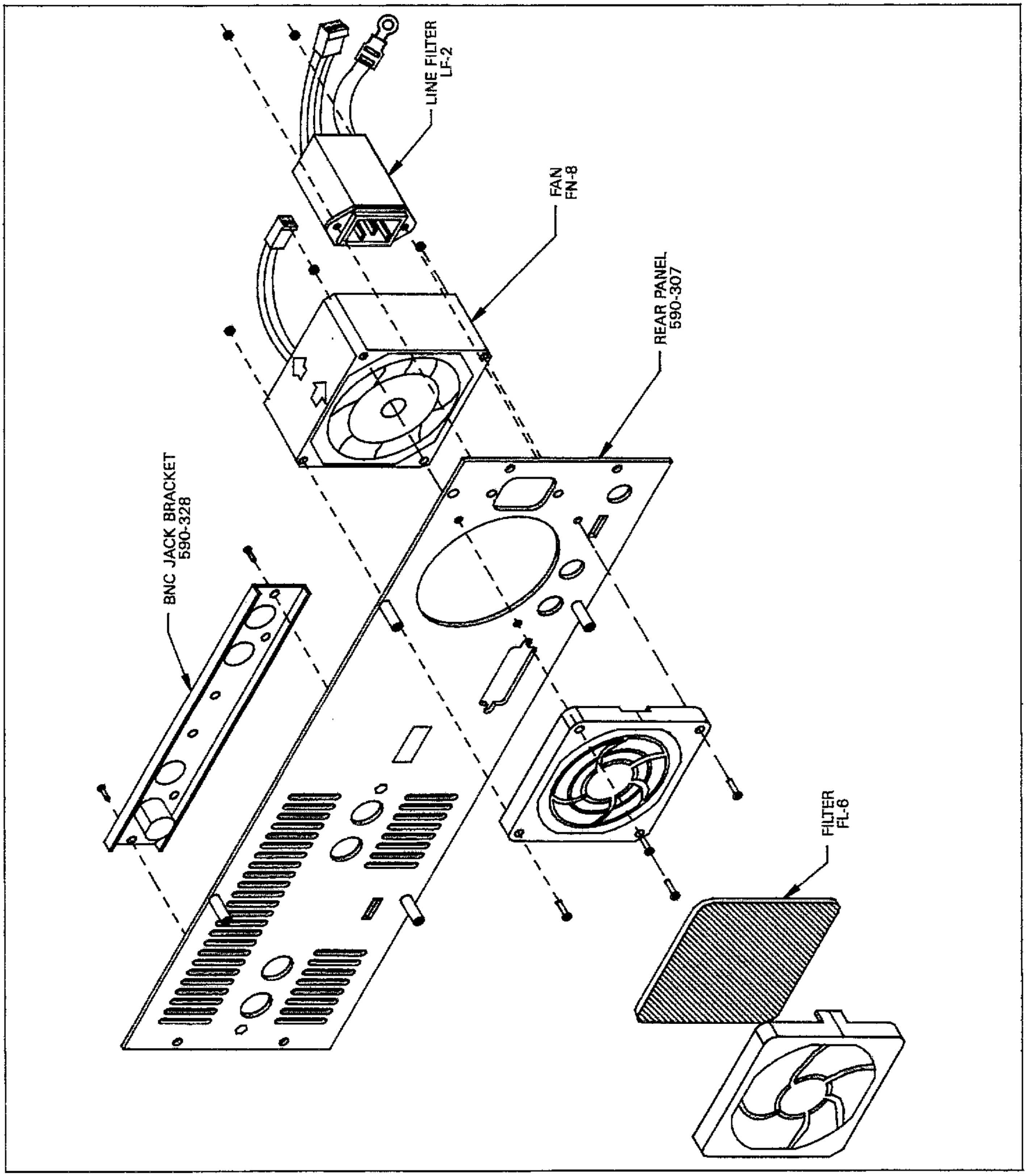


Figure 7-13. Rear Panel Disassembly

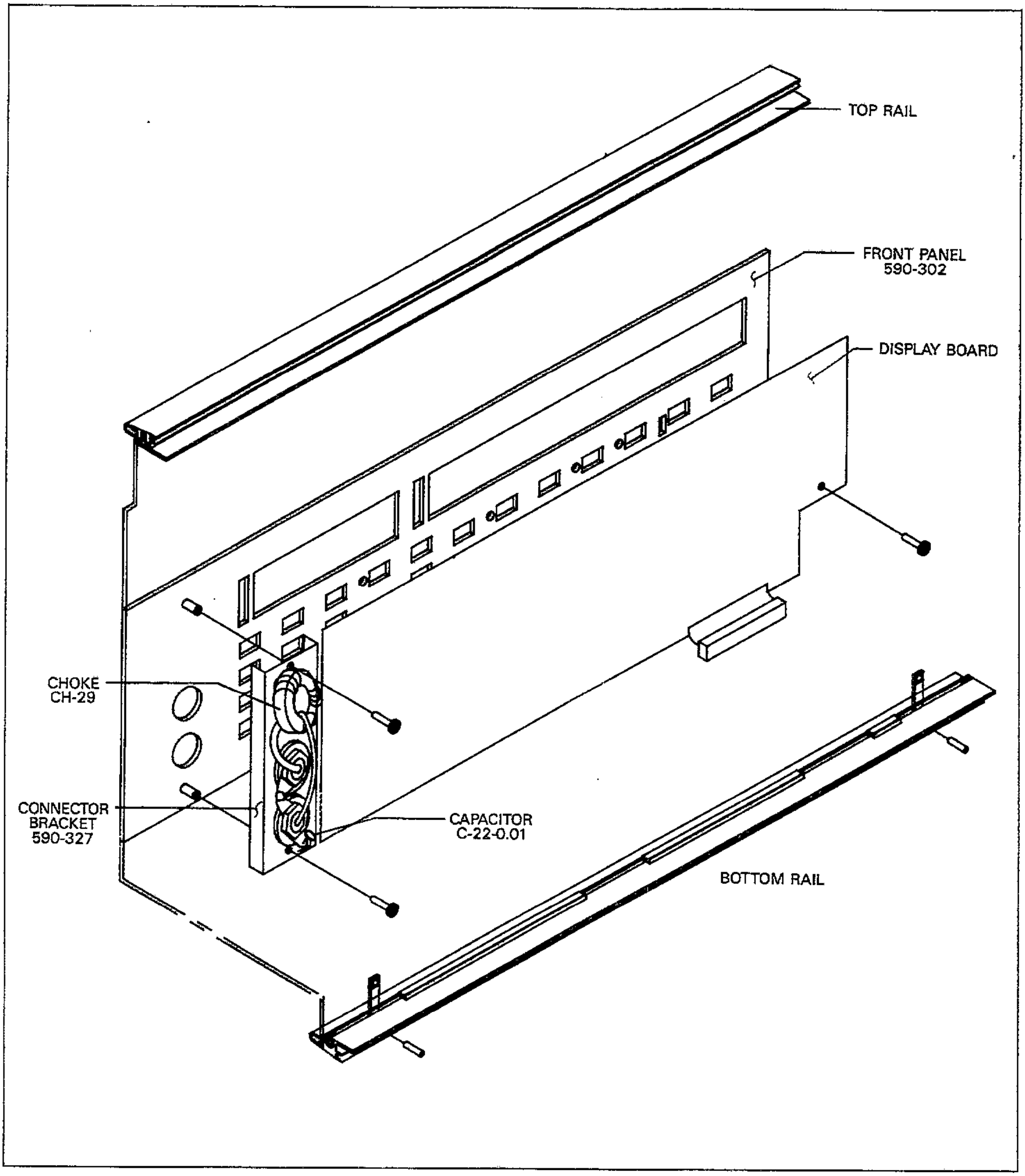


Figure 7-14. Front Panel Disassembly

7.6.3 Diagnostic Program

The diagnostic program can be used as an aid in tracing analog signals through to the input of the A/D converter. Basically, this program selects which of eight signals are routed to the converter for digitization.

Use the diagnostic program as follows:

1. Turn off the power if the instrument is presently turned on.
2. Turn on the power. When the initial Model 590 message is displayed, press and hold CAL until the unit enters the diagnostic program.
3. Use any front panel key to select which multiplexer FET is turned on, as indicated by the associated display message (Table 7-12).
4. To exit the diagnostic program, turn the power off.

Table 7-12. Diagnostic Program Summary

Display Message	Applied Signal*
5901 G	100kHz module conductance
5901 C	100kHz module capacitance
5902 G	1MHz module conductance
5902 C	1MHz module capacitance
COMMON	Analog common
V INT	Internal voltage source
V EXT	External voltage source
V REF	Internal voltage reference source

*Indicated signal is constantly applied to A/D converter input while message is displayed.

7.6.4 Troubleshooting Sequence

The exact troubleshooting sequence will, of course, depend on the particular problem. However, the general sequence shown in the flow chart of Figure 7-15 can be used in many cases. The simplified block diagram in Figure 7-16 indicates which table to consult for procedures to check out various circuits.

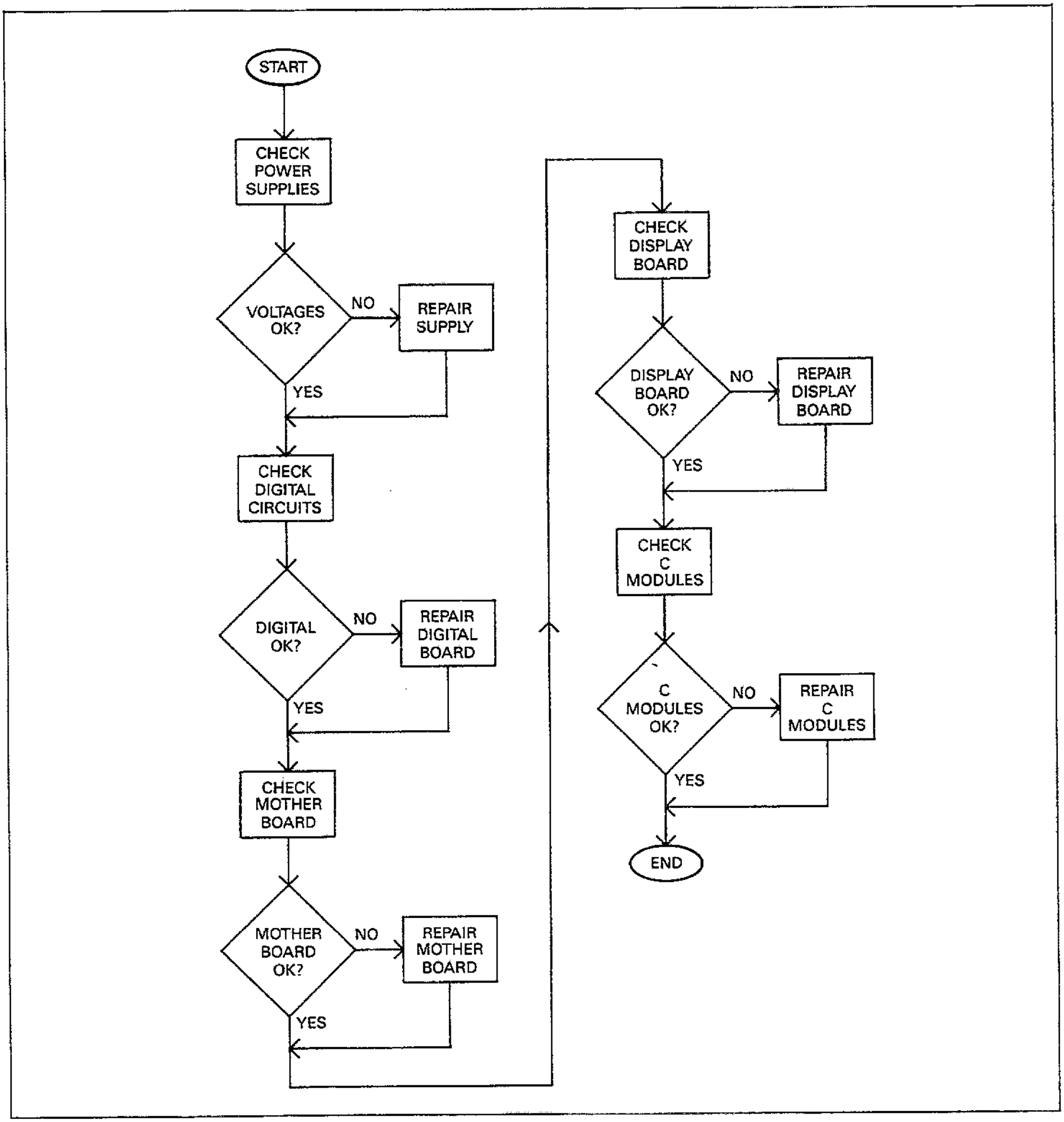


Figure 7-15. Troubleshooting Flow Chart

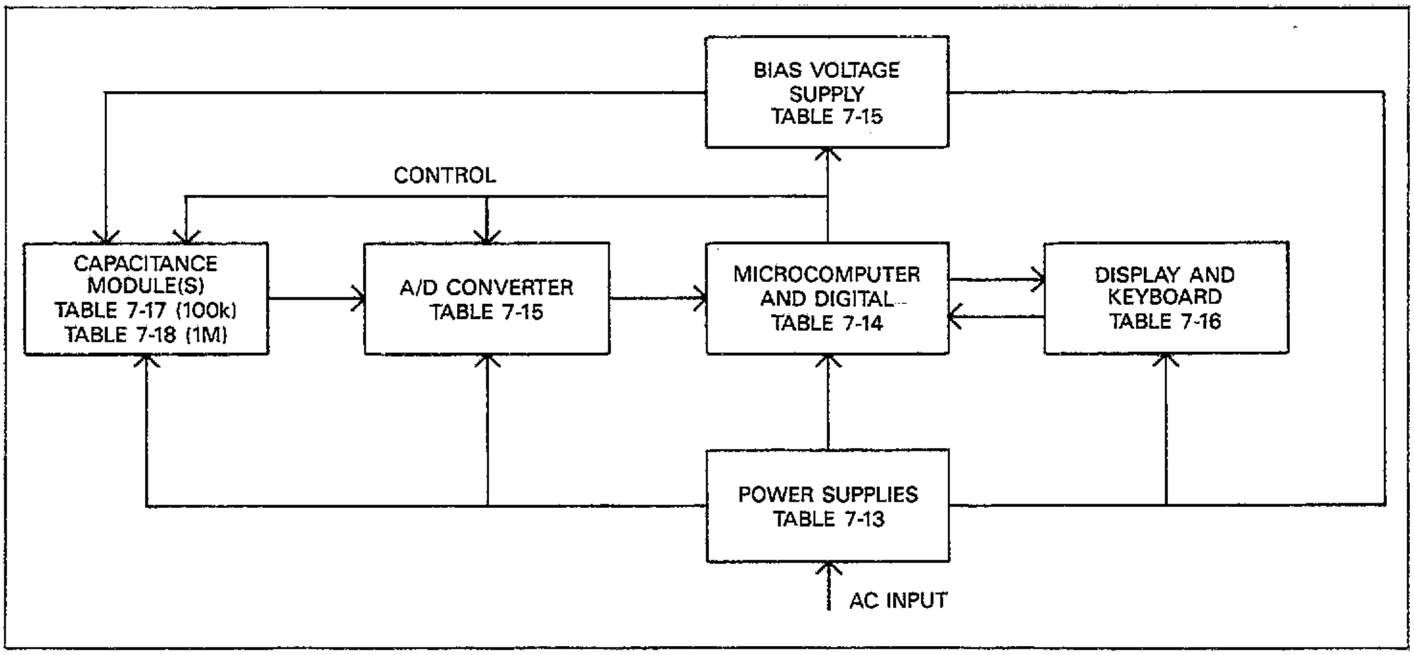


Figure 7-16. Troubleshooting Block Diagram

7.6.5 Power Supply Checks

The various power supplies should be checked first to make sure that all are operating as intended. If the various operating voltages are not within required limits, troubleshooting the remaining circuitry can be quite difficult, if not impossible.

Table 7-13 summarizes the procedure for checking the various power supply voltages. In addition to the usual voltage checks, it is a good idea to check the supplies with an oscilloscope to make sure that no noise or ripple is present.

7.6.6 Microcomputer and Digital Circuitry Checks

Table 7-14 summarizes the procedure to check out the microcomputer and other digital circuitry located on the digital board.

7.6.7 Mother Board

Two of the more important circuits located on the mother board are the A/D converter and the voltage bias source. Check these and other circuits on the board using the procedure summarized in Table 7-15.

7.6.8 Display Board

Check out the display board, including the display and keyboard circuits, by using the procedure in Table 7-16. If some of the signals are incorrect, the problem may be on the digital board.

7.6.9 100kHz and 1MHz Capacitance Modules

Table 7-17 gives the procedure for checking out the 100kHz (5901) capacitance module, and Table 7-18 lists a similar procedure for troubleshooting the 1MHz (5902) capacitance module.

7.7 FAN FILTER CLEANING AND REPLACEMENT

The fan filter, which is located on the rear panel, should be checked periodically for dirt build-up, and cleaned or replaced, as necessary. Use the following procedure to clean or replace the filter, using Figure 7-17 as a guide.

1. Disconnect the line cord from the power line receptacle.
2. Grasp the filter holder, and pull it free of the rear panel.
3. Remove the filter element from the holder.

4. Soak the filter in a solution of warm water and mild detergent until clean. Rinse thoroughly in clean water, and allow the filter to dry completely before installation. If a new filter assembly is required, one may be obtained from Keithley Instruments, Inc. Order part number FL-6.

NOTE

Do no operate the instrument with the filter removed to avoid dirt build-up within the instrument.

5. If necessary, clean the fan guard with a damp cloth.
6. Install the filter element in the holder and snap the holder back onto the fan guard. The two tabs on the holder should be oriented at the top and bottom.

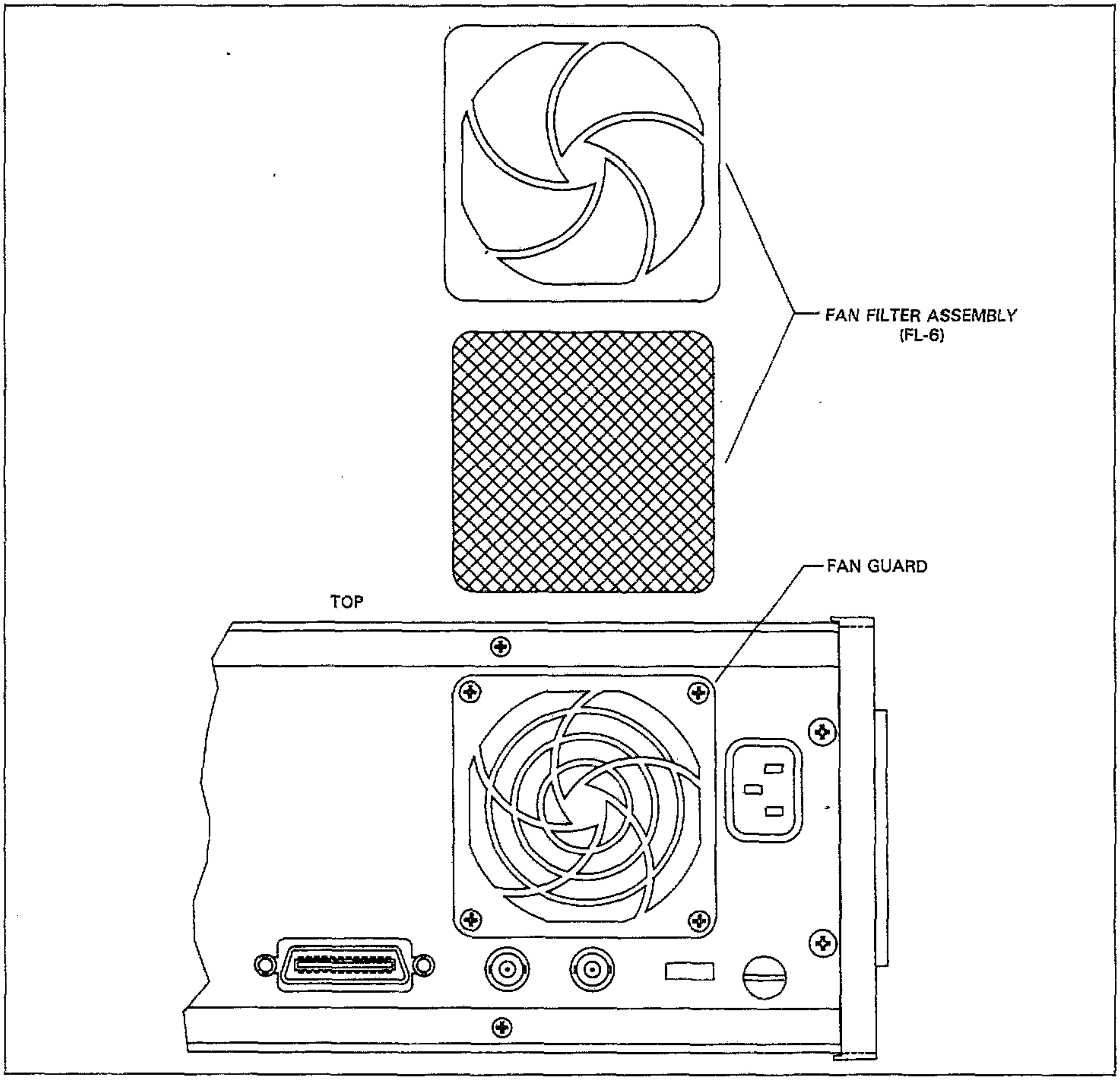


Figure 7-17. Fan Filter Removal

Table 7-13. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S302 (Line voltage select)	115V or 230V as required	Operate on correct voltage
2	Line fuse (F300)	Continuity	Check with ohmmeter
3	Power on		Plugged into live outlet
4	VR300, pin 1	+11V, ±20%	Referenced to analog common
5	VR300, pin 2	+5V, ±5%	Referenced to analog common
6	VR301, pin 2	−11V, ±20%	Referenced to analog common
7	VR301, pin 3	−5V, ±5%	Referenced to analog common
8	VR302, pin 1	+23V, ±20%	Referenced to analog common
9	VR302, pin 2	+15V, ±5%	Referenced to analog common
10	VR303, pin 2	−23V, ±20%	Referenced to analog common
11	VR303, pin 3	−15V, ±5%	Referenced to analog common
12	Q300, collector	+43V, ±20%	Referenced to analog common
13	Q300, emitter	+30V, ±5%	Referenced to analog common
14	Q301, collector	−43V, ±20%	Referenced to analog common
15	Q301, emitter	−30V, ±5%	Referenced to analog common
16	VR304, pin 1	+12V, ±20%	Referenced to digital common
17	VR304, pin 2	+5V, ±5%	Referenced to digital common

Table 7-14. Microcomputer and Digital Checks

Step	Item/Component	Required Condition	Remarks
1			All signals referenced to digital common
2	U315, pin 37	Goes low for ≈700msec upon power up, then stays high.	RESET signal
3	U315, pin 38	8MHz square wave	MPU clock
4	U315, pin 34	2MHz square wave	E clock
5	U315, pin 35	2MHz square wave	Q clock
6	U315, pin 3	976Hz square wave	1.024msec IRQ clock
7	U315, pins 24-31	Data bus (D0-D7)	Check for stuck bit
8	U315, pins 8-23	Address bus (A0-A15)	Check for stuck bit
9	U321A, pin 2	Variable pulses	A/D status information
10	U332, pin 1	Varying pulses	A/D data
11	U316A, pin 2	Pulse train	Serial clock
12	U316B, pin 4	Pulse train	Serial control data
13	U316C, pin 6	Pulse train	Serial control strobe
14	U313, pin 25	2MHz square wave	VIA clock
15	U311, pin 18	2MHz square wave	IEEE chip clock
16	U313, pins 13-16	Pulse train	A/D data

Table 7-15. Mother Board Checks

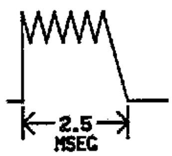
Step	Item/Component	Required Condition	Remarks
1	Signal reference		All voltages referenced to analog common
2	U134, pin 5	8MHz square wave	8MHz clock
3	U134, pin 7	4MHz square wave	4MHz clock
4	U133, pin 11	800kHz square wave	800kHz clock
5	U119, pin 15	Pulse train	Serial control data
6	U119, pin 6	Pulse train	Serial control clock
7	U119, pin 12	Pulse train	Serial control strobe
8	Programming	Select DC waveform, −19V default bias	Sweep inactive
9	U127, pin 15	+9.25V	DAC output
10	U128, pin 6	+9.25V	
11	Q123 emitter	−19V	Voltage source output
12	Programming	Program +19V default bias	
13	U127, pin 15	+9.25V	DAC output
14	U128, pin 6	−9.25V	
15	Q123 emitter	+19V	Voltage source output
16	F100	Check continuity	External bias fuse
17	U104, pin 10	4MHz square wave	A/D clock
18	U106, pin 6	50kHz pulse train	During active sweep
19	U106, pin 2	100kHz pulse train	During active sweep
20	U105, pin 6	400kHz pulse train	During active sweep
21	U110, pin 6		Integrator waveform during sweep
22	U113, pin 1	−10V DC	−10V reference
23	Q110 emitter	+5V DC	+5V reference
24	R122, R123 function	+1V	A/D reference
25	CAL button	Press and hold during power up	Enter diagnostic program
26	Display	Press any key until VREF message is displayed.	
27	U100, pin 1	+1V DC	

Table 7-16. Display Board Checks

Step	Item/Component	Required Condition	Remarks
1	Self Test	Display segments and LEDs	All on at start of self test
2	U201 pins 10-16	Digit select pulses	All voltages referenced to digital common
3	U202 pins 10-16	Digit select pulses	
4	U203 pins 10-16	Digit select pulses	
5	U204, pin 2	1msec negative going pulse every 10msec when S201-S204 closed	Switch matrix strobe
6	U204, pin 2	1msec pulse every 10msec when S205-S208 closed	
7	U204, pin 6	1msec pulse every 10msec when S209-S212 closed	
8	U204, pin 12	1msec pulse every 10msec when S213-S216 closed	
9	U204, pin 10	1msec pulse every 10msec when S217-S220 closed	
10	U204, pin 8	1msec pulse every 10msec when S221-S224 closed	
11	U205, pin 2	1msec pulse every 10msec when S225-S228 closed	
12	U205, pin 4	1msec pulse every 10msec when S229-S232 closed	
13	U205, pin 6	1msec pulse every 10msec when S233 closed	

Table 7-17. 100kHz Capacitance Module Checks

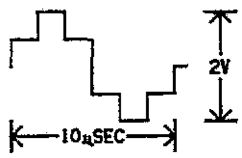
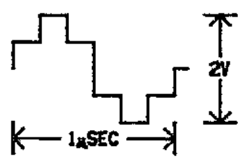
Step	Item/Component	Required Condition	Remarks
1	Reference point		Following voltages reference to digital common.
2	U502, pin 10	800kHz square wave	800kHz clock
3	U506, pin 10	100kHz square wave	Detector A signal
4	U506, pin 12	100kHz square wave	Detector B signal
5	U506, pin 8	100kHz square wave	Detector C signal
6	U506, pin 6	100kHz square wave	Detector D signal
7	Q500 base		Synthesized waveform
8	Reference point		Following voltages referenced to analog common
9	Q500 collector	100kHz, 10V p-p sine wave	Test frequency
10	U508, pin 6	100kHz, 1V p-p sine wave	Test frequency
11	Test output high	100kHz 42mV p-p sine wave	Test frequency
12	U510, pin 6	+4VDC	AGC voltage
13	Range, frequency	Select 2nF range, 100kHz	
14	Reference capacitor	Connect full scale (1.8-2nF) capacitor between test INPUT and test OUTPUT jacks	Leave capacitor connected for following tests
15	U512, pin 6	100kHz, 175mV p-p sine wave	Amplitude depends on capacitance value
16	U513, pin 6	100kHz, 1V p-p sine wave	Amplitude depends on capacitance value
17	U514, pin 6	100kHz, 6.3V p-p sine wave	Amplitude depends on capacitance value
18	U515, pin 7	1.8-2V DC	Voltage analogous to applied capacitance
19	U515, pin 1	1.8-2V DC	Voltage analogous to applied capacitance
20	U516, pin 7	1.8-2V DC	Voltage analogous to applied capacitance
21	Test jacks	Connect 2mS conductance	Leave conductance connected for following tests
22	U517, pin 1	2V DC	Voltage depends on applied conductance
23	U517, pin 1	2V DC	Voltage depends on applied conductance
24	U516, pin 1	2V DC	Voltage depends on applied conductance

Table 7-18. 1MHz Capacitance Module Checks

Step	Item/Component	Required Condition	Remarks
1	Reference point		Following voltages referenced to digital common.
2	U602, pin 13	8MHz square wave	8MHz clock
3	U601, pin 4	1MHz square wave	Detector A signal
4	U601, pin 2	1MHz square wave	Detector B signal
5	U601, pin 6	1MHz square wave	Detector C signal
6	U601, pin 10	1MHz square wave	Detector D signal
7	Q601 base		Synthesized waveform
8	Reference point		Following voltages referenced to analog common
9	Q601 collector	1MHz, 12V p-p sine wave	Test frequency
10	U606, pin 6	1MHz, 4.5 p-p sine wave	Test frequency
11	Test output high	1MHz, 42mV p-p sine wave	Test frequency
12	U608, pin 6	+3VDC	AGC voltgae
13	Range, frequency	Select 2nF range, 1MHz	
14	Reference capacitor	Connect full scale (2nF) capacitor between test INPUT and test OUTPUT jacks	Leave capacitor connected for following tests
15	U610, pins 7 and 8	1MHz, 300mV p-p sine wave	Amplitude depends on capacitance value
16	U611, pins 7 and 8	1MHz, 2.5V p-p sine wave	Amplitude depends on capacitance value
17	U612, pin 8	1MHz, 5V p-p sine wave	Amplitude depends on capacitance value
18	U614, pin 6	1.8-2V DC	Voltage is analogous to capacitance
19	U617, pin 1	1.8-2V DC	Voltage is analogous to capacitance
20	U616, pin 1	1.8-2V DC	Voltage is analogous to capacitance
21	Test jacks	Connect 20mS conductance	Leave conductance connected for following tests
22	U615, pin 6	2V DC	Voltage depends on conductance value
23	U617, pin 7	2V DC	Voltage depends on conductance value
24	U616, pin 7	2V DC	Voltage depends on conductance value

SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 590 CV Analyzer, as well as the 100kHz and 1MHz capacitance modules. Also included is an exploded view showing the general mechanical layout of the instrument for parts identification.

8.2 ELECTRICAL PARTS LISTS

Electrical parts for the Model 590 circuit boards as well as the 100kHz and 1MHz modules are listed in Tables 8-1 through 8-6. Parts in each table are listed alphabetically in order of circuit designation. The parts lists are integrated with the component layout drawings and schematic diagrams for the respective circuit boards.

8.3 MECHANICAL PARTS

Parts for the case assembly are listed in Table 8-7. Miscellaneous mechanical parts are listed in Table 8-8, while Table 8-9 lists parts for the Model 5904 Input Adapter. See the assembly drawings in Section 7 for the location of parts.

8.4 ORDERING INFORMATION

Keithley Instruments, Inc. maintains a complete inventory of all normal replacement parts. To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of this manual for addresses.

When ordering parts, include the following:

1. Instrument model number.
2. Instrument serial number.
3. Part description.
4. Circuit designation, including schematic diagram and component layout numbers (if applicable).
5. Keithley part number.

8.5 FACTORY SERVICE

If the instrument or modules are to be returned to the factory for service, carefully pack them and include the following information:

1. Complete the service form at the back of this manual and return it with the instrument.
2. Advise as to the warranty status of the instrument (see the inside front cover of this manual for warranty information.
3. Write the following on the shipping label: ATTENTION REPAIR DEPARTMENT.

8.6 COMPONENT LOCATION DRAWINGS AND SCHEMATIC DIAGRAMS

Component location drawings and schematic diagrams for the various circuit boards can be found on the following pages arranged as follows:

Board	Component Layout Number	Schematic Diagram Number	Parts Table Number
Mother	590-100	590-106	8-1
Display	590-110	590-116	8-2
Digital	590-120	590-126	8-3
5901 (100kHz)	5901-100	5901-106	8-4
5902 (1MHz)	5902-100	5902-106	8-5
KI590 Op Amp (U607)	5902-180	5902-186	8-6

Table 8-1. Mother Board, Parts List

Circuit Designation	Description	Keithley Part Number
C100	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C101	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C102	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C103	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C104	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C105	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C106	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C107	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C108	Capacitor, 470pF, Ceramic Disc	C-64-470p
C109	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C110	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C111	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C112	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C113	Capacitor, 0.001μF, Ceramic Disc	C-64-0.001
C114	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C115	Capacitor, 0.0047μF, 10%, 100V, Metallized Polypropylene	C-306-0.0047
C116	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C117	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C118	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C119	Capacitor, 0.47μF, 50V, Ceramic Film	C-237-0.47
C120	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C121	Capacitor, 100pF, Ceramic Disc	C-64-100p
C122	Capcitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C123	Capcitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C124	Capcitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C125	Capacitor, 0.1μF, 250V, Metallized Polyester	C-178-0.1
C126	Capacitor, 220pF, Ceramic Disc	C-64-220p
C127	Capacitor, 0.001μF, 500V, Ceramic Disc	C-22-0.001
C128	Capacitor, 10μF, 35V, Aluminum Electrolytic	C-309-10
C129	Capacitor, 10μF, 35V, Aluminum Electrolytic	C-309-10
C130	Capacitor, 0.1μF, 20%, 50V	C-365-0.01
C131	Capacitor, 0.1μF, 20%, 50V	C-365-0.01
C132	Capacitor, 0.1μF, 20%, 50V	C-365-0.01
C133	Capacitor, 0.1μF, 20%, 50V	C-365-0.01
C134	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C135	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C136	Capacitor, 200pF, 1%, 500V, Mica	C-209-200p
C137	Capacitor, 10μF, 16V, Aluminum Electrolytic	C-321-10
C138	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C139	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C140	Capacitor, 20pF, 5%, 500V Mica	C-236-20
C141	Not Used	
C142	Not Used	
C143	Not Used	
C144	Not Used	
C145	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
CR100	Diode, Silicon, 1N4148	RF-28
CR101	Diode, Silicon, 1N4148	RF-28
CR102	Diode, Silicon, 1N4148	RF-28
CR103	Diode, Silicon, 1N4148	RF-28

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
CR104	Diode, Silicon, 1N4148	RF-28
CR105	Diode, Silicon, 1N4148	RF-28
CR106	Diode, Silicon, 1N4148	RF-28
CR107	Not Used	
CR108	Diode, Silicon, 1N4148	RF-28
F100	Fuse, 1/8A, 250V, 8AG	FU-5
J1017	Connector, SMB Jack	CS-545
J1020	Connector	CS-533-9
J1021	Connector, Modified	590-320-1
J1023	Connector, SMB Jack	CS-545
J1024	Connector, SMB Jack	CS-545
J1025	Connector	CS-533-2
J1026	Connector	CS-533-10
J1027	Connector, Modified	590-320-1
J1029	Connector, SMB Jack	CS-545
J1030	Connector, SMB Jack	CS-545
J1031	Connector	CS-533-2
J1032	Connector, SMB Jack	CS-545
J1033	Connector, SMB Jack	CS-545
J1034	Connector, SMB Jack	CS-545
J1035	Connector, SMB Jack	CS-545
J1036	Connector, SMB Jack	CS-545
J1037	Connector, SMB Jack	CS-545
J1038	Connector, SMB Jack	CS-545
K100	Relay	RL-94
K101	Relay	RL-94
K102	Relay	RL-94
K103	Relay	RL-94
K104	Relay	RL-94
K105	Relay	RL-94
K106	Relay	RL-95
K107	Relay	RL-95
K108	Relay	RL-101
K109	Not Used	
K110	Not Used	
K111	Relay	RL-101
Q100	Transistor, N-Channel JFET, PF5301	TG-139
Q101	Transistor, N-Channel JFET, PF5301	TG-139
Q102	Transistor, N-Channel JFET, PF5301	TG-139
Q103	Transistor, N-Channel JFET, PF5301	TG-139
Q104	Transistor, N-Channel JFET, PF5301	TG-139
Q105	Transistor, N-Channel JFET, PF5301	TG-139
Q106	Transistor, N-Channel JFET, PF5301	TG-139
Q107	Transistor, N-Channel JFET, PF5301	TG-139
Q108	Transistor, N-Channel JFET, PF5301	TG-139
Q109	Transistor, N-Channel JFET, PF5301	TG-139
Q110	Transistor, Silicon, NPN, 2N3904	TG-47

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
Q111	Transistor, N-Channel FET, 2N4392	TG-128
Q112	Transistor, N-Channel FET, 2N5434	TG-174
Q113	Not Used	
Q114	Not Used	
Q115	Not Used	
Q116	Transistor, MP8099	TG-157
Q117	Transistor, Power, NPN, MJE240	TG-185
Q118	Transistor, Power, PNP, MJE250	TG-186
Q119	Transistor, Power, PNP, MPS8599	TG-158
Q120	Diode, Current Regulator, J505	TG-140
Q121	Diode, Current Regulator, J505	TG-140
Q122	Transistor, Silicon, PNP, 2N3906	TG-84
Q123	Transistor, Silicon, PNP, 2N3904	TG-47
Q124	Transistor, N-Channel FET, 2N4392	TG-128
R100	Resistor, Thick Film	TF-177-3
R101	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R102	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R103	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R104	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R105	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R106	Resistor, 200Ω, 0.1%, 1/10W, Metal Film	R-263-1k
R107	Resistor, 11.5kΩ, 1%, 1/8W	R-88-11.5k
R108	Resistor, 26.7kΩ, 1%, 1/8W	R-88-26.7k
R110	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R111	Resistor, 7.78kΩ, 0.1%, 1/8W	R-176-7.78k
R112	Resistor, 142.8kΩ, 0.1%, 1/8W	R-176-142.8k
R113	Resistor, 1MΩ, 0.1%, 1/8W	R-176-1M
R114	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R115	Resistor, 3.9kΩ, 5%, ¼W, Composition	R-76-3.9k
R116	Resistor, 3kΩ, 5%, ¼W, Composition	R-76-3k
R117	Resistor, 3kΩ, 5%, ¼W, Composition	R-76-3k
R118	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R119	Resistor, 220kΩ, 5%, ¼W, Composition	R-76-220k
R120	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R121	Resistor, 7.87kΩ, 1%, 1/8W	R-88-7.87k
R122	Resistor, 1kΩ, 0.1%, 1/10W, Metal Film	R-263-1k
R123	Resistor, 4kΩ, 0.1%. 1/10W, Metal Film	R-263-4k
R124	Resistor, 1.33kΩ, 0.1%, 1/10W, Metal Film	R-263-1.33k
R125	Resistor, 1kΩ, 1%, 1/8W	R-88-1k
R126	Resistor, 3.65kΩ, 1%, 1/8W	R-88-3.65k
R127	Resistor, 6.49kΩ, 1%, 1/8W	R-88-6.49k
R128	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R129	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R130	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R131	Resistor, Thick Film	TF-108
R132	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R133	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R134	Resistor, Thick Film	TF-179-1
R135	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R136	Not Used	

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R137	Resistor, 10kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-10k
R138	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R139	Resistor, 6.2kΩ, 5%, ¼W, Composition	R-76-6.2k
R140	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R141	Resistor, 6.2kΩ, 5%, ¼W, Composition	R-76-6.2k
R142	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R143	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R144	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R145	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R146	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R147	Resistor, 2.2MΩ, 5%, ¼W, Composition	R-76-2.2M
R148	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R149	Resistor, 20kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-20k
R150	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R151	Resistor, 20kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-20k
R152	Potentiometer, 10kΩ, ½W, Cermet	RP-97-10k
R153	Resistor, 301kΩ, 1%, $^1/_8$W	R-88-301k
R154	Resistor, 6.04kΩ, 1%, $^1/_8$W	R-88-6.04k
R155	Resistor, 301kΩ, 1%, $^1/_8$W	R-88-301k
R156	Potentiometer, 100kΩ, ½W, Cermet	RP-97-100k
R157	Potentiometer, 100kΩ, ½W, Cermet	RP-97-100k
R158	Resistor, 1MΩ, 1%, $^1/_8$W	R-88-1M
R159	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R160	Resistor, 49.9kΩ, 1%, $^1/_8$W	R-88-49.9k
R161	Resistor, 9.76kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-9.76k
R162	Resistor, 20kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-20k
R163	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R164	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R165	Resistor, 191kΩ, 1%, $^1/_8$W	R-88-191k
R166	Resistor, 200Ω, 5%, ¼W, Composition	R-76-200
R167	Resistor, 200Ω, 5%, ¼W, Composition	R-76-200
R168	Resistor, 12Ω, 5%, ¼W, Composition	R-76-12
R169	Resistor, 12Ω, 5%, ¼W, Composition	R-76-12
R170	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R171	Resistor, 866Ω, 1%, $^1/_8$W	R-88-866
R172	Resistor, 3.83kΩ, 1%, $^1/_8$W	R-88-3.83k
R173	Resistor, 6.19kΩ, 1%, $^1/_8$W	R-88-6.19k
R174	Resistor, Thick Film	TF-39
R175	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R176	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R177	Resistor, 866Ω, 1%, $^1/_8$W	R-88-866
R178	Resitor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R179	Resistor, Thick Film	TF-178-1
R180	Resistor, 1.8kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-1.8k
R181	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R182	Resistor, 990kΩ, 0.1%, ¼W, Metal Film	R-264-990k
R183	Resistor, 100kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-100k
R184	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R185	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R186	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R187	Not Used	

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R188	Resistor, 900kΩ, 0.1%, ¼W, Metal Film	R-264-900k
S100	Switch	SW-318
U100	IC, LF442A	IC-410
U101	IC, Triple 2-Channel Analog Mux, CD4053B	IC-283
U102	IC, Selected	31847-1
U103	IC, Quad 2-Input NAND Gate, 74HC00	IC-351
U104	IC, Quad 2-Input NOR Gate, 74HC02	IC-412
U105	IC, Synchronous Decade Counter, 74HC192	IC-417
U106	IC, Synchronous Binary Counter, 74HC193	IC-416
U107	IC, Quad Comparator, LM339	IC-219
U108	IC, Dual D Flip-Flop, 74HC74	IC-337
U109	IC, Dual D Flip-Flop, 74HC74	IC-337
U110	IC, Operational Amplifier, LM356	IC-209
U111	IC, Dual Comparator, LM393	IC-343
U112	IC, JFET Operational Amplifier, LM356	IC-209
U113	IC, Dual JFET Operational Amplifier, LF442C	IC-325
U114	IC, Quad Comparator, LM339	IC-219
U115	IC, 1-of-8 Decoder, 74HC138	IC-431
U116	IC, Quad Comparator, LM339	IC-219
U117	IC, Quad Comparator, LM339	IC-219
U118	IC, CMOS, Quad 2-Input NAND Gate, 4011	IC-102
U119	IC, CMOS, Hex Inverter, 4049	IC-106
U120	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U121	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U122	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U123	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U124	IC, Darlington Transistor Array, 2003	IC-206
U125	IC, CMOS 8-Stage Shift Register, 4021	IC-130
U126	IC, Quad Comparator, LM339	IC-219
U127	IC, D/A Converter, DAC80	IC-323
U128	IC, Operational Amplifier, AD-3247	IC-77
U129	IC, Quad Comparator, LM339	IC-219
U130	IC, High Voltage Operational Amplifier, LM343H	IC-432
U131	IC, Quad CMOS Analog Switch, DG211	IC-320
U132	Not Used	
U133	IC, Counter, 74LS90	IC-377
U134	IC, Dual Power MOSFET Driver, TSC426	IC-437
U135	IC, Hex Inverter, 74HC04	IC-354
VR100	Regulator, Zener Diode, 6.33V, 400mW, 1N4577A	DZ-58
VR101	Regulator, Zener Diode, 5.1V, 10%, 400mW, 1N751	DZ-59
Y100	Crystal, 8MHz, ±100ppm	CR-25-4

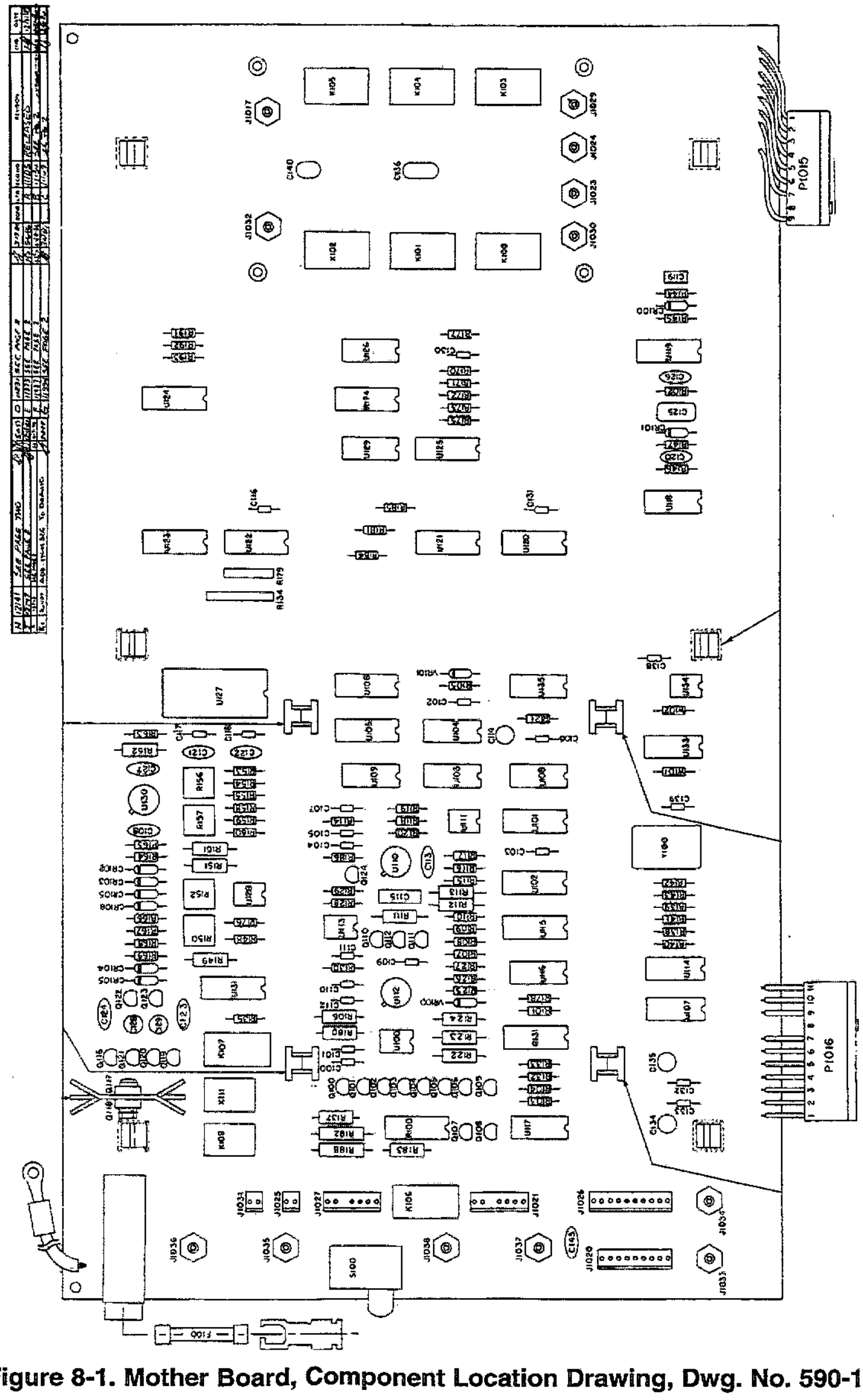


Figure 8-1. Mother Board, Component Location Drawing, Dwg. No. 590-100

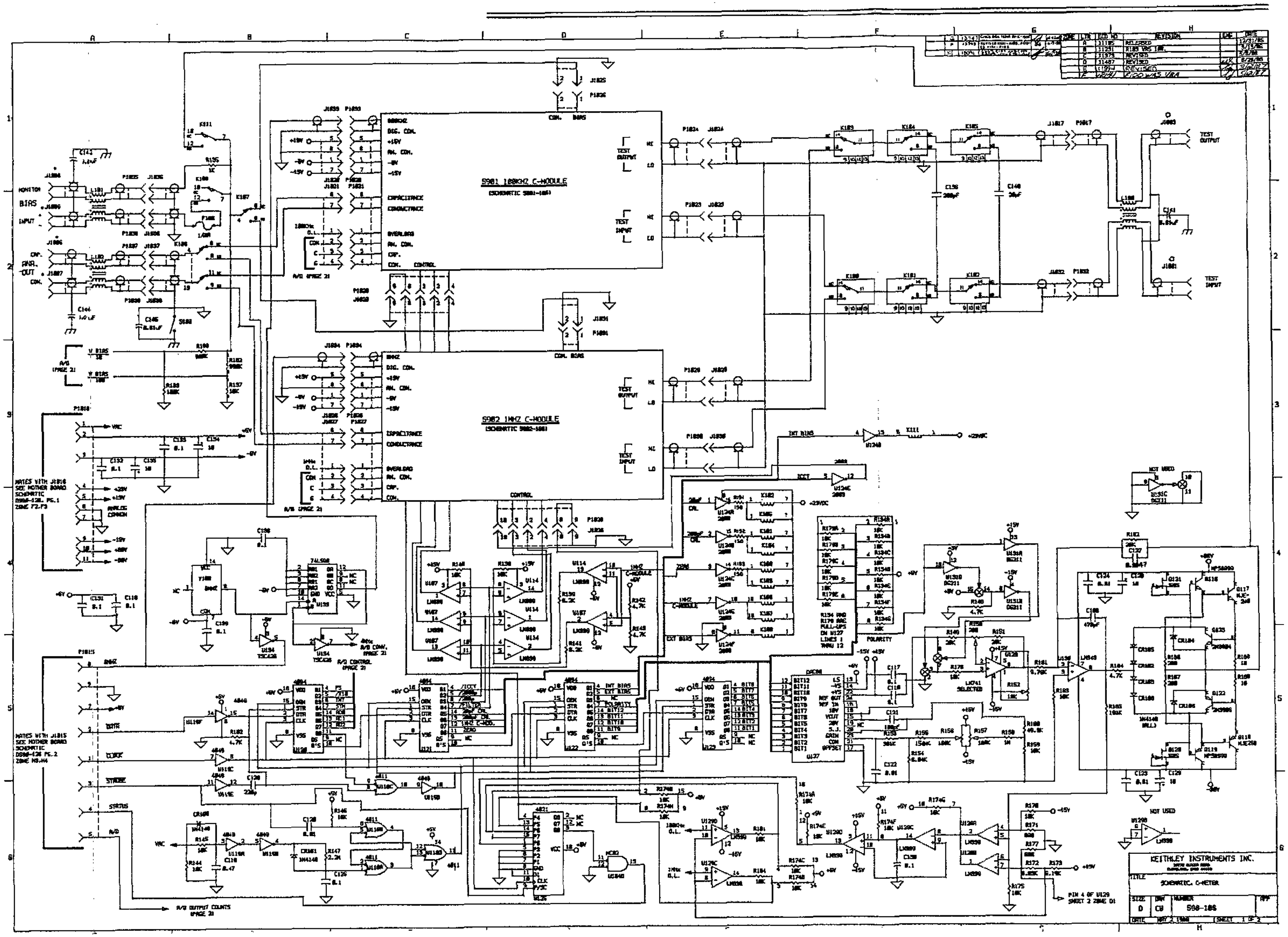


Figure 8-2. Mother Board, Schematic Diagram, Dwg. No. 590-106 (sheet 1 of 2)

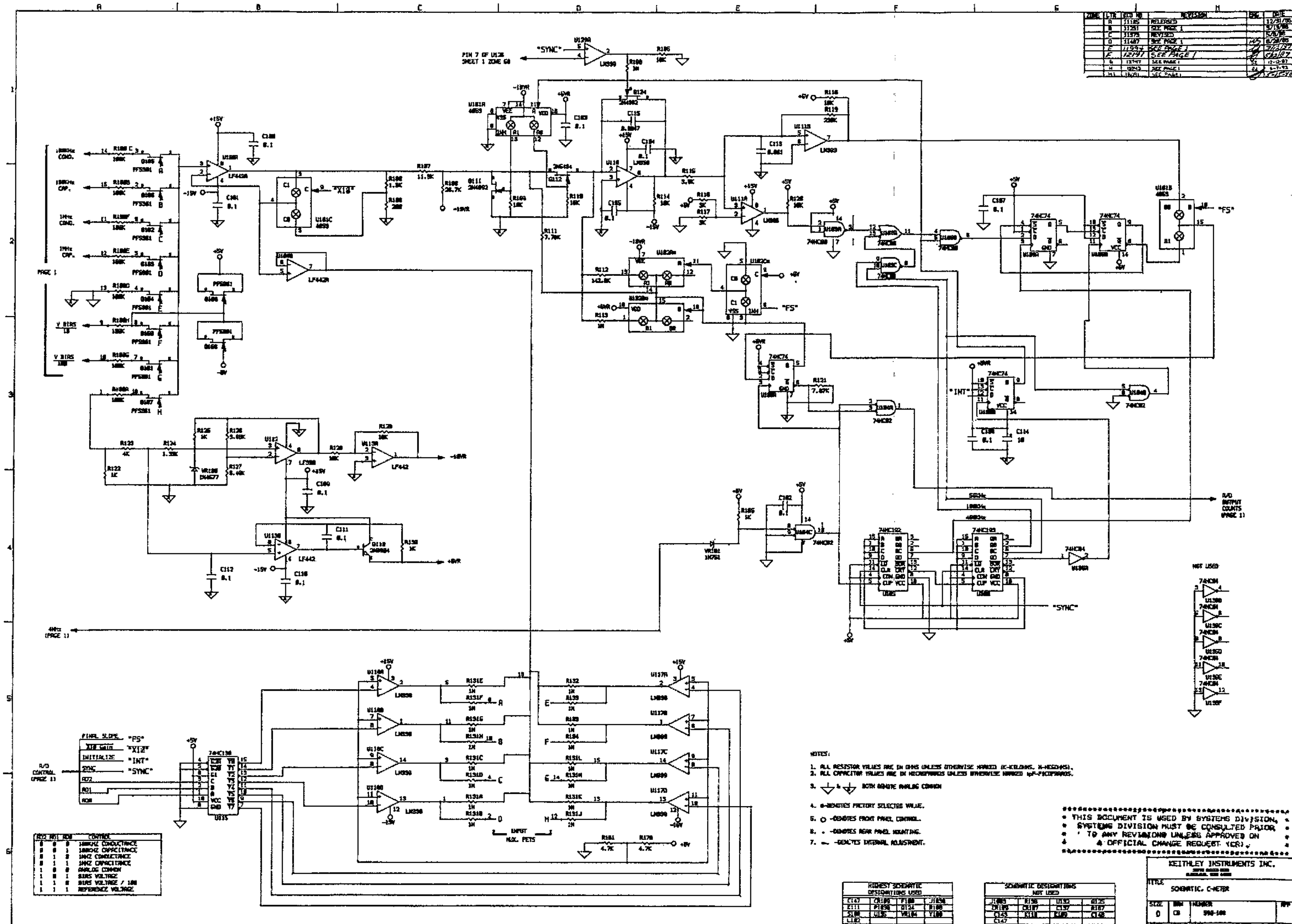


Figure 8-2. Mother Board, Schematic Diagram, Dwg. N. 590-106 (sheet 2 of 2)

Table 8-2. Display Board, Parts List

Circuit Designation	Description	Keithley Part Number
C201	Capacitor, 0.1μF, 20%, 50V	C-365-.1
C202	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
DS201	Digital Display, Dual-Digit, 14-Segment	DD-39
DS202	Digital Display, Dual-Digit, 14-Segment	DD-39
DS203	Digital Display, Dual-Digit, 14-Segment	DD-39
DS204	Digital Display, Dual-Digit, 14-Segment	DD-39
DS205	Digital Display, Dual-Digit, 14-Segment	DD-39
DS206	Digital Display, Dual-Digit, 14-Segment	DD-39
DS207	Digital Display, Dual-Digit, 14-Segment	DD-39
DS208	Digital Display, Dual-Digit, 14-Segment	DD-39
DS209	Digital Display, Dual-Digit, 14-Segment	DD-39
DS210	Digital Display, Dual-Digit, 14-Segment	DD-39
DS211	LED, Red	PL-71
DS212	LED, Red	PL-71
DS213	LED, Red	PL-71
DS214	LED, Red	PL-71
DS215	LED, Red	PL-71
DS216	LED, Red	PL-71
DS217	LED, Yellow	PL-72
DS218	LED, Red	PL-71
DS219	LED, Red	PL-71
DS220	LED, Red	PL-71
DS221	LED, Red	PL-71
DS222	LED, Red	PL-71
DS223	LED, Yellow	PL-72
P1014	Cable Assembly	CA-32-5
S201	Switch, Pushbutton Momentary Contact	SW-435
S202	Switch, Pushbutton Momentary Contact	SW-435
S203	Switch, Pushbutton Momentary Contact	SW-435
S204	Switch, Pushbutton Momentary Contact	SW-435
S205	Switch, Pushbutton Momentary Contact	SW-435
S206	Switch, Pushbutton Momentary Contact	SW-435
S207	Switch, Pushbutton Momentary Contact	SW-435
S208	Switch, Pushbutton Momentary Contact	SW-435
S209	Switch, Pushbutton Momentary Contact	SW-435
S210	Switch, Pushbutton Momentary Contact	SW-435
S211	Switch, Pushbutton Momentary Contact	SW-435
S212	Switch, Pushbutton Momentary Contact	SW-435
S213	Switch, Pushbutton Momentary Contact	SW-435
S214	Switch, Pushbutton Momentary Contact	SW-435
S215	Switch, Pushbutton Momentary Contact	SW-435
S216	Switch, Pushbutton Momentary Contact	SW-435
S217	Switch, Pushbutton Momentary Contact	SW-435
S218	Switch, Pushbutton Momentary Contact	SW-435
S219	Switch, Pushbutton Momentary Contact	SW-435
S220	Switch, Pushbutton Momentary Contact	SW-435
S221	Switch, Pushbutton Momentary Contact	SW-435
S222	Switch, Pushbutton Momentary Contact	SW-435

Table 8-2. Display Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
S223	Switch, Pushbutton Momentary Contact	SW-435
S224	Switch, Pushbutton Momentary Contact	SW-435
S225	Switch, Pushbutton Momentary Contact	SW-435
S226	Switch, Pushbutton Momentary Contact	SW-435
S227	Switch, Pushbutton Momentary Contact	SW-435
S228	Switch, Pushbutton Momentary Contact	SW-435
S229	Switch, Pushbutton Momentary Contact	SW-435
S230	Switch, Pushbutton Momentary Contact	SW-435
S231	Switch, Pushbutton Momentary Contact	SW-435
S232	Switch, Pushbutton Momentary Contact	SW-435
S233	Switch, Pushbutton Momentary Contact	SW-435
U201	Int. Circuit (2003)	IC-206
U202	Int. Circuit (2003)	IC-206
U203	Int. Circuit (2003)	IC-206
U204	Int. Circuit (74LS05)	IC-141
U205	Int. Circuit (74LS05)	IC-141
U206	Int. Circuit (74HCT164)	IC-456
U207	Int. Circuit (74HCT164)	IC-456

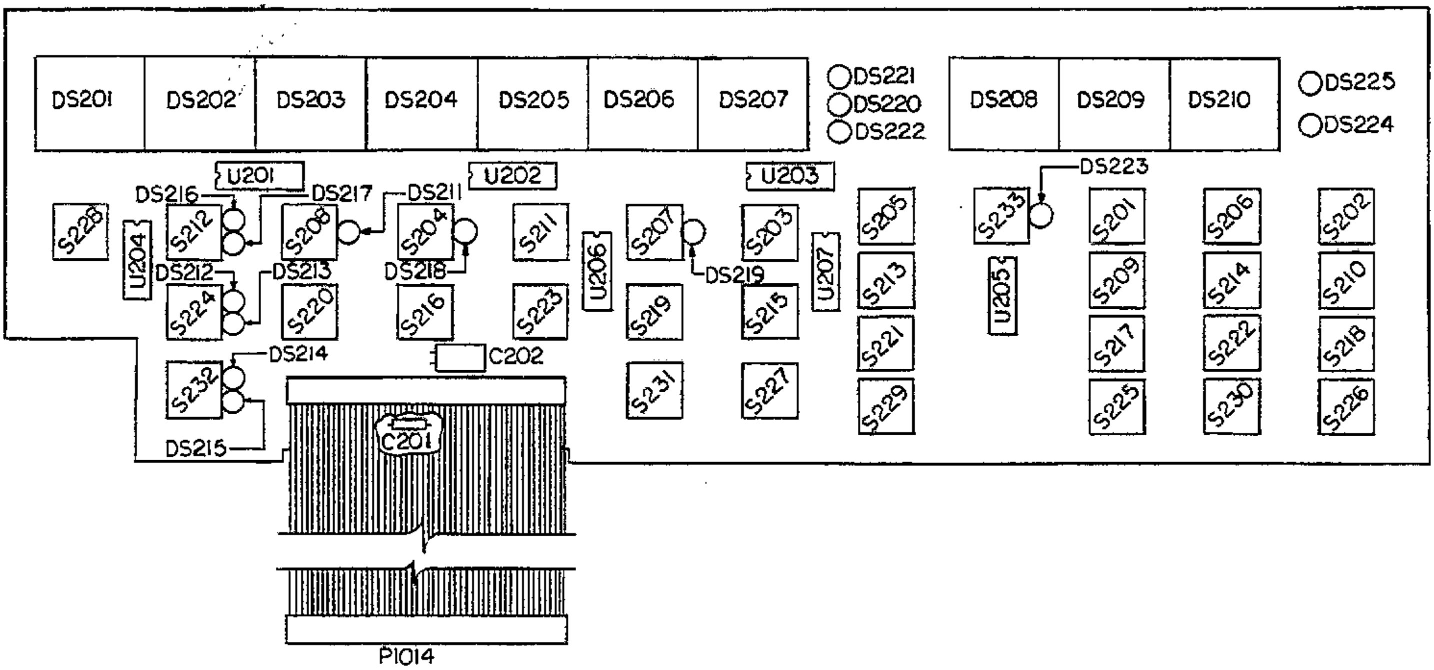


Figure 8-3. Display Board, Component Location Drawing, Dwg. No. 590-110

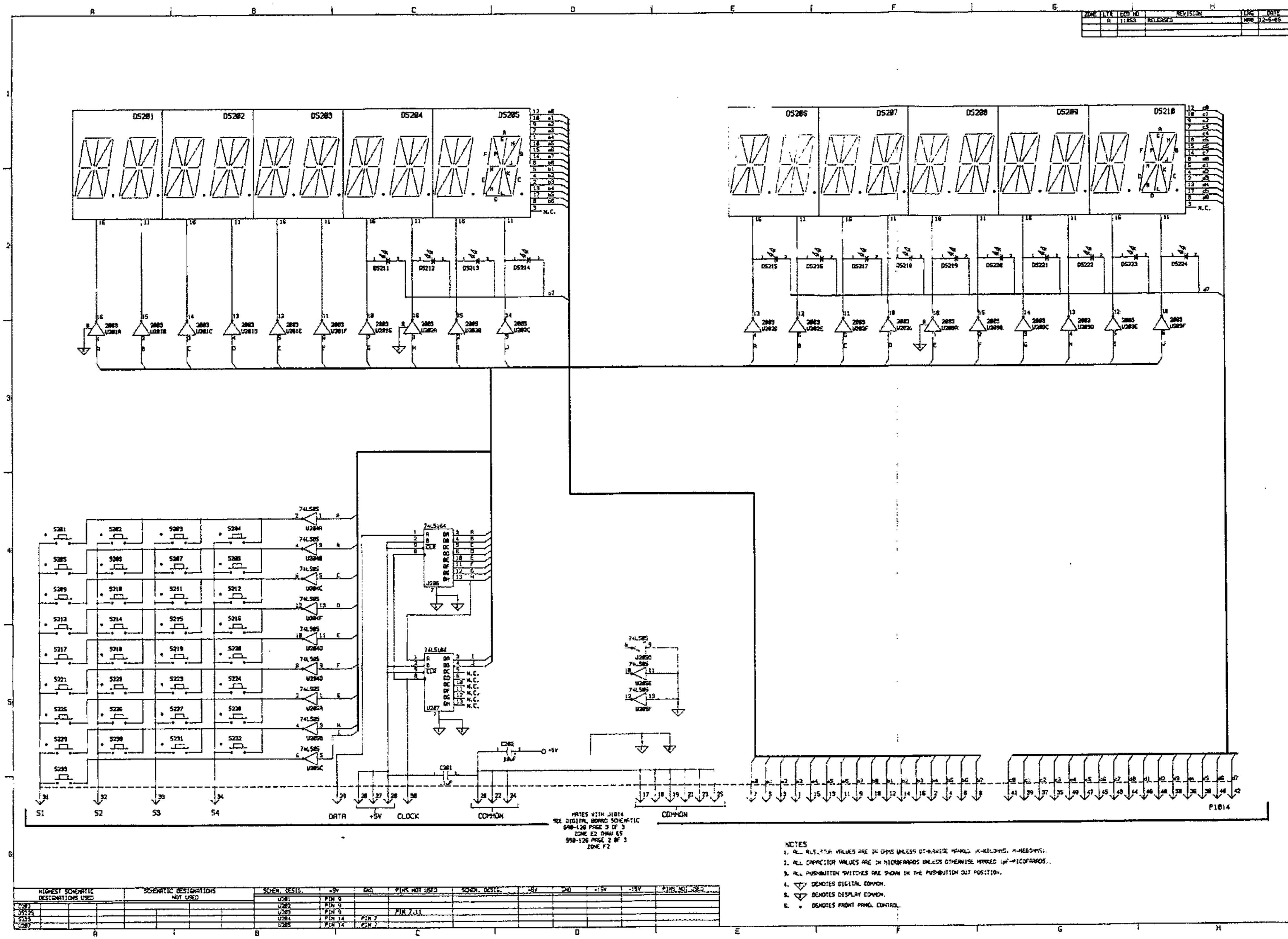


Figure 8-4. Display Board, Schematic Diagram, Dwg. No. 590-116

Table 8-3. Digital Board, Parts List

Circuit Designation	Description	Keithley Part Number
C301	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C302	Not Used	
C303	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C304	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C305	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C306	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C307	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C308	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C309	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C310	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C311	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C312	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C313	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C314	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C315	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C316	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C317	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C318	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C319	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C320	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C321	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C322	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C323	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C324	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C325	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C326	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C327	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C328	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C329	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C330	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C331	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C332	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C333	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C334	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C335	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C336	Not Used	
C337	Not Used	
C338	Not Used	
C339	Not Used	
C340	Capacitor, 6800μF, 25V, Aluminum Electrolytic	C-314-6800
C341	Capacitor, 470μF, 50V, Aluminum Electrolytic	C-276-470
C342	Capacitor, 470μF, 50V, Aluminum Electrolytic	C-276-470
C343	Capacitor, 2200μF, 35V, Aluminum Electrolytic	C-309-2200
C344	Capacitor, 2200μF, 35V, Aluminum Electrolytic	C-309-2200
C345	Capacitor, 4700μF, 16V, Aluminum Electrolytic	C-313-4700
C346	Capacitor, 2200μF, 16V, Aluminum Electrolytic	C-351-2200
C347	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C348	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C349	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C350	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C351	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C352	Not Used	
C353	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.1
CR301	Diode, Silicon, 1N4148	RF-28
CR302	Diode, Silicon, 1N4148	RF-28
CR303	Rectifier, Bridge, 1A, 100PIV	RF-52
CR304	Not Used	
CR305	Rectifier, Bridge, 5A, 50PIV, PE05	RF-48
CR306	Rectifier, Bridge, 1A, 100PIV	RF-52
CR307	Rectifier, Bridge, 1A, 100PIV	RF-52
CR308	Rectifier, Bridge, 1A, 100PIV	RF-52
CR309	Diode, 1A, 800PIV, 1N4006	RF-38
F300	Fuse, 3AG, 0.5A, (180-220V Operation)	FU-4
F300	Fuse, 3AG, 1A, (90-110V Operation)	FU-10
F300	Fuse, 3AG, 3/8A, (210-250V Operation)	FU-18
F300	Fuse, 3AG, ¾A, (105-125V Operation)	FU-19
F300	Fuse, 5mm, 0.8A, (105-125V; requires FH-26 Fuse Carrier)	FU-71
F300	Fuse, 5mm, 0.4A, (210-250V; requires FH-26 Fuse Carrier)	FU-80
J1004	Connector, BNC	CS-506
J1005	Connector, BNC	CS-506
J1011	Connector, IEEE-488	CS-501
J1012	Connector, Modified	740-309
J1013	Connector Pins	CS-288-2
J1014	Connector Pins	CS-389-9
J1015	Connector, Modified	590-314-2
J1016	Connector, Modified	590-314-1
Q300	Transistor, Power, PNP, 2N5193	TG-107
Q301	Transistor, Power, NPN, 2N5190	TG-108
R301	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R302	Resistor, 510Ω, 5%, ¼W, Composition	R-76-510
R303	Resistor, 61.9kΩ, 1%, 1/8W	R-88-61.9K
R304	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R305	Resistor, 20kΩ, 1%, 1/8W	R-88-20k
R306	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R307	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R308	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R309	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R310	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R311	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R312	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R313	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R314	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R315	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R316	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R317	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R318	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R319	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R320	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R321	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R322	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R323	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R324	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R325	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R326	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R327	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R328	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R329	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R330	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R331	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R332	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R333	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R334	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R335	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R336	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R337	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R338	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R339	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R340	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R341	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R342	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R343	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R344	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R345	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R346	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R347	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R348	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R349	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R350	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R351	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R352	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R353	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R354	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R355	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R356	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R357	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R358	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R359	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R360	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R361	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R362	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R363	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R364	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R365	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R366	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R367	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R368	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R369	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R370	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k

Table 8-3. Digital Board, Parts List (Cont.)

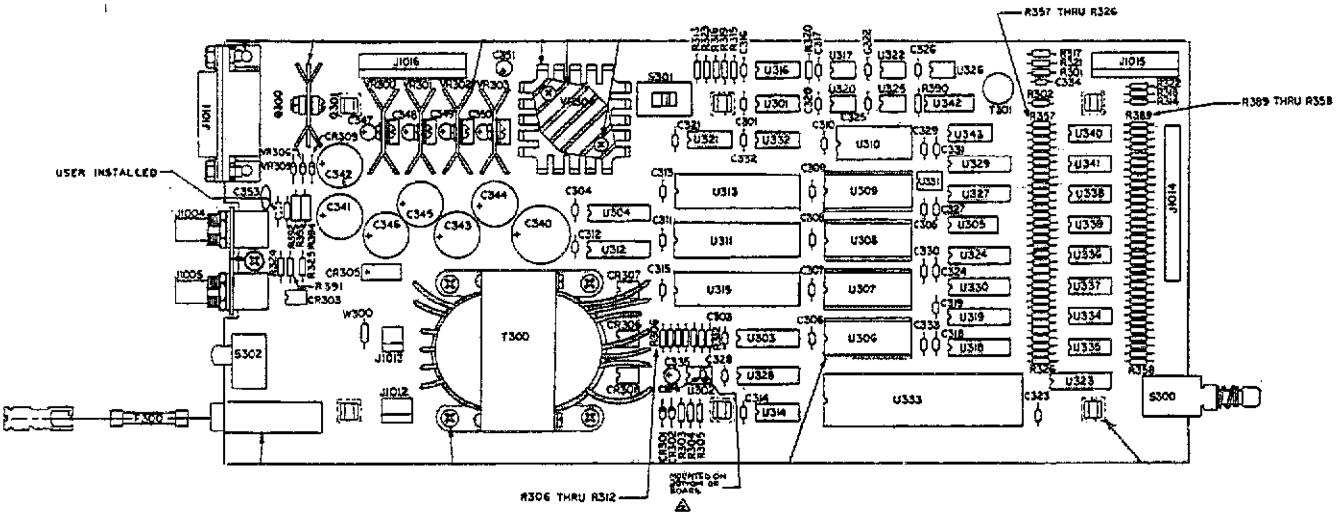
Circuit Designation	Description	Keithley Part Number
R371	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R372	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R373	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R374	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R375	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R376	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R377	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R378	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R379	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R380	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R381	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R382	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R383	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R384	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R385	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R386	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R387	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R388	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R389	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R390	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R391	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100k
R392	Resistor, 220k, 5%, ¼W, Composition	R-76-220k
R393	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R394	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
S300	Switch, Off/On	SW-466
S301	Switch, Calibration Lock	SW-397
S302	Switch, Voltage Select	SW-318
T300	Transformer, Power, 105-125V, 210-250V	TR-226
T300	Transformer, Power, 90-110V, 180-220V	TR-229
T301	Transformer	TR-228
U301	IC, Quad 2-Input NOR Gate, 74HCT02	IC-510
U302	IC, Micropower Bipolar Monolithic, 8211	IC-177
U303	IC, AND, OR Array, PAL16P8A	590-802*
U304	IC, Octal Bus Transceiver, 75160A	IC-298
U305	IC, 1-of-8 Decoder, 74HCT138	IC-398
U306	IC, ROM, 8k × 8 Bit, 2764	590-800*
U307	IC, ROM, 64k × 8 Bit, 27256	590-801*
U308	IC, 8k Byte Static CMOS, RAM, HM6264LP-15	LSI-66
U309	IC, 8k Byte Static CMOS, RAM, HM6264LP-15	LSI-66
U310	IC, Programmable E²ROM, 2816	LSI-83
U311	IC, General Purpose Interface, 9914A	LSI-49
U312	IC, Octal Bus Transceiver, 75161A	IC-299
U313	IC, Versatile Interface Adapter (VIA), 6522A	LSI-45
U314	IC, Quad 2-Input OR Gate, 74HCT32	IC-443
U315	IC, 8-Bit Microprocessor (2MHz), 68B09	LSI-65
U316	IC, Hex Inverter, 74HCT04	IC-444
U317	IC, Opto-coupler, HCPL-2601	IC-239
U318	IC, CMOS, Octal D-Type Flip-Flop, 74HCT374	IC-397

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
U319	IC, CMOS, Octal D-Type Flip-Flop, 74HCT374	IC-397
U320	IC, Optocoupler, HCPL-2601	IC-239
U321	IC, 12-Stage Binary Counter, 4040B	IC-348
U322	IC, Optocoupler, HCPL-2601	IC-239
U323	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U324	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U325	IC, Optocoupler, HCPL-2601	IC-239
U326	IC, Optocoupler, HCPL-2601	IC-239
U327	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U328	IC, AND, OR Array, PAL16P8A	590-803*
U329	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U330	IC, 74LS273	IC-263
U331	IC, 75157	IC-429
U332	IC, 74HCT393	IC-462
U333	IC, 16 × 16 Bit Parallel Multiplier, 7216	LSI-71
U334	IC, Transistor Array, MPQ3906	IC-396
U335	IC, Transistor Array, MPQ3906	IC-396
U336	IC, Transistor Array, MPQ3906	IC-396
U337	IC, Transistor Array, MPQ3906	IC-396
U338	IC, Transistor Array, MPQ3906	IC-396
U339	IC, Transistor Array, MPQ3906	IC-396
U340	IC, Transistor Array, MPQ3906	IC-396
U341	IC, Transistor Array, MPQ3906	IC-396
U342	IC, 12-Stage Binary Counter, 74HC4040	IC-407
U343	IC, Dual D-Type Flip-Flop, 74LS74	IC-144
VR300	Regulator, IC, +5V, 7805	IC-93
VR301	Regulator, IC, −5V, 7905	IC-184
VR302	Regulator, IC, +15V, 78M15CV	IC-194
VR303	Regulator, IC, −15V, MC7915CT	IC-174
VR304	Regulator, IC, +5V, 323	IC-240
VR305	Zener Diode, 30V, 1W, 1N4751	DZ-78
VR306	Zener Diode, 30V, 1W, 1N4751	DZ-78
W300	Jumper	J-3

*Order same digits as present revision level marked on IC.

ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	11055	RELEASED	[illegible]	12-3-85
	B	11134	[illegible]	[illegible]	1-24-86
	C	11223	SEE PAGE 2	[illegible]	2-27-86
	D	11255	SEE PAGE 2	[illegible]	3-4-86
	E	11297	SEE PG. 2	[illegible]	4-2-86
	F	11405	SEE PG. 2	[illegible]	5-6-86
	G	11511	SEE PG 2	[illegible]	7-23-86
	H	11816	SEE PG. 2	[illegible]	12/8/86
	J	11868	SEE PG. 2	[illegible]	[illegible]
	K	11929	SEE PG. 2	[illegible]	2/5/87
	L	12248	SEE PG. 2	[illegible]	[illegible]
	M	12824	SEE PG. 2	[illegible]	8-22-88
	N	[illegible]	[illegible]	[illegible]	[illegible]
	P	[illegible]	[illegible]	[illegible]	[illegible]
	R	14617	SEE PAGE TWO	[illegible]	[illegible]
	S	16192	SEE PAGE TWO	[illegible]	[illegible]
	S1	16449	ADD ITEM 326	[illegible]	[illegible]
	S2	18031	ADD C359	[illegible]	[illegible]



108-125V	AMERICAN	FH-25	FU-19
210-250V			FU-18
105-125V	EUROPEAN	FH-26	FU-52
210-250V			FU-53
90-110V	JAPANESE	FH-26	FU-72
180-220V			FU-71

Figure 8-5. Digital Board, Bomponent Location Drawing, Dwg. No. 590-120

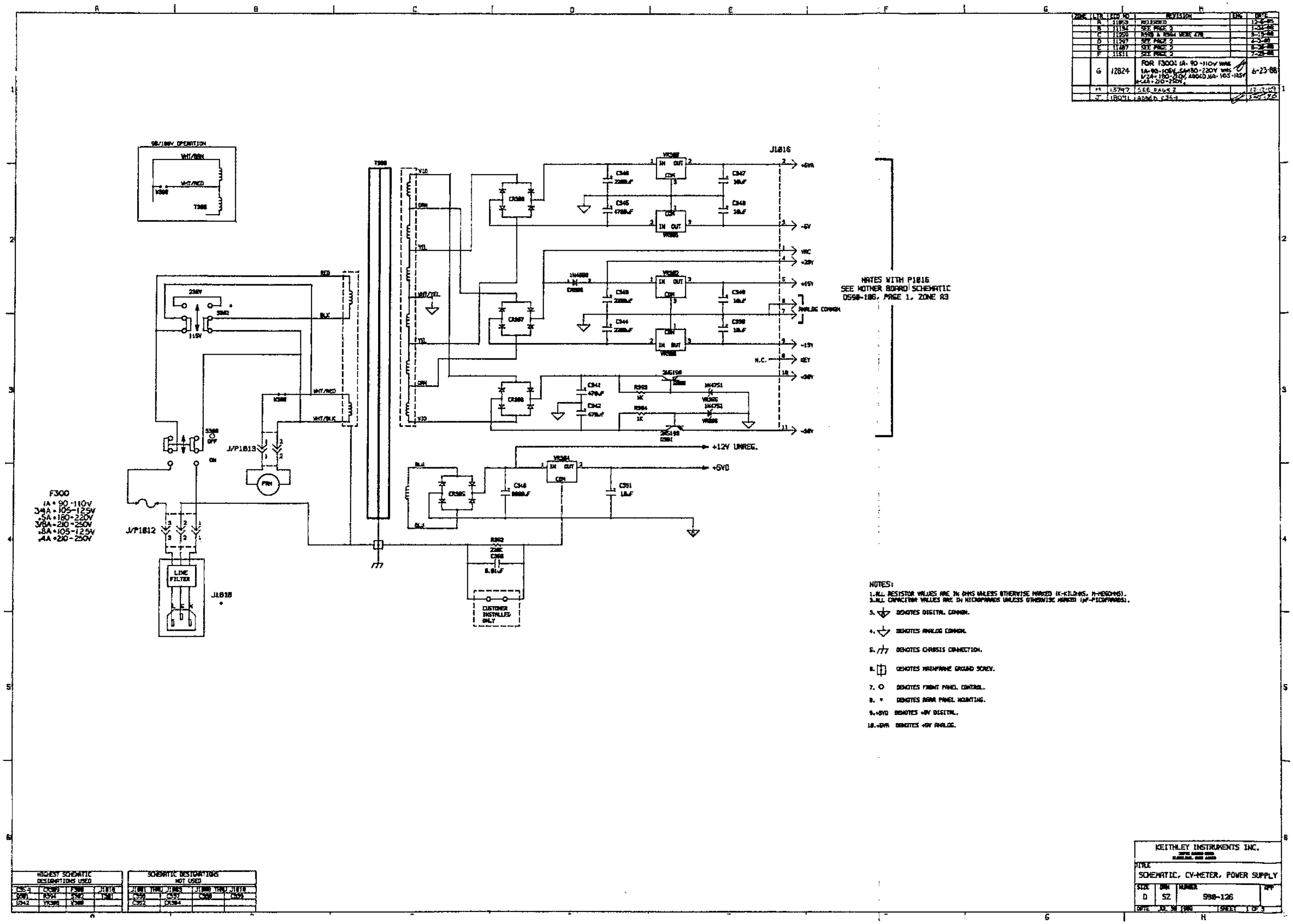


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 1 of 3)

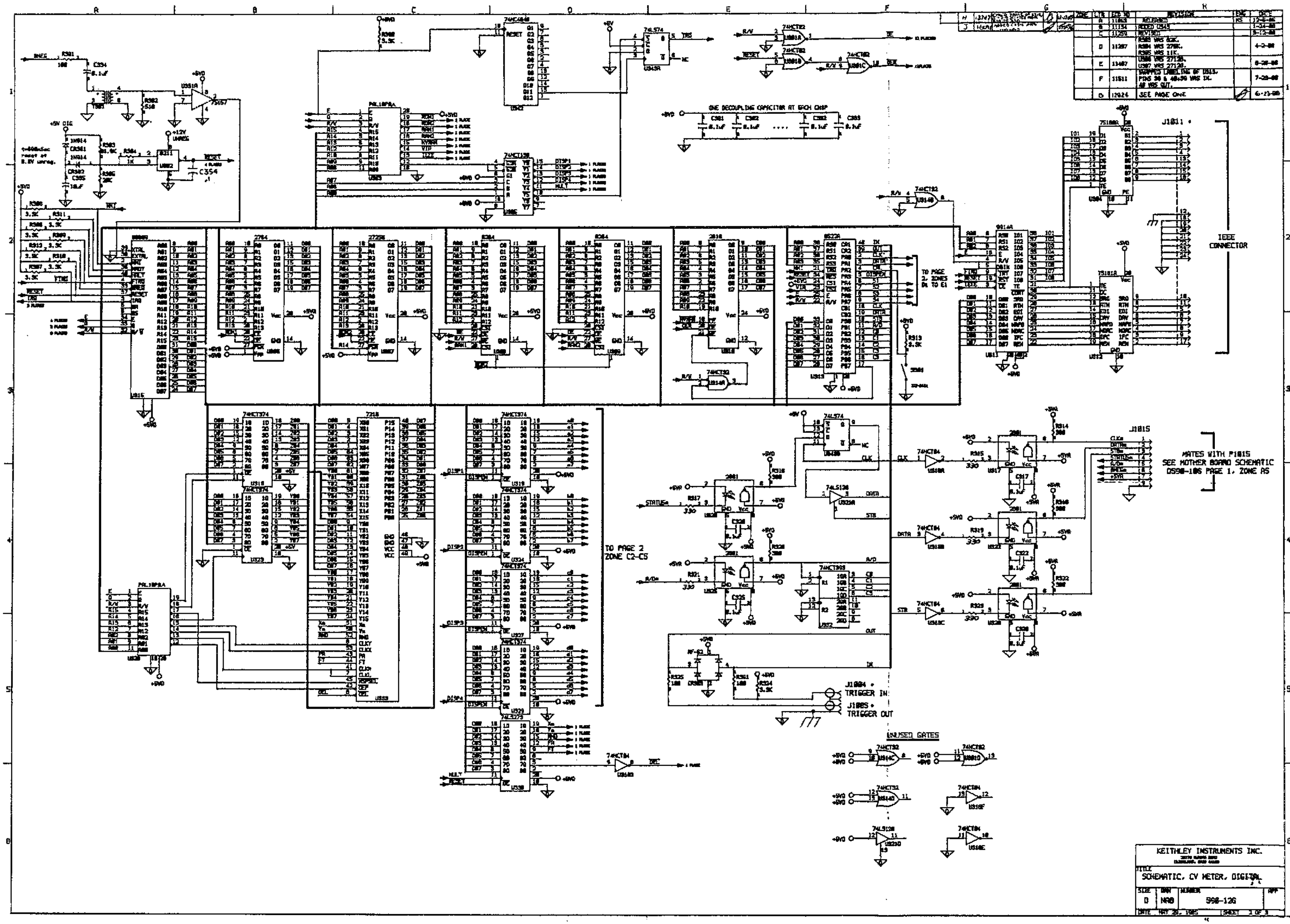


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 2 of 3)

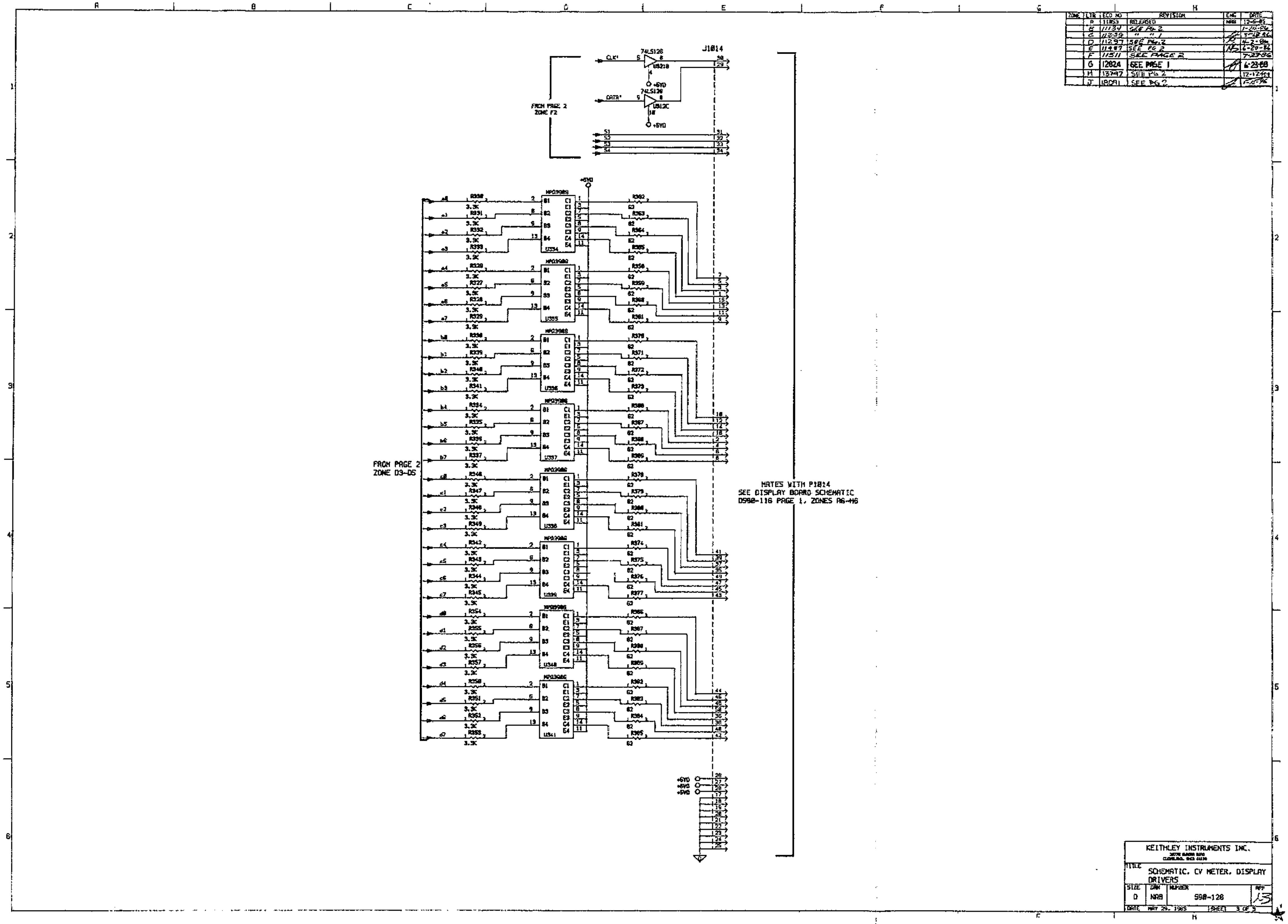


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 3 of 3)

Table 8-4. 100kHz (5901) Module, Parts List

Circuit Designation	Description	Keithley Part Number
AT500	IC, Optocoupler, CLM6500	IC-440
C500	Not Used	
C501	Not Used	
C502	Capacitor, 1000pF, 100V, Ceramic	C-372-1000p
C503	Capacitor, 1000pF, 100V, Ceramic	C-372-1000p
C504	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C505	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C506	Capacitor, 22pF, 500V, Ceramic Disc	C-22-22p
C507	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C508	Capacitor, 1µF, 50V, Metallized Polyester	C-350-1
C509	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C510	Capacitor, 0.01µF, 50V, Metallized Polycarbonate	C-201-.01
C511	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C512	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C513	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C514	Capacitor, 0.1µF, 50V, Metallized Polycarbonate	C-201-0.1
C515	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C516	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C517	Not Used	
C518	Not Used	
C519	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C520	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C521	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C522	Not Used	
C523	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C524	Not Used	
C525	Capacitor, 100pF	C-201-100p
C526	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C527	Capacitor, Trimmer, 7-70pF	C-345
C528	Capacitor, 150pF, 100V, Ceramic	C-372-150p
C529	Capacitor, Trimmer, 3-10pF	C-346
C530	Capacitor, 10pF, 100V, Ceramic	C-372-10p
C531	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C532	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C533	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C534	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C535	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C536	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C537	Capacitor, 10pF, 500V Ceramic Disc	C-22-10p
C538	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C539	Capacitor, 1000p, 100V, Ceramic	C-372-1000p
C540	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C541	Capacitor, 15pF, 100V, Ceramic	C-372-15p
C542	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C543	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C544	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C545	Capacitor, 15pF, 100V, Ceramic	C-372-15p
C546	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C547	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C548	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C549	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C550	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C551	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C552	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C553	Capacitor, 0.022μF, 100V	C-371-0.022
C554	Capacitor, 0.033μF, 100V	C-371-0.033
C555	Capacitor, 100pF, 500V, Ceramic Disc	C-22-100p
C556	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C557	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C558	Capacitor, 100pF, 500V, Ceramic Disc	C-22-100p
C559	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C560	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C561	Not Used	
C562	Not Used	
C563	Not Used	
C564	Not Used	
C565	Not Used	
C566	Not Used	
C567	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C568	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C569	Not Used	
C570	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C571	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
CR500	Diode, Schottky Barrier, 1N5711	RF-69
CR501	Diode, Schottky Barrier, 1N5711	RF-69
CR502	Diode, Silicon, 1N4148	RF-28
CR503	Diode, Silicon, 1N4148	RF-28
CR504	Diode, Silicon, 1N4148	RF-28
CR505	Diode, Silicon, 1N4148	RF-28
CR506	Diode, Silicon, 1N4148	RF-28
CR507	Diode, Silicon, 1N4148	RF-28
CR508	Diode, Silicon, 1N4148	RF-28
CR509	Rectifier Bridge, 1A, 100PIV	RF-52
CR510	Not Used	
CR511	Not Used	
CR512	Diode, Silicon, 1N4148	RF-28
K500	Relay	RL-65
K501	Relay	RL-65
K502	Relay	RL-95
K503	Relay	RL-48
L500	Choke	CH-24
L501	Choke	CH-23
P1020	Connector Housing	CS-534-9
P1021	Connector Housing	CS-534-7
P1023	Cable Assembly	CA-50-3
P1024	Cable Assembly	CA-50-1
P1025	Connector Housing	CS-534-2

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
Q500	Transistor, Silicon, NPN, 2N3904	TG-47
Q501	Transistor, Silicon, NPN, 2N3904	TG-47
Q502	Transistor, N-Channel JFET, 2N4393	TG-130
Q503	Transistor, N-Channel JFET, 2N4393	TG-130
Q504	Transistor, N-Channel JFET, 2N4393	TG-130
Q505	Transistor, N-Channel JFET, 2N4393	TG-130
Q506	Transistor, N-Channel JFET, 2N4393	TG-130
Q507	Transistor, N-Channel JFET, 2N4393	TG-130
Q508	Transistor, N-Channel JFET, 2N4393	TG-130
Q509	Transistor, N-Channel JFET, 2N4393	TG-130
Q510	Transistor, Matched Dual-channel JFET, DN5566	TG-188
Q511	Not Used	
Q512	Transistor, Silicon, NPN, 2N3904	TG-47
Q513	Transistor, Silicon, NPN, 2N3904	TG-47
R500	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R501	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R502	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R503	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R504	Resistor, 1.07kΩ, 1%, 1/8W	R-88-1.07k
R505	Resistor, 2.32kΩ, 1%, 1/8W	R-88-2.32k
R506	Resistor, 2kΩ, 1%, 1/8W	R-88-2k
R507	Resistor, 499Ω, 1%, 1/8W	R-88-499
R508	Resistor, 510Ω, 5%, ¼W, Composition	R-76-510
R509	Resistor, 4.99kΩ, 1%, 1/8W	R-88-4.99k
R510	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R511	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R512	Resistor, 856Ω, 0.1%, 1/10W, Metal Film	R-263-856
R513	Potentiometer, 50Ω, ½W, Cermet	RP-97-50
R514	Resistor, 510Ω, 0.1%, 1/10W, Metal Film	R-263-510
R515	Potentiometer, 500Ω, ½W, Cermet	RP-97-500
R516	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R517	Resistor, 100kΩ, 5%, ¼w, Composition	R-76-100k
R518	Resistor, 4.32kΩ, 1%, 1/8W	R-88-4.32k
R519	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R520	Resistor, 79.6kΩ, 0.1%, 1/10W, Metal Film	R-263-79.6k
R521	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R522	Resistor, 8.75kΩ, 0.1%, 1/10W, Metal Film	R-263-8.75k
R523	Potentiometer, 20Ω, ½W, Cermet	RP-97-20
R524	Resistor, 794Ω, 0.1%, 1/10W, Metal Film	R-263-794
R525	Resistor, 100Ω, 5%, ½W, Composition	R-76-100
R526	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R527	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R528	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R529	Resistor, 100Ω, 5%, ½W, Composition	R-76-100
R530	Resistor, 1.5kΩ, 0.1%, 1/10W, Metal Film	R-263-1.5k
R531	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R532	Resistor, 1.67kΩ, 0.1%, 1/10W, Metal Film	R-263-1.67k
R533	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R534	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R535	Resistor, 1.67kΩ, 0.1%, 1/10W, Metal Film	R-263-1.67k

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R536	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R537	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R538	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R539	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R540	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R541	Resistor, 10MΩ, 10%, ¼W, Composition	R-76-10M
R542	Resistor, 6.8MΩ, 5%, ¼W, Composition	R-76-6.8M
R543	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R544	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R545	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R546	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R547	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R548	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R549	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R550	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R551	Not Used	
R552	Not Used	
R553	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R554	Resistor, selected with VR500	5901-600
R555	Not Used	
R556	Not Used	
R557	Not Used	
R558	Not Used	
R559	Not Used	
R560	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R561	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R562	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R563	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R564	Resistor, 866Ω, 1%, 1/8W	R-88-866
R565	Not Used	
R566	Not Used	
R567	Not Used	
R568	Not Used	
R569	Resistor, 100kΩ, 10%, ½W, Composition	R-1-100k
R570	Resistor, 3.9Ω, 10%, ½W, Composition	R-1-3.9
T500	Transformer	TR-221
T501	Transformer	TR-222
T502	Transformer	TR-220
U500	Not Used	
U501	Not Used	
U502	IC, Quad 2-Input NOR Gate, 74F02	IC-435
U503	Not Used	
U504	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U505	IC, Dual D Edeg Triggered Flip-Flop, 74F74	IC-446
U506	IC, Hex Inverter, 74F04	IC-436
U507	IC, Quad 2-Input NAND Buffer, 74F38	IC-434
U508	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U509	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U510	IC, Bi-FET Operational Amplifier, AD542	IC-165

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
U511	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U512	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U513	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U514	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U515	IC, Bi-FET Operational Amplifier, LF442A	IC-410
U516	IC, Wideband Dual JFET Operational Amplifier, LF353N	IC-246
U517	IC, Bi-FET Operational Amplifier, LF442A	IC-410
U518	IC, Voltage Regulator, −5V, LM320LZ-5	IC-395
VR500	Zener Diode, Selected with R554	5901-600
W500	Connector Pin	CS-339-3
W500	Connector Pin Jumper	CS-476

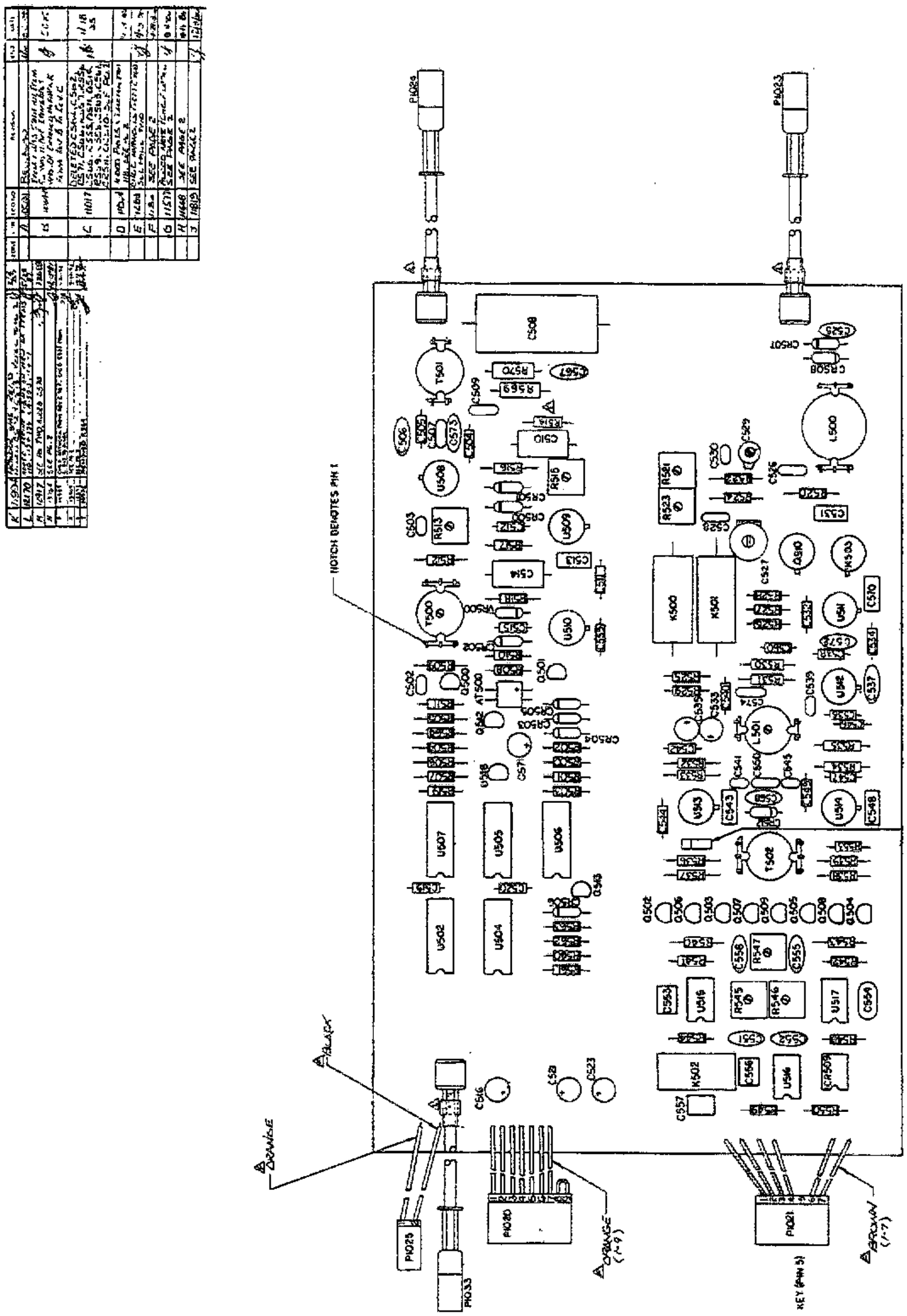


Figure 8-7. Model 5901 (100kHz), Component Location Drawing, Dwg. No. 5901-100

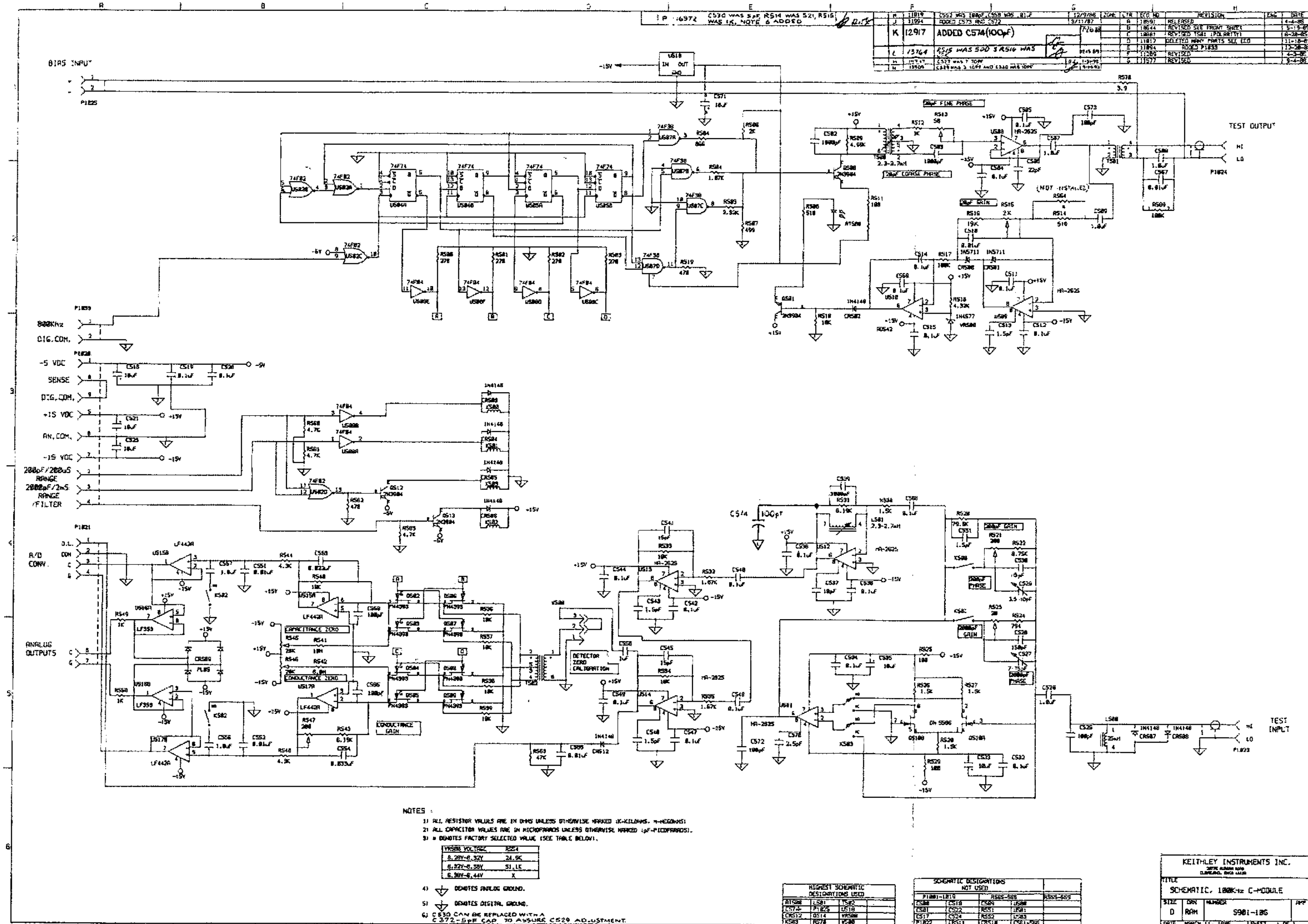


Figure 8-8. Model 5901 (100kHz), Schematic Diagram, Dwg. No. 5901-106

Table 8-5. 1MHz (5902) Module, Parts List

Circuit Designation	Description	Keithley Part Number
AT601	IC, Optocoupler, 6500	IC-440
C601	Capacitor, 100pF, 500V, Mica	C-209-100p
C602	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C603	Capacitor, 100pF, 500V, Mica	C-209-100p
C604	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C605	Capacitor, 0.033μF, 100V	C-371-.033
C606	Not Used	
C607	Capacitor, 1μF, 10%, 200V, Metallized Polypropylene	C-357-1
C608	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C609	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C610	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C611	Capacitor, 0.1μF, 50V, Metallized Polycarbonate	C-201-0.1
C612	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C613	Capacitor, 0.022μF, 100V	C-371-.022
C614	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C615	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C616	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C617	Not Used	
C618	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C619	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C620	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C621	Not Used	
C622	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C623	Not Used	
C624	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C625	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C626	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C627	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C628	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C629	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C630	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C631	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C632	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C633	Capacitor, 0.022μF, 100V	C-371-0.022
C634	Capacitor, 15pF, Ceramic Disc	C-64-15p
C635	Capacitor, 100pF, Ceramic Disc	C-64-100p
C636	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C637	Capacitor, 15pF, Ceramic Disc	C-64-15p
C638	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C639	Capacitor, 100pF, Ceramic Disc	C-64-100p
C640	Capacitor, 0.033μF, 100V	C-371-0.033
C641	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C642	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C643	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C644	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C645	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C646	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C647	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C648	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C649	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C650	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C651	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C652	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C653	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C654	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C655	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C656	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C657	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C658	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C659	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C660	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C661	Capacitor, 100pF, 500V, Mica	C-209-100p
C662	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C663	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C664	Capacitor, 1800pF, 500V, Mica	C-209-1800p
C665	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C666	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C667	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C668	Capacitor, 33pF, Ceramic Disc	C-64-33p
C669	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C670	Capacitor, 100pF, Ceramic Disc	C-64-100p
C671	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C672	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C673	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C674	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C675	Caapcitor, 1000pF, Ceramic Disc	C-64-1000p
C676	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C677	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C678	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C679	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
CR601	Diode, Silicon, 1N4148	RF-28
CR602	Diode, Schottky Barrier, 1N5711	RF-69
CR603	Rectifier, Bridge, 1A, 100PIV	RF-52
CR604	Diode, Silicon, 1N4148	RF-28
CR605	Diode, Silicon, 1N4148	RF-28
CR606	Diode, Silicon, 1N4148	RF-28
CR607	Diode, Silicon, 1N4148	RF-28
CR608	Diode, Silicon, 1N4148	RF-28
K601	Relay	RL-102
K602	Relay	RL-102
K603	Relay	RL-102
K604	Relay	RL-102
K605	Relay	RL-102
K606	Realy	RL-95
K607	Relay	RL-101
L601	Choke	CH-26-220
L602	Choke	CH-33
L603	Choke	CH-33

Table 8-5. 1MHz (5902) Module, Parts List

Circuit Designation	Description	Keithley Part Number
L604	Choke	CH-33
L605	Choke	CH-33
L606	Choke	CH-33
L607	Choke	CH-33
L608	Choke	CH-33
L609	Choke	CH-33
L610	Choke	CH-33
L611	Choke	CH-33
L612	Choke	CH-33
L613	Choke	CH-26-220
L614	Choke	CH-33
L615	Choke	CH-33
L616	Choke	CH-33
L617	Choke	CH-26-15
L618	Choke	CH-33
P1026	Connector	CS-534-10
P1027	Connector	CS-534-7
P1029	Cable Assembly, 50Ω	CA-50-2
P1030	Cable Assembly, 50Ω	CA-50-1
P1031	Connector	CS-534-2
P1034	Cable Assembly, 50Ω	CA-50-3
Q601	Transistor, Silicon, NPN, 2N3904	TG-47
Q602	Transistor, Silicon, NPN, 2N3904	TG-47
Q603	Transistor, Silicon, NPN, 2N3904	TG-47
Q604	Transistor, N-Channel JFET, 2N4393	TG-130
Q605	Transistor, N-Channel JFET, 2N4393	TG-130
Q606	Transistor, N-Channel JFET, 2N4393	TG-130
Q607	Transistor, N-Channel JFET, 2N4393	TG-130
Q608	Transistor, N-Channel JFET, 2N4393	TG-130
Q609	Transistor, N-Channel JFET, 2N4393	TG-130
Q610	Transistor, N-Channel JFET, 2N4393	TG-130
Q611	Transistor, N-Channel JFET, 2N4393	TG-130
R601	Not Used	
R602	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R603	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R604	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R605	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R606	Resistor, 866Ω, 1%, 1/8W	R-88-866
R607	Resistor, 2kΩ, 1%, 1/8W	R-88-2k
R608	Resistor, 1.07kΩ, 1%, 1/8W	R-88-1.07
R609	Resistor, 2.32kΩ, 1%, 1/8W	R-88-2.32k
R610	Resistor, 499Ω, 1%, 1/8W	R-88-499
R611	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R612	Resistor, 390Ω, 5%, ¼W, Composition	R-76-390
R613	Resistor, 1.5kΩ, 5%, ¼W, Composition	R-76-1.5k
R614	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R615	Resistor, 4.59kΩ, 0.1%, 1/10W, Metal Film	R-263-4.59k
R616	Resistor, 500Ω, 0.1%, 1/10W, Metal Film	R-263-500

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R617	Resistor, 100Ω, 1%, 1/8W	R-88-100
R618	Resistor, 100Ω, 1%, 1/8W	R-88-100
R619	Resistor, 1kΩ, 1%, 1/8W	R-88-1k
R620	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R621	Resistor, 1.1kΩ, 1%, 1/8W	R-88-1.1k
R622	Resistor, 4.42kΩ, 1%, 1/8W	R-88-4.42k
R623	Resistor, 3.9Ω, 10%, ½W, Composition	R-1-3.9
R624	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R625	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R626	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R627	Resistor, 100kΩ, 10%, ½W, Composition	R-1-100k
R628	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R629	Resistor, 8.25kΩ, 1%, 1/8W	R-88-8.25k
R630	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R631	Resistor, 100kΩ, 5%, ¼W, Composition	R-76-100k
R632	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R633	Resistor, 13kΩ, 0.1%, 1/10W, Metal Film	R-263-13k
R634	Potentiometer, 500Ω, ½W, Cermet	RP-97-500
R635	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R636	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R637	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R638	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R639	Resistor, 20kΩ, 5%, ¼W, Composition	R-76-20k
R640	Resistor, 22kΩ, 5%, ¼W, Composition	R-76-22k
R641	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470k
R642	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R643	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R644	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R645	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R646	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R647	Resistor, 3.9MΩ, 5%, ¼W, Composition	R-76-3.9M
R648	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R649		
R650	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R651	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R652	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R653	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R654	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R655	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R656	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R657	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R658	Resistor, 10MΩ, 10%, ¼W, Composition	R-76-10M
R659	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R660	Resistor, 1.005kΩ, 0.1%, 1/10W, Metal Film	R-263-1.005k
R661	Resistor, 100Ω, 0.1%, 1/10W, Metal Film	R-263-100
R662	Resistor, 1.005kΩ, 0.1%, 1/10W, Metal Film	R-263-1.005k
R663	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R664	Resistor, 1.33kΩ, 1%, 1/8W	R-88-1.33k
R665	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R666	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R667	Resistor, 750Ω, 5%, ¼W, Composition	R-76-750

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R668	Resistor, 750Ω, 5%, ¼W, Composition	R-76-750
R669	Potentiometer, 200Ω	RP-104-200
R670	Resistor, 634Ω, 1%, ⅛W	R-88-634
R671	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R672	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R673	Resistor, 150Ω, 5%, ¼W, Composition	R-76-150
R674	Resistor, 54.9Ω, 1%, ⅛W	R-88-54.9
R675	Potentiometer, 100Ω, ½W, 25 Turn Cermet	RP-104-100
R676	Resistor, 464Ω, 1%, ⅛W	R-88-464
R677	Resistor, 4.7Ω, 5%, ¼W, Composition	R-76-4.7
R678	Resistor, 49.9Ω, 1%, ⅛W	R-88-49.9
R679	Resistor, 4.32kΩ, 1%, ⅛W	R-88-4.32k
R680	Resistor, 845Ω, 1%, ⅛W	R-88-845
R681	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R682	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62
T601	Transformer	TR-224
T602	Transformer	TR-225
T603	Transformer	TR-225
T604	Transformer	TR-246
T605	Transformer	TR-244
U601	IC, Hex Inverter, 74F04	IC-436
U602	IC, Quad 2-Input NOR Gate, 74F02	IC-435
U603	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U604	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U605	IC, Quad 2-Input NAND Buffer, 74F38	IC-434
U606	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U607	Operational Amplifier, KI590 (see Table 8-6 for parts)	
U608	IC, Bi-FET Operational Amplifier, AD542	IC-165
U609	IC, Very High Slew Rate Operational Amplifier, 2539	IC-512
U610	IC, Video Amplifier, NE592	IC-511
U611	IC, Video Amplifier, NE592	IC-511
U612	IC, Very High Slew Rate Operational Amplifier, 2539	IC-512
U613	IC, Darlington Transistor Array, 2003A	IC-206
U614	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U615	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U616	IC, LF442A	IC-410
U617	IC, LF442A	IC-410
U618	IC, Voltage Regulator, −5V, LM320L-5	IC-395
W601	Connector Pins	CS-339-3
W602	Connector Pins	CS-339-3
W601	Jumper	CS-476
W602	Jumper	CS-476

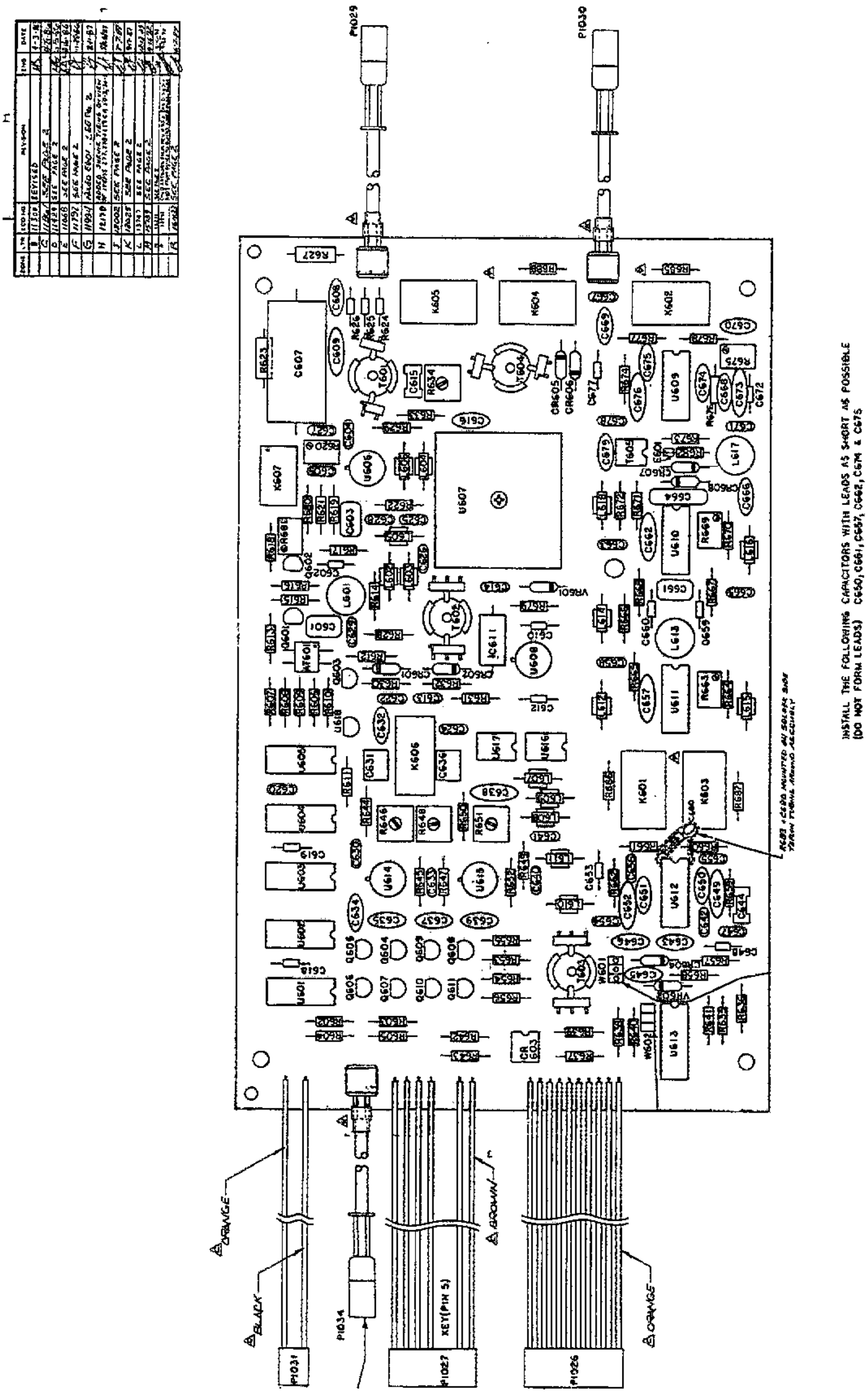


Figure 8-9. Model 5902 (1MHz), Component Location Drawing, Dwg. No. 5902-100

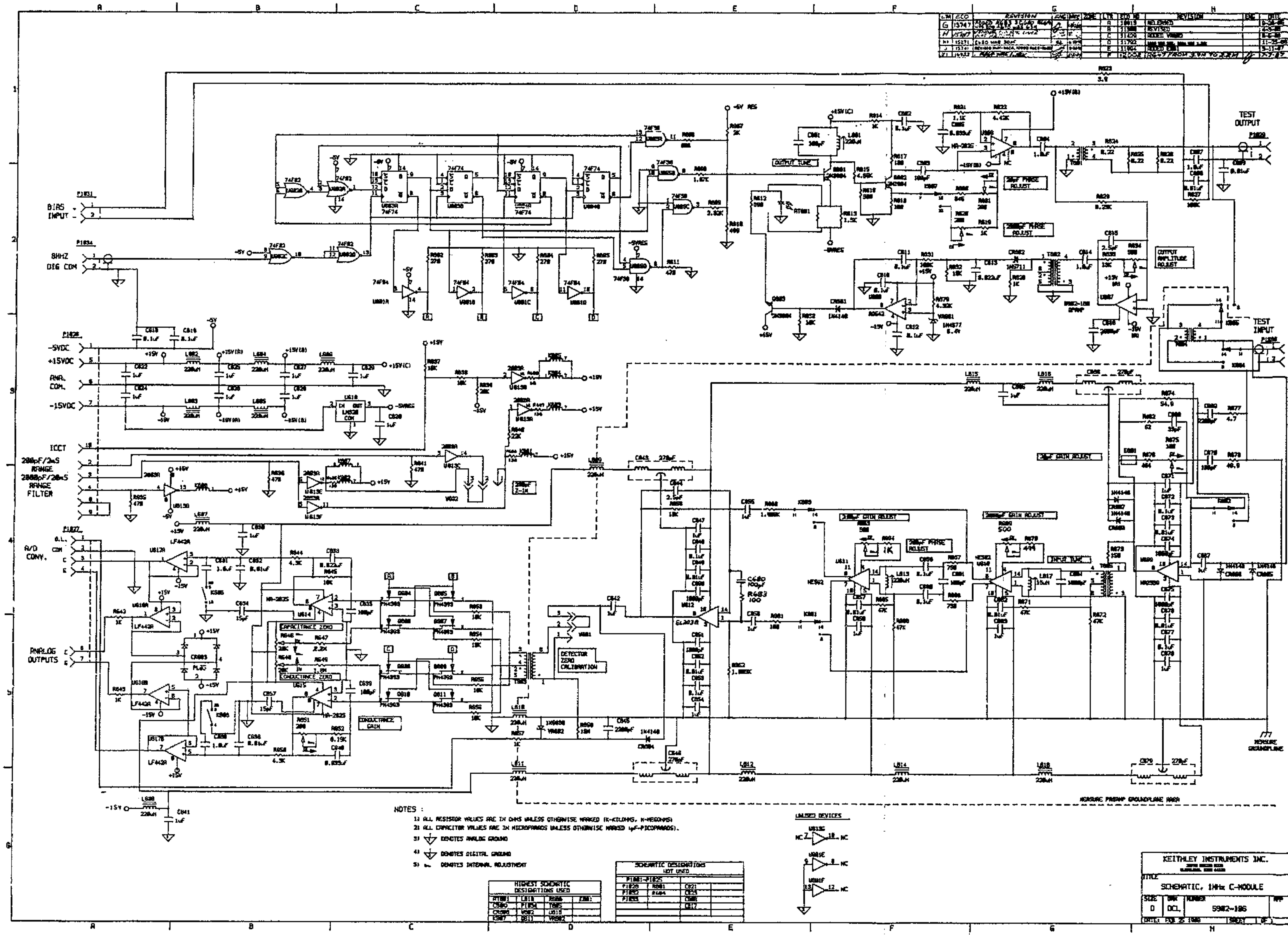
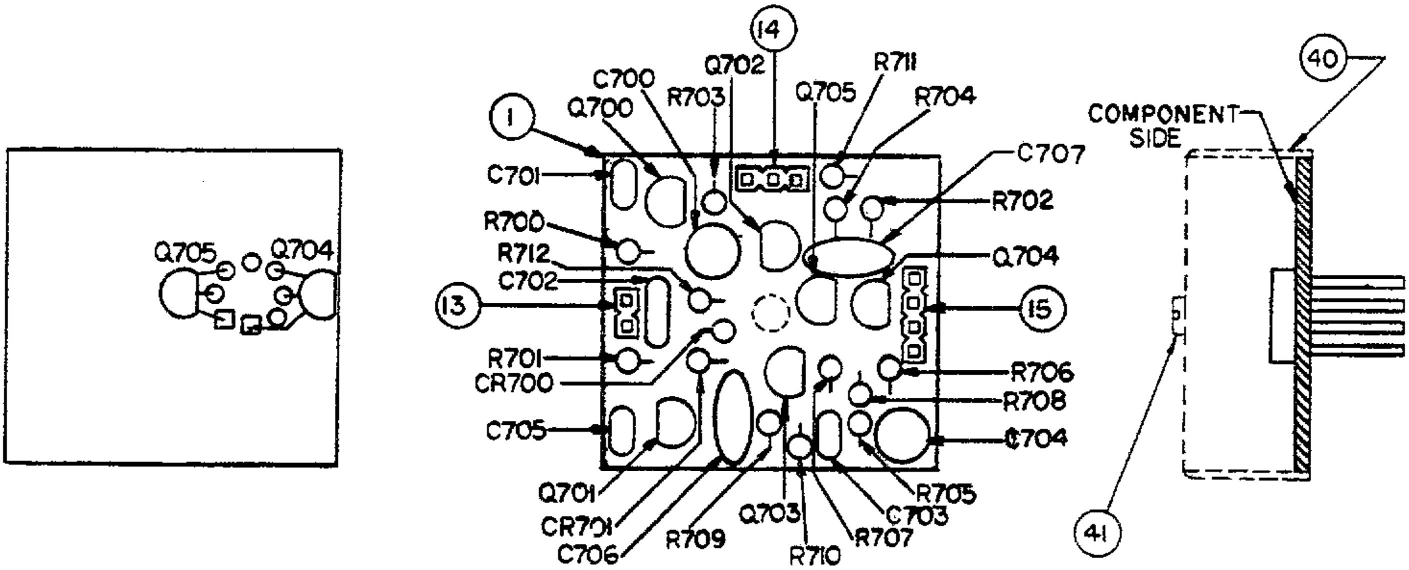


Figure 8-10. Model 5902 (1MHz), Schematic Diagram, Dwg. No. 5902-106

Table 8-6. KI590 Operational Amplifier (4607), Parts List

Circuit Designation	Description	Keithley Part Number
C700	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-377-10
C701	Capacitor, 0.1μF, 50V, Ceramic Film	C-237-0.1
C702	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C703	Capacitor, 0.1μF, 50V, Ceramic Film	C-237-0.1
C704	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-377-10
C705	Capacitor, 0.1μF, 50V, Ceramic Film	C-237-0.1
C706	Capacitor, 5pF, Ceramic Disc	C-64-5p
CR700	Diode, Silicon, 1N4148	RF-28
CR701	Diode, Silicon, 1N4148	RF-28
Q700	Transistor, Silicon, NPN, 2N3904	TG-47
Q701	Transistor, Silicon, PNP, 2N3906	TG-84
Q702	Transistor, Silicon, PNP, 2N3906	TG-84
Q703	Transistor, Silicon, NPN, 2N3904	TG-47
Q704	Transistor, Silicon, NPN, 2N3904	TG-47
Q705	Transistor, Silicon, NPN, 2N3904	TG-47
R700	Resistor, 20Ω, 5%, ¼W, Composition	R-76-20
R701	Resistor, 20Ω, 5%, ¼W, Composition	R-76-20
R702	Resistor, 1kΩ, 1%, ⅛W	R-88-1k
R703	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R704	Resistor, 432Ω, 1%, ⅛W	R-88-432
R705	Resistor, 2.15kΩ, 1%, ⅛W	R-88-2.15k
R706	Resistor, 10Ω, 1%, ⅛W	R-88-10
R707	Resistor, 15.8kΩ, 1%, ⅛W	R-88-15.8k
R708	Resistor, 10Ω, 1%, ⅛W	R-88-10
R709	Resistor, 866Ω, 1%, ⅛W	R-88-866
R710	Resistor, 4.99kΩ, 1%, ⅛W	R-88-4.99k
R711	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R712	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82

ZONE	LTR.	ECO NO.	REVISION	ENG.	DATE
	A	10641-	RELEASED	[illegible]	9-16-86
	A1	11003	ADDED NOTE	[illegible]	11-21-85
	B	11994	ADDED C707 (C-64-100P)	[illegible]	3-6-87
	B1	16166	[illegible]	[illegible]	1-28-94



gure 8-11. KI590 Operational Amplifier (U607), Component Location Drawing, Dwg. N. 5902-180

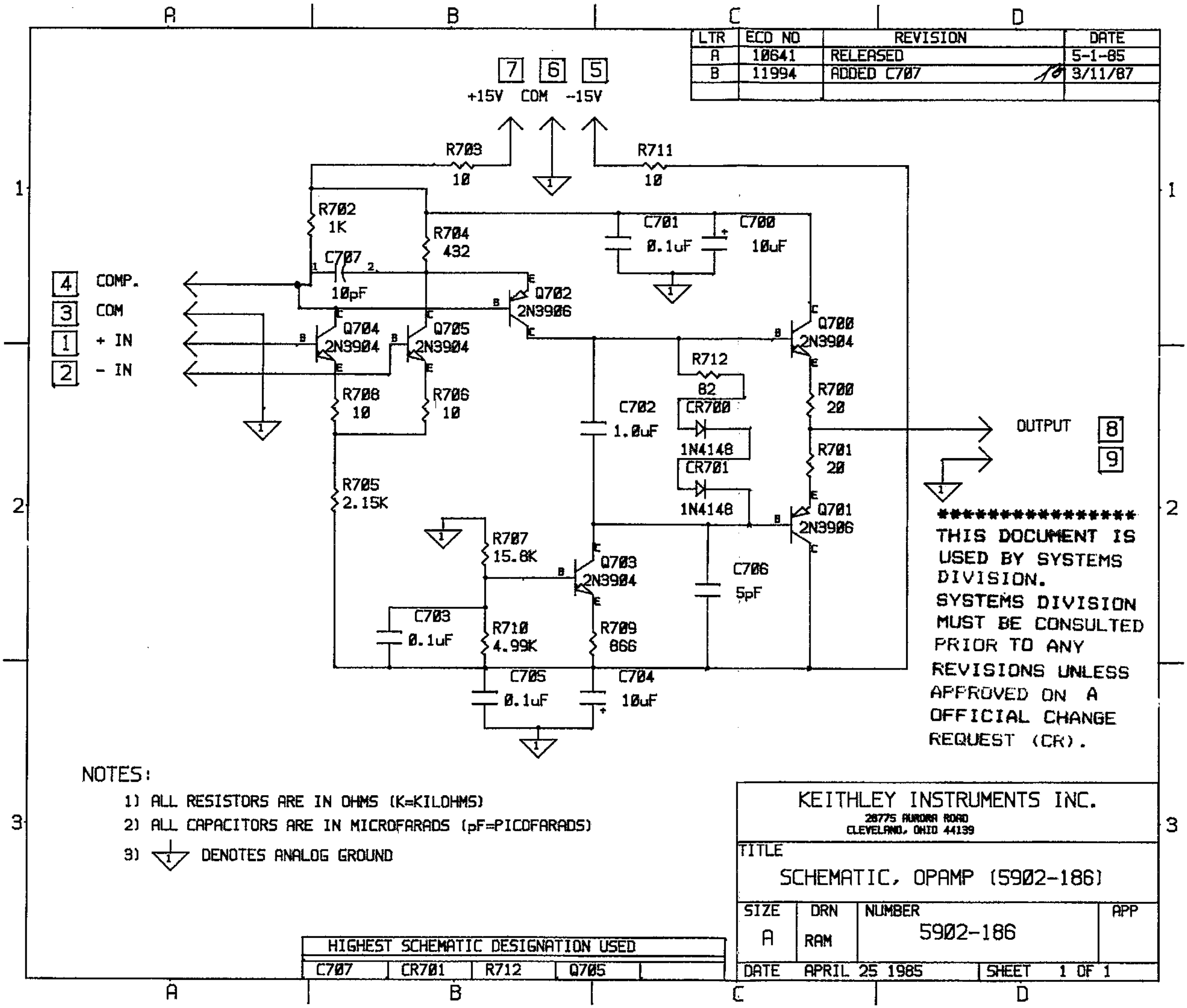


Figure 8-12. KI590 Operational Amplifier (U607), Schematic Diagram, Dwg. No. 5902-186

Table 8-7. Case Parts

Quantity	Description	Keithley Part Number
2	Side Panel	228-301
1	Front Bezel	228-303
3	P.C. Support	228-318
1	Modified P.C. Support	228-314-3
1	Modified P.C. Support	228-314-4
1	Front Panel	590-302
1	Display Window	590-304-1
1	Display Window	590-304-2
1	Front Panel Overlay	590-305
1	Connector Bracket	590-327
1	Capacitor (Bracket-to-Case)	C-22-.01
1	Choke	CH-29
1	Fastener (Routing Clip for CH-29)	FA-195
5	Mounting Rails	228-319
1	Module Mounting Shelf	590-317
1	Rear Panel	590-307
1	Fan	FN-8
1	Fan Filter	FL-6
1	BNC Bracket	590-328
1	Capacitor, (Bracket-to-Case)	C-22-.01
1	Choke	CH-29
1	Fastener for CH-29	FA-195
1	Top Cover	228-312
1	Bottom Cover	228-313
2	Rear Foot	706-316
2	Front Foot Assembly	706-317
2	Decorative Strip	706-321
2	Decorative Strip	706-339

Note: See assembly drawings in Section 7 for parts locations.

Table 8-8. Miscellaneous Mechanical Parts

Quantity	Description	Keithley Location	Part Number
2	Fuse Holder (Bias Fuse)	Mother Board	FH-12
1	Heat Sink (for TG-185 and TG-186)	Mother Board	HS-30
2	Mounting Kit (for TG-185 and TG-186)	Mother Board	MK-23
1	Shield, A/D Converter	Mother Board	590-313
1	Shield, Input Multiplexer	Mother Board	CN-57
2	Pushbutton (LOCAL, SHIFT)	Display Board	228-317-4
7	Pushbutton (RANGE through CAL)	Display Board	228-317-5
8	Pushbutton (MANUAL through SETUP)	Display Board	228-317-6
16	Pushbutton (▲ through C vs t)	Display Board	228-317-7
1	Heat Sink (for IC-240)	Digital Board	HS-22
1	Mounting Kit (for IC-240)	Digital Board	MK-16
1	Heat Sink (for IC-240)	Digital Board	HS-27
1	Mounting Kit (for IC-240)	Digital Board	MK-20
5	Heat Sink (for IC-93 and IC-174)	Digital Board	HS-30
4	Mounting Kit (for IC-93 and IC-174)	Digital Board	MK-18
1	Mounting Kit (for TG-107 and TG-108)	Digital Board	MK-23
1	BNC Jack Bracket	Digital Board	590-310
2	Socket (for LSI-56)	Digital Board	SO-69
1	Fuse Holder Body	Digital Board	FH-21
1	Fuse Carrier (for 3AG Fuse)	Digital Board	FH-25
1	Fuse Carrier (for 5mm Fuse)	Digital Board	FH-26
1	Line Cord		CO-7
1	Shield, Top	5901 Module	5901-302
1	Shield, Bottom	5901 Module	5901-304
1	Shield, Op Amp	5902 Module	5902-307
1	Shield	5902 Module	5902-304

Table 8-9. Model 5904 Input Adapter, Parts List

Circuit Quantity	Description	Keithley Part Number
1	Box, Modified	5904-302
2	Connector, BNC (Female)	CS-249
2	Connector, BNC (Male)	CS-552
1	Choke	CH-33
1	Transformer	TR-242
1	Lug	LU-27
1	Lug	LU-100
2	Washer, Black Neoprene	WA-86-2

APPENDIX A

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	-	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	^	MTA 30
95	5F	—	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60	∩	MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX B
CONTROLLER PROGRAMS

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you send a device-dependent command string to the instrument and obtain and display an instrument reading string.

Programs for the following controllers are included:

- IBM PC or XT (with Keithley Model 8573A IEEE-488 Interface)
- Apple II (equipped with the Apple II IEEE-488 Interface)
- Hewlett-Packard Model 85
- Hewlett-Packard Model 9816
- Hewlett-Packard Model 9825A
- DEC LSI 11

NOTE

The Model 590 uses commas to separate parameters in some commands. Many controllers also *use commas to delimit input strings. Use quotes around the command string to avoid problems.*

IBM PC OR XT (KEITHLEY MODEL 8573A INTERFACE)

The following program sends a command string to the Model 590 from an IBM PC or XT computer and displays the instrument reading string on the CRT. The computer must be equipped with the Keithley Model 8573A IEEE-488 Interface and the DOS 2.00 operating system. Model 8573A software must be installed and configured as described in the instruction manual.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disc in the default drive, type LOAD"DECL", and press the return key.
5. Add the lines below to lines 1-6 which are now in memory. Modify the address in lines 1 and 2, as described in the Model 8573A Instruction Manual.
6. Run the program and type in the desired command string. For example, to place the instrument in autorange and 1MHz frequency, type in R0F1X and press the return key.
7. The instrument reading string will then appear on the display. For example, the display might show NCPM+1.2345E−12.
8. To exit the program, type in EXIT at the command prompt and press the return key.

PROGRAM	COMMENTS
10 CLS	Clear screen.
20 NA$="GPIB0":CALL IBFIND (NA$,BRD0%)	Find board descriptor.
30 NA$="DEV1":CALL IBFIND (NA$,M590%)	Find instrument descriptor.
40 V%=15:CALL IBPAD(M590%,V%)	Set primary address to 15.
50 V%=&H102:CALL IBPOKE(BRD0%,V%)	Set timeouts.
60 V%=1:CALL IBSRE(BRD0%,V%)	Set REN true.
70 INPUT"COMMAND STRING";CMD$	Prompt for command.
80 IF CMD$="EXIT" THEN 150	See if program is to be halted.
90 IF CMD$="" THEN 70	Check for null input.
95 CMD$=CMD$+CHR$(13)+CHR$(10)	
100 CALL IBWRT(M590%,CMD$)	Address 590 to listen, send string.
110 RD$=SPACE$(100)	Define reading input buffer.
120 CALL IBRD(M590%,RD$)	Address 590 to talk, get reading.
130 PRINT RD$	Display the string.
140 GOTO 70	Repeat.
150 V%=0:CALL IBONL(M590%,V%)	Close the instrument file.
160 CALL IBONL(BRD0%, V%)	Close the board file.

NOTE: For conversion to numeric variable, make the following changes:

```
130 RD=VAL(MID$(RD$,5,15))
135 PRINT RD
```

APPLE II (APPLE II IEEE-488 INTERFACE)

The following program sends a command string to the Model 590 from an Apple II computer and displays the instrument reading string on the computer CRT.

The computer must be equipped with the Apple II IEEE-488 Interface installed in slot 5. Note that the program assumes that the computer is running under Apple DOS 3.3 or ProDOS.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IEEE-488 interface installed in the Apple II computer.
3. Enter the lines in the program below, using the RETURN key after each line.
4. Run the program and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the return key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPK+1.2345E−12.

PROGRAM	COMMENTS
10 Z$=CHR$(26):D$=CHR$(4)	Terminator.
20 ADDR=15: SLOT=5	Define address, slot variables.
30 INPUT ''COMMAND STRING''; B$	Input command string.
40 PRINT D$;''PR#''; SLOT	Set output to IEEE-488 bus.
50 PRINT D$;''IN#''; SLOT	Define input from IEEE-488 bus.
60 PRINT ''RA''	Enable remote.
70 PRINT ''LF1''	Line feed on.
80 PRINT ''WT'';CHR$(32+ADDR);Z$;B$	Address 590 to listen, send string.
90 PRINT ''RD'';CHR$ (64+ADDR);Z$	Address 590 to talk.
100 INPUT '''';A$	Input data.
110 PRINT ''UT''	Untalk the bus.
120 PRINT D$; ''PR#0''	Define output to CRT.
130 PRINT D$; ''IN#0''	Define input from keyboard.
140 PRINT A$	Display string.
150 GOTO 30	Repeat.

NOTES:

1. If conversion to numeric variable is required, make the following changes:

```
120 A=VAL(MID$(A$,5,15))
125 PRINT A
```

2. The Apple II INPUT statement terminates on commas. To avoid problems, program the Model 590 for the O1, O2, or O3 data format to eliminate commas.

HEWLETT-PACKARD MODEL 85

The following program sends a command string to the Model 590 from an HP-85 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and an I/O ROM.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the HP82937A GPIB interface installed in the HP-85 computer.
3. Enter the lines in the program below, using the END LINE key after each line.
4. Press the HP-85 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz average modes, type in R0F1X and press the END LINE key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 DIM A$[25],B$[50]`	Dimension strings.
`20 REMOTE 715`	Place 590 in remote.
`30 DISP''COMMAND STRING'';`	Prompt for command.
`40 INPUT A$`	Input command string.
`50 OUTPUT 715; A$`	Address 590 to listen, send string.
`60 ENTER 715; B$`	Address 590 to talk, input reading.
`70 DISP B$`	Display reading string.
`80 GOTO 30`	Repeat
`90 END`	

NOTE: For conversion to numeric variable, change line 70 as follows:

```
70 DISP VAL(B$[5,15])
```

HEWLETT-PACKARD MODEL 9816

The following program sends a command string to the Model 590 from a Hewlett-Packard Model 9816 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and BASICA 2.0.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the HP82937A GPIB interface installed in the 9816 computer.
3. Type EDIT and press the EXEC key.
4. Enter the lines in the program below, using the ENTER key after each line.
5. Press the 9816 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the ENTER key.
6. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 REMOTE 715`	Place 590 in remote.
`20 INPUT''COMMAND STRING'';A$`	Prompt for and input command.
`30 OUTPUT 715; A$`	Address 590 to listen, send string.
`40 ENTER 715; B$`	Address 590 to talk, input reading.
`50 PRINT B$`	Display reading string.
`60 GOTO 20`	Repeat.
`70 END`	

NOTE: For conversion to a numeric variable, change the program as follows:

```
40 ENTER 715;B
50 PRINT B
```

HEWLETT-PACKARD MODEL 9825A

Use the following program to send a command string to the Model 590 from a Hewlett-Packard Model 9825A and display the instrument reading string on the computer printer. The computer must be equipped with the HP98034A HPIB Interface and a 9872A extended I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the 98034A HPIB interface installed in the 9825A.
3. Enter the lines in the program below, using the STORE key after each line. Line numbers are automatically assigned by the 9825A.
4. Press the 9825A RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the CONT key.
5. The instrument reading string will then appear on the computer print out. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
0 dim A$[25],B$[20]	Dimension data strings.
1 dev''590'',715	Define 590 at address 15.
2 rem''590''	Place 590 in remote.
3 ent''COMMAND STRING'',B$	Prompt for command string.
4 wrt''590'',B$	Address 590 to listen, send string.
5 red''590'',A$	Address 590 to talk, input data.
6 prt A$	Print data string on printer.
7 gto 3	Repeat.

NOTE: For conversion to numeric variable, modify the program as follows:

```
6 prt val(A$[5])
```

DEC LSI 11

The following program sends a command string to the Model 590 from a DEC LSI 11 minicomputer and displays the instrument reading string on the DEC CRT terminal. The LSI 11 must be configured with 16K words of RAM and an IBV 11 IEEE-488 interface. The software must be configured with the IB software as well as FORTRAN and the RT 11 operating system.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IBV 11 IEEE-488 interface cable.
3. Enter the program below, using the editor under RT 11 and the name IEEE.FOR.
4. Compile using the FORTRAN compiler as follows: FORTRAN IEEE.
5. Link with the system and IB libraries as follows: LINK IEEE,IBLIB.
6. Type RUN IEEE and press the RETURN key.
7. The display will read "ENTER ADDRESS".
8. Type in 15 and press the RETURN key.
9. The display will read "TEST SETUP".
10. Type in the desired command string and press the RETURN key. For example, to program the instrument for the autorange and 1MHz modes, type in R0F1X and press RETURN.
11. The instrument data string will appear on the computer display. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`PROGRAM IEEE`	
`INTEGER*2 PRIADR`	
`LOGICAL*1 MSG(80),INPUT(80)`	
`DO 2 I = 1,10`	
`CALL IBSTER(I,0)`	Turn off IB errors.
`2 CONTINUE`	
`CALL IBSTER(15,5)`	Allow 5 error 15's.
`CALL IBTIMO(120)`	Allow 1 second bus timeout.
`CALL IBTERM(10)`	Set line feed as terminator.
`CALL IBREN`	Turn on remote.
`4 TYPE 5`	
`5 FORMAT (1X,'ENTER ADDRESS:',$)`	Input primary address.
`ACCEPT 10,PRIADR`	
`10 FORMAT (I2)`	
`12 TYPE 15`	
`15 FORMAT (1X,'TEST SETUP:',$)`	Prompt for command string.
`CALL GETSTR (5,MSG,72)`	Program instrument.
`CALL IBSEOI (MSG,-1,PRIADR)`	Address 590 to listen, send string.
`18 I=IBRECV (INPUT,80,PRIADR)`	Get data from instrument.
`INPUT (I+1) = 0`	
`CALL PUTSTR (7,INPUT,'0')`	
`CALL IBUNT`	Untalk the 590.
`GOTO 12`	Repeat.
`END`	

PET/CBM 2001

The following program sends a command string to the Model 590 from a PET/CBM 2001 computer and displays the instrument reading string on the computer CRT. As the PET/CBM computer has a standard IEEE-488 interface, no additional equipment is necessary.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the PET/CBM IEEE-488 interface.
3. Enter the lines of the program below, using the RETURN key after each line is typed.
4. Type RUN and press the RETURN key. Type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the RETURN key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 OPEN 1,15`	Open file 1, primary address 15.
`20 INPUT"COMMAND STRING";B$`	Prompt for, input command string.
`30 PRINT#1,B$`	Address 590 to listen, send string.
`40 INPUT#1,A$`	Address 590 to talk, input data.
`50 IF ST = 2 THEN 40`	If bus timeout, input again.
`60 PRINT A$`	Display reading string.
`70 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, modify the program as follows:

```
60 A = VAL(MID$(A$,5,15))
70 PRINT A
80 GOTO 20
```

2. The PET INPUT# statement terminates on a comma. Thus, when reading Model 590 strings which include commas, you should input each portion of the string into a separate string variable. For example, in the O0 mode, to obtain and display readings, the program above can be modified as follows:

```
40 INPUT#1, A$,B$,C$
60 PRINT A$","B$","C$
```

APPENDIX C

IEEE-488 BUS OVERVIEW

BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer with a minimum number of bus lines. In keeping with this goal, the bus has eight data lines that are used both for data and many commands. Additionally, the bus has five management lines, which are used to control bus operation, and three handshake lines that are used to control the data byte transfer sequence.

A typical configuration for controlled bus operation is shown in Figure C-1. A typical system will have one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), and a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener. The Model 590 has both talker and listener capabilities.

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

The bus is limited to 15 devices, including the controller. Thus, any number of devices may be present on the bus at one time. Although several active listeners may be present simultaneously, only one active talker may be present on the bus, or communications would be scrambled.

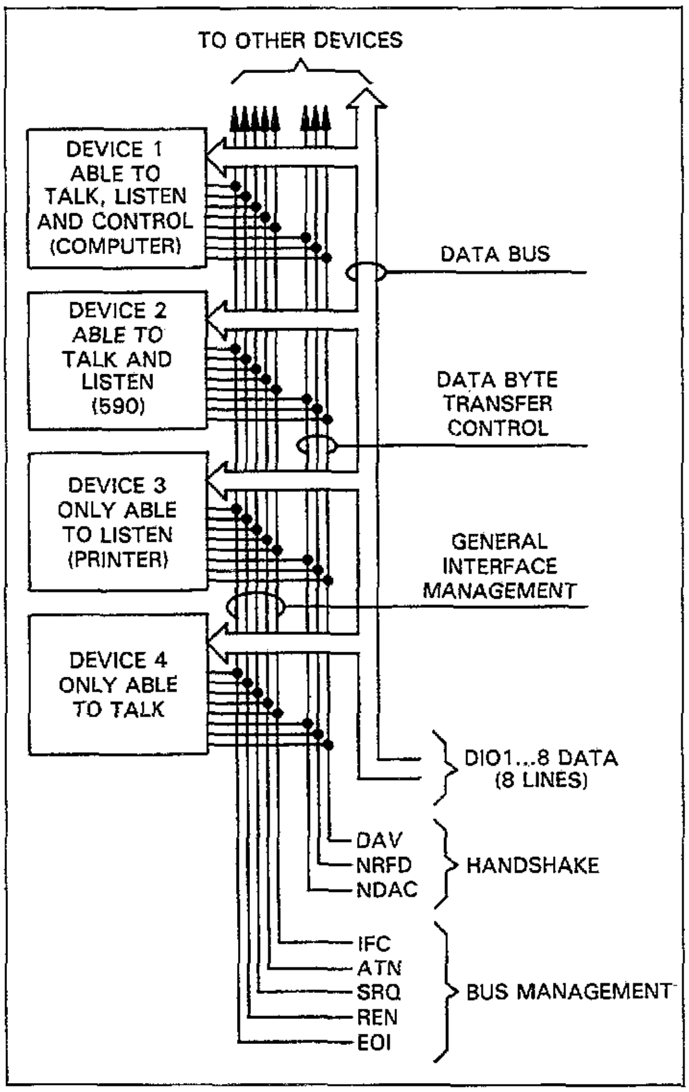


Figure C-1. IEEE Bus Configuration

A device is placed in the talk or listen mode from the controller by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30 and is generally set by rear panel switches or programmed in from the front panel (as in the case of the Model 590). The actual listen command value sent over the bus is derived by ORing the primary address with $20 (the $ symbol preceding the number designates a hexadecimal, or base 16 value). For example, if the primary address is 15 (the default Model 590 value), the actual listen command byte value is $2F ($0F + $20 = $2F). In a similar manner, the talk command byte is derived by ORing the primary address with $40. With a primary address of 15, the actual talk command byte would be $4F ($40 + $0F = $4F).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary address byte values lie in the range of $60-$7F. Note, however, that many devices, including the Model 590, do not use secondary addressing.

Once the device is properly addressed, bus transmission sequences are set to take place. For example, if an instrument is addressed to talk, it will usually output its data string on the bus one byte at a time. The listening device (frequently the controller) will then read this information as transmitted.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three categories: data lines, management lines, and handshake lines. The eight data lines handle bus data and many commands, while the management and handshake lines ensure orderly bus operation. Each bus line is active low with approximately zero volts representing logic 1 (true). The following paragraphs briefly describe the operation of these lines.

Data Lines

The bus uses eight data lines to transmit and receive data in bit-parallel, byte serial fashion. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining bus lines, low is considered to be true.

Bus Management Lines

The five bus management lines ensure proper interface control and management. These lines are used to send uniline commands.

ATN (Attention)—The state of ATN determines how information on the data lines is to be interpreted.

IFC (Interface Clear)—IFC allows the clearing of active talkers or listeners from the bus.

REN (Remote Enable)—REN is used to place devices in the remote mode. Usually, devices must be in remote before they can be programmed over the bus.

EOI (End Or Identify)—EOI is used to mark the end of a multi-byte data transfer sequence. EOI is also used along with ATN, to send the IDY (identify) message for parallel polling.

SRQ (Service Request)—SRQ is used by devices to request service from the controller.

Handshake Lines

Three handshake lines that operate in an interlocked sequence are used to ensure reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus. These handshake lines are:

DAV (Data Valid)—The source (talker) controls the state of DAV to indicate to any listeners when data is valid.

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

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

Figure C-2 shows the basic handshake sequence for the transmission of one data byte. This sequence is used to transfer data, talk and listen addresses, as well as multiline commands.

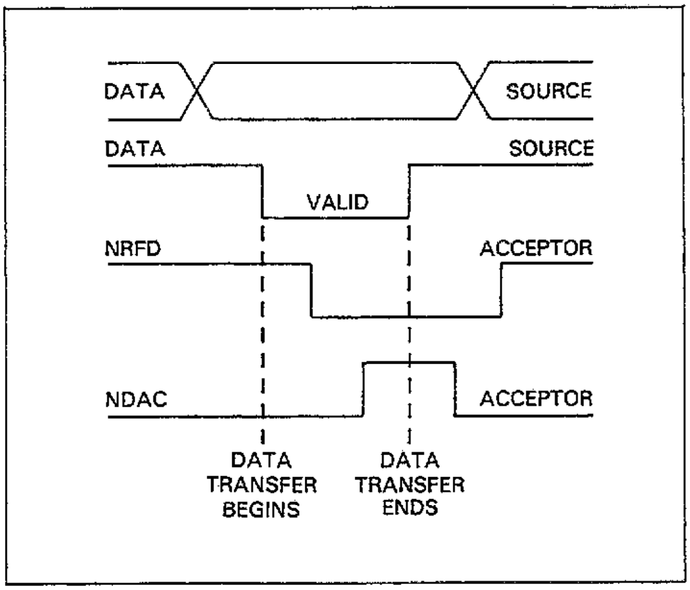


Figure C-2. IEEE Handshake Sequence

BUS COMMANDS

Commands associated with the IEEE-488 bus can be grouped into the following three general categories. Refer to Table C-1.

Uniline Commands—These commands are asserted by setting the associated bus line true. For example, to assert REN (Remote Enable), the REN line would be set low (true).

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

Device-dependent Commands—Commands whose meanings depend on the device in question. These commands are transmitted via the data lines while ATN is false.

Table C-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 590 for various modes.

*Don't Care.

Uniline Commands

The five uniline commands include REN, EOI, IFC, ATN, and SRQ. Each command is associated with a dedicated bus line, which is set low to assert the command in question.

REN (Remote Enable)—REN is asserted by the controller to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be asserted before attempting to program instruments over the bus.

EOI (End or Identify)—EOI may be asserted either by the controller or by external devices to identify the last byte in a multi-byte transfer sequence, allowing data words of various lengths to be transmitted.

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

ATN (Attention)—The controller asserts ATN while sending addresses or multiline commands.

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

Universal Multiline Commands

Universal multiline commands are those commands that required no addressing as part of the command sequence. All devices equipped to implement these commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out front panel or local operation of the instrument.

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

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

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

Addressed Multiline Commands

Addressed multiline commands are those commands that must be preceded by an appropriate listen address before the instrument will respond to the command in question. Note that only the addressed device will respond to the command. Both the command and the address preceding it are sent with ATN true.

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

GTL (Go To Local)—GTL is used to remove instruments from the remote mode and place them in local. With many instruments, GTL may also restore operation of front panel controls if previously locked out.

GET (Group Execute Trigger)—GET is used to trigger devices to perform a specific action that will depend on device configuration (for example, perform a measurement sequence). Although GET is an addressed command, many devices may respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups, and a secondary address group. ATN is true when these commands are asserted. These commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 590) do not use these commands.

Unaddress Commands

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

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

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

Device-Dependent Commands

The purpose of device-dependent commands will depend on instrument configuration. Generally, these commands are sent as one or more ASCII characters that command the device to perform a specific action. For example, the command string R0X is used to control the measurement range of the Model 590.

The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure C-3. Hexadecimal and and decimal values for the various commands are listed in Table C-2.

D7 D6 D5 D4					X 0 0 0	COMMAND	X 0 0 1	COMMAND	X 0 1 0	PRIMARY ADDRESS	X 0 1 1	PRIMARY ADDRESS	X 1 0 0	PRIMARY ADDRESS	X 1 0 1	PRIMARY ADDRESS	X 1 1 0		X 1 1 1	
BITS D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		|	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	_	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE), PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 590.

NOTE: D_0 = DIO1 ... D_7 = DIO8
X = DON'T CARE

Figure C-3. Command Codes

Table C-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table C-3 lists a typical bus sequence for sending an addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table C-3. Typical Addressed Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	/	2F	47
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 15.

Table C-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

Table C-4. Typical Device-Dependent Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	/	2F	47
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 15.

IEEE Command Groups

Command groups supported by the Model 590 are listed in Table C-5. Device-dependent commands are not included in this list.

Table C-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
- DAC=DATA ACCEPTED
- RFD=READY FOR DATA
- DAV=DATA VALID

UNIVERSAL COMMAND GROUP
- ATN=ATTENTION
- DCL=DEVICE CLEAR
- IFC=INTERFACE CLEAR
- LLO=LOCAL LOCKOUT
- REN=REMOTE ENABLE
- SPD=SERIAL POLL DISABLE
- SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUN
- LISTEN: LAG=LISTEN ADDRESS GROUP
- MLA=MY LISTEN ADDRESS
- UNL=UNLISTEN
- TALK: TAG=TALK ADDRESS GROUP
- MTA=MY TALK ADDRESS
- UNT=UNTALK
- OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
- ACG=ADDRESSED COMMAND GROUP
- GET=GROUP EXECUTE TRIGGER
- GTL=GO TO LOCAL
- SDC=SELECTIVE CLEAR

STATUS COMMAND GROUP
- RQS=REQUEST SERVICE
- SRQ=SERIAL POLL REQUEST
- STB=STATUS BYTE
- EOI=END

APPENDIX D

USING THE MODEL 590 WITH THE KEITHLEY MODEL 8573A IEEE-488 INTERFACE

INTRODUCTION

This information will help you use the Model 590 with the Keithley Model 8573A IEEE-488 interface. The Model 8573A interfaces the IBM PC, XT, and AT computers (and certain IBM compatibles such as the Compaq) to the IEEE-488 bus. Information presented here is necessarily brief in nature, for more complete information, consult the Model 8573A Instruction Manual.

PROGRAMMING STATEMENT SUMMARY

An abridged listing of Model 8573A programming statements is given in Table on the next page. More complex applications may require other programming statements, as discussed in the Model 8573A Instruction Manual.

SOFTWARE CONFIGURATION

Before using Model 8573A programs, you must configure the software using the procedure below. This procedure assumes that you will be using the Model 590 with its primary address at the default value of 15.

1. Build a working disk as discussed in the Model 8573A Instruction Manual. Among other files, this diskette must include the GPIB.COM, BIB.M, and CONFIG.SYS files, as discussed in that manual.
2. Boot up the computer using the working disk discussed in step 1 above and enter BASICA.
3. Load the Model 8573A declaration file called "DECL.BAS". Modify the program by changing the XXXXX values as described in the Model 8573A Instruction Manual.
4. Delete lines 7-99 and add the following lines to the declaration file.

```
7 NA$=''GPIB0'':CALL IBFIND(NA$,BRD0%)
8 NA$=''DEV15'':CALL IBFIND(NA$,M590%)
9 V%=15:CALL IBPAD(M590%,V%)
```

5. Now save this modified declaration file for use with BASIC programs you write. Remember that this modified file must appear at the front of every program.

Progamming Example—The program below will allow you to send simple device-dependent command strings for the Model 590. Keep in mind that the statements in the modified declaration file discussed above must be included at the front of every program.

PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Set REN true.
`20 INPUT''COMMAND'';C$`	Prompt for command string.
`30 CALL IBWRT(M590%,C$)`	Send command string to 590.
`40 R$=SPACE$(100)`	Define reading input buffer.
`50 CALL IBRD(M590%,R$)`	Get reading string from 590.
`60 PRINT R$`	Display reading string.
`70 GOTO 20`	Repeat.

Table D-1.

Model 8573A Statement	Description	Equivalent HP-85 Statement*
CALL IBWRT(M590%,A$)	Send string to unit.	OUTPUT 715; A$
CALL IBRD(M590%,A$)	Input string from unit.	ENTER 715; A$
CALL IBLOC(M590%)	Send GTL to 590.	LOCAL 715
CALL IBCLR(M590%)	Send SDC to 590.	CLEAR 715
A$=CHR$(&H14):CALL IBCMD(BRD0%,A$)	Send DCL to all devices.	CLEAR 7
V%=1:CALL IBSRE(BRD0%,V%)	Set REN true.	REMOTE 7
V%=0:CALL IBSRE(BRD0%,V%)	Set REN false.	LOCAL 7
CALL IBRSP(M590%,SB%)	Serial poll unit.	SPOLL(715)
A$=CHR$(&H11):CALL IBCMD(BRD0%,A$)	Send local lockout.	LOCAL LOCKOUT 7
CALL IBTRG(M590%)	Send GET to device.	TRIGGER 715
CALL IBSIC(BRD0%)	Send IFC.	ABORTIO 7

*Assumes interface select code 7, primary address 15.

APPENDIX E

EQUIVALENT IEEE-488 COMMANDS FOR FRONT PANEL KEYS

Front Panel Key	IEEE-488 Command(s)
RANGE	R
FREQ	F
MODEL	O
FILTER	P
RATE	S
ZERO	Z
CAL	Q0
TRIGGER MODE/SOURCE	T
BIAS ON	N
WAVEFORM	W
PARAMETER	W, V
PLOT	A0
GRID	A1
SETUP	A2-A8
BUFFER	B1, B2
A → B	B3
CABLE CAL	IO, C1
CABLE #	CO
SELF TEST	J
SAVE	L1
RECALL	L0
$1/C^2$	O4
C/C_O	O5
C_{max}	U16, U19
C_A-C_B	O6
[$V_A$$V_B$] C=CONST	O7
C vs t	U8, U15

APPENDIX F

SETUP CONFIGURATION WORKSHEETS

Worksheet #1

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #2

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #3

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #4

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #5

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

APPENDIX G

ENGINEERING UNITS AND SCIENTIFIC NOTATION CONVERSION

Engineering Symbol	Prefix	Scientific Notation
femto-	f	10^{-15}
pico-	p	10^{-12}
nano-	n	10^{-9}
micro-	μ	10^{-6}
milli-	m	10^{-3}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}
peta-	P	10^{15}

APPENDIX H
GLOSSARY OF TERMS

Abort—To terminate or break off an operation.

Accuracy—The maximum error in terms of measurement made by an instrument. For digital instruments, accuracy is usually specified as a percent of reading plus so many counts of error.

A/D (Analog-to-Digital) Converter—A device that changes an analog signal into binary or digital values.

Analog—Pertaining to electronic devices in which the output varies as a continuous function of the input.

Analog Output—An output that provides an analog signal derived from the digital information within the instrument.

ASCII—Abbreviation for American Standard Code for Information Interchange (pronounced ask-ee). A standard code used extensively in computers and data transmission in which 128 letters, numbers, symbols, and special control characters are represented by 7-bit binary numbers.

BASIC—Abbreviation for Beginners All-purpose Symbolic Instruction Code. A high-level programming language used in many small computers.

Bias Voltage—A voltage applied to a semiconductor for the purpose of establishing a reference level for the operation of the device during testing.

Binary—A number system based on the number 2; used extensively in computer-based equipment.

Bit—An abbreviation for binary digit. A unit of binary information is equal to one binary decision, or the designation of one of two possible states, generally represented by 1 and 0.

BNC—A type of coaxial connector used in situations requiring shielded cable for signal connections.

Buffer—A dedicated area of memory in which some form of binary data is stored for later access. The two Model 590 buffers each store 450 words of capacitance, conductance, and bias voltage information.

Bus—In computerized equipment, one or more conductors used as a path over which information is transmitted from any of several sources to any of several destinations.

Byte—A group of bits processed together in parallel; by definition a byte is made up of eight bits.

Capacitance—Abbreviated C. In a capacitor or a system of conductors and dielectrics, that property which permits the storage of electrically separated charges when potential differences exist between the conductors. Capacitance is related to charge and voltage as follows: $C = Q/V$, where C is the capacitance in farads, Q is the charge in coulombs, and V is the voltage in volts.

Chassis Ground—A connection to a common metal structure within the instrument. Generally, chassis ground is connected through power line ground to earth ground via a 3-wire power cord for safety purposes.

Clock—A pulse generator or signal waveform used to achieve synchronization of digital circuits.

Coaxial Cable—A cable in which one conductor completely surrounds the other, the two being coaxial and separated by continuous solid dielectric.

Conductance—Abreviated G. The reciprocal (1/R) of resistance, usually specified in Siemens (S).

Command—A signal, originating within a computer, that triggers or initiates some form of action within the instrument.

Common Mode Voltage—A voltage applied between input low and chassis ground of the instrument.

Complex Waveform—A periodic waveform made up of a combination of several frequencies or several sine waves superimposed on one another.

Controller—A device which governs the operation of the IEEE-488 bus; generally a controller is a small computer or microcomputer.

Count—The minimum step size that an instrument display can resolve. Display size is often defined in counts, as in a 20,000 count display.

CRT—Cathode Ray Tube. A term generally used when referring to a computer or terminal display screen.

Cursor—A brightened display digit or segment used to indicate the next digit affected by data entry.

DAC—Abbreviation for Digital-to-Analog Converter. A device which converts digital or binary information into an analog signal.

Data Entry—The process of keying in data from the front panel using the numeric keys.

dB—Abbreviation for decibel, which is a logarithmic unit used to measure and compare voltage, current, and power levels.

Digital—Circuitry in which the data-carrying signals are restricted to one of two voltage levels. These voltage levels are used to represent the binary values 1 and 0.

Digitize—To convert an analog signal into a series of binary numbers representing its amplitude at discrete intervals of time.

Earth Ground—A connection from an electrical circuit or instrument to the earth through a water pipe or metal rod driven into the ground.

EMI—Abbreviation for Electromagnetic Interference. A term that defines unwanted electromagnetic radiation from a device which could interfere with desired signals in electronic receiving equipment such as television and radio. RFI (Radio Frequency Interference) and EMI are often used interchangeably.

GPIB—Abbreviation for General Purpose Interface Bus. Another term for the IEEE-488 bus.

Hexadecimal—A number system based on the number 16 that uses values 0-9, and A through F to represent the 16 possible values of a 4-bit binary number. Hexadecimal numbers are represented by preceding them with a $ or following them with a letter H. Thus, $7F and 7FH would be equivalent.

IC—Abbreviation for Integrated Circuit. A combination of interconnected circuit elements inseparably contained on or within a single substrate.

IEEE-488 Bus—A parallel instrumentation data and control bus standardized by the Institute of Electrical and Electronic Engineers.

I/O—Abbreviation for input/output, which refers to the transmission of information from an instrument to an external device (output), or the transfer of information from an external device to an instrument (input).

K—Abbreviation for kilo. In computer terms, 1K equals 1024. For example, a 16K byte memory has 16,384 bytes.

LED—Light-Emitting Diode. A PN junction diode that emits light when forward biased. LEDs are used in front panel annunciators as well as the individual segments of numeric displays on instrumentation.

Listener—A device which, when connected to the IEEE-488 bus, is capable if receiving information over that bus.

Microprocessor—The control and processing portion of a small computer, microcomputer, or computerized device, which is usually contained within one LSI (Large Scale Integration) IC.

Module—A complete subassembly of the instrument combined in a single package (for example, a 5901 100kHz CV module).

Noise—Any unwanted signal appearing in an electronic device.

Normal Mode Voltage—A voltage applied between the input high and input low terminals of an instrument.

NVRAM—Abbreviation for Non-volatile Random Access Memory. A special type of electrically alterable ROM that is used to store information such a calibration constants on a semi-permanent basis. Stored information is retained when power is removed from the device.

Parallel—The simultaneous storage, transmission, or logical operation on a group of bits at one time.

Periodic Waveform—An electronic waveform that repeats itself regularly in time and form.

Plotter—A device that produces an inscribed display of the variation of a dependent variable (Y axis) as a function of an independent variable (X axis).

Programmable Instrument—An instrument whose operation can be determined by keystroke sequences entered from the front panel or with commands sent over the IEEE-488 bus.

RAM—Abbreviation for Random Access Memory. A type of memory where information can be stored (written) and accessed (read). RAM memory is usually volatile, meaning that data is lost when the power is turned off.

Random Access—Access to any location in instrument memory where each location can be accessed in the same amount of time.

Reading—A group of data consisting of capacitance, conductance and measured bias voltage. The result is then shown on the front panel display, stored in buffer, or sent over the IEEE-488 bus.

Resolution—The smallest increment of change in voltage that can be detected by the instrument.

ROM—Abbreviation for Read Only Memory. A type of memory which permanently stores program information for a microprocessor. ROM memory is non-volatile, which means that programmed information remains intact after power is removed.

Sequential Access—Serial access to instrument memory where lower or higher memory locations must be passed through before reaching the desired location.

Serial—The technique for handling a binary data word which has more than one bit. The bits are processed one at a time in single-file sequence.

Sinusoidal—Varying in proportion to the sine of an angle or time function (for example, ordinary alternating current).

Software—The program instruction coding within an instrument or computer that makes the unit operate.

Talker—A device that can transmit information over the IEEE-488 bus.

Transfer Standard—An accurate value used to calibrate an instrument. The accuracy of the standard is generally traceable to a known standard for the unit in question.

Transient Waveform—An electronic signal that results in a sudden change in circuit conditions which persists only for a brief period of time.

Translator Mode—A mode which allows English-like words to be used in place of instrument bus commands.

Trigger—A stimulus of some sort that initiates a one shot, single sweep, or continuous reading sequence, depending on the selected trigger mode. Trigger stimuli include: front panel, an external trigger pulse, and IEEE-488 bus X, talk, and GET triggers.

Word—A group of characters stored in one location in a computer or computerized device. Generally, a word is made up of two or more bytes.

Zero—A mode that allows a baseline measurement to be subtracted from subsequent measurements.

APPENDIX I

BASIC 2.0/4.0 PROGRAM CONVERSIONS

All example programs included in this manual are written in HP-85 BASIC. The syntax used by other Hewlett-Packard computers running under BASIC 2.0 or BASIC 4.0 (9816, 9826 and 9836) is very similar. However, there are a few differences between these programming languages, as indicated below.

Table I-1. HP-85 and BASIC 2.0/4.0 Programming Language Differences

HP-85 Statement	BASIC 2.0(4.0) Equivalent Statement(s)*	Comments
CLEAR	C$=CHR$(255) & CHR$(75) H$=CHR$(255) & CHR$(84) OUTPUT KBD; C$; H$	Clear screen, home cursor
DISP	PRINT	Display variables or literals on CRT.
ENABLE INTR 7; 8	ENABLE INTR 7; 2	Enable SRQ interrupt
STATUS 7, 1; S	STATUS 7, 5; S	Clear SRQ interrupt
DISP ''MESSAGE'', INPUT A$	INPUT ''MESSAGE'', A$	Prompt for and input variable.
IF...THEN...ELSE...	IF...THEN... ... ELSE... ... END IF	Conditional branching
ABORTIO 7	ABORT 7	Send IFC

*Used by HP-9816, 9826 and 9836.

MODEL 590 DEVICE-DEPENDENT COMMANDS

Execute (X)	
X	Execute Commands

Frequency (F)	
F0	100kHz
F1	1MHz
F2	Disconnect test signal

Range (R)		
	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	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
S1	75/sec, 3½ digits
S2	18/sec, 4½ digits
S3	10/sec, 4½ digits
S4	1/sec, 4½ digits

NOTE: Reading rates are nominal

Trigger (T)	
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 pulse
T3,1	Sweep on external pulse
T4,0	One-shot on front panel
T4,1	Sweep on front panel

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 rate)

Waveform (W)	
W(waveform)(,start)(,stop)(,step)	Waveform: 0 = DC; 1 = Single stair; 2 = Dual stair; 3 = Pulse; 4 = External; Start = start time; Stop = stop time; Step = step time; $1msec \leq T \leq 65sec$

NOTE: Multiply programmed times by 1.024 to obtain actual times.

Bias Control (N)	
N0	Bias off
N1	Bias on

Data Format (G)	
G0	Prefix on, suffix off, 1rdg
G1	Prefix off, suffix off, 1 rdg
G2	Prefix on, suffix on, 1 rdg
G3	Prefix on, suffix off, n rdgs
G4	Prefix off, suffix off, n rdgs
G5	Prefix on, suffix on, n rdgs
	n rdgs = # readings in buffer

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: $0 \leq C_O \leq 20E-9$

Buffer (B)	
B0	Current Reading
B1(,first)(,last)	A/D buffer, first, last limits
B2(,first)(,last)	Plot buffer, first, last limits
B3	Transfer A/D buffer to plot buffer

Plotter (A)	
A0	Execute plot
A1	Execute grid
A2, plot	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
A3, grid	Grid: 0 = Full grid; 1 = Axis only
A4, buffer	Buffer: 0 = A/D buffer (A); 1 = Plot buffer (B)
A5, pen	Pen: 0 = No pen; 1 = Pen #1; 2 = Pen #2
A6, line	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
A7, label	Label: 0 = Full labels; 1 = Label axis and divisions; 2 = Label axis only
A8,n, Xmin, Xmax	X axis limits. n = 0: Autoscaling (minimum/maximum bias). n = 1: Program X axis minimum (Xmin) and maximum (Xmax) values.
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	Disable zero
Z1	Enable zero

Filter (P)	
P0	Filter off
P1	Filter on

Status (U)	
U0	Hardware/software revision
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
U7	Buffer A bias time
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
U14	Buffer B bias time
U15	Buffer B position and times
U16	Buffer A maximum/minimum capacitance
U17	Buffer A maximum/minimum conductance
U18	Buffer A maximum/minimum voltage
U19	Buffer B maximum/minimum capacitance
U20	Buffer B maximum/minimum conductance
U21	Buffer B maximum/minimum voltage
U22	Global parameters (series/parallel, C_0 value)
U23	Plotter parameters (plot, grid, line, etc.)
U24	IEEE output parameters (O, G, B, Y, K)
U25	IEEE input parameters (L, C, H, K, M)
U26	Cable correction parameters
U27	Translator user name list
U28	Not used
U29	Translator reserved word list
U30	Translator NEW/OLD state
U31	Translator user translation list
U32	Not Used

SRQ (M)	
M0	Disabled
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)
L1,n	Save configuration n (1≤n≤7)

Cable Parameters (I)	
I0	Measure cable parameters (driving point)
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)
C1,n	Save cable #n (1≤n≤7)

Self Test (J)	
J1	Perform self test

Calibration (Q)	
Q0	Drift correction
	NORMAL MODE
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>
Y1	<LF><CR>
Y2	<CR>
Y3	<LF>

EOI and Hold-off (K)	
K0	EOI and hold-off enabled
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)
DX	Return display to normal

Hit Button (H)	
	Emulate button press:
H12	SHIFT
H15	ENTER
H16	(A↔B)
H20	ON
H23	MANUAL
H25	ZERO
H26	CAL
H27	FILTER
H29	RANGE
H30	FREQ
H31	MODEL

KEITHLEY

Service Form

Model No. ____________ **Serial No.** ____________ **Date** ____________

Name and Telephone No. ________________________________

Company ________________________________

List all control settings, describe problem and check boxes that apply to problem. ________________________________

____

____

- ❑ Intermittent
- ❑ IEEE failure
- ❑ Front panel operational
- ❑ Analog output follows display
- ❑ Obvious problem on power-up
- ❑ All ranges or functions are bad
- ❑ Particular range or function bad; specify ____________
- ❑ Batteries and fuses are OK
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unstable
- ❑ Overload
- ❑ Unable to zero
- ❑ Will not read applied input

- ❑ Calibration only
- ❑ Data required
- ❑ Certificate of calibration required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

____

____

What power line voltage is used? ____________ Ambient temperature? ____________°F

Relative humidity? ____________ Other? ____________

Any additional information. (If special modifications have been made by the user, please describe.)

____

____

Be sure to include your name and phone number on this service form.

Specifications are subject to change without notice.

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