

KEITHLEY

Models 5905, 5906, 5907, and 5955

Calibration Sources

Instruction Manual

A GREATER MEASURE OF CONFIDENCE

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Models 5905, 5906, 5907, and 5955 Calibration Sources Instruction Manual

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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.

5905 SPECIFICATIONS

CALIBRATION SOURCES FOR MODEL 590/1M

VALUE	ACCURACY, 23° ±2°C			
	24 HOUR		*90 DAY	
	100kHz	1MHz	100kHz	1MHz
1.8 nF	465ppm	645ppm	640ppm	820ppm
470 pF	375ppm	420ppm	550ppm	595ppm
180 pF	375ppm	390ppm	550ppm	565ppm
47 pF	375ppm	380ppm	550ppm	555ppm
18 pF	375ppm	375ppm	550ppm	550ppm
4.7 pF	375ppm	375ppm	550ppm	550ppm
18 mS	300ppm	300ppm	375ppm	375ppm
1.8mS	300ppm	300ppm	375ppm	375ppm
180 μS	300ppm	300ppm	375ppm	375ppm

*Typical Accuracies for >90 days from calibration:
 add 350ppm × √years to 24 hour capacitance specifications.
 add 150ppm × √years to 24 hour conductance specifications.

CAPACITANCE FROM EITHER TERMINAL TO CASE:
 3.5pF maximum.

TEMPERATURE COEFFICIENT OF DIRECT CAPACITANCE (0 to 50°C): +140ppm/°C typical.

MAXIMUM VOLTAGE: ±300V.

INSULATION RESISTANCE (terminal to terminal or case): 10¹³Ω min. (1.8nF, 470pF), 10¹⁴Ω min. (180pF or less).

TERMINALS: 2 male BNC push-on connectors spaced on 1 inch centers.

OPERATING ENVIRONMENT: 0° to +50°C; 0% to 70% relative humidity up to +35°C.

DIMENSIONS: Each calibration source is 1.38 × 2.25 × 1.75 inches (35 × 57 × 44 mm). Carrying case with calibration sources is 9.75 × 9.00 × 2.88 inches (248 × 229 × 73 mm); weight 4 lbs. 12 oz. (2.16 kg).

STORAGE TEMPERATURE: -25° to +65°C.

5906 SPECIFICATIONS

CALIBRATION SOURCES FOR MODELS 590/100k, 590/1M, 590/100k/1M, 5904, 595

VALUE	ACCURACY, 23° ±2°C			
	24 HOUR		*90 DAY	
	100kHz	1MHz	100kHz	1MHz
18 nF	490ppm		665ppm	
4.7nF	470ppm		645ppm	
1.8nF	465ppm	645ppm	640ppm	820ppm
470 pF	375ppm	420ppm	550ppm	595ppm
180 pF	375ppm	390ppm	550ppm	565ppm
47 pF	375ppm	380ppm	550ppm	555ppm
18 pF	375ppm	375ppm	550ppm	550ppm
4.7pF	375ppm	375ppm	550ppm	550ppm
1.5pF	375ppm	375ppm	550ppm	550ppm
0.5pF	375ppm	375ppm	550ppm	550ppm
18 mS	300ppm	300ppm	375ppm	375ppm
1.8mS	300ppm	300ppm	375ppm	375ppm
180 μS	300ppm	300ppm	375ppm	375ppm
18 μS	300ppm	300ppm	375ppm	375ppm
1.8μS	300ppm	300ppm	375ppm	375ppm

CAPACITANCE FROM EITHER TERMINAL TO CASE:
3.5pF maximum; 7.0pF maximum for 18nF and 4.7nF.

TEMPERATURE COEFFICIENT OF DIRECT CAPACITANCE (0 to 50°C): +140ppm/°C typical.

MAXIMUM VOLTAGE: ±300V.

INSULATION RESISTANCE (terminal to terminal or case): 10¹²Ω min. (18nF, 4.7nF), 10¹³Ω min. (1.8nF, 470pF), 10¹⁴Ω min. (180pF or less).

TERMINALS: 2 male BNC push-on connectors spaced on 1 inch centers.

OPERATING ENVIRONMENT: 0° to +50°C; 0% to 70% relative humidity up to +35°C.

DIMENSIONS: Each calibration source is 1.38 × 2.25 × 1.75 inches (35 × 57 × 44 mm). Two carrying cases provided. One carrying case with calibration sources is 9.75 × 9.00 × 2.88 inches (248 × 229 × 73 mm); weight 4 lbs. 12 oz. (2.16 kg) second carrying case with calibration sources is 9.75 × 6.5 × 2.88 inches (248 × 165 × 73 mm); weight 2 lbs. 10 oz. (1.20 kg).

STORAGE TEMPERATURE: -25°C to +65°C.

*Typical Accuracies for >90 days from calibration:
add 350ppm × √years to 24 hour capacitance specifications.
add 150ppm × √years to 24 hour conductance specifications.

5907 SPECIFICATIONS

CABLE/MATRIX CALIBRATION SOURCES

VALUE	ACCURACY, 23° ±2°C			
	24 HOUR		*90 DAY	
	100kHz	1MHz	100kHz	1MHz
1.8 nF	465ppm	645ppm	640ppm	820ppm
470 pF	375ppm	420ppm	550ppm	595ppm

*Typical Accuracies for >90 days from calibration:
add $350\text{ppm} \times \sqrt{\text{years}}$ to 24 hour capacitance specifications.

CAPACITANCE FROM EITHER TERMINAL TO CASE:
3.5pF maximum.

TEMPERATURE COEFFICIENT OF DIRECT CAPACITANCE (0 to 50°C): +140ppm/°C typical.

MAXIMUM VOLTAGE: ±300V.

INSULATION RESISTANCE (terminal to terminal or case): $10^{13}\Omega$ minimum.

TERMINALS: 2 male BNC push-on connectors spaced on 1 inch centers.

OPERATING ENVIRONMENT: 0° to +50°C; 0% to 70% relative humidity up to +35°C.

DIMENSIONS: Each Calibration source is 1.38 × 2.25 × 1.75 inches (35 × 57 × 44 mm). Carrying case with calibration sources is 9.75 × 6.50 × 2.88 inches (248 × 165 × 73 mm); weight 2 lbs. 10 oz. (1.20 kg).

STORAGE TEMPERATURE: -25° to +65°C.

5955 SPECIFICATIONS

CALIBRATION SOURCES FOR MODEL 595

VALUE	ACCURACY 23° ±3°C, 1 YR.		INSULATION RESISTANCE
	DC to 100kHz	DC to 1MHz	
18 nF	0.2 %	0.4 %	10 ¹² Ω min.
1.8nF	0.2 %	0.2 %	10 ¹³ Ω min.
180 pF	0.2 %	0.2 %	10 ¹⁴ Ω min.

TEMPERATURE COEFFICIENT OF DIRECT CAPACITANCE (0 to 50°C): +140ppm/°C typical.

MAXIMUM VOLTAGE: ±300V.

TERMINALS: 2 male BNC push-on connectors spaced on 1 inch centers.

OPERATING ENVIRONMENT: 0° to +50°C; 0% to 70% relative humidity up to +35°C.

DIMENSIONS: Each calibration source is 1.38 × 2.25 × 1.75 inches (35 × 57 × 44 mm). Carrying case with calibration sources is 9.75 × 6.50 × 2.88 inches (248 × 165 × 73 mm); weight 2 lbs. 10 oz. (1.20 kg).

STORAGE TEMPERATURE: -25° to +65°C.

Contains an overview of the available calibration sources, including source values, unpacking instructions, and warranty information.

SECTION 1

General Information

Discusses the mechanical construction and calibration theory of the capacitance and conductance sources.

SECTION 2

Design Considerations

Gives the procedures necessary to calibrate the Model 590 CV Analyzer at both 100kHz and 1MHz using the Models 5905 and 5906 Calibration Sources.

SECTION 3

Model 590 Calibration

Details step-by-step instructions for calibrating the Model 595 Quasistatic CV Meter using the Model 5955 Calibration Sources.

SECTION 4

Model 595 Calibration

Covers the procedures for using the sources to perform cable correction that should be used with the Model 590 when measuring at 1MHz.

SECTION 5

Cable Correction

Gives the procedures to re-characterize the sources.

SECTION 6

Characterization

Gives a list of replacement parts for the calibration sources.

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SECTION 1 GENERAL INFORMATION

1.1 INTRODUCTION

This section contains general information concerning the Models 5905, 5906, 5907, and 5955 Calibration Sources. The Models 5905 and 5906 are intended to aid in calibrating the Model 590 CV Analyzer, and the Model 5955 provides capacitance sources to calibrate the Model 595 Quasistatic CV Meter. The Model 5907 is intended for use with the Model 590 cable correction feature.

1.2 SOURCE VALUES

Table 1-1 summarizes the sources supplied with each set and the instruments requiring them. Note that nominal values are shown; each source is marked with actual value(s). Capacitance sources are marked with 1kHz, 100kHz, and 1MHz values along with an inductance value to be used when characterizing the source. The 1kHz values should be used when calibrating the Model 595, while the 100kHz and 1MHz values are to be used when calibrating the Model 590.

Table 1-1. Calibration Source Values

Model Number	Capacitance Values	Conductance Values
5905*	4.7pF, 18pF, 47pF, 180pF, 470pF, 1.8nF	180 μ S, 1.8mS, 18mS
5906*	0.5pF, 1.5pF, 4.7pF, 18pF, 47pF, 180pF, 470pF, 1.8nF, 4.7nF, 18nF	1.8 μ S, 18 μ S, 180 μ S, 1.8mS, 18mS
5907*	470pF, 1.8nF	None
5955**	180pF, 1.8nF, 18nF	None

*Used with Model 590 CV Analyzer

**Used with Model 595 Quasistatic CV Meter

NOTE: All values shown are nominal; use marked value when calibrating unit.

Table 1-2 summarizes the calibration sources to be used with various available versions of the Model 590: 590/100k, 590/1M, and 590/100k/1M. The Models 590/100k and 590/1M measure at 100kHz and 1MHz respectively, and the Model 590/100k/1M measures at both 100kHz and 1MHz.

Table 1-2. Model 590 Calibration Source Complement

Calibration Sources	CV Analyzer Model	590/100k	590/1M	590/100k/1M
5905			X	
5906		X		X
5907			*	*

*The Model 5907 is used only for correcting external cable errors at 1MHz, and includes only selected values of calibration sources that are included both in the Model 5905 and 5906.

1.3 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. Should you require warranty service, contact the Keithley representative or authorized repair facility in your area for further information.


1.4 MANUAL ADDENDA


Any improvements or changes concerning the sources or this manual will be explained on an addendum included with the sources. Please be sure to note these changes and incorporate them into the manual before using the sources.

1.5 SAFETY SYMBOLS AND TERMS

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

GENERAL INFORMATION

The symbol  on an instrument shows that high voltage may be present on the terminal(s). Use standard safety practices to avoid personal contact with these voltages.

The symbol  on the instrument indicates that the user should refer to the operating instructions.

The **WARNING** heading used in this manual explains hazards that might 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 unit. Such damage may void the warranty.

1.6 SPECIFICATIONS

Detailed specifications for the sources may be found at the front of this manual.

1.7 UNPACKING AND INSPECTION

Upon receiving the Calibration Sources carefully unpack them from their shipping carton and inspect all sources for any obvious signs of physical damage. Report any damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

The following items are included with every order:

- Model 5905, 5906, 5907, or 5955 Calibration Sources (see Table 1-1).
- Supplied accessories (Table 1-3).
- A copy of this instruction manual.
- Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 5900-901-00). The manual package includes an instruction manual and any applicable addenda.

Table 1-3. Supplied Accessories

Model Number	Accessories
5905	Large Case, Small Case Calibration labels (capacitance and conductance) BNC right angle male-to-female adapter BNC shorting cap BNC female-to-female adapters (2)
5906	Large Case, Small Case BNC right angle male-to-female adapter BNC female-to-female adapters (2) BNC shorting cap Calibration labels (capacitance and conductance)
5907	Small Case BNC female-to-female adapters (2) Calibration labels (capacitance)
5955	Small Case Calibration labels (capacitance)

1.8 REPACKING FOR SHIPMENT

Should it become necessary to return the sources, carefully pack them in the original packing carton or its equivalent. Be sure to include the following:

- Advise as to the warranty status.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form at the back of this manual.

1.9 CALIBRATION LABELS

Each source has two labels, as shown in Figures 1-1 and 1-2. The permanent label for the capacitance sources (Figure 1-1(a)) includes information on the part number, serial number, as well as series capacitance and inductance values. A replaceable label (Figure 1-1(b)) indicates the measured 1kHz capacitance value along with extrapolated 100kHz and 1MHz values.

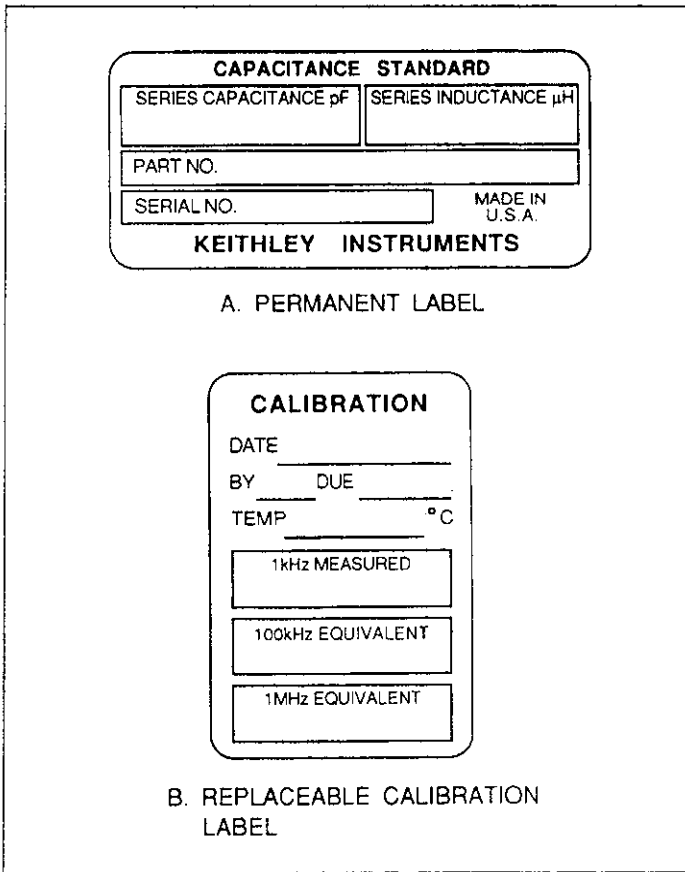


Figure 1-1. Capacitance Source Labels

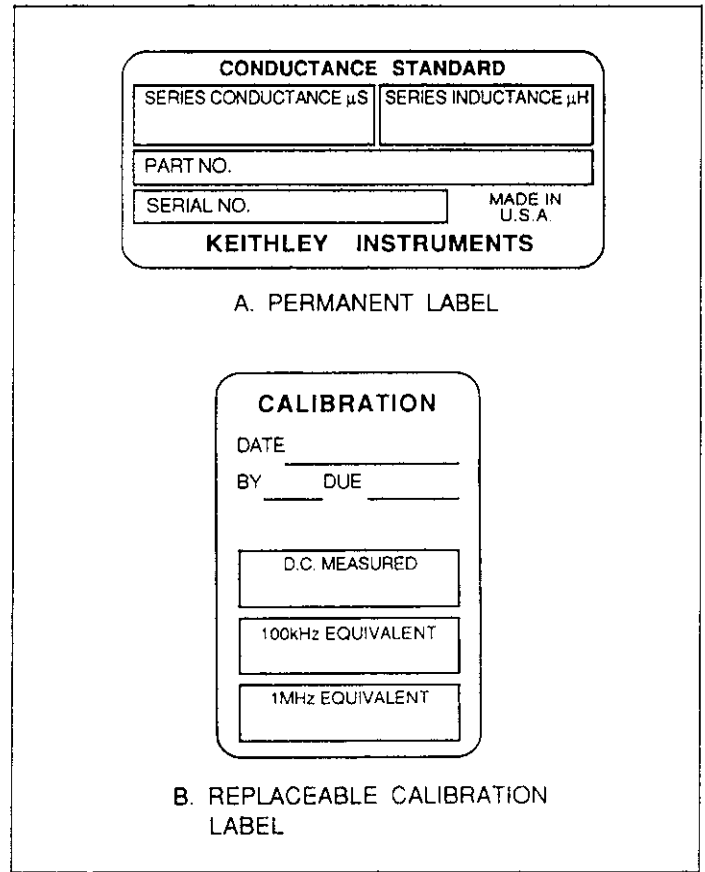


Figure 1-2. Conductance Source Labels

Similarly, each conductance source has a permanent label (Figure 1-2(a)) identifying the part number, serial number, and series conductance and inductance values. The replaceable label (Figure 1-2(b)) includes information on the measured DC conductance along with 100kHz and 1MHz values.

Note that replacement labels are supplied with each set of sources to update these values at the time of characterization.

SECTION 2

DESIGN CONSIDERATIONS

2.1 INTRODUCTION

This section discusses important mechanical and electrical design considerations and calibration methods for the calibration sources.

2.2 MECHANICAL DESIGN CONSIDERATIONS

2.2.1 Capacitance Sources

Dielectric

Glass dielectric capacitors are used for the sources because of several desirable characteristics when compared to other dielectric types. Key important characteristics of the glass capacitor include:

- No noticeable frequency-dependent dielectric constant changes.
- Better time stability than all other dielectrics with the possible exception of air capacitors.
- Dissipation factor sufficiently low to allow use with the Model 590.
- Stable and repeatable temperature coefficient.
- High DC insulation resistance allowing use with the Model 595.

Connectors

The BNC connectors were chosen to allow quick and easy connection of the source to the front panel of the Model 590. The connectors have Teflon® insulation for high leakage resistance, and they are specified for use at frequencies as high as 4GHz. The 4GHz specification indicates that both the shunt capacitance and the series inductance are carefully controlled during the manufacturing process, resulting in low SWR for optimum high-frequency operation.

Case Construction

The capacitor is internally mounted between the two BNC connectors, as shown in Figure 2-1. To minimize the capacitance to guard (the metal case acts as the guard), the

capacitor is suspended as far as possible from the sides of the case. For the larger capacitor values only, the capacitor is glued to a glass standoff so that impacts and vibration will not cause the capacitor to move, thus preventing changes in shunt capacitance. The standoff has sufficient length and small enough cross sectional area so that it does not contribute to the shunt capacitance, and it also results in a very high DC resistance to ground. To further improve DC resistance to ground, care is taken during assembly not to get a pathway of adhesive, either between the two capacitor terminals, or between either terminal and guard.

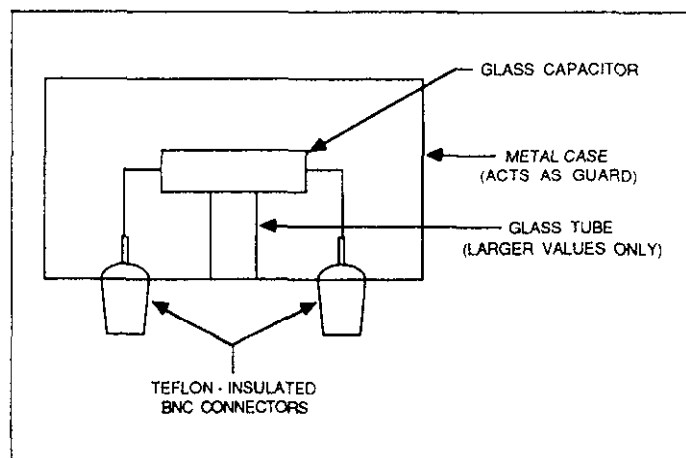


Figure 2-1. Capacitance Source Construction

Series Inductance

The series inductance is the principle error term, and it is minimized by placing the capacitor directly between the ends of the BNC connectors. The lead length, and thus the series inductance, is made as small as possible.

2.2.2 Conductance Sources

The conductance sources are constructed in essentially the same manner as the capacitance sources, with the exception that a high-quality film resistor is used instead of a glass capacitor. The initial tolerance of this resistor is $\pm 0.1\%$, but the time and temperature stability is much better, permitting characterization of this resistor to a higher accuracy.

2.3 CAPACITANCE SOURCE CALIBRATION

The capacitance sources are designed to be characterizable at frequencies up to 1MHz. However, since no direct measurement method known provides the required measurement accuracy to 1MHz, the method discussed in the following paragraphs was developed to transfer a traceable calibration of these sources at 1kHz to higher frequencies by analyzing any effects which could alter the capacitance reading at higher frequencies. This method is similar to the method described in the reference¹ at the end of this section.

2.3.1 High Frequency Circuit Model

As shown in Figure 2-2, the capacitor in the metal box can be modeled as an ideal capacitor (C_1) whose value is the measured 1kHz value in series with an inductor (L) representing the inductance of the capacitor, capacitor leads, and BNC connectors. Any shunt capacitance between this network and guard is ignored by the capacitance meter, which makes a guarded measurement.

To obtain the effective capacitance at a given high frequency, the value of the reactance of C_1 and L are computed at that frequency and then added together (keeping in mind that capacitance reactance is negative, and inductive reactance is positive). The resulting reactance is then converted back to an equivalent capacitance at the 100kHz or 1MHz frequency of interest.

The value for L includes the inductance in the BNC connectors up to some reference point on the BNC connector pins. If a different point on the connector pins is chosen, the effective capacitance will be different because L will have a different value.

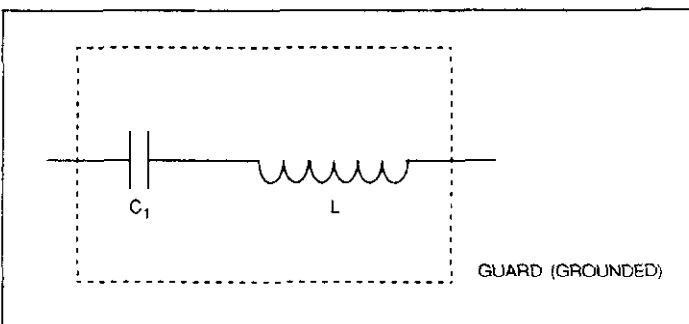


Figure 2-2. High Frequency Model

2.3.2 Calibration Method

The two measurements necessary to calibrate each capacitance source include the 1kHz capacitance, and the series inductance.

1kHz Capacitance Measurement

The 1kHz capacitance is measured in a conventional manner by a precision capacitance bridge utilizing a 3-terminal guarded measurement. Temperature of the capacitance source is accurately monitored during the measurement so that an accurate determination of the temperature can be made. This temperature measurement is necessary because the capacitor has a sufficiently high temperature coefficient to degrade the accuracy of the ultimate user's measurements unless correction is made for changes in capacitance due to temperature variations. Any uncertainty in temperature at the time of source calibration enters into the total uncertainty of the capacitance value.

Series Inductance Measurement

The series inductance is somewhat more difficult to measure than the 1kHz capacitance. The method consists of making a resonant circuit of the capacitor and its series inductance by shorting the external terminals together, as shown in Figure 2-3. Assuming that the 1kHz capacitance value is the same as the capacitance at the resonant frequency, the series inductance can then be calculated from those two factors.

For optimum accuracy, it is necessary to subtract the inductance of the shorting bar from the series inductance of the resonant circuit to obtain the true series inductance of the capacitance source. For that reason, a precision shorting bar is used. This bar has a known inductance, and it also contacts the connecting terminals at the same point each time it is attached minimizing variations.

The resonant frequency is measured by placing a coupling coil close the shorting bar and looking for a dip in the impedance across the coupling coil with a network analyzer. The dip indicates that the resonant circuit is extracting energy from the coupling coil at the point of resonance.

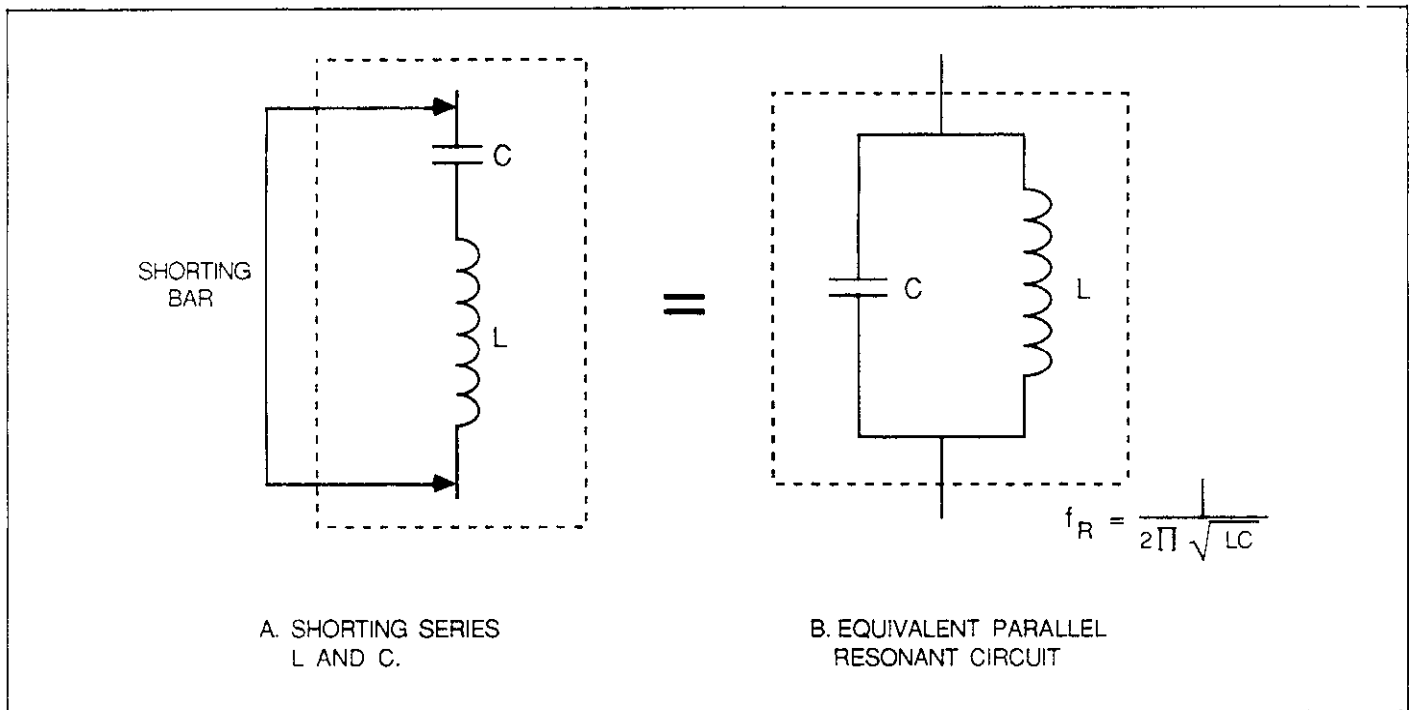


Figure 2-3. Shorting L and C to Form Parallel Resonant Circuit

2.4 CONDUCTANCE SOURCE CALIBRATION

The conductance sources are designed to be useful over the same frequency range as the capacitance sources. The calibration of each conductance source is performed by making a DC resistance measurement. This resistance value is valid as the real component of the conductance source impedance at higher frequencies. However, the imaginary component of the impedance varies, as discussed below.

2.4.1 High Frequency Circuit Model

As shown in Figure 2-4, the conductance source can be modeled as a resistor (R), with a capacitance (C) in parallel with the resistor, representing the body capacitance, and an inductor (L) in series with the RC combination, representing the inductance of the resistor leads and BNC connectors. As is the case with the capacitance source 1kHz measurement, a guarded impedance measurement will eliminate stray impedance effects between this network and guard.

The inductance, L, is the result of the physical size and shape of the resistor leads and BNC connectors. These dimensions are the same as for the corresponding parts in the capacitance sources that have a nominal value of 180pF or less. Therefore, the conductance source inductance is the same as the capacitance sources, with a calculated value of 0.0492μH. Measurements on capacitance sources support this inductance value. The capacitance, C, is the capacitance across the resistor body, and it is essentially the same for all resistor values of a particular size and construction. Measurements on high-value resistors of the type used for the conductance sources show a capacitance of approximately 0.16pF.

The resistance, R, is the measured DC resistance corrected for RF skin effect. The resistors used have a thin resistance film which exhibits no significant change in resistance at the frequencies used. The resistor leads and BNC connectors, however, are thick enough to exhibit an increase in resistance of approximately 0.0038Ω at 1MHz as compared to the DC resistance. This increase is significant only for the 18mS conductance when used at 1MHz.

To obtain the effective conductance and parallel capacitance that an instrument will measure at a particular frequency, it is necessary to transform the circuit shown in Figure 2-4 into the parallel equivalent shown in Figure 2-5. Note that the values are valid only at the one frequency for which equivalent values are computed.

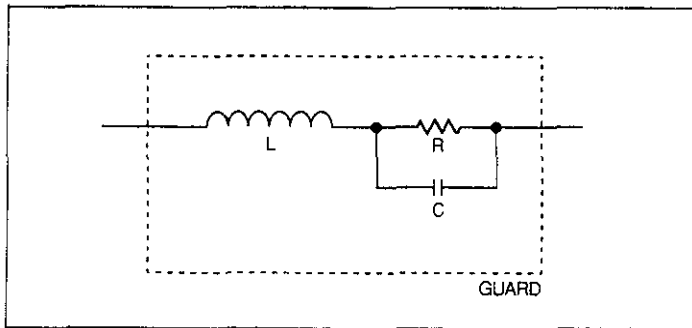


Figure 2-4. High Frequency Model of Conductance Source

The values R' and C' of Figure 2-5 are related to the R , L , and C values shown in Figure 2-4 at the single frequency $\omega = 2\pi f$ as follows:

$$\frac{1}{R'} + j\omega C' = \frac{R}{(R - (RCL\omega^2))^2 + (L\omega)^2} + j\omega \left[\frac{(CR^2 - L) - L(RC\omega)^2}{(R - (RCL\omega^2))^2 + (L\omega)^2} \right]$$

Evaluating this equation for the nominal conductance values yields the results shown in Table 2-1. Note that the stray reactances have a very minor effect on the equivalent high-frequency resistance, but significantly alter the effective capacitance reading.

As with the capacitance sources, the value of the inductance, L , includes the inductance in the BNC connectors up to some reference point on the BNC connector pins. This point is nominally defined as the tips of the pins, but, if a different reference point is chosen, the inductance will be different, thus altering the capacitance reading for the higher conductance values at higher frequencies.

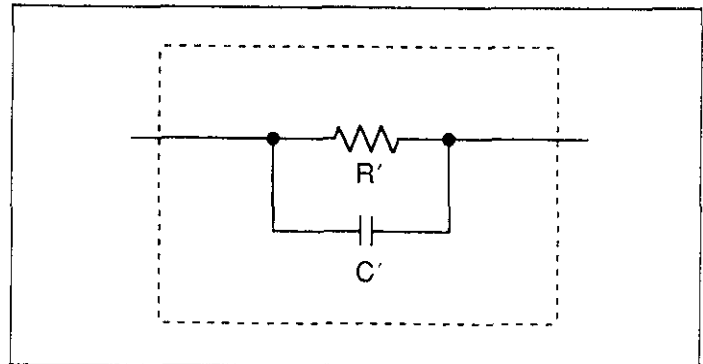


Figure 2-5. Equivalent Parallel Circuit of Conductance Source

Table 2-1. Conductance Source Summary

Nominal Conductance	DC and 100kHz Resistance	1MHz Resistance	100kHz and 1MHz Capacitance Reading
18 mS	56.2 Ω	56.2055 Ω^{**}	-15.42 pF*
1.8mS	562 Ω	562.000 Ω	+ 0.004pF
180 μ S	5.62k Ω	5.62000k Ω	+ 0.158pF
18 μ S	56.2 k Ω	56.2000 k Ω	+ 0.160pF
1.8 μ S	562 k Ω	562.000 k Ω	+ 0.160pF

*Negative capacitance indicates inductance term dominates.

**The 0.0055 Ω increase in resistance is composed of 0.0017 Ω due to stray L and C, plus 0.0038 Ω caused by RF skin effect in resistor leads and BNC connectors.

2.4.2 Calibration Method

The only calibration necessary for the conductance sources is to accurately measure the DC resistance. For the 18mS conductance only, a four-terminal resistance measurement is necessary to eliminate the effects of contact resistance. The contact resistance does not significantly degrade measurement accuracy for other conductance source values.

References

- ¹ Jones, R.N., Evaluation of Three-Terminal and Four-Terminal Pair Capacitors at High Frequencies, Nat. Bur. Stand. (U.S.) Tech Note 1024, 15 pages (Sept. 1980)

SECTION 3

MODEL 590 CALIBRATION

3.1 INTRODUCTION

The following paragraphs discuss various aspects of capacitance and conductance calibration for the Model 590 CV analyzer. For voltage calibration procedures, consult the Model 590 Instruction Manual.

3.2 CALIBRATION CYCLE

Calibration should be performed every 12 months, or if the performance verification procedures discussed in Section 5 of the Model 590 Instruction Manual show that the instrument is operating outside its stated specifications (detailed Model 590 specifications may be found at the front of the instruction manual for that instrument).

3.3 ENVIRONMENTAL CONDITIONS

Calibration should be performed under laboratory conditions having an ambient temperature of $23^{\circ} \pm 2^{\circ}\text{C}$ and a relative humidity of less than 70%. If the instrument or the sources have been subjected to temperatures outside this range, or to higher humidity allow at least one additional hour for temperature stabilization before beginning the calibration procedure.

NOTE

Do not hold the sources in your hand for more than one minute at a time, as doing so will cause inaccurate calibration due to temperature rise of the source.

3.4 WARM UP PERIOD

Turn on the Model 590 and allow it to warm up for at least one hour before beginning the calibration procedure.

3.5 CALIBRATION SOURCES AND EQUIPMENT

Table 3-1 summarizes the capacitance and conductance sources necessary to calibrate the capacitance and conductance functions of the Model 590. The Model 5905 is required to calibrate 1MHz version of the instrument, while the Model 5906 is required for those units equipped to measure at 100kHz.

NOTE

Make sure that none of the sources are past the calibration due date before attempting instrument calibration (see label on sources). Characterize any past due sources using the procedure given in Section 6 of this manual before attempting calibration.

In addition to the calibration sources, a DMM capable of measuring 0-2V DC with an accuracy of 0.1% or better will be required. A Keithley Model 196 or 197 DMM is recommended for this application.

To perform digital calibration, a suitable IEEE-488 bus controller will also be necessary to send calibration commands to the instrument. A sample program, written in HP-85 BASIC, is included in this section.

Table 3-1. Calibration Sources

Model	Capacitance Sources (Nominal Values)	Conductance Sources (Nominal Values)	Application
5905 or 5906	0.5pF*, 1.5pF*, 4.7pF, 18pF, 47pF, 180pF, 470pF, 1.8nF, 4.7nF*, 18nF*	1.8 μS *, 18 μS *, 180 μS , 18mS	Calibrate 100kHz and 1MHz, 5904.

*These values are included only in the Model 5906.

3.6 CONNECTING THE SOURCES TO THE INSTRUMENT

In all cases the source being used must be connected directly to the front panel test jack(s) of the instrument (or the test jacks of the Model 5904 Input Adapter when calibrating that unit). Do not connect the sources to the instrument using cables, as doing so may degrade calibration accuracy.

For driving point cable calibration only, one source connector is to be shorted (using adapters supplied), and the other connector attaches to the Model 590 test INPUT jack.

3.7 CALIBRATION SWITCH

An internal switch, located on the mother board (see Figure 3-1), must be set to the enabled position before the instrument will accept calibration commands.

WARNING

Take care not to contact live circuits when the

top cover is removed. Failure to observe these precautions may result in personal injury or death because of electric shock.

Sending calibration commands with the switch in the disabled position will result in the following front panel error message:

CAL LOCKED

No calibration will take place under these conditions.

The CAL LOCKED bit in the U1 status word will also be set, and the Model 590 can be programmed to generate an SRQ under these conditions (see Section 4 of the Model 590 Instruction Manual for details).

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.

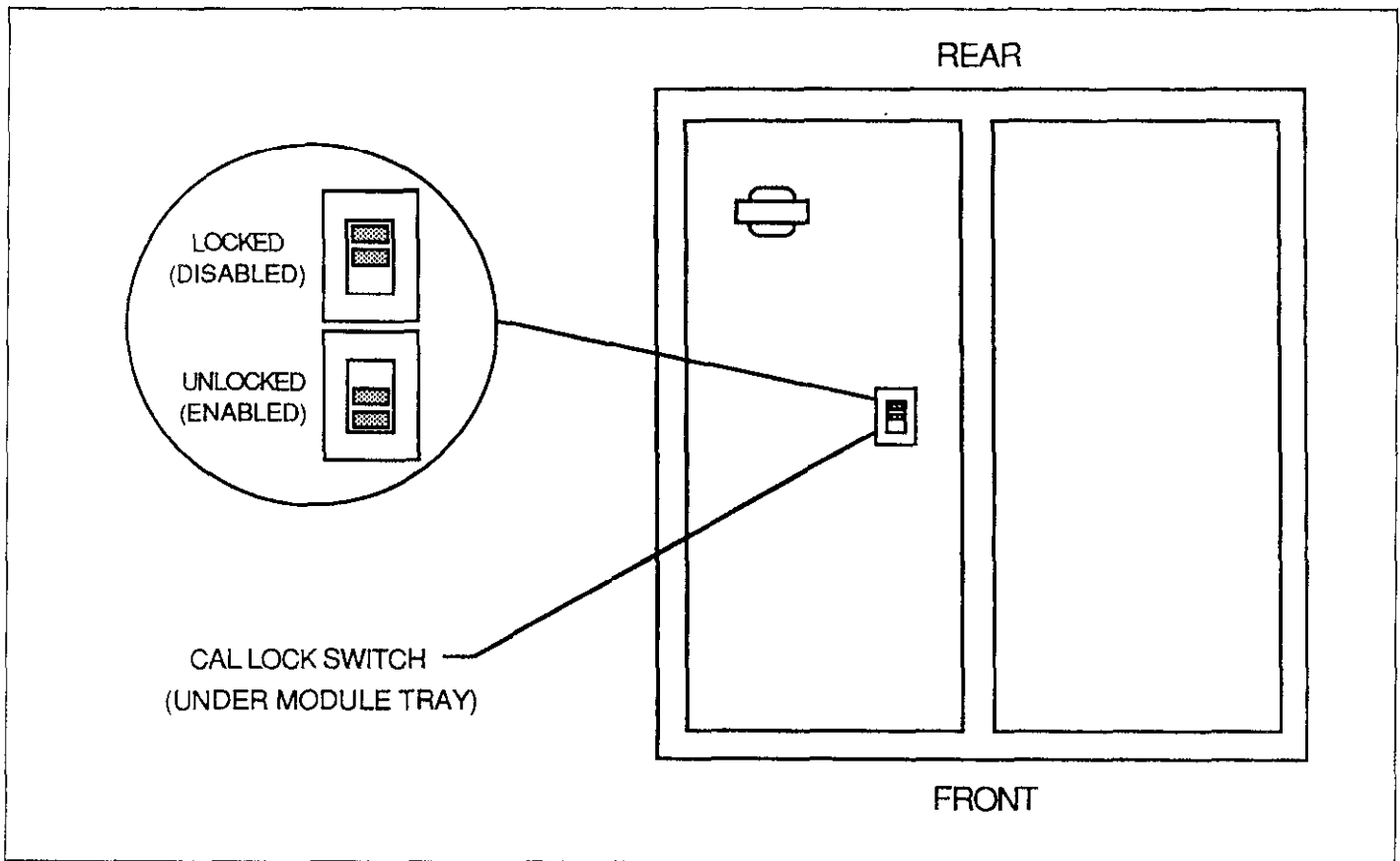


Figure 3-1. Calibration Lock Switch Location and Positions

3.8 CALIBRATION COMMANDS

3.8.1 Command Summary

Table 3-2 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.

3.8.2 Programming Zero Capacitance and Conductance Values

Although provisions for both C and G values are included in most of the calibration commands, you can assume a

conductance value of 0 when using the capacitance sources, and a capacitance value of 0 when using the conductance sources. Be sure to include the 0 value at the appropriate point in the command string.

3.8.3 Command String Examples

The following are typical command string examples.

Q2,471E-12,0X	Program 471pF value.
Q1X	Calibrate offsets.
Q4,0,1.805E-6X	Program 1.8 μ S value.

3.9 CALIBRATION PROGRAM

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.

NOTE

Place quotes around the Model 590 command strings containing commas when typing them in at the command prompt.

Table 3-2. Calibration Command Summary

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

PROGRAM	COMMENTS
10 REMOTE 715	! Put 590 in remote.
20 CLEAR	
30 DIM A\$(100)	! Dimension input string.
40 DISP "COMMAND"	! Prompt for command 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 100	! Bit set indicates an error.
90 GOTO 40	! Repeat.
100 RESTORE	! Clear data pointer.
110 OUTPUT 715: "UIX"	! 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)="" THEN DISP B\$: "ERROR"	! Display error message.
160 NEXT I	! Loop for next message.
170 RETURN	
180 DATA "TRIGGER OVERRUN", "NEED 100K"	
190 DATA "NEED 1M", "NOT USED"	
200 DATA "CAL LOCKED", "CONFLICT"	
210 DATA "TRANSLATOR", "NO REMOTE"	
220 DATA "IDDC", "IDDCO", "INVALID"	
230 END	

3.10 CONDUCTANCE SOURCE INDUCTANCE CONSIDERATIONS

Each conductance source has a small amount of series inductance, which is marked on the source. For all intents and purposes, this inductance can be assumed to be negligible when calibrating the Model 590, and is thus considered to be zero. Although this assumption has no effect on calibration accuracy, it is possible that the Model 590 will display small negative or positive capacitance values when measuring the conductance sources after calibration. This phenomenon is considered normal, and it should in no way be considered as indicative of miscalibration.

Because of variations in shunt capacitance and series inductance, the capacitance reading displayed by the Model 590 under these circumstances will depend on the particular conductance source. Table 3-3 summarizes typical displayed capacitance readings for the various conductance sources.

Table 3-3. Typical Display Capacitance of Conductance Sources at 1MHz

Source Value	Typical Displayed Capacitance
1.8 μ S	+ 0.16 pF
18 μ S	+ 0.16 pF
180 μ S	+ 0.158pF
1.8mS	+ 0.004pF
18 mS	-15.42 pF

3.11 MODULE CALIBRATION

The calibration procedures for the 100kHz (5901) and 1MHz (5902) capacitance modules are covered below. Be sure to carry out the procedures in the order presented here.

NOTE

The modules should be calibrated before attempting digital calibration, which is covered in paragraph 3.12.

3.11.1 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 3-2 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 source value to voltage. For example, a nominal 180pF source value will yield a nominal 1.8V DMM reading with the Model 590 on the 200pF range.

3.11.2 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. See Figure 3-2.

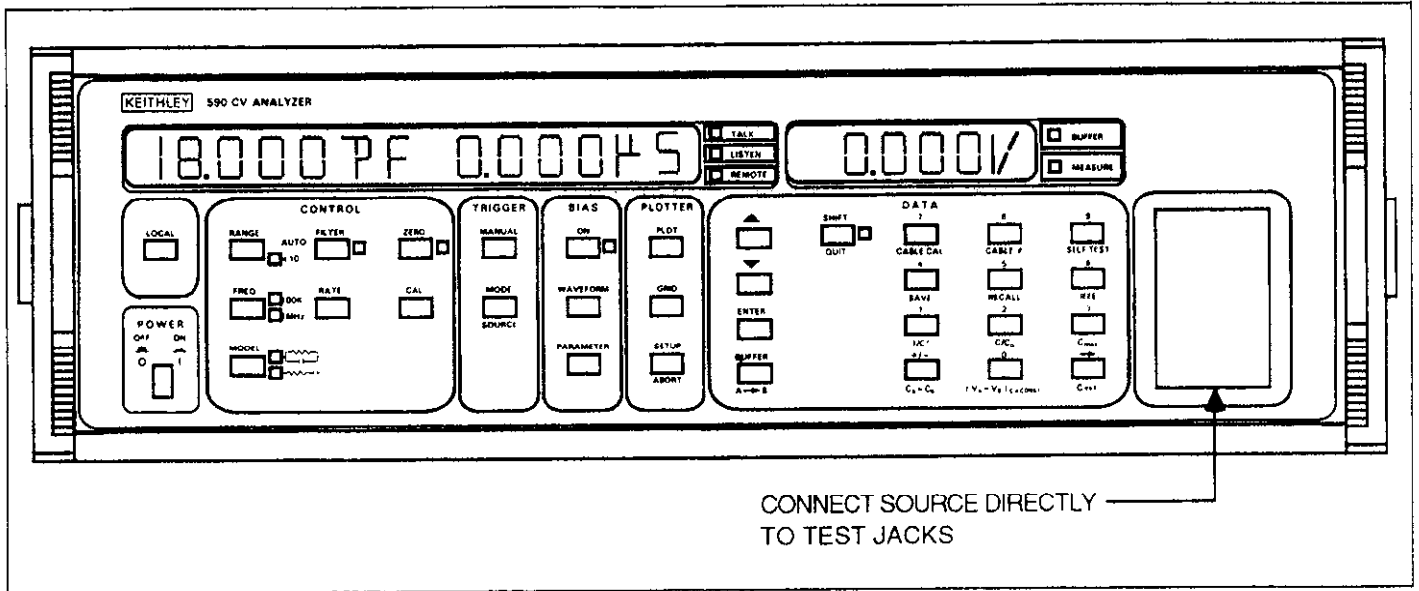


Figure 3-2. Model 5905 and 5906 Source Connections

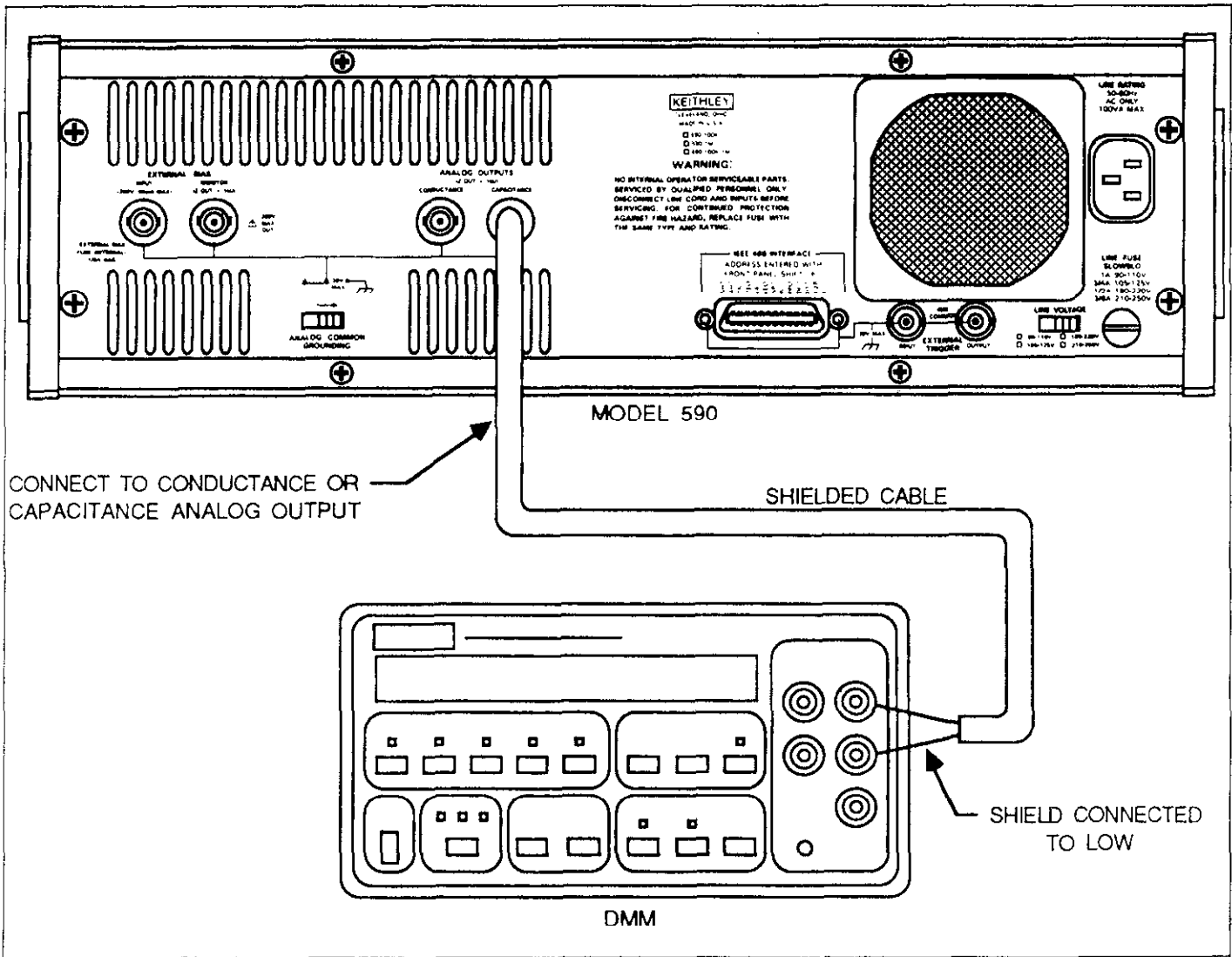


Figure 3-3. Connections for Module Calibration

3.11.3 Calibration Adjustment Locations

The calibration adjustments and jumpers are shown in Figure 3-4.

3.11.4 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 3-4.
5. Adjust R545 (CAPACITANCE ZERO) for a reading of 0V $\pm 100\mu V$ as measured on the DMM connected to the CAPACITANCE OUTPUT.

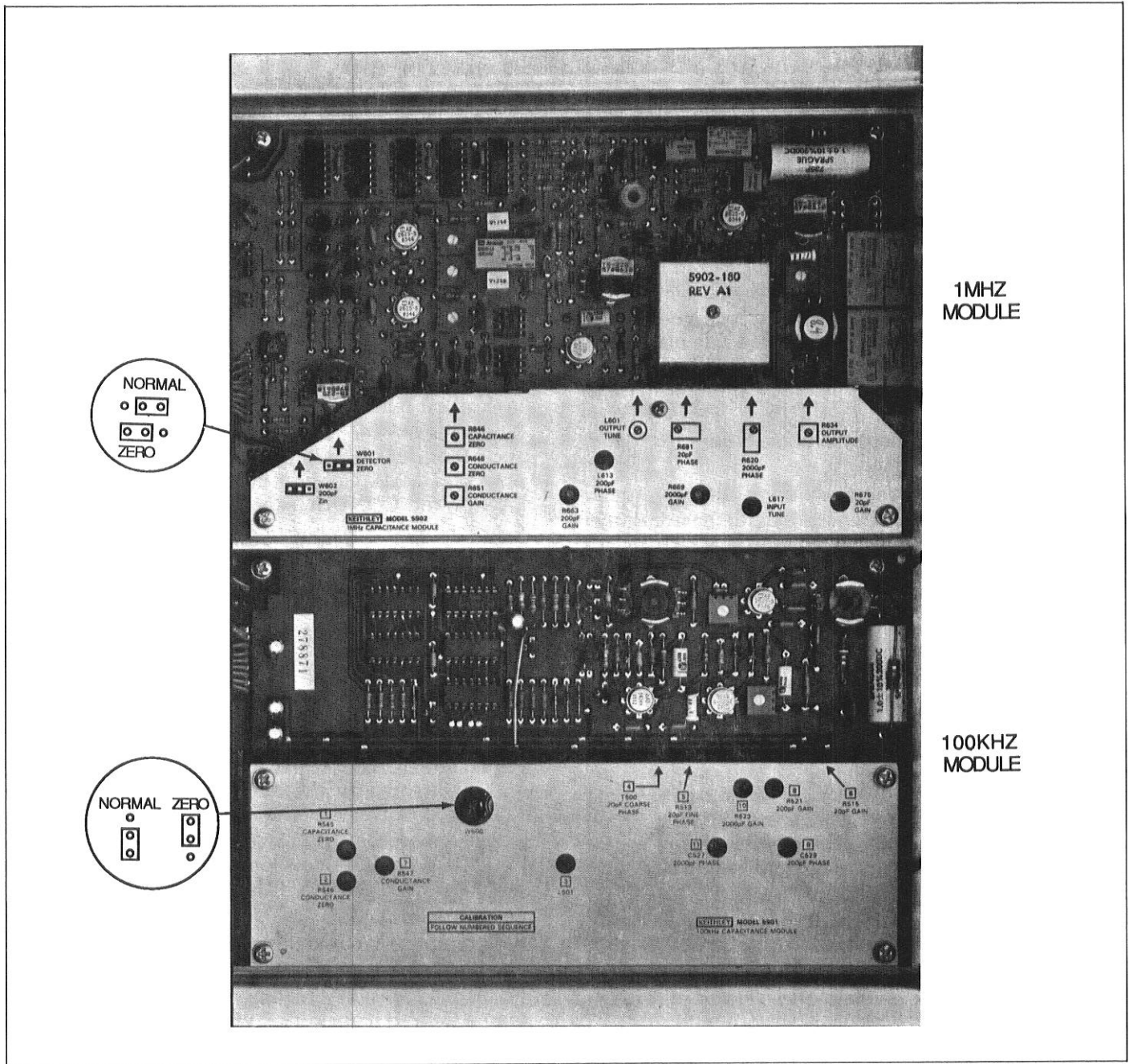


Figure 3-4. Module Adjustments

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 source, $\pm 1mV$. For example, if the marked 100kHz source 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 3.12 for digital calibration procedures.

3.11.5 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 3-4).
 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 of $0V \pm 1mV$ 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. Select the 2mS range and re-zero the DMMs.
26. Connect the 1.8mS source to the front panel test INPUT and OUTPUT jacks.
27. 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 $1.802V \pm 14mV$.
28. Remove the 1.8mS source from the instrument.

This concludes 1MHz module calibration. Proceed to paragraph 3.12 for digital calibration procedures.

3.12 DIGITAL CALIBRATION PROCEDURES

The steps below will take you through the step-by-step procedures for digital capacitance and conductance calibration. Note that the procedures should be performed in the order shown here. Use the program listed in paragraph 3.9 to send the necessary commands to the instrument.

3.12.1 Connections

Figure 3-2 shows how to connect the sources to the instru-

ment for all but driving point calibration. Note that the source in question is to be connected at the front panel. Under no circumstances are cables to be used, as doing so will degrade calibration accuracy.

Figure 3-5 shows connections for driving point calibration. One jack of the source is to be shorted by the supplied BNC short. The other jack is to be connected to the test INPUT of the Model 590 through the supplied right angle adapter.

3.12.2 100kHz Calibration

Follow the steps below in the order shown to calibrate the unit at 100kHz. Table 3-4 summarizes the procedure, commands, and necessary sources. Note that you should always use the 100kHz values marked on the sources for this procedure.

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 capacitance source.
5. Connect the 0.5pF source and send the command "Q3,C,0X" where C is the actual 100kHz capacitance value.
6. Connect the 1.8 μ S source and send the command "Q4,0,GX", using the actual 100kHz value for 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 capacitor to the instrument and send the command "Q2,C,0X" where C represents the actual 100kHz capacitance value.
10. Connect the 4.7pF source to the Model 590 and send the command "Q3,C,0X", using the actual 100kHz C value.
11. Connect the 18 μ S source to the instrument and send "Q4,0,GX" where G is the marked 100kHz 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 3-4.

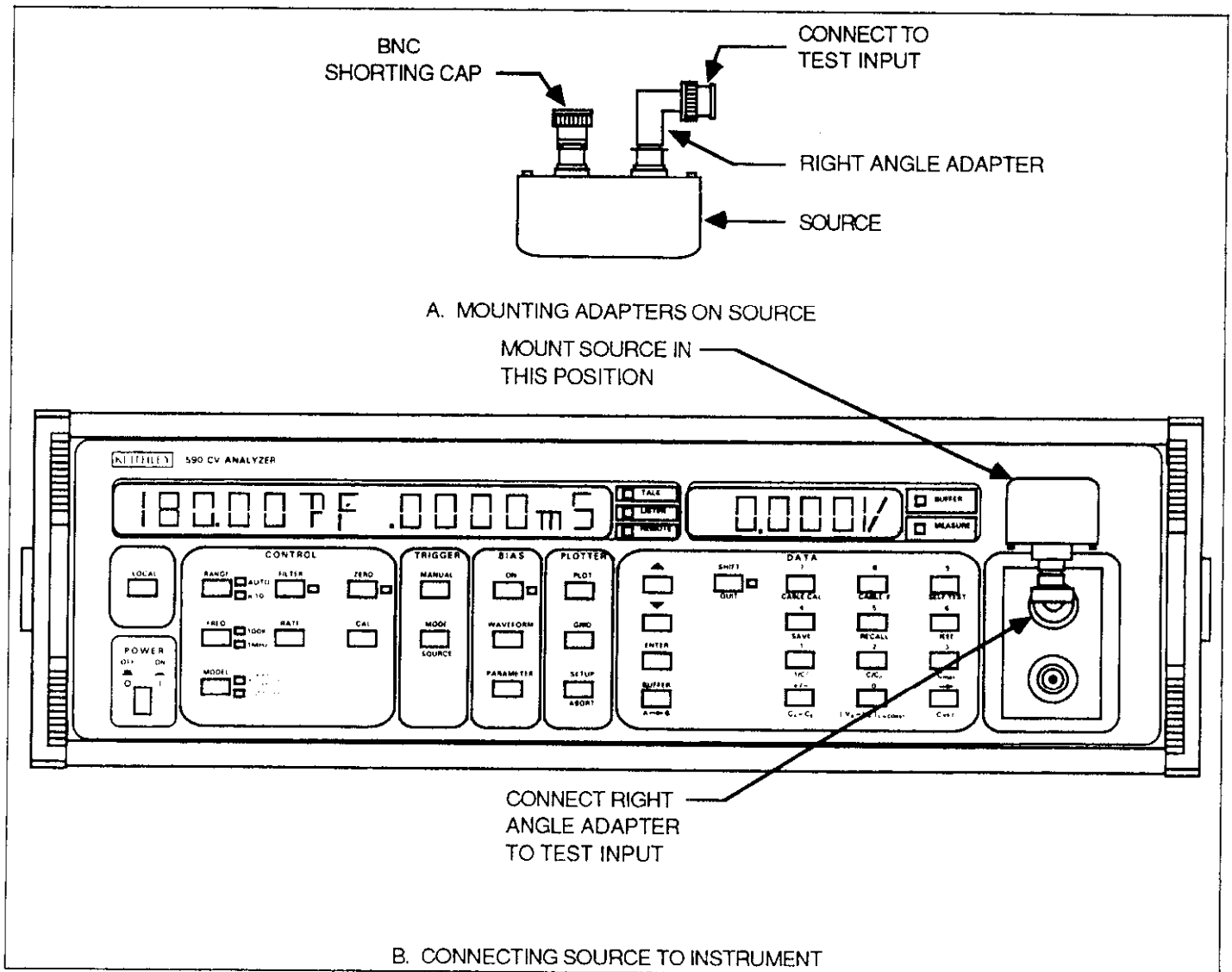


Figure 3-5. Driving Point Calibration Connections

Table 3-4. 100kHz Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	Initialize 590
2		FOR1X	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 G value
6	1.8 μ S	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	18 μ S	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	180 μ S	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 commands.

3.12.3 20nF/20mS Range 5904 Input Adapter Calibration

Use the procedure below to calibrate the 590/5904 for use on the 20nF/20mS range. This procedure is summarized in Table 3-5. Be sure to use the 100kHz values for the sources when programming them.

1. Turn on the power and allow the unit to warm up for one hour. Send the command "S3T2X".
2. Connect the Model 5904 Input Adapter to the test INPUT and OUTPUT jacks of the Model 590. Be sure not to mount the adapter upside down.
3. Send the command string "FOR8X" 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 represents the 100kHz value marked on the capacitor.
6. Connect the 4.7nF source and send the command

"Q3,C,0X" where C is the marked 100kHz capacitance value.

7. Connect the 18mS conductance source to the instrument and send the command "Q4,0,GX" using the actual 100kHz G value.

Table 3-5. Model 5904 Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	Initialize 590
2		FOR8X	Select 100kHz, 20nF range
3	None	Q1X	Calibrate offsets
4	18nF	Q2, C, 0X	Use actual C value
5	4.7nF	Q3, C, 0X	Use actual C value
6	18mS	Q4, 0, GX	Use actual G value

3.12.4 1MHz Calibration

Follow the steps below in the order shown to calibrate the unit at 1MHz. Table 3-6 summarizes the procedure, commands, and necessary sources. Use the 1MHz values marked on the sources for this procedure.

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 1MHz C value.
5. Connect the 4.7pF source to the Model 590 and send the command "Q3,C,0X", using the 1MHz C value.
6. Connect the 180µS source to the instrument and send "Q4,0,GX" where G is the actual 1MHz value.
7. Repeat steps 3 through 7 for the 200pF and 2nF ranges by using the appropriate sources and the R3 and R4 commands, as summarized in Table 3-4.

Table 3-6. 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

3.12.5 Cable Correction Calibration

Use the procedure below to calibrate the driving point cable

correction mode of the Model 590. Since this form of cable correction can only be used at 1MHz, the procedure below is applicable only to units equipped to measure at that frequency.

Connections

Since this procedure is performed by making a single-ended measurement of the source capacitor, it will be necessary to short one of the BNC jacks on the source. To do so, connect the right-angle adapter and shorting cap to the source, as shown in Figure 3-5 (these adapters are supplied with the Models 5905 and 5906). Connect the right angle adapter to the test INPUT connector on the front panel of the Model 590.

Procedure

Perform the steps below in the indicated order. Table 3-7 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. Send the command string "S3T2Z0X" to setup the unit.
2. Send the command string "F1R4X" 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 (with one connector shorted as indicated above) to the Model 590 INPUT jack, and send the command "Q6,C,0X", using the actual 1MHz C value marked on the source.
5. Connect the 180pF capacitor (again with one connector shorted) to the INPUT jack instrument and send the command "Q7,C,0X" where C represents the actual 1MHz source value.

Table 3-7. Driving Point Calibration Summary

Step	Source (Nominal Value)	Command	Comments
1		S3T2X	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

SECTION 4

MODEL 595 CAPACITANCE CALIBRATION

4.1 INTRODUCTION

This section outlines the procedures for capacitance calibration of the Model 595 Quasistatic CV Meter using the Model 5955 Calibration Sources. Note that there are a variety of other aspects to complete Model 595 calibration, as discussed in Section 8 of the Model 595 Instruction Manual.

4.2 CALIBRATION CYCLE

Calibration should be performed every 12 months, or if the performance verification procedures in Section 6 of the Model 595 Instruction Manual show that the instrument is out of specification.

4.3 RECOMMENDED CALIBRATION SOURCES

Table 4-1 lists the three capacitance sources used for capacitance calibration; these sources are supplied with the Model 5955. Note that the 180pF, 1.8nF and 18nF sources from the Model 5906 calibration set can also be used; be sure to use the 1kHz values when calibrating the unit.

NOTE

Make sure none of the sources are past due for calibration (see source label). Characterize any past due sources by using the procedure discussed in Section 6 of this manual.

Table 4-1. Calibration Sources

Nominal Value	Calibrated 595 Range	1kHz Actual Value*
180 pF	200pF	_____
1.8nF	2nF	_____
18 nF	20nF	_____

*Record and use marked 1kHz value.

4.4 ENVIRONMENTAL CONDITIONS

Calibration should be performed under laboratory conditions having an ambient temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and a relative humidity of less than 70%.

NOTE

Do not hold the sources in your hand for more than one minute, as doing so may cause inaccurate calibration due to temperature coefficient of the sources.

4.5 WARM-UP PERIOD

Turn on the instrument and allow it to warm up for at least two hours before beginning the calibration procedure. If the instrument has been subjected to extremes of temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

4.6 CALIBRATION JUMPER

A jumper, located on the mother board, allows you to disable or enable front panel and IEEE-488 bus calibration. When the jumper is in the disabled position, permanent storage of calibration constants will not take place. However, temporary calibration values may be entered and used even if permanent calibration storage is disabled. Note, however, that any calibration parameters will be lost once the power is turned off, unless they are permanently stored in nonvolatile memory (NVRAM).

WARNING

Disconnect the line cord and all other equipment from the Model 595 before removing the top cover to access the calibration jumper. Replace the top cover before performing calibration.

The calibration jumper is located on the mother board near the AC line receptacle (see Figure 4-1). The disabled/enabled positions are also shown in Figure 4-1. Note that the jumper is in the disabled position as shipped from the factory.

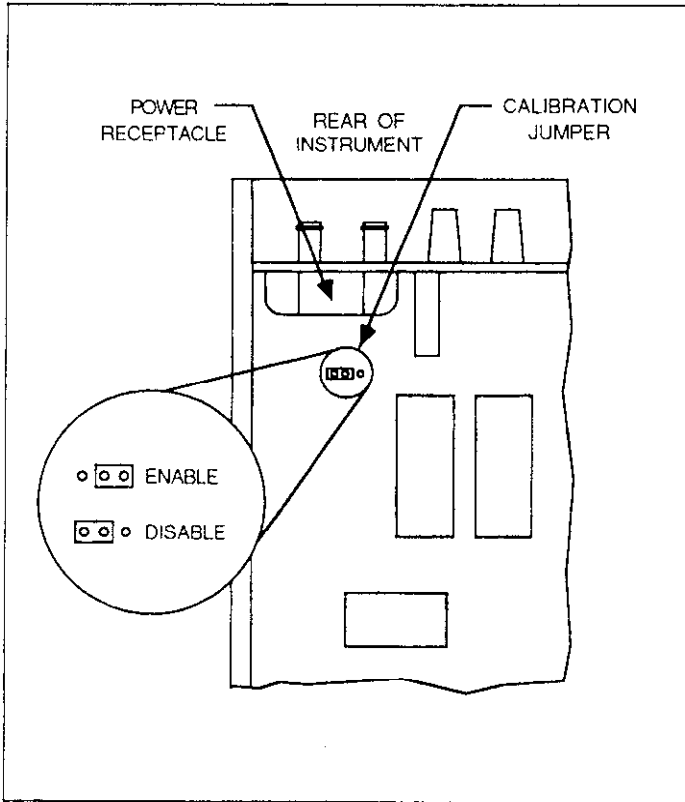


Figure 4-1. Calibration Jumper Location

4.7 SOURCE CONNECTIONS

The sources should be connected directly to the rear panel METER C,I INPUT and VOLTAGE SOURCE OUTPUT jacks. Under no circumstances should cables be used to connect the source to the instrument when performing calibration.

4.8 IEEE-488 BUS CALIBRATION PROGRAM

The program below can be used to send calibration commands to the instrument using an HP-85 computer. Table 4-2 summarizes bus commands necessary to calibrate the capacitance function.

PROGRAM	COMMENTS
10 REMOTE 728	Send remote enable.
20 DISP 'CALIBRATION COMMAND'	Prompt for command.
30 INPUT A#	Input command string from keyboard.
40 OUTPUT 728:A#	Send command string to 595.
50 GOTO 20	Repeat.
60 END	

To run the program, press the HP-85 RUN key. At the command prompt, type in the desired calibration command and press return. For example, to perform permanent calibration constant storage, type in J19X and press return. To stop the program, press the HP-85 PAUSE key.

Table 4-2. Capacitance Calibration Commands

Command*	Description
Annn.nnE-nn	Capacitance calibration value
F0	Capacitance function
Innn.nn	Delay time
J16	Capacitance offset compensation
J19	Store calibration in NVRAM
N0	Suppress off
N1	Suppress on
P2	Filter 2
P3	Filter 3
R1	200pF range
R2	2nF range
R3	20nF range
S0	10mV step
S1	20mV step
S3	100mV step
W2	Square wave

*All commands must be terminated with X to execute.

4.9 CALIBRATION SEQUENCE

When performing complete Model 595 calibration, the steps must be performed in a specified sequence. Since detailed instrument calibration is beyond the scope of this manual, you should refer to the Model 595 Instruction Manual for detailed information on additional calibrating procedures.

4.10 DIGITAL CALIBRATION

If digital calibration is to be performed from the front panel, the instrument must be placed in the calibration program. If digital calibration is to be performed over the IEEE-488 bus, the instrument will enter the calibration mode automatically when the calibration command (A) is sent.

For front panel digital calibration, select the calibration program as follows:

1. Turn off the Model 595.
2. While holding in the program MENU button, turn on the Model 595.
3. After the display blanks for approximately one second, release the MENU button. The calibration program will now be included in the program menu, and it will remain there as long as the instrument remains on.
4. Repeatedly press the MENU button until the following message is briefly displayed:

CAL

5. With the CAL message displayed, release the MENU button. The instrument will now be in the calibration program as indicated by the decimal points in the exponent digits of the display.

4.11 CAPACITANCE OFFSET COMPENSATION

Perform the following procedure to compensate for capacitance offset before you attempt capacitance calibration. For front panel compensation, omit step 4; for IEEE-488 bus compensation, bypass step 3.

1. Select the 200pF range, filter 3, 0.07 second delay, and a 0.01V squarewave step. Also, disable zero check if currently enabled. Over the bus, these modes can be programmed by sending the following command string: F0R1P3I0.07W2S0Z0X.
2. Place the protection cap on the METER INPUT connector.
3. For front panel compensation only, perform the following steps:
 - A. Select the front panel calibration program (paragraph 4.10).
 - B. Press the SHIFT and SELECT ▲ buttons in that order. The display should settle to a reading of 00.00pF ± 2 counts.
 - C. Press the ADJUST ▲ or ADJUST ▼ button.
4. For offset compensation over the IEEE-488 bus, send the command J16X after performing steps 1 and 2 above.

At this point, compensation is stored in temporary memory. Go on to paragraph 4.12 to perform the capacitance calibration procedure, after which you should store all the calibration constants in NVRAM by performing the procedure covered in paragraph 4.13.

4.12 CAPACITANCE CALIBRATION

Capacitance calibration consists of connecting the Model 5955 capacitors to the Model 595 input and programming the 1kHz characterized values from the front panel or over the bus. Before using the capacitors, make sure that the date for re-characterization has not passed. The characterization procedure for the Model 5955 capacitors is located in Section 6 of this manual.

Perform the following procedure to calibrate the capacitance function of the Model 595. Table 4-3 summarizes the procedure, which must be performed in the order shown.

1. Record the 1kHz values of the Model 5955 characterized capacitors in Table 4-3. The 1kHz characterized values are marked on the capacitors.
2. Select the 20nF range, filter 2, 0.1V square-wave step, and a delay of 0.2 seconds by using the appropriate front panel buttons. Over the bus, send the command string F0R3P2W2S3I0.2X. This setup data is listed in the first entry of Table 4-3.
3. Place the protection cap on the METER INPUT connector and make sure the calibration program is selected if calibration is to be done from the front panel.
4. Disable ZERO CHECK, wait 15 seconds, and enable SUPPRESS in that order. Over the bus, send Z0X to disable zero check, wait 15 seconds, then send N1X to enable suppress.
5. Remove the protection cap and connect the 18nF (nominal) capacitor to the METER C,I INPUT and VOLTAGE SOURCE OUTPUT jacks.
6. For front panel calibration, use the ADJUST keys to set the display to the capacitance value recorded in the first line of Table 4-3. For IEEE-488 bus calibration, send the actual 1kHz characterized value using the A command. For example, if the 1kHz characterized value is 18.036nF, send A18.036E-9X over the bus.
7. Disable SUPPRESS and enable ZERO CHECK. To do so over the bus, send the command string N0Z1X.
8. Repeat steps 2 through 7 for the remaining entries in Table 4-3. Each table entry defines the instrument setup (range, filter, step V, delay, capacitance standard value, and IEEE-488 bus command string). Remember that calibration must be performed in the order shown in the table.

Table 4-3. Capacitance Calibration Summary

Step	Range	Filter	Step V*	Delay	Nominal Source Value	Actual 1kHz Value**
1	20nF	2	00.10	00.20s	18 nF	_____
2	200pF	3	00.10	00.20s	180 pF	_____
3	200pF	3	00.01	00.20s	180 pF	_____
4	2nF	2	00.10	00.20s	1.8nF	_____
5	2nF	2	00.05	00.20s	1.8nF	_____
6	2nF	2	00.02	00.20s	1.8nF	_____
7	2nF	2	00.01	00.20s	1.8nF	_____

*Use square-wave for all steps.

**Record value marked on source.

4.13 STORAGE OF CALIBRATION PARAMETERS

The digital calibration procedures given in the preceding paragraphs temporarily store calibration constants in internal RAM (Random Access Memory). For calibration to be permanent, you must perform permanent storage into NVRAM (Non-volatile Random Access Memory) once all digital calibration procedures have been performed.

4.13.1 Front Panel NVRAM Storage

To store calibration constants in permanent memory, press the MENU button. The following message will be displayed momentarily:

Stor

The instrument will then exit the calibration program.

4.13.2 IEEE-488 Bus NVRAM Storage

If storage is to be done from over the IEEE-488 bus, simply send the following command:

J19X

Note that these storage procedures need be performed only once after all calibration parameters have been entered. Keep in mind that the calibration jumper must be in the correct position, as described in paragraph 4.6.

4.13.3 Storage Error Recovery

If storage is aborted because the calibration jumper is in the disabled position, the exponent decimal points will blink to indicate that storage did not occur. Storage can still be accomplished as follows:

1. Place the calibration jumper to the enabled position (see paragraph 4.6).
2. Select the calibration program from the program menu (exponent decimal points displayed, but not blinking).
3. Press the ADJUST ▲ button to increment the reading by one count, and then press the ADJUST ▼ button to decrement the reading by one count. (Pressing an ADJUST button tells the instrument that a calibration adjustment has occurred.)
4. Press the MENU button and the "Stor" message will then be displayed.

NOTE

If an ADJUST button is not pressed in step 3, storage will not occur in step 4. Instead, the MENU button will scroll the program menu.

SECTION 5 CABLE CORRECTION

5.1 INTRODUCTION

This section contains information on using Model 5905, 5906, or 5907 Calibration Sources to perform cable correction necessary to optimize measurement accuracy of the Model 590 CV Analyzer. Two other methods of cable correction are also available, as discussed in the Model 590 Instruction Manual. Cable correction should always be used at 1MHz, and it can also be used at 100kHz if desired.

NOTE

Although the Model 5907 sources are intended for use with cable correction, the 470pF and 1.8nF capacitance sources from the Models 5905 and 5906 can be used as well.

5.2 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, with a typical accuracy of $\pm 0.5\%$ not including other accuracy considerations.

5.3 RECOMMENDED SOURCES

Table 5-1 lists the recommended Calibration Sources for cable correction. Note that the values listed are nominal, and you should use the actual 1MHz values marked on each source when programming them over the bus.

Table 5-1. Capacitance Sources Required for Cable Correction

Value*	Keithley Model Number
470pF	5905, 5906, or 5907
1.8nF	5905, 5906, or 5907

*Nominal values shown. 100kHz or 1MHz value marked on source should be used.

5.4 CONNECTIONS

Figure 5-1 shows typical connections for this method of cable correction. Here, 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 pathways. Typically, the test fixture will be disconnected from the cables and the source capacitor connected in its place. Use the supplied female-to-female BNC adapters to connect the source to the cables.

5.5 CALIBRATION CAPACITOR CORRECTION METHOD COMMANDS

Table 5-2 summarizes the IEEE-488 bus commands necessary to perform calibration capacitor correction and save or recall cable setups. Commands for the other methods of correction are summarized in the Model 590 Instruction Manual.

Table 5-2. Cable Correction Commands

Command	Description
C0, n	Recall cable set n ($0 \leq n \leq 7$)
C1, n	Save cable set n ($1 \leq n \leq 7$)
I4	Offset correction
I5, C, G	First correction point (1.8nF)
I6, C, G	Second correction point (470pF)

5.6 CORRECTION 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 R4X over the bus.
3. Program the 100kHz or 1MHz frequency by sending F0X or F1X over the bus.
4. Perform drift correction by sending the command Q0X.
5. Disconnect the cables normally connected to the test fixture and leave the test fixture ends open. The opposite ends should remain connected to the test INPUT

CABLE CORRECTION

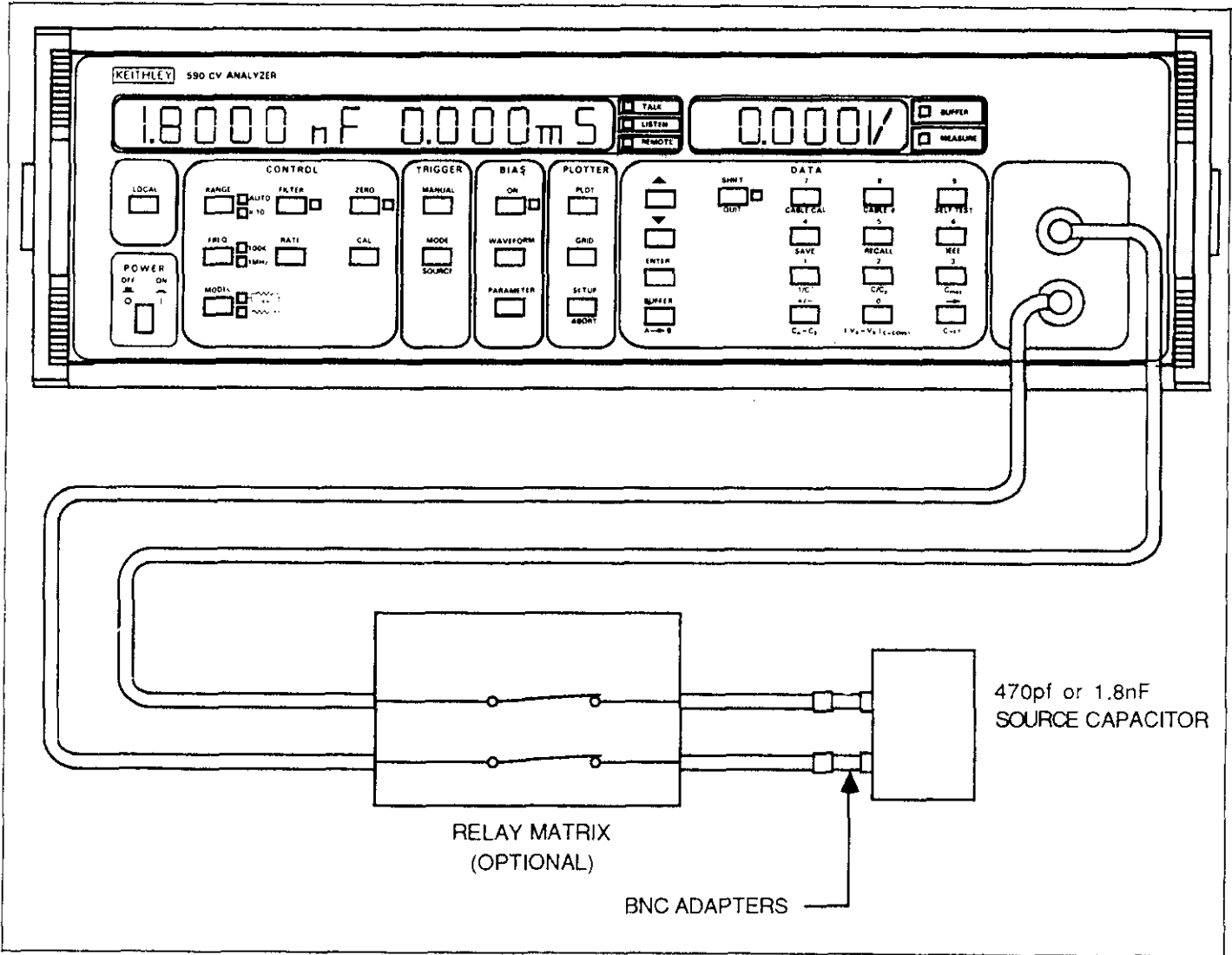


Figure 5-1. Connections for Calibration Source Correction

and OUTPUT jacks. Close any relay contacts 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 in place of your test fixture as shown in Figure 5-1.
8. Program the actual 100kHz or 1MHz capacitance value by using the I5 command. A typical HP-85 statement is:

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

Here we have assumed an actual capacitance value of 1.8nF.

9. Disconnect the 1.8F source and connect the 470pF source in its place.
10. Program the actual 100kHz or 1MHz source value with the I6 command, as in this HP-85 example:

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

11. After the second 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, and will be corrected for cable effects.

5.7 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.

5.7.1 Saving Cable Setups

To save a cable setup, first perform the correction procedure 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'
```

5.7.2 Recalling Cable Setups

The C0,n command reverses 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 and restore correction to the front panel test jacks only:

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

5.8 INTERNAL CORRECTION CONSTANTS

5.8.1 Description

When cable correction is performed, 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.

5.8.2 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 5-2) 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 below demonstrates this process.

5.8.3 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 destroy any presently stored cable setups.

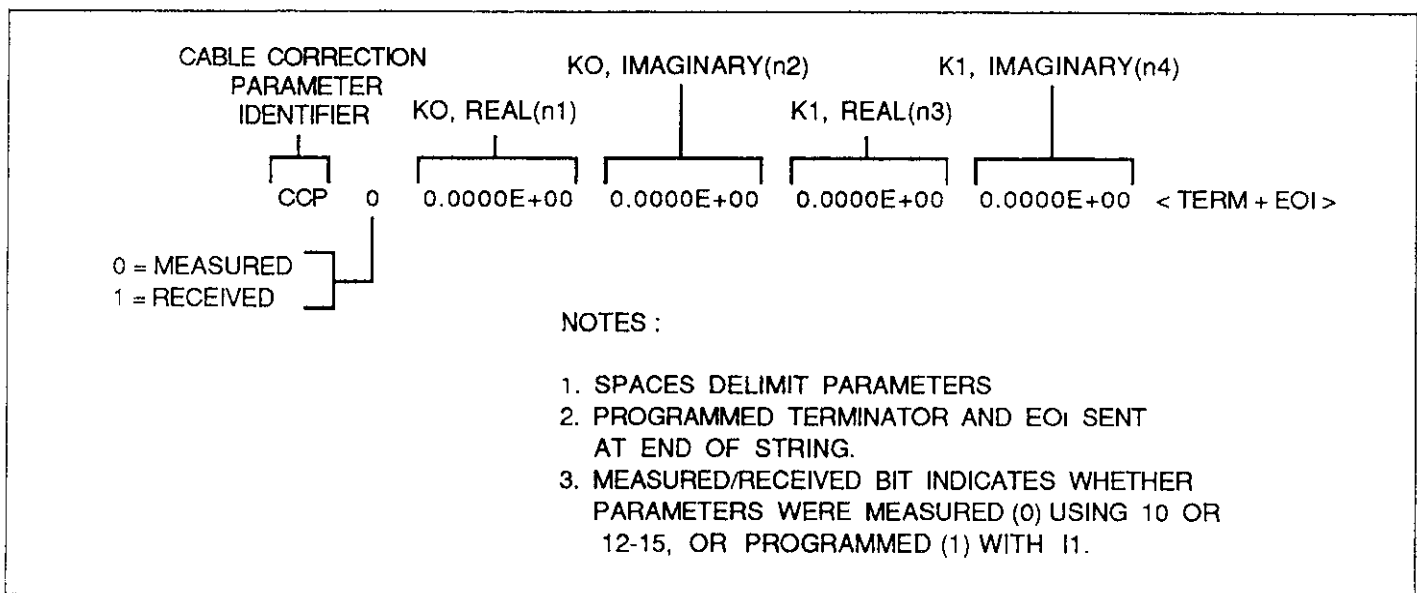


Figure 5-2. U26 Status Word Showing K0, K1 Real and Imaginary Parameters

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])	
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 420	
290 DISP 'WARNING-CABLE SETUPS'	! Display warning message.
300 DISP 'WILL BE OVERWRITTEN'	
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	

SECTION 6 CHARACTERIZATION

6.1 INTRODUCTION

This section contains procedures for characterizing both the capacitance and conductance sources. Recommended equipment and environmental conditions are also discussed.

6.2 RECOMMENDED EQUIPMENT

Table 6-1 summarizes the equipment recommended to characterize the sources to the accuracy given in the specifications at the front of this manual. In order to maintain that accuracy, the specifications for any substitute equipment must be at least as good as those given in Table 6-1. Also, it is important that the test equipment be calibrated to NBS traceable standards.

6.3 ENVIRONMENTAL CONDITIONS

Source characterization should be done under laboratory conditions with an ambient temperature of $23^{\circ} \pm 1^{\circ}\text{C}$ and at a relative humidity of less than 70%.

6.4 TEMPERATURE STABILIZATION

Before characterization, allow the sources to stabilize in a free air environment at the ambient temperature for at least four hours.

NOTE

Do not handle a source for more than one minute at any any given time to avoid inaccurate characterization caused by temperature rise. Typically, it takes 20 minutes for a source to stabilize to rated accuracy after being handled for several minutes.

6.5 WARM UP PERIOD

Before characterization, turn on the test equipment and allow it to warm up for the period stated in the instruction manual for that equipment.

Table 6-1. Recommended Characterization Equipment

Description	Specifications	Manufacturer and Model	Application
1kHz Capacitance Bridge	10ppm (0.001%) accuracy, 0.02ppm/ $^{\circ}\text{C}$ stability	Andeen-Hagerling Model 2500	Measure 1kHz capacitance of C source
DMM (ohmmeter, RTD temperature)	0.01% accuracy (ohms), 0.16 $^{\circ}\text{C}$ accuracy (temperature)	Keithley Model 193A	Measure G source resistance and temperature (probe required below)
4-wire RTD temperature probe	100 $\Omega \pm 0.1\Omega$ platinum RTD, DIN43760, alpha 0.00385 or 0.00392	Omega PR-11-3-100	Measure ambient temperature with Model 193A

6.6 CAPACITANCE SOURCE CHARACTERIZATION

The following paragraphs discuss the procedure for measuring the 1kHz values of the capacitance sources. The factory calibration value for series inductance is used to calculate the 100kHz and 1MHz values. The series inductance measurement discussed in paragraph 2.3.2 is not required for characterization because the value of inductance does not significantly drift during the life of the sources. Before performing these procedures, the test equipment and sources must be temperature stabilized as discussed in the preceding paragraphs.

6.6.1 Connections

Where possible, the source being characterized should be connected directly to the 1kHz capacitance bridge. If connections must be made through cables, use the type and

maximum length specified by the manufacturer of the capacitance bridge.

6.6.2 1kHz Capacitance Measurement

Measure the 1kHz capacitance of each source as follows:

1. Connect the source being characterized to the capacitance bridge.
2. Allow the source to temperature stabilize for at least 10 minutes after handling. Measure the ambient temperature to within 0.1°C.
3. Measure the 1kHz capacitance and record the value in Table 6-2.
4. Repeats steps 1 through 3 for the remaining capacitance sources.

Table 6-2. Capacitance Characterization

Nominal Value	Measured 1kHz Capacitance	Calculated 100kHz Capacitance*	Calculated 1MHz Capacitance*
0.5pF	_____	_____	_____
1.5pF	_____	_____	_____
4.7pF	_____	_____	_____
18 pF	_____	_____	_____
47 pF	_____	_____	_____
180 pF	_____	_____	_____
470 pF	_____	_____	_____
1.8nF	_____	_____	_____
4.7nF	_____	_____	_____
18 nF	_____	_____	_____

*Calculated as follows:

$$C_E = C_{1k} [(T_A - 23)(0.00014) + 1] \left(1 + \frac{\omega^2 L C_{1k}}{1 - \omega^2 L C_{1k}} \right)$$

Where: C_E = Extrapolated 100kHz or 1MHz value.

C_{1k} = Measured 1kHz capacitance.

$\omega^2 = (2\pi f)^2 = 3.9478417 \times 10^{11}$ (100kHz) or 3.9478417×10^{13} (1MHz)

L = Series inductance marked on source

T_A = Ambient temperature during 1kHz measurement (°C)

6.6.3 100kHz Capacitance Calculation

Use the 1kHz measured value and the inductance marked on each source to calculate the 100kHz value at 23°C as follows:

$$C_{100k} = C_{1k} [(T_A - 23)(0.00014) + 1] \left[1 + \frac{\omega^2 L C_{1k}}{1 - \omega^2 L C_{1k}} \right]$$

Where: C_{100k} = capacitance at 100kHz
 C_{1k} = capacitance at 1kHz (measured)
 L = series inductance (marked on each source)
 $\omega^2 = (2\pi f)^2 = 3.9478417 \times 10^{11}$
 T_A = Ambient temperature during 1kHz measurement (°C)

After calculating each 100kHz value, record it in the appropriate space in Table 6-2.

Example: Assume that the measured 1kHz value of a nominal 180pF source is 181pF, and that the marked series inductance is 0.0492μH. The 100kHz capacitance at 25°C is:

$$C_{100k} = (181 \times 10^{-12}) [(25 - 23)(0.00014) + 1] \left[1 + \frac{(3.9478417 \times 10^{11})(0.0492 \times 10^{-6})(181 \times 10^{-12})}{1 - ((3.9478417 \times 10^{11})(0.0492 \times 10^{-6})(181 \times 10^{-12}))} \right]$$

$$C_{100k} = 181.05131 \times 10^{-12}$$

$$C_{100k} = 181.05131 \text{ pF}$$

6.6.4 1MHz Capacitance Calculation

The 1MHz capacitance value at 23°C can be determined in the same manner as the 100kHz value as follows:

$$C_{1M} = C_{1k} [(T_A - 23)(0.00014) + 1] \left[1 + \frac{\omega^2 L C_{1k}}{1 - \omega^2 L C_{1k}} \right]$$

Where: C_{1M} = capacitance at 1MHz (calculated)
 C_{1k} = capacitance at 1kHz (measured)

L = series inductance (marked on each source)
 $\omega^2 = (2\pi f)^2 = 3.9478417 \times 10^{13}$
 T_A = Ambient temperature during 1kHz measurement (°C)

After calculating each 1MHz value, record it in Table 6-2.

Example: Assume the same 180pF (nominal) source is used. With a measured 1kHz capacitance of 181pF and a marked series inductance of 0.0492μH, the 1MHz capacitance at 25°C is:

$$C_{1M} = (181 \times 10^{-12}) [(25 - 23)(0.00014) + 1] \left[1 + \frac{(3.9478417 \times 10^{13})(0.0492 \times 10^{-6})(181 \times 10^{-12})}{1 - ((3.9478417 \times 10^{13})(0.0492 \times 10^{-6})(181 \times 10^{-12}))} \right]$$

$$C_{1M} = 181.1144 \times 10^{-12}$$

$$C_{1M} = 181.1144 \text{ pF}$$

6.6.5 Capacitance Source Calibration Labels

After the 1kHz, 100kHz, and 1MHz capacitance values have been determined, write the values on the calibration labels (supplied). Also include other pertinent information such as due date, and place the labels on the source over the existing labels.

6.7 CONDUCTANCE SOURCE VERIFICATION

Information on characterizing the conductance sources is contained in the following paragraphs. Be sure that the test equipment and sources are temperature stabilized as discussed in earlier paragraphs.

6.7.1 Test Connections

The source being measured should be connected to the DMM using the 4-wire method, as shown in Figure 6-1. Note that connections should be made only to the center conductor of each source jack; use a small piece of bare wire or fabricate a suitable adapter. Be sure not to short either connecting point to the outer ring of the jack.

6.7.2 DC Conductance Measurement

Measure the DC conductance of each source as follows:

1. Measure the ambient air temperature to within 0.1°C. If the temperature is not 23° ±2°C, stabilize the temperature at that value before characterizing the source.
2. Select the ohms function on the DMM.
3. Select a resistance range consistent with the anticipated measurement. The resistance is simply the reciprocal of the conductance:

$$R=1/G$$

4. Temporarily disconnect the test leads from the source, short the test lead ends, then enable zero on the DMM.
5. Connect the test leads to the source (Figure 6-1) then measure the resistance value with the DMM.
6. Calculate the conductance value as follows:

$$G = 1/R$$

Where: G is the conductance in siemens
 R is the measured resistance in ohms.

7. Record the calculated DC conductance in Table 6-3.
8. Repeat steps 2 through 7 for the remaining sources and record the values in Table 6-3.

6.7.3 100kHz and 1MHz Conductance Values

For all values of conductance except 18mS, the 100kHz and 1MHz conductance values can be considered to be the same as the DC measured value. Thus, the characterized values at those frequencies will be the same as the characterized DC value. The 18mS conductance source must have its 1MHz value corrected for the effects of stray reactance and RF skin effect. The correction factor is:

$$G_{1MHz} = G_{DC} \times (0.9999)$$

At 100kHz, no correction is necessary:

$$G_{100kHz} = G_{DC}$$

6.7.4 Conductance Source Calibration Labels

As with the capacitance sources, the measured conductance values should be recorded on the replacement calibration labels and placed on each source for future reference of the characterized values.

Table 6-3. Conductance Characterization

Nominal Value	Measured DC Conductance*	1MHz Conductance**
1.8 μS	_____	
18 μS	_____	
180 μS	_____	
1.8mS	_____	
18 mS	_____	_____

*Conductance determined from measured resistance:
 $G = 1/R$. 100kHz and 1MHz values are the same as DC conductance except 18mS 1MHz value.

**Calculate 1MHz 18mS conductance as follows:

$$G_{1MHz} = G_{DC} \times 0.9999$$

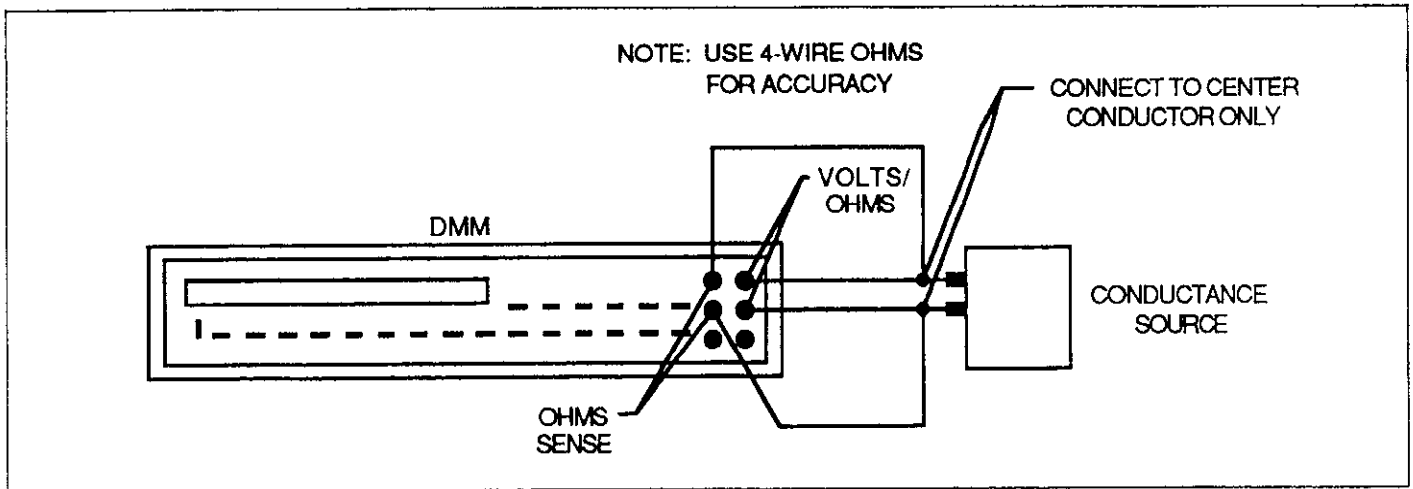


Figure 6-1. Conductance Source Characterization Connection

SECTION 7 REPLACEABLE PARTS

7.1 INTRODUCTION

This section contains information on replaceable parts for the Models 5905, 5906, 5907, and 5955.

7.2 PARTS LISTS

Parts for the Models 5905, 5906, 5907, and 5955 are listed in Tables 7-1 through 7-4 respectively. The capacitance and conductance values listed in each table are nominal. Also note that the part numbers listed for the capacitance and conductance sources are for factory calibrated units.

7.3 ORDERING INFORMATION

To place a parts order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see the inside front cover for addresses). When ordering parts, be sure to include the following information:

1. Model number (5905, 5906, 5907, or 5955).
2. Serial number (where applicable).
3. Part description.
4. Keithley part number.

Table 7-1. Model 5905 Parts List

Quantity	Description*	Keithley Part Number**
1	Capacitance source, 4.7pF	5900-301-3
1	Capacitance source, 18pF	5900-301-4
1	Capacitance source, 47pF	5900-301-5
1	Capacitance source, 180pF	5900-301-6
1	Capacitance source, 470pF	5900-301-7
1	Capacitance source, 1.8nF	5900-301-8
1	Conductance source, 180 μ S	5900-302-3
1	Conductance source, 1.8mS	5900-302-2
1	Conductance source, 18mS	5900-302-1
2	BNC, female-to-female adapter	CS-565
1	BNC, right angle male-to-female adapter	CS-566
1	BNC, plug shorting cap	CS-567
1	Case, calibration source, large	5900-313
6	Capacitance calibration label set, replaceable	MC-444
3	Conductance calibration label set, replaceable	MC-446

*Source values shown are nominal.

**Capacitance and conductance numbers are for calibrated units.

Table 7-2. Model 5906 Parts List

Quantity	Description*	Keithley Part Number**
1	Capacitance source, 0.5pF	5900-301-1
1	Capacitance source, 1.5pF	5900-301-2
1	Capacitance source, 4.7pF	5900-301-3
1	Capacitance source, 18pF	5900-301-4
1	Capacitance source, 47pF	5900-301-5
1	Capacitance source, 180pF	5900-301-6
1	Capacitance source, 470pF	5900-301-7
1	Capacitance source, 1.8nF	5900-301-8
1	Capacitance source, 4.7nF	5900-301-9
1	Capacitance source, 18nF	5900-301-10
1	Conductance source, 1.8 μ S	5900-302-5
1	Conductance source 18 μ S	5900-302-4
1	Conductance source 180 μ S	5900-302-3
1	Conductance source 1.8mS	5900-302-2
1	Conductance source 18mS	5900-302-1
2	BNC, female-to-female adapter	CS-565
1	BNC, right angle male-to-female adapter	CS-566
1	BNC, shorting cap	CS-567
1	Case, calibration set, small	5900-314
1	Case, calibration set, large	5900-313
10	Capacitance calibration label set, replaceable	MC-444
5	Conductance calibration label set, replaceable	MC-446

*Source values shown are nominal.

**Capacitance and conductance part numbers are for calibrated units.

Table 7-3. Model 5907 Parts List

Quantity	Description*	Keithley Part Number**
1	Capacitance source, 470pF	5900-301-7
1	Capacitance source, 1.8nF	5900-301-8
2	BNC, female-to-female adapter	CS-565
1	Case, calibration set, small	5900-312
2	Capacitance calibration label set, replaceable	MC-444

*Source values shown are nominal.

**Capacitance source part numbers are for calibrated units.

Table 7-4. Model 5955 Parts List

Quantity	Description*	Keithley Part Number**
1	Capacitance source, 180pF	5900-301-6
1	Capacitance source, 1.8pF	5900-301-8
1	Capacitance source, 18nF	5900-301-10
1	Case, calibration source, small	5900-315
3	Capacitance calibration label set, replaceable	MC-444

*Source values shown are nominal.

**Capacitance source part numbers are for calibrated units.

APPENDIX A

MODEL 590 CALIBRATION PROGRAM

INTRODUCTION

A program included in this section will allow you to perform digital calibration of the Model 590 on a semi-automated basis. Program 1 is written in Hewlett-Packard Model 85 BASIC, which is similar to the syntax used in BASIC 4.0 used in the Series 200 and 300 computers. Note that the HP-85 must be equipped with an HP-IB interface and an I/O ROM.

RUNNING THE PROGRAM

1. With the power off, connect the Model 590 to the IEEE-488 bus of the computer. Make sure the primary address of the instrument is set to 15.
2. Enter the program into the computer. Note that the DATA statements at the end of the programs must be modified for the actual 100kHz and 1MHz values marked on your sources. For example, if the actual 100kHz value of the 1.5pF nominal source is 1.502pF, modify line 450 of the program to read:

```
450 DATA '1.5PF',1.502E-12
```

Note that the 100kHz and 1MHz values must be separately entered in the appropriate data statements.

3. After entering all statements, run the program and follow the prompts. The first prompt will ask you to select the frequency, after which a separate prompt to connect or disconnect each source will be made.

PROGRAMMING NOTES

1. Make certain that the calibration switch is in the unlocked position before attempting calibration.
2. Since the program contains no error checking, make certain you select only the frequency installed. Also, only one frequency will be calibrated with each run through. If your Model 590 is equipped with both modules, run through the program twice, once for each frequency.
3. The program does not calibrate the unit for use with the Model 5904 Input Adapter or driving point cable correction.

APPENDIX A

Program 1 Model 590 Digital Calibration

```
10 CLEAR
20 DIM A$(25)
30 DISP "THIS PROGRAM PERFORMS"
40 DISP "DIGITAL CALIBRATION ON THE"
50 DISP "590 CV ANALYZER"
60 DISP
70 DISP "PRESS 'CONT'"
80 PAUSE
90 CLEAR
100 REMOTE 715 !           PUT UNIT IN REMOTE
110 CLEAR 7 !           SEND DEVICE CLEAR
120 DISP "SELECT FREQUENCY"
130 DISP "0-100KHZ"
140 DISP "1-1MHZ"
150 DISP
160 DISP "SELECTION"
170 INPUT F
180 IF F<0 OR F>1 THEN 120
190 IF F=0 THEN 210
200 FOR J=1 TO 12 @ READ A$,A@ NEXT J ! SET DATA POINTER TO 1MHZ VALUES
210 OUTPUT 715 ;"L0,0X" !   RECALL DEFAULT SETUP
220 OUTPUT 715 ;"S3T2F";F;"X" ! PROGRAM RATE,TRIGGER,FREQUENCY
230 FOR R=1 TO 4 !       LOOP FOR ALL RANGES
240 IF F=1 AND R=1 THEN R=2 ! NO 2PF 1MHZ RANGE
250 OUTPUT 715 ;"R";R;"X" !   PROGRAM RANGE
260 DISP "DISCONNECT SOURCE,PRESS CONT"
270 PAUSE
280 OUTPUT 715 ;"Q1X" !   PROGRAM OFFSET CAL
290 READ C$,C !         READ PROMPT STRING AND COMMAND VALUE
300 DISP "CONNECT ";C$;" SOURCE,PRESS CONT"
310 PAUSE
320 OUTPUT 715 ;"Q2,";C$;" ,0X" ! PROGRAM FIRST C CAL POINT
330 READ C$,C
340 DISP "CONNECT ";C$;" SOURCE,PRESS CONT"
350 PAUSE
360 OUTPUT 715 ;"Q3,";C$;" ,0X" ! PROGRAM SECOND C CAL POINT
370 READ C$,C
380 DISP "CONNECT ";C$;" SOURCE,PRESS CONT"
390 PAUSE
400 OUTPUT 715 ;"Q4,0,";C$;"X" ! PROGRAM 6 CAL POINT
410 NEXT R ! LOOP BACK FOR NEXT RANGE
420 DISP "CALIBRATION COMPLETE"
430 END
```

Program 1 Model 590 Digital Calibration (Cont.)

```
440 REM *** 100KHZ DATA STATEMENTS*****
450 DATA "1.5PF",1.5E-12
460 DATA "0.5PF",5.E-13
470 DATA "1.8US",.0000018
480 DATA "18PF",.000000000018
490 DATA "4.7PF",4.7E-12
500 DATA "18US",.000018
510 DATA "180PF",.000000000018
520 DATA "47PF",.000000000047
530 DATA "180US",.00018
540 DATA "1.8NF",.0000000018
550 DATA "470PF",.00000000047
560 DATA "1.8MS",.0018
570 REM *** 1MHZ SOURCE VALUES *****
580 DATA "18PF",.000000000018
590 DATA "4.7PF",4.7E-12
600 DATA "180US",.00018
610 DATA "180PF",.000000000018
620 DATA "47PF",.000000000047
630 DATA "1.8MS",.0018
640 DATA "1.8NF",.0000000018
650 DATA "470PF",.00000000047
660 DATA "18MS",.018
```

APPENDIX B

MODEL 595 CALIBRATION PROGRAM

INTRODUCTION

A program included in this appendix is intended to perform capacitance calibration of the Model 595 Quasistatic CV Meter. Program 2 is written in Hewlett-Packard Model 85 BASIC, and must be run on an HP-85 computer equipped with an HP-IB interface and an I/O ROM.

RUNNING THE PROGRAM

1. Connect the Model 595 to the IEEE-488 bus of the computer with the power turned off.
2. Make sure the primary address of the Model 595 is set to 28.
3. If you intend to store new calibration in NVRAM, make sure the calibration jumper is in the enabled position (see Section 4).
4. Enter the program into the computer. Note that the DATA statements at the end of each program must be modified for the actual 1kHz values on your particular sources. For example, if your 180pF source has an actual

1kHz value of 179.95pF, modify line 530 of the HP-85 program as follows:

```
530 DATA '180PF', '180PF', 179.95E-12
```

Note that only the capacitance source values need be modified; the command strings and prompt strings should not be changed.

5. Run the program and follow the prompts. The program will guide you through the necessary steps. At the conclusion of the program, you will be given a choice as to whether to store calibration in NVRAM. In order to do so, the calibration jumper must be in the enabled position.

NOTE

Although a 15 second time delay is built into the program for the reading to settle after connecting the source, this time period may not be sufficient in some cases. To ensure the reading is properly settled, wait at least 5-10 seconds after connecting the source each time before continuing the program.

Program 2 Model 595 Capacitance Calibration

```
10 CLEAR
20 DIM B$(25)
30 DISP "THIS PROGRAM PERFORMS"
40 DISP "CAPACITANCE CALIBRATION OF THE"
50 DISP "MODEL 595 QUASISTATIC CV METER"
60 DISP
70 DISP "PRESS CONT TO BEGIN"
80 DISP
90 CLEAR 7
100 PAUSE
110 OUTPUT 728 ;"F0R1P3I0.07W2S0Z0X" ! INITIALIZE 595
120 DISP "PLACE PROTECTION CAP ON"
130 DISP "METER INPUT,PRESS CONT"
140 PAUSE
150 OUTPUT 728 ;"J16X" !          PROGRAM OFFSET COMPENSATION
160 DISP
170 OUTPUT 728 ;"W2I.2X" !          PROGRAM SQUARE WAVE,0.2S DELAY
180 FOR I=1 TO 7 !          LOOP FOR ALL CAL POINTS
190 READ A$ !          READ 595 COMMAND STRING
200 IF I=1 OR I=2 OR I=4 THEN READ B$,A ! READ PROMPT AND C SOURCE VALUE
210 OUTPUT 728 ;A$ !          SEND COMMAND STRING TO 595
220 IF I=1 THEN 270 !          BYPASS MESSAGE ON FIRST TIME THROUGH
230 DISP "PLACE PROTECTION CAP ON"
240 DISP "METER INPUT,PRESS CONT"
250 DISP
260 PAUSE
270 OUTPUT 728 ;"Z0X" !          TURN OFF ZERO CHECK
280 DISP "WAITING FOR READING TO SETTLE"
290 WAIT 15000
300 OUTPUT 728 ;"N1X" !          TURN SUPPRESS ON
310 DISP
320 DISP "REMOVE PROTECTION CAP AND"
330 DISP "CONNECT ";B$;" SOURCE TO"
340 DISP "MODEL 595, PRESS CONT"
350 DISP
360 PAUSE
370 DISP
380 DISP "WAITING FOR READING TO SETTLE"
390 DISP
400 WAIT 15000
410 OUTPUT 728 ;"A";A;"X" !          SEND CAL COMMAND TO 595
420 OUTPUT 728 ;"N0Z1X" !          TURN OFF SUPPRESS, TURN ON ZERO CHECK
430 NEXT I
440 DISP
450 DISP "CALIBRATION COMPLETE"
460 DISP
```

Program 2 Model 595 Capacitance Calibration (Cont.)

```
470 DISP "STORE CAL IN NVRAM (Y/N)"
480 INPUT A$
490 IF A$(1,1)="Y" THEN OUTPUT 728 ;"J19X"
500 END
510 REM *** DATA STATEMENTS CONTAINING COMMAND STRINGS AND C VALUES *****
520 DATA "R3P2S3X","18NF",.000000018
530 DATA "R1P3X","180PF",.00000000018
540 DATA "S0X"
550 DATA "R2P2S3X","1.8NF",.00000000018
560 DATA "S2X"
570 DATA "S1X"
580 DATA "S0X"
```



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. _____

- | | | |
|--|--|--|
| <input type="checkbox"/> Intermittent | <input type="checkbox"/> Analog output follows display | <input type="checkbox"/> Particular range or function bad; specify |
| <input type="checkbox"/> IEEE failure | <input type="checkbox"/> Obvious problem on power-up | <input type="checkbox"/> Batteries and fuses are OK |
| <input type="checkbox"/> Front panel operational | <input type="checkbox"/> All ranges or functions are bad | <input type="checkbox"/> Checked all cables |

Display or output (check one)

- | | |
|-----------------------------------|--|
| <input type="checkbox"/> Drifts | <input type="checkbox"/> Unable to zero |
| <input type="checkbox"/> Unstable | <input type="checkbox"/> Will not read applied input |
| <input type="checkbox"/> Overload | |

- | | |
|---|--|
| <input type="checkbox"/> Calibration only | <input type="checkbox"/> Certificate of calibration required |
| <input type="checkbox"/> Data 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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