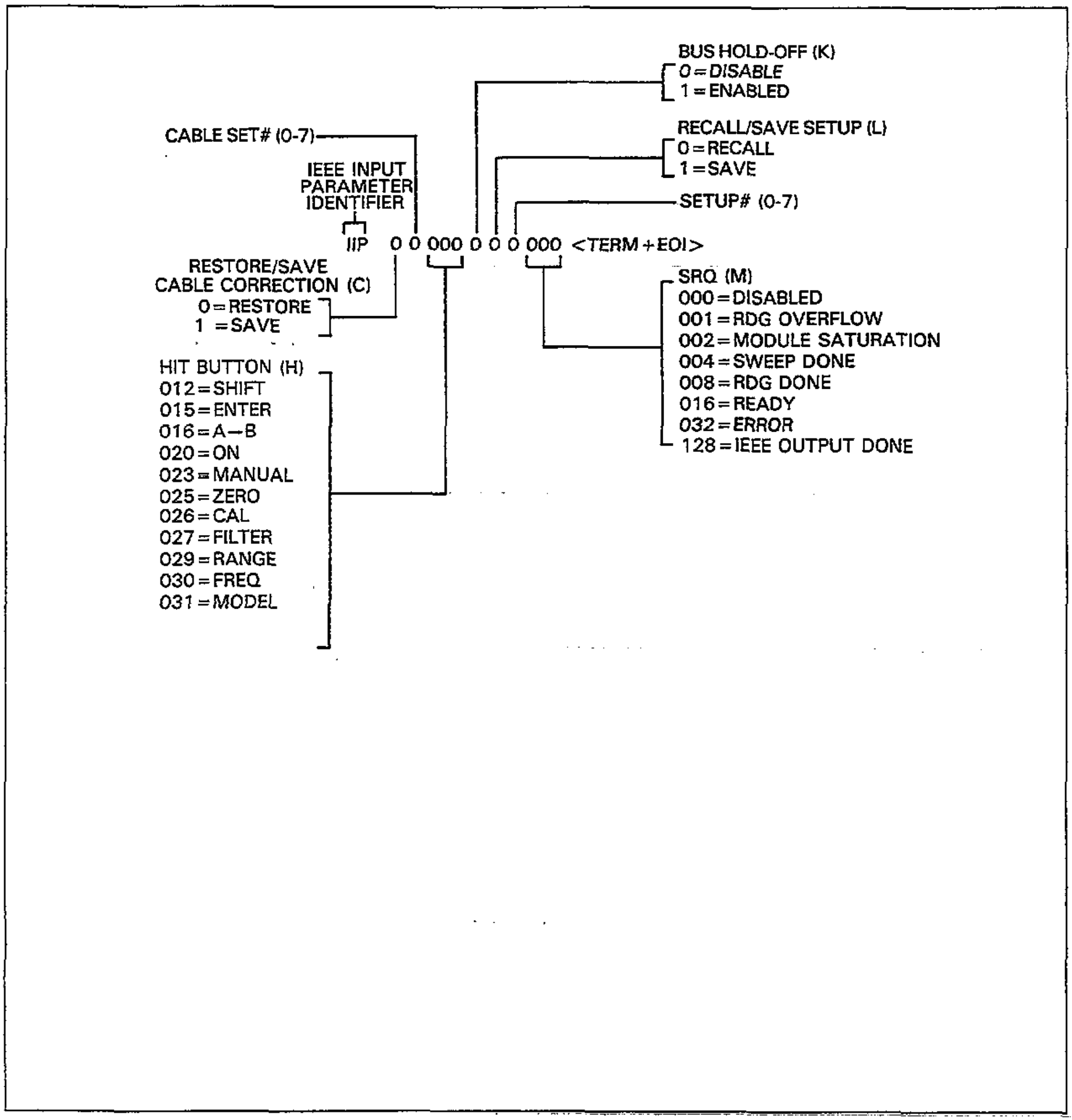


Figure 4-33. U25 Status Word Format (IEEE Input Parameters)

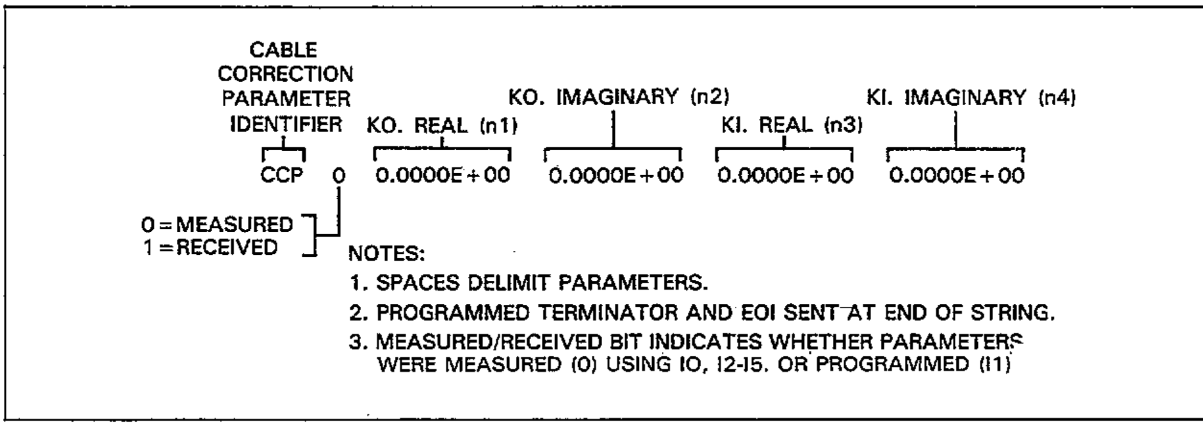


Figure 4-34. U26 Status Word Format (Cable Correction Parameters)

4.9.16 SRQ (M) and Status Byte Format

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

Format **Mn**

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

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

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

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

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

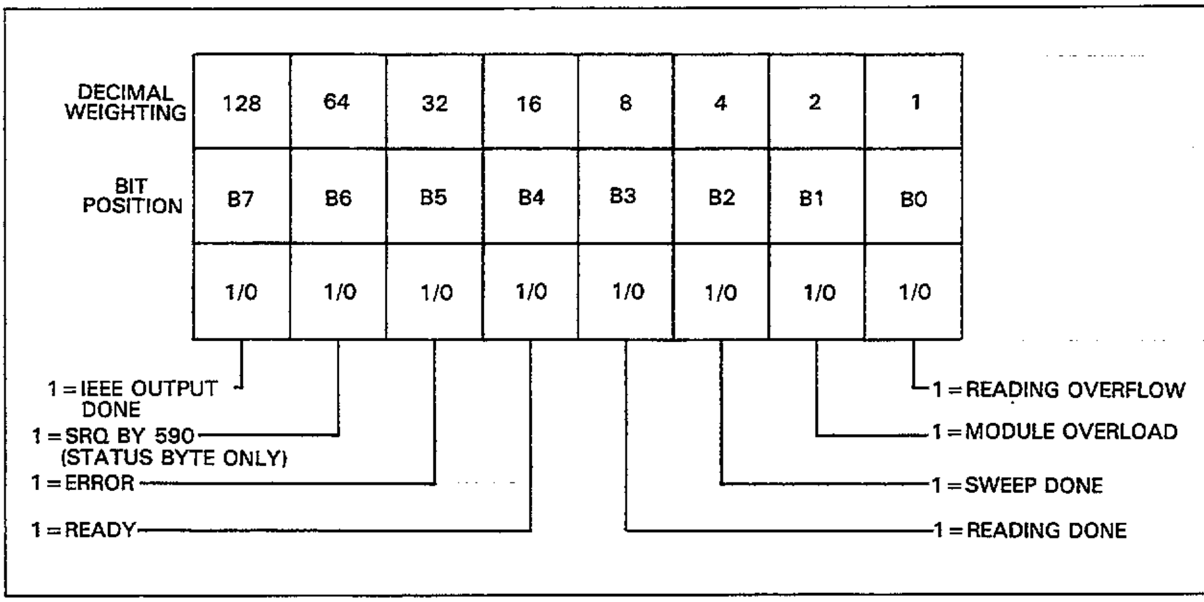


Figure 4-35. SRQ Mask and Status Byte Format

SRQ Timing and Trigger Modes

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

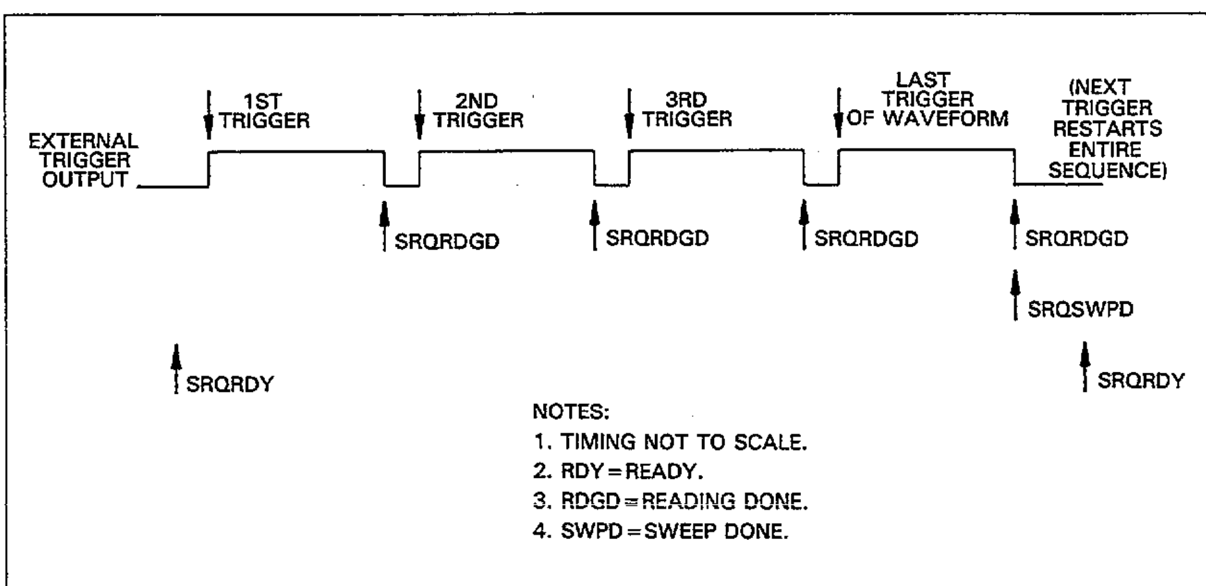


Figure 4-36. SRQ Timing with One-Shot Trigger Mode

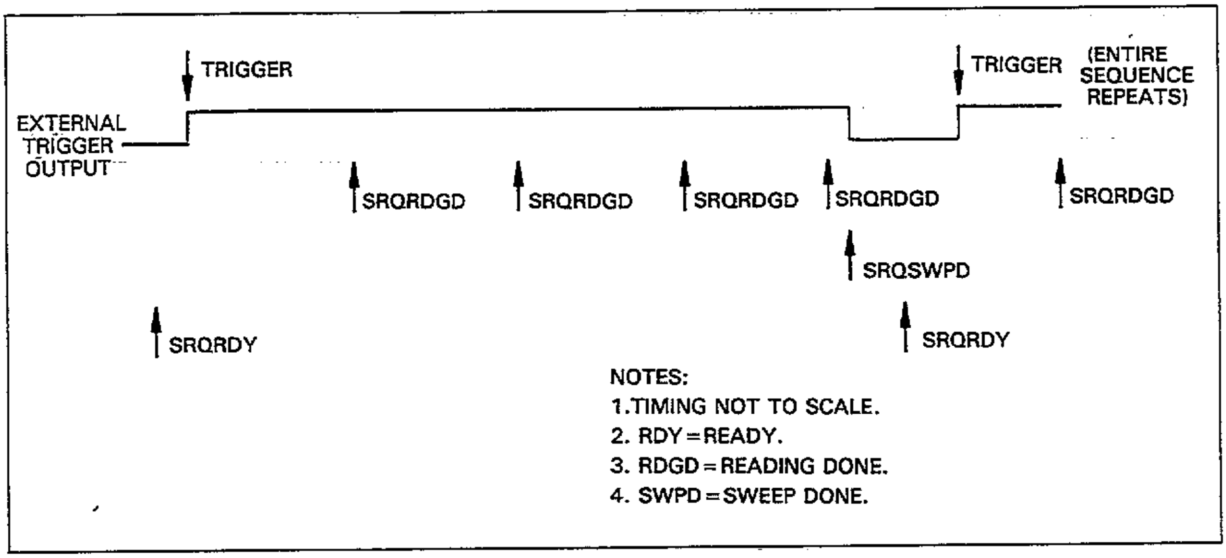


Figure 4-37. SRQ Timing with Sweep Trigger Mode

Status Byte Format

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

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

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

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

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

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

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

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

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

Programming Notes

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

Programming Examples

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

4.9.17 Save and Recall (L)

Purpose To save and recall instrument setups stored in NVRAM.

Format **Ln,m**

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

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

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

Programming Notes

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

4.9.18 Measure and Assign Cable Parameters (I)

Purpose

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

Formats

In(,parameters)

Parameters

I0 Measure cable parameters (driving point)

I1,n1,n2,n3,n4 Assign cable parameters: K0(n1+jn2), K1(n3+jn4)

I2,n1,n2,n3,n4,n5,n6,n7,n8 Assign test OUTPUT matrix parameters:
A(n1+jn2),B(n3+jn4),C(n5+jn6),D(n7+jn8)

I3,n1,n2,n3,n4,n5,n6,n7,n8 Assign test INPUT matrix parameters:
A(n1+jn2),B(n3+jn4),C(n5+jn6),D(n7+jn8)

I4 Perform offset correction

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

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

Description

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

Cable correction commands include:

I0: Driving Point Method

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

I1: Assigning Internal Correction Constants

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

I2 and I3: Matrix Parameter Method

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

I4, I5, and I6: Calibration Capacitor Method

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

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

Programming Examples

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

4.9.19 Save and Recall Cable Corrections (C)

Purpose To save or recall of cable correction parameters.

Format **Cn,m**

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

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

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

Programming Notes

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

Programming Examples

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

4.9.20 Calibration (Q)

Purpose To calibrate the instrument to known standards.

Format **Qn(,parameters)**

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

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

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

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

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

4.9.21 Terminator (Y)

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

Format **Yn**

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

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

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

Programming Notes

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

Programming Examples

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

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

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

Format **Kn**

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

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

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

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

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

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

Table 4-15. Typical Bus Hold-off Times

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

4.9.23 Display (D)

Purpose To write messages to the front panel display.

Format **Daaa**

Parameters aaa ASCII characters (20 maximum)

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

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

Programming Notes

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

Programming Examples

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

4.9.24 Hit Button (H)

Purpose To allow emulation of front panel key press sequence.

Format **Hn**

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

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

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

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

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

Programming Notes

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

Programming Examples

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

4.9.25 Self Test (J)

Purpose To test front panel display and internal circuitry.

Format **Jn**

Parameters J1 Perform self test

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

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

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

Programming Examples

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

4.10 TRANSLATOR

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

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

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

Table 4-17. Translator Reserved Words and Characters

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

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

Commands associated with Translator are discussed in the following paragraphs.

4.10.1 Defining Translator Words (ALIAS)

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

Format **ALIAS WORD COMMAND ;**

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

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

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

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

   TRANSLATOR-ERR

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

Programming Examples

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

4.10.2 Enabling the Translator (NEW)

Purpose To enable Translator using previously defined words.

Format **NEW**

Parameters None

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

Programming Notes

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

Programming Example

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

4.10.3 Disabling the Translator (OLD)

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

Format **OLD**

Parameters None

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

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

Programming Example

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

4.10.4 Combining Translator Words (ALIAS and NEW)

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

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

Parameters

ALIAS: Defines the Translator word.

NEWWORD: The new word to be defined.

OLDWORD1 and OLDWORD2: Existing Translator words.

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

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

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

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

Programming Notes

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

Programming Examples

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

4.10.5 Reading Back Translator Words (LIST)

Purpose To obtain a list of defined Translator words.

Format **LIST**

Parameters None

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

Programming Notes

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

Programming Eamples

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

4.10.6 Purging Translator Words (FORGET)

Purpose To erase previously defined user Translator words from memory.

Format **FORGET**

Parameters None

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

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

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

4.10.7 Obtaining Translator Status (U27-U31)

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

Format **Un**

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

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

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

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

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

Table 4-18. Translator Status Word Summary

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

Programming Notes

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

Programming Examples

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

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

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

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

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

```
AAA <TERM+EOI>
 |
 └─[ NEW=TRANSLATOR ENABLED
   [ OLD=TRANSLATOR DISABLED
```

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

```
USER TRANSLATION
      LIST
   IDENTIFIER
       |
      UTL ALIAS WORD 1   DDC 1; . . . ALIAS WORD N DDC N; <TERM+EOI>
           TRANSLATOR     ASSOCIATED
              WORD     DEVICE-DEPENDENT
                           COMMAND
                            STRING
```

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

4.10.8 Translator Parameter Passing ($)

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

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

Parameters ALIAS: The reserved word that defines Translator words.

Cmd: A device-dependent command letter.

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

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

;: Semicolon is necessary to terminate the ALIAS string.

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

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

VOLTS 1 10 0.5 <TERMINATOR>

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

Programming Notes

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

Programming Examples

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

4.10.9 Translator Error Handling

Purpose To flag Translator error conditions.

Format **TRANSLATOR-ERR**

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

TRANSLATOR-ERR

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

Conditions that can cause a Translator error include:

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

Programming Examples

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

4.11 CABLE CORRECTION

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

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

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

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

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

NOTE

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

Table 4-19. Cable Correction Methods

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

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

NOTE: Cable correction does not affect linearity specifications.

Table 4-20. Cable Correction Commands

Command	Description
C0,n	Recall cable setup n ($0 \leq n \leq 7$)*
C1,n	Save cable setup n ($1 \leq n \leq 7$)
I0	Perform driving point correction
I1,n1,n2,n3,n4	Assign correction constants K0(n1+jn2), K1(n3+jn4)
I2,n1,n2,n3,n4, n5,n6,n7,n8	Assign test OUTPUT matrix parameters: A(n1+jn2), B(n3+jn4), C(n5+jn6), D(n7+jn8)
I3,n1,n2,n3,n4, n5,n6,n7,n8	Assign test INPUT matrix parameters: A(n1+jn2), B(n3+jn4), C(5n+jn6), D(n7+jn8)
I4, C, G	Zero cable open
I5, C, G	Program C and G values, step 1
I6, C, G	Program C and G values, step 2
U26	Obtain cable correction constants

*To cancel cable correction, use C0,0

4.11.1 Driving Point Correction

Description

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

Required Equipment

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

Procedure

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

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

   In this instance, we have chosen 1MHz.

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

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

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

Limitations and Considerations

The driving point cable correction method assumes the following:

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

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

4.11.2 Matrix Parameter Correction

Description

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

Required Equipment

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

Table 4-21. Equipment Required for Matrix Parameter Correction

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

Connections

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

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

Characteristic Impedance Determination

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

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

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

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

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

Measuring S (Scattering) Parameters

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

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

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

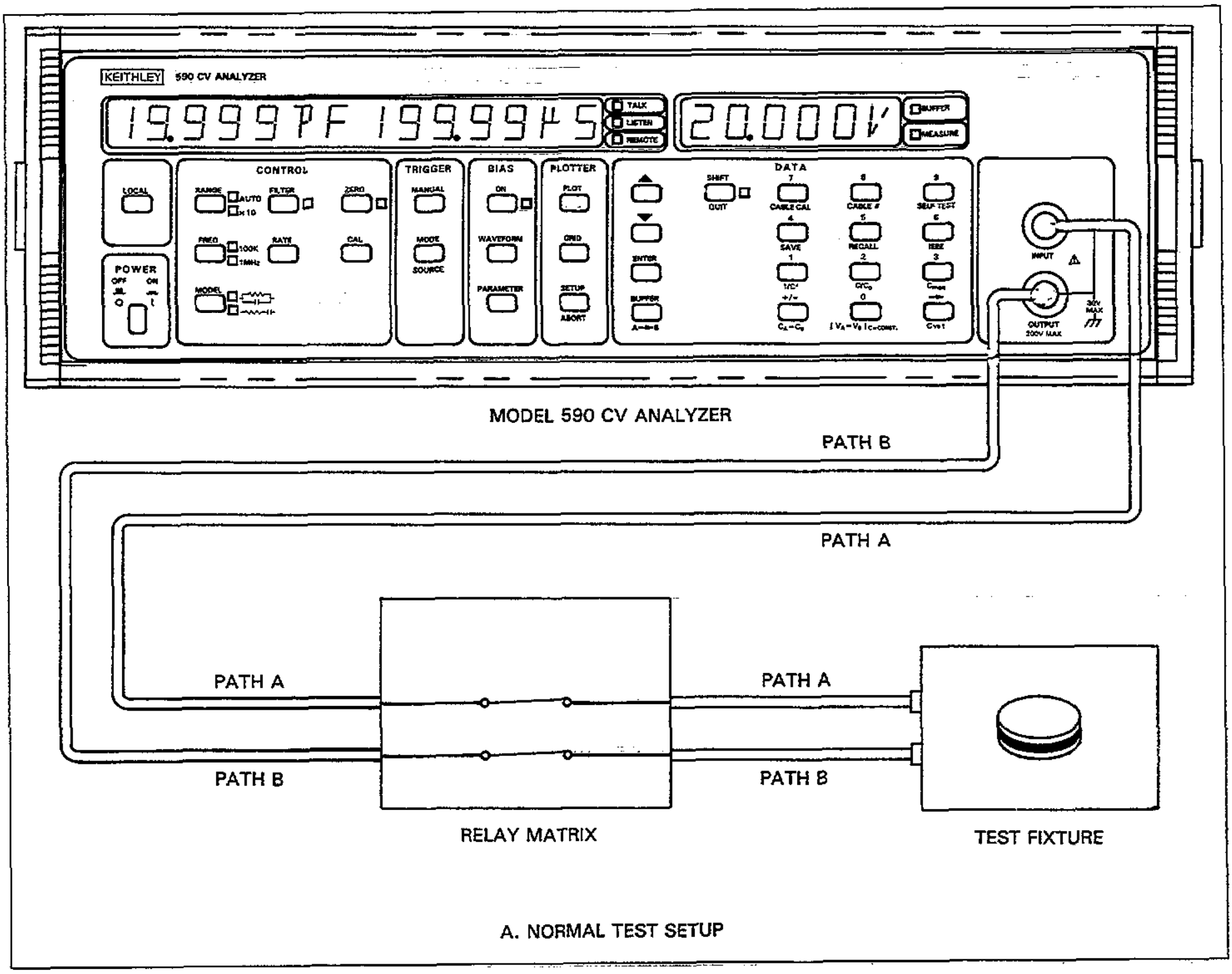


Figure 4-42A. Connecting Methods

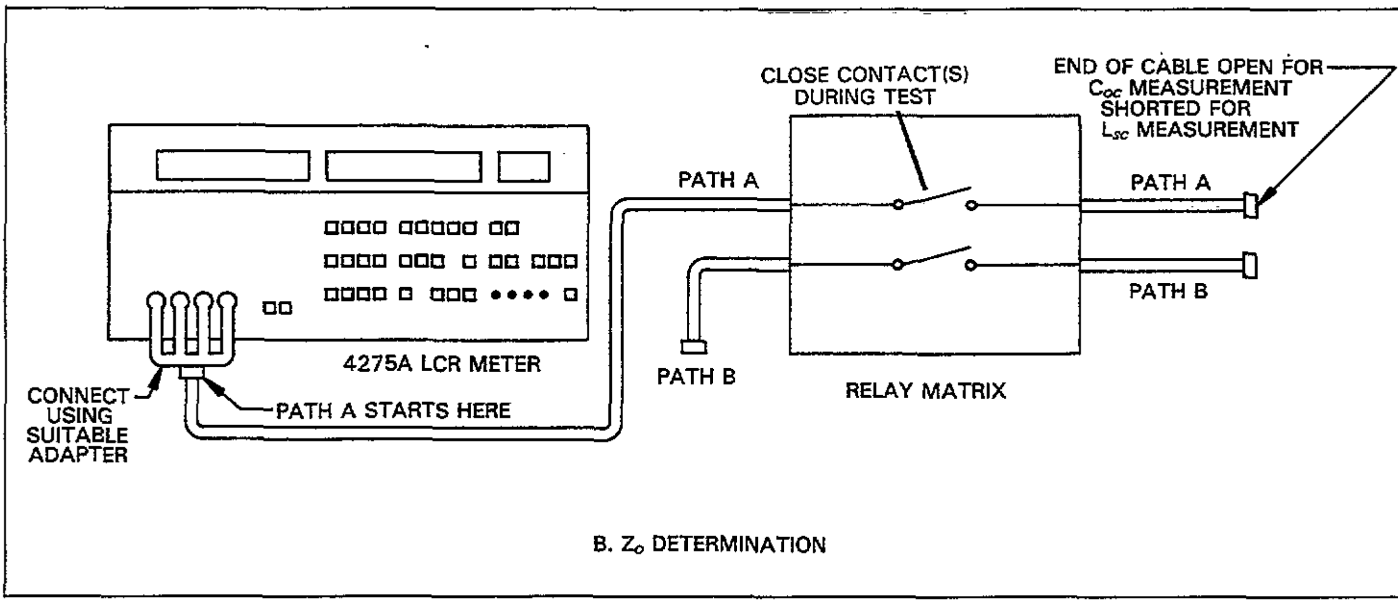


Figure 4-42B. Connecting Methods (Cont.)

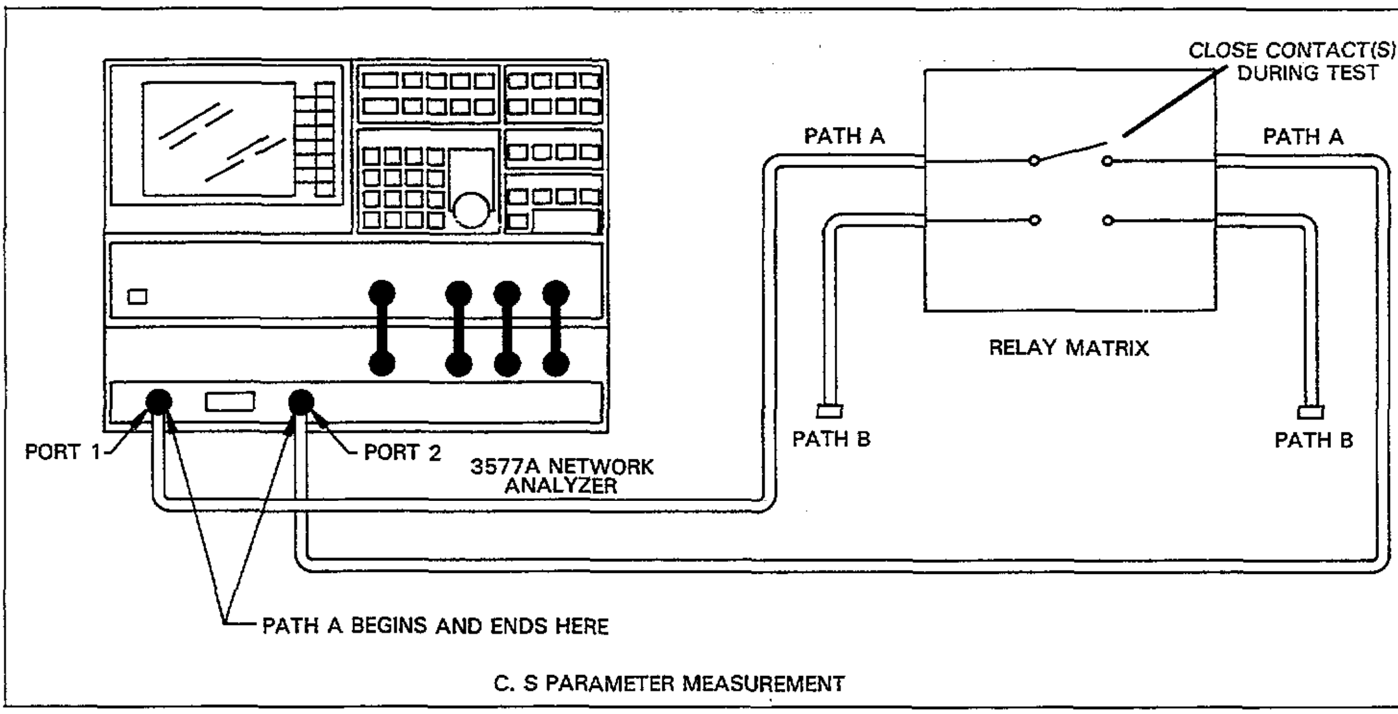
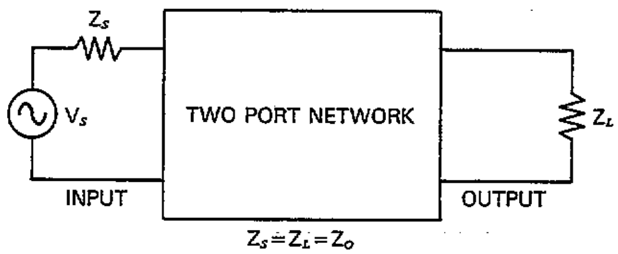


Figure 4-42C. Connecting Methods (Cont.)



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

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

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

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

= TRANSDUCER POWER GAIN WITH Z_o LOAD AND SOURCE

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

Figure 4-43. Simplified Parameter Definition

Calculating Matrix Parameters

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

$$a + jb$$

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

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

Programming Matrix Parameters

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

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

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

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

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

Table 4-22. Matrix Parameter Calculation

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

```
PROGRAM                           COMMENTS

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

A Practical Example

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

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

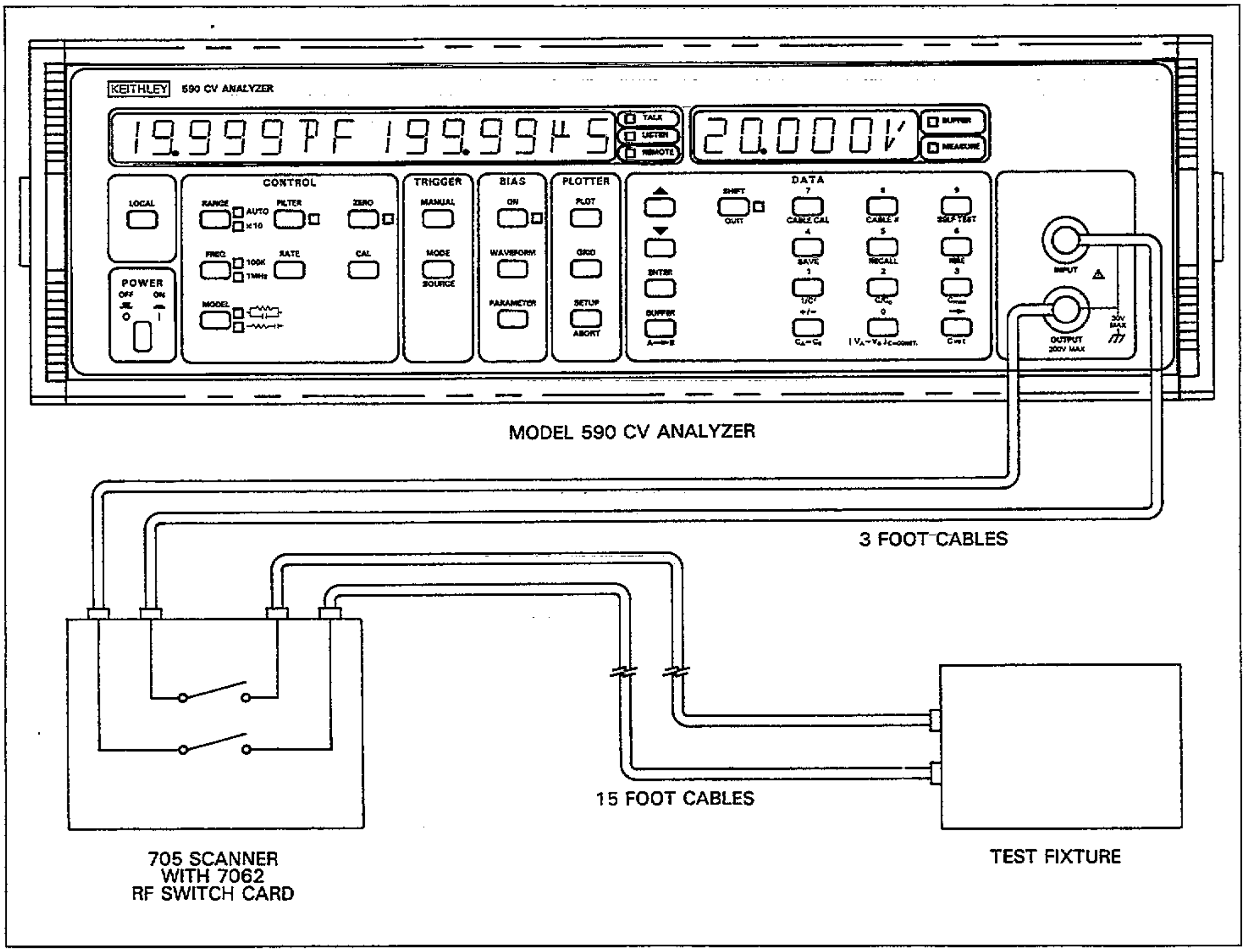


Figure 4-44. Test Configuration for S Parameter Examples

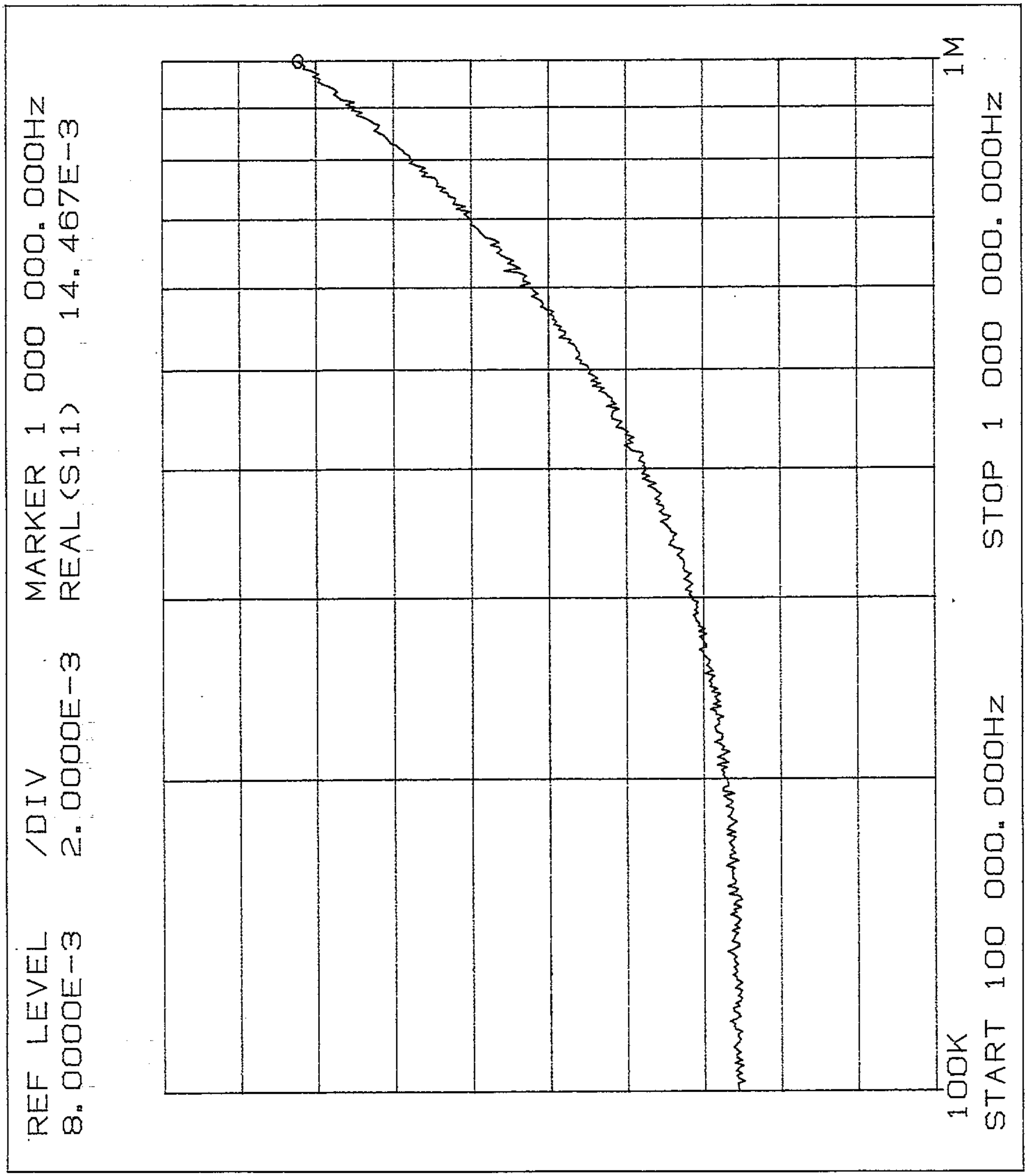


Figure 4-45. S_{11} Real Component

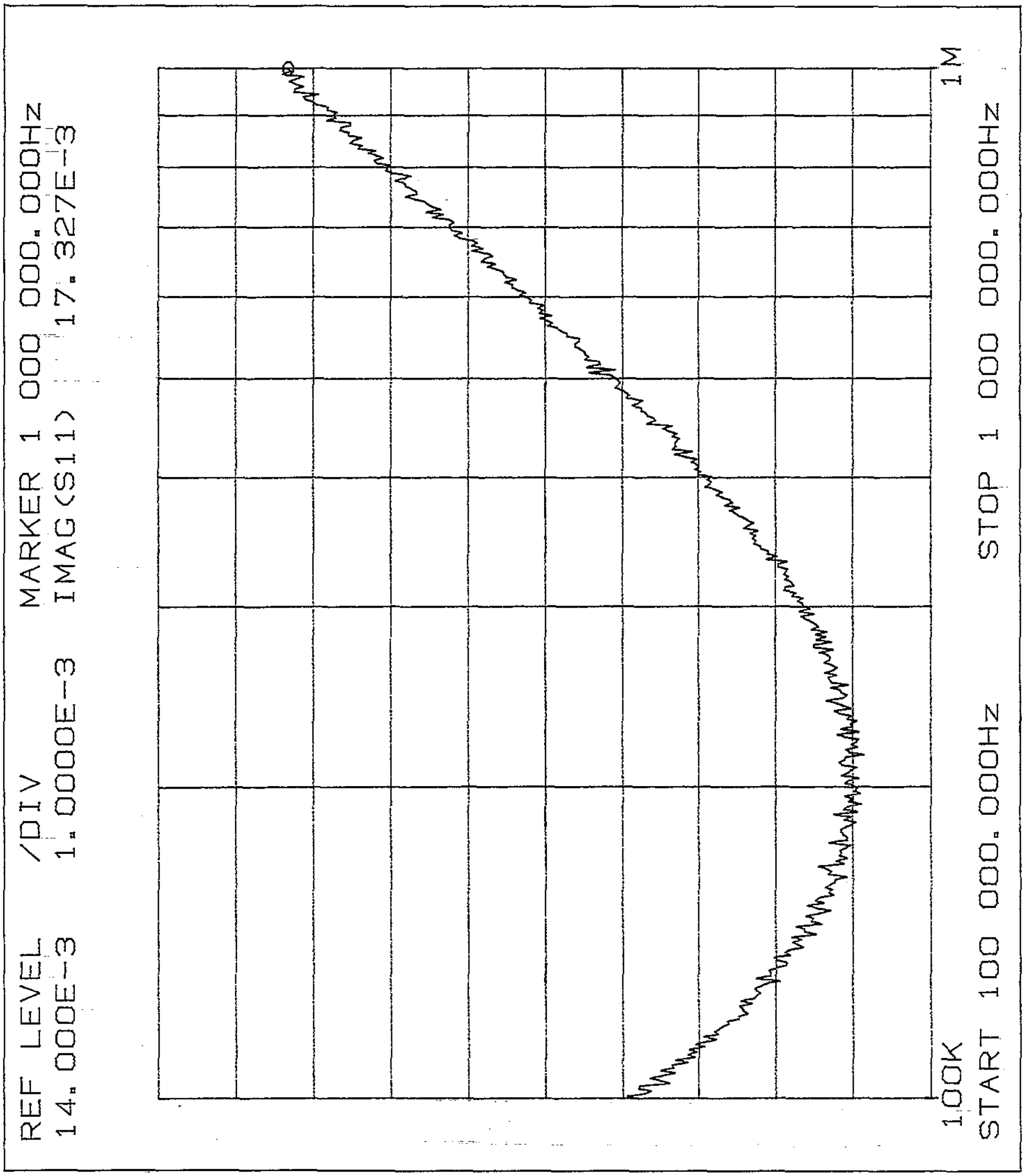


Figure 4-46. S_{11} Imaginary Component

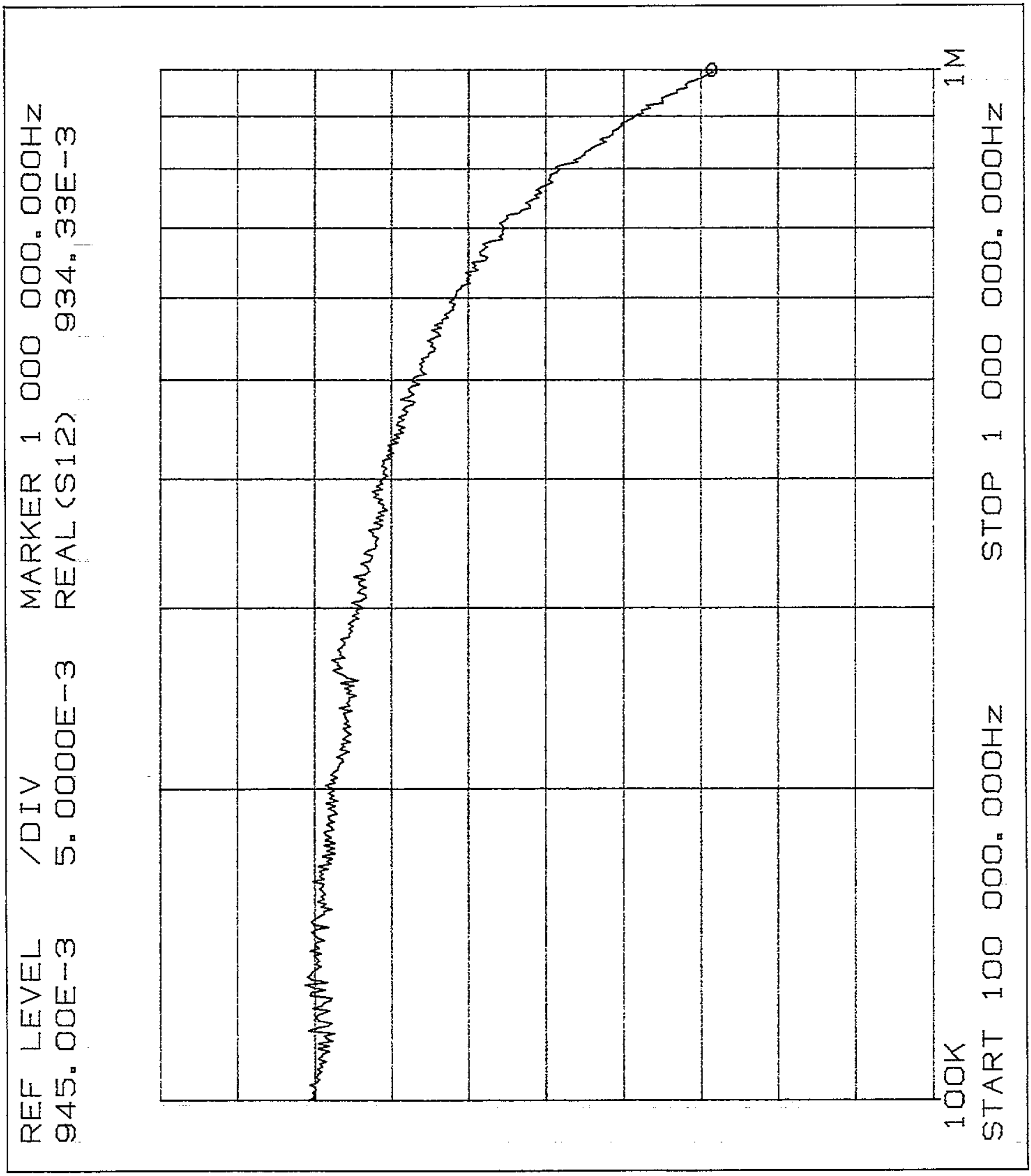


Figure 4-47. S_{12} Real Component

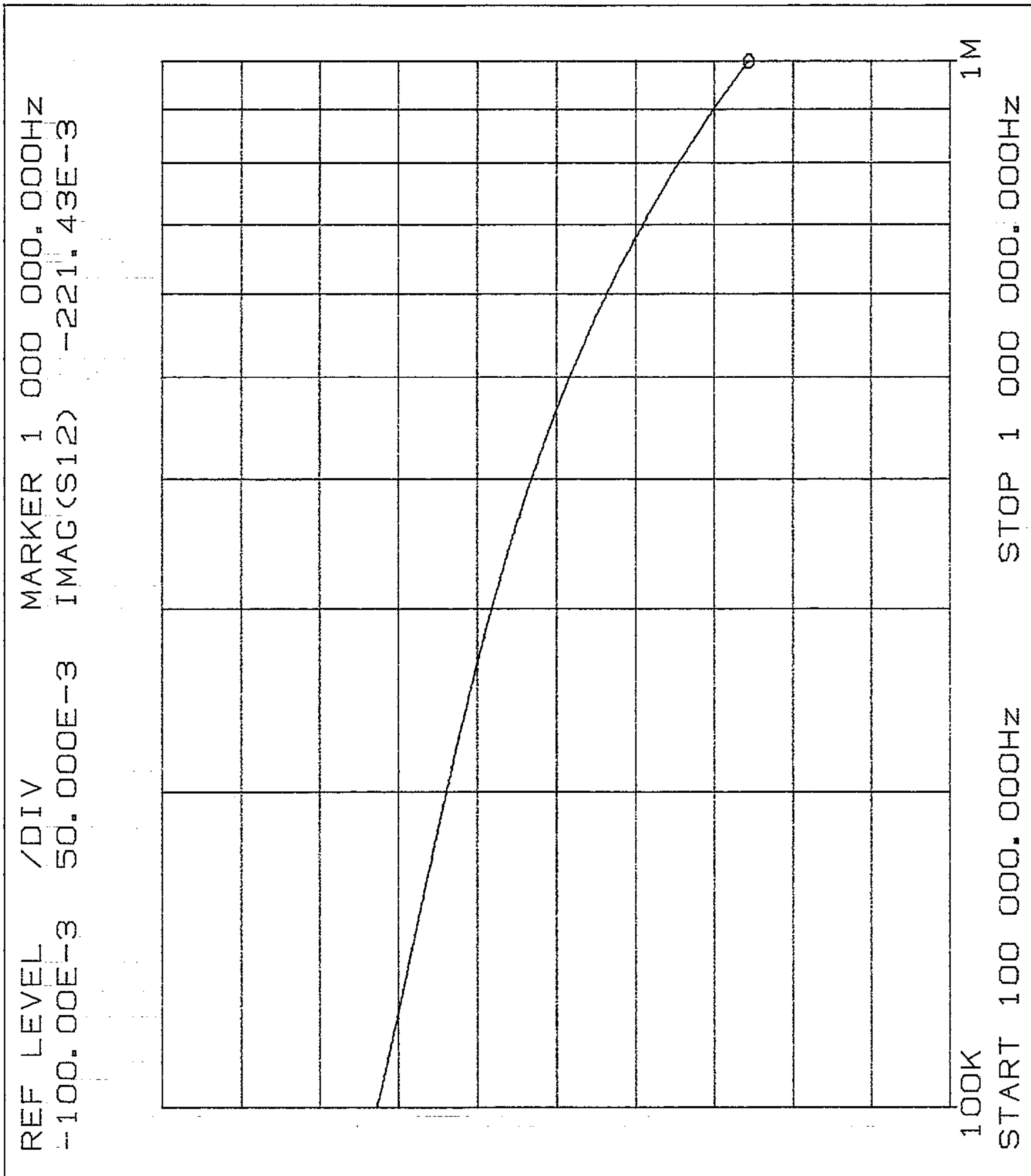


Figure 4-48. S_{12} Imaginary Component

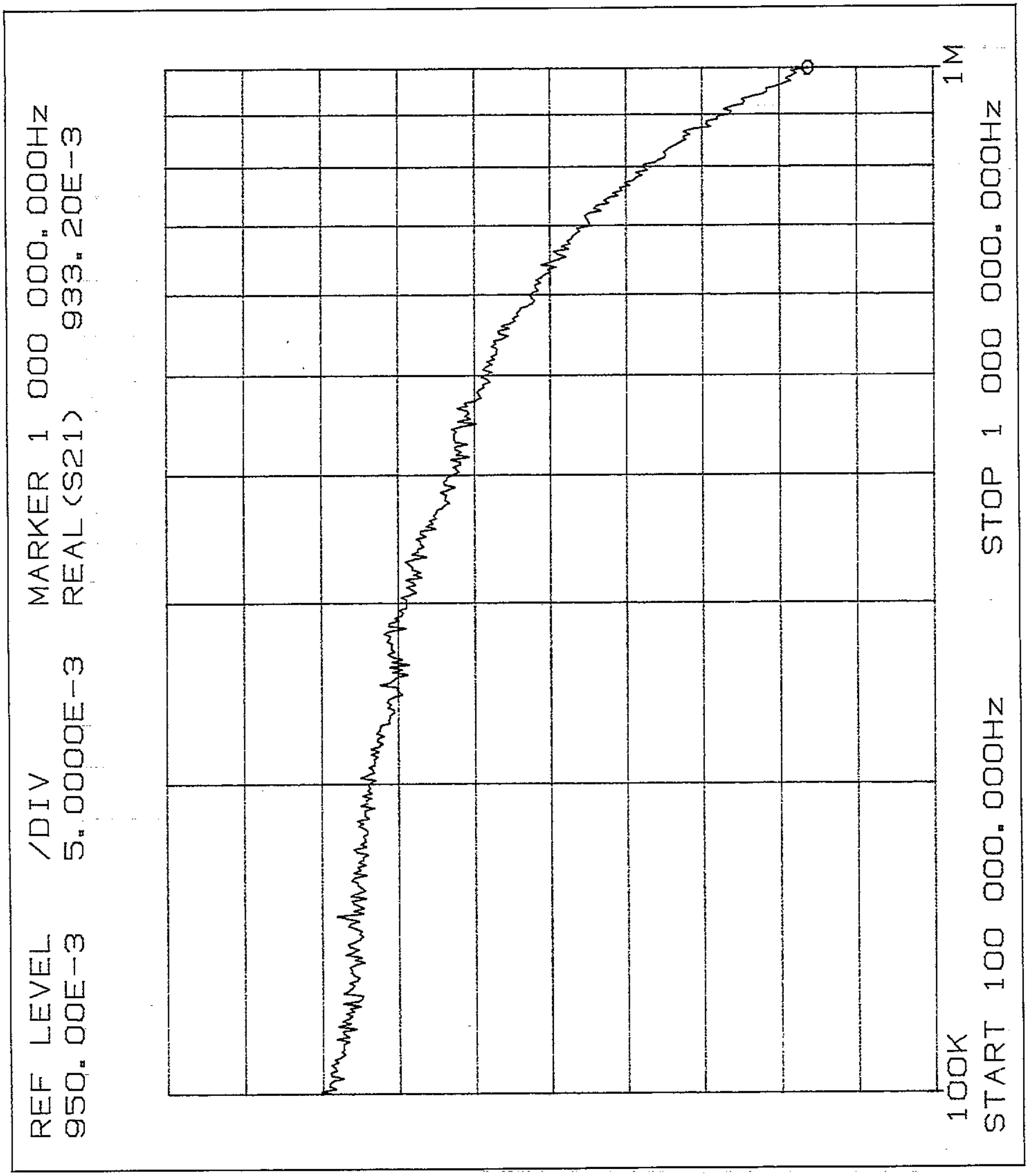


Figure 4-49. S_{21} Real Component

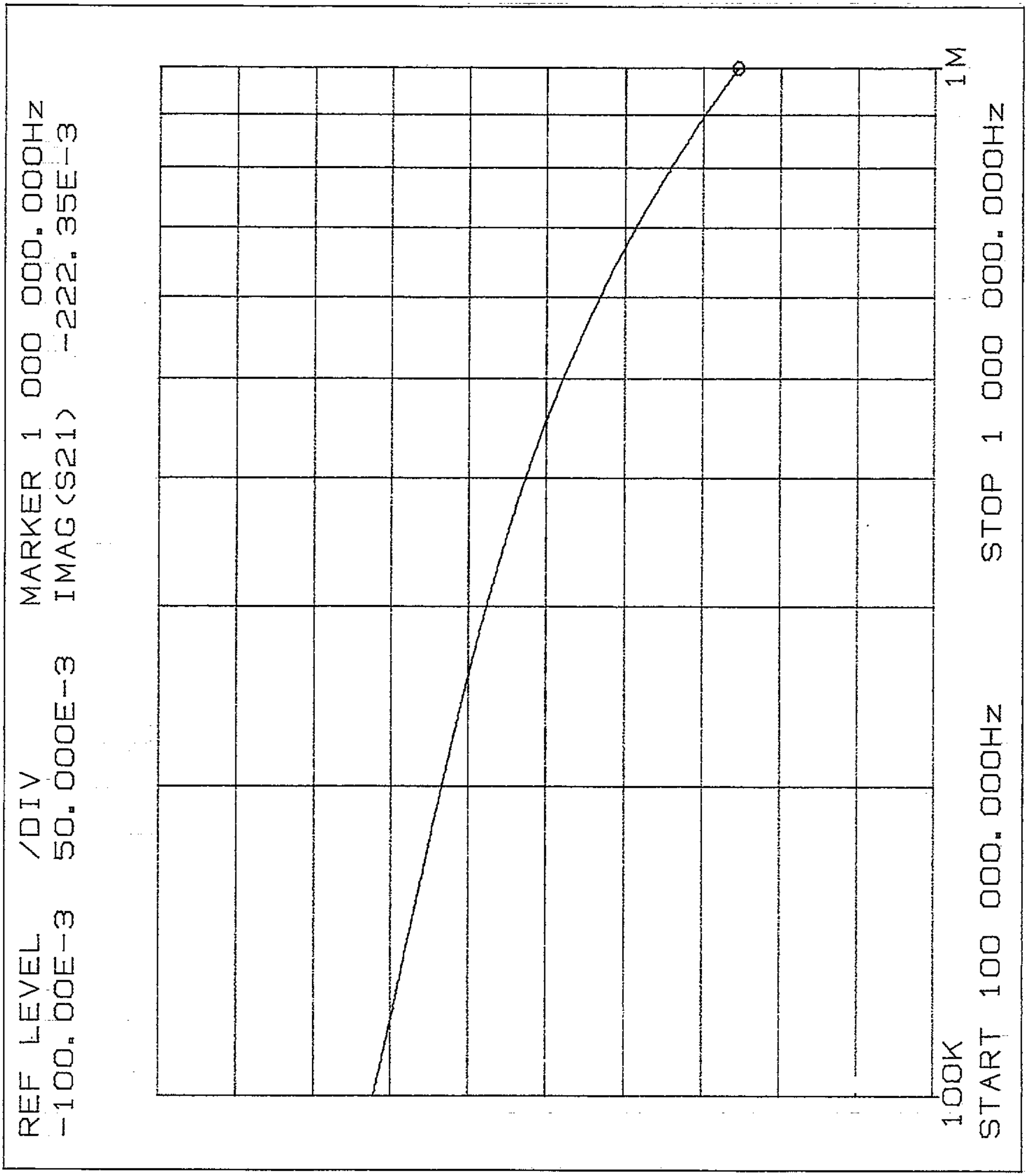


Figure 4-50. S_{21} Imaginary Component

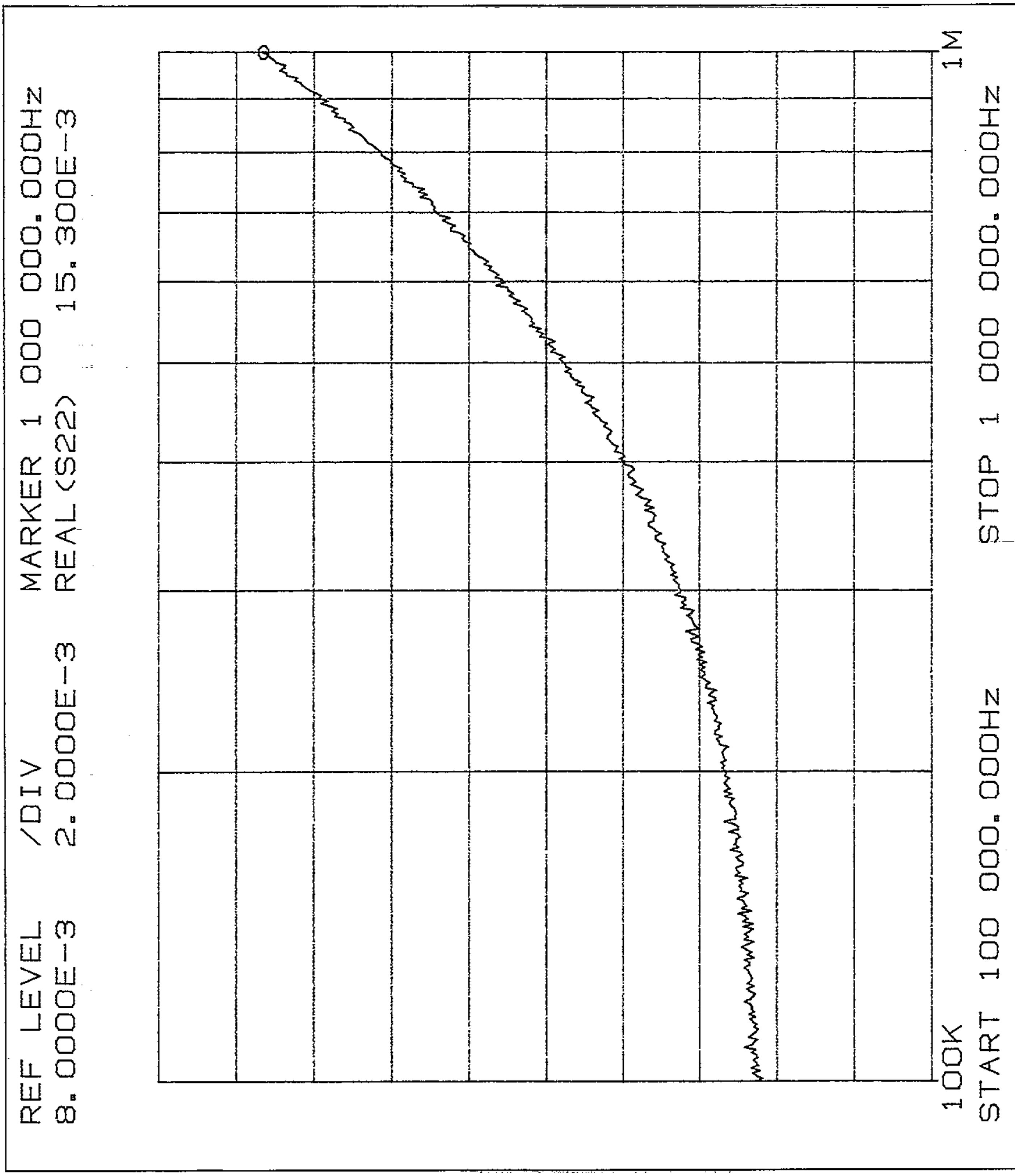


Figure 4-51. S_{22} Real Component

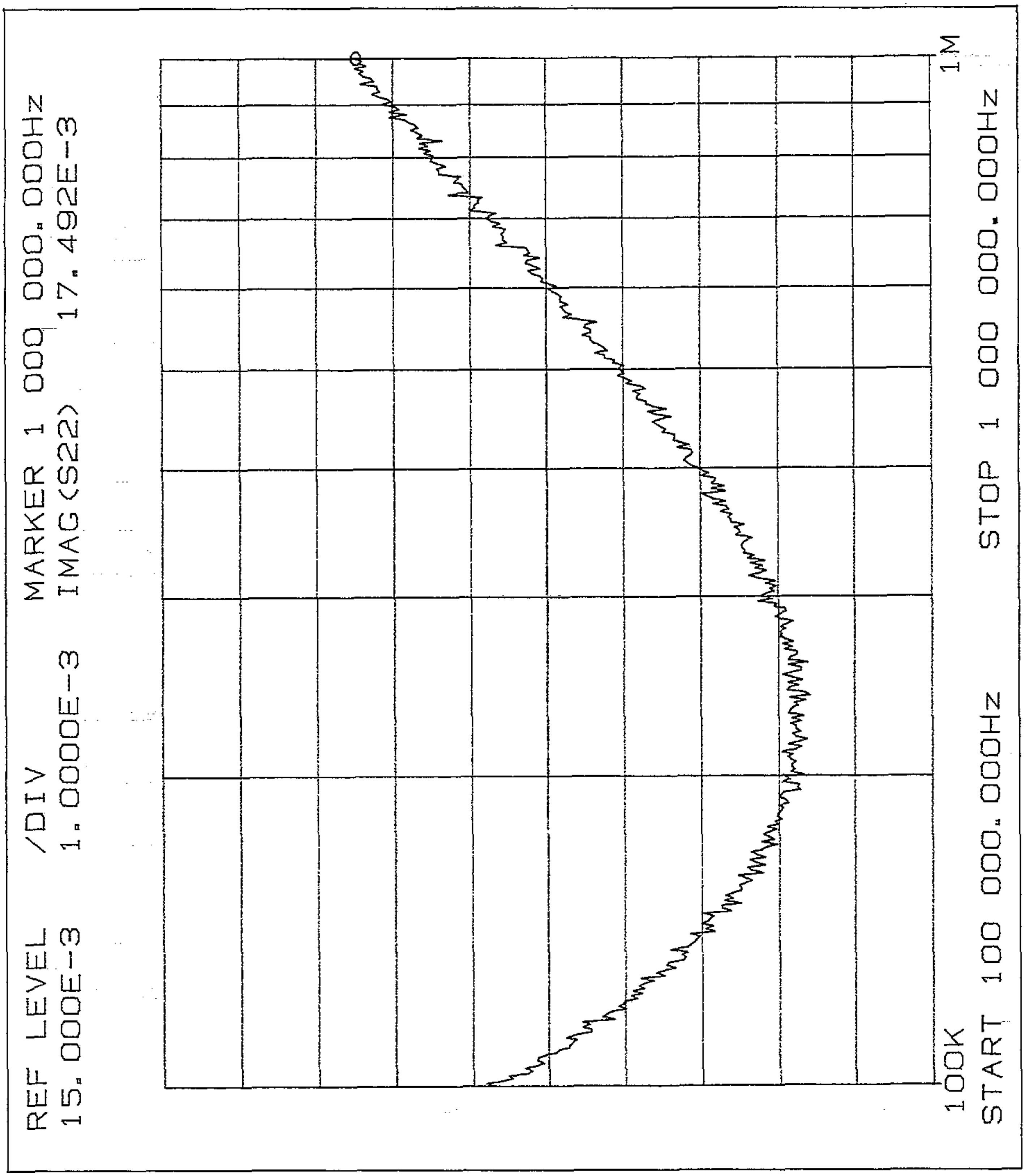


Figure 4-52. S_{22} Imaginary Component

4.11.3 Calibration Capacitor Correction

Description

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

NOTE

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

Recommended Sources

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

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

Table 4-23. Capacitance Sources Required for Cable Correction

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

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

Connections

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

Procedure

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

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

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

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

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

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

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

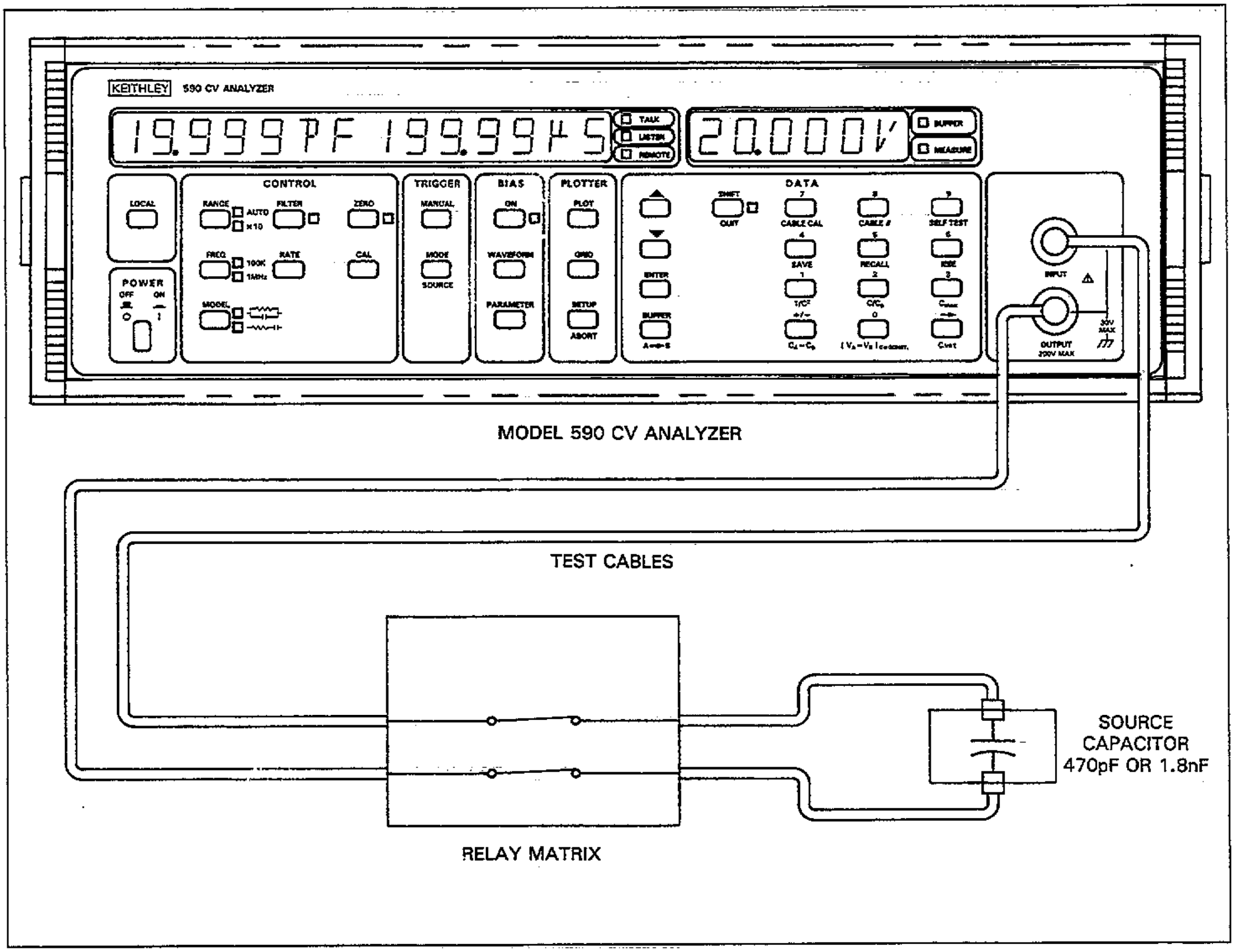


Figure 4-53. Connections for Calibration Capacitor Correction

4.11.4 Saving and Recalling Cable Setups

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

Saving Cable Setups

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

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

Recalling Cable Setups

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

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

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

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

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

NOTES:

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

4.11.5 Internal Correction Constants

Description

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

$$a + jb$$

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

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

Requesting Correction Constants

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

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

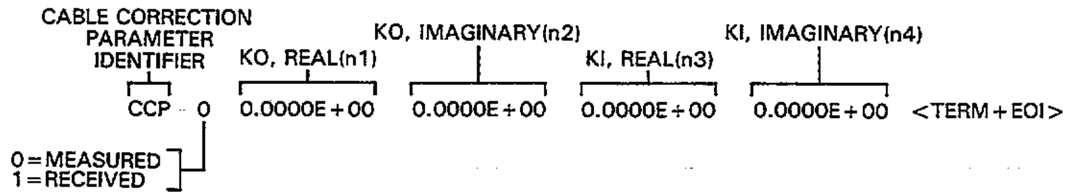
```
OUTPUT 715; ''U26X''
```

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

```
ENTER 715; A$
```

In this instance, the U26 status word, which contains the four cable correction parameters, would be placed in the A$ variable (A$ must be previously dimensioned, by the way, because the data string is longer than 18 characters).

4. The data string can be parsed and broken up into four discrete numeric variables, placed in computer memory, or placed on a mass storage medium, as desired. The example program on the next page demonstrates this process.



NOTES:
1. SPACES DELIMIT PARAMETERS
2. PROGRAMMED TERMINATOR AND EOI SENT AT END OF STRING.
3. MEASURED/RECEIVED BIT INDICATES WHETHER PARAMETERS WERE MEASURED (0) USING I0 OR I2-I5. OR PROGRAMMED (1) WITH I1.

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

Sending Correction Constants to the Instrument

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

I1,n1,n2,n3,n4

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

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

Programming Example

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

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

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

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

4.12 PROGRAMMING EXAMPLES

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

4.12.1 Programming for One-Point Measurements

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

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

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

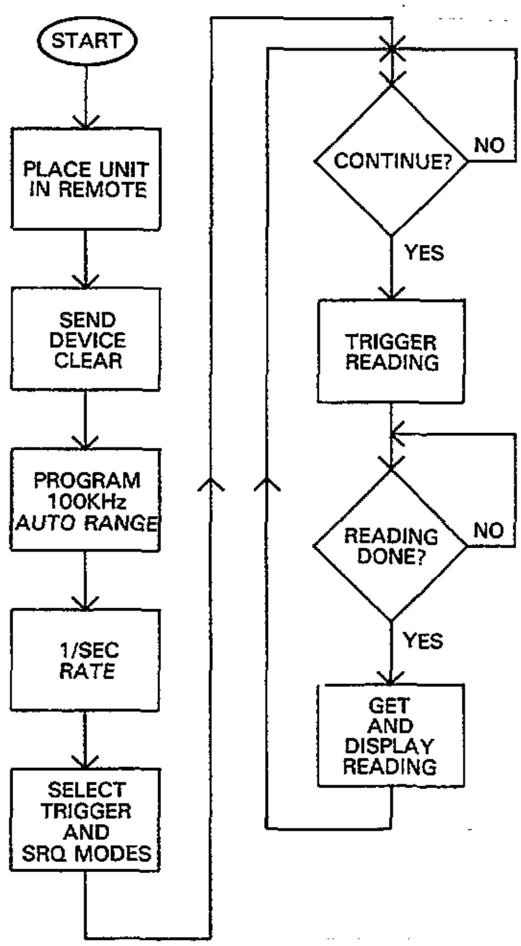


Figure 4-55. Flowchart of One-Point Program

4.12.2 CV Plotter Programming

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

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

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

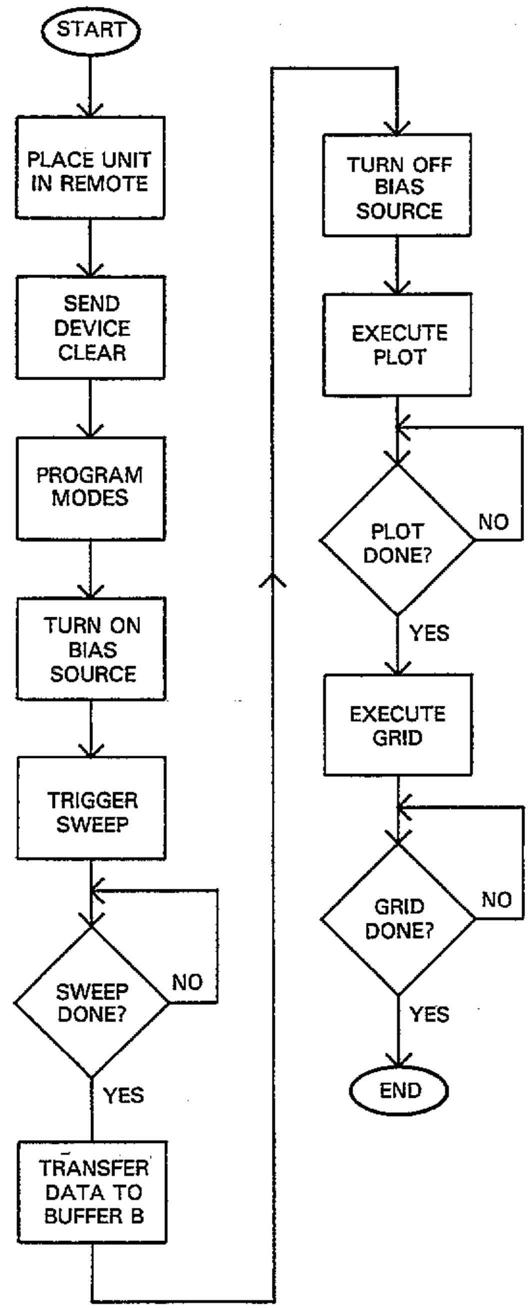


Figure 4-56. Flowchart of C vs V Plotting Example Program

4.12.3 C vs t Programming

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

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

Figure 4-57 shows a flowchart of the program.

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

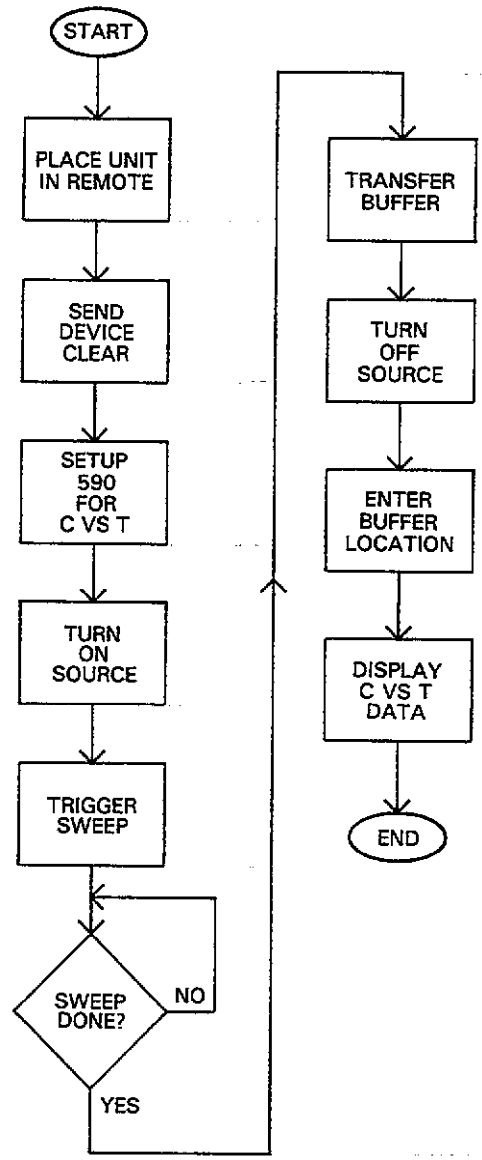


Figure 4-57. Flowchart of C vs t Program

4.12.4 Accessing Buffer Information

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

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

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

Program / **Comments**

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

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

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

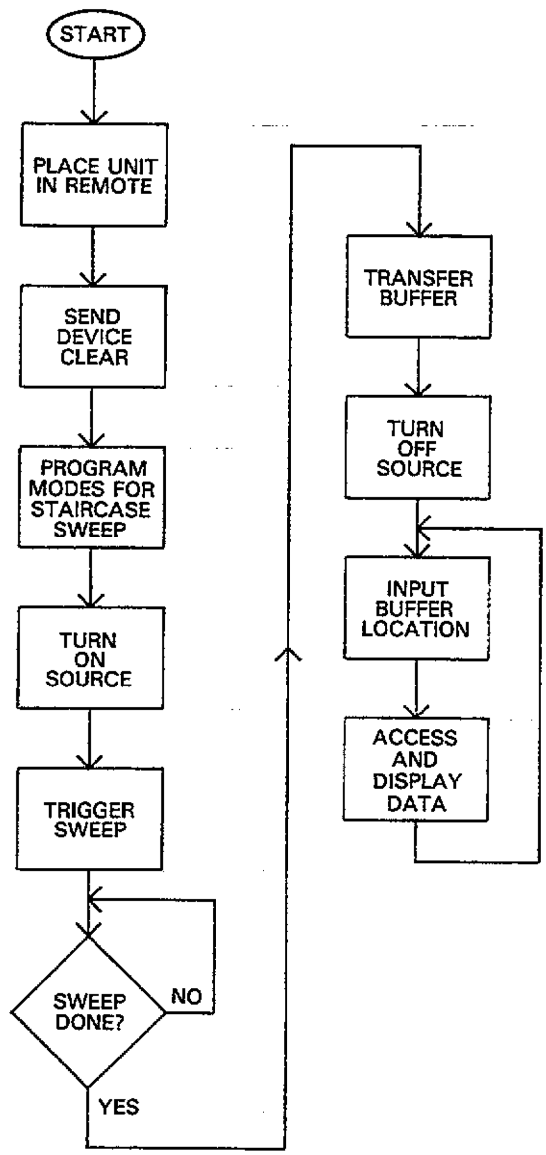


Figure 4-58. Flowchart of Buffer Program

4.12.5 Obtaining Complete Instrument Status

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

Figure 4-59 shows a program flowchart.

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

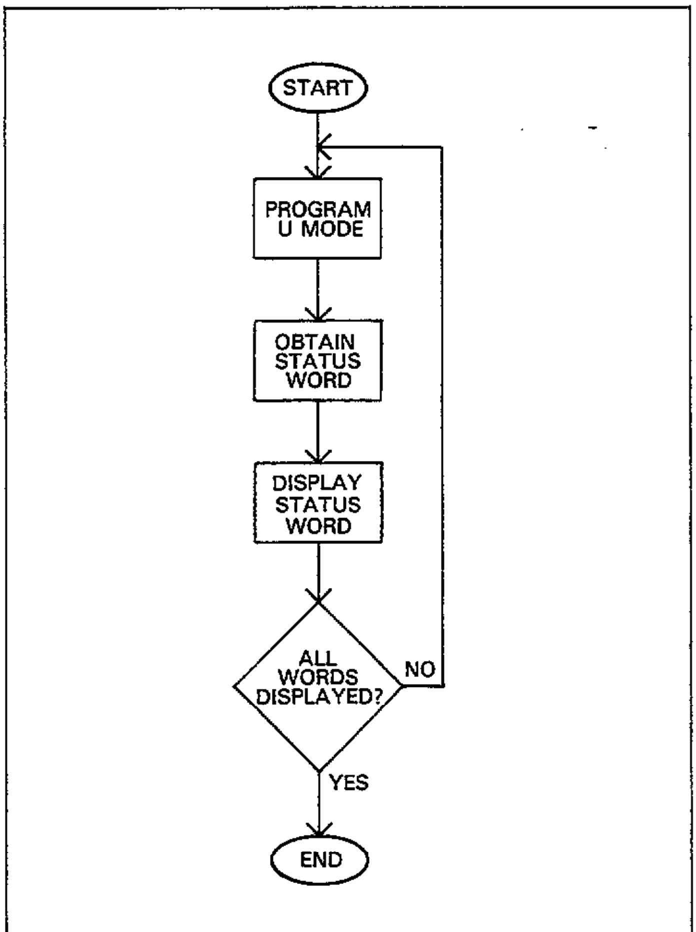


Figure 4-59. Flowchart of Status Word Program

4.12.6 Using the Translator

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

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

Figure 4-60 shows a programming flowchart.

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

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

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

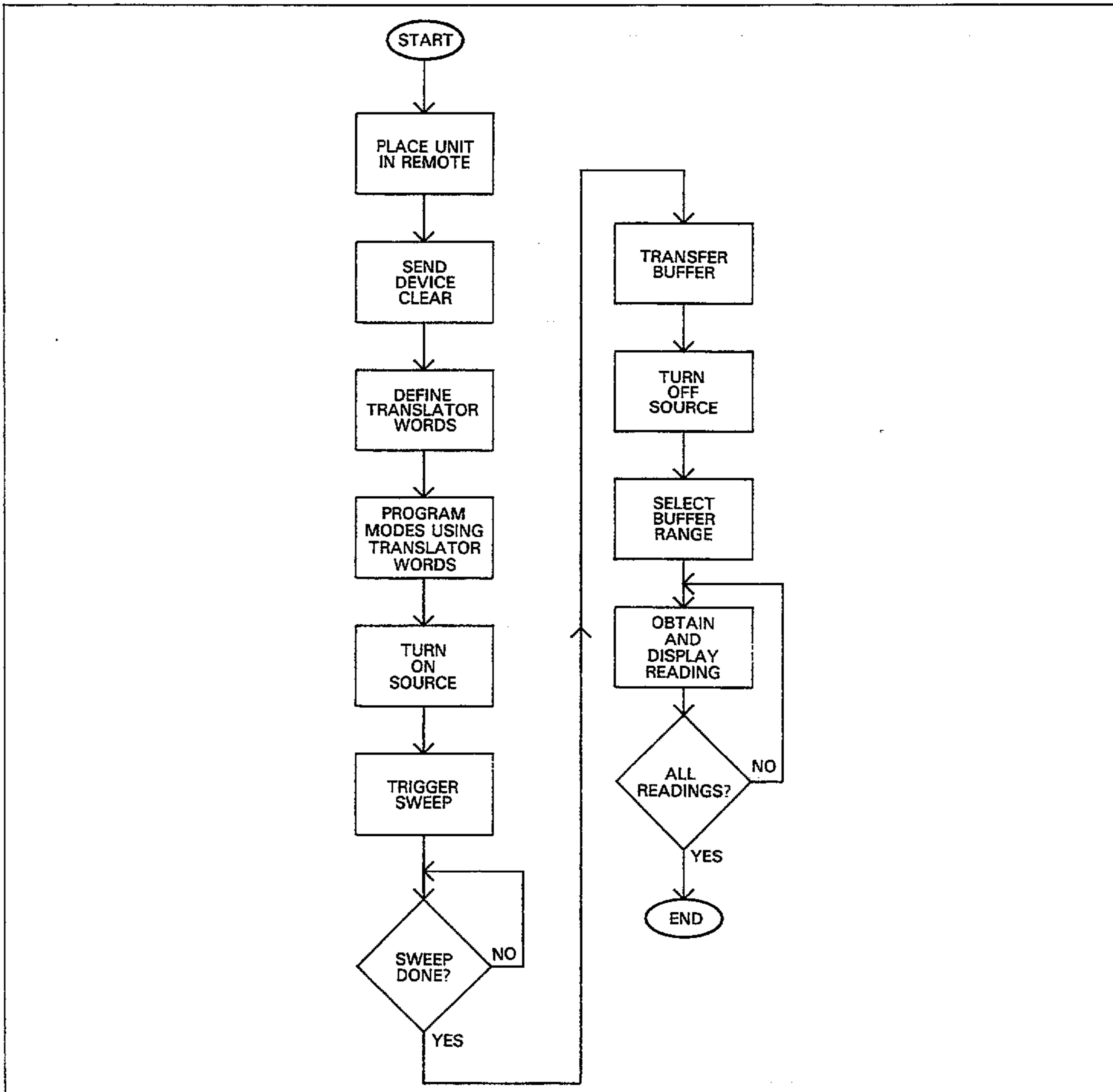


Figure 4-60. Translator Program Flow Chart

4.12.7 Using an External Bias Source

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

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

Instrument Connections

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

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

Programming Considerations

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

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

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

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

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

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

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

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

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

4.13 BUS TRANSMISSION TIMES

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

4.13.1 Factors Affecting Bus Times

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

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

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

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

4.13.2 Optimizing Measurement Speed

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

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

4.13.3 Programming Example

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

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

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

Program / **Comments**

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

SECTION 5
PERFORMANCE VERIFICATION

5.1 INTRODUCTION

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

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

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

Information in this section is arranged as follows:

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

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

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

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

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

5.2 ENVIRONMENTAL CONDITIONS

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

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

5.3 INITIAL CONDITIONS

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

5.4 RECOMMENDED TEST EQUIPMENT AND SOURCES

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

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

Table 5-1. Equipment and Sources Required for Verification

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

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

5.5 VERIFICATION LIMIT CALCULATIONS

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

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

5.5.1 Specification Format

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

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

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

5.5.2 Full Scale Accuracy

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

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

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

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

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

and,

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

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

5.5.3 Spillover Calculations

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

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

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

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

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

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

5.5.4 Conductance Specification Considerations

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

5.5.5 Analog Output Calculations

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

5.5.6 Absolute Values

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

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

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

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

5.6 VERIFICATION PROCEDURES

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

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

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

5.6.1 Front Panel Verification

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

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

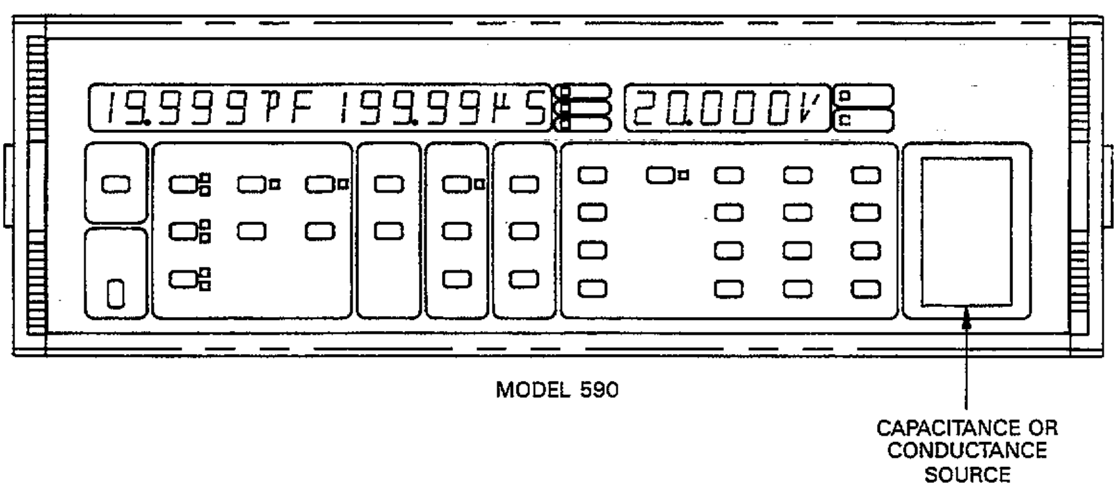


Figure 5-1. Mounting Source on Instrument

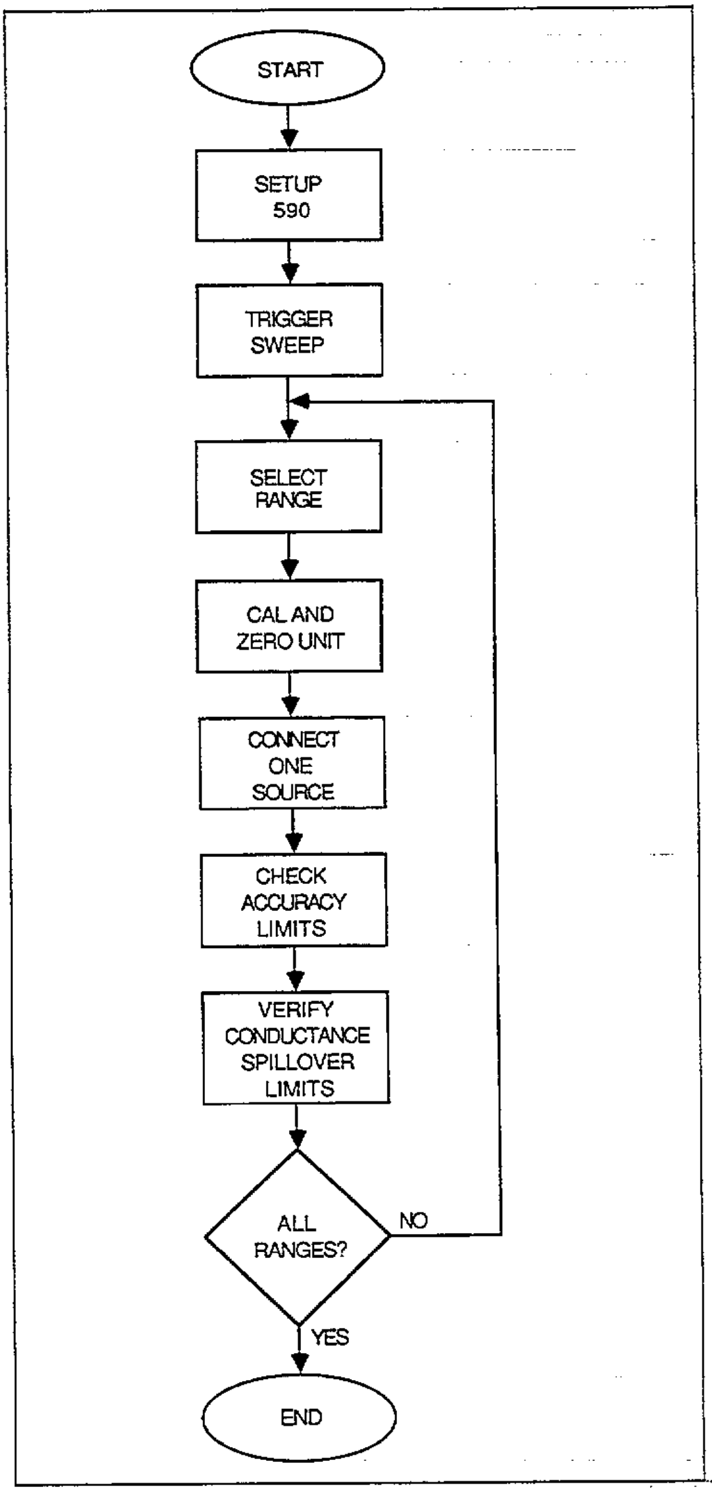


Figure 5-2. General Flowchart of Instrument Verification

100kHz Capacitance Verification

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

Table 5-3. Instrument 100kHz Capacitance Verification

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

*Calculated as follows:

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

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

**Calculated as follows:

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

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

†This range applicable only to Model 5904 Input Adapter.

NOTE: Use absolute C and G values.

100kHz Conductance Verification

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

Table 5-4. Instrument 100kHz Conductance Verification

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

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

1MHz Capacitance Verification

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

1MHz Conductance Verification

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

Table 5-5. Instrument 1MHz Capacitance Verification

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

*Calculated as follows:

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

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

**Calculated as follows:

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

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

NOTE: Use absolute C and G values.

Table 5-6. Instrument 1MHz Conductance Verification

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

*Using Keithley Model 5905 or 5906 sources.

5.6.2 Analog Output Verification

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

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

100kHz Capacitance Verification

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

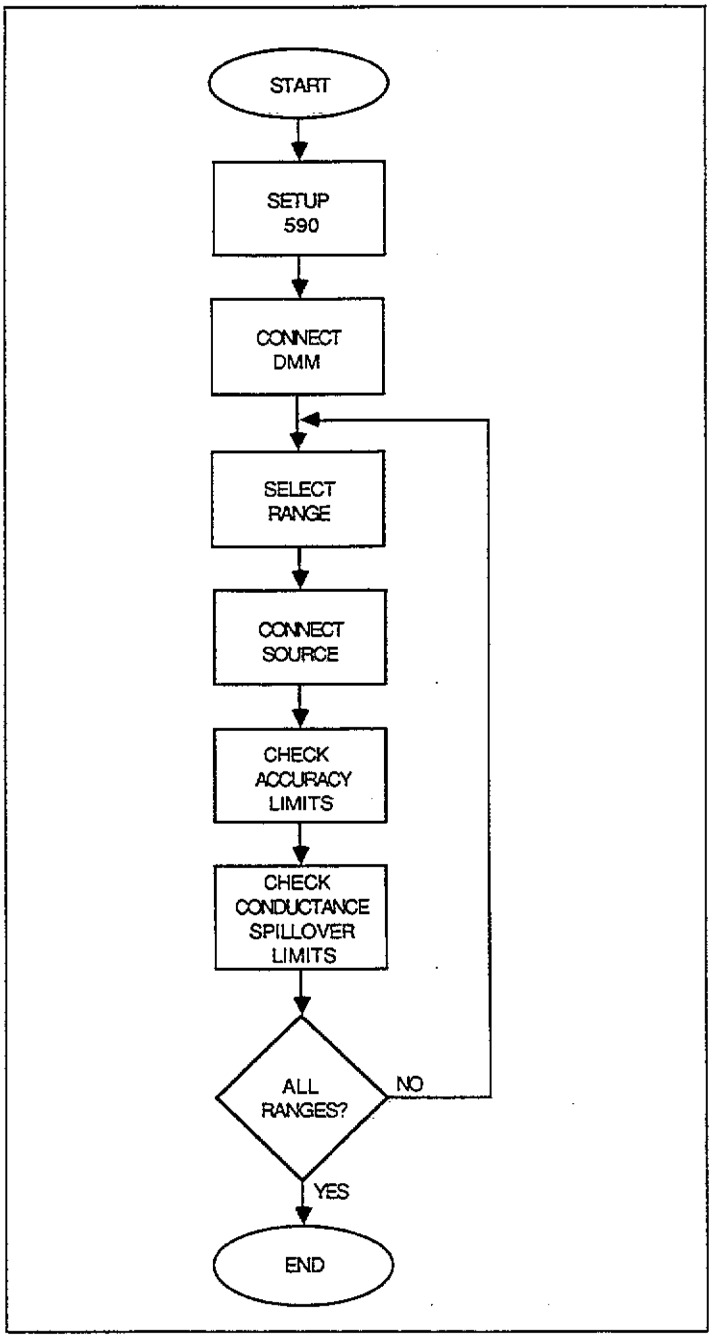


Figure 5-3. General Flowchart of Analog Output Verification

Table 5-7. Analog Output 100kHz Capacitance Verification

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

*Calculated as follows:

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

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

**Calculated as follows:

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

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

†This range applicable only to Model 5904 Input Adapter.

NOTE: Use absolute values for C and G readings.

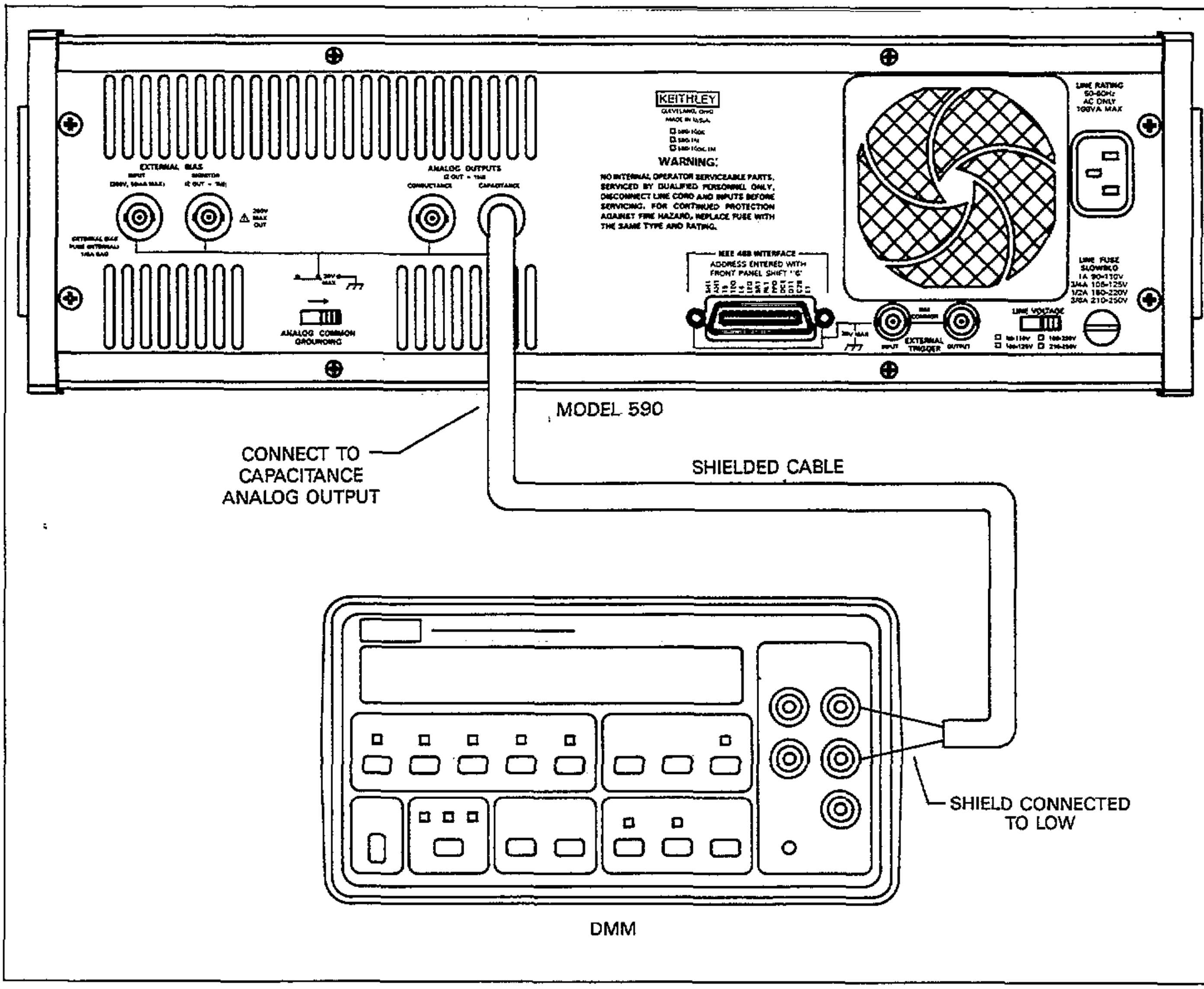


Figure 5-4. Connecting for Analog Output Capacitance Verification

100kHz Conductance Verification

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

1MHz Capacitance Verification

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

Table 5-8. Analog Output 100kHz Conductance Verification

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

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

1MHz Conductance Verification

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

Table 5-9. Analog Output 1MHz Capacitance Verification

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

*Calculated as follows:

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

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

**Calculated as follows:

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

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

NOTE: Use absolute values for C and G readings.

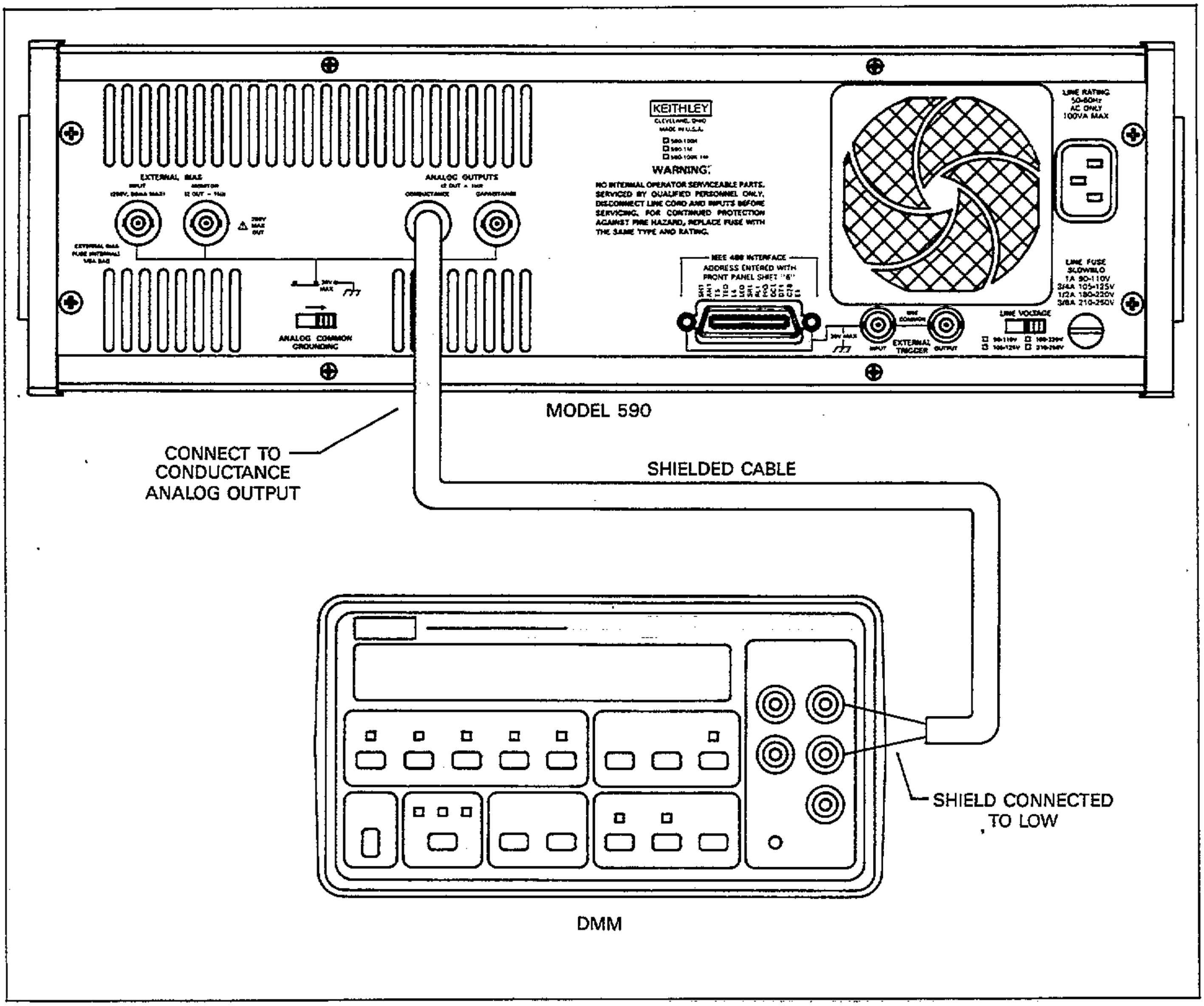


Figure 5-5. Connections for Analog Output Conductance Verification

Table 5-10. Analog Output 1MHz Conductance Verification

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

*Using Keithley Model 5905 or 5906 sources.

5.6.3 Complete Model 5904 Verification

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

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

5.6.4 Voltage Verification

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

Internal Bias Source and 20V Range Read-Back Accuracy

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

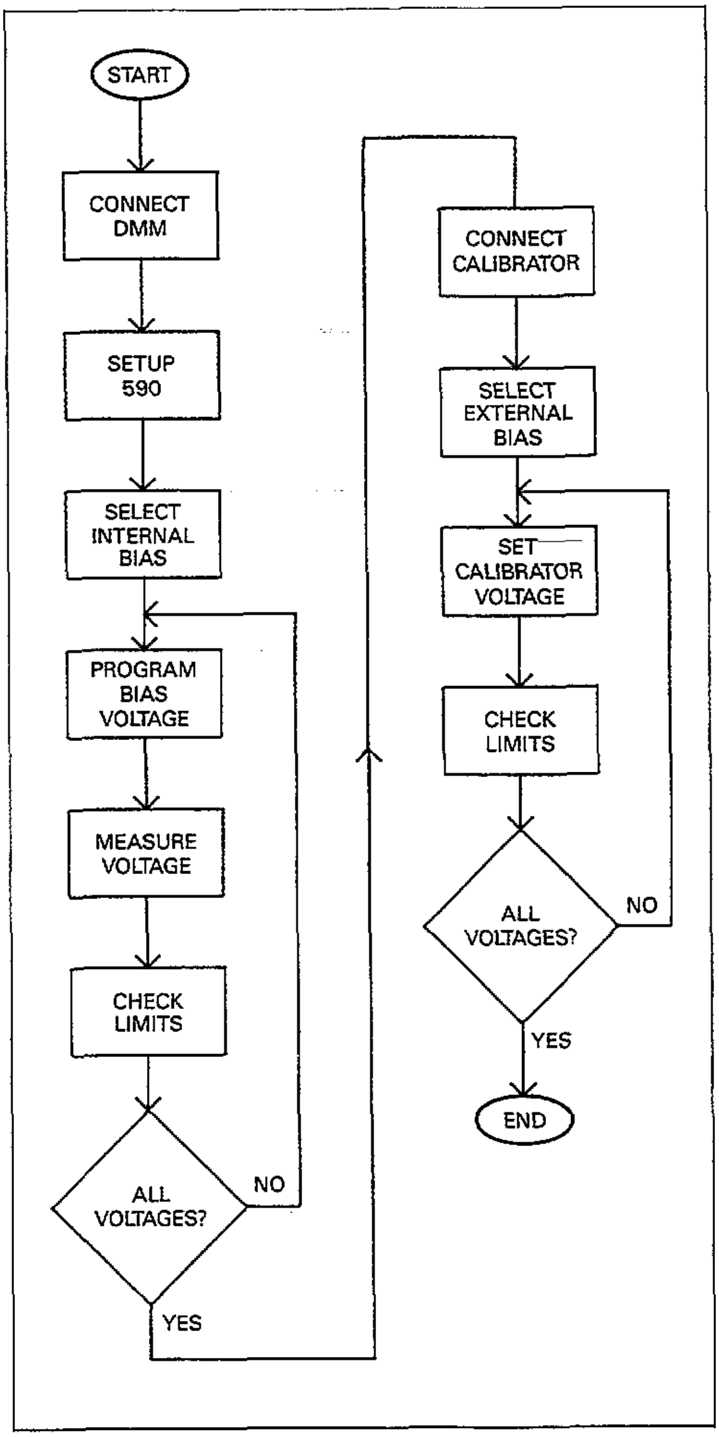


Figure 5-6. Voltage Verification Flowchart

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

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

*Calculated as follows:

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

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

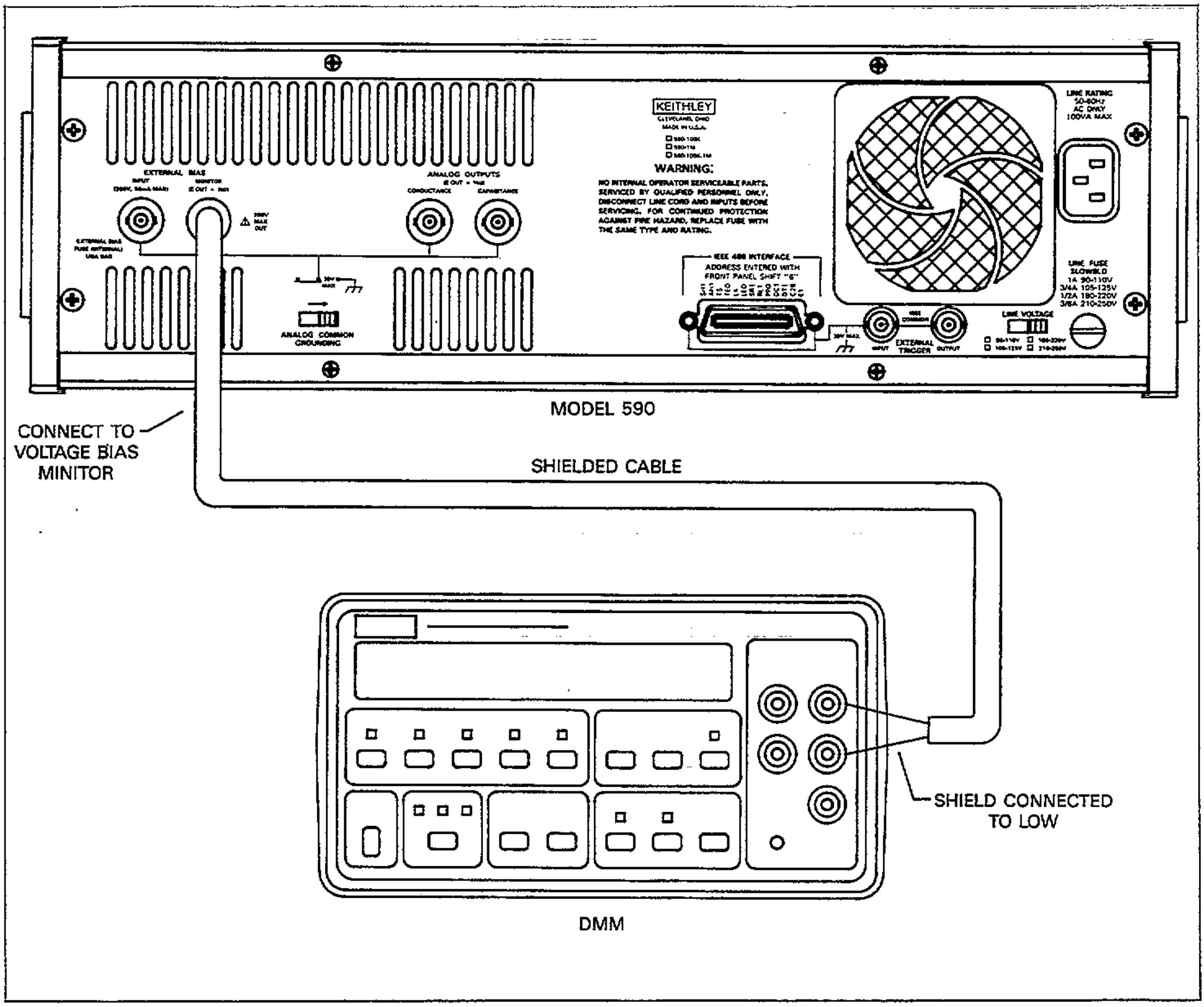


Figure 5-7. Connections for Voltage Verification

200V Range Read-Back Accuracy Check

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

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

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

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

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

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

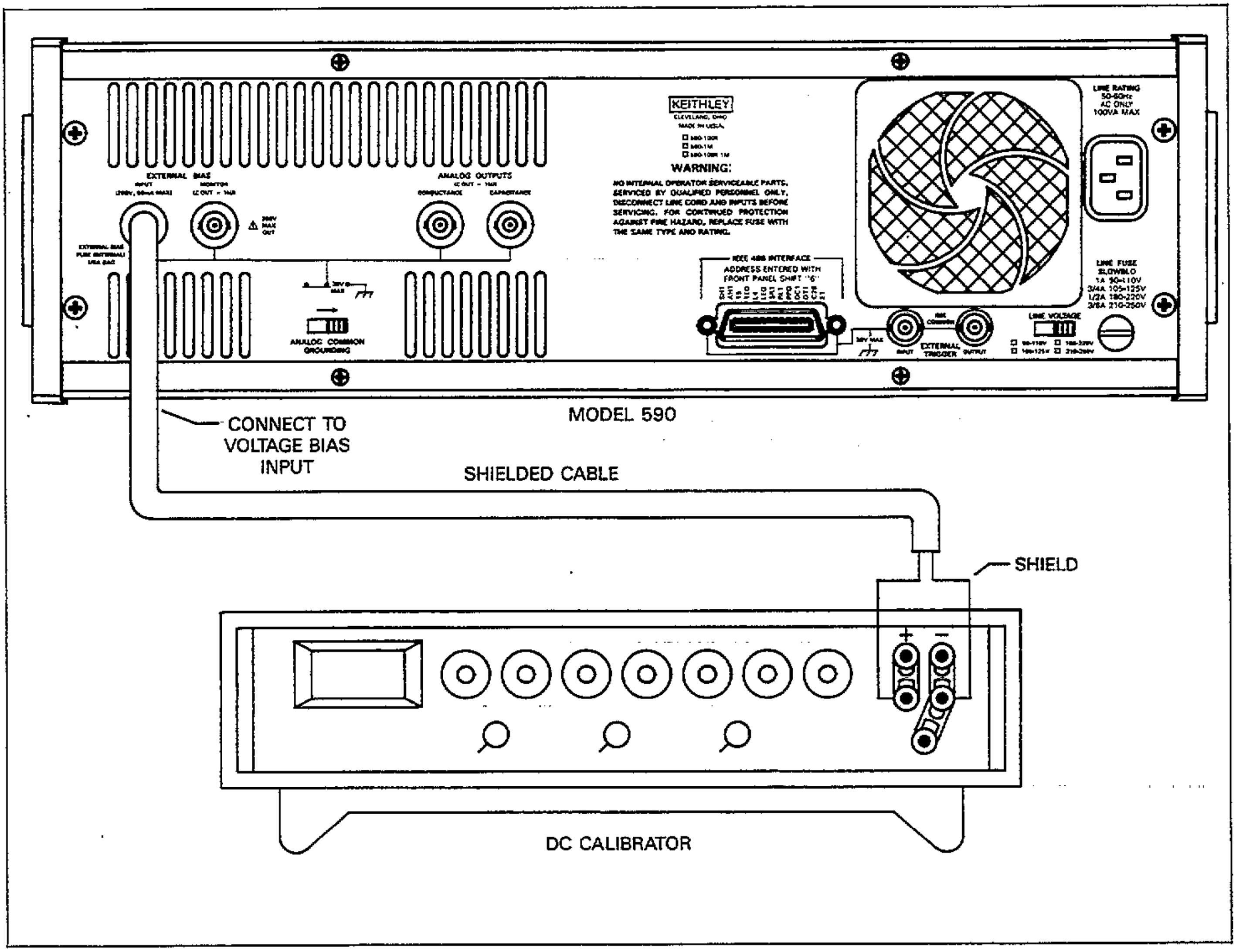


Figure 5-8. Connections for 200V Read-Back Verification

SECTION 6
PRINCIPLES OF OPERATION

6.1 INTRODUCTION

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

Section 6 is arranged as follows:

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

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

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

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

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

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

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

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

6.2 FUNCTIONAL DESCRIPTION

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

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

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

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

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

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

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

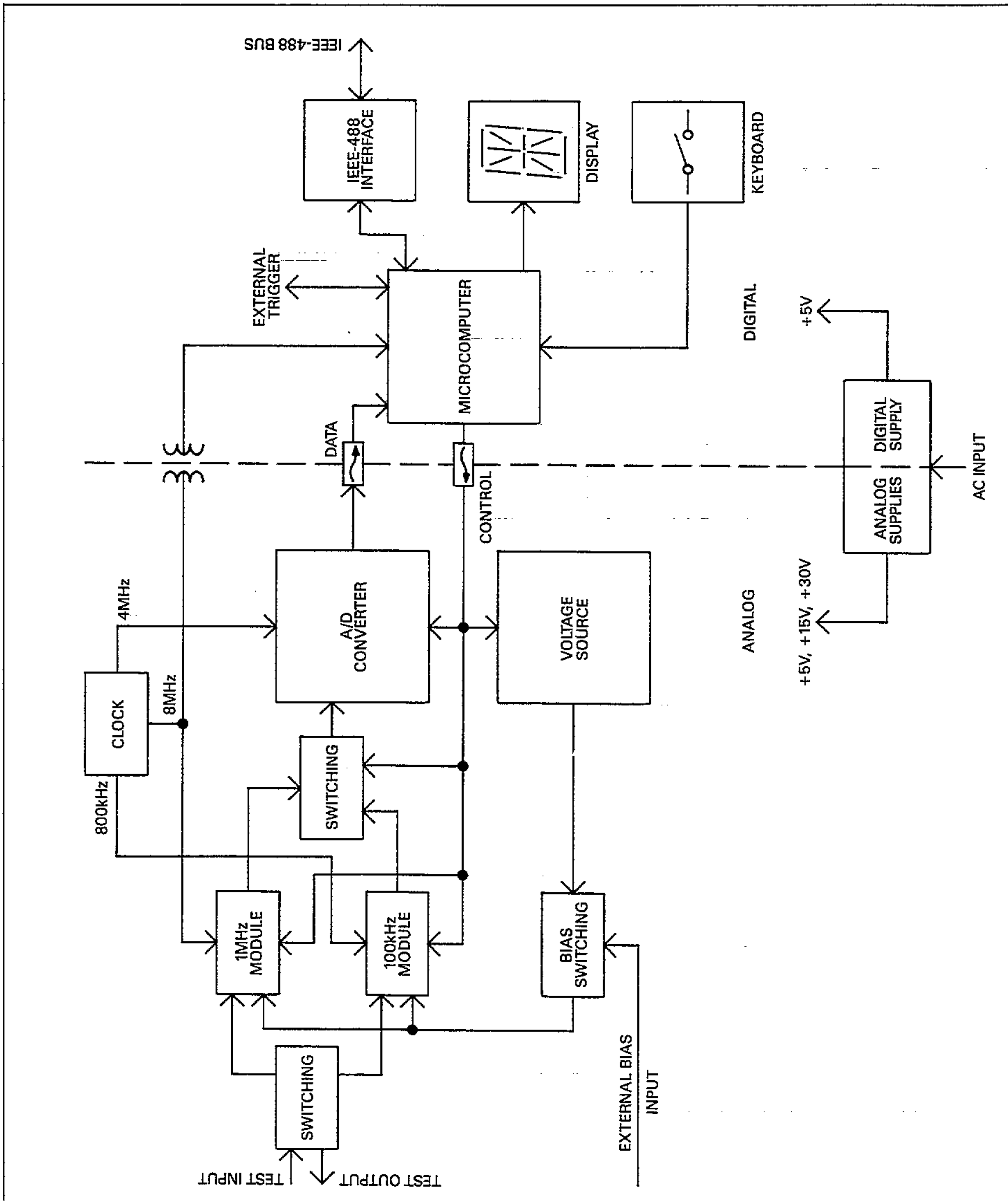


Figure 6-1. Block Diagram

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

6.3 DIGITAL CIRCUITRY

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

6.3.1 Microprocessor

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

Key 6809 signal lines include:

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

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

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

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

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

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

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

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

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

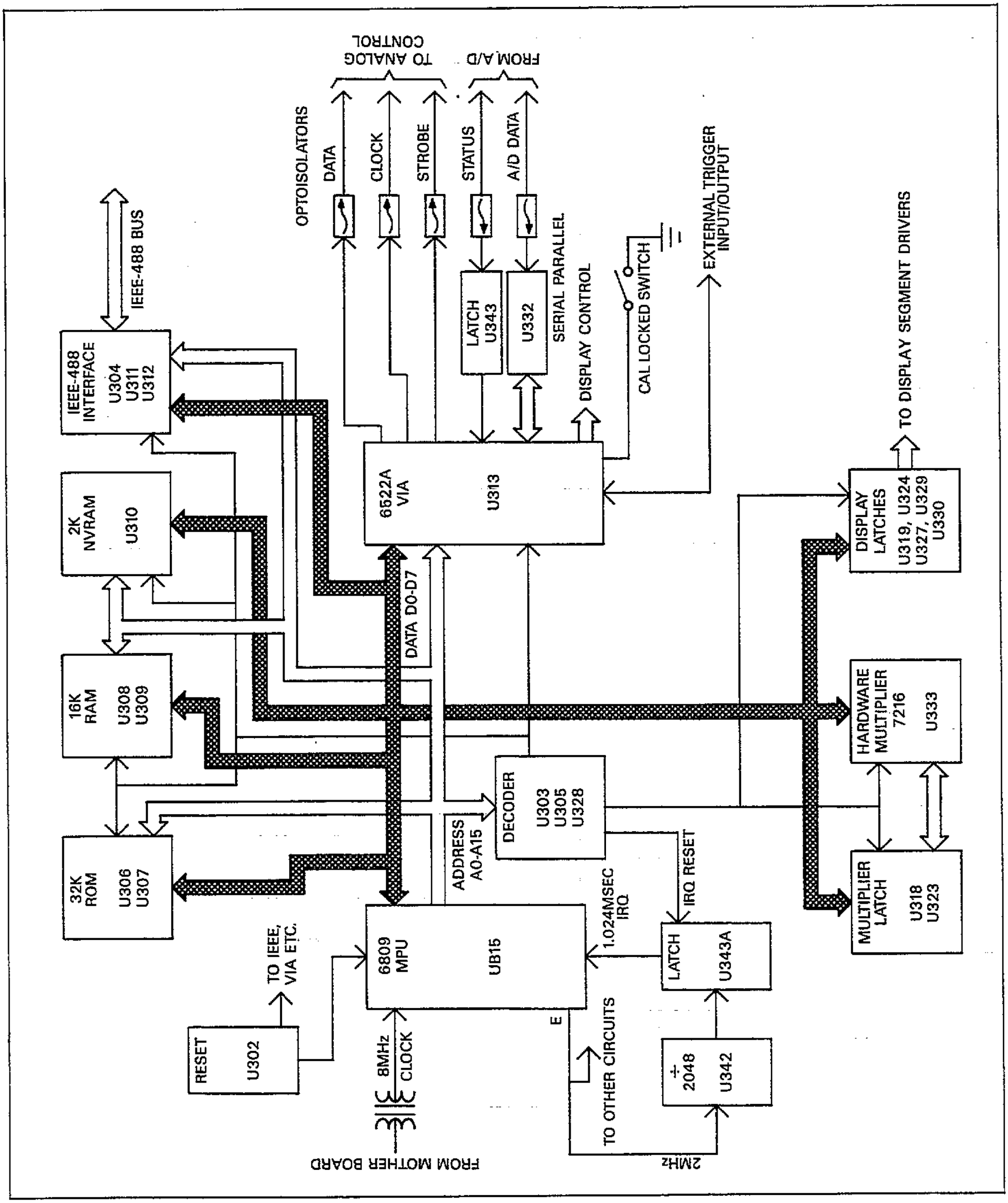


Figure 6-2. Digital Circuit Block Diagram

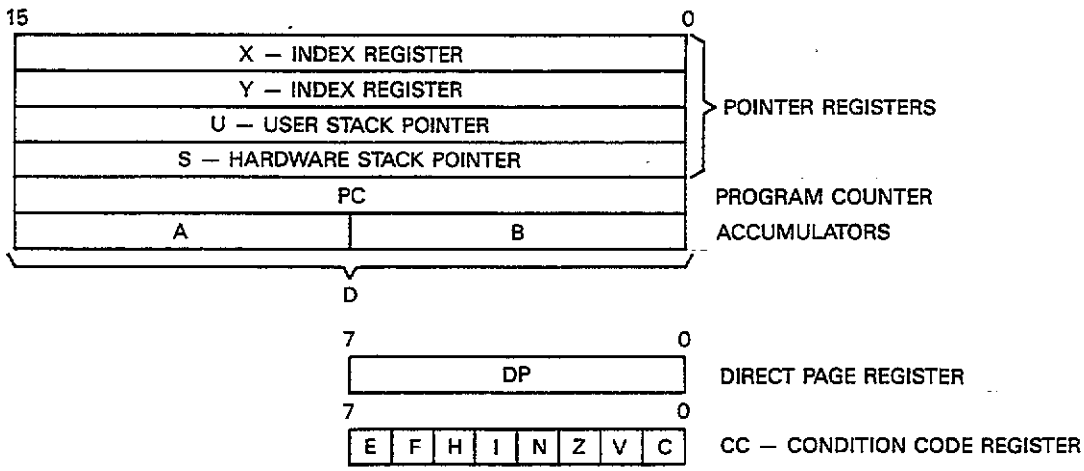


Figure 6-3. 6809 Microprocessor Programming Mode

6.3.2 Memory Circuits

ROM Memory

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

RAM Memory

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

NVRAM

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

Address Decoding

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

Memory Mapping

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

Table 6-1. Memory Map

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

6.3.3 Hardware Multiplier

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

Multiplier IC Connections

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

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

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

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

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

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

Multiplier/MPU Interfacing

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

Typical Calculation Sequence

A typical multiplication sequence is as follows:

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

6.3.4 Input/Output

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

The input/output functions performed by U313 include:

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

6.3.5 IEEE-488 Interface

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

MPU Interfacing

Terminals on the MPU side of the GPIA include:

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

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

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

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

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

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

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

Bus Interfacing

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

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

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

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

6.3.6 Data Segment Latches and Drivers

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

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

6.4 ANALOG CIRCUITRY

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

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

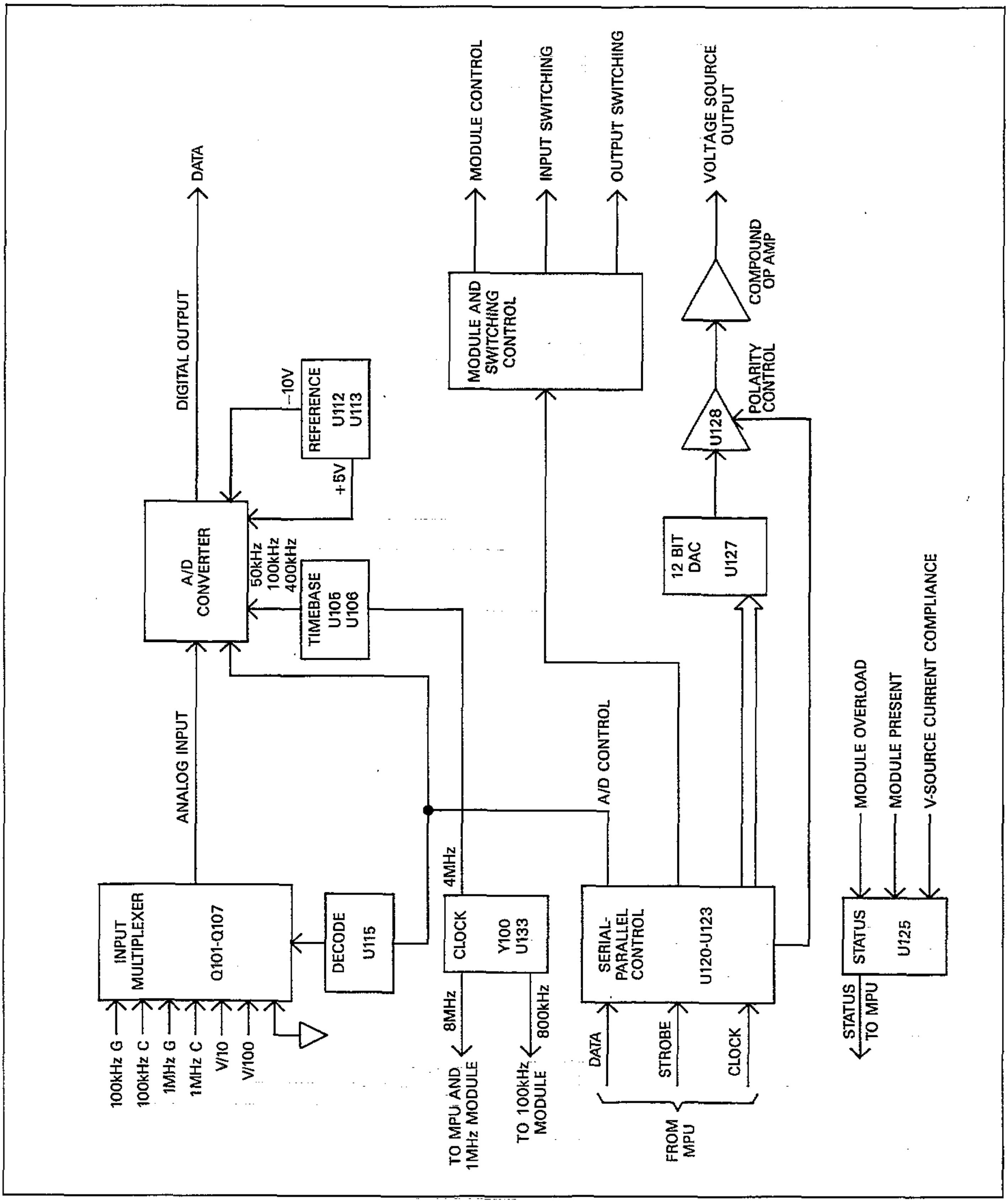


Figure 6-4. Analog Circuitry Block Diagram

6.4.1 Clock Signals

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

6.4.2 Serial Control

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

Control Bit Configuration

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

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

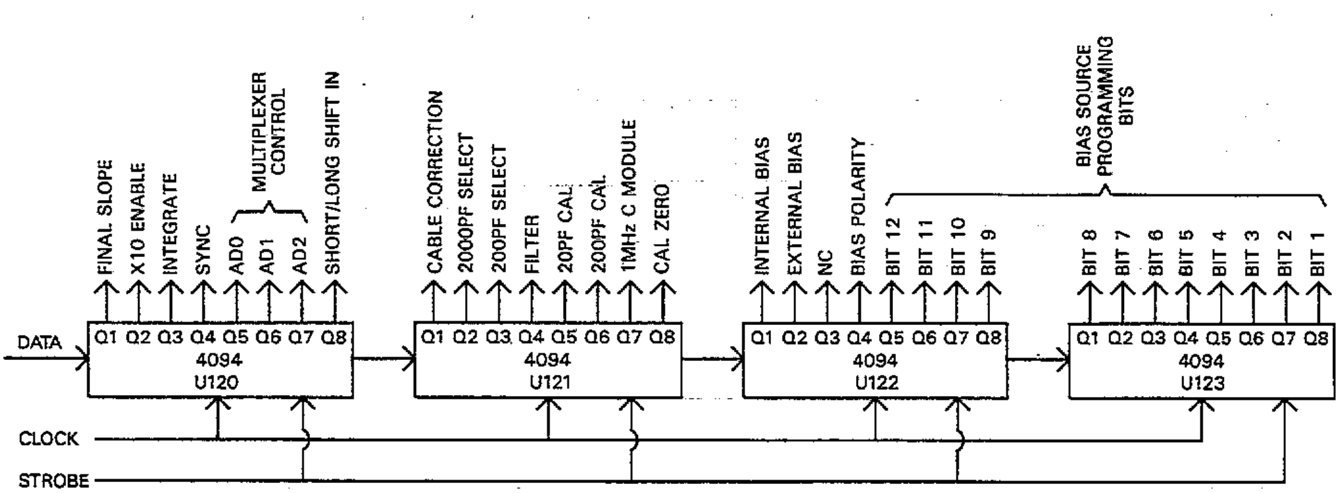


Figure 6-5. Serial Control Bit Format

Relay Drive and Relays

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

Table 6-2. Relay Functions

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

Power-on Safeguard

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

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

6.4.3 Status Circuits

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

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

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

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

6.4.4 Input Multiplexer

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

Multiplexer Control

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

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

Table 6-3. Multiplexer Control Signals

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

Multiplexer Operation

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

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

Meausurement Phases

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

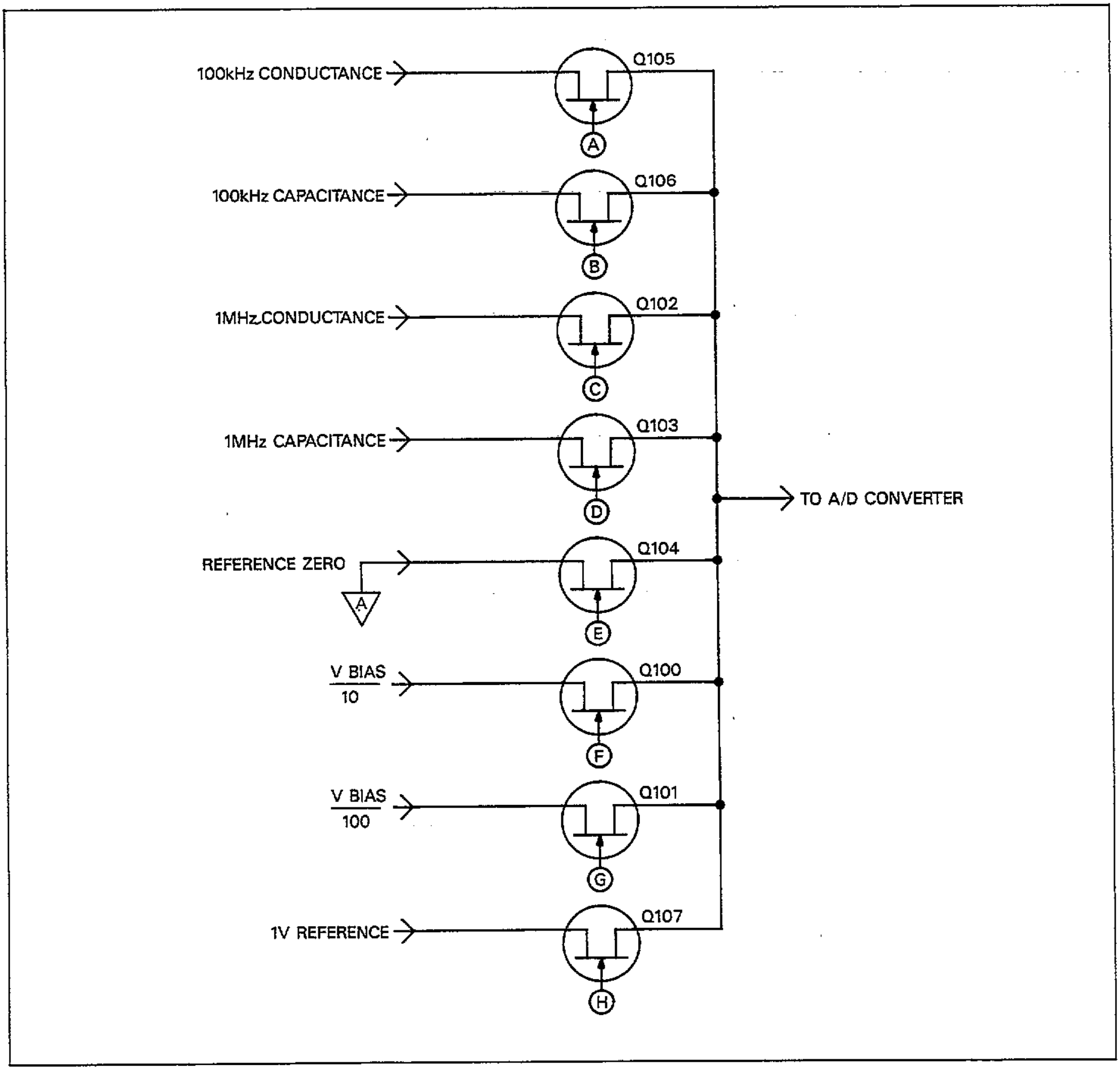


Figure 6-6. Simplified Schematic of Input Multiplexer

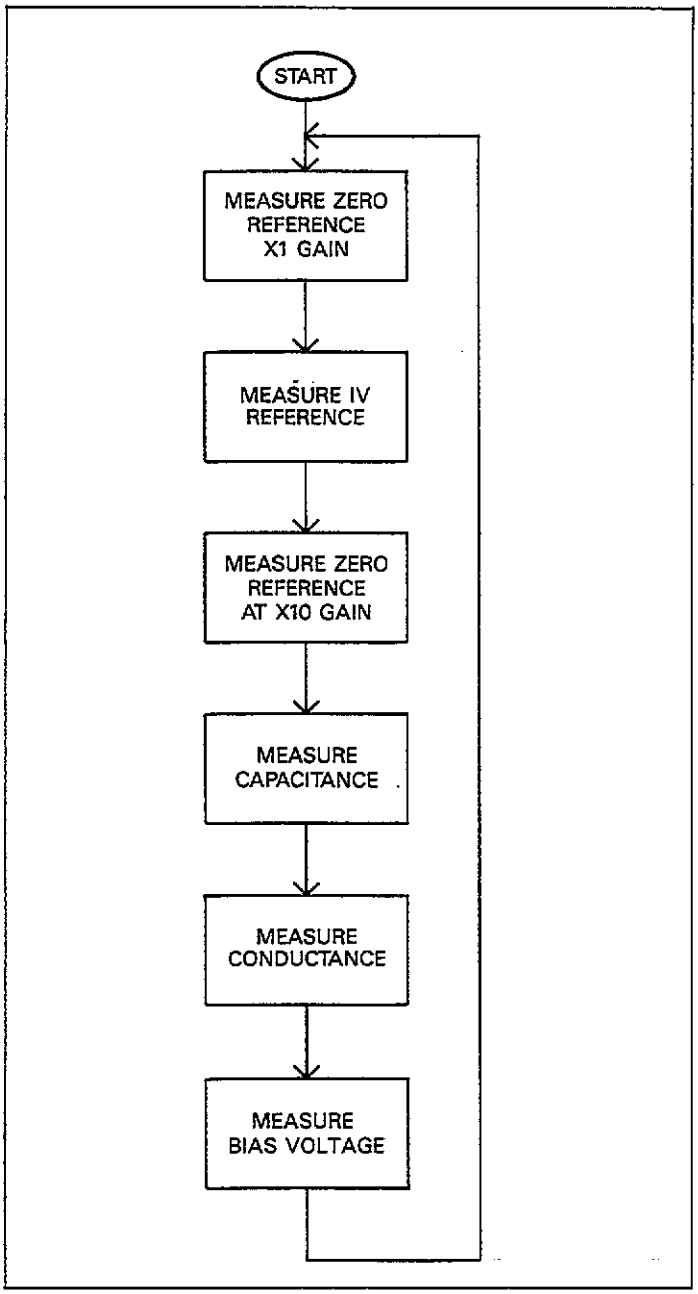


Figure 6-7. Measurement Phase

6.4.5 A/D Converter

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

Time Base Circuits

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

Reference Voltages

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

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

X1/X10 Gain Amplifier

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

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

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

A/D Converter Operation

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

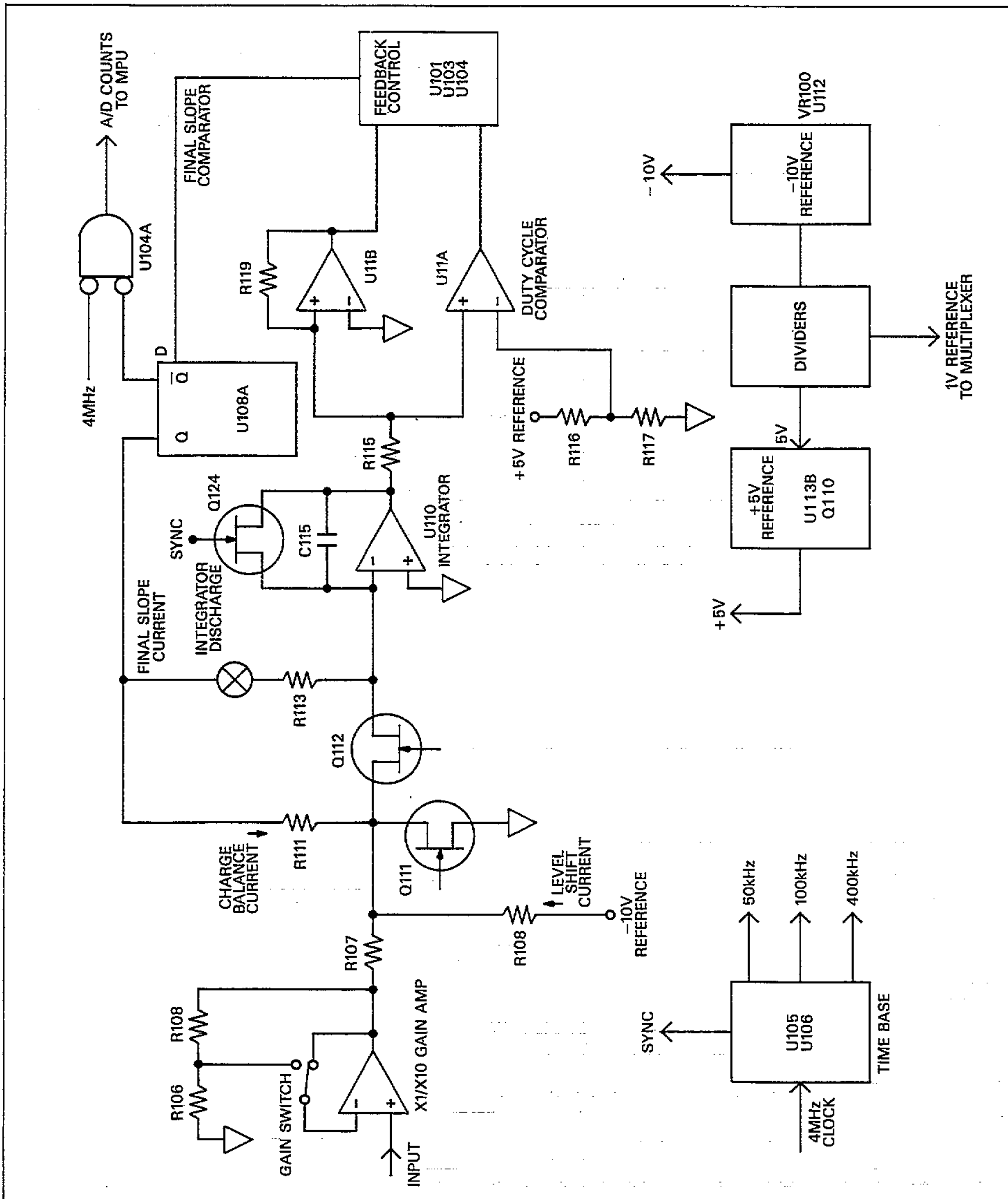


Figure 6-8. Simplified Schematic of A/D Converter

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

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

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

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

6.4.6 Voltage Source

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

Digital-to-Analog Converter

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

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

Polarity Switching

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

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

Output Stage

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

A = −R162/161
A = −20k/9.76k
A = −2.049

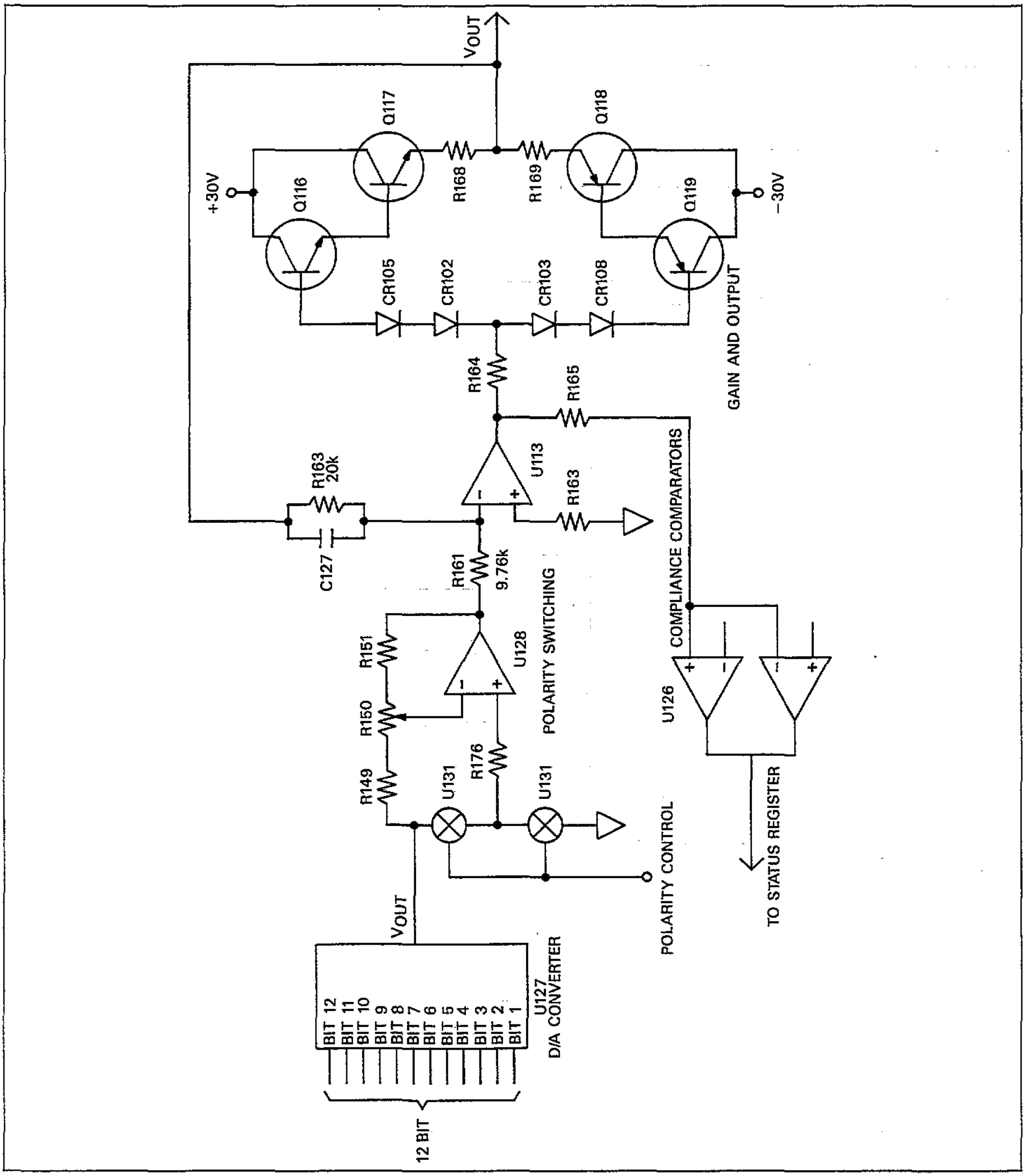


Figure 6-9. Simplified Schematic of Voltage Source

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

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

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

Compliance Detection

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

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

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

6.5 100kHz CAPACITANCE MODULE

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

6.5.1 Circuit Overview

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

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

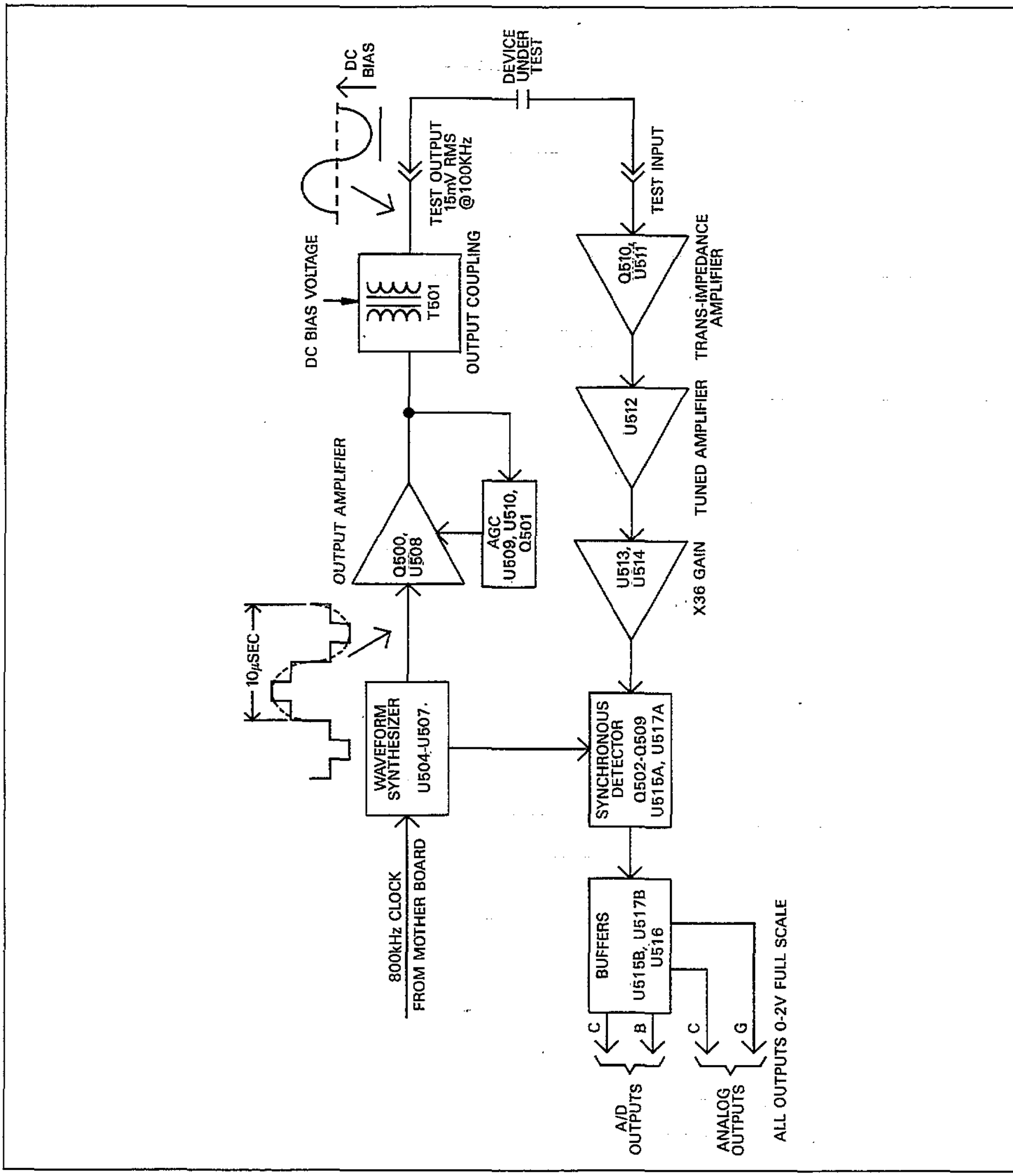


Figure 6-10. Block Diagram of 100kHz Capacitance Module

6.5.2 Waveform Synthesizer

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

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

6.5.3 Output Amplifier

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

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

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

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

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

6.5.4 Automatic Gain Control

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

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

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

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

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

6.5.5 Input Amplifiers

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

Trans-impedance Amplifier

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

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

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

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

Tuned Stage Amplifier

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

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

X36 Amplifier

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

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

6.5.6 Synchronous Detector

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

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

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

6.5.7 Buffers

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

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

6.6 1MHz CAPACITANCE MODULE

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

6.6.1 Circuit Overview

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

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

6.6.2 Waveform Synthesizer

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

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

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

6.6.3 Output Amplifier

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

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

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

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

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

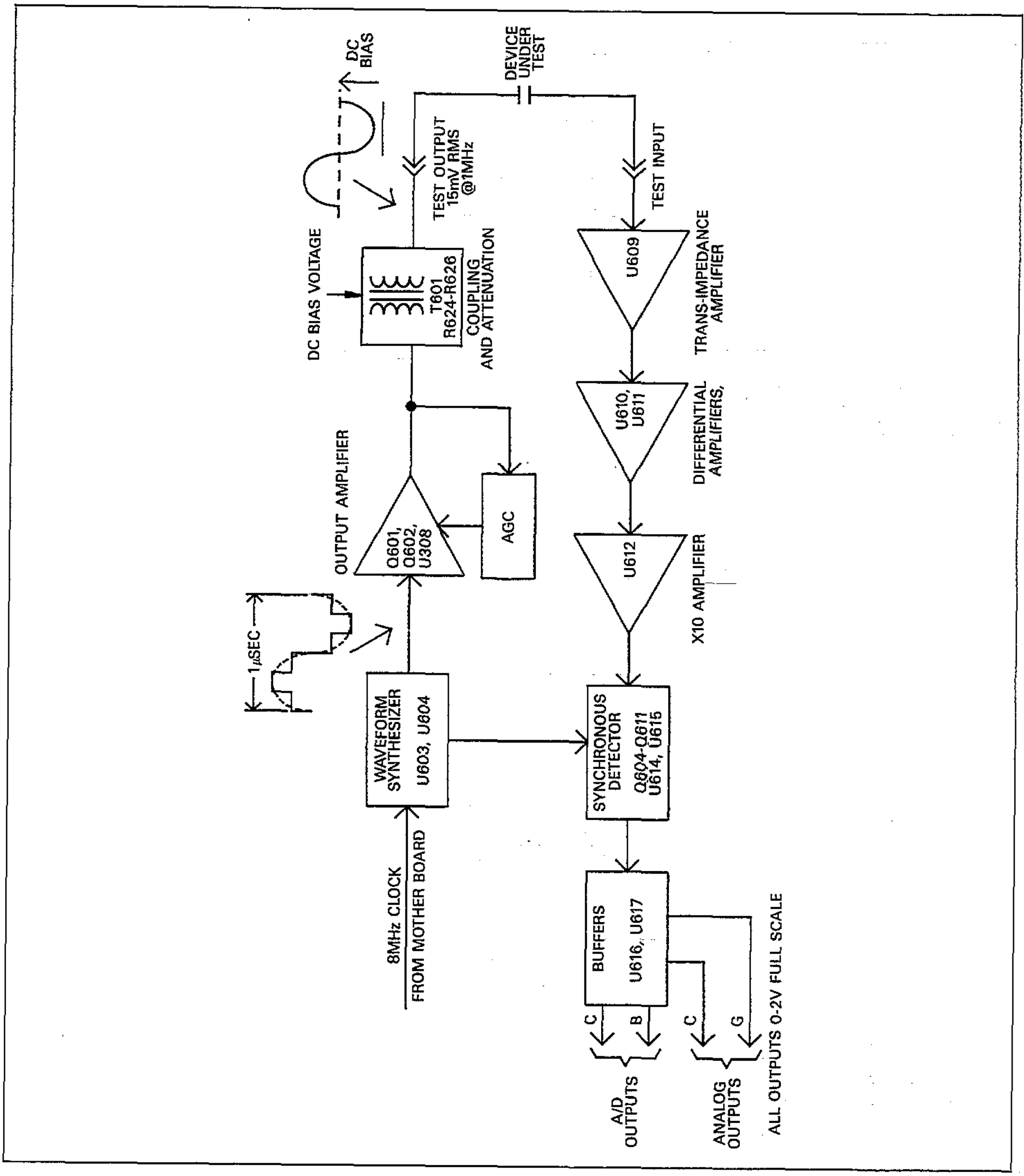


Figure 6-11. Block Diagram of 1MHz Capacitance Module

6.6.4 Automatic Gain Control

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

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

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

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

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

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

6.6.5 Input Amplifiers

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

Trans-impedance Amplifier

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

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

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

Differential Amplifiers

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

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

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

X10 Amplifier

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

6.6.6 Synchronous Detector

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

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

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

6.6.7 Buffers

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

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

6.7 POWER SUPPLIES

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

6.7.1 AC Line Input

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

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

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

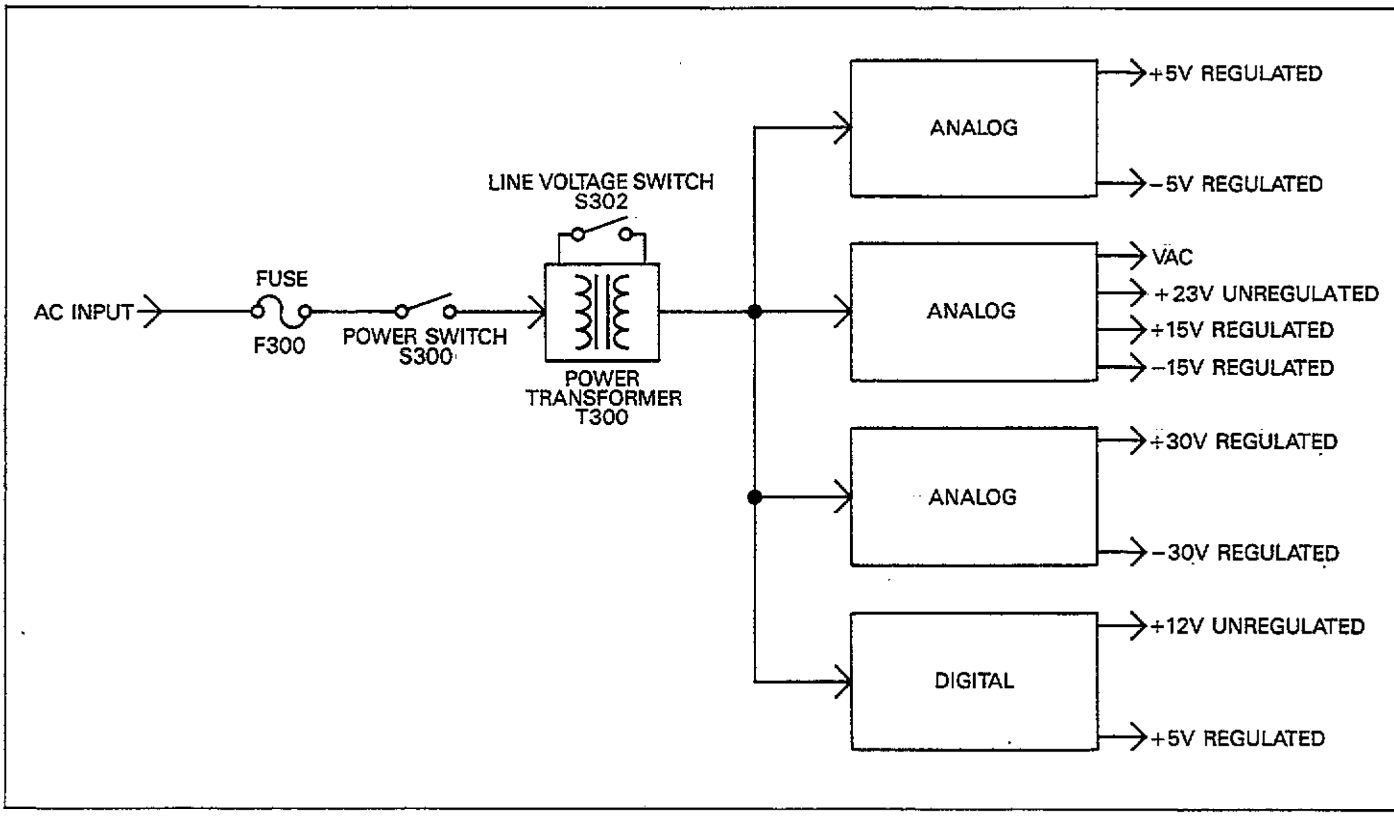


Figure 6-12. Block Diagram of Power Supply

6.7.2 Analog Supplies

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

±5V Supplies

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

±15V Supplies

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

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

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

±30V Supplies

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

6.7.3 Digital Supplies

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

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

6.8 DISPLAY AND KEYBOARD CIRCUITS

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

6.8.1 Display

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

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

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

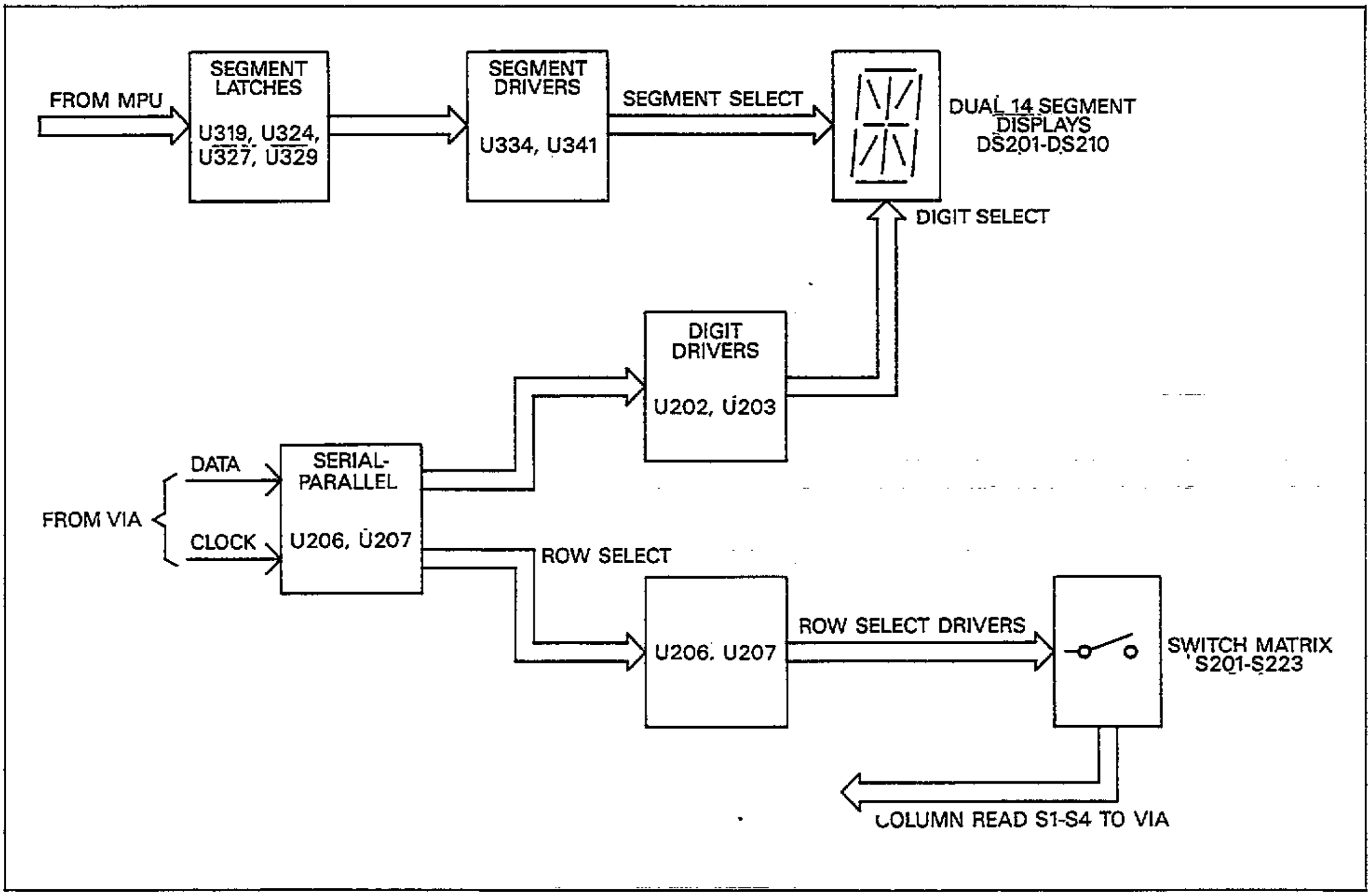


Figure 6-13. Block Diagram of Display and Keyboard

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

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

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

6.8.2 Keyboard

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

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

6.9 CABLE CORRECTION PRINCIPLES

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

6.9.1 Error Models

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

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

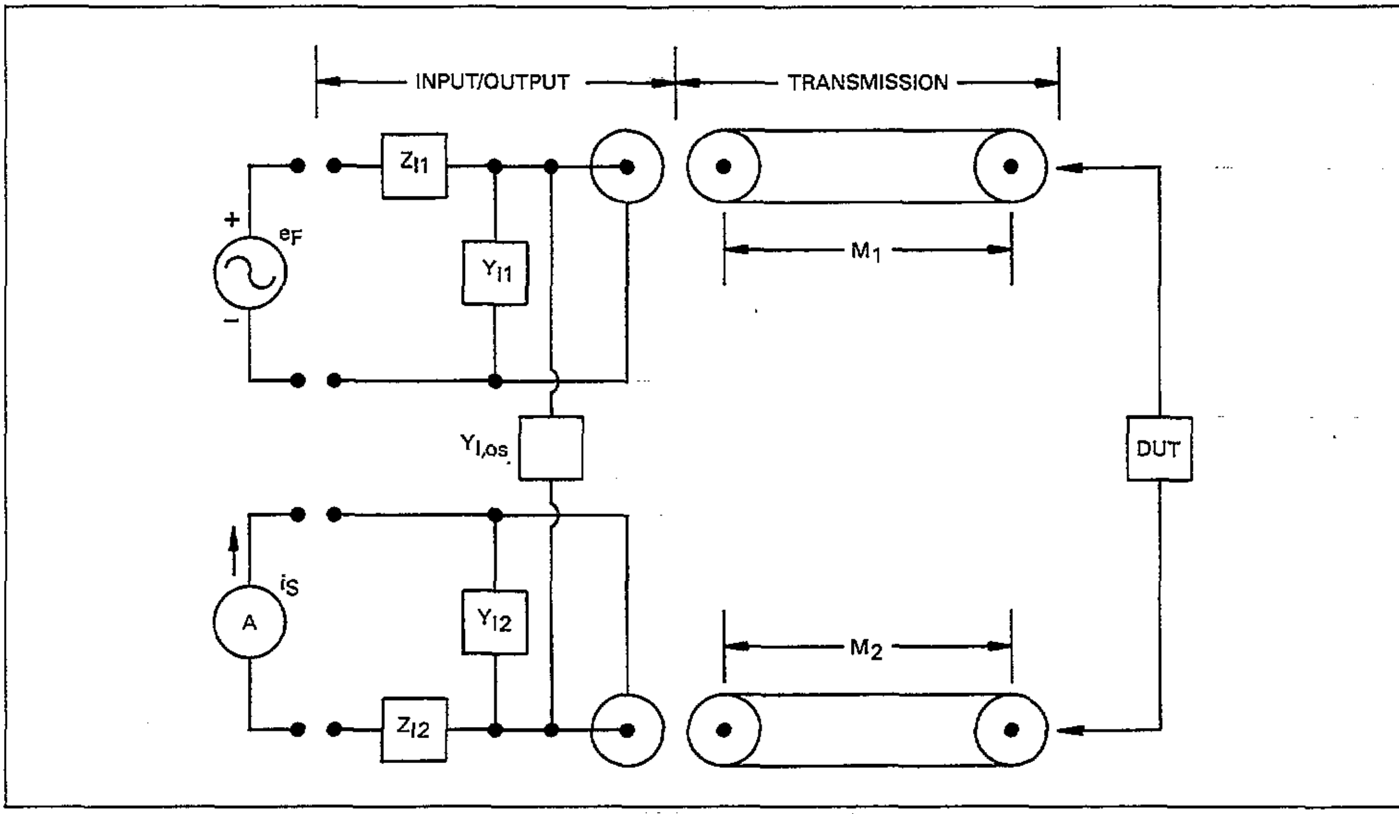


Figure 6-14. Transmission Path Error Model

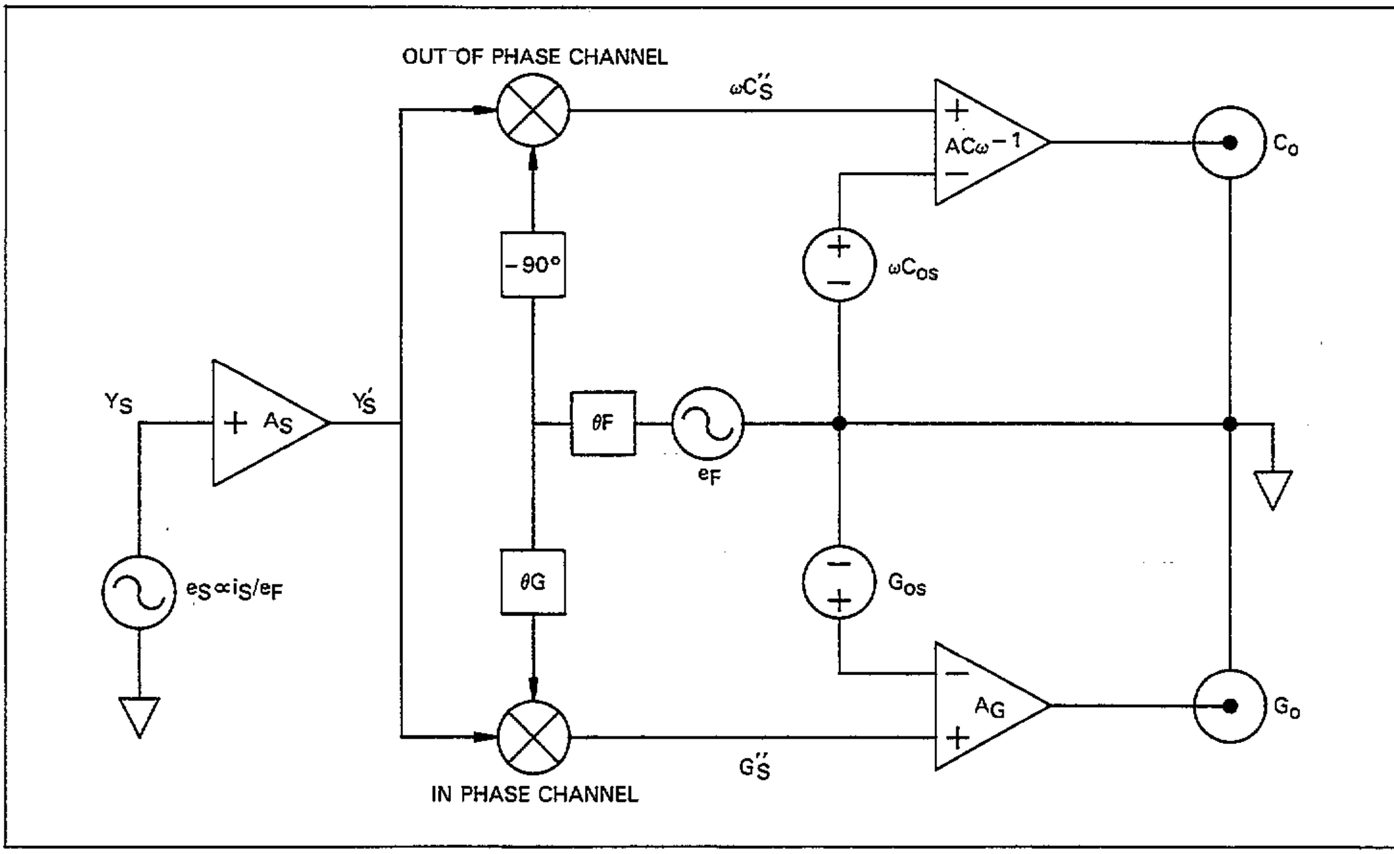


Figure 6-15. Electronics Error Model

6.9.2 Internal Model Corrections

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

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

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

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

6.9.3 I/O and Transmission Model Corrections

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

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

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

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

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

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

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

Since,

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

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

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

That is;

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

with A_N and B_N all complex numbers.

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

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

if

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

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

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

$$= -Y_{XFER}$$

Then;

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

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

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

or

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

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

6.9.4 Cable Correction Algorithm

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

6.9.5 Driving Point Correction

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

Basic Assumptions

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

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

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

6.9.5 Calibration Source Correction

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

6.9.7 S-Parameter Correction

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

SECTION 7
MAINTENANCE

7.1 INTRODUCTION

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

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

This section is outlined as follows:

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

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

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

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

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

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

7.2 FUSE REPLACEMENT

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

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

7.2.1 Line Fuse Replacement

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

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

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

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

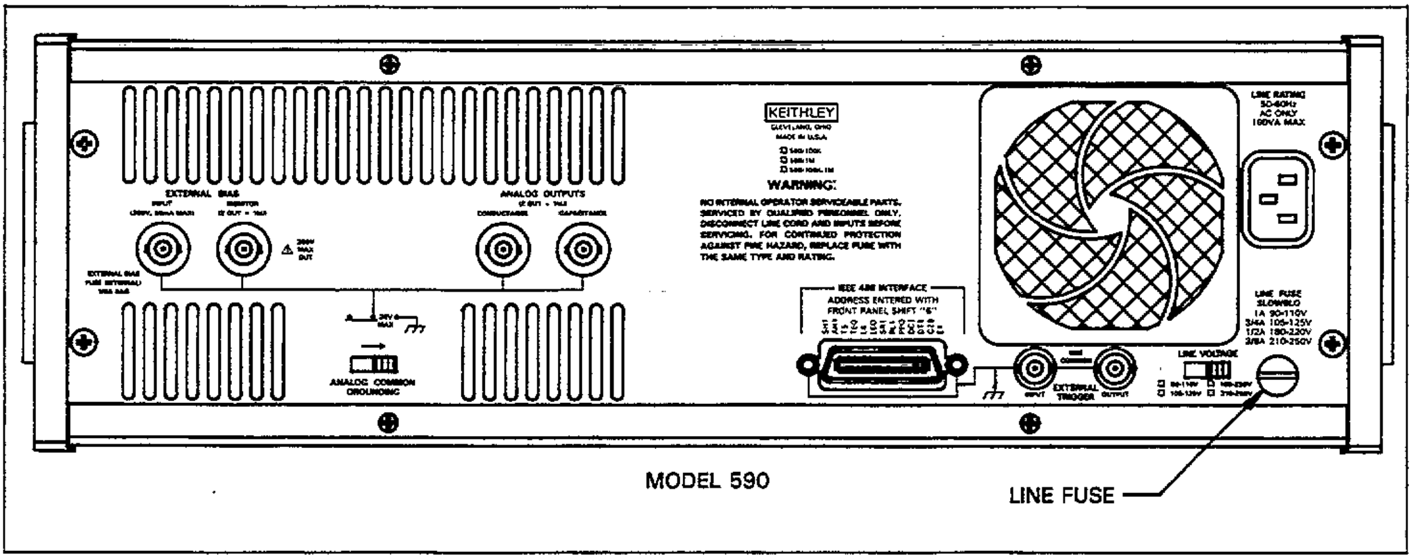


Figure 7-1. Line Fuse Location

Table 7-1. Line Fuse Values

Line Voltage Range	Fuse Rating	Keithley Part No.
90-110V	1A, slow blow, 250V, 3AG	FU-10
105-125V	$\frac{3}{4}$A, slow blow, 250V, 3AG	FU-19
180-220V	$\frac{1}{2}$A, slow blow, 250V, 3AG	FU-4
210V-250V	$3/8$A, slow blow, 250V, 3AG	FU-18
105-125V	0.8A, slow blow, 5mm	FU-71*
210-250V	0.4A, slow blow, 5mm	FU-80*

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

7.2.2 External Bias Input Fuse

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

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

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

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

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

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

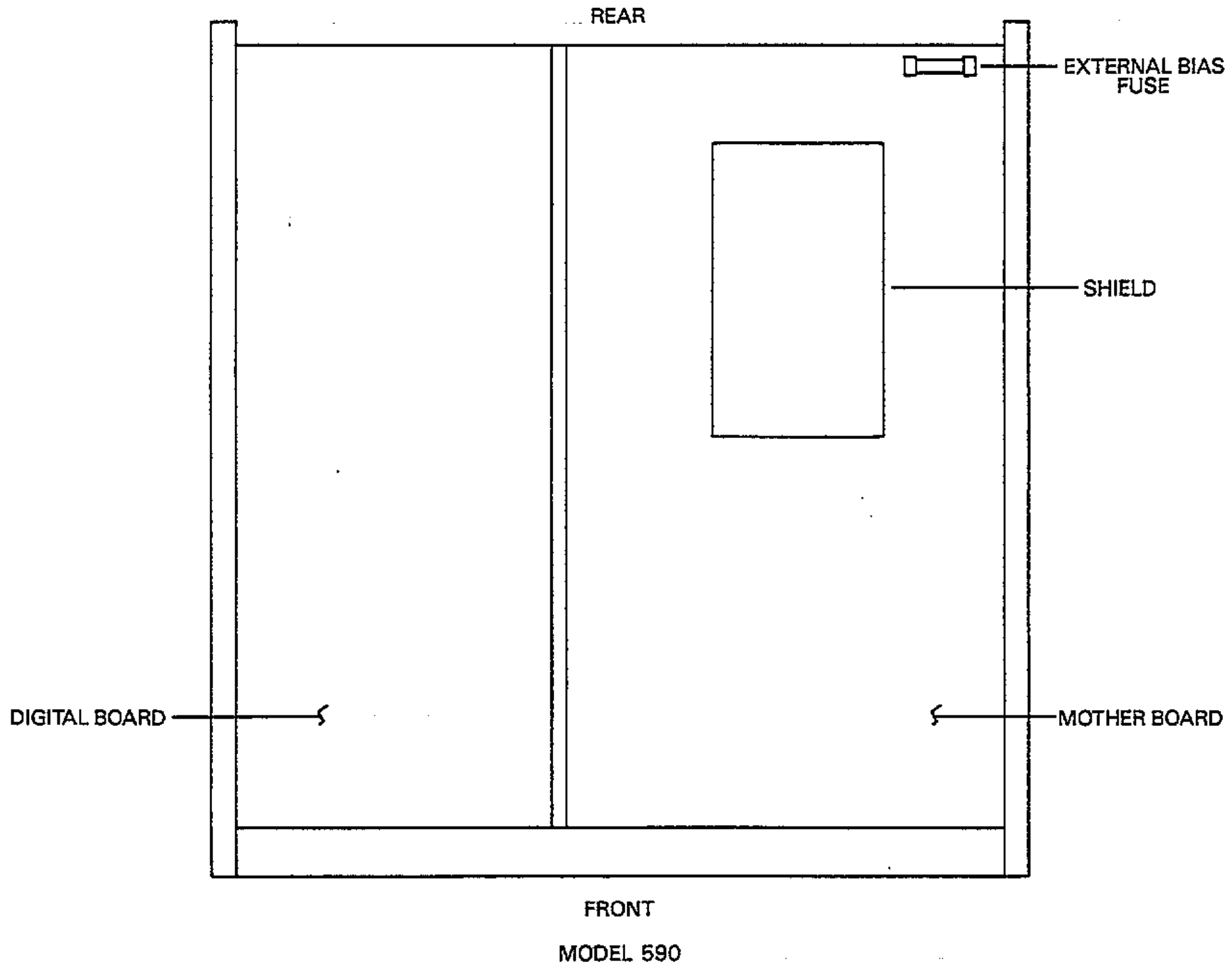


Figure 7-2. External Bias Fuse Location

7.3 CALIBRATION

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

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

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

7.3.1 Factory Calibration

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

7.3.2 Calibration Cycle

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

7.3.3 Environmental Conditions

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

NOTE

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

7.3.4 Recommended Calibration Equipment and Sources

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

NOTE

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

7.3.5 Calibration Switch

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

CAL LOCKED

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

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

Table 7-2. Recommended Calibration Equipment and Sources

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

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

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

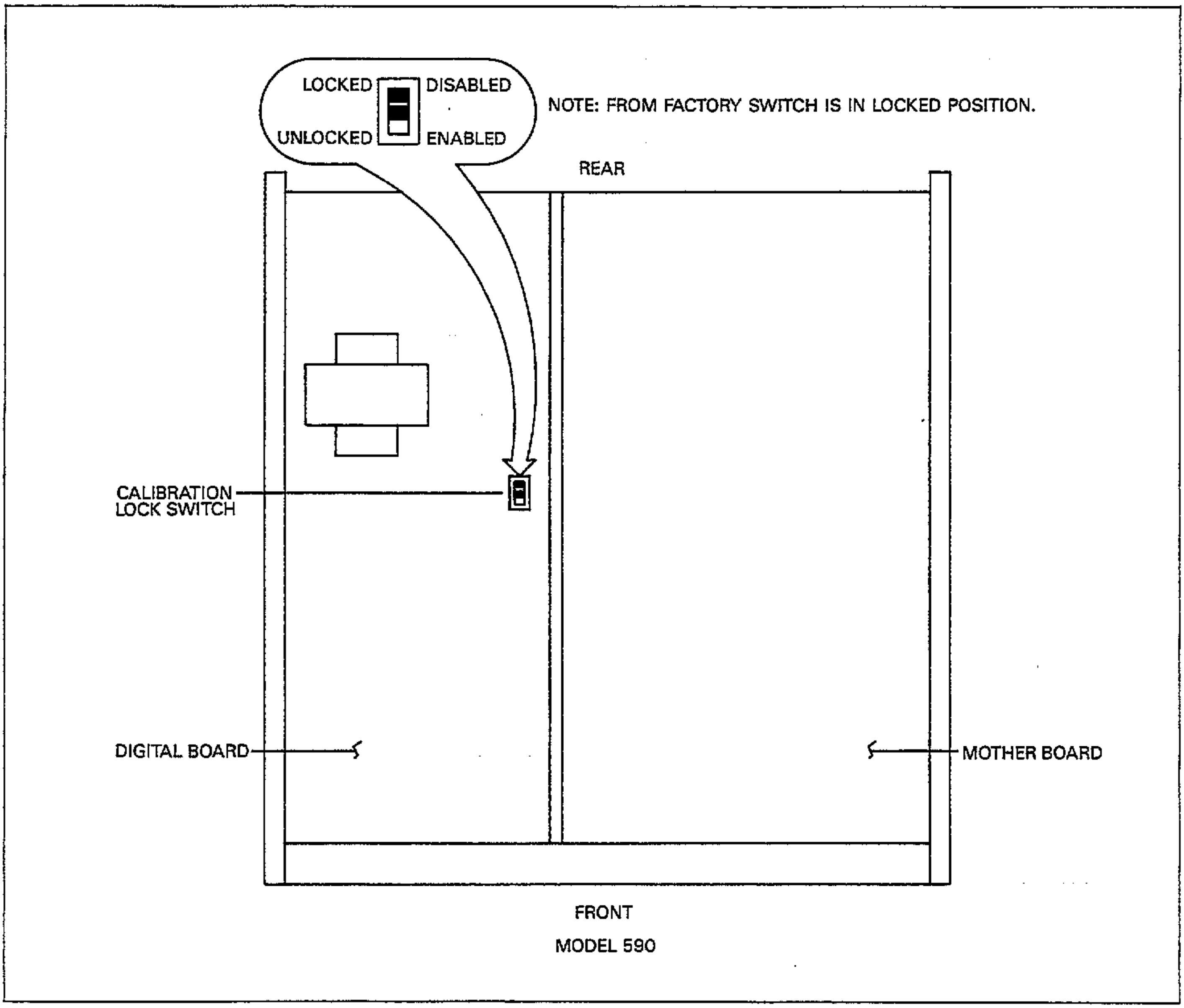


Figure 7-3. Calibration Lock Switch Location

7.3.6 Calibration Commands

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

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

Table 7-3. Calibration Command Summary

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

7.3.7 Calibration Program

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

Program **Comments**

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

7.3.8 Module Calibration

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

NOTE

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

DMM Connections

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

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

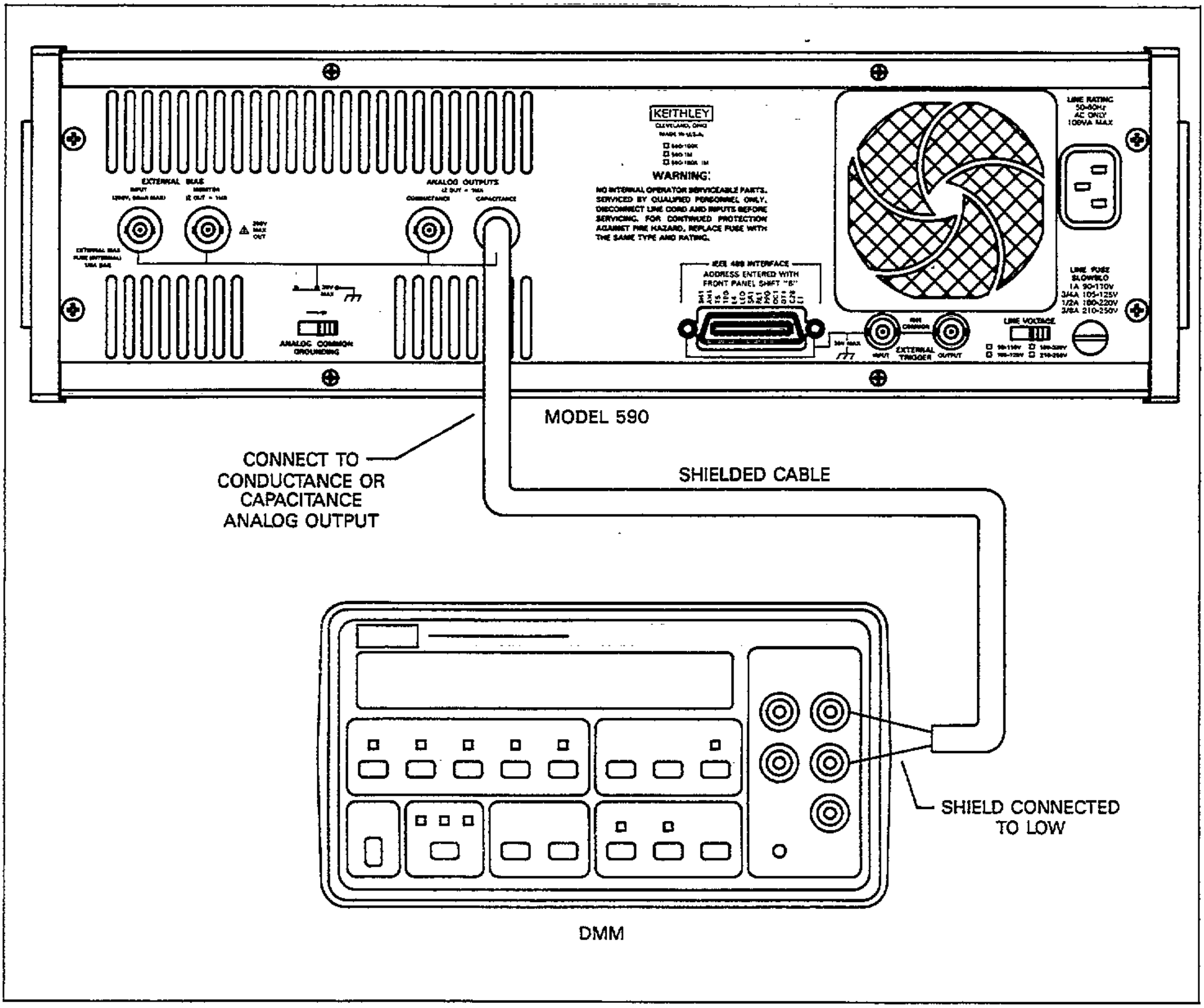


Figure 7-4. Module Calibration Connections

Source Connections

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

Calibration Adjustment Locations

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

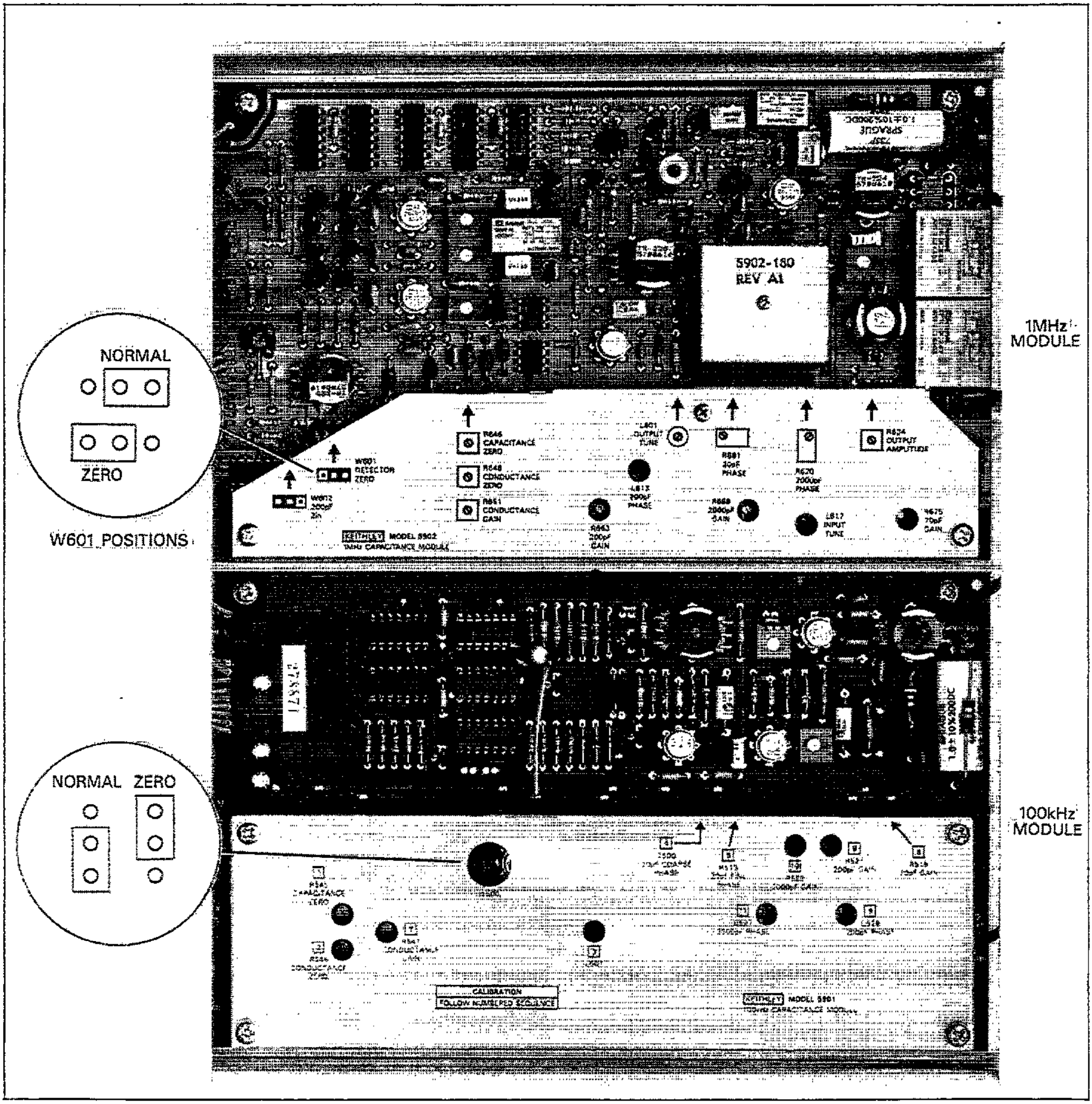


Figure 7-5. Module Calibration Adjustments

100kHz (5901) Module Calibration

Calibrate the 100kHz module as follows:

1. Turn on the Model 590 and allow it to warm up for at least one hour before beginning calibration. Also allow the DMMs to warm up for the period stated in their instruction manuals.
2. Select the following operating modes on the Model 590:
   Frequency: 100kHz
   Filter: ON
   Range: 2nF
3. Select the 2V DC range on both DMMs. Temporarily short the ends of the DMM connecting cables, and then enable zero on both DMMs. Make sure the DMMs are connected to the analog outputs after zeroing them.
4. Change the position of jumper W500 to the ZERO position, as shown in Figure 7-5.
5. Adjust R545 (CAPACITANCE ZERO) for a reading of 0V ±100μV as measured on the DMM connected to the CAPACITANCE OUTPUT.
6. Adjust R546 (CONDUCTANCE ZERO) for a reading of 0V ±100μV, 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 ±100μV as measured on the conductance DMM.
11. Adjust R515 (20pF GAIN) for a voltage reading analogous to the 100kHz capacitance value marked on the standard, ±1mV. For example, if the marked 100kHz standard value is 18.05pF, adjust for a DMM reading of 1.805V ±1mV.
12. Disconnect the 18pF source and make sure the Model 590 is on the 20μS range.
13. Re-zero the DMMs connected to the analog outputs.
14. Connect the 18μS 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, ±1mV. For example, if the marked value is 18.1μS, adjust for a voltage reading of 1.81V ±1mV.
15. Remove the 18μS 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, ±1mV on the capacitance DMM. For example, if the source value is 180.6pF, adjust for a DMM reading of 1.806 ±1mV.
19. Adjust C529 (200pF PHASE) for a reading of 0V ±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, ±1mV on the capacitance DMM. For example, if the marked source value is 1.795nF, adjust for a voltage reading of 1.795V ±1mV.
24. Adjust C527 (2000pF PHASE) for a reading of 0V ±1mV on the conductance DMM.
25. Remove the 1.8nF capacitance source from the unit.

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

1MHz (5902) Module Calibration

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

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

   Initially, nothing should be connected to the front panel test jacks.
4. Move jumper W601 to the ZERO position (see Figure 7-5).
5. Adjust R646 (CAPACITANCE ZERO) for a reading of 0V ±100μV on the capacitance DMM (the DMM connected to the CAPACITANCE OUTPUT).
6. Adjust R648 (CONDUCTANCE ZERO) for a reading of 0V ±100μV 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 ±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 ±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, ±2mV. For example, if the 1MHz value is 1.7996nF, adjust for a DMM reading of 1.7996V ±2mV.
14. Remove the 1.8nF source from the instrument.
15. Select the 200pF range on the Model 590 and re-zero both DMMs.
16. Connect the 180pF capacitance source to the front panel test INPUT and OUTPUT jacks.
17. Adjust L613 (200pF PHASE) for a reading on 0V ±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 ±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 ±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 ±1mV.
24. Remove the 18pF source from the instrument.
25. Repeat steps 11 through 24 until no further adjustment is required.
26. Select the 2mS range an re-zero the DMMs.
27. Connect the 1.8mS source to the front panel test INPUT and OUTPUT jacks.
28. Adjust R651 (CONDUCTANCE GAIN) for a conductance DMM reading analogous to the marked conductance source value to within 14mV. For example, if the marked value is 1.802mS, adjust R651 for a DMM reading of 1.802V ±14mV.
29. Remove the 1.8mS source from the instrument.

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

7.3.9 Digital Calibration

Initial Instrument Setup

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

Voltage Read-Back Calibration

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

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

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

Table 7-4. Voltage Read-Back Calibration Summary

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

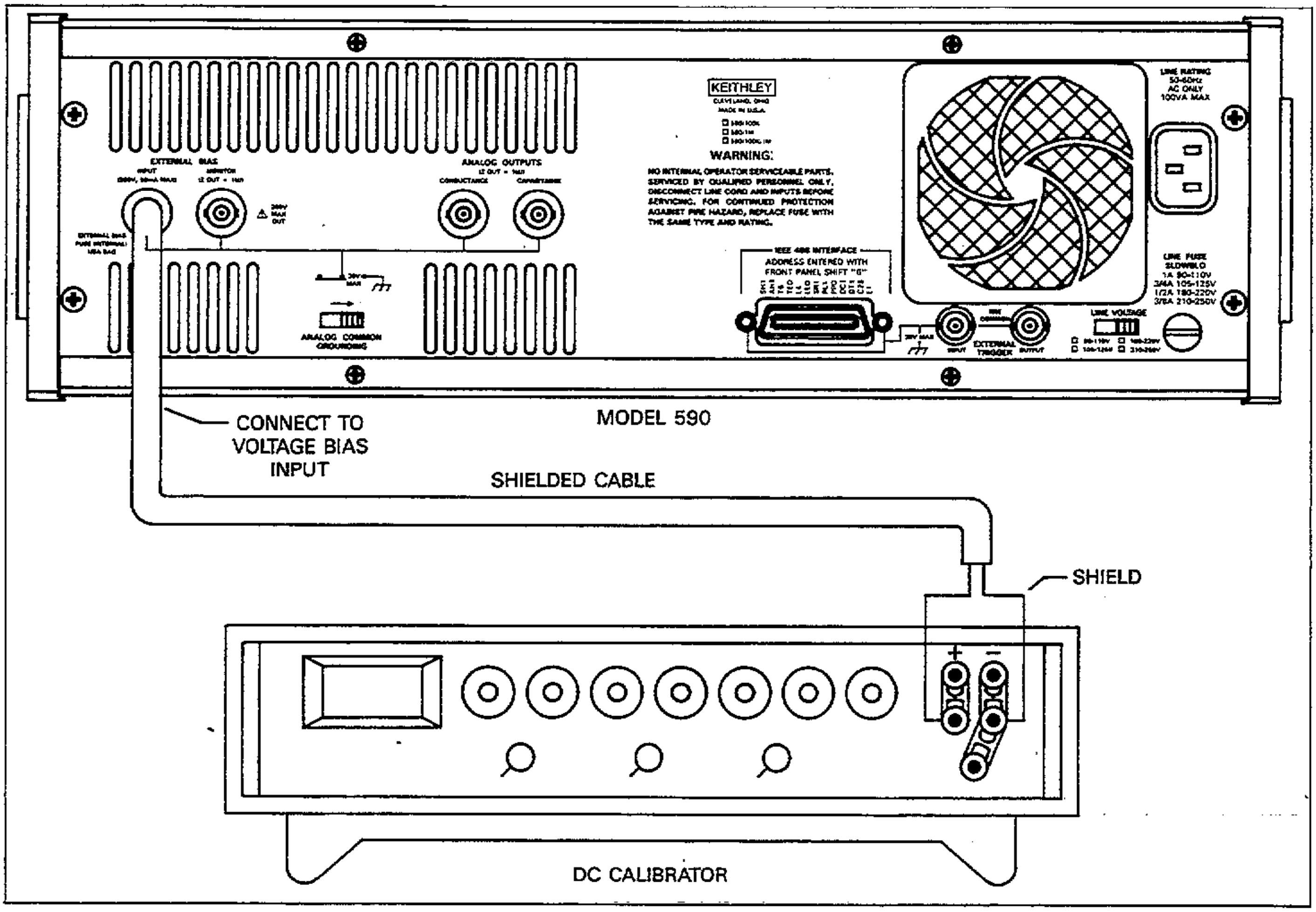


Figure 7-6. Connections for 200V Read-Back Calibration

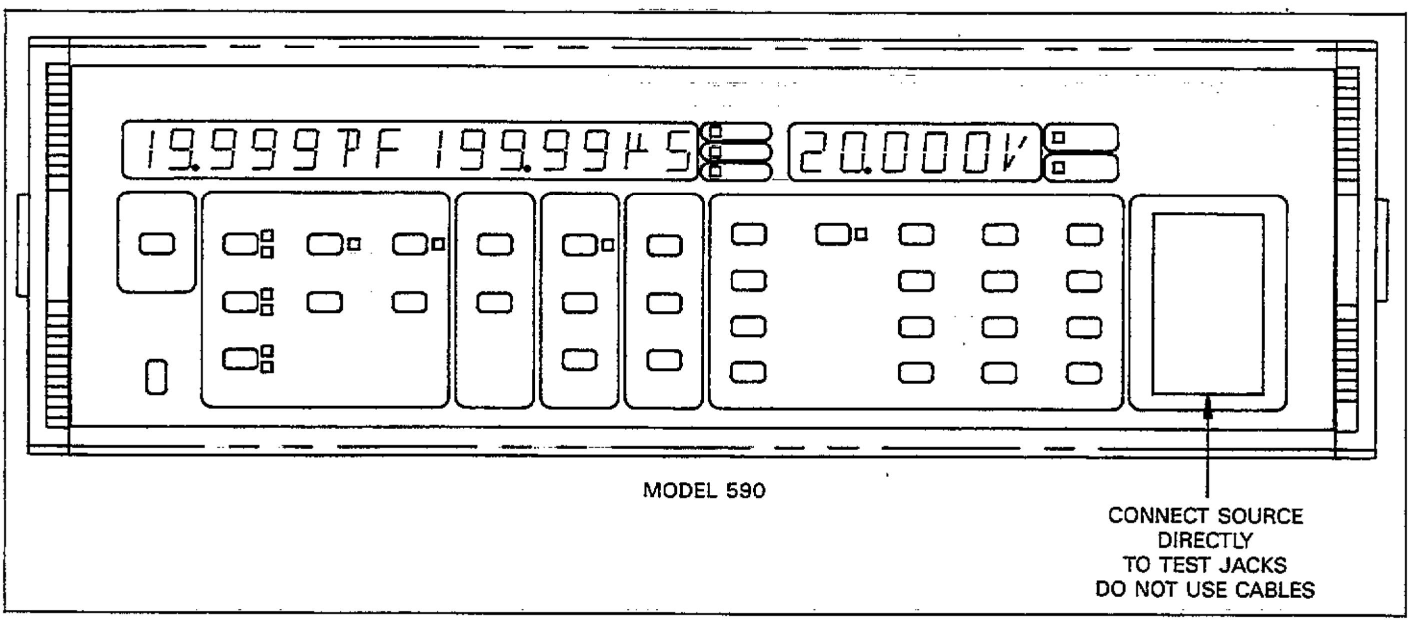


Figure 7-7. Source Connections

Internal Bias Voltage Source Calibration

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

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

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

Table 7-5. Voltage Source Calibration Summary

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

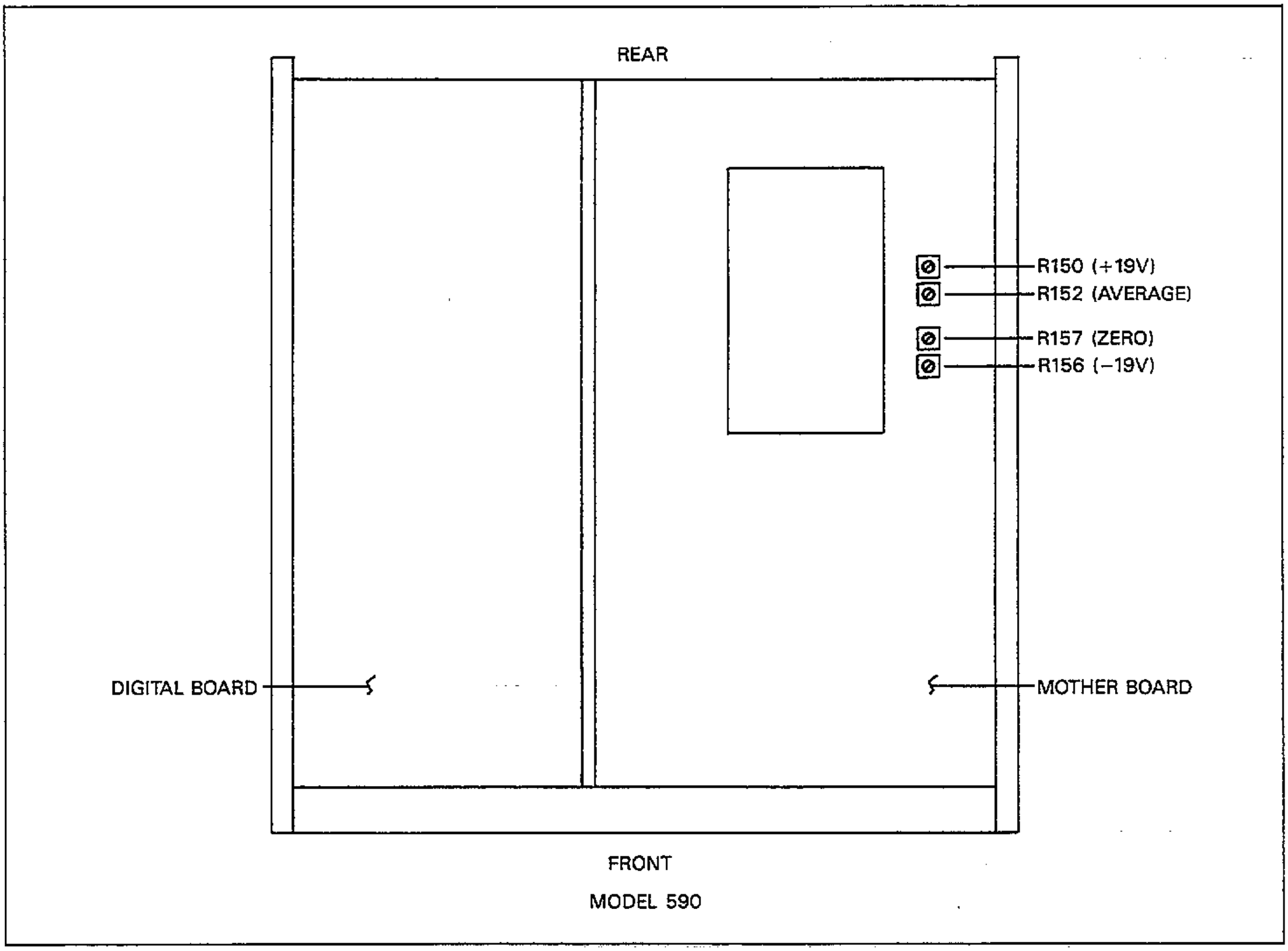


Figure 7-8. Voltage Source Calibration Adjustment Locations

100kHz Calibration

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

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

Table 7-6. 100kHz Calibration Summary

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

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

20nF/20mS Range Model 5904 Input Adapter Calibration

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

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

Complete Model 5904 Input Adapter Calibration

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

NOTE

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

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

Table 7-7. Model 5904 Calibration Summary

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

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

1MHz Calibration

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

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

Table 7-8. 1MHz Calibration Summary

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

Cable Correction Calibration

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

NOTE

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

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

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

Table 7-9. Driving Point Calibration Summary

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

*Use F0R4X for 100kHz.

7.4 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

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

Use the precautions below when handling static-sensitive devices.

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

7.5 DISASSEMBLY

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

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

7.5.1 Top and Bottom Cover Removal

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

Top Cover Removal

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

Bottom Cover Removal

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

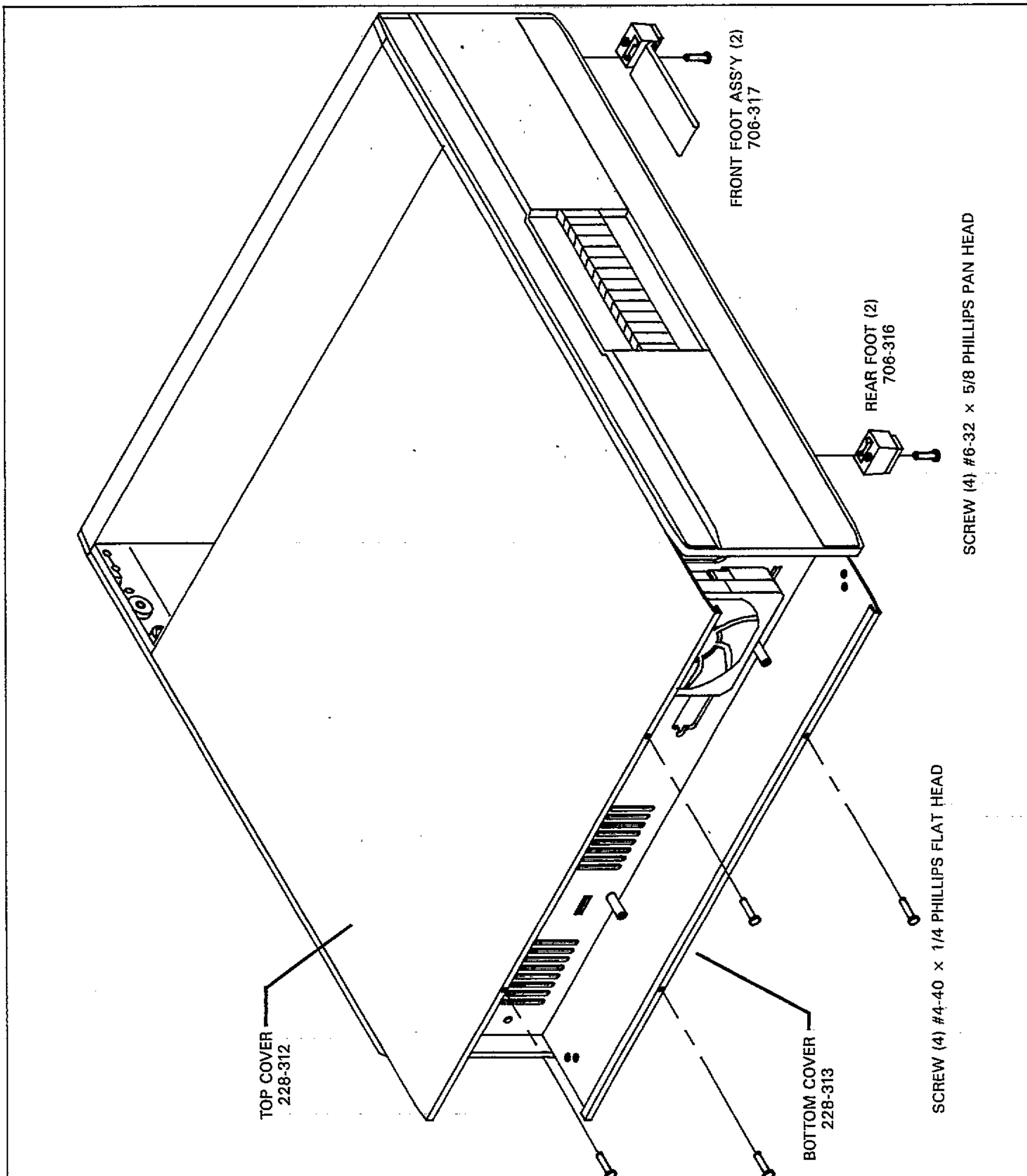


Figure 7-9. Top and Bottom Cover Removal

7.5.2 Module and Circuit Board Removal and Replacement

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

Removal

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

Circuit Board and Module Installation

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

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

7.5.3 Case Disassembly

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

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

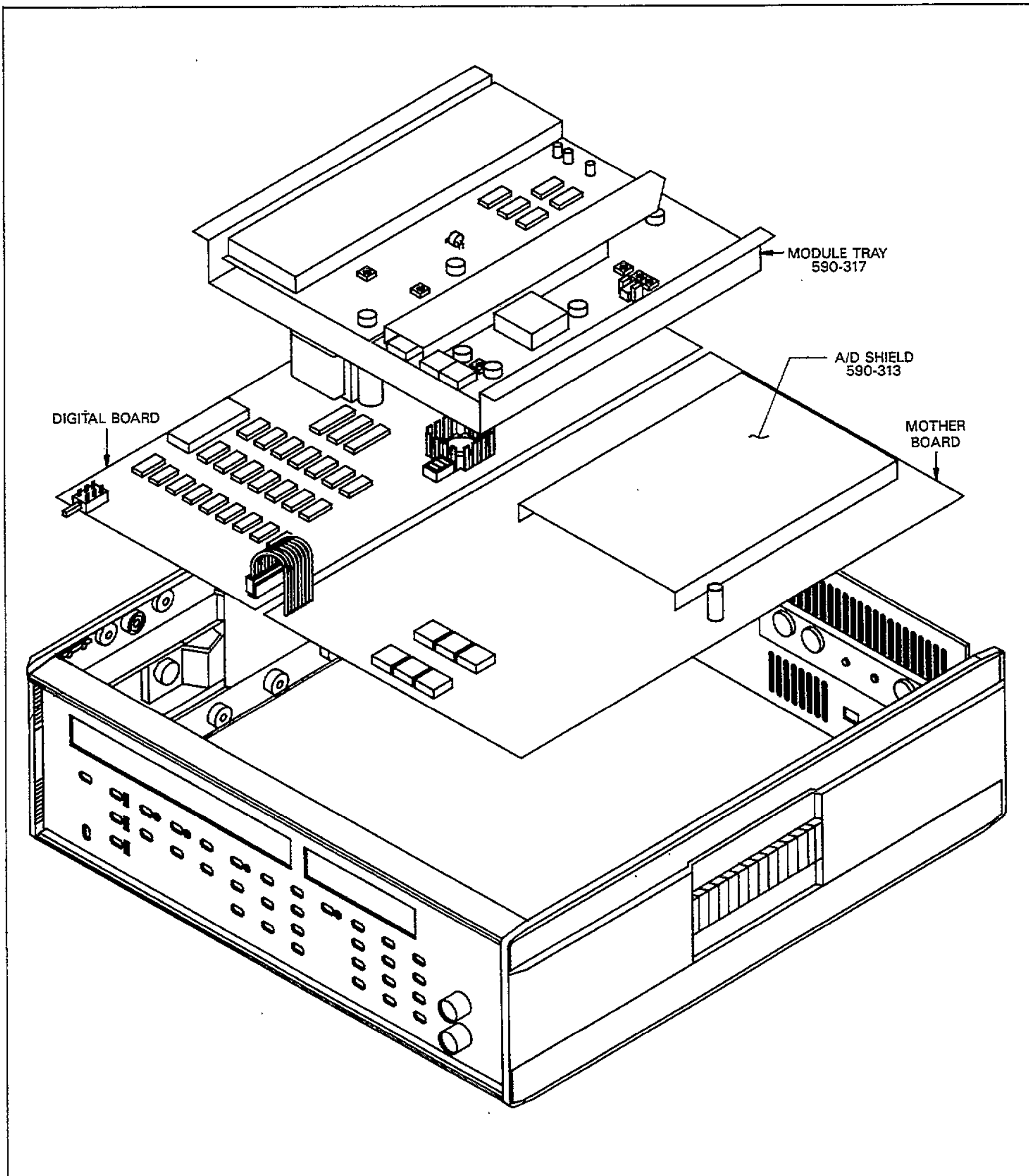


Figure 7-10. Circuit Board Removal and Replacement

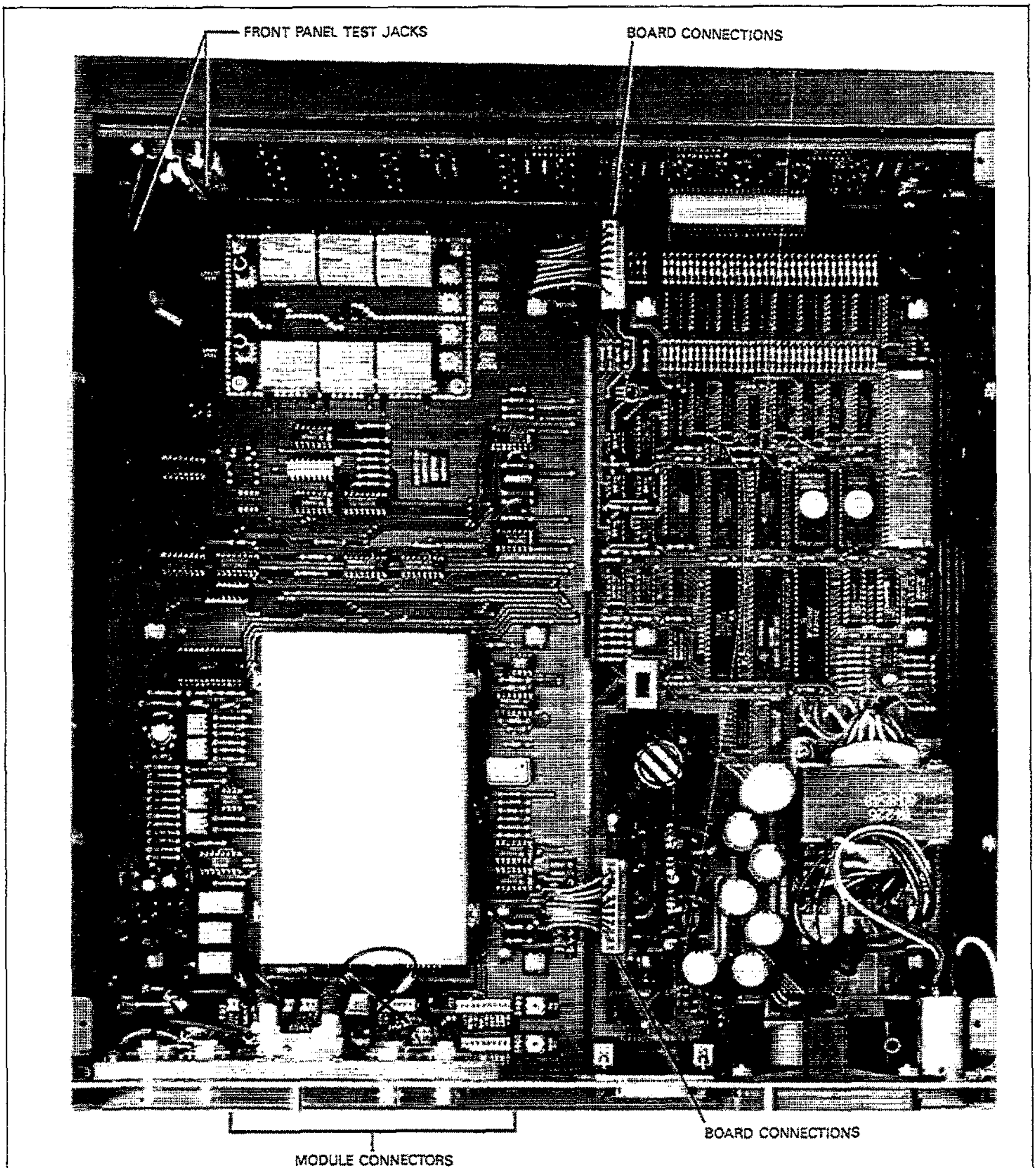


Figure 7-11. Cable Connections

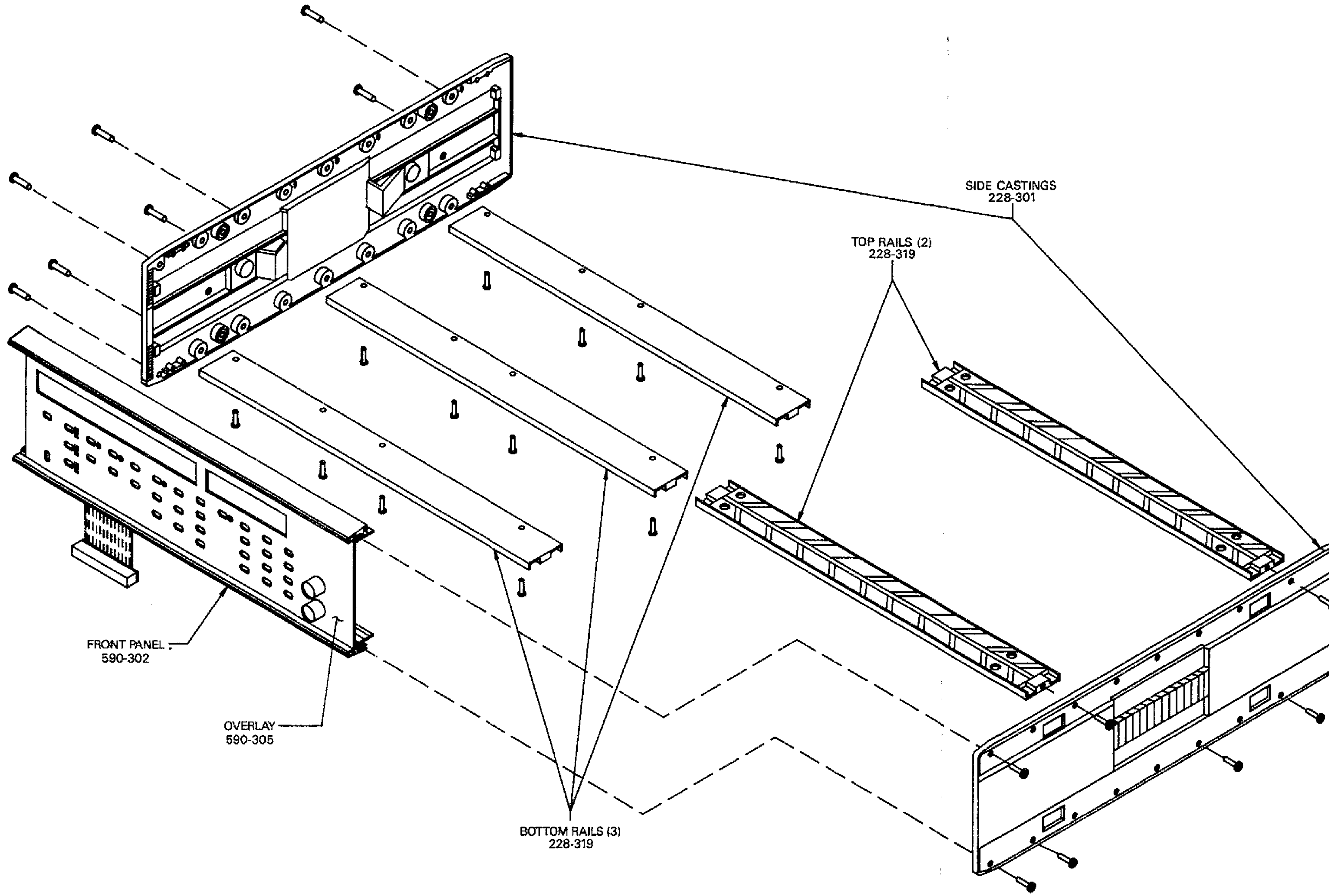


Figure 7-12. Case Disassembly

7.5.4 Rear Panel Disassembly

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

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

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

7.5.5 Front Panel Disassembly

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

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

7.6 TROUBLESHOOTING

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

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

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

7.6.1 Recommended Test Equipment

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

Table 7-10. Recommended Troubleshooting Equipment

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

7.6.2 Self Test

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

Table 7-11. Self Test Display Messages

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

*Indicates excessive offsets or possible range calibration problem.

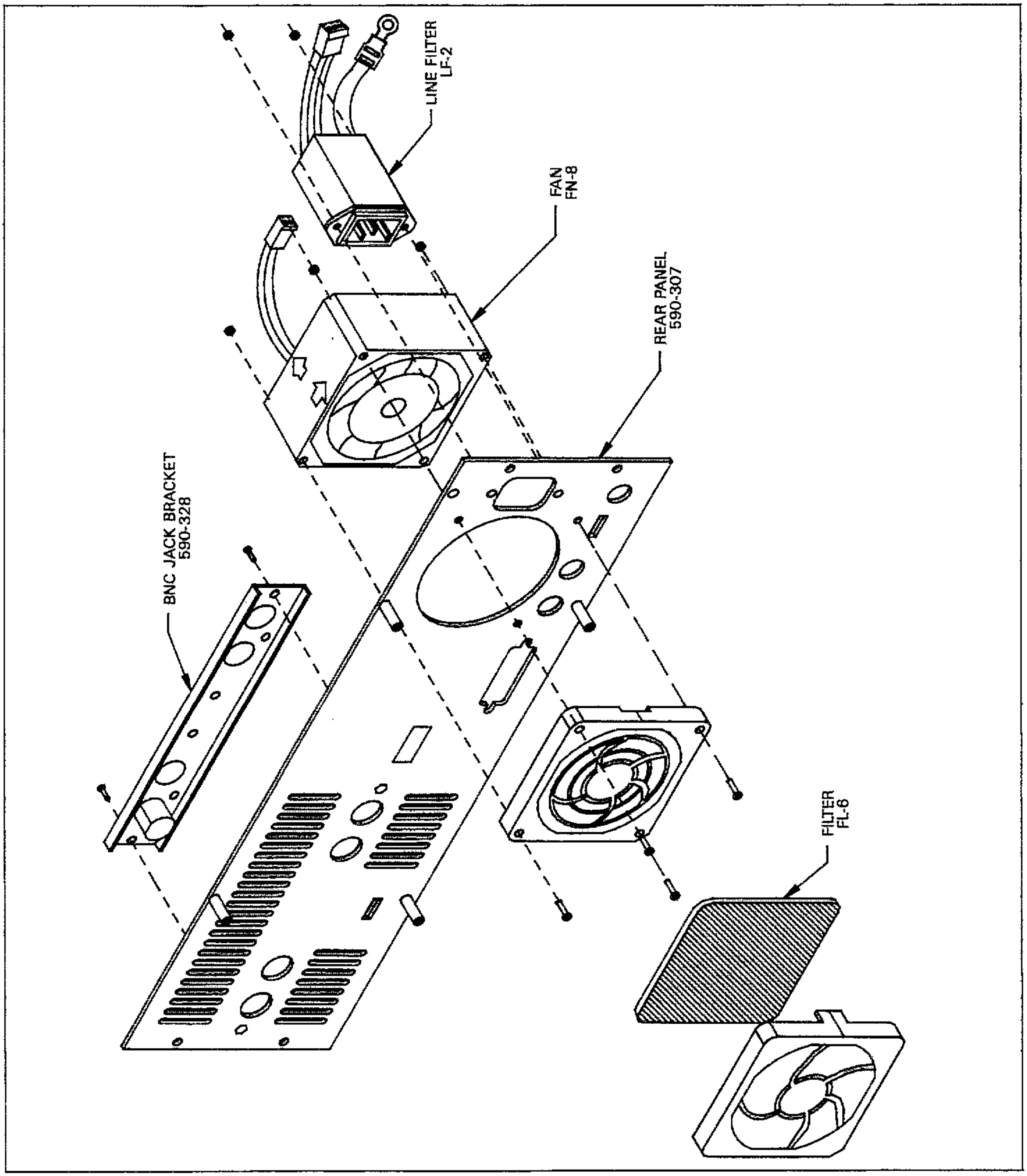


Figure 7-13. Rear Panel Disassembly

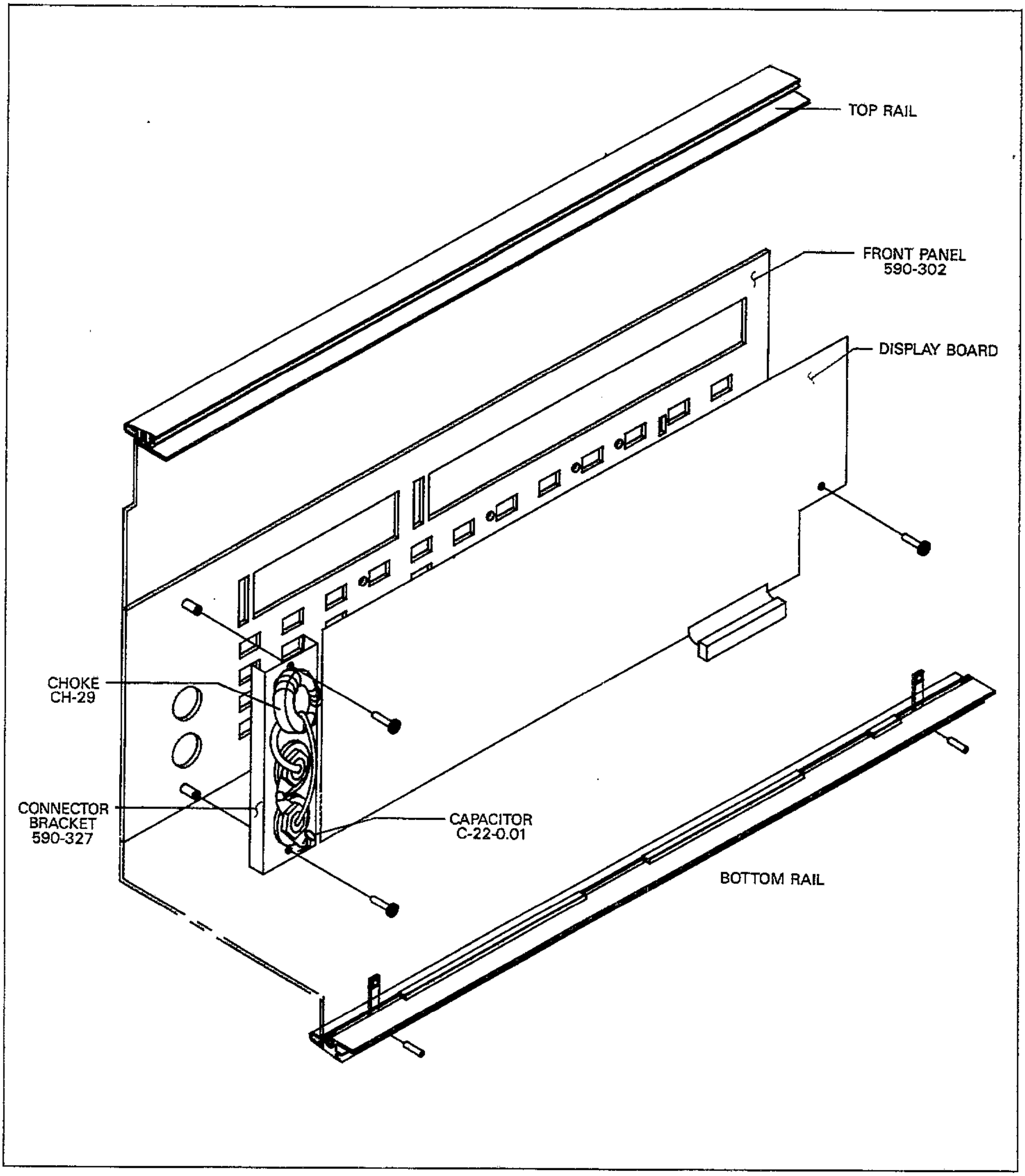


Figure 7-14. Front Panel Disassembly

7.6.3 Diagnostic Program

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

Use the diagnostic program as follows:

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

Table 7-12. Diagnostic Program Summary

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

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

7.6.4 Troubleshooting Sequence

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

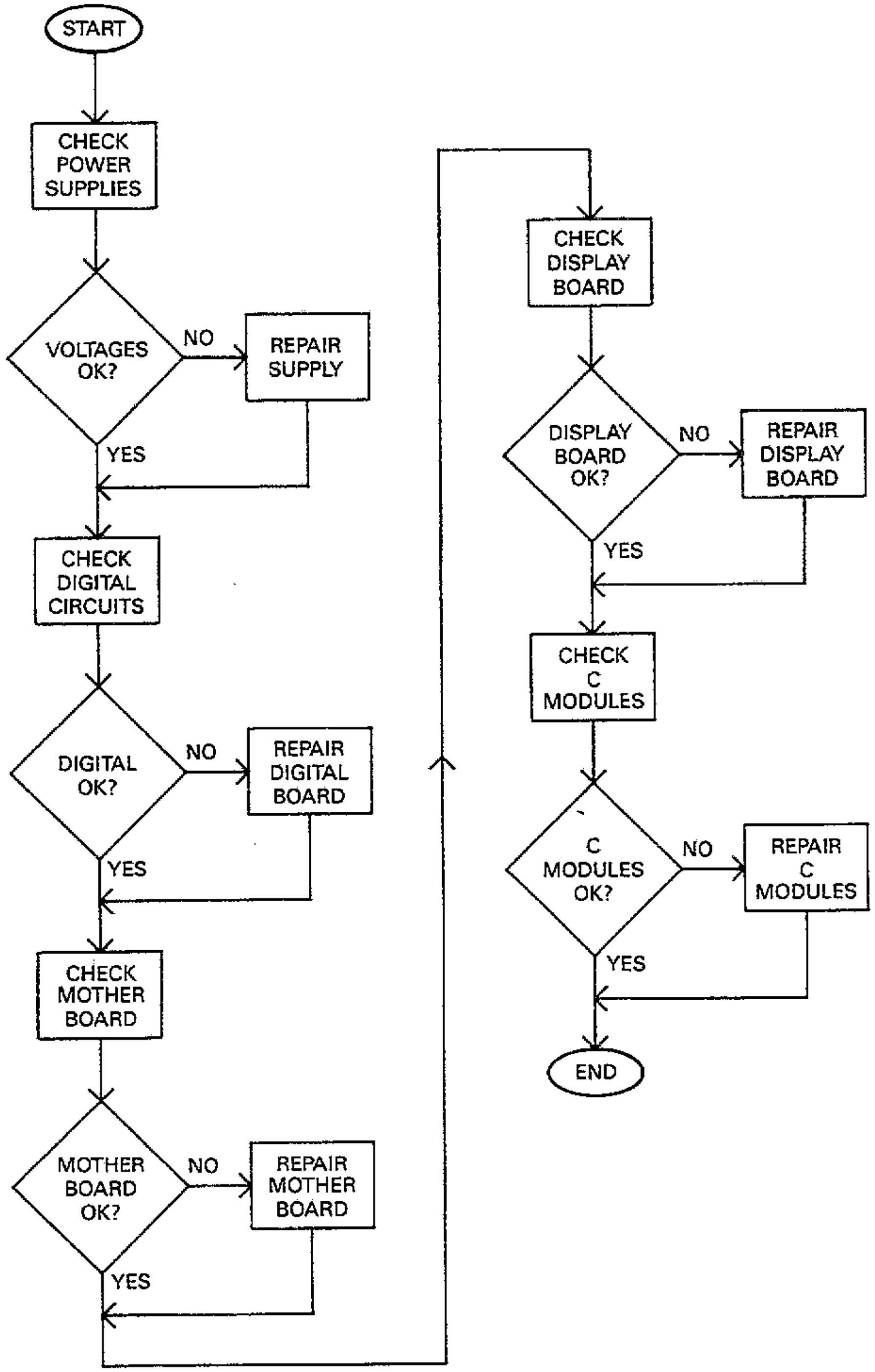


Figure 7-15. Troubleshooting Flow Chart

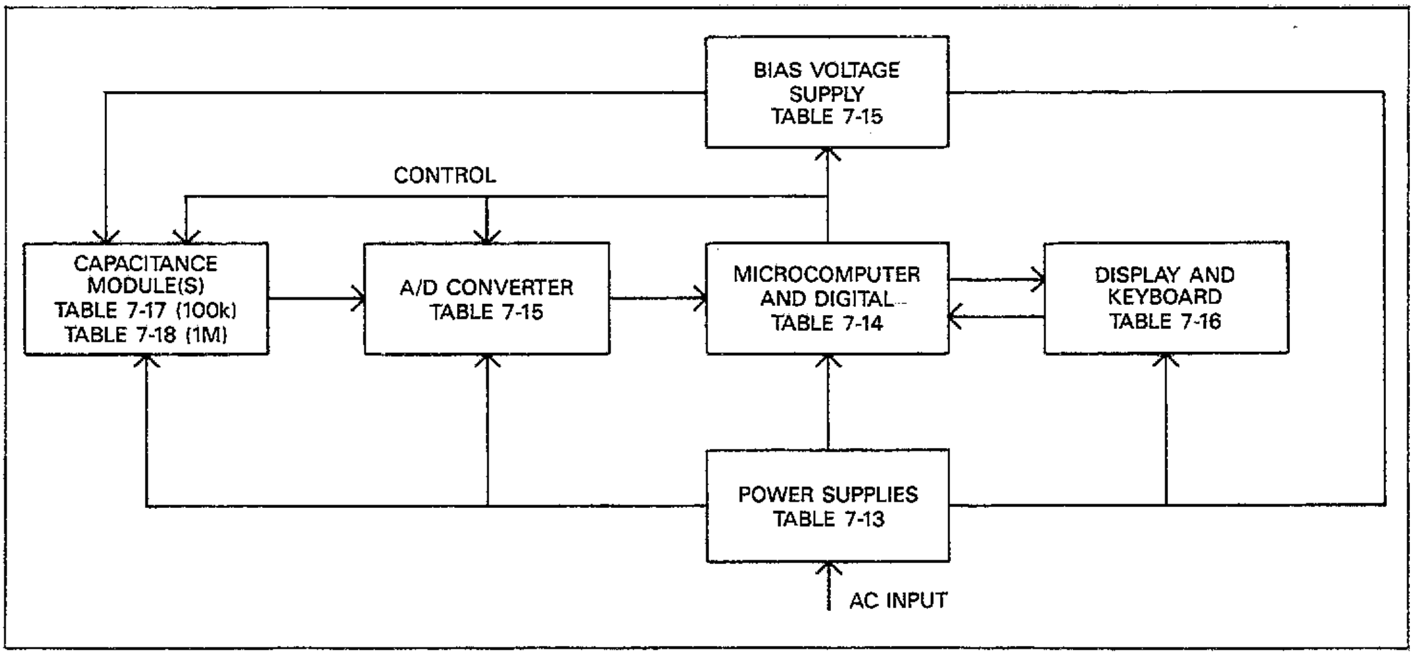


Figure 7-16. Troubleshooting Block Diagram

7.6.5 Power Supply Checks

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

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

7.6.6 Microcomputer and Digital Circuitry Checks

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

7.6.7 Mother Board

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

7.6.8 Display Board

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

7.6.9 100kHz and 1MHz Capacitance Modules

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

7.7 FAN FILTER CLEANING AND REPLACEMENT

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

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

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

NOTE

Do no operate the instrument with the filter removed to avoid dirt build-up within the instrument.

5. If necessary, clean the fan guard with a damp cloth.
6. Install the filter element in the holder and snap the holder back onto the fan guard. The two tabs on the holder should be oriented at the top and bottom.

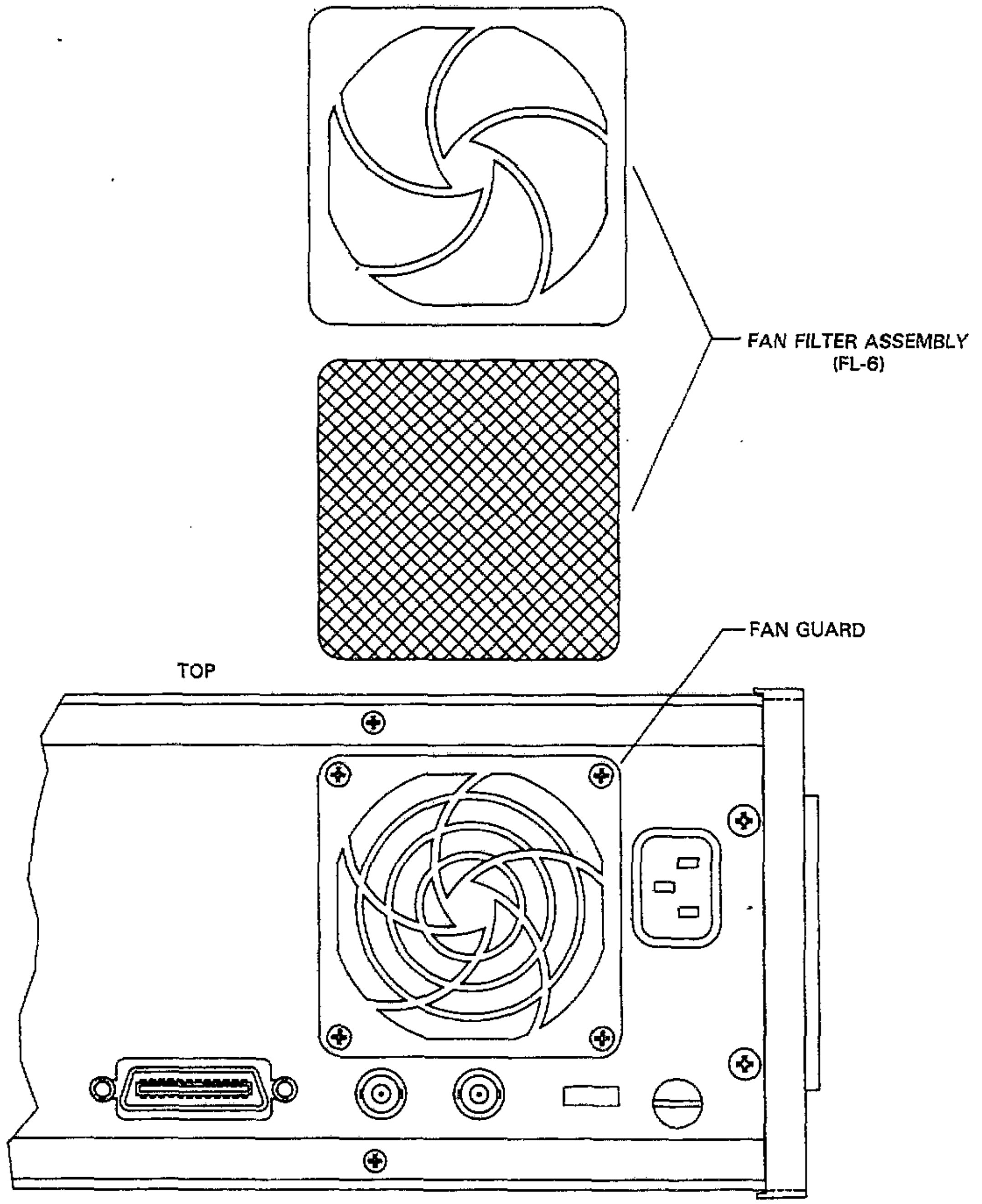


Figure 7-17. Fan Filter Removal

Table 7-13. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S302 (Line voltage select)	115V or 230V as required	Operate on correct voltage
2	Line fuse (F300)	Continuity	Check with ohmmeter
3	Power on		Plugged into live outlet
4	VR300, pin 1	+11V, ±20%	Referenced to analog common
5	VR300, pin 2	+5V, ±5%	Referenced to analog common
6	VR301, pin 2	−11V, ±20%	Referenced to analog common
7	VR301, pin 3	−5V, ±5%	Referenced to analog common
8	VR302, pin 1	+23V, ±20%	Referenced to analog common
9	VR302, pin 2	+15V, ±5%	Referenced to analog common
10	VR303, pin 2	−23V, ±20%	Referenced to analog common
11	VR303, pin 3	−15V, ±5%	Referenced to analog common
12	Q300, collector	+43V, ±20%	Referenced to analog common
13	Q300, emitter	+30V, ±5%	Referenced to analog common
14	Q301, collector	−43V, ±20%	Referenced to analog common
15	Q301, emitter	−30V, ±5%	Referenced to analog common
16	VR304, pin 1	+12V, ±20%	Referenced to digital common
17	VR304, pin 2	+5V, ±5%	Referenced to digital common

Table 7-14. Microcomputer and Digital Checks

Step	Item/Component	Required Condition	Remarks
1			All signals referenced to digital common
2	U315, pin 37	Goes low for ≈700msec upon power up, then stays high.	RESET signal
3	U315, pin 38	8MHz square wave	MPU clock
4	U315, pin 34	2MHz square wave	E clock
5	U315, pin 35	2MHz square wave	Q clock
6	U315, pin 3	976Hz square wave	1.024msec IRQ clock
7	U315, pins 24-31	Data bus (D0-D7)	Check for stuck bit
8	U315, pins 8-23	Address bus (A0-A15)	Check for stuck bit
9	U321A, pin 2	Variable pulses	A/D status information
10	U332, pin 1	Varying pulses	A/D data
11	U316A, pin 2	Pulse train	Serial clock
12	U316B, pin 4	Pulse train	Serial control data
13	U316C, pin 6	Pulse train	Serial control strobe
14	U313, pin 25	2MHz square wave	VIA clock
15	U311, pin 18	2MHz square wave	IEEE chip clock
16	U313, pins 13-16	Pulse train	A/D data

Table 7-15. Mother Board Checks

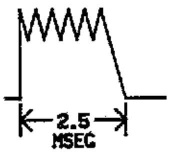
Step	Item/Component	Required Condition	Remarks
1	Signal reference		All voltages referenced to analog common
2	U134, pin 5	8MHz square wave	8MHz clock
3	U134, pin 7	4MHz square wave	4MHz clock
4	U133, pin 11	800kHz square wave	800kHz clock
5	U119, pin 15	Pulse train	Serial control data
6	U119, pin 6	Pulse train	Serial control clock
7	U119, pin 12	Pulse train	Serial control strobe
8	Programming	Select DC waveform, −19V default bias	Sweep inactive
9	U127, pin 15	+9.25V	DAC output
10	U128, pin 6	+9.25V	
11	Q123 emitter	−19V	Voltage source output
12	Programming	Program +19V default bias	
13	U127, pin 15	+9.25V	DAC output
14	U128, pin 6	−9.25V	
15	Q123 emitter	+19V	Voltage source output
16	F100	Check continuity	External bias fuse
17	U104, pin 10	4MHz square wave	A/D clock
18	U106, pin 6	50kHz pulse train	During active sweep
19	U106, pin 2	100kHz pulse train	During active sweep
20	U105, pin 6	400kHz pulse train	During active sweep
21	U110, pin 6		Integrator waveform during sweep
22	U113, pin 1	−10V DC	−10V reference
23	Q110 emitter	+5V DC	+5V reference
24	R122, R123 function	+1V	A/D reference
25	CAL button	Press and hold during power up	Enter diagnostic program
26	Display	Press any key until VREF message is displayed.	
27	U100, pin 1	+1V DC	

Table 7-16. Display Board Checks

Step	Item/Component	Required Condition	Remarks
1	Self Test	Display segments and LEDs	All on at start of self test
2	U201 pins 10-16	Digit select pulses	All voltages referenced to digital common
3	U202 pins 10-16	Digit select pulses	
4	U203 pins 10-16	Digit select pulses	
5	U204, pin 2	1msec negative going pulse every 10msec when S201-S204 closed	Switch matrix strobe
6	U204, pin 2	1msec pulse every 10msec when S205-S208 closed	
7	U204, pin 6	1msec pulse every 10msec when S209-S212 closed	
8	U204, pin 12	1msec pulse every 10msec when S213-S216 closed	
9	U204, pin 10	1msec pulse every 10msec when S217-S220 closed	
10	U204, pin 8	1msec pulse every 10msec when S221-S224 closed	
11	U205, pin 2	1msec pulse every 10msec when S225-S228 closed	
12	U205, pin 4	1msec pulse every 10msec when S229-S232 closed	
13	U205, pin 6	1msec pulse every 10msec when S233 closed	

Table 7-17. 100kHz Capacitance Module Checks

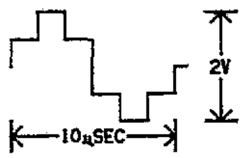
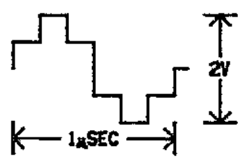
Step	Item/Component	Required Condition	Remarks
1	Reference point		Following voltages reference to digital common.
2	U502, pin 10	800kHz square wave	800kHz clock
3	U506, pin 10	100kHz square wave	Detector A signal
4	U506, pin 12	100kHz square wave	Detector B signal
5	U506, pin 8	100kHz square wave	Detector C signal
6	U506, pin 6	100kHz square wave	Detector D signal
7	Q500 base		Synthesized waveform
8	Reference point		Following voltages referenced to analog common
9	Q500 collector	100kHz, 10V p-p sine wave	Test frequency
10	U508, pin 6	100kHz, 1V p-p sine wave	Test frequency
11	Test output high	100kHz 42mV p-p sine wave	Test frequency
12	U510, pin 6	+4VDC	AGC voltage
13	Range, frequency	Select 2nF range, 100kHz	
14	Reference capacitor	Connect full scale (1.8-2nF) capacitor between test INPUT and test OUTPUT jacks	Leave capacitor connected for following tests
15	U512, pin 6	100kHz, 175mV p-p sine wave	Amplitude depends on capacitance value
16	U513, pin 6	100kHz, 1V p-p sine wave	Amplitude depends on capacitance value
17	U514, pin 6	100kHz, 6.3V p-p sine wave	Amplitude depends on capacitance value
18	U515, pin 7	1.8-2V DC	Voltage analogous to applied capacitance
19	U515, pin 1	1.8-2V DC	Voltage analogous to applied capacitance
20	U516, pin 7	1.8-2V DC	Voltage analogous to applied capacitance
21	Test jacks	Connect 2mS conductance	Leave conductance connected for following tests
22	U517, pin 1	2V DC	Voltage depends on applied conductance
23	U517, pin 1	2V DC	Voltage depends on applied conductance
24	U516, pin 1	2V DC	Voltage depends on applied conductance

Table 7-18. 1MHz Capacitance Module Checks

Step	Item/Component	Required Condition	Remarks
1	Reference point		Following voltages referenced to digital common.
2	U602, pin 13	8MHz square wave	8MHz clock
3	U601, pin 4	1MHz square wave	Detector A signal
4	U601, pin 2	1MHz square wave	Detector B signal
5	U601, pin 6	1MHz square wave	Detector C signal
6	U601, pin 10	1MHz square wave	Detector D signal
7	Q601 base		Synthesized waveform
8	Reference point		Following voltages referenced to analog common
9	Q601 collector	1MHz, 12V p-p sine wave	Test frequency
10	U606, pin 6	1MHz, 4.5 p-p sine wave	Test frequency
11	Test output high	1MHz, 42mV p-p sine wave	Test frequency
12	U608, pin 6	+3VDC	AGC voltgae
13	Range, frequency	Select 2nF range, 1MHz	
14	Reference capacitor	Connect full scale (2nF) capacitor between test INPUT and test OUTPUT jacks	Leave capacitor connected for following tests
15	U610, pins 7 and 8	1MHz, 300mV p-p sine wave	Amplitude depends on capacitance value
16	U611, pins 7 and 8	1MHz, 2.5V p-p sine wave	Amplitude depends on capacitance value
17	U612, pin 8	1MHz, 5V p-p sine wave	Amplitude depends on capacitance value
18	U614, pin 6	1.8-2V DC	Voltage is analogous to capacitance
19	U617, pin 1	1.8-2V DC	Voltage is analogous to capacitance
20	U616, pin 1	1.8-2V DC	Voltage is analogous to capacitance
21	Test jacks	Connect 20mS conductance	Leave conductance connected for following tests
22	U615, pin 6	2V DC	Voltage depends on conductance value
23	U617, pin 7	2V DC	Voltage depends on conductance value
24	U616, pin 7	2V DC	Voltage depends on conductance value

SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 590 CV Analyzer, as well as the 100kHz and 1MHz capacitance modules. Also included is an exploded view showing the general mechanical layout of the instrument for parts identification.

8.2 ELECTRICAL PARTS LISTS

Electrical parts for the Model 590 circuit boards as well as the 100kHz and 1MHz modules are listed in Tables 8-1 through 8-6. Parts in each table are listed alphabetically in order of circuit designation. The parts lists are integrated with the component layout drawings and schematic diagrams for the respective circuit boards.

8.3 MECHANICAL PARTS

Parts for the case assembly are listed in Table 8-7. Miscellaneous mechanical parts are listed in Table 8-8, while Table 8-9 lists parts for the Model 5904 Input Adapter. See the assembly drawings in Section 7 for the location of parts.

8.4 ORDERING INFORMATION

Keithley Instruments, Inc. maintains a complete inventory of all normal replacement parts. To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of this manual for addresses.

When ordering parts, include the following:

1. Instrument model number.
2. Instrument serial number.
3. Part description.
4. Circuit designation, including schematic diagram and component layout numbers (if applicable).
5. Keithley part number.

8.5 FACTORY SERVICE

If the instrument or modules are to be returned to the factory for service, carefully pack them and include the following information:

1. Complete the service form at the back of this manual and return it with the instrument.
2. Advise as to the warranty status of the instrument (see the inside front cover of this manual for warranty information.
3. Write the following on the shipping label: ATTENTION REPAIR DEPARTMENT.

8.6 COMPONENT LOCATION DRAWINGS AND SCHEMATIC DIAGRAMS

Component location drawings and schematic diagrams for the various circuit boards can be found on the following pages arranged as follows:

Board	Component Layout Number	Schematic Diagram Number	Parts Table Number
Mother	590-100	590-106	8-1
Display	590-110	590-116	8-2
Digital	590-120	590-126	8-3
5901 (100kHz)	5901-100	5901-106	8-4
5902 (1MHz)	5902-100	5902-106	8-5
KI590 Op Amp (U607)	5902-180	5902-186	8-6

Table 8-1. Mother Board, Parts List

Circuit Designation	Description	Keithley Part Number
C100	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C101	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C102	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C103	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C104	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C105	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C106	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C107	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C108	Capacitor, 470pF, Ceramic Disc	C-64-470p
C109	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C110	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C111	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C112	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C113	Capacitor, 0.001µF, Ceramic Disc	C-64-0.001
C114	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C115	Capacitor, 0.0047µF, 10%, 100V, Metallized Polypropylene	C-306-0.0047
C116	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C117	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C118	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C119	Capacitor, 0.47µF, 50V, Ceramic Film	C-237-0.47
C120	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C121	Capacitor, 100pF, Ceramic Disc	C-64-100p
C122	Capcitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C123	Capcitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C124	Capcitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C125	Capacitor, 0.1µF, 250V, Metallized Polyester	C-178-0.1
C126	Capacitor, 220pF, Ceramic Disc	C-64-220p
C127	Capacitor, 0.001µF, 500V, Ceramic Disc	C-22-0.001
C128	Capacitor, 10µF, 35V, Aluminum Electrolytic	C-309-10
C129	Capacitor, 10µF, 35V, Aluminum Electrolytic	C-309-10
C130	Capacitor, 0.1µF, 20%, 50V	C-365-0.01
C131	Capacitor, 0.1µF, 20%, 50V	C-365-0.01
C132	Capacitor, 0.1µF, 20%, 50V	C-365-0.01
C133	Capacitor, 0.1µF, 20%, 50V	C-365-0.01
C134	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C135	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C136	Capacitor, 200pF, 1%, 500V, Mica	C-209-200p
C137	Capacitor, 10µF, 16V, Aluminum Electrolytic	C-321-10
C138	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C139	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C140	Capacitor, 20pF, 5%, 500V Mica	C-236-20
C141	Not Used	
C142	Not Used	
C143	Not Used	
C144	Not Used	
C145	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
CR100	Diode, Silicon, 1N4148	RF-28
CR101	Diode, Silicon, 1N4148	RF-28
CR102	Diode, Silicon, 1N4148	RF-28
CR103	Diode, Silicon, 1N4148	RF-28

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
CR104	Diode, Silicon, 1N4148	RF-28
CR105	Diode, Silicon, 1N4148	RF-28
CR106	Diode, Silicon, 1N4148	RF-28
CR107	Not Used	
CR108	Diode, Silicon, 1N4148	RF-28
F100	Fuse, 1/8A, 250V, 8AG	FU-5
J1017	Connector, SMB Jack	CS-545
J1020	Connector	CS-533-9
J1021	Connector, Modified	590-320-1
J1023	Connector, SMB Jack	CS-545
J1024	Connector, SMB Jack	CS-545
J1025	Connector	CS-533-2
J1026	Connector	CS-533-10
J1027	Connector, Modified	590-320-1
J1029	Connector, SMB Jack	CS-545
J1030	Connector, SMB Jack	CS-545
J1031	Connector	CS-533-2
J1032	Connector, SMB Jack	CS-545
J1033	Connector, SMB Jack	CS-545
J1034	Connector, SMB Jack	CS-545
J1035	Connector, SMB Jack	CS-545
J1036	Connector, SMB Jack	CS-545
J1037	Connector, SMB Jack	CS-545
J1038	Connector, SMB Jack	CS-545
K100	Relay	RL-94
K101	Relay	RL-94
K102	Relay	RL-94
K103	Relay	RL-94
K104	Relay	RL-94
K105	Relay	RL-94
K106	Relay	RL-95
K107	Relay	RL-95
K108	Relay	RL-101
K109	Not Used	
K110	Not Used	
K111	Relay	RL-101
Q100	Transistor, N-Channel JFET, PF5301	TG-139
Q101	Transistor, N-Channel JFET, PF5301	TG-139
Q102	Transistor, N-Channel JFET, PF5301	TG-139
Q103	Transistor, N-Channel JFET, PF5301	TG-139
Q104	Transistor, N-Channel JFET, PF5301	TG-139
Q105	Transistor, N-Channel JFET, PF5301	TG-139
Q106	Transistor, N-Channel JFET, PF5301	TG-139
Q107	Transistor, N-Channel JFET, PF5301	TG-139
Q108	Transistor, N-Channel JFET, PF5301	TG-139
Q109	Transistor, N-Channel JFET, PF5301	TG-139
Q110	Transistor, Silicon, NPN, 2N3904	TG-47

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
Q111	Transistor, N-Channel FET, 2N4392	TG-128
Q112	Transistor, N-Channel FET, 2N5434	TG-174
Q113	Not Used	
Q114	Not Used	
Q115	Not Used	
Q116	Transistor, MP8099	TG-157
Q117	Transistor, Power, NPN, MJE240	TG-185
Q118	Transistor, Power, PNP, MJE250	TG-186
Q119	Transistor, Power, PNP, MPS8599	TG-158
Q120	Diode, Current Regulator, J505	TG-140
Q121	Diode, Current Regulator, J505	TG-140
Q122	Transistor, Silicon, PNP, 2N3906	TG-84
Q123	Transistor, Silicon, PNP, 2N3904	TG-47
Q124	Transistor, N-Channel FET, 2N4392	TG-128
R100	Resistor, Thick Film	TF-177-3
R101	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R102	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R103	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R104	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R105	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R106	Resistor, 200Ω, 0.1%, $^1/_{10}$W, Metal Film	R-263-1k
R107	Resistor, 11.5kΩ, 1%, $^1/_8$W	R-88-11.5k
R108	Resistor, 26.7kΩ, 1%, $^1/_8$W	R-88-26.7k
R110	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R111	Resistor, 7.78kΩ, 0.1%, $^1/_8$W	R-176-7.78k
R112	Resistor, 142.8kΩ, 0.1%, $^1/_8$W	R-176-142.8k
R113	Resistor, 1MΩ, 0.1%, $^1/_8$W	R-176-1M
R114	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R115	Resistor, 3.9kΩ, 5%, ¼W, Composition	R-76-3.9k
R116	Resistor, 3kΩ, 5%, ¼W, Composition	R-76-3k
R117	Resistor, 3kΩ, 5%, ¼W, Composition	R-76-3k
R118	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R119	Resistor, 220kΩ, 5%, ¼W, Composition	R-76-220k
R120	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R121	Resistor, 7.87kΩ, 1%, $^1/_8$W	R-88-7.87k
R122	Resistor, 1kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-1k
R123	Resistor, 4kΩ, 0.1%. $^1/_{10}$W, Metal Film	R-263-4k
R124	Resistor, 1.33kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-1.33k
R125	Resistor, 1kΩ, 1%, $^1/_8$W	R-88-1k
R126	Resistor, 3.65kΩ, 1%, $^1/_8$W	R-88-3.65k
R127	Resistor, 6.49kΩ, 1%, $^1/_8$W	R-88-6.49k
R128	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R129	Resistor, 10kΩ, 1%, $^1/_8$W	R-88-10k
R130	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R131	Resistor, Thick Film	TF-108
R132	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R133	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R134	Resistor, Thick Film	TF-179-1
R135	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R136	Not Used	

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R137	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R138	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R139	Resistor, 6.2kΩ, 5%, ¼W, Composition	R-76-6.2k
R140	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R141	Resistor, 6.2kΩ, 5%, ¼W, Composition	R-76-6.2k
R142	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R143	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R144	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R145	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R146	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R147	Resistor, 2.2MΩ, 5%, ¼W, Composition	R-76-2.2M
R148	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R149	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R150	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R151	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R152	Potentiometer, 10kΩ, ½W, Cermet	RP-97-10k
R153	Resistor, 301kΩ, 1%, 1/8W	R-88-301k
R154	Resistor, 6.04kΩ, 1%, 1/8W	R-88-6.04k
R155	Resistor, 301kΩ, 1%, 1/8W	R-88-301k
R156	Potentiometer, 100kΩ, ½W, Cermet	RP-97-100k
R157	Potentiometer, 100kΩ, ½W, Cermet	RP-97-100k
R158	Resistor, 1MΩ, 1%, 1/8W	R-88-1M
R159	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R160	Resistor, 49.9kΩ, 1%, 1/8W	R-88-49.9k
R161	Resistor, 9.76kΩ, 0.1%, 1/10W, Metal Film	R-263-9.76k
R162	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R163	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R164	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R165	Resistor, 191kΩ, 1%, 1/8W	R-88-191k
R166	Resistor, 200Ω, 5%, ¼W, Composition	R-76-200
R167	Resistor, 200Ω, 5%, ¼W, Composition	R-76-200
R168	Resistor, 12Ω, 5%, ¼W, Composition	R-76-12
R169	Resistor, 12Ω, 5%, ¼W, Composition	R-76-12
R170	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R171	Resistor, 866Ω, 1%, 1/8W	R-88-866
R172	Resistor, 3.83kΩ, 1%, 1/8W	R-88-3.83k
R173	Resistor, 6.19kΩ, 1%, 1/8W	R-88-6.19k
R174	Resistor, Thick Film	TF-39
R175	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R176	Resistor, 10kΩ, 1%, 1/8W	R-88-10k
R177	Resistor, 866Ω, 1%, 1/8W	R-88-866
R178	Resitor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R179	Resistor, Thick Film	TF-178-1
R180	Resistor, 1.8kΩ, 0.1%, 1/10W, Metal Film	R-263-1.8k
R181	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R182	Resistor, 990kΩ, 0.1%, ¼W, Metal Film	R-264-990k
R183	Resistor, 100kΩ, 0.1%, 1/10W, Metal Film	R-263-100k
R184	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R185	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R186	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R187	Not Used	

Table 8-1. Mother Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R188	Resistor, 900kΩ, 0.1%, ¼W, Metal Film	R-264-900k
S100	Switch	SW-318
U100	IC, LF442A	IC-410
U101	IC, Triple 2-Channel Analog Mux, CD4053B	IC-283
U102	IC, Selected	31847-1
U103	IC, Quad 2-Input NAND Gate, 74HC00	IC-351
U104	IC, Quad 2-Input NOR Gate, 74HC02	IC-412
U105	IC, Synchronous Decade Counter, 74HC192	IC-417
U106	IC, Synchronous Binary Counter, 74HC193	IC-416
U107	IC, Quad Comparator, LM339	IC-219
U108	IC, Dual D Flip-Flop, 74HC74	IC-337
U109	IC, Dual D Flip-Flop, 74HC74	IC-337
U110	IC, Operational Amplifier, LM356	IC-209
U111	IC, Dual Comparator, LM393	IC-343
U112	IC, JFET Operational Amplifier, LM356	IC-209
U113	IC, Dual JFET Operational Amplifier, LF442C	IC-325
U114	IC, Quad Comparator, LM339	IC-219
U115	IC, 1-of-8 Decoder, 74HC138	IC-431
U116	IC, Quad Comparator, LM339	IC-219
U117	IC, Quad Comparator, LM339	IC-219
U118	IC, CMOS, Quad 2-Input NAND Gate, 4011	IC-102
U119	IC, CMOS, Hex Inverter, 4049	IC-106
U120	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U121	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U122	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U123	IC, CMOS, 8-Stage Shift/Store Register, 14094BCP	IC-251
U124	IC, Darlington Transistor Array, 2003	IC-206
U125	IC, CMOS 8-Stage Shift Register, 4021	IC-130
U126	IC, Quad Comparator, LM339	IC-219
U127	IC, D/A Converter, DAC80	IC-323
U128	IC, Operational Amplifier, AD-3247	IC-77
U129	IC, Quad Comparator, LM339	IC-219
U130	IC, High Voltage Operational Amplifier, LM343H	IC-432
U131	IC, Quad CMOS Analog Switch, DG211	IC-320
U132	Not Used	
U133	IC, Counter, 74LS90	IC-377
U134	IC, Dual Power MOSFET Driver, TSC426	IC-437
U135	IC, Hex Inverter, 74HC04	IC-354
VR100	Regulator, Zener Diode, 6.33V, 400mW, 1N4577A	DZ-58
VR101	Regulator, Zener Diode, 5.1V, 10%, 400mW, 1N751	DZ-59
Y100	Crystal, 8MHz, ±100ppm	CR-25-4

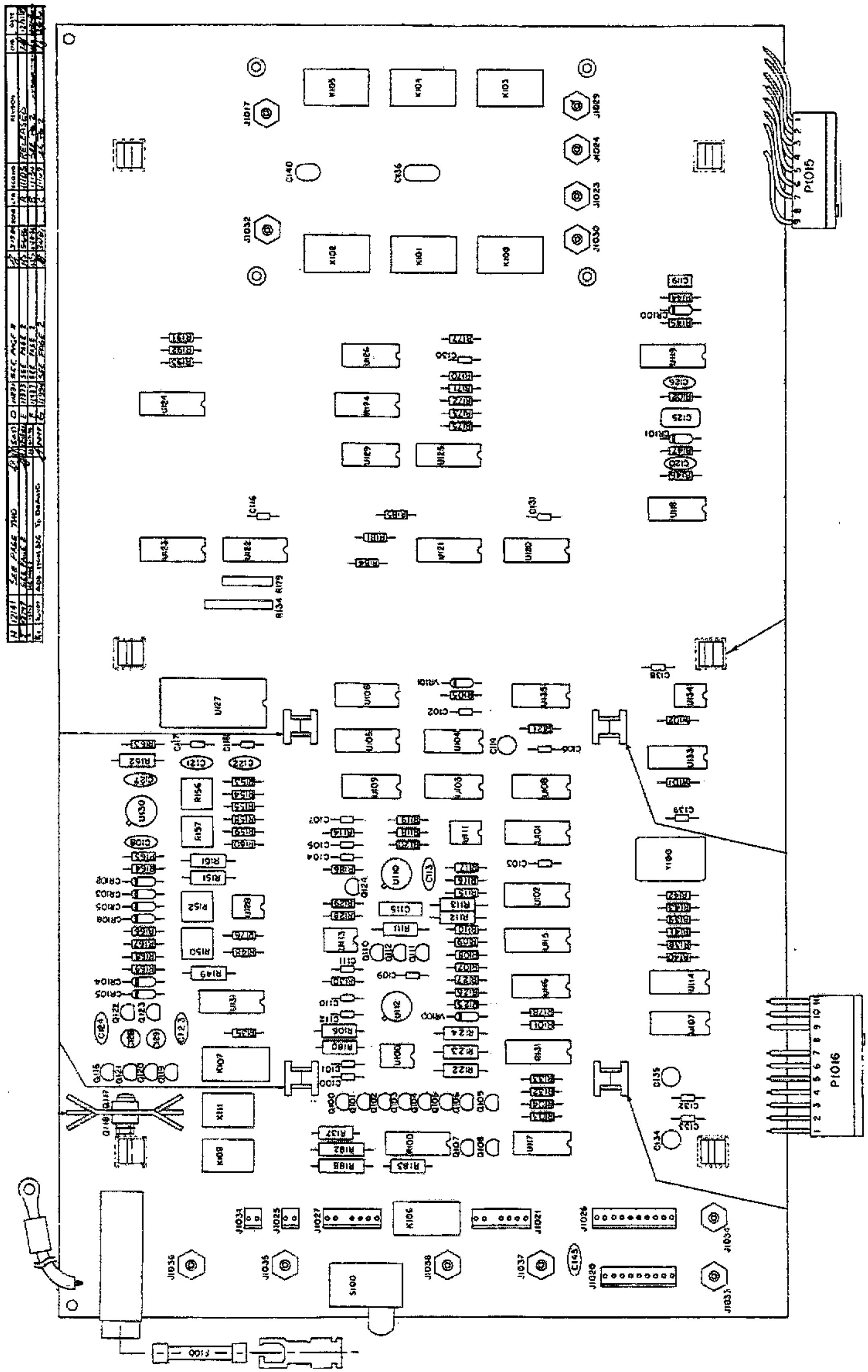


Figure 8-1. Mother Board, Component Location Drawing, Dwg. No. 590-100

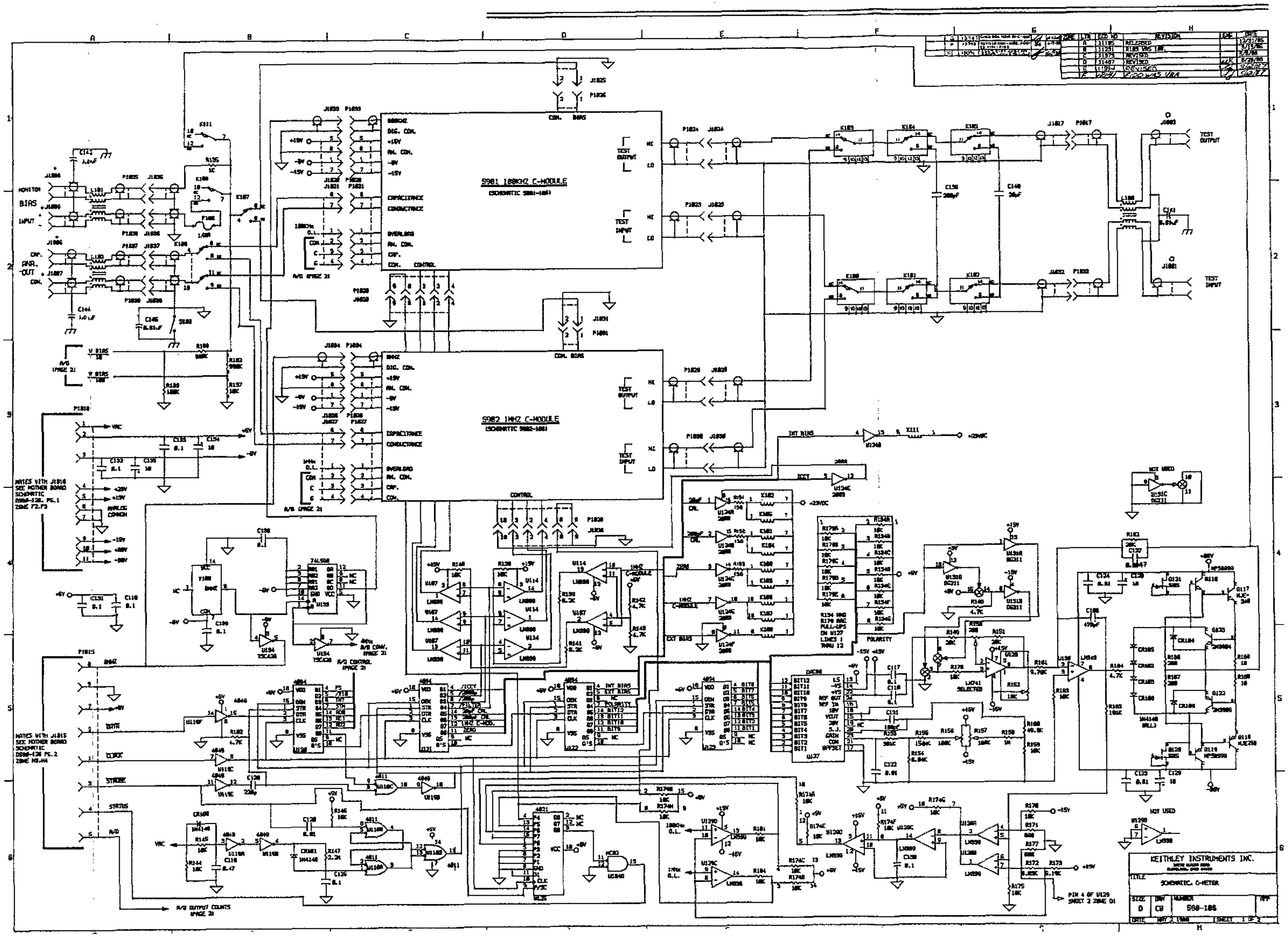


Figure 8-2. Mother Board, Schematic Diagram, Dwg. No. 590-106 (sheet 1 of 2)

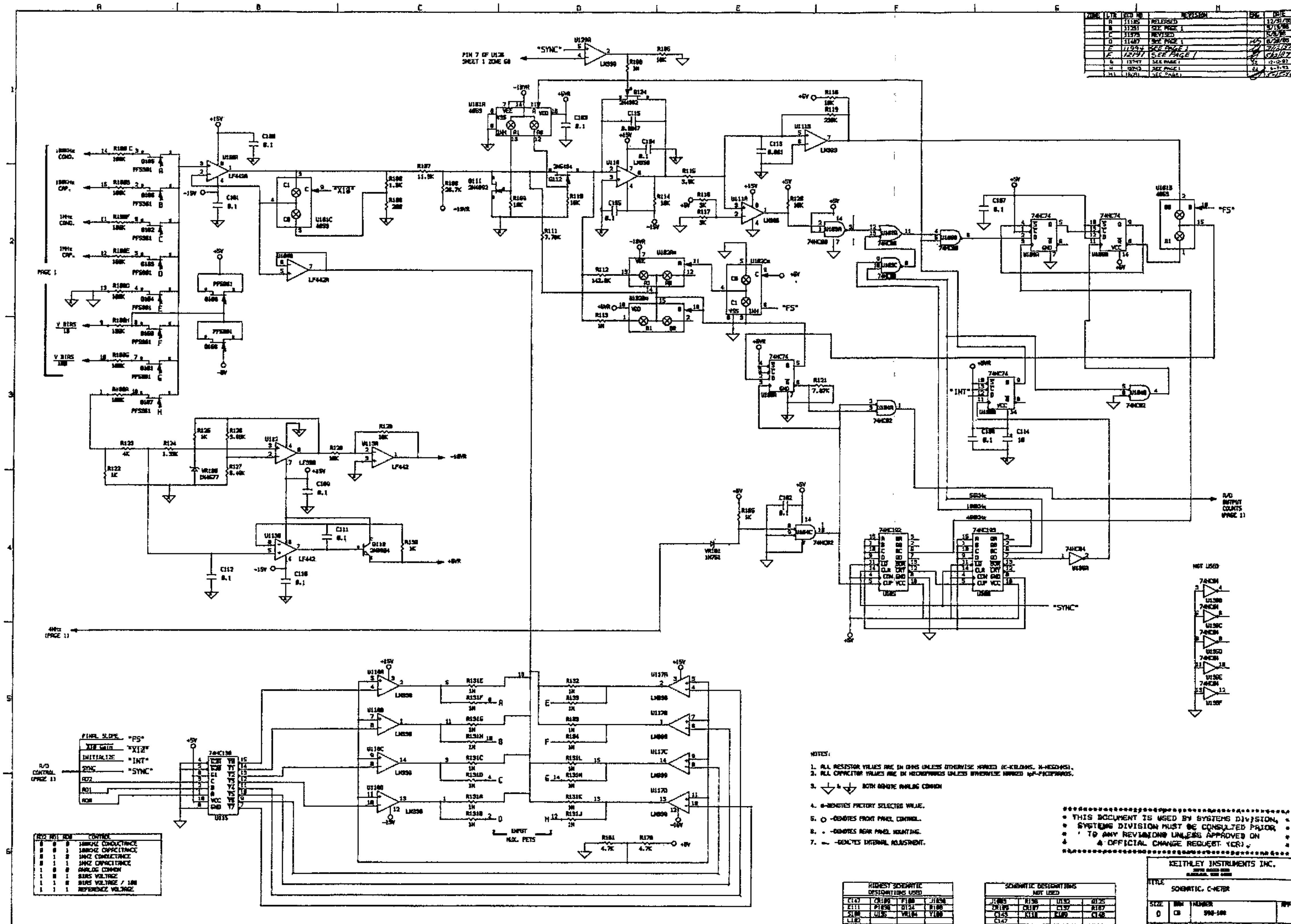


Figure 8-2. Mother Board, Schematic Diagram, Dwg. N. 590-106 (sheet 2 of 2)

Table 8-2. Display Board, Parts List

Circuit Designation	Description	Keithley Part Number
C201	Capacitor, 0.1µF, 20%, 50V	C-365-.1
C202	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
DS201	Digital Display, Dual-Digit, 14-Segment	DD-39
DS202	Digital Display, Dual-Digit, 14-Segment	DD-39
DS203	Digital Display, Dual-Digit, 14-Segment	DD-39
DS204	Digital Display, Dual-Digit, 14-Segment	DD-39
DS205	Digital Display, Dual-Digit, 14-Segment	DD-39
DS206	Digital Display, Dual-Digit, 14-Segment	DD-39
DS207	Digital Display, Dual-Digit, 14-Segment	DD-39
DS208	Digital Display, Dual-Digit, 14-Segment	DD-39
DS209	Digital Display, Dual-Digit, 14-Segment	DD-39
DS210	Digital Display, Dual-Digit, 14-Segment	DD-39
DS211	LED, Red	PL-71
DS212	LED, Red	PL-71
DS213	LED, Red	PL-71
DS214	LED, Red	PL-71
DS215	LED, Red	PL-71
DS216	LED, Red	PL-71
DS217	LED, Yellow	PL-72
DS218	LED, Red	PL-71
DS219	LED, Red	PL-71
DS220	LED, Red	PL-71
DS221	LED, Red	PL-71
DS222	LED, Red	PL-71
DS223	LED, Yellow	PL-72
P1014	Cable Assembly	CA-32-5
S201	Switch, Pushbutton Momentary Contact	SW-435
S202	Switch, Pushbutton Momentary Contact	SW-435
S203	Switch, Pushbutton Momentary Contact	SW-435
S204	Switch, Pushbutton Momentary Contact	SW-435
S205	Switch, Pushbutton Momentary Contact	SW-435
S206	Switch, Pushbutton Momentary Contact	SW-435
S207	Switch, Pushbutton Momentary Contact	SW-435
S208	Switch, Pushbutton Momentary Contact	SW-435
S209	Switch, Pushbutton Momentary Contact	SW-435
S210	Switch, Pushbutton Momentary Contact	SW-435
S211	Switch, Pushbutton Momentary Contact	SW-435
S212	Switch, Pushbutton Momentary Contact	SW-435
S213	Switch, Pushbutton Momentary Contact	SW-435
S214	Switch, Pushbutton Momentary Contact	SW-435
S215	Switch, Pushbutton Momentary Contact	SW-435
S216	Switch, Pushbutton Momentary Contact	SW-435
S217	Switch, Pushbutton Momentary Contact	SW-435
S218	Switch, Pushbutton Momentary Contact	SW-435
S219	Switch, Pushbutton Momentary Contact	SW-435
S220	Switch, Pushbutton Momentary Contact	SW-435
S221	Switch, Pushbutton Momentary Contact	SW-435
S222	Switch, Pushbutton Momentary Contact	SW-435

Table 8-2. Display Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
S223	Switch, Pushbutton Momentary Contact	SW-435
S224	Switch, Pushbutton Momentary Contact	SW-435
S225	Switch, Pushbutton Momentary Contact	SW-435
S226	Switch, Pushbutton Momentary Contact	SW-435
S227	Switch, Pushbutton Momentary Contact	SW-435
S228	Switch, Pushbutton Momentary Contact	SW-435
S229	Switch, Pushbutton Momentary Contact	SW-435
S230	Switch, Pushbutton Momentary Contact	SW-435
S231	Switch, Pushbutton Momentary Contact	SW-435
S232	Switch, Pushbutton Momentary Contact	SW-435
S233	Switch, Pushbutton Momentary Contact	SW-435
U201	Int. Circuit (2003)	IC-206
U202	Int. Circuit (2003)	IC-206
U203	Int. Circuit (2003)	IC-206
U204	Int. Circuit (74LS05)	IC-141
U205	Int. Circuit (74LS05)	IC-141
U206	Int. Circuit (74HCT164)	IC-456
U207	Int. Circuit (74HCT164)	IC-456

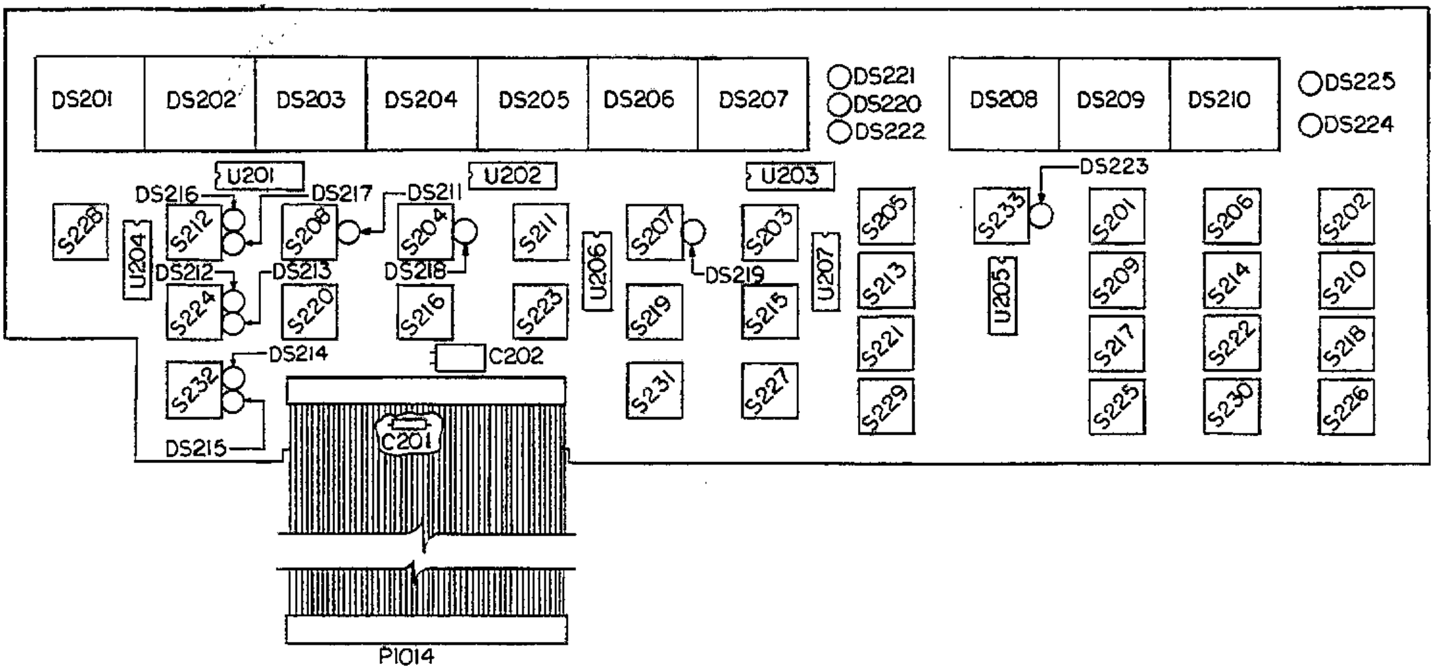


Figure 8-3. Display Board, Component Location Drawing, Dwg. No. 590-110

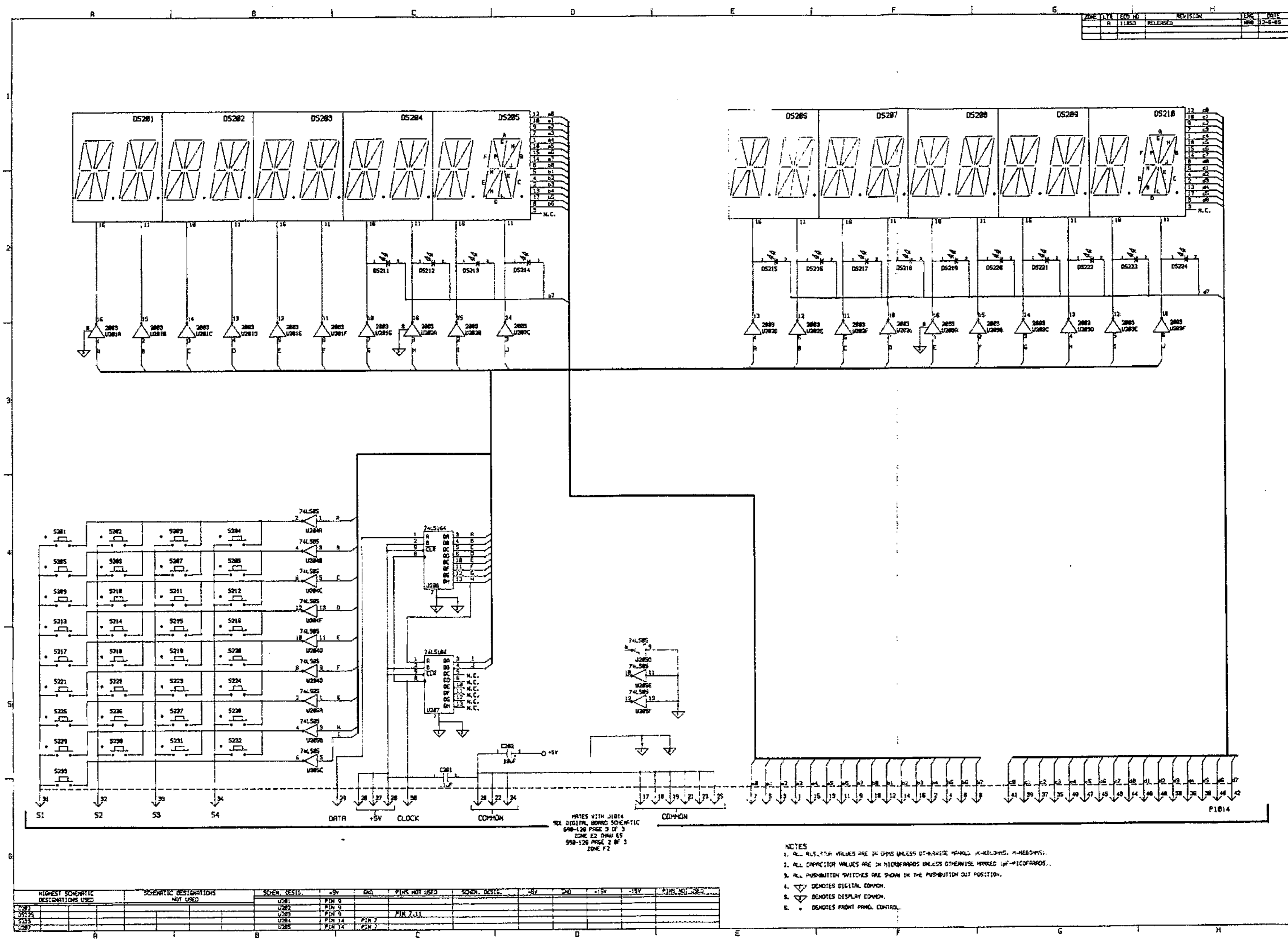


Figure 8-4. Display Board, Schematic Diagram, Dwg. No. 590-116

Table 8-3. Digital Board, Parts List

Circuit Designation	Description	Keithley Part Number
C301	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C302	Not Used	
C303	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C304	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C305	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C306	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C307	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C308	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C309	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C310	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C311	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C312	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C313	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C314	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C315	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C316	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C317	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C318	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C319	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C320	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C321	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C322	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C323	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C324	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C325	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C326	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C327	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C328	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C329	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C330	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C331	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C332	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C333	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C334	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C335	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C336	Not Used	
C337	Not Used	
C338	Not Used	
C339	Not Used	
C340	Capacitor, 6800µF, 25V, Aluminum Electrolytic	C-314-6800
C341	Capacitor, 470µF, 50V, Aluminum Electrolytic	C-276-470
C342	Capacitor, 470µF, 50V, Aluminum Electrolytic	C-276-470
C343	Capacitor, 2200µF, 35V, Aluminum Electrolytic	C-309-2200
C344	Capacitor, 2200µF, 35V, Aluminum Electrolytic	C-309-2200
C345	Capacitor, 4700µF, 16V, Aluminum Electrolytic	C-313-4700
C346	Capacitor, 2200µF, 16V, Aluminum Electrolytic	C-351-2200
C347	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C348	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C349	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C350	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C351	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C352	Not Used	
C353	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.1
CR301	Diode, Silicon, 1N4148	RF-28
CR302	Diode, Silicon, 1N4148	RF-28
CR303	Rectifier, Bridge, 1A, 100PIV	RF-52
CR304	Not Used	
CR305	Rectifier, Bridge, 5A, 50PIV, PE05	RF-48
CR306	Rectifier, Bridge, 1A, 100PIV	RF-52
CR307	Rectifier, Bridge, 1A, 100PIV	RF-52
CR308	Rectifier, Bridge, 1A, 100PIV	RF-52
CR309	Diode, 1A, 800PIV, 1N4006	RF-38
F300	Fuse, 3AG, 0.5A, (180-220V Operation)	FU-4
F300	Fuse, 3AG, 1A, (90-110V Operation)	FU-10
F300	Fuse, 3AG, 3/8A, (210-250V Operation)	FU-18
F300	Fuse, 3AG, ¾A, (105-125V Operation)	FU-19
F300	Fuse, 5mm, 0.8A, (105-125V; requires FH-26 Fuse Carrier)	FU-71
F300	Fuse, 5mm, 0.4A, (210-250V; requires FH-26 Fuse Carrier)	FU-80
J1004	Connector, BNC	CS-506
J1005	Connector, BNC	CS-506
J1011	Connector, IEEE-488	CS-501
J1012	Connector, Modified	740-309
J1013	Connector Pins	CS-288-2
J1014	Connector Pins	CS-389-9
J1015	Connector, Modified	590-314-2
J1016	Connector, Modified	590-314-1
Q300	Transistor, Power, PNP, 2N5193	TG-107
Q301	Transistor, Power, NPN, 2N5190	TG-108
R301	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R302	Resistor, 510Ω, 5%, ¼W, Composition	R-76-510
R303	Resistor, 61.9kΩ, 1%, 1/8W	R-88-61.9K
R304	Resistor, 1MΩ, 5%, ¼W, Composition	R-76-1M
R305	Resistor, 20kΩ, 1%, 1/8W	R-88-20k
R306	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R307	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R308	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R309	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R310	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R311	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R312	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R313	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R314	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R315	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R316	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R317	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R318	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R319	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R320	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R321	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R322	Resistor, 360Ω, 5%, ¼W, Composition	R-76-360
R323	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R324	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R325	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R326	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R327	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R328	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R329	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R330	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R331	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R332	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R333	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R334	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R335	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R336	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R337	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R338	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R339	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R340	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R341	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R342	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R343	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R344	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R345	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R346	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R347	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R348	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R349	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R350	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R351	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R352	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R353	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R354	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R355	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R356	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R357	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R358	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R359	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R360	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R361	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R362	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R363	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R364	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R365	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R366	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R367	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R368	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R369	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R370	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k

Table 8-3. Digital Board, Parts List (Cont.)

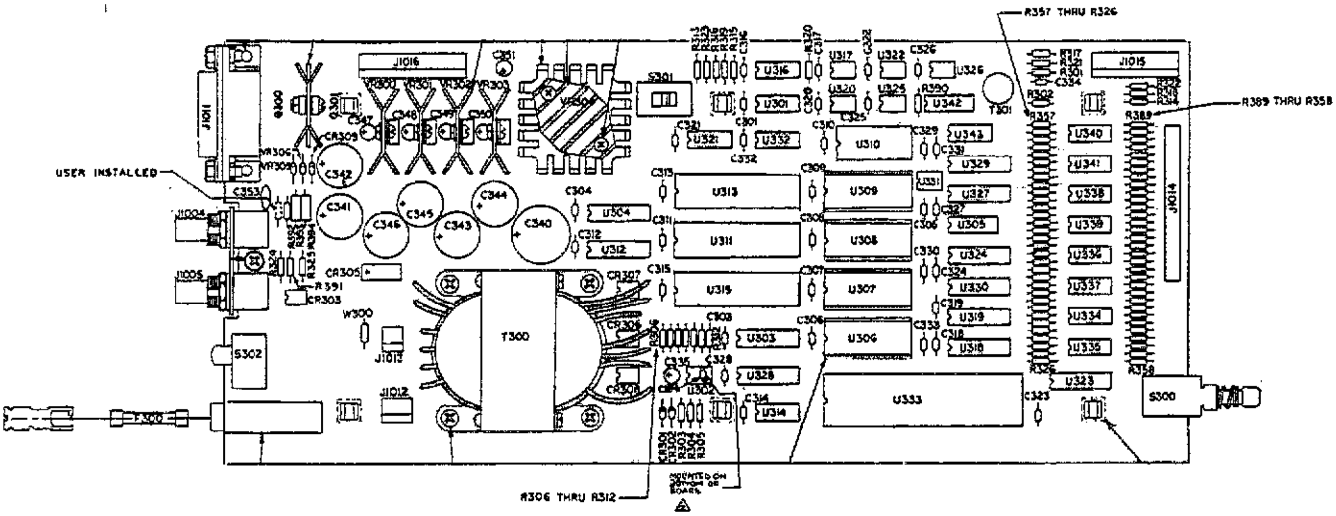
Circuit Designation	Description	Keithley Part Number
R371	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R372	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R373	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R374	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R375	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R376	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R377	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R378	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R379	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R380	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R381	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R382	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R383	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R384	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R385	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R386	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R387	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R388	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R389	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62k
R390	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R391	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100k
R392	Resistor, 220k, 5%, ¼W, Composition	R-76-220k
R393	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R394	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
S300	Switch, Off/On	SW-466
S301	Switch, Calibration Lock	SW-397
S302	Switch, Voltage Select	SW-318
T300	Transformer, Power, 105-125V, 210-250V	TR-226
T300	Transformer, Power, 90-110V, 180-220V	TR-229
T301	Transformer	TR-228
U301	IC, Quad 2-Input NOR Gate, 74HCT02	IC-510
U302	IC, Micropower Bipolar Monolithic, 8211	IC-177
U303	IC, AND, OR Array, PAL16P8A	590-802*
U304	IC, Octal Bus Transceiver, 75160A	IC-298
U305	IC, 1-of-8 Decoder, 74HCT138	IC-398
U306	IC, ROM, 8k × 8 Bit, 2764	590-800*
U307	IC, ROM, 64k × 8 Bit, 27256	590-801*
U308	IC, 8k Byte Static CMOS, RAM, HM6264LP-15	LSI-66
U309	IC, 8k Byte Static CMOS, RAM, HM6264LP-15	LSI-66
U310	IC, Programmable E²ROM, 2816	LSI-83
U311	IC, General Purpose Interface, 9914A	LSI-49
U312	IC, Octal Bus Transceiver, 75161A	IC-299
U313	IC, Versatile Interface Adapter (VIA), 6522A	LSI-45
U314	IC, Quad 2-Input OR Gate, 74HCT32	IC-443
U315	IC, 8-Bit Microprocessor (2MHz), 68B09	LSI-65
U316	IC, Hex Inverter, 74HCT04	IC-444
U317	IC, Opto-coupler, HCPL-2601	IC-239
U318	IC, CMOS, Octal D-Type Flip-Flop, 74HCT374	IC-397

Table 8-3. Digital Board, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
U319	IC, CMOS, Octal D-Type Flip-Flop, 74HCT374	IC-397
U320	IC, Optocoupler, HCPL-2601	IC-239
U321	IC, 12-Stage Binary Counter, 4040B	IC-348
U322	IC, Optocoupler, HCPL-2601	IC-239
U323	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U324	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U325	IC, Optocoupler, HCPL-2601	IC-239
U326	IC, Optocoupler, HCPL-2601	IC-239
U327	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U328	IC, AND, OR Array, PAL16P8A	590-803*
U329	IC, CMOS Octal D-Type Flip-Flop, 74HCT374	IC-397
U330	IC, 74LS273	IC-263
U331	IC, 75157	IC-429
U332	IC, 74HCT393	IC-462
U333	IC, 16 × 16 Bit Parallel Multiplier, 7216	LSI-71
U334	IC, Transistor Array, MPQ3906	IC-396
U335	IC, Transistor Array, MPQ3906	IC-396
U336	IC, Transistor Array, MPQ3906	IC-396
U337	IC, Transistor Array, MPQ3906	IC-396
U338	IC, Transistor Array, MPQ3906	IC-396
U339	IC, Transistor Array, MPQ3906	IC-396
U340	IC, Transistor Array, MPQ3906	IC-396
U341	IC, Transistor Array, MPQ3906	IC-396
U342	IC, 12-Stage Binary Counter, 74HC4040	IC-407
U343	IC, Dual D-Type Flip-Flop, 74LS74	IC-144
VR300	Regulator, IC, +5V, 7805	IC-93
VR301	Regulator, IC, -5V, 7905	IC-184
VR302	Regulator, IC, +15V, 78M15CV	IC-194
VR303	Regulator, IC, −15V, MC7915CT	IC-174
VR304	Regulator, IC, +5V, 323	IC-240
VR305	Zener Diode, 30V, 1W, 1N4751	DZ-78
VR306	Zener Diode, 30V, 1W, 1N4751	DZ-78
W300	Jumper	J-3

*Order same digits as present revision level marked on IC.

ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	11053	RELEASED	[illegible]	12-5-85
	B	11134	[illegible]	[illegible]	1-24-86
	C	11221	SEE PAGE 2	[illegible]	2-7-86
	D	11255	SEE PAGE 2	[illegible]	3-12-86
	E	11297	SEE PG. 2	[illegible]	4-2-86
	F	11405	SEE PG. 2	[illegible]	5-16-86
	G	11511	SEE PG 2	[illegible]	7-23-86
	H	11816	SEE PG. 2	[illegible]	12/8/86
	J	11868	SEE PG. 2	[illegible]	1/6/87
	K	11929	SEE PG. 2	[illegible]	2/5/87
	L	12248	SEE PG. 2	[illegible]	8-18-87
	M	12824	SEE PG. 2	[illegible]	6-22-88
	N	[illegible]	[illegible] U308 AND U309	[illegible]	[illegible]
	P	[illegible]	[illegible]	[illegible]	[illegible]
	R	14617	SEE PAGE TWO	[illegible]	[illegible]
	S	15192	SEE PAGE TWO	[illegible]	[illegible]
	S1	16449	ADD ITEM 326	[illegible]	[illegible]
	S2	18071	ADD C359	[illegible]	[illegible]



108-125V	AMERICAN	FU-25	FU-19
210-250V			FU-18
105-125V	EUROPEAN	FH-26	FU-52
210-250V			FU-53
90-110V	JAPANESE	FH-26	FU-72
180-220V			FU-71

Figure 8-5. Digital Board, Bomponent Location Drawing, Dwg. No. 590-120

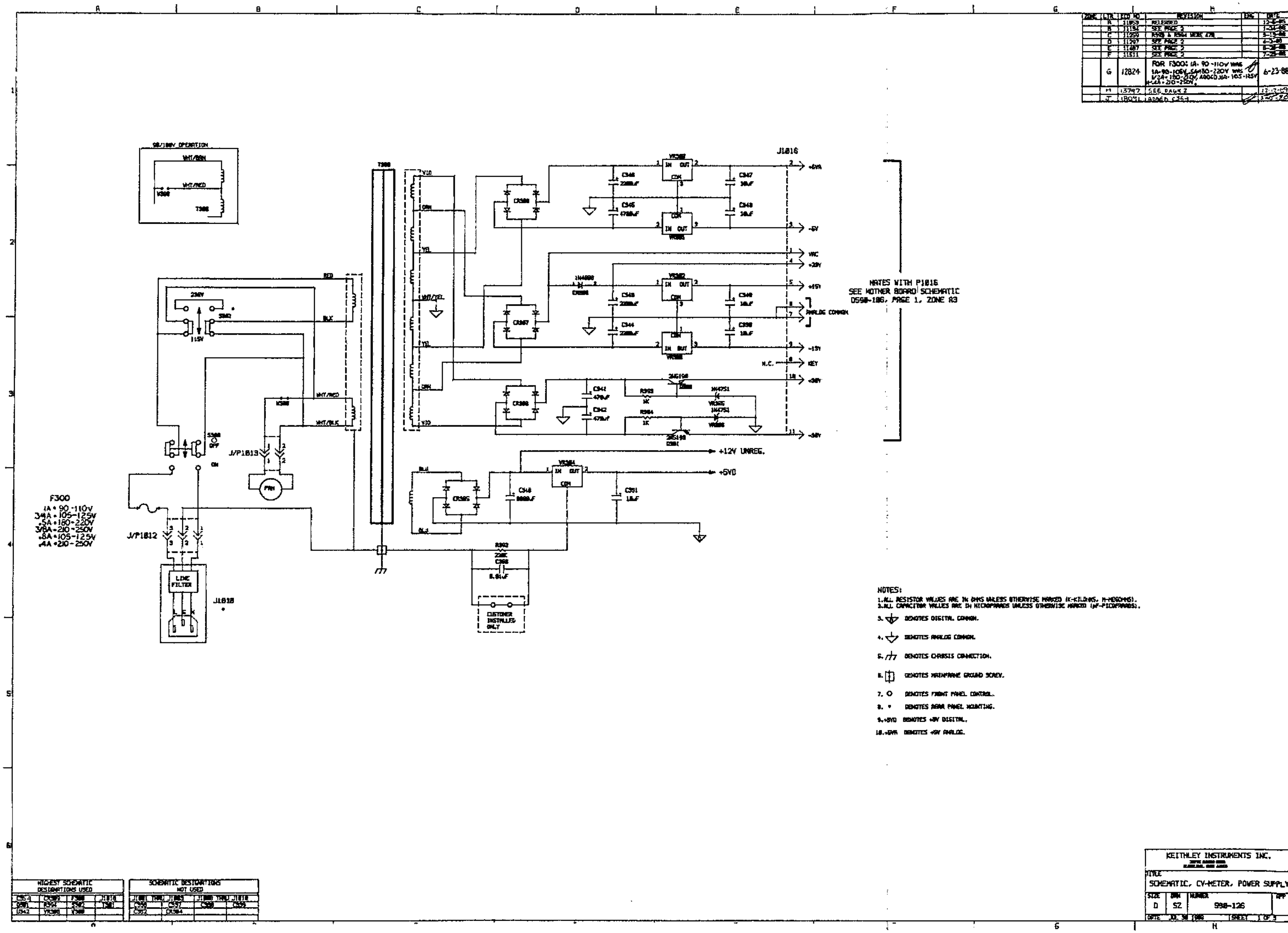


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 1 of 3)

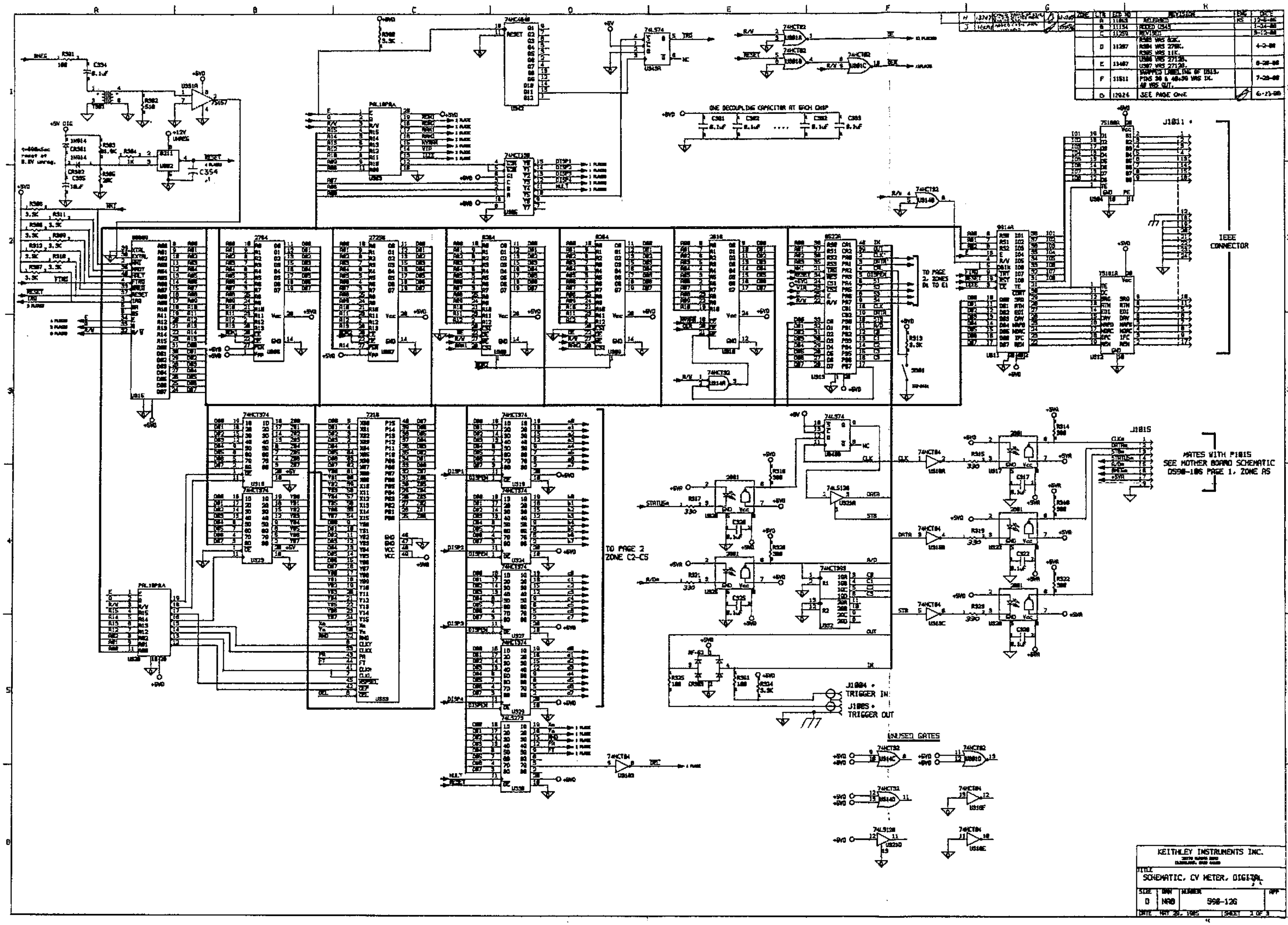


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 2 of 3)

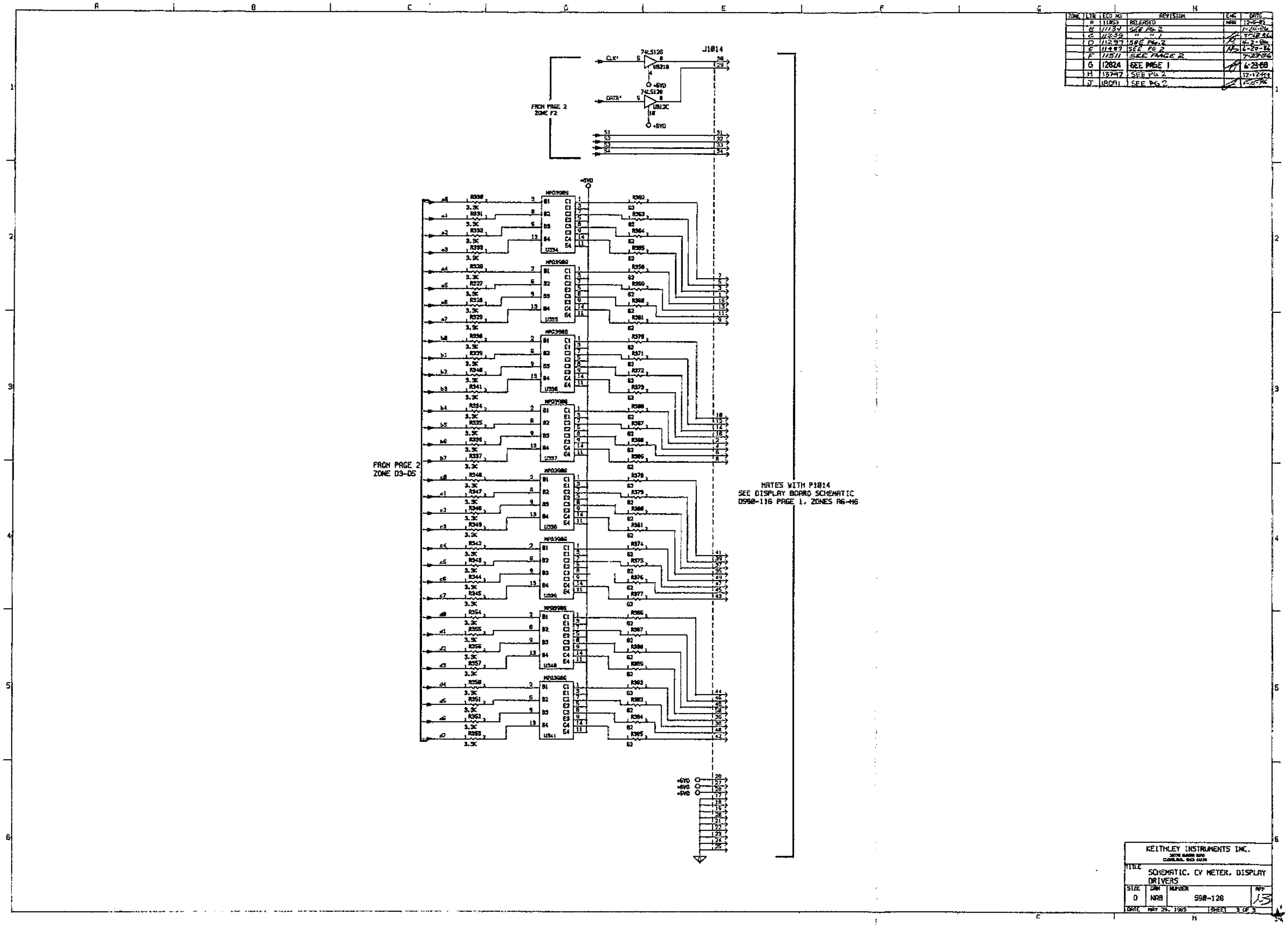


Figure 8-6. Digital Board, Schematic Diagram, Dwg. No. 590-126 (sheet 3 of 3)

Table 8-4. 100kHz (5901) Module, Parts List

Circuit Designation	Description	Keithley Part Number
AT500	IC, Optocoupler, CLM6500	IC-440
C500	Not Used	
C501	Not Used	
C502	Capacitor, 1000pF, 100V, Ceramic	C-372-1000p
C503	Capacitor, 1000pF, 100V, Ceramic	C-372-1000p
C504	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C505	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C506	Capacitor, 22pF, 500V, Ceramic Disc	C-22-22p
C507	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C508	Capacitor, 1µF, 50V, Metallized Polyester	C-350-1
C509	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C510	Capacitor, 0.01µF, 50V, Metallized Polycarbonate	C-201-.01
C511	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C512	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C513	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C514	Capacitor, 0.1µF, 50V, Metallized Polycarbonate	C-201-0.1
C515	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C516	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C517	Not Used	
C518	Not Used	
C519	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C520	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C521	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C522	Not Used	
C523	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C524	Not Used	
C525	Capacitor, 100pF	C-201-100p
C526	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C527	Capacitor, Trimmer, 7-70pF	C-345
C528	Capacitor, 150pF, 100V, Ceramic	C-372-150p
C529	Capacitor, Trimmer, 3-10pF	C-346
C530	Capacitor, 10pF, 100V, Ceramic	C-372-10p
C531	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C532	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C533	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C534	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C535	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-314-10
C536	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C537	Capacitor, 10pF, 500V Ceramic Disc	C-22-10p
C538	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C539	Capacitor, 1000p, 100V, Ceramic	C-372-1000p
C540	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C541	Capacitor, 15pF, 100V, Ceramic	C-372-15p
C542	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C543	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C544	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C545	Capacitor, 15pF, 100V, Ceramic	C-372-15p
C546	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C547	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C548	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C549	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C550	Capacitor, 1μF, 50V, Ceramic Film	C-237-1
C551	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C552	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C553	Capacitor, 0.022μF, 100V	C-371-0.022
C554	Capacitor, 0.033μF, 100V	C-371-0.033
C555	Capacitor, 100pF, 500V, Ceramic Disc	C-22-100p
C556	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C557	Capacitor, 1μF, 50V, Metallized Polyester	C-350-1
C558	Capacitor, 100pF, 500V, Ceramic Disc	C-22-100p
C559	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C560	Capacitor, 0.1μF, 20%, 50V	C-365-0.1
C561	Not Used	
C562	Not Used	
C563	Not Used	
C564	Not Used	
C565	Not Used	
C566	Not Used	
C567	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C568	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-0.01
C569	Not Used	
C570	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C571	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
CR500	Diode, Schottky Barrier, 1N5711	RF-69
CR501	Diode, Schottky Barrier, 1N5711	RF-69
CR502	Diode, Silicon, 1N4148	RF-28
CR503	Diode, Silicon, 1N4148	RF-28
CR504	Diode, Silicon, 1N4148	RF-28
CR505	Diode, Silicon, 1N4148	RF-28
CR506	Diode, Silicon, 1N4148	RF-28
CR507	Diode, Silicon, 1N4148	RF-28
CR508	Diode, Silicon, 1N4148	RF-28
CR509	Rectifier Bridge, 1A, 100PIV	RF-52
CR510	Not Used	
CR511	Not Used	
CR512	Diode, Silicon, 1N4148	RF-28
K500	Relay	RL-65
K501	Relay	RL-65
K502	Relay	RL-95
K503	Relay	RL-48
L500	Choke	CH-24
L501	Choke	CH-23
P1020	Connector Housing	CS-534-9
P1021	Connector Housing	CS-534-7
P1023	Cable Assembly	CA-50-3
P1024	Cable Assembly	CA-50-1
P1025	Connector Housing	CS-534-2

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
Q500	Transistor, Silicon, NPN, 2N3904	TG-47
Q501	Transistor, Silicon, NPN, 2N3904	TG-47
Q502	Transistor, N-Channel JFET, 2N4393	TG-130
Q503	Transistor, N-Channel JFET, 2N4393	TG-130
Q504	Transistor, N-Channel JFET, 2N4393	TG-130
Q505	Transistor, N-Channel JFET, 2N4393	TG-130
Q506	Transistor, N-Channel JFET, 2N4393	TG-130
Q507	Transistor, N-Channel JFET, 2N4393	TG-130
Q508	Transistor, N-Channel JFET, 2N4393	TG-130
Q509	Transistor, N-Channel JFET, 2N4393	TG-130
Q510	Transistor, Matched Dual-channel JFET, DN5566	TG-188
Q511	Not Used	
Q512	Transistor, Silicon, NPN, 2N3904	TG-47
Q513	Transistor, Silicon, NPN, 2N3904	TG-47
R500	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R501	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R502	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R503	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R504	Resistor, 1.07kΩ, 1%, 1/8W	R-88-1.07k
R505	Resistor, 2.32kΩ, 1%, 1/8W	R-88-2.32k
R506	Resistor, 2kΩ, 1%, 1/8W	R-88-2k
R507	Resistor, 499Ω, 1%, 1/8W	R-88-499
R508	Resistor, 510Ω, 5%, ¼W, Composition	R-76-510
R509	Resistor, 4.99kΩ, 1%, 1/8W	R-88-4.99k
R510	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R511	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R512	Resistor, 856Ω, 0.1%, 1/10W, Metal Film	R-263-856
R513	Potentiometer, 50Ω, ½W, Cermet	RP-97-50
R514	Resistor, 510Ω, 0.1%, 1/10W, Metal Film	R-263-510
R515	Potentiometer, 500Ω, ½W, Cermet	RP-97-500
R516	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R517	Resistor, 100kΩ, 5%, ¼w, Composition	R-76-100k
R518	Resistor, 4.32kΩ, 1%, 1/8W	R-88-4.32k
R519	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R520	Resistor, 79.6kΩ, 0.1%, 1/10W, Metal Film	R-263-79.6k
R521	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R522	Resistor, 8.75kΩ, 0.1%, 1/10W, Metal Film	R-263-8.75k
R523	Potentiometer, 20Ω, ½W, Cermet	RP-97-20
R524	Resistor, 794Ω, 0.1%, 1/10W, Metal Film	R-263-794
R525	Resistor, 100Ω, 5%, ½W, Composition	R-76-100
R526	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R527	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R528	Resistor, 1.5kΩ, 5%, ½W, Composition	R-76-1.5k
R529	Resistor, 100Ω, 5%, ½W, Composition	R-76-100
R530	Resistor, 1.5kΩ, 0.1%, 1/10W, Metal Film	R-263-1.5k
R531	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R532	Resistor, 1.67kΩ, 0.1%, 1/10W, Metal Film	R-263-1.67k
R533	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R534	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R535	Resistor, 1.67kΩ, 0.1%, 1/10W, Metal Film	R-263-1.67k

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R536	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R537	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R538	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R539	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R540	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R541	Resistor, 10MΩ, 10%, ¼W, Composition	R-76-10M
R542	Resistor, 6.8MΩ, 5%, ¼W, Composition	R-76-6.8M
R543	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R544	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R545	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R546	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R547	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R548	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R549	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R550	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R551	Not Used	
R552	Not Used	
R553	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R554	Resistor, selected with VR500	5901-600
R555	Not Used	
R556	Not Used	
R557	Not Used	
R558	Not Used	
R559	Not Used	
R560	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R561	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R562	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R563	Resistor, 4.7kΩ, 5%, ¼W, Composition	R-76-4.7k
R564	Resistor, 866Ω, 1%, 1/8W	R-88-866
R565	Not Used	
R566	Not Used	
R567	Not Used	
R568	Not Used	
R569	Resistor, 100kΩ, 10%, ½W, Composition	R-1-100k
R570	Resistor, 3.9Ω, 10%, ½W, Composition	R-1-3.9
T500	Transformer	TR-221
T501	Transformer	TR-222
T502	Transformer	TR-220
U500	Not Used	
U501	Not Used	
U502	IC, Quad 2-Input NOR Gate, 74F02	IC-435
U503	Not Used	
U504	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U505	IC, Dual D Edeg Triggered Flip-Flop, 74F74	IC-446
U506	IC, Hex Inverter, 74F04	IC-436
U507	IC, Quad 2-Input NAND Buffer, 74F38	IC-434
U508	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U509	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U510	IC, Bi-FET Operational Amplifier, AD542	IC-165

Table 8-4. 100kHz (5901) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
U511	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U512	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U513	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U514	IC, Very Wide Band Operational Amplifier, HA2625	IC-439
U515	IC, Bi-FET Operational Amplifier, LF442A	IC-410
U516	IC, Wideband Dual JFET Operational Amplifier, LF353N	IC-246
U517	IC, Bi-FET Operational Amplifier, LF442A	IC-410
U518	IC, Voltage Regulator, −5V, LM320LZ-5	IC-395
VR500	Zener Diode, Selected with R554	5901-600
W500	Connector Pin	CS-339-3
W500	Connector Pin Jumper	CS-476

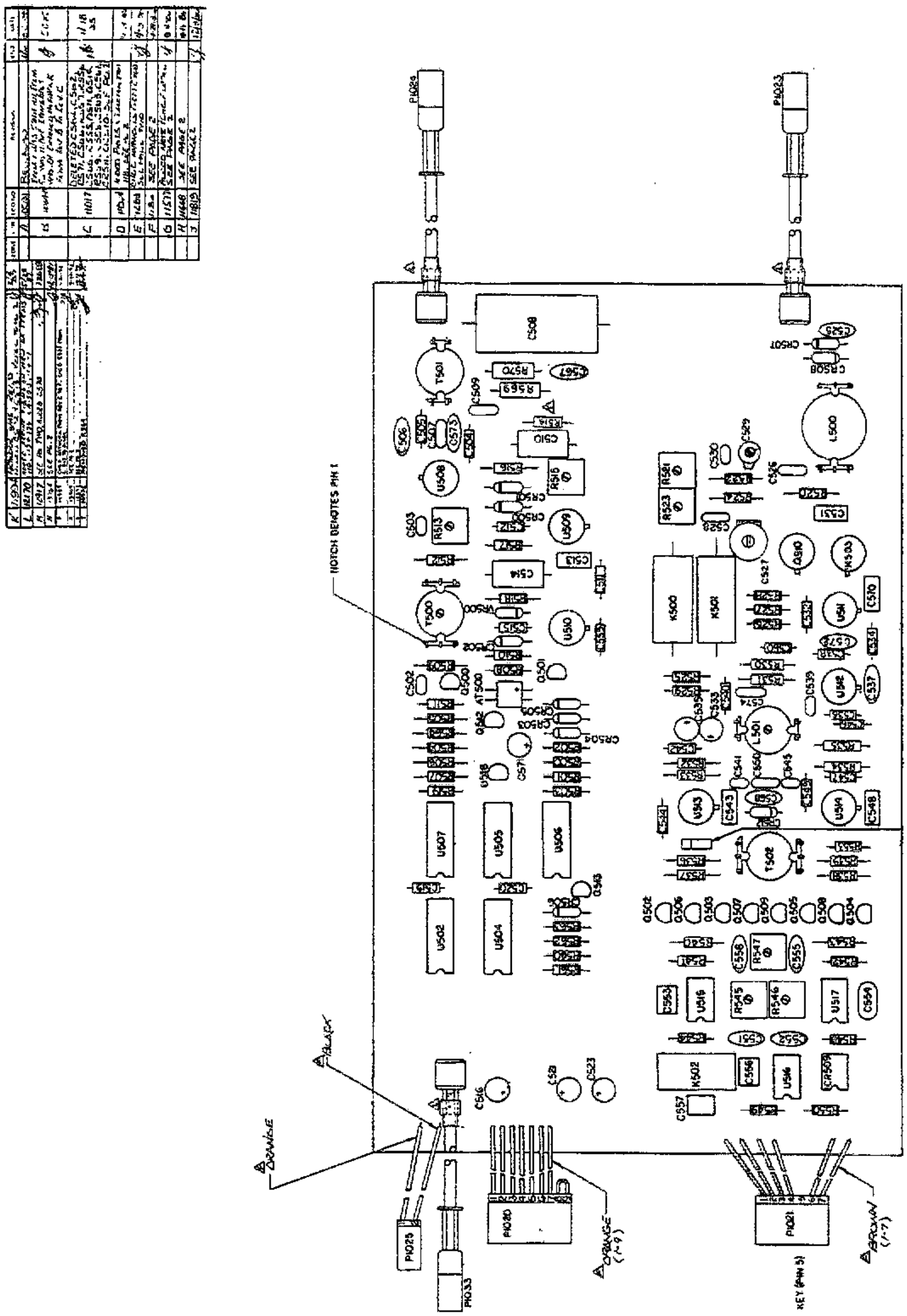


Figure 8-7. Model 5901 (100kHz), Component Location Drawing, Dwg. No. 5901-100

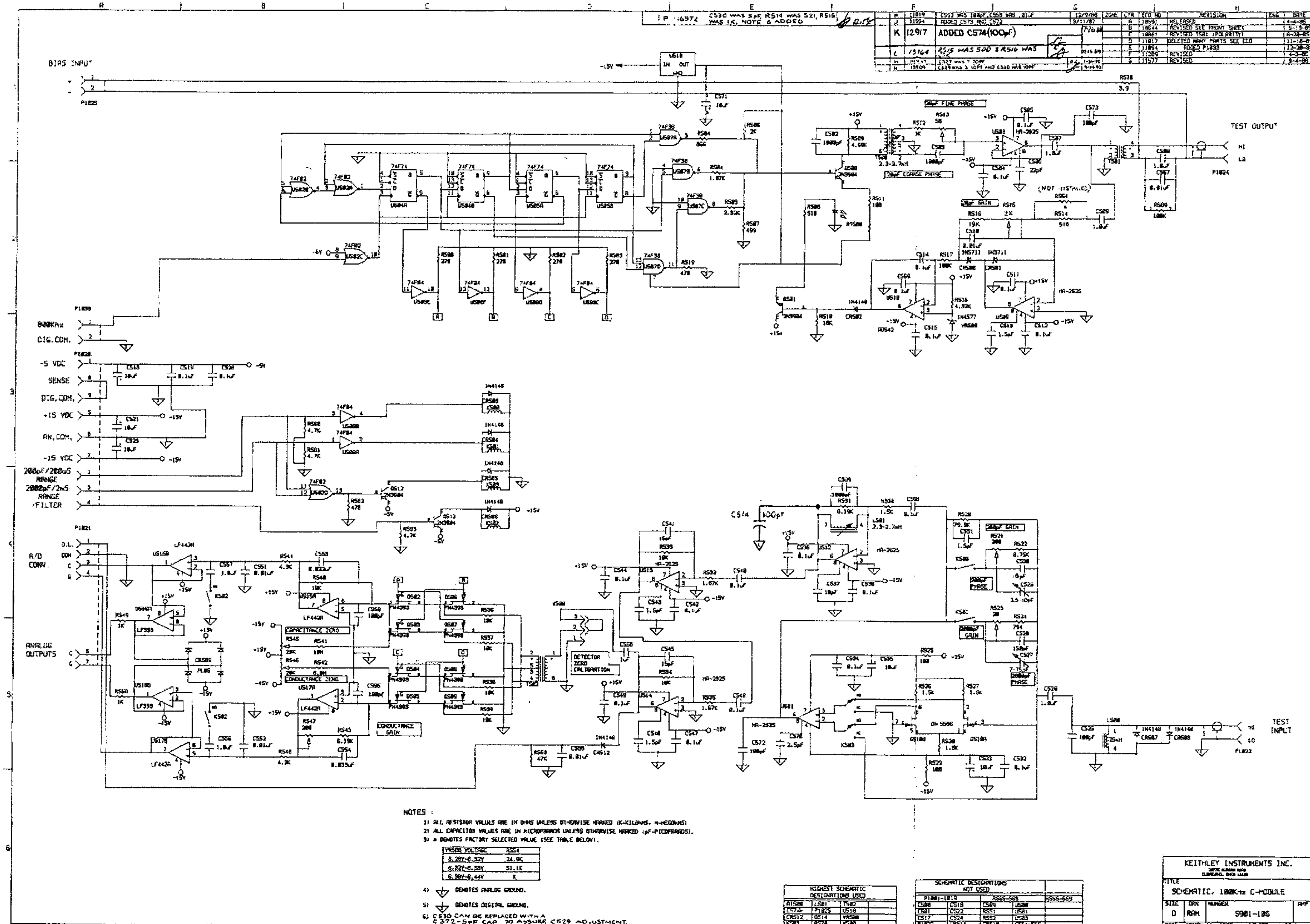


Figure 8-8. Model 5901 (100kHz), Schematic Diagram, Dwg. No. 5901-106

Table 8-5. 1MHz (5902) Module, Parts List

Circuit Designation	Description	Keithley Part Number
AT601	IC, Optocoupler, 6500	IC-440
C601	Capacitor, 100pF, 500V, Mica	C-209-100p
C602	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C603	Capacitor, 100pF, 500V, Mica	C-209-100p
C604	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C605	Capacitor, 0.033µF, 100V	C-371-.033
C606	Not Used	
C607	Capacitor, 1µF, 10%, 200V, Metallized Polypropylene	C-357-1
C608	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C609	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C610	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C611	Capacitor, 0.1µF, 50V, Metallized Polycarbonate	C-201-0.1
C612	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C613	Capacitor, 0.022µF, 100V	C-371-.022
C614	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C615	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C616	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C617	Not Used	
C618	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C619	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C620	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C621	Not Used	
C622	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C623	Not Used	
C624	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C625	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C626	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C627	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C628	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C629	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C630	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C631	Capacitor, 1µF, 50V, Metallized Polyester	C-350-1
C632	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C633	Capacitor, 0.022µF, 100V	C-371-0.022
C634	Capacitor, 15pF, Ceramic Disc	C-64-15p
C635	Capacitor, 100pF, Ceramic Disc	C-64-100p
C636	Capacitor, 1µF, 50V, Metallized Polyester	C-350-1
C637	Capacitor, 15pF, Ceramic Disc	C-64-15p
C638	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C639	Capacitor, 100pF, Ceramic Disc	C-64-100p
C640	Capacitor, 0.033µF, 100V	C-371-0.033
C641	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C642	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C643	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C644	Capacitor, 2.5pF, 50V, Tubular Ceramic	C-282-2.5p
C645	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C646	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C647	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C648	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C649	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
C650	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C651	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C652	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C653	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C654	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C655	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C656	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C657	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C658	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C659	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C660	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C661	Capacitor, 100pF, 500V, Mica	C-209-100p
C662	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C663	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C664	Capacitor, 1800pF, 500V, Mica	C-209-1800p
C665	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C666	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
C667	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C668	Capacitor, 33pF, Ceramic Disc	C-64-33p
C669	Capacitor, 2200pF, Ceramic Disc	C-64-2200p
C670	Capacitor, 100pF, Ceramic Disc	C-64-100p
C671	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C672	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C673	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C674	Capacitor, 1000pF, Ceramic Disc	C-64-1000p
C675	Caapcitor, 1000pF, Ceramic Disc	C-64-1000p
C676	Capacitor, 0.01µF, 500V, Ceramic Disc	C-22-0.01
C677	Capacitor, 0.1µF, 20%, 50V	C-365-0.1
C678	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C679	Capacitor, 270pF, EMI Suppression Filter	C-386-270p
CR601	Diode, Silicon, 1N4148	RF-28
CR602	Diode, Schottky Barrier, 1N5711	RF-69
CR603	Rectifier, Bridge, 1A, 100PIV	RF-52
CR604	Diode, Silicon, 1N4148	RF-28
CR605	Diode, Silicon, 1N4148	RF-28
CR606	Diode, Silicon, 1N4148	RF-28
CR607	Diode, Silicon, 1N4148	RF-28
CR608	Diode, Silicon, 1N4148	RF-28
K601	Relay	RL-102
K602	Relay	RL-102
K603	Relay	RL-102
K604	Relay	RL-102
K605	Relay	RL-102
K606	Realy	RL-95
K607	Relay	RL-101
L601	Choke	CH-26-220
L602	Choke	CH-33
L603	Choke	CH-33

Table 8-5. 1MHz (5902) Module, Parts List

Circuit Designation	Description	Keithley Part Number
L604	Choke	CH-33
L605	Choke	CH-33
L606	Choke	CH-33
L607	Choke	CH-33
L608	Choke	CH-33
L609	Choke	CH-33
L610	Choke	CH-33
L611	Choke	CH-33
L612	Choke	CH-33
L613	Choke	CH-26-220
L614	Choke	CH-33
L615	Choke	CH-33
L616	Choke	CH-33
L617	Choke	CH-26-15
L618	Choke	CH-33
P1026	Connector	CS-534-10
P1027	Connector	CS-534-7
P1029	Cable Assembly, 50Ω	CA-50-2
P1030	Cable Assembly, 50Ω	CA-50-1
P1031	Connector	CS-534-2
P1034	Cable Assembly, 50Ω	CA-50-3
Q601	Transistor, Silicon, NPN, 2N3904	TG-47
Q602	Transistor, Silicon, NPN, 2N3904	TG-47
Q603	Transistor, Silicon, NPN, 2N3904	TG-47
Q604	Transistor, N-Channel JFET, 2N4393	TG-130
Q605	Transistor, N-Channel JFET, 2N4393	TG-130
Q606	Transistor, N-Channel JFET, 2N4393	TG-130
Q607	Transistor, N-Channel JFET, 2N4393	TG-130
Q608	Transistor, N-Channel JFET, 2N4393	TG-130
Q609	Transistor, N-Channel JFET, 2N4393	TG-130
Q610	Transistor, N-Channel JFET, 2N4393	TG-130
Q611	Transistor, N-Channel JFET, 2N4393	TG-130
R601	Not Used	
R602	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R603	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R604	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R605	Resistor, 270Ω, 5%, ¼W, Composition	R-76-270
R606	Resistor, 866Ω, 1%, ⅛W	R-88-866
R607	Resistor, 2kΩ, 1%, ⅛W	R-88-2k
R608	Resistor, 1.07kΩ, 1%, ⅛W	R-88-1.07
R609	Resistor, 2.32kΩ, 1%, ⅛W	R-88-2.32k
R610	Resistor, 499Ω, 1%, ⅛W	R-88-499
R611	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R612	Resistor, 390Ω, 5%, ¼W, Composition	R-76-390
R613	Resistor, 1.5kΩ, 5%, ¼W, Composition	R-76-1.5k
R614	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R615	Resistor, 4.59kΩ, 0.1%, 1/10W, Metal Film	R-263-4.59k
R616	Resistor, 500Ω, 0.1%, 1/10W, Metal Film	R-263-500

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R617	Resistor, 100Ω, 1%, 1/8W	R-88-100
R618	Resistor, 100Ω, 1%, 1/8W	R-88-100
R619	Resistor, 1kΩ, 1%, 1/8W	R-88-1k
R620	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R621	Resistor, 1.1kΩ, 1%, 1/8W	R-88-1.1k
R622	Resistor, 4.42kΩ, 1%, 1/8W	R-88-4.42k
R623	Resistor, 3.9Ω, 10%, ½W, Composition	R-1-3.9
R624	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R625	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R626	Resistor, 0.22Ω, 5%, ⅓W, Metal Film	R-346-0.22
R627	Resistor, 100kΩ, 10%, ½W, Composition	R-1-100k
R628	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R629	Resistor, 8.25kΩ, 1%, 1/8W	R-88-8.25k
R630	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R631	Resistor, 100kΩ, 5%, ¼W, Composition	R-76-100k
R632	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R633	Resistor, 13kΩ, 0.1%, 1/10W, Metal Film	R-263-13k
R634	Potentiometer, 500Ω, ½W, Cermet	RP-97-500
R635	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R636	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R637	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R638	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R639	Resistor, 20kΩ, 5%, ¼W, Composition	R-76-20k
R640	Resistor, 22kΩ, 5%, ¼W, Composition	R-76-22k
R641	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470k
R642	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R643	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R644	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R645	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R646	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R647	Resistor, 3.9MΩ, 5%, ¼W, Composition	R-76-3.9M
R648	Potentiometer, 20kΩ, ½W, Cermet	RP-97-20k
R649		
R650	Resistor, 4.3kΩ, 5%, ¼W, Composition	R-76-4.3k
R651	Potentiometer, 200Ω, ½W, Cermet	RP-97-200
R652	Resistor, 6.19kΩ, 0.1%, 1/10W, Metal Film	R-263-6.19k
R653	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R654	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R655	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R656	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R657	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R658	Resistor, 10MΩ, 10%, ¼W, Composition	R-76-10M
R659	Resistor, 10kΩ, 0.1%, 1/10W, Metal Film	R-263-10k
R660	Resistor, 1.005kΩ, 0.1%, 1/10W, Metal Film	R-263-1.005k
R661	Resistor, 100Ω, 0.1%, 1/10W, Metal Film	R-263-100
R662	Resistor, 1.005kΩ, 0.1%, 1/10W, Metal Film	R-263-1.005k
R663	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R664	Resistor, 1.33kΩ, 1%, 1/8W	R-88-1.33k
R665	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R666	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R667	Resistor, 750Ω, 5%, ¼W, Composition	R-76-750

Table 8-5. 1MHz (5902) Module, Parts List (Cont.)

Circuit Designation	Description	Keithley Part Number
R668	Resistor, 750Ω, 5%, ¼W, Composition	R-76-750
R669	Potentiometer, 200Ω	RP-104-200
R670	Resistor, 634Ω, 1%, $^1/_8$W	R-88-634
R671	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R672	Resistor, 47kΩ, 5%, ¼W, Composition	R-76-47k
R673	Resistor, 150Ω, 5%, ¼W, Composition	R-76-150
R674	Resistor, 54.9Ω, 1%, $^1/_8$W	R-88-54.9
R675	Potentiometer, 100Ω, ½W, 25 Turn Cermet	RP-104-100
R676	Resistor, 464Ω, 1%, $^1/_8$W	R-88-464
R677	Resistor, 4.7Ω, 5%, ¼W, Composition	R-76-4.7
R678	Resistor, 49.9Ω, 1%, $^1/_8$W	R-88-49.9
R679	Resistor, 4.32kΩ, 1%, $^1/_8$W	R-88-4.32k
R680	Resistor, 845Ω, 1%, $^1/_8$W	R-88-845
R681	Potentiometer, 200Ω, ½W, 25 Turn Cermet	RP-104-200
R682	Resistor, 62Ω, 5%, ¼W, Composition	R-76-62
T601	Transformer	TR-224
T602	Transformer	TR-225
T603	Transformer	TR-225
T604	Transformer	TR-246
T605	Transformer	TR-244
U601	IC, Hex Inverter, 74F04	IC-436
U602	IC, Quad 2-Input NOR Gate, 74F02	IC-435
U603	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U604	IC, Dual D Edge Triggered Flip-Flop, 74F74	IC-446
U605	IC, Quad 2-Input NAND Buffer, 74F38	IC-434
U606	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U607	Operational Amplifier, KI590 (see Table 8-6 for parts)	
U608	IC, Bi-FET Operational Amplifier, AD542	IC-165
U609	IC, Very High Slew Rate Operational Amplifier, 2539	IC-512
U610	IC, Video Amplifier, NE592	IC-511
U611	IC, Video Amplifier, NE592	IC-511
U612	IC, Very High Slew Rate Operational Amplifier, 2539	IC-512
U613	IC, Darlington Transistor Array, 2003A	IC-206
U614	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U615	IC, Very Wide Band Operational Amplifier, 2625	IC-439
U616	IC, LF442A	IC-410
U617	IC, LF442A	IC-410
U618	IC, Voltage Regulator, −5V, LM320L-5	IC-395
W601	Connector Pins	CS-339-3
W602	Connector Pins	CS-339-3
W601	Jumper	CS-476
W602	Jumper	CS-476

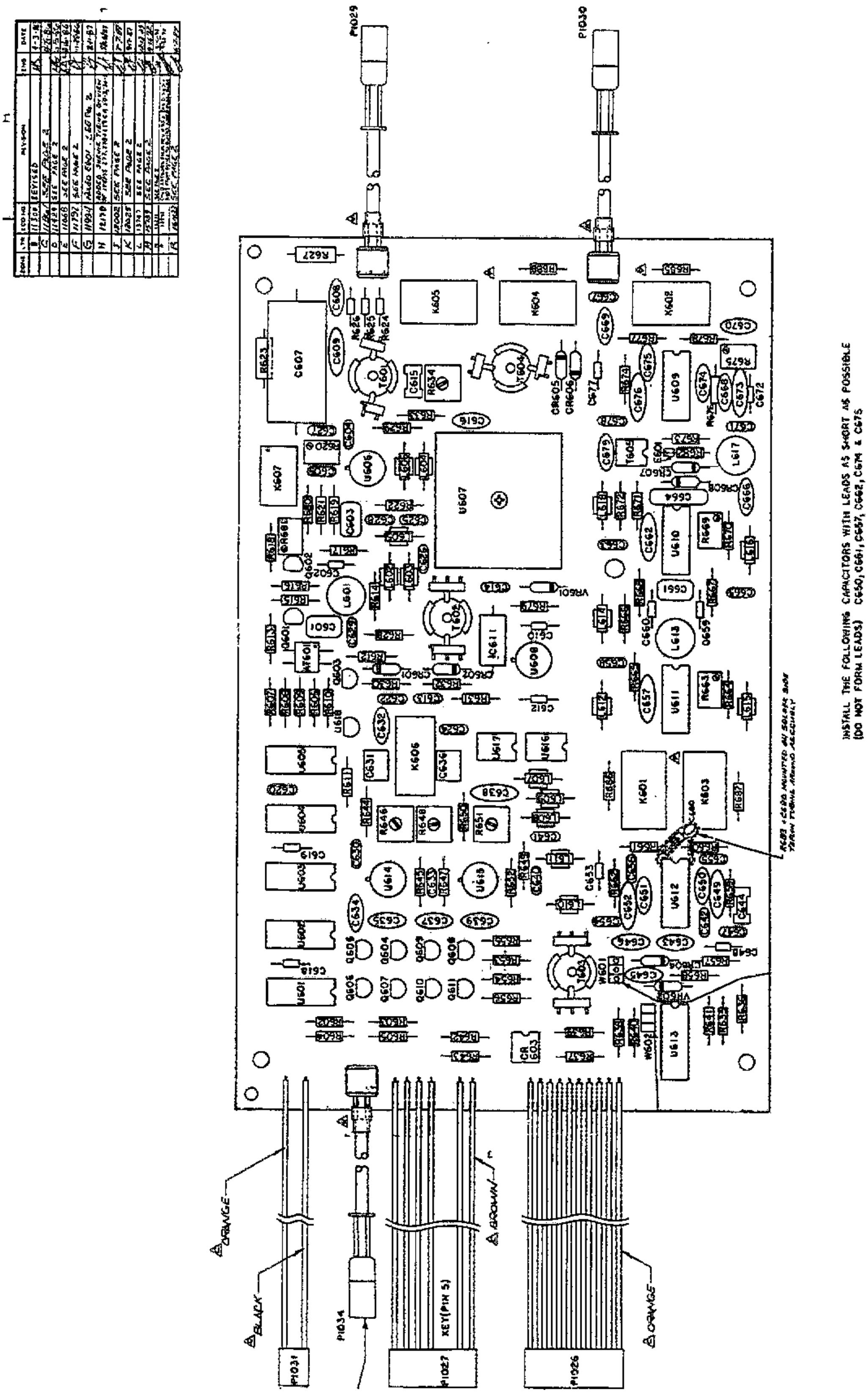


Figure 8-9. Model 5902 (1MHz), Component Location Drawing, Dwg. No. 5902-100

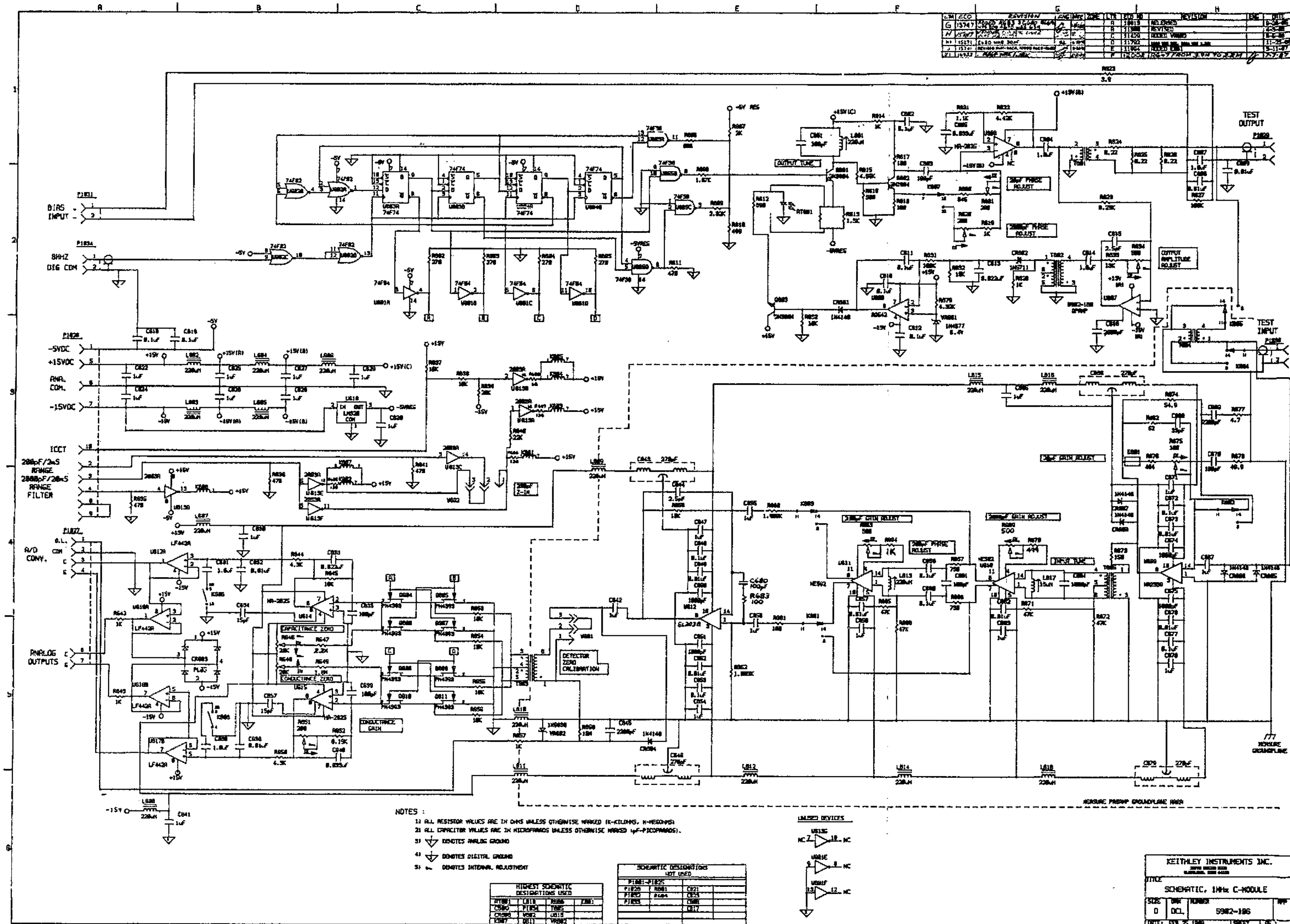
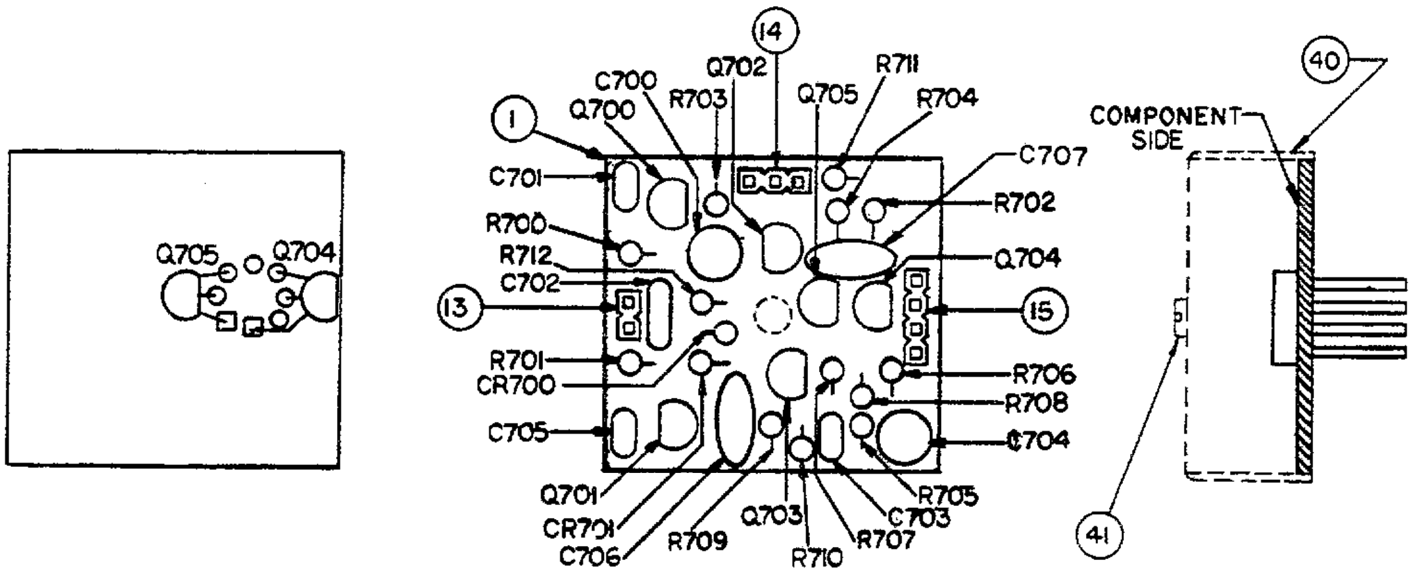


Figure 8-10. Model 5902 (1MHz), Schematic Diagram, Dwg. No. 5902-106

Table 8-6. KI590 Operational Amplifier (4607), Parts List

Circuit Designation	Description	Keithley Part Number
C700	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-377-10
C701	Capacitor, 0.1µF, 50V, Ceramic Film	C-237-0.1
C702	Capacitor, 1µF, 50V, Ceramic Film	C-237-1
C703	Capacitor, 0.1µF, 50V, Ceramic Film	C-237-0.1
C704	Capacitor, 10µF, 25V, Aluminum Electrolytic	C-377-10
C705	Capacitor, 0.1µF, 50V, Ceramic Film	C-237-0.1
C706	Capacitor, 5pF, Ceramic Disc	C-64-5p
CR700	Diode, Silicon, 1N4148	RF-28
CR701	Diode, Silicon, 1N4148	RF-28
Q700	Transistor, Silicon, NPN, 2N3904	TG-47
Q701	Transistor, Silicon, PNP, 2N3906	TG-84
Q702	Transistor, Silicon, PNP, 2N3906	TG-84
Q703	Transistor, Silicon, NPN, 2N3904	TG-47
Q704	Transistor, Silicon, NPN, 2N3904	TG-47
Q705	Transistor, Silicon, NPN, 2N3904	TG-47
R700	Resistor, 20Ω, 5%, ¼W, Composition	R-76-20
R701	Resistor, 20Ω, 5%, ¼W, Composition	R-76-20
R702	Resistor, 1kΩ, 1%, 1/8W	R-88-1k
R703	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R704	Resistor, 432Ω, 1%, 1/8W	R-88-432
R705	Resistor, 2.15kΩ, 1%, 1/8W	R-88-2.15k
R706	Resistor, 10Ω, 1%, 1/8W	R-88-10
R707	Resistor, 15.8kΩ, 1%, 1/8W	R-88-15.8k
R708	Resistor, 10Ω, 1%, 1/8W	R-88-10
R709	Resistor, 866Ω, 1%, 1/8W	R-88-866
R710	Resistor, 4.99kΩ, 1%, 1/8W	R-88-4.99k
R711	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R712	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82

ZONE	LTR.	ECO NO.	REVISION	ENG.	DATE
	A	10641-	RELEASED	[illegible]	9-16-85
	A1	11003	ADDED NOTE	[illegible]	11-21-85
	B	11994	ADDED C707 (C-64-100P)	[illegible]	3-6-87
	B1	16166	[illegible] WAS [illegible]	[illegible]	1-28-94



gure 8-11. KI590 Operational Amplifier (U607), Component Location Drawing, Dwg. N. 5902-180

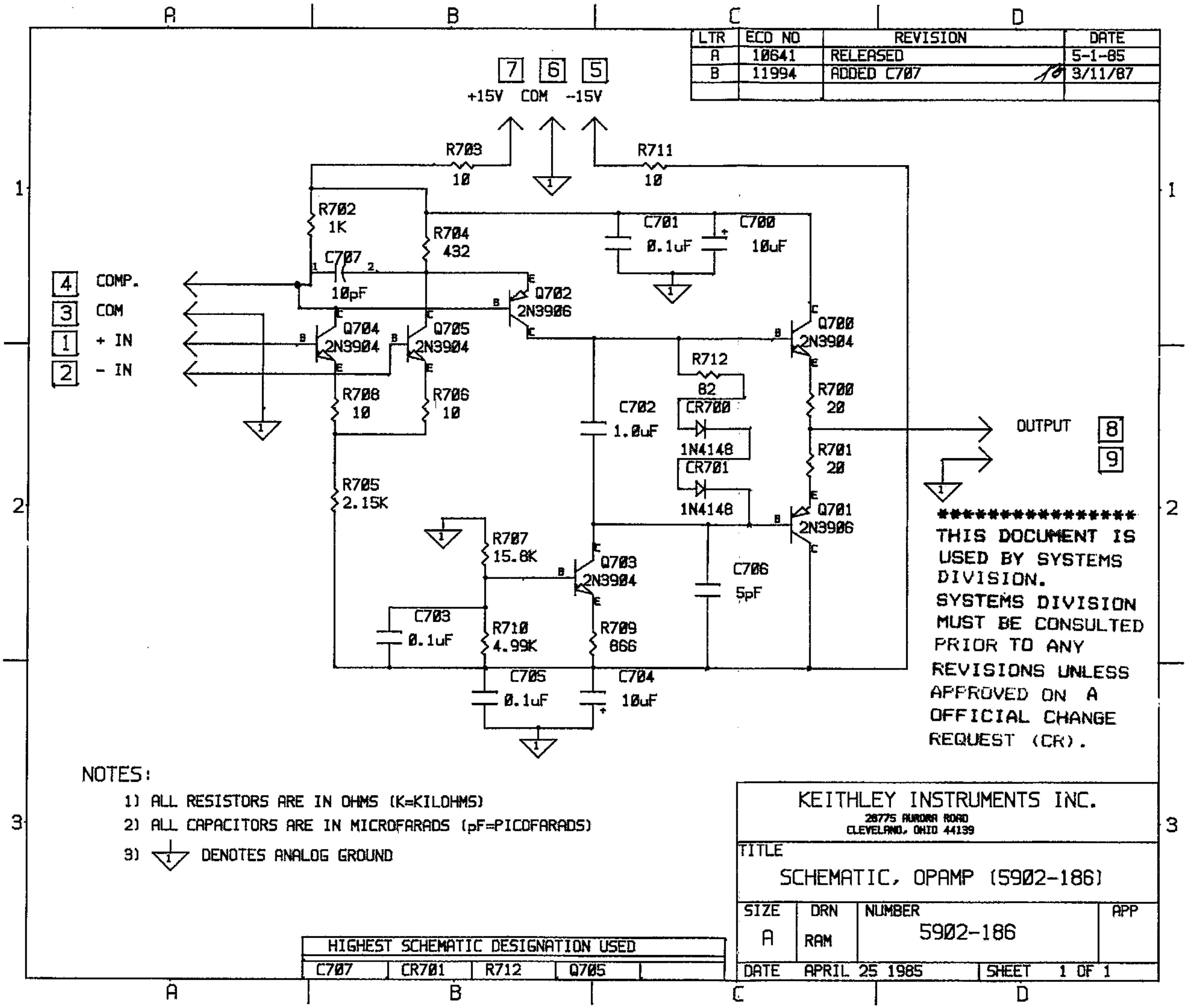


Figure 8-12. KI590 Operational Amplifier (U607), Schematic Diagram, Dwg. No. 5902-186

Table 8-7. Case Parts

Quantity	Description	Keithley Part Number
2	Side Panel	228-301
1	Front Bezel	228-303
3	P.C. Support	228-318
1	Modified P.C. Support	228-314-3
1	Modified P.C. Support	228-314-4
1	Front Panel	590-302
1	Display Window	590-304-1
1	Display Window	590-304-2
1	Front Panel Overlay	590-305
1	Connector Bracket	590-327
1	Capacitor (Bracket-to-Case)	C-22-.01
1	Choke	CH-29
1	Fastener (Routing Clip for CH-29)	FA-195
5	Mounting Rails	228-319
1	Module Mounting Shelf	590-317
1	Rear Panel	590-307
1	Fan	FN-8
1	Fan Filter	FL-6
1	BNC Bracket	590-328
1	Capacitor, (Bracket-to-Case)	C-22-.01
1	Choke	CH-29
1	Fastener for CH-29	FA-195
1	Top Cover	228-312
1	Bottom Cover	228-313
2	Rear Foot	706-316
2	Front Foot Assembly	706-317
2	Decorative Strip	706-321
2	Decorative Strip	706-339

Note: See assembly drawings in Section 7 for parts locations.

Table 8-8. Miscellaneous Mechanical Parts

Quantity	Description	Keithley Location	Part Number
2	Fuse Holder (Bias Fuse)	Mother Board	FH-12
1	Heat Sink (for TG-185 and TG-186)	Mother Board	HS-30
2	Mounting Kit (for TG-185 and TG-186)	Mother Board	MK-23
1	Shield, A/D Converter	Mother Board	590-313
1	Shield, Input Multiplexer	Mother Board	CN-57
2	Pushbutton (LOCAL, SHIFT)	Display Board	228-317-4
7	Pushbutton (RANGE through CAL)	Display Board	228-317-5
8	Pushbutton (MANUAL through SETUP)	Display Board	228-317-6
16	Pushbutton (▲ through C vs t)	Display Board	228-317-7
1	Heat Sink (for IC-240)	Digital Board	HS-22
1	Mounting Kit (for IC-240)	Digital Board	MK-16
1	Heat Sink (for IC-240)	Digital Board	HS-27
1	Mounting Kit (for IC-240)	Digital Board	MK-20
5	Heat Sink (for IC-93 and IC-174)	Digital Board	HS-30
4	Mounting Kit (for IC-93 and IC-174)	Digital Board	MK-18
1	Mounting Kit (for TG-107 and TG-108)	Digital Board	MK-23
1	BNC Jack Bracket	Digital Board	590-310
2	Socket (for LSI-56)	Digital Board	SO-69
1	Fuse Holder Body	Digital Board	FH-21
1	Fuse Carrier (for 3AG Fuse)	Digital Board	FH-25
1	Fuse Carrier (for 5mm Fuse)	Digital Board	FH-26
1	Line Cord		CO-7
1	Shield, Top	5901 Module	5901-302
1	Shield, Bottom	5901 Module	5901-304
1	Shield, Op Amp	5902 Module	5902-307
1	Shield	5902 Module	5902-304

Table 8-9. Model 5904 Input Adapter, Parts List

Circuit Quantity	Description	Keithley Part Number
1	Box, Modified	5904-302
2	Connector, BNC (Female)	CS-249
2	Connector, BNC (Male)	CS-552
1	Choke	CH-33
1	Transformer	TR-242
1	Lug	LU-27
1	Lug	LU-100
2	Washer, Black Neoprene	WA-86-2

APPENDIX A

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	^	MTA 30
95	5F	_	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60	∩	MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX B

CONTROLLER PROGRAMS

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you send a device-dependent command string to the instrument and obtain and display an instrument reading string.

Programs for the following controllers are included:

- IBM PC or XT (with Keithley Model 8573A IEEE-488 Interface)
- Apple II (equipped with the Apple II IEEE-488 Interface)
- Hewlett-Packard Model 85
- Hewlett-Packard Model 9816
- Hewlett-Packard Model 9825A
- DEC LSI 11

NOTE

The Model 590 uses commas to separate parameters in some commands. Many controllers also *use commas to delimit input strings. Use quotes around the command string to avoid problems.*

IBM PC OR XT (KEITHLEY MODEL 8573A INTERFACE)

The following program sends a command string to the Model 590 from an IBM PC or XT computer and displays the instrument reading string on the CRT. The computer must be equipped with the Keithley Model 8573A IEEE-488 Interface and the DOS 2.00 operating system. Model 8573A software must be installed and configured as described in the instruction manual.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disc in the default drive, type LOAD"DECL", and press the return key.
5. Add the lines below to lines 1-6 which are now in memory. Modify the address in lines 1 and 2, as described in the Model 8573A Instruction Manual.
6. Run the program and type in the desired command string. For example, to place the instrument in autorange and 1MHz frequency, type in R0F1X and press the return key.
7. The instrument reading string will then appear on the display. For example, the display might show NCPM+1.2345E−12.
8. To exit the program, type in EXIT at the command prompt and press the return key.

PROGRAM	COMMENTS
`10 CLS`	Clear screen.
`20 NA$="GPIB0":CALL IBFIND (NA$,BRD0%)`	Find board descriptor.
`30 NA$="DEV1":CALL IBFIND (NA$,M590%)`	Find instrument descriptor.
`40 V%=15:CALL IBPAD(M590%,V%)`	Set primary address to 15.
`50 V%=&H102:CALL IBPOKE(BRD0%,V%)`	Set timeouts.
`60 V%=1:CALL IBSRE(BRD0%,V%)`	Set REN true.
`70 INPUT"COMMAND STRING";CMD$`	Prompt for command.
`80 IF CMD$="EXIT" THEN 150`	See if program is to be halted.
`90 IF CMD$="" THEN 70`	Check for null input.
`95 CMD$=CMD$+CHR$(13)+CHR$(10)`	
`100 CALL IBWRT(M590%,CMD$)`	Address 590 to listen, send string.
`110 RD$=SPACE$(100)`	Define reading input buffer.
`120 CALL IBRD(M590%,RD$)`	Address 590 to talk, get reading.
`130 PRINT RD$`	Display the string.
`140 GOTO 70`	Repeat.
`150 V%=0:CALL IBONL(M590%,V%)`	Close the instrument file.
`160 CALL IBONL(BRD0%, V%)`	Close the board file.

NOTE: For conversion to numeric variable, make the following changes:

```
130 RD=VAL(MID$(RD$,5,15))
135 PRINT RD
```

APPLE II (APPLE II IEEE-488 INTERFACE)

The following program sends a command string to the Model 590 from an Apple II computer and displays the instrument reading string on the computer CRT.

The computer must be equipped with the Apple II IEEE-488 Interface installed in slot 5. Note that the program assumes that the computer is running under Apple DOS 3.3 or ProDOS.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IEEE-488 interface installed in the Apple II computer.
3. Enter the lines in the program below, using the RETURN key after each line.
4. Run the program and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the return key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPK+1.2345E−12.

PROGRAM	COMMENTS
`10 Z$=CHR$(26):D$=CHR$(4)`	Terminator.
`20 ADDR=15: SLOT=5`	Define address, slot variables.
`30 INPUT ''COMMAND STRING'';B$`	Input command string.
`40 PRINT D$;''PR#'';SLOT`	Set output to IEEE-488 bus.
`50 PRINT D$;''IN#'';SLOT`	Define input from IEEE-488 bus.
`60 PRINT ''RA''`	Enable remote.
`70 PRINT ''LF1''`	Line feed on.
`80 PRINT ''WT'';CHR$(32+ADDR);Z$;B$`	Address 590 to listen, send string.
`90 PRINT ''RD'';CHR$(64+ADDR);Z$`	Address 590 to talk.
`100 INPUT '''';A$`	Input data.
`110 PRINT ''UT''`	Untalk the bus.
`120 PRINT D$;''PR#0''`	Define output to CRT.
`130 PRINT D$;''IN#0''`	Define input from keyboard.
`140 PRINT A$`	Display string.
`150 GOTO 30`	Repeat.

NOTES:

1. If conversion to numeric variable is required, make the following changes:

```
120 A=VAL(MID$(A$,5,15))
125 PRINT A
```

2. The Apple II INPUT statement terminates on commas. To avoid problems, program the Model 590 for the O1, O2, or O3 data format to eliminate commas.

HEWLETT-PACKARD MODEL 85

The following program sends a command string to the Model 590 from an HP-85 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and an I/O ROM.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the HP82937A GPIB interface installed in the HP-85 computer.
3. Enter the lines in the program below, using the END LINE key after each line.
4. Press the HP-85 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz average modes, type in R0F1X and press the END LINE key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 DIM A$[25],B$[50]`	Dimension strings.
`20 REMOTE 715`	Place 590 in remote.
`30 DISP''COMMAND STRING'';`	Prompt for command.
`40 INPUT A$`	Input command string.
`50 OUTPUT 715; A$`	Address 590 to listen, send string.
`60 ENTER 715; B$`	Address 590 to talk, input reading.
`70 DISP B$`	Display reading string.
`80 GOTO 30`	Repeat
`90 END`	

NOTE: For conversion to numeric variable, change line 70 as follows:

```
70 DISP VAL(B$[5,15])
```

HEWLETT-PACKARD MODEL 9816

The following program sends a command string to the Model 590 from a Hewlett-Packard Model 9816 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and BASICA 2.0.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the HP82937A GPIB interface installed in the 9816 computer.
3. Type EDIT and press the EXEC key.
4. Enter the lines in the program below, using the ENTER key after each line.
5. Press the 9816 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the ENTER key.
6. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 REMOTE 715`	Place 590 in remote.
`20 INPUT''COMMAND STRING'';A$`	Prompt for and input command.
`30 OUTPUT 715; A$`	Address 590 to listen, send string.
`40 ENTER 715; B$`	Address 590 to talk, input reading.
`50 PRINT B$`	Display reading string.
`60 GOTO 20`	Repeat.
`70 END`	

NOTE: For conversion to a numeric variable, change the program as follows:

```
40 ENTER 715;B
50 PRINT B
```

HEWLETT-PACKARD MODEL 9825A

Use the following program to send a command string to the Model 590 from a Hewlett-Packard Model 9825A and display the instrument reading string on the computer printer. The computer must be equipped with the HP98034A HPIB Interface and a 9872A extended I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the 98034A HPIB interface installed in the 9825A.
3. Enter the lines in the program below, using the STORE key after each line. Line numbers are automatically assigned by the 9825A.
4. Press the 9825A RUN key and type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the CONT key.
5. The instrument reading string will then appear on the computer print out. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
0 dim A$[25],B$[20]	Dimension data strings.
1 dev''590'',715	Define 590 at address 15.
2 rem''590''	Place 590 in remote.
3 ent''COMMAND STRING'',B$	Prompt for command string.
4 wrt''590'',B$	Address 590 to listen, send string.
5 red''590'',A$	Address 590 to talk, input data.
6 prt A$	Print data string on printer.
7 gto 3	Repeat.

NOTE: For conversion to numeric variable, modify the program as follows:

```
6 prt val(A$[5])
```

DEC LSI 11

The following program sends a command string to the Model 590 from a DEC LSI 11 minicomputer and displays the instrument reading string on the DEC CRT terminal. The LSI 11 must be configured with 16K words of RAM and an IBV 11 IEEE-488 interface. The software must be configured with the IB software as well as FORTRAN and the RT 11 operating system.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the IBV 11 IEEE-488 interface cable.
3. Enter the program below, using the editor under RT 11 and the name IEEE.FOR.
4. Compile using the FORTRAN compiler as follows: FORTRAN IEEE.
5. Link with the system and IB libraries as follows: LINK IEEE,IBLIB.
6. Type RUN IEEE and press the RETURN key.
7. The display will read "ENTER ADDRESS".
8. Type in 15 and press the RETURN key.
9. The display will read "TEST SETUP".
10. Type in the desired command string and press the RETURN key. For example, to program the instrument for the autorange and 1MHz modes, type in R0F1X and press RETURN.
11. The instrument data string will appear on the computer display. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`PROGRAM IEEE`	
`INTEGER*2 PRIADR`	
`LOGICAL*1 MSG(80),INPUT(80)`	
`DO 2 I = 1,10`	
`CALL IBSTER(I,0)`	Turn off IB errors.
`2 CONTINUE`	
`CALL IBSTER(15,5)`	Allow 5 error 15's.
`CALL IBTIMO(120)`	Allow 1 second bus timeout.
`CALL IBTERM(10)`	Set line feed as terminator.
`CALL IBREN`	Turn on remote.
`4 TYPE 5`	
`5 FORMAT (1X,'ENTER ADDRESS:',$)`	Input primary address.
`ACCEPT 10,PRIADR`	
`10 FORMAT (I2)`	
`12 TYPE 15`	
`15 FORMAT (1X,'TEST SETUP:',$)`	Prompt for command string.
`CALL GETSTR (5,MSG,72)`	Program instrument.
`CALL IBSEOI (MSG,-1,PRIADR)`	Address 590 to listen, send string.
`18 I=IBRECV (INPUT,80,PRIADR)`	Get data from instrument.
`INPUT (I+1) = 0`	
`CALL PUTSTR (7,INPUT,'0')`	
`CALL IBUNT`	Untalk the 590.
`GOTO 12`	Repeat.
`END`	

PET/CBM 2001

The following program sends a command string to the Model 590 from a PET/CBM 2001 computer and displays the instrument reading string on the computer CRT. As the PET/CBM computer has a standard IEEE-488 interface, no additional equipment is necessary.

DIRECTIONS

1. Using the front panel IEEE key, set the primary address of the Model 590 to 15.
2. With the power off, connect the Model 590 to the PET/CBM IEEE-488 interface.
3. Enter the lines of the program below, using the RETURN key after each line is typed.
4. Type RUN and press the RETURN key. Type in the desired command string at the command prompt. For example, to place the instrument in the autorange and 1MHz modes, type in R0F1X and press the RETURN key.
5. The instrument reading string will then appear on the CRT. A typical display is: NCPM+1.2345E−12.

PROGRAM	COMMENTS
`10 OPEN 1,15`	Open file 1, primary address 15.
`20 INPUT"COMMAND STRING";B$`	Prompt for, input command string.
`30 PRINT#1,B$`	Address 590 to listen, send string.
`40 INPUT#1,A$`	Address 590 to talk, input data.
`50 IF ST = 2 THEN 40`	If bus timeout, input again.
`60 PRINT A$`	Display reading string.
`70 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, modify the program as follows:

```
60 A = VAL(MID$(A$,5,15))
70 PRINT A
80 GOTO 20
```

2. The PET INPUT# statement terminates on a comma. Thus, when reading Model 590 strings which include commas, you should input each portion of the string into a separate string variable. For example, in the O0 mode, to obtain and display readings, the program above can be modified as follows:

```
40 INPUT#1, A$,B$,C$
60 PRINT A$",";B$",";C$
```

APPENDIX C

IEEE-488 BUS OVERVIEW

BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer with a minimum number of bus lines. In keeping with this goal, the bus has eight data lines that are used both for data and many commands. Additionally, the bus has five management lines, which are used to control bus operation, and three handshake lines that are used to control the data byte transfer sequence.

A typical configuration for controlled bus operation is shown in Figure C-1. A typical system will have one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), and a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener. The Model 590 has both talker and listener capabilities.

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

The bus is limited to 15 devices, including the controller. Thus, any number of devices may be present on the bus at one time. Although several active listeners may be present simultaneously, only one active talker may be present on the bus, or communications would be scrambled.

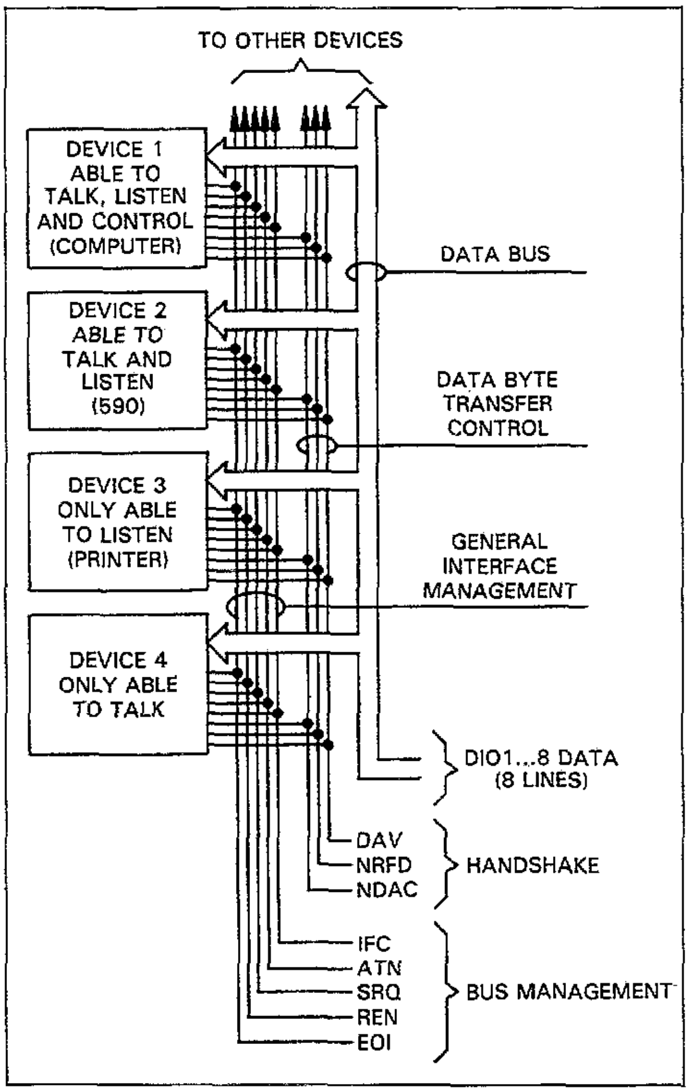


Figure C-1. IEEE Bus Configuration

A device is placed in the talk or listen mode from the controller by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30 and is generally set by rear panel switches or programmed in from the front panel (as in the case of the Model 590). The actual listen command value sent over the bus is derived by ORing the primary address with $20 (the $ symbol preceding the number designates a hexadecimal, or base 16 value). For example, if the primary address is 15 (the default Model 590 value), the actual listen command byte value is $2F ($0F + $20 = $2F). In a similar manner, the talk command byte is derived by ORing the primary address with $40. With a primary address of 15, the actual talk command byte would be $4F ($40 + $0F = $4F).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary address byte values lie in the range of $60-$7F. Note, however, that many devices, including the Model 590, do not use secondary addressing.

Once the device is properly addressed, bus transmission sequences are set to take place. For example, if an instrument is addressed to talk, it will usually output its data string on the bus one byte at a time. The listening device (frequently the controller) will then read this information as transmitted.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three categories: data lines, management lines, and handshake lines. The eight data lines handle bus data and many commands, while the management and handshake lines ensure orderly bus operation. Each bus line is active low with approximately zero volts representing logic 1 (true). The following paragraphs briefly describe the operation of these lines.

Data Lines

The bus uses eight data lines to transmit and receive data in bit-parallel, byte serial fashion. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining bus lines, low is considered to be true.

Bus Management Lines

The five bus management lines ensure proper interface control and management. These lines are used to send uniline commands.

ATN (Attention)—The state of ATN determines how information on the data lines is to be interpreted.

IFC (Interface Clear)—IFC allows the clearing of active talkers or listeners from the bus.

REN (Remote Enable)—REN is used to place devices in the remote mode. Usually, devices must be in remote before they can be programmed over the bus.

EOI (End Or Identify)—EOI is used to mark the end of a multi-byte data transfer sequence. EOI is also used along with ATN, to send the IDY (identify) message for parallel polling.

SRQ (Service Request)—SRQ is used by devices to request service from the controller.

Handshake Lines

Three handshake lines that operate in an interlocked sequence are used to ensure reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus. These handshake lines are:

DAV (Data Valid)—The source (talker) controls the state of DAV to indicate to any listeners when data is valid.

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

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

Figure C-2 shows the basic handshake sequence for the transmission of one data byte. This sequence is used to transfer data, talk and listen addresses, as well as multiline commands.

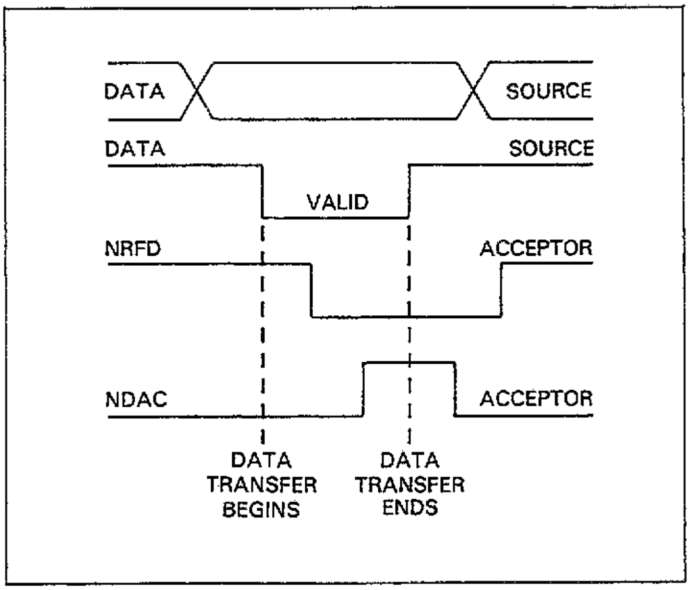


Figure C-2. IEEE Handshake Sequence

BUS COMMANDS

Commands associated with the IEEE-488 bus can be grouped into the following three general categories. Refer to Table C-1.

Uniline Commands—These commands are asserted by setting the associated bus line true. For example, to assert REN (Remote Enable), the REN line would be set low (true).

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

Device-dependent Commands—Commands whose meanings depend on the device in question. These commands are transmitted via the data lines while ATN is false.

Table C-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 590 for various modes.

*Don't Care.

Uniline Commands

The five uniline commands include REN, EOI, IFC, ATN, and SRQ. Each command is associated with a dedicated bus line, which is set low to assert the command in question.

REN (Remote Enable)—REN is asserted by the controller to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be asserted before attempting to program instruments over the bus.

EOI (End or Identify)—EOI may be asserted either by the controller or by external devices to identify the last byte in a multi-byte transfer sequence, allowing data words of various lengths to be transmitted.

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

ATN (Attention)—The controller asserts ATN while sending addresses or multiline commands.

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

Universal Multiline Commands

Universal multiline commands are those commands that required no addressing as part of the command sequence. All devices equipped to implement these commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out front panel or local operation of the instrument.

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

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

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

Addressed Multiline Commands

Addressed multiline commands are those commands that must be preceded by an appropriate listen address before the instrument will respond to the command in question. Note that only the addressed device will respond to the command. Both the command and the address preceding it are sent with ATN true.

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

GTL (Go To Local)—GTL is used to remove instruments from the remote mode and place them in local. With many instruments, GTL may also restore operation of front panel controls if previously locked out.

GET (Group Execute Trigger)—GET is used to trigger devices to perform a specific action that will depend on device configuration (for example, perform a measurement sequence). Although GET is an addressed command, many devices may respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups, and a secondary address group. ATN is true when these commands are asserted. These commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 590) do not use these commands.

Unaddress Commands

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

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

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

Device-Dependent Commands

The purpose of device-dependent commands will depend on instrument configuration. Generally, these commands are sent as one or more ASCII characters that command the device to perform a specific action. For example, the command string R0X is used to control the measurement range of the Model 590.

The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure C-3. Hexadecimal and and decimal values for the various commands are listed in Table C-2.

D_7 D_6 D_5 D_4					X 0 0 0	COMMAND	X 0 0 1	COMMAND	X 0 1 0	PRIMARY ADDRESS	X 0 1 1	PRIMARY ADDRESS	X 1 0 0	PRIMARY ADDRESS	X 1 0 1	PRIMARY ADDRESS	X 1 1 0		X 1 1 1	
BITS D_3	D_2	D_1	D_0	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		|	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	_	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE), PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 590.

NOTE: D_0 = DIO1 ... D_7 = DIO8
X = DON'T CARE

Figure C-3. Command Codes

Table C-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table C-3 lists a typical bus sequence for sending an addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table C-3. Typical Addressed Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	/	2F	47
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 15.

Table C-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

Table C-4. Typical Device-Dependent Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	/	2F	47
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 15.

IEEE Command Groups

Command groups supported by the Model 590 are listed in Table C-5. Device-dependent commands are not included in this list.

Table C-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
- DAC=DATA ACCEPTED
- RFD=READY FOR DATA
- DAV=DATA VALID

UNIVERSAL COMMAND GROUP
- ATN=ATTENTION
- DCL=DEVICE CLEAR
- IFC=INTERFACE CLEAR
- LLO=LOCAL LOCKOUT
- REN=REMOTE ENABLE
- SPD=SERIAL POLL DISABLE
- SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUN

LISTEN:
- LAG=LISTEN ADDRESS GROUP
- MLA=MY LISTEN ADDRESS
- UNL=UNLISTEN

TALK:
- TAG=TALK ADDRESS GROUP
- MTA=MY TALK ADDRESS
- UNT=UNTALK
- OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
- ACG=ADDRESSED COMMAND GROUP
- GET=GROUP EXECUTE TRIGGER
- GTL=GO TO LOCAL
- SDC=SELECTIVE CLEAR

STATUS COMMAND GROUP
- RQS=REQUEST SERVICE
- SRQ=SERIAL POLL REQUEST
- STB=STATUS BYTE
- EOI=END

APPENDIX D

USING THE MODEL 590 WITH THE KEITHLEY MODEL 8573A IEEE-488 INTERFACE

INTRODUCTION

This information will help you use the Model 590 with the Keithley Model 8573A IEEE-488 interface. The Model 8573A interfaces the IBM PC, XT, and AT computers (and certain IBM compatibles such as the Compaq) to the IEEE-488 bus. Information presented here is necessarily brief in nature, for more complete information, consult the Model 8573A Instruction Manual.

PROGRAMMING STATEMENT SUMMARY

An abridged listing of Model 8573A programming statements is given in Table on the next page. More complex applications may require other programming statements, as discussed in the Model 8573A Instruction Manual.

SOFTWARE CONFIGURATION

Before using Model 8573A programs, you must configure the software using the procedure below. This procedure assumes that you will be using the Model 590 with its primary address at the default value of 15.

1. Build a working disk as discussed in the Model 8573A Instruction Manual. Among other files, this diskette must include the GPIB.COM, BIB.M, and CONFIG.SYS files, as discussed in that manual.
2. Boot up the computer using the working disk discussed in step 1 above and enter BASICA.
3. Load the Model 8573A declaration file called "DECL.BAS". Modify the program by changing the XXXXX values as described in the Model 8573A Instruction Manual.
4. Delete lines 7-99 and add the following lines to the declaration file.
```
7 NA$=''GPIB0'':CALL IBFIND(NA$,BRD0%)
8 NA$=''DEV15'':CALL IBFIND(NA$,M590%)
9 V%=15:CALL IBPAD(M590%,V%)
```
5. Now save this modified declaration file for use with BASIC programs you write. Remember that this modified file must appear at the front of every program.

Progamming Example—The program below will allow you to send simple device-dependent command strings for the Model 590. Keep in mind that the statements in the modified declaration file discussed above must be included at the front of every program.

PROGRAM	COMMENTS
`10 V%=1:CALL IBSRE (BRD0%,V%)`	Set REN true.
`20 INPUT''COMMAND'';C$`	Prompt for command string.
`30 CALL IBWRT(M590%,C$)`	Send command string to 590.
`40 R$=SPACE$(100)`	Define reading input buffer.
`50 CALL IBRD(M590%,R$)`	Get reading string from 590.
`60 PRINT R$`	Display reading string.
`70 GOTO 20`	Repeat.

Table D-1.

Model 8573A Statement	Description	Equivalent HP-85 Statement*
CALL IBWRT(M590%,A$)	Send string to unit.	OUTPUT 715; A$
CALL IBRD(M590%,A$)	Input string from unit.	ENTER 715; A$
CALL IBLOC(M590%)	Send GTL to 590.	LOCAL 715
CALL IBCLR(M590%)	Send SDC to 590.	CLEAR 715
A$=CHR$(&H14):CALL IBCMD(BRD0%,A$)	Send DCL to all devices.	CLEAR 7
V%=1:CALL IBSRE(BRD0%,V%)	Set REN true.	REMOTE 7
V%=0:CALL IBSRE(BRD0%,V%)	Set REN false.	LOCAL 7
CALL IBRSP(M590%,SB%)	Serial poll unit.	SPOLL(715)
A$=CHR$(&H11):CALL IBCMD(BRD0%,A$)	Send local lockout.	LOCAL LOCKOUT 7
CALL IBTRG(M590%)	Send GET to device.	TRIGGER 715
CALL IBSIC(BRD0%)	Send IFC.	ABORTIO 7

*Assumes interface select code 7, primary address 15.

APPENDIX E

EQUIVALENT IEEE-488 COMMANDS FOR FRONT PANEL KEYS

Front Panel Key	IEEE-488 Command(s)
RANGE	R
FREQ	F
MODEL	O
FILTER	P
RATE	S
ZERO	Z
CAL	Q0
TRIGGER MODE/SOURCE	T
BIAS ON	N
WAVEFORM	W
PARAMETER	W, V
PLOT	A0
GRID	A1
SETUP	A2-A8
BUFFER	B1, B2
A → B	B3
CABLE CAL	IO, C1
CABLE #	CO
SELF TEST	J
SAVE	L1
RECALL	L0
$1/C^2$	O4
C/C_0	O5
C_{max}	U16, U19
C_A-C_B	O6
[$V_A V_B$] C=CONST	O7
C vs t	U8, U15

APPENDIX F

SETUP CONFIGURATION WORKSHEETS

Worksheet #1

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #2

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #3

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #4

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

Worksheet #5

Operating Mode	Setup 0	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5	Setup 6
Range							
Frequency							
Filter							
Rate							
Zero							
Trigger Source							
Trigger Mode							
Bias on/off							
Waveform							
Start Time							
Stop Time							
Step Time							
First Bias							
Last Bias							
Step Bias							
Default Bias							
Count							

APPENDIX G

ENGINEERING UNITS AND SCIENTIFIC NOTATION CONVERSION

Engineering Symbol	Prefix	Scientific Notation
femto-	f	10^{-15}
pico-	p	10^{-12}
nano-	n	10^{-9}
micro-	μ	10^{-6}
milli-	m	10^{-3}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}
peta-	P	10^{15}

APPENDIX H

GLOSSARY OF TERMS

Abort—To terminate or break off an operation.

Accuracy—The maximum error in terms of measurement made by an instrument. For digital instruments, accuracy is usually specified as a percent of reading plus so many counts of error.

A/D (Analog-to-Digital) Converter—A device that changes an analog signal into binary or digital values.

Analog—Pertaining to electronic devices in which the output varies as a continuous function of the input.

Analog Output—An output that provides an analog signal derived from the digital information within the instrument.

ASCII—Abbreviation for American Standard Code for Information Interchange (pronounced ask-ee). A standard code used extensively in computers and data transmission in which 128 letters, numbers, symbols, and special control characters are represented by 7-bit binary numbers.

BASIC—Abbreviation for Beginners All-purpose Symbolic Instruction Code. A high-level programming language used in many small computers.

Bias Voltage—A voltage applied to a semiconductor for the purpose of establishing a reference level for the operation of the device during testing.

Binary—A number system based on the number 2; used extensively in computer-based equipment.

Bit—An abbreviation for binary digit. A unit of binary information is equal to one binary decision, or the designation of one of two possible states, generally represented by 1 and 0.

BNC—A type of coaxial connector used in situations requiring shielded cable for signal connections.

Buffer—A dedicated area of memory in which some form of binary data is stored for later access. The two Model 590 buffers each store 450 words of capacitance, conductance, and bias voltage information.

Bus—In computerized equipment, one or more conductors used as a path over which information is transmitted from any of several sources to any of several destinations.

Byte—A group of bits processed together in parallel; by definition a byte is made up of eight bits.

Capacitance—Abbreviated C. In a capacitor or a system of conductors and dielectrics, that property which permits the storage of electrically separated charges when potential differences exist between the conductors. Capacitance is related to charge and voltage as follows: $C = Q/V$, where C is the capacitance in farads, Q is the charge in coulombs, and V is the voltage in volts.

Chassis Ground—A connection to a common metal structure within the instrument. Generally, chassis ground is connected through power line ground to earth ground via a 3-wire power cord for safety purposes.

Clock—A pulse generator or signal waveform used to achieve synchronization of digital circuits.

Coaxial Cable—A cable in which one conductor completely surrounds the other, the two being coaxial and separated by continuous solid dielectric.

Conductance—Abreviated G. The reciprocal (1/R) of resistance, usually specified in Siemens (S).

Command—A signal, originating within a computer, that triggers or initiates some form of action within the instrument.

Common Mode Voltage—A voltage applied between input low and chassis ground of the instrument.

Complex Waveform—A periodic waveform made up of a combination of several frequencies or several sine waves superimposed on one another.

Controller—A device which governs the operation of the IEEE-488 bus; generally a controller is a small computer or microcomputer.

Count—The minimum step size that an instrument display can resolve. Display size is often defined in counts, as in a 20,000 count display.

CRT—Cathode Ray Tube. A term generally used when referring to a computer or terminal display screen.

Cursor—A brightened display digit or segment used to indicate the next digit affected by data entry.

DAC—Abbreviation for Digital-to-Analog Converter. A device which converts digital or binary information into an analog signal.

Data Entry—The process of keying in data from the front panel using the numeric keys.

dB—Abbreviation for decibel, which is a logarithmic unit used to measure and compare voltage, current, and power levels.

Digital—Circuitry in which the data-carrying signals are restricted to one of two voltage levels. These voltage levels are used to represent the binary values 1 and 0.

Digitize—To convert an analog signal into a series of binary numbers representing its amplitude at discrete intervals of time.

Earth Ground—A connection from an electrical circuit or instrument to the earth through a water pipe or metal rod driven into the ground.

EMI—Abbreviation for Electromagnetic Interference. A term that defines unwanted electromagnetic radiation from a device which could interfere with desired signals in electronic receiving equipment such as television and radio. RFI (Radio Frequency Interference) and EMI are often used interchangeably.

GPIB—Abbreviation for General Purpose Interface Bus. Another term for the IEEE-488 bus.

Hexadecimal—A number system based on the number 16 that uses values 0-9, and A through F to represent the 16 possible values of a 4-bit binary number. Hexadecimal numbers are represented by preceding them with a $ or following them with a letter H. Thus, $7F and 7FH would be equivalent.

IC—Abbreviation for Integrated Circuit. A combination of interconnected circuit elements inseparably contained on or within a single substrate.

IEEE-488 Bus—A parallel instrumentation data and control bus standardized by the Institute of Electrical and Electronic Engineers.

I/O—Abbreviation for input/output, which refers to the transmission of information from an instrument to an external device (output), or the transfer of information from an external device to an instrument (input).

K—Abbreviation for kilo. In computer terms, 1K equals 1024. For example, a 16K byte memory has 16,384 bytes.

LED—Light-Emitting Diode. A PN junction diode that emits light when forward biased. LEDs are used in front panel annunciators as well as the individual segments of numeric displays on instrumentation.

Listener—A device which, when connected to the IEEE-488 bus, is capable if receiving information over that bus.

Microprocessor—The control and processing portion of a small computer, microcomputer, or computerized device, which is usually contained within one LSI (Large Scale Integration) IC.

Module—A complete subassembly of the instrument combined in a single package (for example, a 5901 100kHz CV module).

Noise—Any unwanted signal appearing in an electronic device.

Normal Mode Voltage—A voltage applied between the input high and input low terminals of an instrument.

NVRAM—Abbreviation for Non-volatile Random Access Memory. A special type of electrically alterable ROM that is used to store information such a calibration constants on a semi-permanent basis. Stored information is retained when power is removed from the device.

Parallel—The simultaneous storage, transmission, or logical operation on a group of bits at one time.

Periodic Waveform—An electronic waveform that repeats itself regularly in time and form.

Plotter—A device that produces an inscribed display of the variation of a dependent variable (Y axis) as a function of an independent variable (X axis).

Programmable Instrument—An instrument whose operation can be determined by keystroke sequences entered from the front panel or with commands sent over the IEEE-488 bus.

RAM—Abbreviation for Random Access Memory. A type of memory where information can be stored (written) and accessed (read). RAM memory is usually volatile, meaning that data is lost when the power is turned off.

Random Access—Access to any location in instrument memory where each location can be accessed in the same amount of time.

Reading—A group of data consisting of capacitance, conductance and measured bias voltage. The result is then shown on the front panel display, stored in buffer, or sent over the IEEE-488 bus.

Resolution—The smallest increment of change in voltage that can be detected by the instrument.

ROM—Abbreviation for Read Only Memory. A type of memory which permanently stores program information for a microprocessor. ROM memory is non-volatile, which means that programmed information remains intact after power is removed.

Sequential Access—Serial access to instrument memory where lower or higher memory locations must be passed through before reaching the desired location.

Serial—The technique for handling a binary data word which has more than one bit. The bits are processed one at a time in single-file sequence.

Sinusoidal—Varying in proportion to the sine of an angle or time function (for example, ordinary alternating current).

Software—The program instruction coding within an instrument or computer that makes the unit operate.

Talker—A device that can transmit information over the IEEE-488 bus.

Transfer Standard—An accurate value used to calibrate an instrument. The accuracy of the standard is generally traceable to a known standard for the unit in question.

Transient Waveform—An electronic signal that results in a sudden change in circuit conditions which persists only for a brief period of time.

Translator Mode—A mode which allows English-like words to be used in place of instrument bus commands.

Trigger—A stimulus of some sort that initiates a one shot, single sweep, or continuous reading sequence, depending on the selected trigger mode. Trigger stimuli include: front panel, an external trigger pulse, and IEEE-488 bus X, talk, and GET triggers.

Word—A group of characters stored in one location in a computer or computerized device. Generally, a word is made up of two or more bytes.

Zero—A mode that allows a baseline measurement to be subtracted from subsequent measurements.

APPENDIX I

BASIC 2.0/4.0 PROGRAM CONVERSIONS

All example programs included in this manual are written in HP-85 BASIC. The syntax used by other Hewlett-Packard computers running under BASIC 2.0 or BASIC 4.0 (9816, 9826 and 9836) is very similar. However, there are a few differences between these programming languages, as indicated below.

Table I-1. HP-85 and BASIC 2.0/4.0 Programming Language Differences

HP-85 Statement	BASIC 2.0(4.0) Equivalent Statement(s)*	Comments

`CLEAR`	`C$=CHR$(255) & CHR$(75)`
	`H$=CHR$(255) & CHR$(84)`
	`OUTPUT KBD; C$; H$`
		Clear screen, home cursor

`DISP`	`PRINT`	Display variables or literals on CRT.
`ENABLE INTR 7; 8`	`ENABLE INTR 7; 2`	Enable SRQ interrupt
`STATUS 7, 1; S`	`STATUS 7, 5; S`	Clear SRQ interrupt
`DISP ''MESSAGE'', INPUT A$`	`INPUT ''MESSAGE'', A$`	Prompt for and input variable.

`IF...THEN...ELSE...`	`IF...THEN...`
	`...`
	`ELSE...`
	`...`
	`END IF`
		Conditional branching

`ABORTIO 7`	`ABORT 7`	Send IFC

*Used by HP-9816, 9826 and 9836.

MODEL 590 DEVICE-DEPENDENT COMMANDS

Execute (X)	
X	Execute Commands

Frequency (F)	
F0	100kHz
F1	1MHz
F2	Disconnect test signal

Range (R)		
	100kHz	**1MHz**
R0	Autorange on	Autorange on
R1	2pF/2μS	20pF/200μS
R2	20pF/20μS	20pF/200μS
R3	200pF/200μS	200pF/2mS
R4	2nF/2mS	2nF/20mS
R5	R1 x10 on	Error
R6	R2 x10 on	Error
R7	R3 x10 on	Error
R8	R4 x10 on	Error
R9	Autorange off, stay on range	

Reading Rate (S)	
S0	1000/sec, 3½ digits
S1	75/sec, 3½ digits
S2	18/sec, 4½ digits
S3	10/sec, 4½ digits
S4	1/sec, 4½ digits

NOTE: Reading rates are nominal

Trigger (T)	
T0,0	One-shot on talk
T0,1	Sweep on talk
T1,0	One-shot on GET
T1,1	Sweep on GET
T2,0	One-shot on X
T2,1	Sweep on X
T3,0	One-shot on external pulse
T3,1	Sweep on external pulse
T4,0	One-shot on front panel
T4,1	Sweep on front panel

Bias Voltage (V)	
V(first)(,last)(,step)(,default)(,count)	First = first bias; Last = last bias; Step = step bias; Default = default bias; $-20.000 \leq V \leq 20.000$ $1 \leq \text{count} \leq 450$ (1,350 at 1,000/sec rate)

Waveform (W)	
W(waveform)(,start)(,stop)(,step)	Waveform: 0 = DC; 1 = Single stair; 2 = Dual stair; 3 = Pulse; 4 = External; Start = start time; Stop = stop time; Step = step time; $1\text{msec} \leq T \leq 65\text{sec}$

NOTE: Multiply programmed times by 1.024 to obtain actual times.

Bias Control (N)	
N0	Bias off
N1	Bias on

Data Format (G)	
G0	Prefix on, suffix off, 1rdg
G1	Prefix off, suffix off, 1 rdg
G2	Prefix on, suffix on, 1 rdg
G3	Prefix on, suffix off, n rdgs
G4	Prefix off, suffix off, n rdgs
G5	Prefix on, suffix on, n rdgs
	n rdgs = # readings in buffer

Operation (O)	
Ooutput(,model)(,C_O)	Output: 0 = C, G, V (triple); 1 = C only; 2 = G only; 3 = V only; 4 = $1/C^2$; 5 = C/C_O; 6 = $C_A - C_B$; 7 = $[V_A - V_B]C_{CONST}$. Model: 0 = Parallel; 1 = Series. C_O (used with C/C_O: $0 \leq C_O \leq 20E-9$

Buffer (B)	
B0	Current Reading
B1(,first)(,last)	A/D buffer, first, last limits
B2(,first)(,last)	Plot buffer, first, last limits
B3	Transfer A/D buffer to plot buffer

Plotter (A)	
A0	Execute plot
A1	Execute grid
A2, plot	Plot: 0 = C vs V; 1 = G vs V; 2 = $1/C^2$ vs V; 3 = C/C_O vs V; 4 = C vs t; 5 = $[C_A - C_B]$ vs V; 6 = $[V_A - V_B]C$ = CONST
A3, grid	Grid: 0 = Full grid; 1 = Axis only
A4, buffer	Buffer: 0 = A/D buffer (A); 1 = Plot buffer (B)
A5, pen	Pen: 0 = No pen; 1 = Pen #1; 2 = Pen #2
A6, line	Line: 0 = DOT at points; 1 = Spaced dots; 2 = Dashes; 3 = Long dash; 4 = Dash dot; 5 = Long dash, short dash; 6 = Long, short, long dash; 7 = Solid line
A7, label	Label: 0 = Full labels; 1 = Label axis and divisions; 2 = Label axis only
A8,n, Xmin, Xmax	X axis limits. n = 0: Autoscaling (minimum/maximum bias). n = 1: Program X axis minimum (Xmin) and maximum (Xmax) values.
A9,n, Ymin, Ymax	Y axis limits. n = 0: Default values, 0 to full scale. n = 1: Program Y axis minimum (Ymin) and maximum (Ymax) values

Zero (Z)	
Z0	Disable zero
Z1	Enable zero

Filter (P)	
P0	Filter off
P1	Filter on

Status (U)	
U0	Hardware/software revision
U1	Error information
U2	Buffer A range group
U3	Buffer A trigger group
U4	Buffer A zero group
U5	Buffer A bias group
U6	Buffer A bias voltage
U7	Buffer A bias time
U8	Buffer A position and time
U9	Buffer B range group
U10	Buffer B trigger group
U11	Buffer B zero group
U12	Buffer B bias group
U13	Buffer B bias voltage
U14	Buffer B bias time
U15	Buffer B position and times
U16	Buffer A maximum/minimum capacitance
U17	Buffer A maximum/minimum conductance
U18	Buffer A maximum/minimum voltage
U19	Buffer B maximum/minimum capacitance
U20	Buffer B maximum/minimum conductance
U21	Buffer B maximum/minimum voltage
U22	Global parameters (series/parallel, C_0 value)
U23	Plotter parameters (plot, grid, line, etc.)
U24	IEEE output parameters (O, G, B, Y, K)
U25	IEEE input parameters (L, C, H, K, M)
U26	Cable correction parameters
U27	Translator user name list
U28	Not used
U29	Translator reserved word list
U30	Translator NEW/OLD state
U31	Translator user translation list
U32	Not Used

SRQ (M)	
M0	Disabled
M1	Reading overflow
M2	Module input overload
M4	Sweep done
M8	Reading done
M16	Ready
M32	Error
M128	IEEE output done

Save/Recall (L)	
L0,n	Recall configuration n (0≤n≤7)
L1,n	Save configuration n (1≤n≤7)

Cable Parameters (I)	
I0	Measure cable parameters (driving point)
I1, n1, n2, n3, n4	Assign cable parameters K0(n1+jn2), K1(n3+jn4)
I2, n1, n2, n3, n4, n5, n6, n7, n8	Assign test output cable parameters: A(n1+jn2), B(n3+jn4), C(n5+jn6), D(n7+jn8)
I3, n1, n2, n3, n4 n5, n6, n7, n8	Assign test INPUT cable parameters: A(n1+jn2), B(n3+jn4), C(n5+jn6) D(n7+jn8)
I4	Zero cable open
I5, C, G	Measure source parameters, step 1
I6, C, G	Measure source parameters, step 2

Save/Recall Cable Setups (C)	
C0,n	Recall cable #n (0≤n≤7)
C1,n	Save cable #n (1≤n≤7)

Self Test (J)	
J1	Perform self test

Calibration (Q)	
Q0	Drift correction
	NORMAL MODE
Q1	Offsets
Q2, C, G	First capacitance cal point
Q3, C, G	Second capacitance cal point
Q4, C, G	Conductance cal point
	DRIVING POINT MODE
Q5	Offsets
Q6, C, G	First capacitance cal point
Q7, C, G	Second capacitance cal point
Q8	Voltage calibration offsets
Q9, V	Calibrate voltmeter gain

Terminator (Y)	
Y0	<CR><LF>
Y1	<LF><CR>
Y2	<CR>
Y3	<LF>

EOI and Hold-off (K)	
K0	EOI and hold-off enabled
K1	EOI disabled, hold-off enabled
K2	EOI enabled, hold-off disabled
K3	EOI and hold-off disabled

Display (D)	
Daaa	Display ASCII characters aa (20 max)
DX	Return display to normal

Hit Button (H)	
	Emulate button press:
H12	SHIFT
H15	ENTER
H16	(A→B)
H20	ON
H23	MANUAL
H25	ZERO
H26	CAL
H27	FILTER
H29	RANGE
H30	FREQ
H31	MODEL

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Service Form

Model No. ____________ **Serial No.** ____________ **Date** ____________

Name and Telephone No. ________________________________

Company ________________________________

List all control settings, describe problem and check boxes that apply to problem. ________________

____

____

- ❑ Intermittent
- ❑ Analog output follows display
- ❑ Particular range or function bad; specify ____________
- ❑ IEEE failure
- ❑ Obvious problem on power-up
- ❑ Batteries and fuses are OK
- ❑ Front panel operational
- ❑ All ranges or functions are bad
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unable to zero
- ❑ Unstable
- ❑ Will not read applied input
- ❑ Overload

- ❑ Calibration only
- ❑ Certificate of calibration required
- ❑ 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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Printed in the U.S.A.
2/03