Errata

Document Title: 8660 Signal Generator and 1000 Computer HP-IB Programming Guide (AN 401-19)

Part Number: 5953-2818

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HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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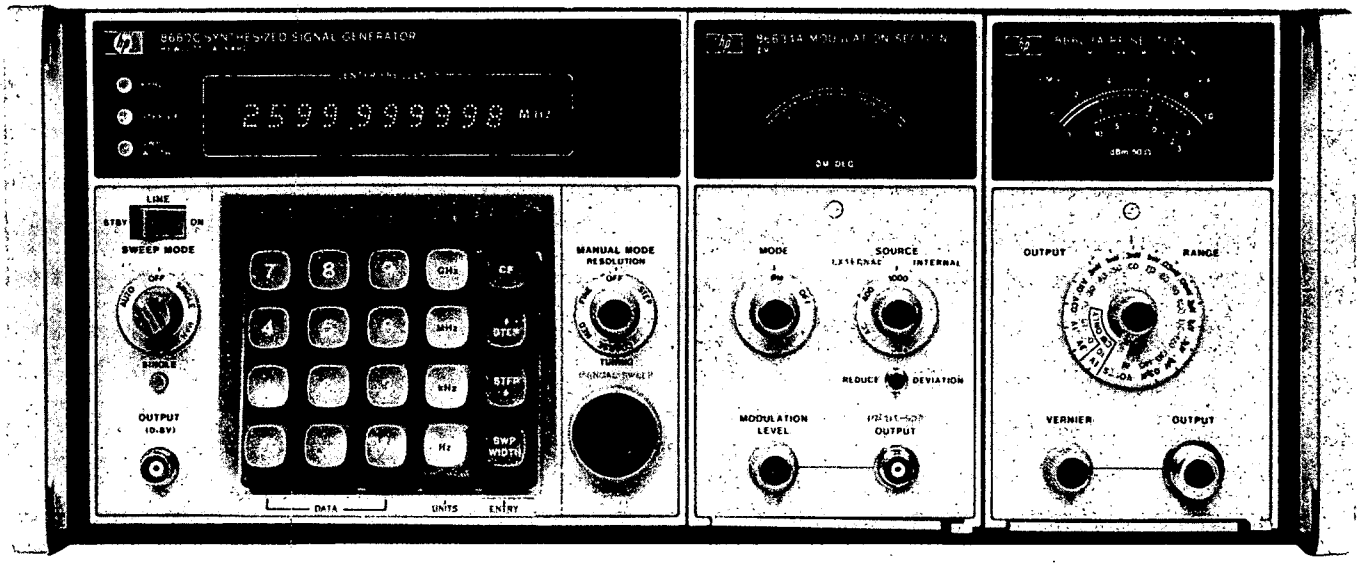
HP 8660 Signal Generator ⟷ HP-IB ⟷ HP 1000 Computer

Programming Guide

Application Note 401-19



Device Introduction

The HP 8660A/B/C family is a modular, solid state synthesized signal generator system.[1] Each system includes:

1. a programmable synthesized signal generator mainframe,
2. an RF section plug-in, and
3. a modulation section plug-in.

There are two different signal generator mainframes currently available — the HP 8660A and the HP 8660C. The HP 8660B was the predecessor of the 8660C and is no longer produced. However, the information in this note is valid for the 8660B and can be utilized.

The HP 8660A and 8660C both provide programming of frequency, output level and modulation. HP-IB operation is included when option 5 is installed. Also, both mainframes can operate from an internal crystal reference or an external frequency standard. The major differences between the mainframes are the front panel design and extended capabilities.

The 8660A mainframe uses thumbwheel switches to select CW output frequencies. Frequencies up to 1300 MHz can be obtained directly with 1 Hz resolution. Frequencies above 1300 MHz can be obtained by installing the 86603A option 3 RF section. One-half of the desired frequency is entered, and a frequency doubling feature is activated.

The 8660C mainframe provides direct keyboard entry of CW frequencies up to 2600 MHz. Added capabilities of the 8660C include digital sweep, frequency stepping, and synthesized search. Also, the 8660C has a 10-digit numeric display, while the 8660A has an optional BCD light annunicator panel to observe frequency.

There are three RF sections for the 8660A/B/C. The 86601A covers 10 kHz to 110 MHz with calibrated output from +13 to −146 dBm. The 86602B covers 1 MHz to 1300 MHz with output from +10 to −146 dBm. The 86603A covers 1 MHz to 2600 MHz with output from +7 to −136 dBm. The 86603A provides 1 Hz resolution below 1300 MHz and 2 Hz resolution from 1300 to 2600 MHz. The output level of all three plug-ins can be varied in 1 dB steps.

Amplitude modulation, modulation source, and modulation depth are programmable with the 86632B and 86333B plug-in sections. Modulation depth is programmable in 1% steps from 0 to 99%.

Frequency modulation, modulation source, and peak FM deviation can be programmed with the 86632B, 86633B or 86535A plug-in sections.

Phase modulation, modulation source, and peak ØM deviation can be programmed with the 86635A plug-in section.

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[1] *The following Operating and Service Manuals contain complete information pertaining to the instrument: 08660-90080 (for 8660A), 08660-90049 (for 8660B) and 08660-90074 (for 8660C). Also, see Application Note 401-1 (part no. 5953-2800).*

Addressing

The 8660A/B/C mainframe is a listen-only device set to address 23 octal by the factory. The address is set with solder-in jumpers on the A3A2 printed circuit board.[2] This address can be changed as follows:

a. Disconnect the power and HP-IB cables, and remove the top cover.

b. Remove the screws holding the A-4 assembly (see figure 19-1), and swing the A-4 assembly out on the hinge still holding it.

c. Loosen the screws in the block containing the edge connectors for the A3 boards, and disconnect the block.

d. Remove the A3A2 board.

e. Solder the jumpers to the desired address. The numerical position of the jumpers is backwards and is shown in figure 19-2.

f. Replace the A3A2 board.

g. Connect the edge connector block, and re-install screws.

h. Re-install the A4 assembly, screws, top cover, cords and cables.

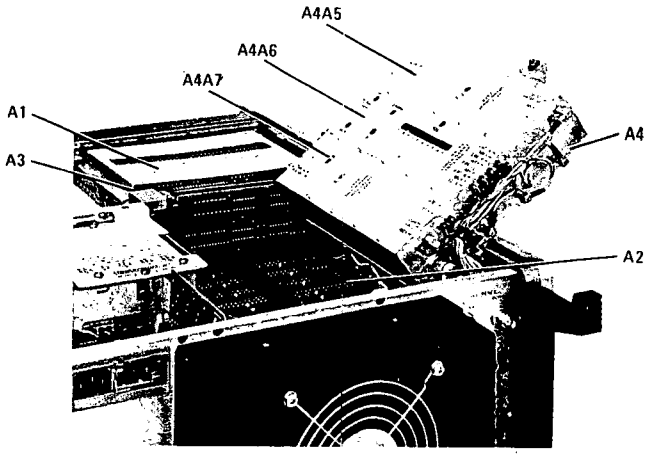


Figure 19-1. A4 Assembly Board Inverted

[2] *Instruments produced with a serial prefix greater than 1947 will have a switch installed on the edge of the A3A2 board which will allow the HP-IB address to be set without disassembly of the instrument.*

System Preparations

LU Assignment

One logical unit number (LU) should be assigned to the 8660A/B/C. After setting the address jumpers as shown, assign an LU to represent the HP-IB address. From File Manager,

```
:SYLU,19,11,23B
```

will assign LU 19 to equipment Table 11. The device address associated with LU 19 will be 23 octal.

Output Buffering

Buffering is normally used when large amounts of data are sent. Since the 8660A/B/C requires few characters, output buffering for the 8660A/B/C EQT is not necessary. The File Manager command,

```
:SYEQ,11,UN
```

will set equipment Table 11 to the unbuffered mode.

Remember, the bus must be unbuffered if the user program performs its own error checking.

Time-out

In certain cases, the 8660A/B/C can delay a response for up to 5 seconds (see the "Performance" section). Any longer delay from the 8660A/B/C mainframe should be considered as a time-out error. When selecting a time-out value, remember that the time-out value will affect all devices on the same EQT, and should encompass the needs of all devices.

From File Manager, a system request may be used to set the time-out value,

```
:SYTO,11,5
```

will set the time-out value for EQT 11 to 50 milliseconds.

A time-out error will be handled through RTE by default. However, a user program may handle the time-out error by altering the device configuration word.

When bit 6 (the E bit) of the device configuration word is zero, the operating system will set the logical unit of the 8660A/B/C down after a time-out, and put the user program into the general wait state. When the problem is corrected, the "UP" operator command is entered to restore the logical unit to the UP condition, and allow execution to resume.

When the E bit is configured to one, the time-out condition will not stop execution of the user program. The user program should check the current bus status (by calling subroutine "IBERR") each time an I/O request is made to determine if a time-out has occurred. The user program can then determine how the time-out will be handled.

Two examples of the device configuration word are shown in figure 19-3. The first example shows the configuration for operating system processing of the time-out condition. The second example shows the configuration for user processing of a time-out condition.[3]

A File Manager request may be used to alter the E bit in the device configuration word. For LU 19,

```
:CN,19,25B,17400B
```

specifies that the time-out condition will be handled by the user program, and,

```
:CN,19,25B,17000B
```

specifies that the operating system will process the time-out.

Configuration

The device configuration word defaults to the correct value for the 8660A/B/C, and does not have to be changed. The 8660A/B/C does not generate SRQ, so the S and R bits, which are used for SRQ processing, do not need to be modified.

DMA is not usually allocated to the 8660A/B/C. Typically, the two DMA channels in the HP 1000 are used for the faster devices in the system, like magnetic tape drives and discs. Because the 8660A/B/C receives short message strings, the interrupt technique is more effectively used.[4] The D bit (bit 13) defaults to zero (which disables DMA) and causes interrupt processing to be used.

The following File Manager statement presents a configuration command for LU 19:

```
:CN,19,25B,17000B
```

This command represents the default state for the device configuration word. The second example in figure 19-3 describes the meaning of each bit.

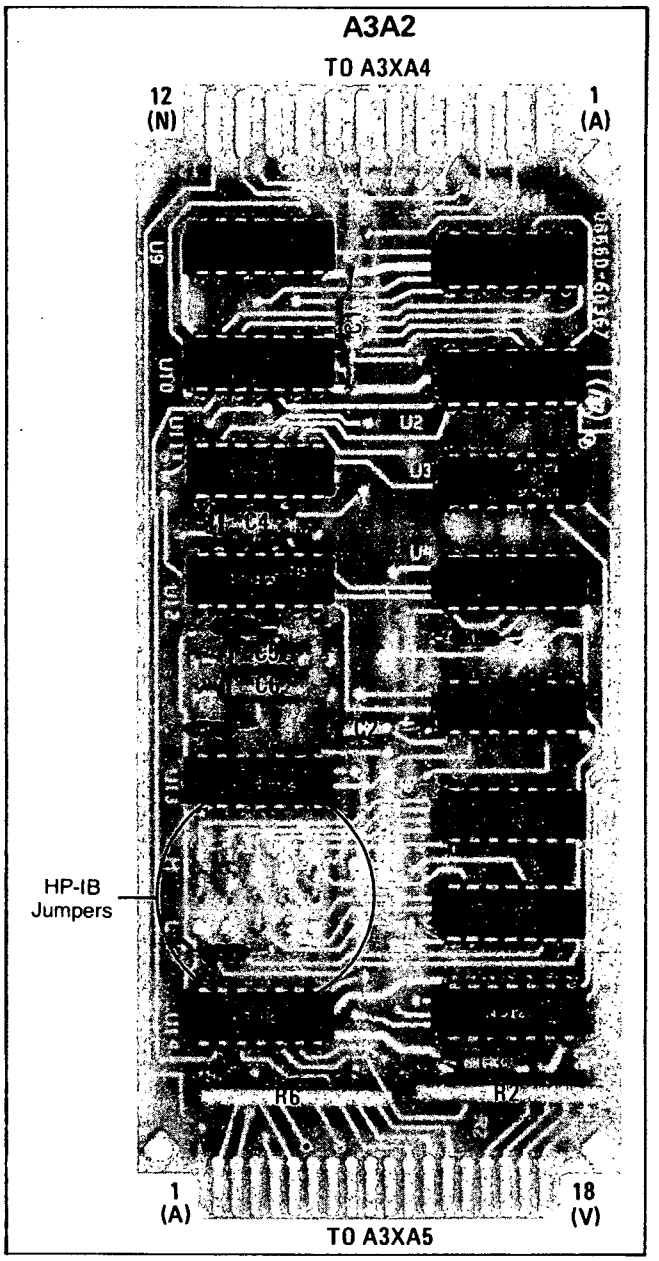
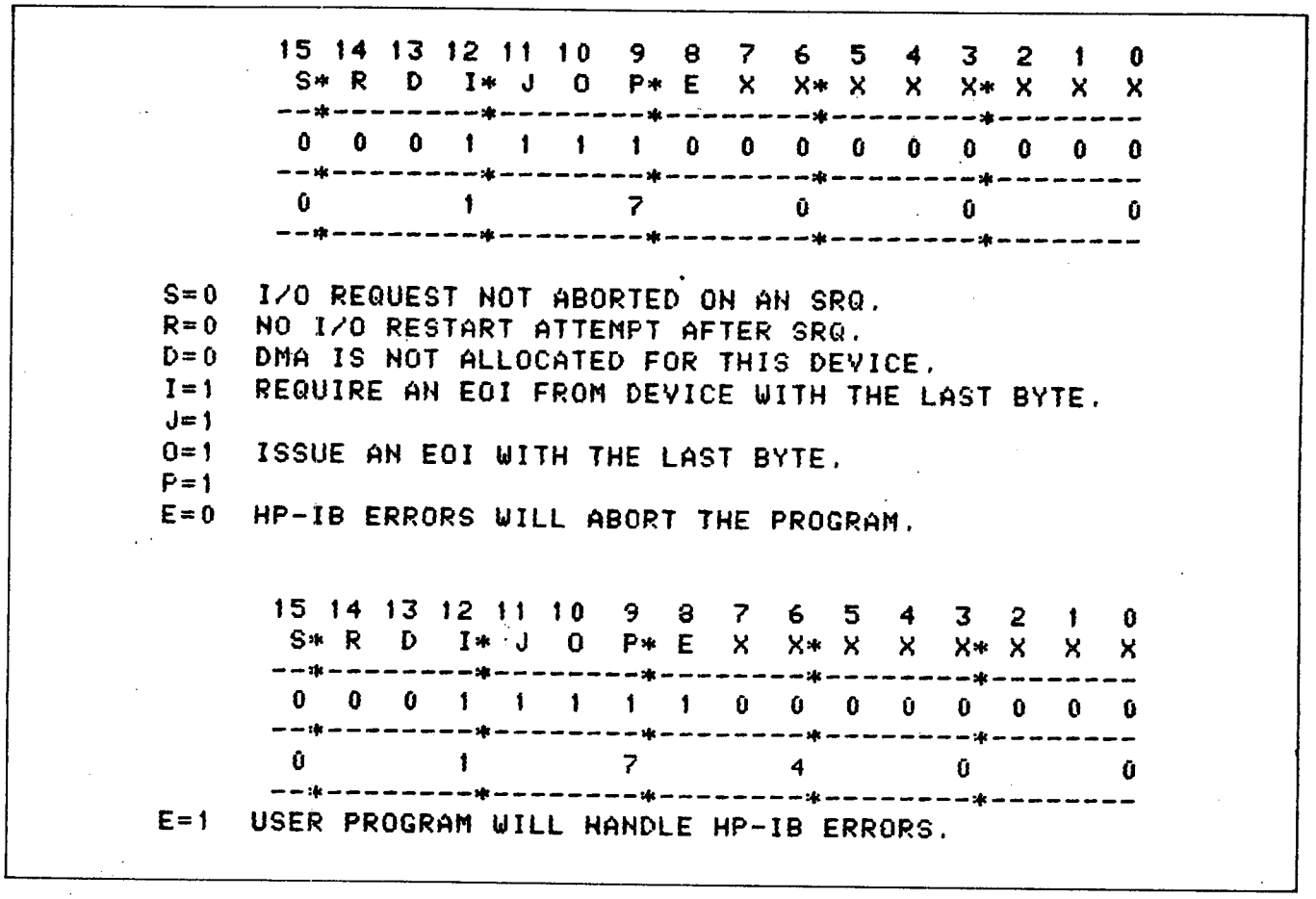


Figure 19-2. A3A2 Component Locations

[3] *Application Note 401-1, Chapter 3, describes a utility program called BSCU that is used to observe the status of the HP-IB, including the configuration word.*



```
          15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
           S* R  D  I* J  O  P* E  X  X* X  X  X* X  X  X
          --*--------*--------*--------*--------*--------*--------
           0  0  0  1  1  1  1  0  0  0  0  0  0  0  0  0
          --*--------*--------*--------*--------*--------*--------
           0        1        7        0        0        0
          --*--------*--------*--------*--------*--------*--------

S=0   I/O REQUEST NOT ABORTED ON AN SRQ.
R=0   NO I/O RESTART ATTEMPT AFTER SRQ.
D=0   DMA IS NOT ALLOCATED FOR THIS DEVICE.
I=1   REQUIRE AN EOI FROM DEVICE WITH THE LAST BYTE.
J=1
O=1   ISSUE AN EOI WITH THE LAST BYTE.
P=1
E=0   HP-IB ERRORS WILL ABORT THE PROGRAM.

          15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
           S* R  D  I* J  O  P* E  X  X* X  X  X* X  X  X
          --*--------*--------*--------*--------*--------*--------
           0  0  0  1  1  1  1  1  0  0  0  0  0  0  0  0
          --*--------*--------*--------*--------*--------*--------
           0        1        7        4        0        0
          --*--------*--------*--------*--------*--------*--------
E=1   USER PROGRAM WILL HANDLE HP-IB ERRORS.
```

Figure 19-3. Example Device Configuration Words

Remote

The 8660A/B/C must be set to the remote state before programming operation can begin. Remote is one of the HP-IB management lines and, once asserted, will remain asserted until cleared. The remote enable command may be executed from the File Manager, or a user program. The File Manager command,

```
:CN,19,16B
```

may be sent, or the FORTRAN statement,

```
CALL RMOTE (19)
```

may be used. For convenience, the remote statement can be included in the WELCOM file. Then, it will automatically be executed at bootup.

When set to remote, the front panel of the 8660A/B/C is automatically locked out. Front panel operator control may be restored by returning the *bus* to local. The File Manager command:

```
:CN,IBLU,17B
```

or the FORTRAN request,

```
CALL LOCAL (IBLU)
```

will return the bus to local. Special care must be taken to assure that other devices on the bus are not affected. When sent, the LOCAL request (17B) returns *all* devices on the same bus to local, and some devices respond by resetting themselves or going to a predetermined state.

Programming

The HP 8660A/B/C was one of the original HP-IB devices (created even before HP-IB became the IEEE Standard), and presents some requirements different from present day devices. The 8660A/B/C was retrofitted to allow HP-IB operation. As a result, the 8660A/B/C expects all data strings to be sent to it in reverse order (least significant digit to most significant digit). Leading zeroes are also needed, and each function has a specific requirement for the number of allowable digits as shown in table 19-1.

Table 19-1. Programmable Significant Digits

Function	Number of Significant Digits
Frequency	10
Output Level	3
% AM	2
FM Deviation (all ranges)	2
ϕM	2

For example, frequency is programmed in hertz with 10 significant digits. The frequency 57.34 MHz is 0057340000 Hz (to 10 digits). Reversing the string yields 0000437500 — that is the string needed by the 8660A/B/C.

A generalized method of string reversal is not simple when using the HP 1000 because the HP 1000 stores floating point (and double precision) values in "logarithimic" format as an exponent and mantissa in base 2. Division by 10 is not just a shifting of the decimal place, but a full floating point operation.

The solution to 8660A/B/C control is the creation of a group of device subroutines. These subroutines reverse the data, translate it to a proper reference level, zero fill as appropriate, and send the data to the 8660A/B/C complete with the proper control characters as shown in table 19-2.

Figures 19-4 through 19-8 are listings for five routines. The first four are device subroutines to set frequency, amplitude modulation, FM deviation, and output level. The fifth routine is a utility program to run diagnostic tests with the 8660A/B/C. With this utility program, any of the above four parameters can be sent from a terminal to an 8660A/B/C remotely.[5]

Each device subroutine requires two parameters. The first is the LU of the 8660A/B/C. The second parameter is the value for the respective function to be performed. Note that the RFF (frequency set) routine requires a double precision value. All other parameter values are real, and of course, the LU values are integers.

The utility program looks for and requires three parameters when run. The first parameter is the LU of the terminal that you are operating from. The program will obtain it if you leave the parameter blank. The second parameter is the LU of the HP-IB, and the third is the LU of the 8660. The calling sequence will look like:

```
:RU,T8660,LUTERM,LUBUS,LU8660
```

The utility program will then interactively prompt the user for commands. First, it will ask for a function to perform, then for a value. The set of functions which the program recognizes is:

- A Set AM modulation
- D Set FM deviation
- F Set frequency (double precision required)
- L Set RF level
- S STOP

[4] *Application Note 201-4 presents a thorough discussion on evaluating the use of DMA versus the interrupt technique for HP-IB data transfers.*

[5] *The device subroutines shown control the major functions for the HP 8660A/B/C. There are other functions which can be programmed. For a complete discussion on the 8660A/B/C, refer to the operation and service manual and the HP-IB Users Guide for the HP 1000 (Part No. 59310-90064). Also, Application Note 164-2, "Calculator Control of the 8660A/B/C Synthesized Signal Generator" details most of the information needed to control the synthesizer on HP-IB.*

Table 19-2. Program Codes, Addresses, and Modulation Codes

Program Codes	Character
Center Frequency	(
[1] Frequency Step ↑	A
[1] Frequency Step ↓	B
[2] Frequency x2	G
[2] Frequency x1	I
Output Level	C
AM-FM-φM Function	$
Modulation Level	%
[3] FM CAL	&
Modulation Source (Output Before Mode)	
INT 1 kHz	1
INT 400 Hz	2
EXT DC	4
EXT AC	8
[4] EXT AC Unleveled	9
Modulation Mode (Output After Source)	
Modulation OFF	0
[5] FM x 10	1
FM x 1.0	2
FM x 0.1	4
[6] AM	8
[7] φM	≤

[1] 8660B/C only.
[2] 8660A/B equipped with 86603A (Option 003) RF Section.
[3] 86632A/B, 86635A.
[4] 86633A/B only.
[5] 86632A/B and 86635A only.
[6] 86632A/B, 86633A/B only.
[7] 86635A only.

```
0001  FTN4,L
0002        SUBROUTINE RFA(DLU,AMP), 8660 AM MODULATION SET NHK-5/78
0003  C
0004  C     THIS ROUTINE SETS UP AM MODULATION AND THE % MODULATION FOR THE 8660
0005  C     THE PROGRAM RECEIVES THE LU OF THE 8660 AND THE PERCENTAGE MODULATION
0006  C     THE PROGRAM REVERSES THE ORDER OF THE MODULATION DIGITS, AND SENDS
0007  C     THE PROPER CHARACTERS TO THE 8660 TO SET UP AM, AND THE PERCENTAGE
0008  C     REQUESTED.
0009        INTEGER IBUF1(2),IBUF2(2),DLU
0010        CALL CODE
0011        WRITE(IBUF1,101) AMP
0012  101   FORMAT(I12)
0013        IL=IAND(IBUF1(1)/400B,377B)
0014        IF(IL.EQ.040B) IL=060B
0015        IH=IAND(IBUF1(1),377B)
0016        IF(IH.EQ.040B) IH=060B
0017  88    IBUF2(1)=IH*400B+IL
0018        WRITE(DLU,102)IBUF2(1)
0019  102   FORMAT("88$",1A2,"%")
0020        RETURN
0021        END

  ** NO WARNINGS **  NO ERRORS **   PROGRAM = 00093      COMMON = 00000
```

Figure 19-4. AM Modulation Subroutine

```
0001  FTN4,L
0002        SUBROUTINE RFD(DLU,DEV), 8660 FM DEVIATION  SET NHK-5/78
0003  C
0004  C     THIS ROUTINE SETS UP FM DEVIATION FOR THE 8660.  THE ROUTINE
0005  C     RECEIVES THE LU OF THE 8660, AND THE AMOUNT OF DEVIATION.  SINCE
0006  C     ONLY TWO DIGITS ARE SENT OUT TO THE 8660, THIS ROUTINE WILL
0007  C     DETERMINE THE SCALING OF THE VALUE (LESS THAN OR GREATER THAN
0008  C     10 KILOHERTZ).  THE ROUTINE THEN REVERSES THE DIGITS, AND SENDS
0009  C     CONTROL CHARACTERS TO SET THE MODE AND SOURCE, THE VALUE, AND THE
0010  C     PROPER TERMINATOR CHARACTER.
0011        INTEGER IBUF1(2),IBUF2(2),DLU
0012        IRNG=0
0013        IF(DEV.LT.10.0) GO TO 88
0014        CALL CODE
0015        WRITE(IBUF1,101) DEV
0016  101   FORMAT(I12)
0017  44    IL=IAND(IBUF1(1)/400B,377B)
0018        IF(IL.EQ.040B) IL=060B
0019        IH=IAND(IBUF1(1),377B)
0020        IF(IH.EQ.040B) IH=060B
0021        IBUF2(1)=IH*400B+IL
0022        IRNG=2+(IRNG*2)
0023        WRITE(DLU,102)IRNG,IBUF2(1)
0024  102   FORMAT("8",I1,"$",1A2,"%")
0025        RETURN
0026  88    IRNG=1
0027        A=DEV*10
0028        CALL CODE
0029        WRITE(IBUF1,101) A
0030        GO TO 44
0031        END

  ** NO WARNINGS **  NO ERRORS **   PROGRAM = 00138      COMMON = 00000
```

Figure 19-5. FM Deviation Subroutine

```
PAGE 0001  FTN.   4:15 PM  THU., 30  NOV., 1978

0001  FTN4,L
0002        SUBROUTINE RFF(DLU,FRQ), 8660 FREQUENCY SET NHK-5/78
0003  C
0004        INTEGER IBUF1(5),IBUF2(5),DLU
0005  C     THIS ROUTINE SETS UP THE FREQUENCY FOR THE 8660.  THE FREQUENCY
0006  C     IS SENT TO THIS ROUTIE AS A DOUBLE PRECISION VALUE SINCE TEN DIGITS
0007  C     ARE REQUIRED.  THE ROUTINE RECEIVES THE LU OF THE 8660 AND THE FREQ.
0008  C     IT REVERSES THE ORDER OF THE DIGITS, AND SENDS THE VALUE TO THE 8660
0009        DOUBLE PRECISION FRQ,A
0010        A=FRQ*1E6
0011        CALL CODE
0012        WRITE(IBUF1,101) A
0013  101   FORMAT(1I10)
0014        DO 88 I=1,5
0015        IL=IAND(IBUF1(I)/400B,377B)
0016        IF(IL.EQ.040B) IL=060B
0017        IH=IAND(IBUF1(I),377B)
0018        IF(IH.EQ.040B) IH=060B
0019  88    IBUF2(6-I)=IH*400B+IL
0020        WRITE(DLU,102)IBUF2
0021  102   FORMAT(5A2,"(")
0022        RETURN
0023        END

  **  NO WARNINGS **  NO ERRORS **   PROGRAM = 00130      COMMON = 00000
```

Figure 19-6. Frequency Subroutine

```
0001  FTN4,L
0002        SUBROUTINE RFL(DLU,LVL), 8660 RF OUTPUT LEVEL NHK-5/78
0003  C
0004  C     THIS IS A ROUTINE TO SET OUTPUT LEVEL TO THE 8660. THE PROGRAM
0005  C     RECEIVES THE LU OF THE SIG GEN, AND THE LEVEL IN DBM.  THIS
0006  C     ROUTINE REFERENCES THE LEVEL TO 13 DBM, REVERSES THE ORDER
0007  C     OF THE DIGITS AND OUTPUTS THEM TO THE 8660 LU WITH THE PROPER
0008  C     CONTROL CHARACTER.
0009        INTEGER IBUF1(2),IBUF2(2),DLU
0010        REAL LVL
0011        A=ABS(13-LVL)
0012        CALL CODE
0013        WRITE(IBUF1,101) A
0014  101   FORMAT(1I4)
0015        DO 88 I=1,2
0016        IL=IAND(IBUF1(I)/400B,377B)
0017        IF(IL.EQ.040B) IL=060B
0018        IH=IAND(IBUF1(I),377B)
0019        IF(IH.EQ.040B) IH=060B
0020  88    IBUF2(3-I)=IH*400B+IL
0021        IBUF2(2)=IAND(IBUF2(2),177400B)
0022        IBUF2(2)=IBUF2(2)+103B
0023        WRITE(DLU,102) IBUF2
0024  102   FORMAT(2A2)
0025        RETURN
0026        END

  **  NO WARNINGS **  NO ERRORS **   PROGRAM = 00128      COMMON = 00000
```

Figure 19-7. RF Output Subroutine

```
0001  FTN4,L
0002        PROGRAM T8660
0003  C
0004  C     THIS IS A UTILITY ROUTINE TO DRIVE THE 8660 SYNTHESIZED SIGNAL
0005  C     GENERATOR.  THIS ROUTINE PERFORMS THE FOLLOWING FUNCTIONS:
0006  C
0007  C        :-----------------------------------------------:
0008  C        : OPERATION CODE :          FUNCTION             :
0009  C        :----------------:------------------------------:
0010  C        :        A       :          SETS AM MODULATION  :
0011  C        :        D       :          SETS FM DEVIATION   :
0012  C        :        F       :          SETS FREQUENCY      :
0013  C        :        L       :          SETS LEVEL          :
0014  C        :        S       :          STOP                :
0015  C        :-----------------------------------------------:
0016  C
0017  C     THE CALLING PARAMETERS FOR THIS ROUTINE ARE:
0018  C
0019  C     :RU,T8660,TERMINAL,BUSLU,8660LU
0020  C
0021  C     WHERE TERMINAL IS THE LU OF YOUR TERMINAL,
0022  C           BUSLU IS THE LU OF THE HPIB BUS
0023  C       AND 8660LU IS THE LU FOR THE 8660.
0024        INTEGER IP(5),TLU,BLU
0025        DOUBLE PRECISION DVAL
0026        CALL RMPAR(IP)
0027        TLU=IP
0028        IF(IP.EQ.0) TLU=1
0029        ILU=IP(3)
0030        BLU=IP(2)
0031        CALL RMOTE(BLU)
0032        WRITE(ILU,333)
0033  333   FORMAT("/1000(351C88$00%")
0034  66    WRITE(TLU,101)
0035  101   FORMAT("ENTER COMAND")
0036        READ(TLU,102) ICMD
0037  102   FORMAT(1A1)
0038        IF(ICMD.EQ.1HA) GO TO 11
0039        IF(ICMD.EQ.1HD) GO TO 22
0040        IF(ICMD.EQ.1HL) GO TO 33
0041        IF(ICMD.EQ.1HF) GO TO 44
0042        IF(ICMD.EQ.1HS) GO TO 99
0043        GO TO 88
0044  103   FORMAT("ENTER VALUE _")
0045  11    WRITE(TLU,103)
0046        READ(TLU,*) VAL
0047        CALL RFA(ILU,VAL)
0048        GO TO 66
0049  22    WRITE(TLU,103)
0050        READ(TLU,*) VAL
0051        CALL RFD(ILU,VAL)
0052        GO TO 66
0053  33    WRITE(TLU,103)
0054        READ(TLU,*) VAL
0055        CALL RFL(ILU,VAL)
0056        GO TO 66
0057  44    WRITE(TLU,103)
0058        READ(TLU,*) DVAL
0059        CALL RFF(ILU,DVAL)
0060        GO TO 66
0061  88    WRITE(TLU,104)
0062  104   FORMAT("BAD COMMAND--TRY AGAIN")
0063        GO TO 66
0064  99    STOP
0065        END

 ** NO WARNINGS ** NO ERRORS **   PROGRAM = 00230      COMMON = 00000
```

Figure 19-8. Driver Utility Routine

Performance

All analog instruments have a time delay between program input and desired output. If such delays are not taken into account with the 8660A/B/C, it is possible to make measurements before the 8660A/B/C has settled. To prevent premature readings from occurring, a jumper labeled J1 is provided on the HP-IB output assembly board. When this jumper is in place, the 8660A/B/C inhibits operation of the HP-IB until the 8660A/B/C is reasonable close to its desired state.

When jumper J1 is installed, the following delays occur:

a. 5 msec after a frequency program code is received.

b. 5 msec after a modulation program code is received.

c. 5 seconds after an FM CAL program code is received.

d. 50 msec after an output level program command is received.

e. Whatever time is required for the 86633A/B modulation section plug-in to acquire phase lock (up to 5 seconds).

The inhibit feature can be disabled by disconnecting jumper J1. However, the user program must assure that the 8660A/B/C has settled or locked before a measurement is taken. Table 19-3 presents the programming response times which are encountered when using the 8660A/B/C.

Table 19-3. Programming Response Times

Frequency Settling Time	
Within 100 Hz of final value	<5 msec*
Within 5 Hz of final value	<100 msec
Output Level Settling Time	
Within 1 dB of final value	<50 msec*
Modulation Settling Time (86632A/B, 86635A)	
Switching from OFF to:	
INT. 400 Hz or 1 kHz	5 seconds
EXT. AC	5 seconds
EXT. DC	2 - 3 msec*
Modulation level (with ±5% of setting)	2 - 3 msec*
FM CAL	5 seconds
Modulation Settling Times (86633A/B)	
Switching from OFF to:	
INT. 400 Hz or 1 kHz (AM only)	5 seconds
EXT. AC LEV (AM only)	5 seconds
EXT. AC UNLEV (AM only)	5 seconds
EXT. DC (AM only)	2 - 3 msec*
Changing % AM depth (within ±5% of settling)	2 - 3 msec*
Changing FM deviation to new value on same mode range (within ±5% of setting)	3 - 4 msec*
Changing FM deviation to new value on different range (within ±5% of setting)	1.5 seconds
Switching from AM or OFF to:	
EXT AC LEV (FM only)	Time required for 86633A/B to achieve phase lock*
EXT AC UNLEV (FM only)	
INT 400 Hz or 1 kHz (FM only)	

* These situations are completely covered by the 8660A/B/C's inhibit feature.