HEWLETT hp PACKARD   *8620 SWEEP OSCILLATORS*
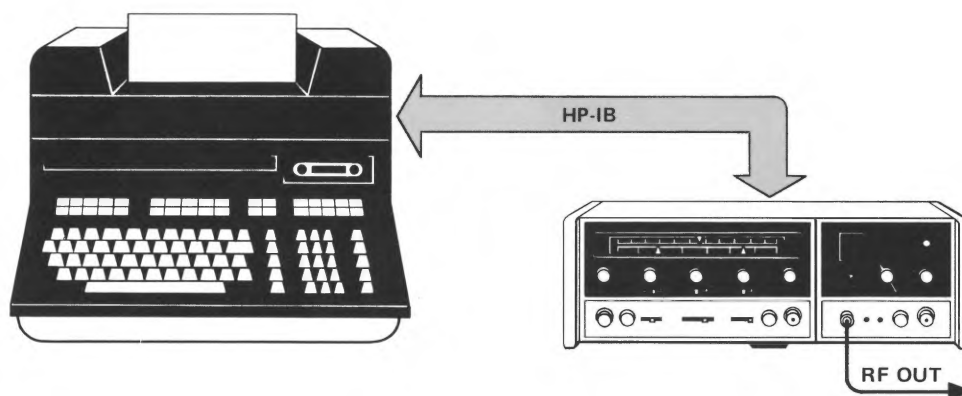
Calculator Control
of the
8620C Sweep Oscillator
using the
Hewlett-Packard Interface Bus

   The HP 8620 family of sweep oscillators offers many features which are desirable in a source used for sweep testing, signal simulation, or as a CW generator. The HP 8620C Option 011 Sweep Oscillator mainframe is frequency-programmable via the HP-IB.* When used with the appropriate sweeper plug-ins, this means that frequencies between 10 MHz and 18 GHz may be easily controlled by a calculator, computer, or card-reader.

   This application note describes programmable capabilities of the 8620C and the procedures required to control it with the HP 9820A, 9821A, 9825A or 9830A/B calculators via the HP-IB. It also contains sample programs which can effectively improve the CW accuracy of the sweeper to approximately ± 0.005% of the bandwidth of the plug-in by using a counter feedback scheme.

*HP-IB is Hewlett-Packard's implementation of IEEE Standard 488 and identical ANSI Standard MC1.1. "Digital interface for programmable instrumentation."

APPLICATION
NOTE   187-5   hp

INTRODUCTION

The HP-Interface Bus permits complex and tedious measurements to be performed by the calculator with instructions that are simple and straightforward. Up to fourteen bus-compatible instruments may be attached to the HP-IB at one time. This permits great flexibility in measurement and simulation applications.

The 8620C Option 011 offers a very cost-effective source for RF and microwave measurements. It can be programmed into any of three digital or four analog modes, with over 10,000 points-per-band resolution. Any of four bands may be selected, allowing use of all four bands of the HP 86290A 2-18 GHz plug-in or up to three bands with the HP 8621B RF drawer. This application note will focus on controlling the 8620C with the 9820A/21A, 9825A and 9830A/B calculator. However, the 8620C Opt. 011 may be programmed by any controller capable of HP-IB I/O.

PROGRAMMING THE 8620C

It is assumed that the reader is familiar with the HP-IB concept and with the operation of the calculators. If not, refer to the "Hewlett-Packard Interface Bus User's Guide" and the Operating and Programming Manual of the calculator to be used.

The 8620C is a Listener on the HP-IB. That is, it cannot output data onto the bus. In this note its Listen Address will be assumed to be the ASCII symbol "&". (Address switches A_5 - A_1 set to 00110). In some applications, it may be desirable to change the address. The address switches are located inside the sweeper. (See the 8620C Operating and Service Manual).

Since the programming connector on the 8620C can handle functions in addition to HP-IB frequency programming, it is a fifty-pin connector. A special adapter is included with the Option 011 which has a standard HP-IB connector on one side and a 50-pin connector on the other. This allows a stackable 50-pin connector to be inserted between the sweeper and the HP-IB to permit,

for example, interface with the HP 8410B Network Analyzer for automatic multi-octave operation, and at the same time complete HP-IB interface. In addition, if the 8620C has the 8621B Option 010 RF drawer with 70 dB step attenuator installed, simultaneous remote control of the RF signal level is possible through this connector.

PROGRAM MODES

The programming flexibility of this source allows several modes of digital and analog frequency control via the HP-IB. Table 1 summarizes these modes. Mode M1 is probably the most popular mode for automatic systems. In this mode, the output frequency can be totally independent of front panel control settings. It offers 10,000 points of frequency resolution per band allowing fine frequency selection.

For even more resolution (limited only by the residual FM and drift of the sweeper) modes M2 and M4 are available. In these modes, the digital frequency resolution is determined by front panel frequency control settings on the 8620C. For example, with mode M2 selected, the front panel CW control set at 7.5 GHz, and the ΔF control set at 1 GHz, the source would have a digital frequency resolution of 10,000 points between 7.0 GHz and 8.0 GHz or a minimum increment of 100 kHz. The START MARKER and STOP MARKER controls might then be set at 8.0 and 9.0 GHz respectively allowing 10,000 points resolution between those settings in mode M4. In combination, this would provide a resolution or minimum increment capability of 100 kHz from 7.0 - 9.0 GHz in modes M2 and M4.

Often, it is desirable to be able to view a dynamic swept display, especially during set-up and fine-tuning of a device prior to final test, or as a quick preview to insure no gross discontinuities exist. Modes M5, M6 and M8 allow this flexibility. Mode M5 produces an analog sweep of the full band selected. Sweep speed, sweep mode, and trigger are all determined by 8620C front panel controls. Similarly, modes M6 and M8 produce analog ΔF and MARKER SWEEP as determined by appropriate front

Table 1. Program Modes

	Description	ASCII Code
Digital Modes	0.000 Volts → Low End of Band Selected = F_L 10.000 Volts → High End of Band Selected = F_U	M1
	0.000 Volts → Setting of Front Panel CW Control Minus $\dfrac{\Delta F \text{ Setting}}{2} = F_L$ 10.000 Volts → Setting of Front Panel CW Control Plus $\dfrac{\Delta F \text{ Setting}}{2} = F_U$	M2
	0.000 Volts → Setting of Front Panel Start Marker = F_L 10.000 Volts → Setting of Front Panel Stop Marker = F_U	M4
Analog Sweep Modes	Analog Sweep of Full Band Selected	M5
	Analog ΔF Sweep Controlled by Front Panel ΔF and CW Controls	M6
	Analog Marker Sweep Controlled by Front Panel Start- and Stop-Marker Controls.	M8
Analog CW Mode	Output = Front Panel CW Control Setting	M3 or M7

panel control settings. In these three modes, mainframe markers or a digitally programmed marker are available. See below.

The capability to place the sweeper in mainframe-controlled CW mode is provided in modes M3 and M7. This allows the operator to manually set CW frequencies or, with a counter, to accurately set the center frequency for ΔF modes.

If no mode is programmed, the sweeper retains its most recent mode. At the initial turn-on of the sweeper, it is in mode M5.

BAND PROGRAMMING

Any of the four bands of the 8620C Option 011 may be selected externally via the HP-IB. Bands 1 through 4 are designated simply by the ASCII characters "B1" through "B4". In addition, band selection control may be returned to the 8620C front panel lever by programming "BØ". At turn-on, the sweeper is in BØ. As with Mode programming, the sweeper retains its most recent Band instruction if not instructed otherwise.

Band programming capability is most useful with the multi-band plug-ins such as the 86290A 2-18 GHz plug-in and the 8621B RF drawer with HP 86300 series RF modules. Since the 86200 series of single-band plug-ins will operate equally with any band selected, this instruction is not necessary.

Table 2. Band Programming (All Modes)

Description	ASCII Code
Local Band (As Selected by Front Panel Lever)	BØ
Band 1	B1
Band 2	B2
Band 3	B3
Band 4	B4

FREQUENCY (VOLTAGE) PROGRAMMING

Since the YIG-tuned oscillators in the 8620 plug-ins are essentially VCO's, the programming instructions are in volts or millivolts. This allows the flexibility to use a large number of frequency plug-ins covering a wide variety of bandwidths and absolute frequencies.

For this reason, it is necessary to use the calculator to convert desired frequency to the required voltage information. This involves a simple conversion equation:

$$V_X = \frac{F_X - F_L}{F_U - F_L} \times 10$$

where F_X = the desired frequency

F_L = lower frequency limit of the Mode selected (See Table 1)

F_U = upper frequency limit of the Mode selected (See Table 1)

The 8620C Option 011 requires the following format to output the proper frequency: "Va.bcdE". The letter "E" indicates the end of the voltage string. The decimal point is optional and is disregarded by the sweeper. It processes up to four digits of information and assumes the infor-

mation is in millivolts with leading zeros suppressed. If more than four digits come down the HP-IB, the 8620C processes only the four digits immediately preceding the "E".

EXAMPLE: With this information, we are prepared to execute an example using literals for the programming information. In this and following examples, we will use the 86290A 2-18 GHz plug-in with the 8620C. It has four bands covering 2-6.2 GHz, 6-12.4 GHz, 12-18 GHz, and 2-18 GHz respectively. Bands 1 through 3 allow greater resolution than band 4; so, in general, we will be more likely to use these narrower bands than the full 2-18 GHz band.

Let's assume the desired output frequency is 15 GHz. One approach is to use mode M1 and band B3. The required voltage is then:

$$\frac{15-12}{18-12} \times 10 = 5.000.$$

The calculator statement required to output 15 GHz is:

```
10 CMD "?U&","M1B3V5.000E"
```

Note that the order of execution is unimportant, (i.e., CMD "?U&", "B3V5000EM1" would produce the same results). Note also that the 3 zeros must be present after the "5" whether or not the decimal point is present.

As mentioned above, if more than four voltage digits travel down the HP-IB, only the last four are processed. What if the frequency desired is the same as F_U? This would require 10.000 volts. But only the last four zeros would be processed resulting in F_L instead of F_U! To obtain ten volts or more then, there is a special ASCII character which signifies 10. The character is the colon (:). So for 18 GHz output, the above string would be modified to:

```
10 CMD "?U&","M1B3V:000E"
```

The colon is produced in the quote field on the 9820A/21A by pressing the R ( ) key.

Table 3. Frequency (Voltage) Programming (Modes M1, M2, M4)

0.000 Volts correspond to low end of band and mode selected.

10.000 Volts correspond to high end of band and mode selected.

Examples		
Frequency (% of Band/Mode)	Voltage Required (Volts)	ASCII Codes
0%	0	VØE or VØØØØØE
0.1%	0.01	V.010E " V10E
55%	5.5	V5.500E " V5500E
100%	10.000	V:.000E " V:000E

MARKERS

In modes M5, M6 and M8, a digitally programmed marker is available in addition to the standard mainframe markers. The programmable marker is selected by outputting the ASCII character "R" (which also disables the mainframe marker). The frequency of the marker is

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dictated by a voltage string programmed in the same manner as the digital frequency described above with F_L and F_U being the end points of the band selected. For example, to obtain a marker at 14 GHz in modes M5, M6 or M8, the following string is required:

```
10 CMD "?U&","B3V3333ER"
```

This will result in either an AMPLitude or INTENsity marker dependent on the setting of the 8620C front panel switch. In this mode, the mainframe-controlled markers are disabled.

To enable the mainframe markers and disable the programmable marker, output the ASCII character "L". This places the markers into totally local control.

FORMAT STATEMENTS

In order to program the frequency with variables, a format statement is required to insure the proper characters and sequence are used on the HP-IB. For the Band and Mode information, suppression of leading spaces is required. With the frequency information in volts, three digits are required after the decimal point; with the information in millivolts, of course, it is required that no digits follow the decimal point.

EXAMPLE: In this example, the variable B is defined as the band number, X is defined as the voltage required (in volts for 9820A/21A and 9830A/B, millivolts for 9825A), and mode M1 is used to output a CW frequency. The following program steps would output the proper frequency:

9820A/9821A

```
0:
CMD "?U&";FMT "M
1B",*.0,"V",*.3,
"E"⊢
1:
WRT 13,B,X⊢
```

9825A

```
2: fmt 1,"M1B",f.0,"V",f4.0,"E"
3: wrt 706.1,B,X
```

9830A/B

```
10 CMD "?U&"
20 OUTPUT (13,30)B,X
30 FORMAT "M1B",F1000.0,"V",F1000.3,"E"
```

There are two ways to handle ≥10 volts when programming in variables. If F_U is desired to the accuracy of the sweeper, a conditional statement resetting X to 9.999 (9999 for 9825A) whenever it is greater than or equal to 9.9995 will produce virtually 10 volts and a frequency within 0.005% of that produced with 10.000 volts. For frequency correction (see example below) or where frequencies >F_U are required, a conditional output statement may be used. If X is ≥9.9995, then the program would branch to the following output steps:

9820A/9821A

```
7:
CMD "?U&"⊢
```

```
8:
IF 10.0005<X;
FMT "M1B",FXD *.
0,"V:",FXD *.3,"
E";WRT 13,B,X-10
;GTO +2⊢
9:
FMT "M1B",FXD *.
0,"V:000E";WRT 1
3,B⊢
```

9825A

```
5: fmt 2,"M1B",f.0,"V:",fz3.0,"E"
6: wrt 706.2,B,abs(X-10000)
```

9830A/B

```
70 CMD "?U&"
80 OUTPUT (13,90)B,X-10
90 FORMAT "M1B",F1000.0,"V:",F1000.3,"E"
```

The following example describes a very simple way to automatically improve accuracy to better than ±0.005% of the bandwidth of the frequency band being used. The only additional piece of gear required is a microwave counter with HP-IB I/O.

COUNTER FEEDBACK LOOP
FOR IMPROVED ACCURACY

The programmable accuracy of the 8620 octave band plug-ins is approximately ±1% of the bandwidth; the accuracies of the 86222A/B (0.01-2.4 GHz) and the 86290A (2-18 GHz) are approximately ±0.5% and ±0.1% respectively. The accuracy of any of these plug-ins may be improved to ±0.005% through the use of a simple counter-feedback scheme. See Figure 1. In this example, the 86290A plug-in is used, although any plug-in could be used with proper changes in software and equipment set-up. The 86290A provides a unique advantage in this application because of its AUX OUT. The 86290A produces 2-18 GHz using the first, second or third harmonic of a fundamental 2-6 GHz oscillator. The AUX OUT signal is sampled from the fundamental oscillator and as such, has an exactly defined relationship to the RF OUTPUT. This removes the need for an external 2-18 GHz coupler or power splitter and the associated degradation of power, source match and flatness specs.

To operate the source, simply connect the 86290A AUX OUT to the HP 5340A Opt 011 Frequency Counter; key the appropriate program into the calculator (Figures 2, 3 and 4) and run the program. First, the system will be "calibrated" by measuring the rough volts/GHz sensitivity of each band. The user then enters the desired frequency via the calculator keyboard, and a coarse-frequency-set, read-frequency, correct-frequency loop is initiated. It continues until the actual frequency is within ±350 kHz of the desired frequency (usually <2 iterations). It then requests the next frequency. The previous frequency will be retained (± the drift of the sweeper) until a new one is entered.

To operate with another frequency plug-in, merely couple a portion of the output frequency with a coupler or power splitter. Change the calibration subroutine to cover only the number of bands ("B") to be used; change the upper and lower frequency limits, and the "switch-points" to suit the configuration; and in the count subroutine, since the counter is reading the direct frequency, delete the band multiplier ("*B").

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Figure 1. Counter Feedback Diagram

```
0:
"8620C/COUNTER
FEEDBACK LOOP"⊢
1:
"7/29/76"⊢
2:
'ADDRESSES--8620
C-&;5340-4(LSTN)
;T(TALK)'⊢
3:
GSB "CAL"⊢
4:
"INP";ENT "ENTER
 FREQ(GHZ)",A;
IF (A>18)+(2>A);
GTO "OOR"⊢
5:
GSB "FSET"⊢
6:
DSP "";GSB "DLY"
⊢
7:
GSB "CNT"⊢
8:
"CORR";X+(A-C)R(
3+B)→X⊢
```

```
9:
GSB "VSET"⊢
10:
DSP "";GSB "DLY"
⊢
11:
GSB "CNT"⊢
12:
IF (ABS (C-A)>.0
0035)(X>0);GTO "
CORR"⊢
13:
GTO "INP"⊢
14:
"CAL";1→B⊢
15:
"NXTB";0→X;GSB "
VSET"⊢
16:
DSP "**CALIBRATI
NG**";GSB "DLY"⊢
17:
GSB "CNT"⊢
18:
C→RB;9.999→X;
GSB "VSET"⊢
```

```
19:
DSP "**CALIBRATI
NG**";GSB "DLY"⊢
20:
GSB "CNT"⊢
21:
9.999/(C-RB)→R(3
+B);IF (B+1→B)>3
;RET ⊢
22:
GTO "NXTB"⊢
23:
"FSET";(A>6.1)+(
A>12.2)+1→B;(A-R
B)R(B+3)→X⊢
24:
"VSET";CMD "?U6"
⊢
25:
IF 10.0005≤X;
FMT "M1B",FXD *.
0,"V:",FXD *.3,"
E";WRT 13,B,X-10
;RET ⊢
26:
IF 9.9995≤X;FMT
"M1B",FXD *.0,"V
:000E";WRT 13,B;
RET ⊢
```

```
27:
FMT "M1B",FXD *.
0,"V",FXD *.3,"E
";WRT 13,B;(X>0)
X;RET ⊢
28:
"CNT";CMD "?U4",
"3TKMOH","?T5";
FMT *;RED 13,C⊢
29:
C/1E9*B→C;RET ⊢
30:
"DLY";DSP ;DSP ;
DSP ;RET ⊢
31:
"OOR";DSP "OUT O
F RANGE";GSB "DL
Y"⊢
32:
GSB "DLY"⊢
33:
GTO "INP"⊢
34:
END ⊢
R324
```
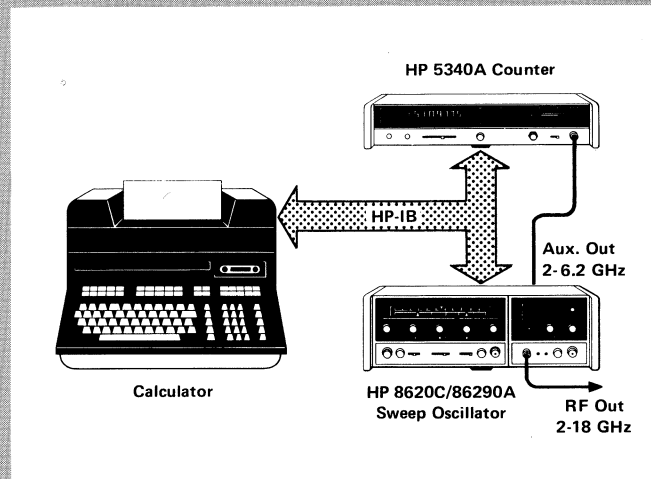
Figure 2. 9820A/9821A Program Listing

```
0: "8620C/COUNTER FEEDBACK LOOP":
1: "7/29/76":
2: "HP-IB select code: 7":
3: "Addresses--8620C:6;5340:4,T":
4: dev "SWP",706,"CNT",720
5: gsb "CAL"
6: "INP":ent "ENTER FREQ(GHz)",A;if A>18 or A<2;gto "OOR"
7: gsb "FSET"
8: dsp "";gsb "DLY"
9: gsb "CNT"
10: "CORR":X+(A-C)r(3+B)→X
11: gsb "VSET"
12: dsp "";gsb "DLY"
13: gsb "CNT"
14: if (abs(C-A)>.00035)(X>0);gto "CORR"
15: gto "INP"
16: "CAL":for B=1 to 3
17: 0→X;gsb "VSET"
18: dsp "**CALIBRATING**";gsb "DLY"
19: gsb "CNT"
20: C→rB;9999→X;gsb "VSET"
21: gsb "DLY"
22: gsb "CNT"
23: 9999/(C-rB)→r(3+B);next B
24: ret
25: "FSET":
26: "SWITCHPOINTS":(A>6.1)+(A>12.2)+1→B;(A-rB)r(B+3)→X
27: "VSET":
28: if X>=9999.5;fmt 1,"M1B",f.0"V:",fz3.0,"E";wrt "SWP.1",B,abs(X-1e5);ret
29: fmt 2,"M1B",f.0,"V",f4.0,"E";wrt "SWP.2",B,(X>0)X;ret
30: "cnt":cmd 7,"?U4","3TKMOH";red "CNT",C
31: C/1e9*B→C;ret
32: "DLY":wait 500;ret
33: "OOR":dsp "OUT OF RANGE!!!";beep;gsb "DLY"
34: gsb "DLY"
35: gto "INP"
36: end
*17658
```

Figure 3. 9825A Program Listing

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```
10  REM------------8620C/COUNTER FEEDBACK LOOP-------------
20  REM------------12/4/75-------------------
30  REM-----------ADDRESSES:8620C=&;5340A=4,T
40  DISP "**CALIBRATING**";
50  GOSUB 400
60  DISP
70  DISP "ENTER FREQUENCY(GHZ)";
80  INPUT F
90  REM--UPPER,LOWER FREQ LIMITS
100 IF F<2 OR F>18 THEN 530
110 GOSUB 180
120 GOSUB 330
130 V=V+(F-C)*G[B]
140 GOSUB 220
150 GOSUB 340
160 IF ABS(C-F)>0.00035 AND V>0 THEN 130
170 GOTO 70
180 REM-----------TUNE FREQUENCY----------
190 REM--"SWITCHPOINTS"
200 B=(F>6.1)+(F>12.2)+1
210 V=(F-F[B])*G[B]
220 CMD "?U&"
230 IF V >= 9.9995 THEN 290
240 V=(V>0)*V
250 OUTPUT (13,260)B,V
260 FORMAT "M1B",F1000.0,"V",F1000.3,"E"
270 WAIT 500
280 RETURN
290 OUTPUT (13,300)B,ABS(V-10)
300 FORMAT "M1B",F1000.0,"V:",F1000.3,"E"
310 GOTO 270
320 REM
330 REM----------COUNT FREQUENCY----------
340 CMD "?U4","3TKMOH","?T5"
350 ENTER (13,360)C
360 FORMAT 4X,F12.6
370 C=(C/1E+09)*B
380 RETURN
390 REM
400 REM--------CALIBRATION SUBROUTINE---
410 REM--B IS BAND NO.
420 FOR B=1 TO 3
430 V=0
440 GOSUB 220
450 GOSUB 330
460 F[B]=C
470 V=9.999
480 GOSUB 220
490 GOSUB 330
500 G[B]=9.999/(C-F[B])
510 NEXT B
520 RETURN
530 REM
540 REM-------OUT OF RANGE ROUTINE------
550 DISP "OUT OF RANGE!!!";
560 WAIT 1000
570 GOTO 60
580 END
```

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