Application Note 218-2
Microwave Synthesizer Series

HEWLETT PACKARD

Obtaining Millihertz Resolution from the 8671A & 8672A

The standard frequency resolution of the HP 8671A Microwave Frequency Synthesizer and HP 8672A Synthesized Signal Generator is 1 to 3 kHz. Though this is sufficient for most applications, increased resolution may be highly desirable for certain others. In these cases the 8671A or 8672A with special options H04 or H05 can be used in combination with other Hewlett-Packard synthesizers to obtain resolutions as fine as 1 to 3 millihertz at microwave frequencies.

This note describes the operation and performance of these combinations, or systems. It describes how the HP 8660A, B, or C Synthesized Signal Generator can be used to obtain 1 to 3 Hz resolution, the HP 3330B Automatic Synthesizer to obtain 0.1 to 0.3 Hz resolution, or the HP 3335A Synthesizer/Level Generator to obtain 1 to 3 millihertz resolution.

These systems can be used manually or controlled remotely through the Hewlett-Packard Interface Bus (HP-IB).* Remote control greatly simplifies operation by eliminating the need to manually calculate and enter the frequencies required from each synthesizer. Remote control is recommended except when frequencies are changed infrequently. This note provides instrument driver subroutines for controlling these systems with the HP 9825A and HP 9830A or B Computing Controllers.

System Operation

In the 8671A and 8672A four phase-locked loops generate the synthesized output frequency (Figure 1). One of these loops, the LFS (Low Frequency Section) loop, operates between 20 and 30 MHz. Its output is translated directly up to microwave frequencies by the YTO (YIG-tuned oscillator) phase-locked loop and determines the four least significant digits of the output frequency. For increased resolution all that is required is for this signal to be replaced by one having the desired resolution.

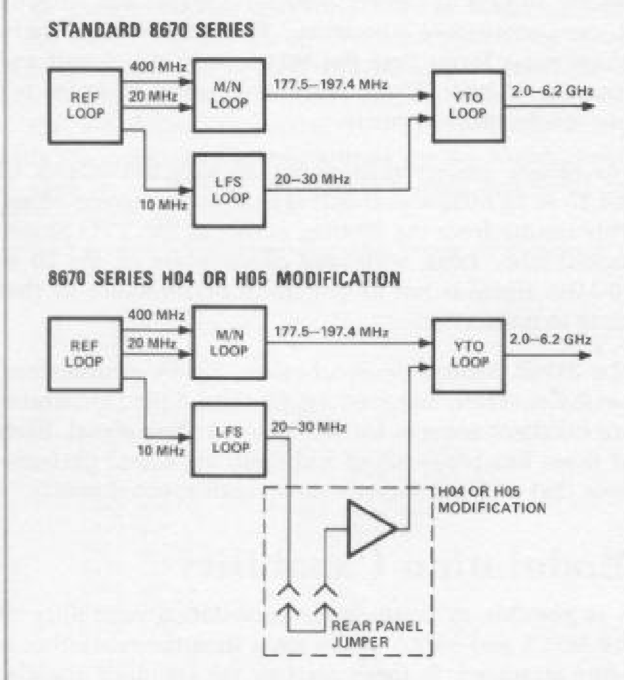


Figure 1. 8670 Series simplified block diagram and block diagram showing H04 or H05 modification.

Options H04 and H05 allow the 8671A and 8672A to operate using either the internal LFS loop or an external 20 to 30 MHz signal. This allows the 8671A and 8672A to have frequency resolution comparable to frequency synthesizers in the 20 to 30 MHz range. With these options the resolution at microwave frequencies is one, two, or three times that of the external 20 to 30 MHz signal used. For example, using an 8660 Synthesized Signal Generator with 1 Hz resolution for the external signal results in 1 Hz resolution between 2.0 and 6.2 GHz, 2 Hz resolution between 6.2 and 12.4 GHz, and 3 Hz resolution between 12.4 and 18.0 GHz. The decreasing resolution above 6.2 GHz occurs because these bands are multiples of two or three times the fundamental 2.0 to 6.2 GHz.

* HP-IB is Hewlett-Packard's implementation of IEEE Standard 488.

Options H04 and H05 are identical in operation except that Option H04 requires +4 dBm input level and Option H05 will accept any level between −7 and +6 dBm. Option H04 is designed to operate with the 3335A or 8660 synthesizers. Option H05 will operate with the 3330B, 3335A, or 8660.

With the 3330B it is necessary to use its auxiliary rear panel output for the required 20 to 30 MHz signal. This output covers 20 to 33 MHz and is 20 MHz higher in frequency than the displayed frequency of the 3330B.

Spectral Purity

If spectral purity is important in an application using an 8671A or 8672A with increased resolution, it is necessary to consider the purity of the source used as the external 20 to 30 MHz signal. Since this signal is translated to microwave frequency its spectral purity affects the spectral purity of the resulting signal.

All phase noise and spurious signals within approximately 20 kHz of the 20 to 30 MHz signal add directly to the microwave spectrum. This signal must have phase noise lower than the 8671A or 8672A output and spurious at least 70 dB below the carrier in order not to degrade spectral purity.

For offsets greater than about 20 kHz the effects of the 20 to 30 MHz signal decrease with increasing offset. This results from the filtering action of the YTO phase-locked loop. Thus, wideband phase noise of the 20 to 30 MHz signal is not as critical to performance as that close to the carrier.

The 3330B Automatic Synthesizer, 3335A Synthesizer/Level Generator, and 8660 Synthesized Signal Generator are excellent sources for the 20 to 30 MHz signal. Each of these has phase noise and spurious signal performance that will not degrade the overall spectral purity.

Modulation Capability

It is possible to increase the modulation capability of the 8671A and 8672A at the same time the resolution is being increased. In these systems the standard modulation capability of the 8671A and 8672A remains unchanged, but the modulation of the whole system can be expanded by modulating the 20 to 30 MHz signal. Because any phase or frequency modulation on the 20 to 30 MHz signal is translated with the signal up to microwave frequency by the YTO loop, it is possible to phase modulate the carrier or perform frequency modulation with high modulation index. The 8660 Synthesized Signal Generator, when used as the 20 to 30 MHz source, can be used for either of these capabilities.

It is possible to phase modulate at rates up to the YTO loop bandwidth, approximately 10 kHz (Figure 2). At these rates, peak phase deviations of at least five radians (286 degrees) can be input on the 20 to 30 MHz signal.

Frequency modulation is limited only by the ability of the YTO loop to respond, and at low rates peak deviations in excess of 1 MHz are possible (Figure 3). Switching the 8671A or 8672A to FM mode (with no input) allows the FM OVERMOD indicator on the front panel to be used to determine if the frequency deviation applied to the 20 to 30 MHz signal is so large the YTO loop cannot respond properly. This technique can also be used to determine the maximum phase deviation possible while phase modulating. There is no meter indication on the 8672A of the modulation level on the 20 to 30 MHz signal.

The peak phase or frequency deviation that results from modulating the 20 to 30 MHz signal is the same as that of the 20 to 30 MHz signal for frequencies between 2.0 and 6.2 GHz. For frequencies between 6.2 and 12.4 GHz the deviation is twice that of the 20 to 30 MHz signal and triple for frequencies above 12.4 GHz. This occurs because frequencies above 6.2 GHz are obtained by multiplication.

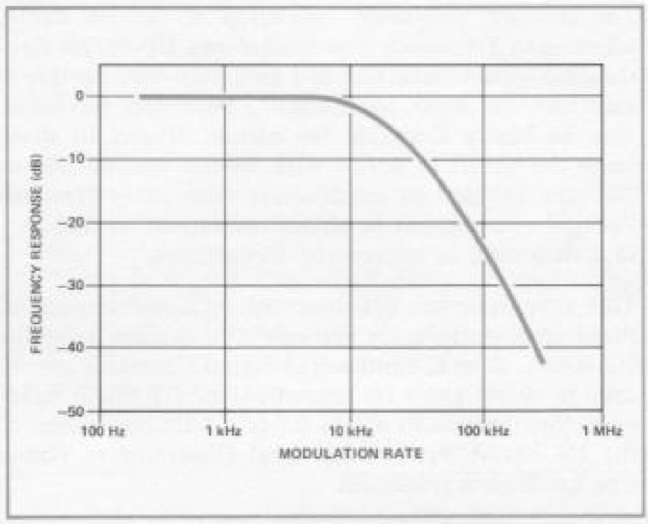


Figure 2. Frequency response resulting from phase modulated 20-30 MHz input signal.

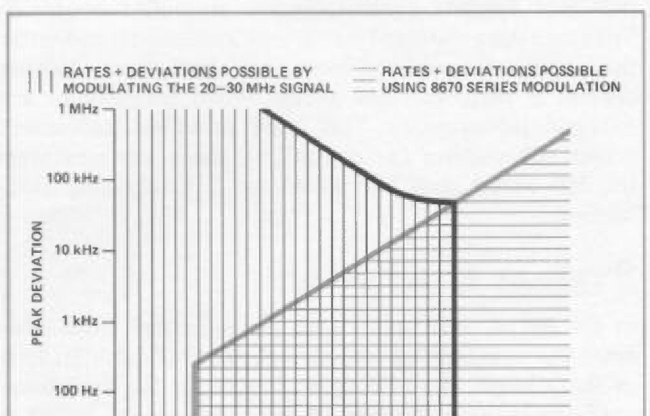


Figure 3. Frequency modulation rates and deviations possible by frequency modulating the 20-30 MHz input signal.

Frequency Algorithms

For any desired frequency the necessary 20 to 30 MHz frequency and the 8671A or 8672A setting can be readily determined. In order to determine the 20 to 30 MHz frequency the fundamental frequency of the 8671A or 8672A must first be determined. The fundamental frequency is between 2.0 and 6.2 GHz. If the desired frequency is not in the fundamental band, the fundamental frequency is one half of frequencies between 6.2 and 12.4 GHz and one third of frequencies between 12.4 and 18 GHz. The required 20 to 30 MHz signal is then the 1 MHz and less significant digits of the fundamental frequency subtracted from 30 MHz. For example, to generate a frequency of 10 003.735 058 MHz the fundamental frequency is one half of the desired frequency or 5001.867 529. The MHz and lesser digits are 1.867 529 which when subtracted from 30 MHz yield 28.132 471 MHz as the required 20 to 30 MHz frequency.

The required frequency setting for the 8671A or 8672A is the desired frequency with digits 100 kHz or less significant set to zero. In the previous example of 10 003.735 058 MHz the required setting on an 8672A is 10 003.000 MHz.

Any rounding in the last digits of the 8672A has no effect on the output frequency except between 12 400 MHz and 12 401 MHz. Between these frequencies the 8672A must not be allowed to round the displayed frequency down; the most significant digits must remain 12 400 MHz. In remote operation this can be ensured by taking the integer of the frequency and adding 0.002 MHz which ensures the synthesizer will always round up between 12 400 MHz and 12 401 MHz.

Frequency Algorithm Equations

For frequencies between 2.0 and 6.2 GHz

$F_1 = 30 - F + 10 \times INT(F/10)$

$F_2 = INT(F) + 0.002$*

For frequencies between 6.2 and 12.4 GHz

$F_1 = 30 - F/2 + 10 \times INT(F/20)$

$F_2 = INT(F) + 0.002$*

For frequencies between 12.4 and 18 GHz

$F_1 = 30 - F/3 + 10 \times INT(F/30)$

$F_2 = INT(F) + 0.002$

Where

F is the desired output frequency in MHz.

F_1 is the required 20 to 30 MHz signal in MHz.

F_2 is the 8670 Series frequency setting in MHz.

INT(X) is the integer value $\leq$ the value of X.

Example: $INT(9.7) = 9$

Calculator Subroutines

The subroutines on the following page are designed to be incorporated into an overall program. They set the frequency of the 8671A or 8672A and the 3330B, 3335A, or 8660 used as the 20 to 30 MHz source. The subroutines for the 9825A require the General I/O and Advanced Programming ROM's. Those for the 9830 require the Extended I/O ROM. The listen addresses must be set to those shown.

To access the 9825A subroutines for the 3330B and 8660 the command cll'freq' (F) is used, where F is the desired frequency in MHz and can be a number or variable. To access the 9830 subroutines for the 3330B and 8660 the command GOSUB 6000 is used and F must previously have been assigned to be the desired frequency in MHz (Figure 4).

The subroutines for the 3335A require that two numbers be input to the subroutine because the 9825A and 9830 operate with twelve significant digits while the 8670 Series/3335A system offers up to fourteen digits of resolution. In order to obtain enough digits of resolution the frequency is separated into two numbers: the integer portion of the frequency in MHz and the fractional part. For example 12345.678901234 MHz is separated into 12345 and 0.678901234. With the 9825A the subroutine is accessed by cll'freq' (X,Y) where X is the integer portion and Y is the fractional portion of the frequency (Figure 5). With the 9830A the command GOSUB 6000 is used and F0 and F1 must have been assigned to be the integer and fractional portions of the frequency, respectively. If twelve significant digits are sufficient the subroutines for the 3330B could be used by modifying the output format statement to that for the 3335A.

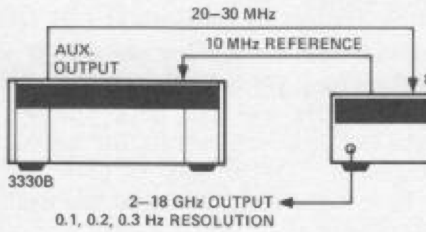
```
10 CMD "?U4","K00071"
20 DISP "FREQUENCY IN MHZ";
30 INPUT F
40 GOSUB 6000
50 GOTO 20
60 END
6000 CMD "?U4"
6010 FORMAT "P",F1000.7,"Z0"
6020 OUTPUT (13,6010)1E-04*(INTF+0.002)
6030 F0=1+(F >= 6200)+(F >= 12400)
6040 F1=30-F/F0+10*INT(0.1*F/F0)
6050 CMD "?U3"
6060 FORMAT "/",F1000.0,"(900C"
6070 OUTPUT (13,6060)FNI(0.001*F1)
6080 RETURN
6090 DEF FNI(X)
6100 W=1
6110 Y=ABSX
6120 Z=0
6130 Z=Z+W*INTY
6140 Y=10*(Y-INTY)
6150 W=10*W
6160 IF Y#0 THEN 6130
6170 RETURN Z
```

Figure 4. Example 9830 program showing use of 8660 instrument subroutine.

```
0: dim F$[10]
1: wrt 719,"K00071"
2: ent "Frequency in MHz",F$
3: int(val(F$))→X;frc(val(F$[3]))→Y
4: cll 'freq'(X,Y)
5: gto 1
6: end
7: "freq":fmt "P",fz9.3,"Z9";wrt 719,int(p1)+.002
8: 1+(p1>=6200)+(p1>=12400)→p4
9: 10(int(.1p1)modp4)+10frc(.1int(p1))+frc(p2)→p3
10: 30-p3/p4+10int(.1p3/p4)→p0
11: fmt "QA4KF",f13.9,"M";wrt 704,p0;ret
```

Figure 5. Example 9825A program showing fourteen digit resolution with the 3335A.

* The addition of 0.002 MHz in these cases is not necessary but only included for consistency.



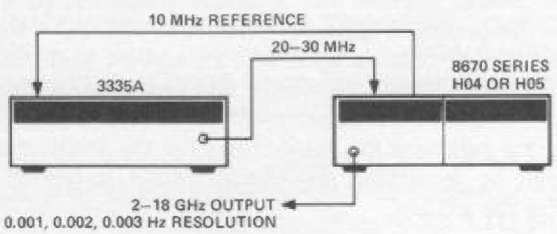
3330B Listen Address: $
8670 Series Listen Address: 3

9825A

```
"freq":fmt "P",fz9.3,"Z9";wrt 719,int(p1)+.002
1+(p1)=6200)+(p1)=12400)→p4;10-p1/p4+10int(.1p1/p4)→p0
fmt "L",f.7,"?";wrt 704,p0;ret
```

9830

```
6000 CMD "?U3"
6010 FORMAT "P",F1000.7,"Z0"
6020 OUTPUT (13,6010)1E-04*(INTF+0.002)
6030 F0=1+(F >= 6200)+(F >= 12400)
6040 F1=10-F/F0+10*INT(0.1*F/F0)
6050 CMD "?U$"
6060 FORMAT "L",F1000.7,"?"
6070 OUTPUT (13,6060)F1
6080 RETURN
```



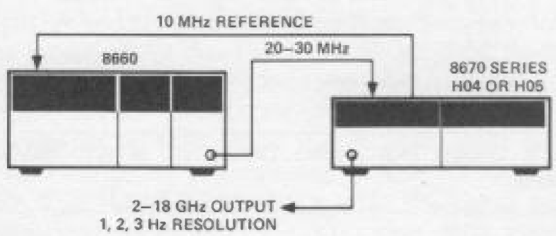
3335A Listen Address: $
8670 Series Listen Address: 3

9825A

```
"freq":fmt "P",fz9.3,"Z9";wrt 719,int(p1)+.002
1+(p1)=6200)+(p1)=12400)→p4
10(int(.1p1)modp4)+10frc(.1int(p1))+frc(p2)→p3
30-p3/p4+10int(.1p3/p4)→p0
fmt "QA4KF",f13.9,"M";wrt 704,p0;ret
```

9830

```
6000 CMD "?U3"
6010 FORMAT "P",F1000.7,"Z0"
6020 OUTPUT (13,6010)1E-04*(INTF0+0.002)
6030 F2=1+(F0 >= 6200)+(F0 >= 12400)
6040 F3=INTF0-10*F2*INT(INT(0.1*F0)/F2)+F1-INTF1
6050 F4=30-F3/F2+10*INT(0.1*F3/F2)
6060 CMD "?U$"
6070 FORMAT "QA4KF",F1000.9,"M"
6080 OUTPUT (13,6070)F4
6090 RETURN
```



8660 Listen Address: 3
8670 Series Listen Address: 4

9825A

```
"freq":fmt "P",fz9.3,"Z9";wrt 720,int(p1)+.002
1+(p1)=6200)+(p1)=12400)→p4;30-p1/p4+10int(.1p1/p4)→p0
fmt "/",f.0,"(900C";wrt 719,'inv'(prnd(p0,-6)*.001);ret
"inv":.1→p2
gto +0;(10p2→p2)int(p1)+p3→p3;if (10frc(p1)→p1)=0;ret p3
```

9830

```
6000 CMD "?U4"
6010 FORMAT "P",F1000.7,"Z0"
6020 OUTPUT (13,6010)1E-04*(INTF+0.002)
6030 F0=1+(F >= 6200)+(F >= 12400)
6040 F1=30-F/F0+10*INT(0.1*F/F0)
6050 CMD "?U3"
6060 FORMAT "/",F1000.0,"(900C"
6070 OUTPUT (13,6060)FNI(0.001*F1)
6080 RETURN
6090 DEF FNI(X)
6100 W=1
6110 Y=ABSX
6120 Z=0
6130 Z=Z+W*INTY
6140 Y=10*(Y-INTY)
6150 W=10*W
6160 IF Y#0 THEN 6130
6170 RETURN Z
```

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