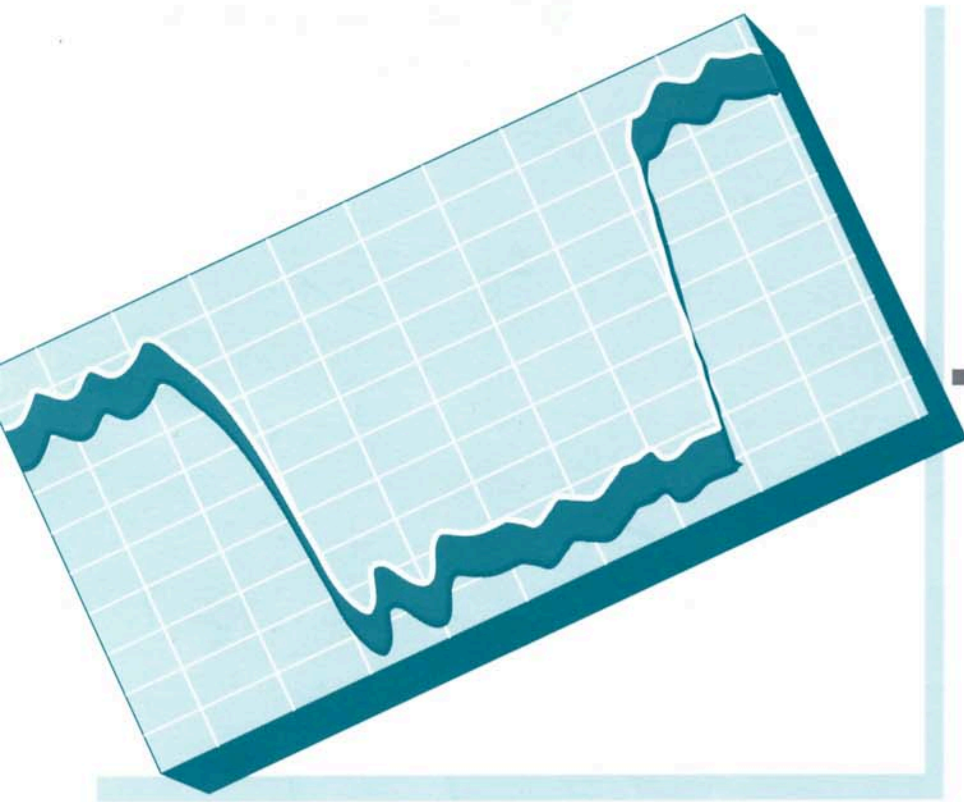
HEWLETT PACKARD

Application Note 377-3
Frequency Profiling Without A Pulse Generator

Using the HP 5361A 20 GHz Pulse/CW Microwave Counter's Built-In Profiling



High Resolution Pulse Profiling . . . without a Pulse Generator

■ A revolutionary new profiling technique invented by Hewlett-Packard now makes it possible to profile frequency pulses without the need for an external pulse generator. Called Built-In Profiling, this technique is featured in the HP 5361A 20 GHz Pulse/CW Microwave Counter and enables profiling of pulsed signals using gate widths as narrow as 10.5 nsec.

Figure 1 shows the results of profiling a 4 MHz frequency step on a 5.3 GHz carrier using only the HP 5361A and a technical computer.

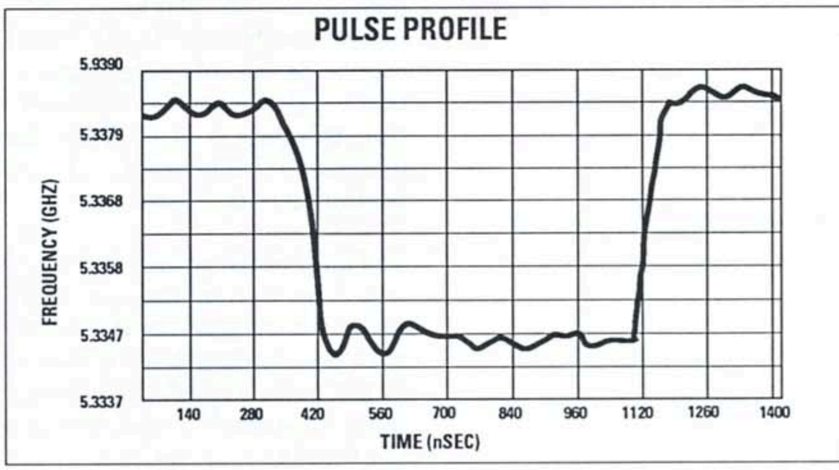


Figure 1. Built-In Profiling of a 4 MHz step on a 5.3 GHz carrier.

Built-In Profiling

■ This new pulse profiling method requires only an HP 5361A counter and a computer with HP-IB capability. While traditional profiling methods require an external delaying pulse generator, Built-In Profiling makes use of the counter's internal gating functions in a unique way.

Built-In Profiling offers several distinct advantages over other, more conventional profiling methods:

- No external delay generator is needed
- Gate widths are as narrow as 10.5 nsec
- Higher frequency accuracy is possible
- Jitter in gate position is eliminated
- Profiling is quick and easy

Event Gating

The HP 5361A provides four main methods of gating a measurement: external gating, automatic internal gating, time gating, and event gating. (See the HP 5361A Data Sheet (5952-7986) or Application Note 377-1 (5952-7987) for more details on the first three methods.) It is the powerful capabilities of event gating that enable Built-In Pulse Profiling.

Single Event Measurement

When used with a controller and the BASIC program described on pages 4-8, the HP 5361A first automatically acquires the pulsed signal, determines the pulse width and average pulse frequency, and begins the gating, or profiling, process. During this process, the frequency is determined by measuring the time of occurrence of each cycle of the downconverted signal.

An internal digital divider performs the function of the gate generator, producing a measurement gate that always opens on the pulse's second IF cycle. The end of the gate, however, is variable and programmable via the HP 5361A's front panel or HP-IB. The counter is initially programmed to set a gate width equal to exactly three cycles of the downconverted signal, and to record the length of time this gate is open. (Note that the number of cycles (three) divided by this time gives the downconverted frequency for the beginning of the pulse.)

The gate width is then increased to contain four IF cycles, and the new time interval measured. This measurement process is continued, with the gate width systematically increased by one IF cycle for each measurement, until the end of the pulse is reached. (For larger pulse widths, the user may want to step the gate width by more than one IF cycle. The program described in this note chooses the number of IF cycles such that 100 data points can be obtained.) This process is illustrated in Figure 2.

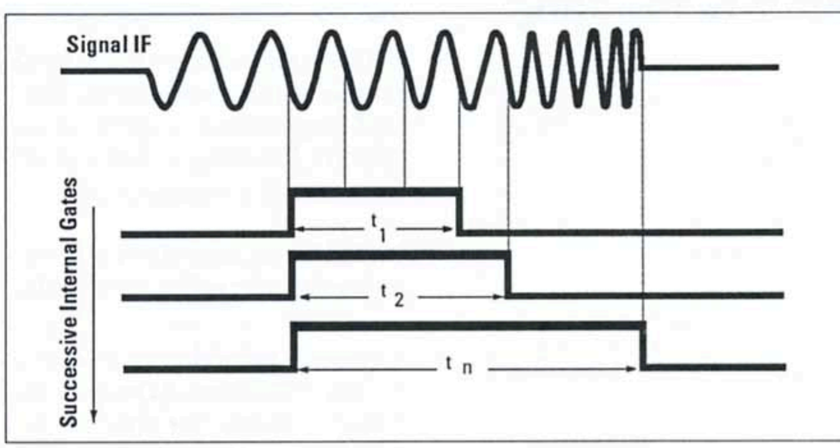


Figure 2. Measuring the time of each IF cycle by using event gating.

Each integral number of cycles thus has a corresponding time measurement. This table of time and events (cycles of the downconverted frequency) is stored manually or in a computer, and converted to frequency by simple subtraction and division.

Frequency Determination

The frequency at any point in time can be found easily and accurately by looking at the time required for one complete IF cycle at that point. Frequency is just the reciprocal of this time.

For example, the frequency at a point 100 nsec into a pulse is found by first locating 100 nsec in the stored table and noting the corresponding number of cycles (n). One cycle is subtracted, and the time corresponding to this new number of cycles is found (t_{n-1}). The downconverted frequency is then just the number of events (one) divided by the elapsed time (t_n - t_{n-1}).*

Minimum Equivalent Gate Width of 10.5 nSec

Because the counter can record time for each cycle of the downconverted signal frequency, this method can provide a data point for frequency determination on every cycle. The HP 5361A downconverts the unknown signal to between 45 MHz and 95 MHz (nominally centered about 70 MHz). Thus, the measurement gate time will be between (1/95 MHz) and (1/45 MHz), or between 10.5 nsec and 22.2 nsec (14 nsec nominal).

Simple Computer Control

■ A short HP BASIC computer program can be written to automate Built-In Profiling and to perform the simple data reduction. For convenience, a sample program can be found at the end of this Note or ordered with the enclosed reply card. This program provides the gating control for the HP 5361A, collects and analyzes the data, and graphs the resulting frequency profile. In addition, optional digital filtering to smooth the data and improve resolution can be implemented.

Versatile Profiling

■ The HP 5361A is the first microwave frequency counter that offers the versatility of pulse profiling with conventional techniques (using a delaying pulse generator) as well as the new Built-In Profiling technique. For a highly accurate, simple method of profiling repetitive frequency chirps, steps, and pulses, try the HP 5361A and its new Built-In Profiling capabilities.

* See the HP 5361A Demo/Getting Started Guide (5952-7985) for details on using Scope-View to see the gating process.

Automated Built-In Profiling Sample Program

```
10  DIM Man_freq$[80],Ans1$[80],Events(101),Times(101),Hi(101),Lo(101)
20  DIM Freq(100),Freq2(100),If2(101),Freq3(100),If3(101),If1(101),S$[24]
30  COM /Profile_data/ Freq_max,Freq_min,Ans,Stop_val,Increment_value
40  ASSIGN @Hp5361a TO 814
50  No_of_events   =3
60  Increment_value=1
70  Stop_val       =100
80  Freq_min       =MAXREAL
90  Freq_max       =MINREAL
100 S$="   *** PROFILING ***"
110 !
120 OUTPUT @Hp5361a;"INIT"              ! INITIALIZE THE HP 5361A
130 OUTPUT @Hp5361a;"DISPLAY,"&S$       ! DISPLAY "PROFILING" MESSAGE
140 OUTPUT @Hp5361a;"MMOD,PULSE"        ! LOCK INTO PULSE MEAS MODE
150 OUTPUT @Hp5361a;"SAMPLE,HOLD"       ! PUT INTO SAMPLE HOLD MODE
160 OUTPUT @Hp5361a;"CHIRP,ON"          ! TURN ON CHIRP MODE
170 TRIGGER @Hp5361a                    ! TRIGGER A MEAS. THE FIRST MEAS
180 WAIT 1                              ! IN 'HOLD' MODE IN NOT ALWAYS GOOD
190 TRIGGER @Hp5361a                    ! SO TRIGGER AGAIN
200 ENTER @Hp5361a;Ans                  ! GET THE AVERAGE FREQUENCY FOR SETTING
210                                     ! MANUAL MODE
220 OUTPUT @Hp5361a;"PAVER,1"           ! SETUP TO GET THE NUMBER OF EVENTS
230 OUTPUT @Hp5361a;"EFUN,33"
240 TRIGGER @Hp5361a
250 OUTPUT @Hp5361a;"EFUN?"
260 ENTER @Hp5361a;Ans1$
270 Events(1)=VAL(Ans1$[2,12])          ! EXTRACT THE NUMBER OF EVENTS
280 IF (Events(1)<100) THEN             ! IF IT IS LESS THAN 100, USE THAT NUMBER
290   Stop_val=Events(1)
300 ELSE                                ! OR USE 100 POINTS WITH A LARGER STEP SIZE
310   Increment_value=Events(1) DIV 100
320 END IF
330 !
340 OUTPUT @Hp5361a;"PAVER,3000"        ! SETUP TO PROFILE THE PULSE
350 Man_freq$="MANUAL,"&VAL$(Ans)       ! USE THE FREQUENCY FOUND ABOVE
360 OUTPUT @Hp5361a;Man_freq$
370 OUTPUT @Hp5361a;"EFUN,33"           ! SETUP TO READ THE EVENTS AND TIMES
380 !
390 FOR I=1 TO Stop_val+1               ! RUN THE MAIN LOOP
400   OUTPUT @Hp5361a;"GWID,"&VAL$(No_of_events)&",EVENT"
410   OUTPUT @Hp5361a;"TRIGGER"
420   OUTPUT @Hp5361a;"EFUN?"
430   ENTER @Hp5361a;Ans1$
440   Events(I)=VAL(Ans1$[2,12])
450   Times(I)=VAL(Ans1$[14,24])
460   !
470   ! IF THE NUMBER OF EVENTS PROGRAMMED ARE GREATER THAN 47 AND DIVISIBLE
480   ! BY 16, THEN THE COUNTER CHOOSES ONE LESS EVENT FOR THE GATE WIDTH
490   ! e.g.  NUMBER OF EVENTS = 64
500   !       COUNTER CHOOSES 63 EVENTS
510   !
520   IF (I>40) THEN ! INTERPOLATE FOR GATE WIDTH MENTIONED ABOVE
530     IF NOT ((I>=40) AND (((I+2) MOD 16)=1)) THEN
540       IF (Times(I)=Times(I-1)) THEN GOTO 400 ! RARE, BUT COULD HAPPEN
550       Events(I-1)=(Events(I)+Events(I-2))/2
560       Times(I-1)=(Times(I)+Times(I-2))/2
570     END IF
580   END IF
590   !
600   No_of_events=No_of_events+Increment_value
610 NEXT I
```

```
620  !
630  ! RUN DATA THROUGH SMOOTHING FILTER
640  Lo(1)=1
650  Hi(1)=Stop_val
660  Kmax=1
670  Filter_f5(If2(*),Lo(*),Hi(*),Events(*),Times(*),Kmax) ! FIVE POLE FILTER
680  Filter_f7(If3(*),Lo(*),Hi(*),Events(*),Times(*),Kmax) ! SEVEN POLE FILTER
690  !
700  FOR I=2 TO Stop_val+1                    ! CALCULATE 'IF' FROM EVENTS AND TIME
710    If1(I-1)=(Events(I)-Events(I-1))/(Times(I)-Times(I-1))*1.E+9
720  NEXT I
730  !
740  OUTPUT @Hp5361a;"EFUN,4"                 ! DETERMINE THE LOCAL OSCILLATOR FREQUENCY
750  TRIGGER @Hp5361a
760  OUTPUT @Hp5361a;"EFUN?"
770  ENTER @Hp5361a;Ans1$
780  Local_osc_freq=VAL(Ans1$[3])*100000
790  !
800  OUTPUT @Hp5361a;"EFUN,68"                ! DETERMINE THE HARMONIC NUMBER AND THE
810  TRIGGER @Hp5361a                         ! SIDEBAND
820  OUTPUT @Hp5361a;"EFUN?"
830  ENTER @Hp5361a;Ans1$
840  Harm_num=VAL(Ans1$[12])/100
850  N_lo=Harm_num*Local_osc_freq
860  !
870  IF Ans1$[18,18]="L" THEN ! CALCULATE THE FREQUENCY FOR THE LOWER
880   FOR I=1 TO Stop_val                     ! SIDEBAND
890    Freq(I)=N_lo-If1(I)
900    Freq2(I)=N_lo-If2(I)
910    Freq3(I)=N_lo-If3(I)
920    IF (Freq(I)<Freq_min) THEN Freq_min=Freq(I)
930    IF (Freq(I)>Freq_max) THEN Freq_max=Freq(I)
940   NEXT I
950  ELSE                                     ! OR THE UPPER SIDEBAND
960   FOR I=1 TO Stop_val
970    Freq(I)=N_lo+If1(I)
980    Freq2(I)=N_lo+If2(I)
990    Freq3(I)=N_lo+If3(I)
1000    IF (Freq(I)<Freq_min) THEN Freq_min=Freq(I)
1010    IF (Freq(I)>Freq_max) THEN Freq_max=Freq(I)
1020   NEXT I
1030 END IF
1040 !
1050 Freq_max=(INT(Freq_max/1.E+5)+1)*1.E+5
1060 Freq_min=(INT(Freq_min/1.E+5)-1)*1.E+5
1070 !
1080 OUTPUT @Hp5361a;"DISPLAY,""
1090 OUTPUT @Hp5361a;"INIT"
1100 LOCAL @Hp5361a
1110 !
1120 Graph_it(Freq(*))
1130 !
1140 PRINT "PRESS CONTINUE TO PLOT THE FILTERED DATA ( FIVE POLES )"
1150 PAUSE
1160 Graph_it(Freq2(*))                       ! GRAPH THE FIVE POLE FILTERED DATA
1170 !
1180 PRINT "PRESS CONTINUE TO PLOT THE FILTERED DATA ( SEVEN POLES )"
1190 PAUSE
1200 Graph_it(Freq3(*))                       ! GRAPH THE SEVEN POLE FILTERED DATA
1210 !
1220 END
1230 !
1260 SUB Graph_it(Freq(*))
1270   COM /Profile_data/ Freq_max,Freq_min,Ans,Stop_val,Increment_value
1280   IF ((Freq_max-Ans)>(Ans-Freq_min)) THEN
```

```
1290    Max_deviation=Freq_max-Ans
1300  ELSE
1310    Max_deviation=Ans-Freq_min
1320  END IF
1330  !
1340  SELECT Max_deviation/1.E+4 ! AUTO SCALE THE FREQUENCY AXIS
1350  CASE <10
1360    Division=1.0E+3
1370    Div2=1.E+6
1380  CASE <100
1390    Division=1.E+4
1400    Div2=1.E+5
1410  CASE ELSE
1420    Division=1.E+5
1430    Div2=1.E+4
1440  END SELECT
1450  !
1460   Max_deviation=INT(Max_deviation/Division)*Division
1480  GINIT  ! SETUP TO PLOT THE DATA
1490  GCLEAR
1500  GRAPHICS ON
1510  PLOTTER IS CRT,"INTERNAL"
1520  !
1530  ! LABEL THE GRAPHS
1540  !
1550  LORG 4
1560  FOR I=1 TO 1.6 STEP .1
1570    MOVE 60+I,65
1580    LABEL "PULSE PROFILE"
1590  NEXT I
1600  DEG
1610  LDIR 90
1620  LORG 6
1630  CSIZE 3.5
1640  MOVE 0,40
1650  LABEL "FREQUENCY (GHz)"
1660  LORG 4
1670  LDIR 0
1680  MOVE 60,3
1690  LABEL "TIME (nSec)"
1700  !
1710  ! SETUP THE DRAWING AREA
1720  !
1730  VIEWPORT 15,115,10,60
1740  FRAME
1750  WINDOW 1,Stop_val,Freq_min,Freq_max
1760  GRID 1,Max_deviation/10,-2,Ans,10,10,0
1770  !
1780  !  DRAW THE DATA !!
1790  !
1800  MOVE 1,Freq(1)
1810  FOR I=1 TO Stop_val
1820    IF NOT ((I>=40) AND (((I+3) MOD 16)=0)) THEN PLOT I,Freq(I)
1830  NEXT I
1840  !
1850  ! NUMBER AXIS
1860  !
1870  CLIP OFF
1880  CSIZE 2.6,.6
1890  LORG 8
1900  FOR I=Ans TO Freq_max STEP Max_deviation/5
1910    MOVE 1,I
1920    LABEL USING "#,DD.DDDD";(INT(I/Division)/Div2)
1930  NEXT I
1940  FOR I=Ans TO Freq_min STEP -Max_deviation/5
```

```
1950      MOVE 1,I
1960      LABEL USING "#,DD.DDDD";(INT(I/Division)/Div2)
1970    NEXT I
1980    !
1990    LORG 6
2000    FOR I=8 TO Stop_val STEP 10
2010      MOVE I,Freq_min-1
2020      LABEL USING "#,DDDD";(I+2)*(Increment_value*14)
2030    NEXT I
2040  SUBEND
2070  !
2080  SUB Filter_f5(Freq(*),Lo(*),Hi(*),E(*),T(*),Kmax)
2090 Filter_f5:!   Freq(*) computed over 5 points, less at the edges
2100    INTEGER I,L,H,K
2110    IF Kmax<1 THEN SUBEXIT
2120    FOR K=1 TO Kmax
2130      L=Lo(K)
2140      H=Hi(K)
2150      Freq(L)=(E(L+1)-E(L))/(T(L+1)-T(L))*1.E+9
2160      Freq(H)=(E(H)-E(H-1))/(T(H)-T(H-1))*1.E+9
2170      IF H-L>2 THEN
2180        Freq(L+1)=(E(L+2)-E(L))/(T(L+2)-T(L))*1.E+9
2190        Freq(H-1)=(E(H)-E(H-2))/(T(H)-T(H-2))*1.E+9
2200        IF H-L>4 THEN
2210          De1=E(L+3)-E(L)
2220          Dt1=T(L+3)-T(L)
2230          FOR I=L+2 TO H-2
2240            De2=E(I+2)-E(I-1)
2250            Dt2=T(I+2)-T(I-1)
2260            Freq(I)=((De2+De1)/(Dt2+Dt1))*1.0E+9
2270            De1=De2
2280            Dt1=Dt2
2290          NEXT I
2300        END IF
2310      END IF
2320    NEXT K
2330  SUBEND   !Filter_f5
2340  !
2350  SUB Filter_f7(Freq(*),Lo(*),Hi(*),E(*),T(*),Kmax)
2360 Filter_f7:!
2370    INTEGER I,L,H,K,J
2380    IF Kmax<1 THEN SUBEXIT
2390    FOR K=1 TO Kmax
2400      L=Lo(K)
2410      H=Hi(K)
2420      Freq(L)=(E(L+1)-E(L))/(T(L+1)-T(L))*1.E+9
2430      Freq(H)=(E(H)-E(H-1))/(T(H)-T(H-1))*1.E+9
2440      IF H-L>2 THEN
2450        Freq(L+1)=(E(L+2)-E(L))/(T(L+2)-T(L))*1.E+9
2460        Freq(H-1)=(E(H)-E(H-2))/(T(H)-T(H-2))*1.E+9
2470        IF H-L>4 THEN
2480          FOR J=L TO H-4 STEP H-L-4
2490            De1=E(J+3)-E(J)
2500            Dt1=T(J+3)-T(J)
2510            De2=E(J+4)-E(J+1)
2520            Dt2=T(J+4)-T(J+1)
2530            Freq(J+2)=(De1+De2)/(Dt1+Dt2)*1.E+9
2540          NEXT J
2550          IF H-L>6 THEN
2560            De1=E(L+4)-E(L)
2570            De2=E(L+5)-E(L+1)
2580            Dt1=T(L+4)-T(L)
```

```
2590         Dt2=T(L+5)-T(L+1)
2600         FOR I=L+3 TO H-3
2610           De3=E(I+3)-E(I-1)
2620           Dt3=T(I+3)-T(I-1)
2630           Freq(I)=(De1+De2+De3)/(Dt1+Dt2+Dt3)*1.E+9
2640           De1=De2
2650           De2=De3
2660           Dt1=Dt2
2670           Dt2=Dt3
2680         NEXT I
2690       END IF
2700     END IF
2710   END IF
2720 NEXT K
2730 SUBEND  !Filter_f7
```

For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

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