# 5345 ELECTRONIC COUNTER

HEWLETT hp PACKARD

## MEASURING THE STABILITY OF A FREQUENCY SOURCE

Stability measurements on frequency sources are made possible by the high resolution capability of the 5345 Electronic Counter. This application note describes the use of the 5345A Electronic Counter in a calculator based HP Interface Bus system which automatically measures and plots frequency deviation as a function of time. The system is extremely useful in obtaining high resolution plots of parameters such as oscillator long term drift and crystal oscillator warm up characteristics. The program automatically sets the counter gate time to give the necessary measurement resolution and uses the 5345 computer dump output mode to obtain a constant resolution of 2 parts in $10^9$ per second of gate time.

APPLICATION NOTE 174-6

hp

## INTRODUCTION

In the 5345A counter, two scalers (registers) are used to totalize events during the time that the gate is open. One totalizes input events and the other totalizes clock pulses. A processor in the 5345A operates upon these two numbers and provides the desired output display (frequency, period, ratio, etc.). As a result of the requirement that the display resolution can not exceed 2 parts in $10^9$ per second of gate time, the resolution of the displayed result is variable. Figure 1 shows resolution in parts in $10^9$ per second of gate time versus the most significant digits in the displayed number.

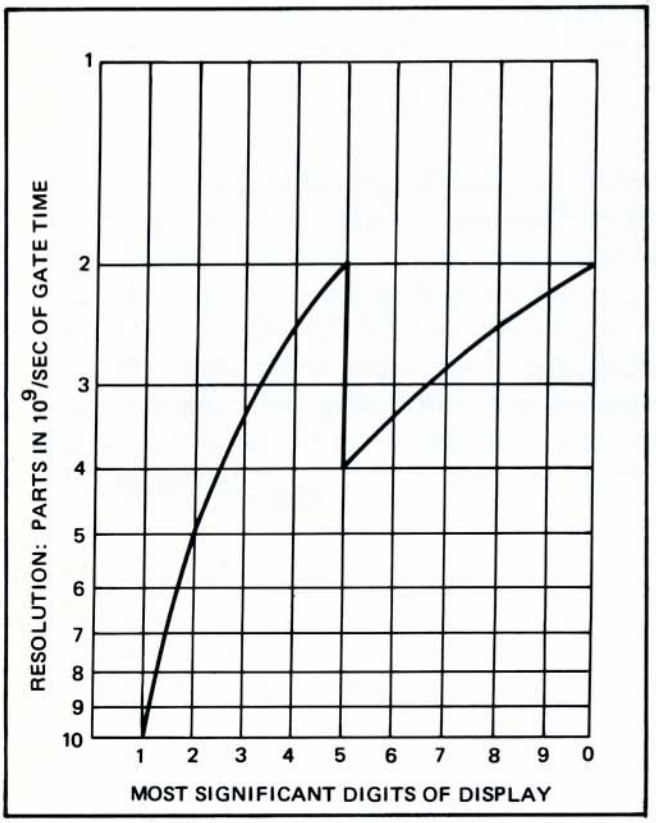


Figure 1. Resolution of the 5345 counter is a function of the most significant digits in the display. For a display of 499999999, the resolution would be 2 parts in $10^9$ (for 1 sec of gate time) whereas a display of 500000000 would be resolved to 4 parts in $10^9$ (for 1 sec of gate time).

The 5345A has two output modes: the talk mode and the computer dump mode. The computer dump mode of output bypasses the processor and is normally used when it is desired to output 5345A readings at a very high rate (up to 5000 readings/sec). It can also be used whenever it is desired to analyze or process the raw measurement data. In this application note, a calculator is used to reduce the raw data. Since the calculator is not subject to the constraints of a display, a constant resolution of 2 parts in $10^9$ per second of gate time can be obtained regardless of the input frequency. Figure 2 is a plot of measurement accuracy (effects of time base error and trigger error must be accounted for separately) versus gate time when using the computer dump mode of output.

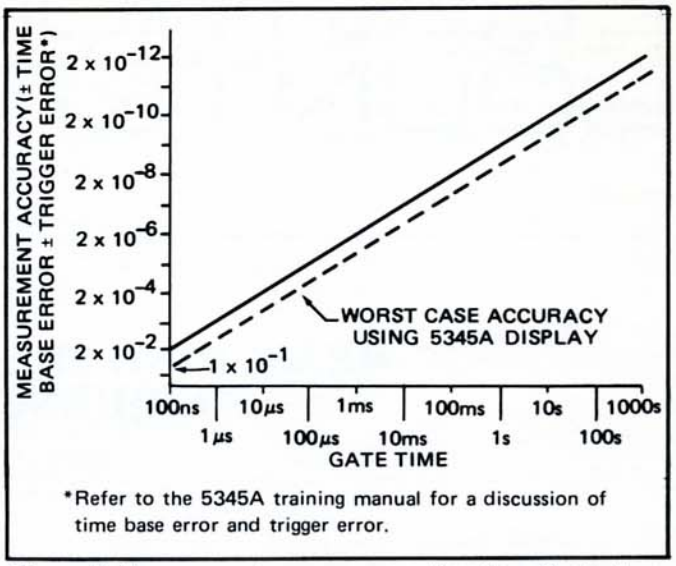


Figure 2. Measurement accuracy as a function of gate time for the computer dump mode of output (constant resolution of 2 parts in $10^9$).

Figure 3 is a plot of accuracy in terms of frequency as a function of gate time and input frequency. Again, the effects of time base error and trigger error must

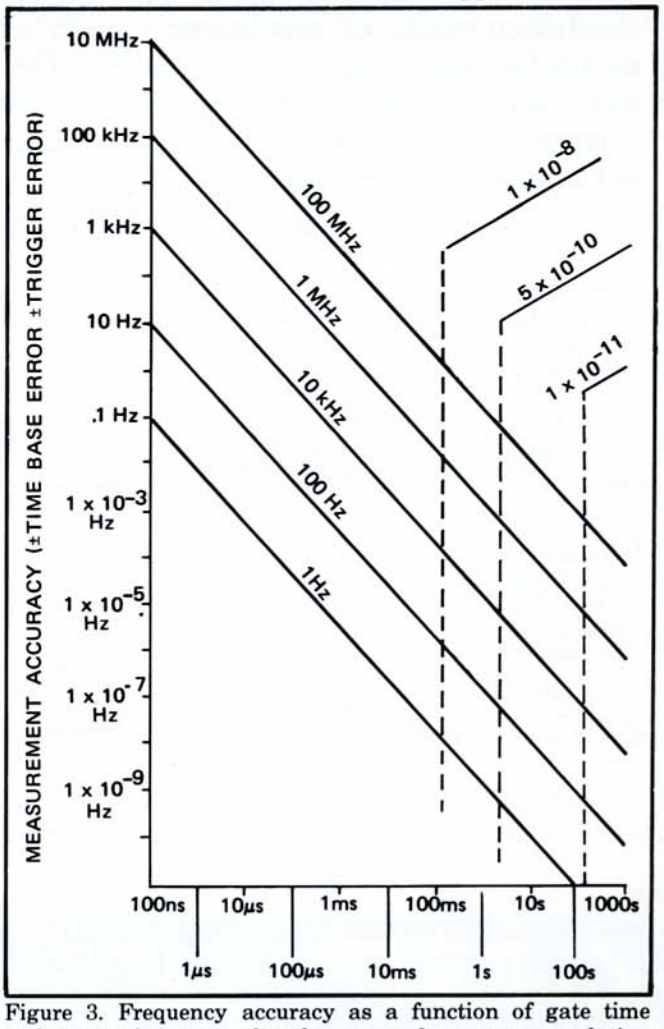


Figure 3. Frequency accuracy as a function of gate time and input frequency for the case of constant resolution (computer dump mode) of 2 parts in $10^9$/sec gate time.

be accounted for separately. The dashed vertical lines indicate where time base accuracies are of the same magnitude as the measurement accuracy. At this point, of course, extending the gate time cannot improve the measurement accuracy since the time base is limiting. Table I gives the stability characteristics of various time bases used in the 5345A and frequency standards which could be used to phase lock the 5345A clock by connecting the standard to the counter's rear panel EXT FREQ. STD INPUT connector.

Table 1

| Identification | Temperature | Short Term | Long Term | Normalized Long Term |
|---|---|---|---|---|
| Option 001 VT RT XO | $2 \times 10^{-6}$ (25°-35°C) | $2 \times 10^{-9}$/sec | $3 \times 10^{-7}$/mth | $1 \times 10^{-8}$/day |
| Standard Crystal 10544 Oven XTAL | $3 \times 10^{-9}$ (0°-55°C) | $1 \times 10^{-11}$/sec | $5 \times 10^{-10}$/day | $5 \times 10^{-10}$/day |
| Rubidium 5065 | $4 \times 10^{-11}$ (0°-50°C) | $5 \times 10^{-12}$/sec | $1 \times 10^{-11}$/mth | $3 \times 10^{-13}$/day |
| Cesium 5061A-Opt.004 | $5 \times 10^{-12}$ (0°-50°C) | $5 \times 10^{-12}$/sec | $3 \times 10^{-12}$/life of tube | — |

## MEASUREMENT SET-UP

The measurement system consists of the 5345A Electronic Counter (Opt. 011), the 9820A Calculator (Opt. 001 Extended Memory), the ASCII Interface Card and PCII ROM (both included in 10593A), 11221A Math ROM, 11220A PCI ROM, and 9862A Calculator Plotter (Opt. 20). The instruments are connected to the calculator as shown in Figure 4.

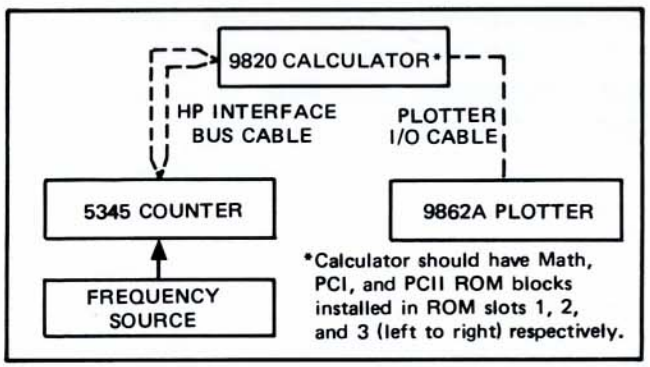


Figure 4

Since the 9820 Calculator remotely controls all front panel controls of the counter, there is no need to set these controls to any particular positions. The 5345A Electronic Counter is interfaced to the 9820 Calculator in the following manner: insert the ASCII Bus Interface card into any of the four slots on the rear panel of the 9820 Calculator; connect an ASCII Interface Cable (10631A, B, or C) from the interface card of the calculator to the rear panel plug of the 5345A Electronic Counter. To interface the plotter to the calculator, plug the 9862 Plotter I/O Card into any of the three remaining slots on the rear panel of the 9820 Calculator.

Set the Talk/Listen address on the frequency counter as specified in the following table:

Table 2

| | Talk/Listen Address | Mode Switch | A5 | A4 | A3 | A2 |
|---|---|---|---|---|---|---|
| 5345A Counter | K/* (K=computer dump mode) | addressable | 0 | 1 | 0 | 1 |

These switches are located on the rear panel of the instrument and must be set so as to agree with the Talk/Listen address in the program.

## OPERATION

Key into the calculator the provided program. The program will request the following parameters:

1) "NO. OF POINTS" — enter the number of measurements to be made and plotted.
2) "CENTER FREQ" — enter the nominal frequency of the frequency source in Hz.
3) "VERTICAL DEV EXP" — enter the vertical deviation exponent. For parts in $10^6$ resolution, enter 6. For parts in $10^8$, enter 8.

The program automatically sets the 5345A gate time so that the counter resolution is 50 times greater than the major divisions on the plotter output. After lettering the plot, the program halts to allow changing of the plotter pen. Push the RUN PROGRAM key to resume execution. The calculator then reads the two scalers in the counter, computes the frequency, and outputs the data to the plotter. Figure 5 shows the frequency stability of the 8601A Generator/Sweeper over a time period of approximately 1/2 minute.

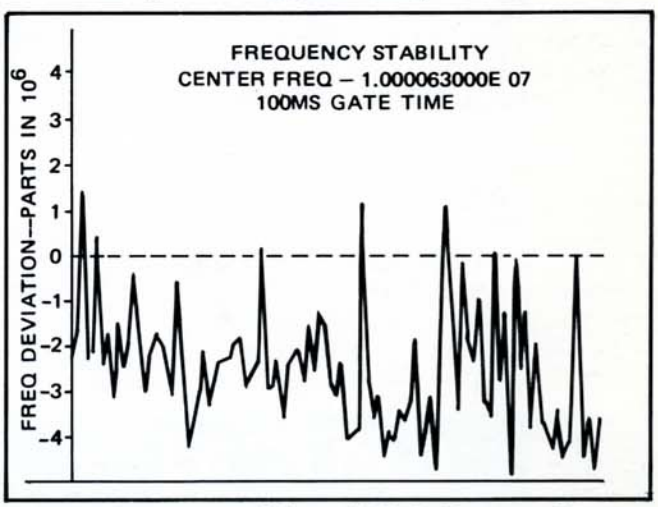


Figure 5. Frequency stability of 8601A Generator/Sweeper. 100 measurements were made over a time period of approximately one half minute.

## MEASUREMENT CONSIDERATIONS

a) Resolution is a constant 2 parts in $10^9$. High resolution plots will result in long gate times and hence, large time intervals between measurements.

b) Misleading results will be obtained if the requested resolution exceeds the stability of the crystal in the counter. For very high resolutions, phase lock the counter clock to a "house standard".

Program Listing

```
0:
DSP "FREQ. CHAR.
";DSP ;DSP ⊢
1:
ENT "NO. OF POIN
TS",A;ENT "CENTE
R FREQ.",B;ENT "
VERTICAL DEV EXP
",C⊢
2:
-C→C⊢
3:
5B*10↑C→R0⊢
4:
SCL -.1A,A,-R0,R
0⊢
5:
IF FLG 0;GTO "M"
⊢
6:
AXE 0,-R0,A,2R0/
10⊢
7:
LTR .25(1.1A),.9
4R0,421⊢
8:
PLT "FREQUENCY S
TABILITY"⊢
9:
FLT 9;LTR .29(1.
1A),.88R0,211;
PLT "CENTER FREQ
.--";PLT B⊢
10:
FXD 0⊢
11:
LTR -.04A,-.5R0,
322⊢
12:
PLT "FREQ DEVIAT
ION--PARTS IN 10
";LTR -.055A,.55
R0,212;PLT -C⊢
13:
0→R1⊢
14:
PLT R1,0;PLT R1+
.01A,0;PEN ;R1+.
03A→R1;GTO +0;
IF R1>A;GTO +1⊢
15:
-.81→Z⊢
16:
LTR -.03A,ZR0,21
1;PLT Z/.2;Z+.2→
Z;GTO +0;IF Z>-.
2;JMP 1⊢
17:
LTR -.02A,ZR0,21
1;PLT Z/.2;Z+.2→
Z;GTO +0;IF Z>.8
;JMP 1⊢
18:
"M";CMD "U?*","I
2E8I1";GSB "GATE
"⊢
19:
DSP "CHANGE PEN?
";STP ⊢
20:
CMD "K?5";0→R4→R
5⊢
21:
"LOOP";0→R5→R6⊢
22:
0→R7;1→R8⊢
23:
RDB 13-48→X;R6+1
→R6⊢
24:
X*R8+R7→R7;R8*10
→R8⊢
25:
IF R6=16;R5+1→R5
;R7→RR5;GTO +2⊢
26:
GTO -3⊢
27:
IF R5=1;0→R6;
GTO -5⊢
28:
R1/(R2*2E-9)→R3⊢
29:
IF R4;PLT R4-1,B
-Y⊢
30:
FLT 9;DSP R3;
DSP ;DSP ;PLT R4
,B-R3;PEN ;R4+1→
R4;R3→Y⊢
31:
GTO "LOOP";IF R4
>A;JMP 1⊢
32:
DSP "END OF PLOT
";CMD "U?*","I1"
;LTR A,R0;STP ;
GTO 1⊢
33:
"GATE";LTR .33(1
,1A),.82R0,211;
IF C>-6;CMD "","
G>";PLT "10MS GA
TE TIME";RET ⊢
34:
IF C>-7;CMD "","
G?";PLT "100MS G
ATE TIME";RET ⊢
35:
IF C>-8;CMD "","
G0";PLT "1S GATE
 TIME";RET ⊢
36:
IF C>-9;CMD "","
G1";PLT "10S GAT
E TIME";RET ⊢
37:
IF C>-10;CMD "",
"G2";PLT "100 S
GATE TIME";RET ⊢
38:
IF C>-11;CMD "",
"G3";PLT "1000S
GATE TIME";RET ⊢
39:
IF C>-12;CMD "",
"G4";PLT "10000S
 GATE TIME";RET
⊢
40:
END ⊢
R269
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