5345 ELECTRONIC COUNTER

HEWLETT PACKARD

MEASURING FRACTIONAL FREQUENCY DEVIATION (SHORT TERM STABILITY OF OSCILLATORS)

The high resolution capability of the 5345 Electronic Counter coupled with the computational power of the 9820A Calculator permit fast and accurate determination of the fractional frequency standard deviation of frequency sources. This application note describes a calculator based HP Interface Bus system which automatically determines and plots the fractional frequency standard deviation of sources for averaging times from one microsecond to one second. The calculator program exercises complete control over the measurement process, thereby enhancing repeatability and accuracy of the measurements as compared to manual methods. Use of the HP Interface Bus ensures that the instruments need not be dedicated to a particular configuration (as in the case of hard-wired systems). The bus allows instruments to be quickly and easily reconfigured to meet the changing requirements of production, R&D, or quality control.

INTRODUCTION

The fractional frequency standard deviation, $\sigma(\Delta f/f)$ is a measure of the short term stability of a frequency source. It provides a time-domain characterization of the phase noise inherent in all frequency sources. For meaningful characterization, however, the parameter must be specified with the averaging time and sample size used since the longer the averaging time, the more the deviation is obscured.

For the particular types of random processes involved in precision frequency sources, the variance of the frequency fluctuation* may be estimated as:

$$\sigma_N^2\left(\frac{\Delta f}{f}\right) = \frac{1}{f_o^2\,(N-1)}\left[\sum_{i=1}^{N} f_i^2 - \frac{1}{N}\left(\sum_{i=1}^{N} f_i\right)^2\right]$$

For N = 2, this becomes:

$$\sigma_2^2\left(\frac{\Delta f}{f}\right) = \frac{\left(f_1 - f_2\right)^2}{2\, f_o^2}$$

In order to improve the estimate, the relation should be averaged over many measurements. The average of the standard deviation is:

$$< \sigma_2\left(\frac{\Delta f}{f}\right) > \; = \frac{1}{f_o}\sqrt{\frac{1}{2M}\sum_{i=1}^{M}\left(f_{2i} - f_{2i-1}\right)^2}$$

where M = number of pairs of measurements and fo = the nominal output frequency.

The 9820A Calculator program described in this note controls a 5345A Electronic Counter to automatically measure M pairs of frequencies from a frequency source at gate times from 1 μsec to 1 second. The program then computes the average fractional frequency standard deviation $\langle \sigma_2\, (\Delta f/f) \rangle$ for each gate time and plots this information on the plotter.

*Statistics of Atomic Frequency Standards
David W. Allan N.B.S.
Proc. IEEE, Vol. 54, No. 2, February 1966.

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MEASUREMENT SET-UP

The measurement system consists of the 5345A Electronic Counter (Opt. 011), the 9820A Calculator (Opt. 001 Extended Memory), the ASCII Bus 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 1.

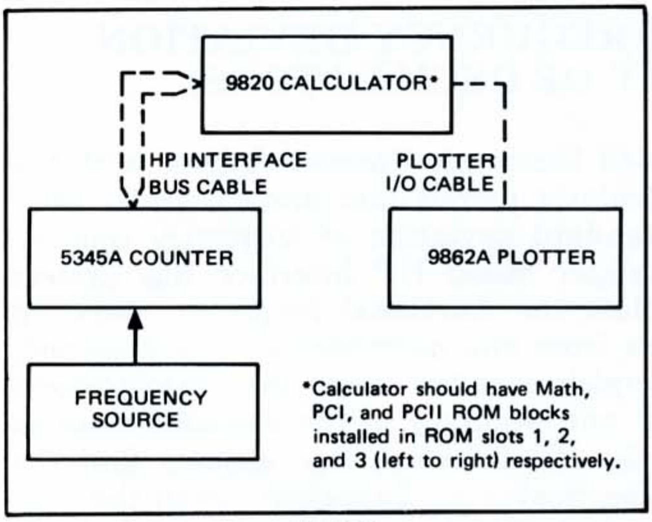


Figure 1

Since the 9820A 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 9820A Calculator in the following manner: plug the ASCII Bus Interface card into any one of the four slots on the rear panel of the 9820A 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 1

	Talk/Listen Address	Mode Switch	A5	A4	A3	A2
5345A Counter	J/*	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

To automatically measure and plot the fractional frequency standard deviation as a function of averaging time, key into the calculator the listed program. The program will request the number (M) of pairs of measurements which are to be made. The averaging times are fixed by the program at 1 μsec, 10 μsec, 100 μsec, 1 msec, 10 msec, 100 msec, and 1 sec.

The program flow diagram describes the various steps which occur during program execution. After the computation of the average fractional frequency standard deviation at a particular gate time, the calculator printer prints the gate time and the corresponding $\langle\sigma_2(\Delta f/f)\rangle$. If the calculated average fractional frequency standard deviation is less than or equal to the rms resolution limit of the counter (8.2×10^{-10} per second of gate time), the message "RESOLUTION EXCEEDED" is printed by the calculator printer and the plotter does not plot the point. The graph of Figure 2 shows the rms resolution limit of the counter as a function of gate time. Values of $\langle\sigma_2(\Delta f/f)\rangle$ falling above the line are valid. Figure 3 shows the plot which resulted for the case of 50 pairs of measurements on the 8640B Signal Generator and 3310A Function Generator both set at 1 MHz. As can be seen, the resolution limit was exceeded at several of the lesser gate times.

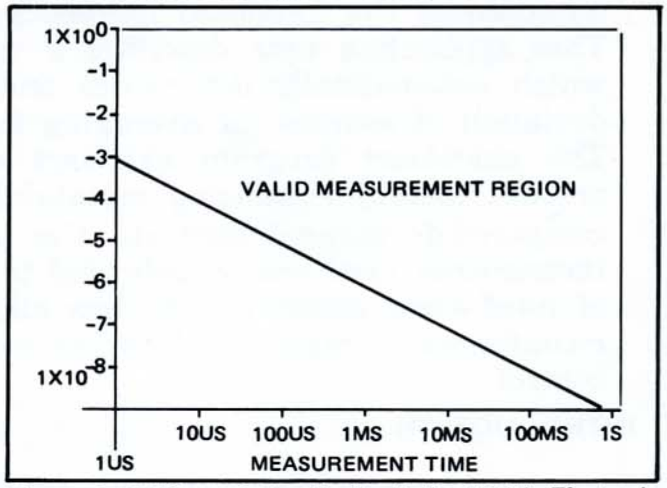


Figure 2. RMS resolution limit of the 5345A Electronic Counter ($.82 \times 10^{-9}$ per second of gate time). Fractional frequency standard deviations above the line are valid measurements.

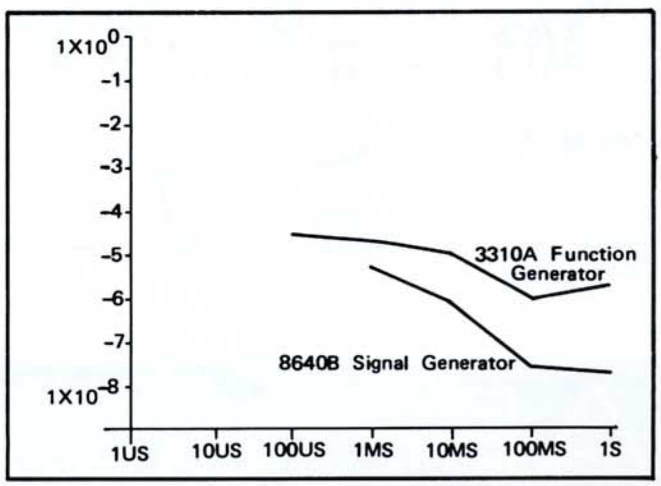


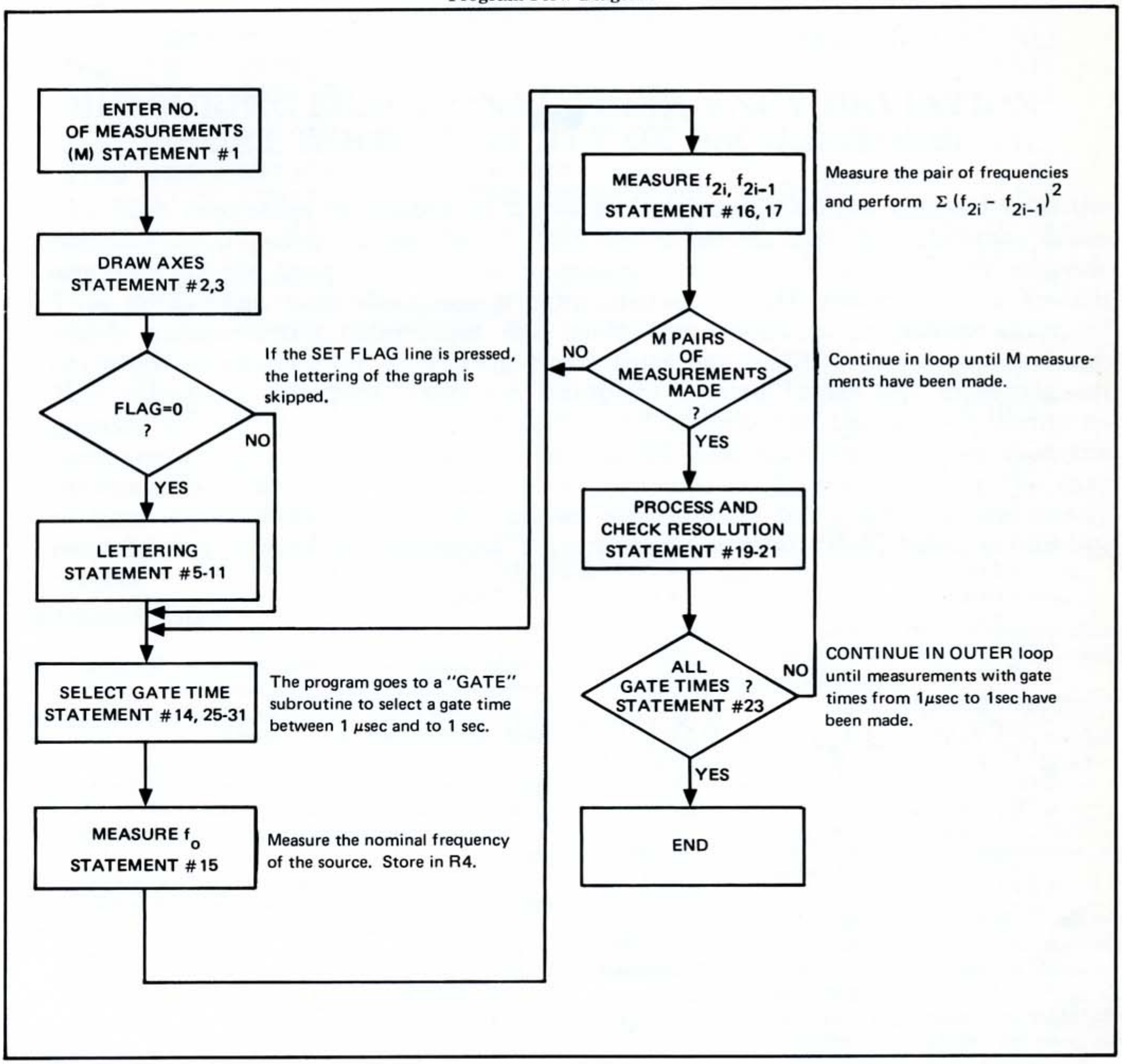
Figure 3. Fractional frequency standard deviation for 3310A Function Generator and 8640B Signal Generator.

MEASUREMENT CONSIDERATIONS

a) By modifying the software, averaging times (gate times) from 100 nsec to 10,000 sec are possible.

b) There is no limit to the number of pairs of measurements which may be made.

Program Flow Diagram



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0:
DSP "FRAC FREQ D
EV";DSP ;DSP ;
DSP ⊢
1:
ENT "NO OF MEAS"
,A;CFG 1⊢
2:
SCL -6.6,.1,-10,
.15⊢
3:
AXE -6,-9,1,1⊢
4:
IF FLG 0;GTO "M"
⊢
5:
LTR -4.8,-.3,421
;PLT "FRACTIONAL
 FREQUENCY DEVIA
TION"⊢
6:
LTR -5.99,-9.3,3
11⊢
7:
PLT "1US
   10US
 100US
  1MS"⊢
8:
PLT "
 10MS
100MS
 1S"⊢
9:
LTR -4,-9.7,321;
PLT "MEASUREMENT
 TIME"⊢
10:
-8.1→Y;FXD 0⊢
11:
LTR -6.5,Y,311;
PLT "1X10";LTR -
6.2,Y+.1,211;
PLT Y;Y+1→Y;GTO
+0;IF Y>0;JMP 1⊢
12:
"M";1→C⊢
13:
"G";CMD "U?*","I
2E8I1";0→R3;0→B⊢
14:
CMD "U?*";GSB "G
ATE"⊢
15:
CMD "J?5";FMT *;
RED 13,R4⊢
16:
"LOOP";FMT *;
RED 13,R1;FMT *;
RED 13,R2⊢
17:
R3+(R2-R1)↑2→R3;
B+1→B;GTO "LOOP"
;IF B>A;JMP 1⊢
18:
IF FLG 1;PLT C-8
,LOG R6⊢
19:
R3/2A→R5⊢
20:
IF R5/R4R4≤(.82E
-9/TN↑ (C-7))↑2;
PRT "RESOLUTION
";PRT "  EXCEEDE
D";CFG 1;JMP 3⊢
21:
SFG 1;√R5/R4→R5⊢
22:
PLT C-7,LOG R5;R
5→R6;PEN ;FLT 3;
PRT R5⊢
23:
C+1→C;GTO "G";
IF C>7;JMP 1⊢
24:
DSP "END OF PLOT
";LTR .1,.15;
GTO 1;STP ⊢
25:
"GATE";IF C>6;
CMD "","G0";PRT
"1S GATE TIME";
RET ⊢
26:
IF C>5;CMD "","G
?";PRT "100MS GA
TE TIME";RET ⊢
27:
IF C>4;CMD "","G
>";PRT "10MS GAT
E TIME";RET ⊢
28:
IF C>3;CMD "","G
=";PRT "1MS GATE
 TIME";RET ⊢
29:
IF C>2;CMD "","G
≤";PRT "100US GA
TE TIME";RET ⊢
30:
IF C>1;CMD "","G
;";PRT "10US GAT
E TIME";RET ⊢
31:
IF C>0;CMD "","G
:";PRT "1US GATE
 TIME";RET ⊢
32:
END ⊢
R293
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