5345 ELECTRONIC COUNTER

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MEASURING FREQUENCY SWEEP LINEARITY OF SWEEP GENERATORS

Application Note 174-12 describes the use of the 5345A Electronic Counter and the 59308A Timing Generator in a calculator based HP Interface Bus system to measure frequency sweep linearity of sweep generators. The program plots the frequency versus time characteristic of the sweeper under test and then computes and plots the differential nonlinearity curve. The calculator program exercises complete control over the measurement process, thereby enhancing repeatability, accuracy, and speed of the measurements as compared to manual methods. Use of the HP Interface Bus ensures that the instruments need not be dedicated to this particular configuration. The bus allows instruments to be quickly and easily reconfigured to solve a wide variety of measurement problems.

APPLICATION NOTE 174-12

hp

INTRODUCTION

In swept frequency measurements, which are often used to characterize loss and phase as a function of frequency for an unknown device or system, the signal source is a controlled oscillator which is made to vary in frequency between two limits in a prescribed manner, usually linear frequency change with time. Accurate frequency identification in the display depends to a great degree upon the linearity of the sweeper. Usually, the linearity of a sweeper is tested by measuring the linearity of the modulating ramp waveform. However, this assumes that the modulator is linear. The only way to ensure sweep linearity is to actually measure the frequency out of the sweeper as a function of time. In this application, the 5345A measures the frequency out of the sweep generator at user specified time intervals. The 9820A Calculator plots the frequency versus time curve and then computes and plots the differential nonlinearity ($\Delta f/\Delta t$) as a function of time.

MEASUREMENT SET-UP

The measurement system consists of the 5345A Electronic Counter (opt. 011), the 59308A Timing Generator, the 59405A opt. 020/021A HP-IB Calculator Interface, the 11221A Math ROM block, the 11220A PCI ROM block, the 9862A Calculator Plotter, and the 9820/21A Calculator with opt. 001 Extended Memory. The instruments are connected to the calculator as shown in Figure 1.

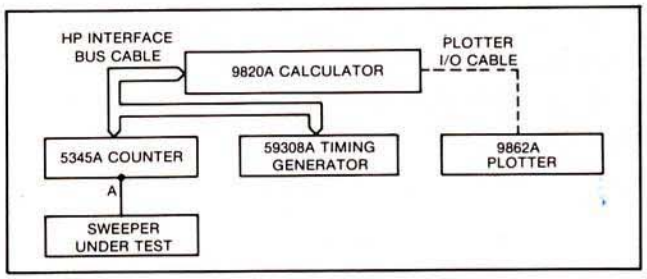

Figure 1

Set the Talk/Listen address switches on the frequency counter and timing generator as specified in Table 1. These switches are located on the rear panels of the instruments and must be set so as to agree with the Talk/Listen addresses in the program.

Table 1

	Talk/Listen Addresses	Mode Switch	A5	A4	A3	A2	A1
5345A Counter	J/*	addressable	0	1	0	1	††
59308A Timing Generator	R/2	addressable	1	0	0	1	0

††*not used*

Place the Math, PCI, and PCII ROM blocks into ROM slots 1, 2, and 3 respectively of the 9820A Calculator. To interface the instruments to the calculator, perform the following: plug the ASCII Bus Interface Card into any of the four slots on the rear panel of the 9820A Calculator. Connect ASCII Interface Cables (10631A, B, or C) from the interface card of the calculator to the rear panel plugs of the 5345A Counter and the 59308A Timing Generator (choose cable lengths such that the total length of ASCII cable does not exceed 18 feet). Plug the 9862A Calculator Plotter I/O Card into any of the three remaining slots on the rear panel of the calculator.

Set the following 5345A controls as a function of the sweeper under test: Channel A impedance (50 ohm or 1 Meg ohm), Channel A trigger level to preset (for symmetrical waveforms about 0 volts), Channel A attenuation (X1 or X20), AC or DC, and the SEP/COM switch to separate. Since the calculator remotely controls all other front panel controls of the counter and all the controls of the timing generator, there is no need to set these controls to any particular positions.

OPERATION

Key into the calculator the program listed on the back of this application note. Take care when keying in PLT (PLOT), FMT (FORMAT), WRT (WRITE), and RED (READ) statements that a PCI key is not used when a PCII key is intended (keys labeled as above appear on both PCI and PCII ROM blocks — they provide different functions and may *not* be interchanged). All statements which are used in plotting refer to the PCI keys. All statements which involve transfer of data over the HP Interface Bus refer to the PCII keys. In this program, all PLT statements refer to PCI and all FMT, WRT, and RED statements refer to the PCII keys. If the program fails to operate, ensure that PCI and PCII statements have not been interchanged. After keying in the program, record it on a magnetic card for future use.

The program will request the user to enter the following parameters:

"DELTA TIME?" — enter the desired time interval (in seconds) between measurements. Since the measurement portion of the program cannot be executed faster than approximately once every 90 msec, the "DELTA TIME" should be greater than or equal to .1 sec.

"NO. OF POINTS?" — enter the number of measurements which are to be taken. This number must be less than or equal to 230 and is limited by the storage capacity of the 9820A Calculator (option 001).

"PLUG-IN (Y = 1)" — enter 1 if measurements are to be made through a plug-in (e.g., the 5354A Automatic

Frequency Converter for sweepers in the 15 MHz to 4 GHz range).

Figure 2 is a flow diagram of the 9820A Calculator program. After entry of the necessary parameters, the counter gate time is selected and the timing generator is loaded with the required time delay. A trigger is

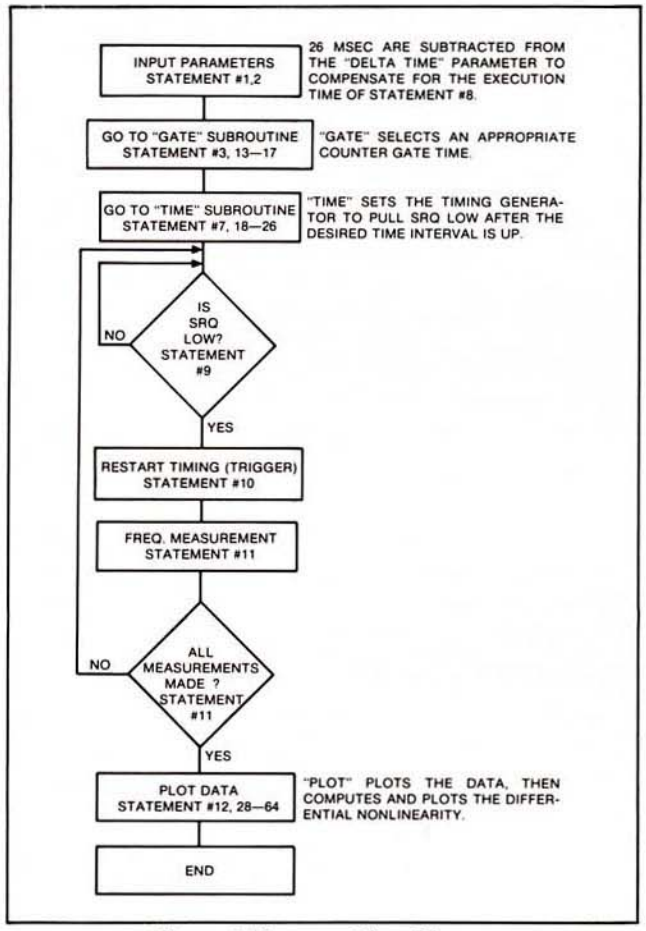

Figure 2. Program Flow Diagram

given to the timing generator; the program then waits for SRQ (service request) line to be pulled low which indicates that the requested delay is up. A frequency measurement is made, the timer is triggered and the process repeats until the desired number of measurements is made. The program then plots frequency versus time and computes and plots the differential nonlinearity of the data. The differential nonlinearity curve is a sensitive measure of device linearity since it plots $\Delta f/\Delta t$ as a function of time (t). Ideally, this curve for a linear sweeper would be a horizontal straight line. The plot of Figure 3 was generated by the program for the HP 8601A Generator/Sweeper.

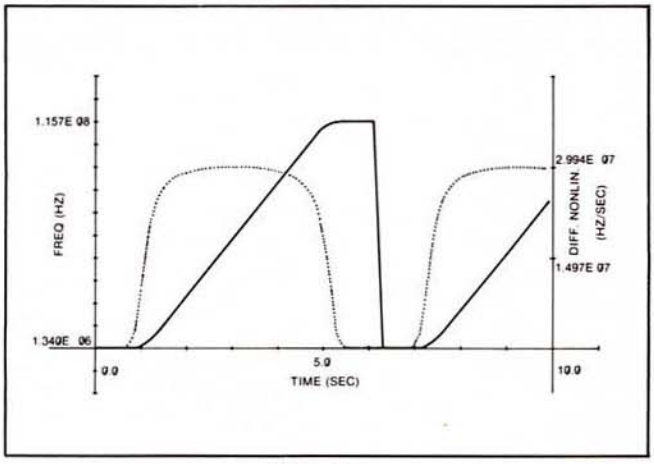

Figure 3

MEASUREMENT CONSIDERATIONS

a. Since the system cannot take measurements faster than every .1 seconds, the fastest practical sweep rate measurable with the system is on the order of 1 sweep/second.

b. The gate time programmed for the 5345A Counter must be of sufficient duration to give the necessary resolution. The program automatically selects a gate time which is 1/100 the time between measurements ("DELTA TIME"). Since the worst case resolution of the counter is 1 part in 10^8 per second of gate time, the frequency must change enough between successive measurements such that the counter can measure the change. For example, with a 100 kHz signal and a time between measurements of .1 seconds (1 msec gate time), changes in frequency on the order of 1 Hz may be detected.

c. The accuracy of the timing measurements is limited by the execution time of certain program statements in the program. The error is on the order of ±5 msec.

9820/21A Program Listing

```
0:                      -IN ?(Y=1)",X⊢          IF X=1;CMD "",":F
DSP "FREQ VS TIM        3:                      2I1"⊢
E";DSP ;DSP ;           1→B;CMD "?U*","I        6:
DSP ⊢                   2";GSB "GATE"⊢          CMD "?J";DSP ⊢
1:                      4:                      7:
ENT "DELTA TIME         CMD "?U*";FMT Y2        GSB "TIME"⊢
?",A;A-.026→A⊢          ,Z;WRT 13;WTB 13        8:
2:                      ,71;WTB 13,C⊢           CMD "?U2","R"⊢
ENT "NO OF POINT        5:                      9:
S?",R0;ENT "PLUG        CMD "","E89:I1";        "WAIT";IF RDS 13
```

```
>1.9;GTO "WAIT"⊢
10:
CMD "?U2","R"⊢
11:
CMD "?U*","J1";
CMD "?J5";FMT +;
RED 13,RB;B+1→B;
CMD "?";IF B≤R0;
GTO "WAIT"⊢
12:
GTO "PLT"⊢
13:
"GATE";A/100→C⊢
14:
IF C≤1.E-3;61→C;
RET ⊢
15:
IF C≤1.E-2;62→C;
RET ⊢
16:
IF C≤1.E-1;63→C;
RET ⊢
17:
48→C;RET ⊢
18:
"TIME";FLT 5;-7→
Z⊢
19:
"LP";INT (A/1.
TN↑ Z)→X⊢
20:
IF X≤999;GTO "EX
";⊢
21:
Z+1→Z;GTO "LP"⊢
22:
"EX";INT (X/100)
→C⊢
23:
INT (X/10)-C*10→
Y⊢
24:
X-100*C-10*Y→X;Z
+6→Z⊢
25:
CMD "?U2","ST";
FMT Y2,Z;WRT 13;
WTB 13,C+48;WTB
13,Y+48;WTB 13,X
+48;WTB 13,69⊢
26:
WTB 13,Z+48⊢
27:
RET ⊢
28:
"PLT";A+.026→A;2
→Z;R1→X→Y⊢
29:
"LOP";IF RZ≤X;RZ
→X⊢
30:
IF RZ>Y;RZ→Y⊢
31:
Z+1→Z;IF Z≤R0;
GTO "LOP"⊢
32:
FLT 5;PRT "YMIN
(HZ)=",X;PRT "YM
AX (HZ)=",Y⊢
33:
SCL -.1*A*R0,A*R
0*1.1,X-(Y-X)*.2
,Y+(Y-X)*.2⊢
34:
IF FLG 0;CFG 0;
GTO "M"⊢
35:
AXE 0,X,A*R0/10,
(Y-X)/10⊢
36:
X-(Y-X)*.1→Z⊢
37:
FXD 1;LTR 0,Z,21
1;PLT 0⊢
38:
LTR A*R0/2,Z;
PLT A*R0/2⊢
39:
LTR A*R0,Z;PLT A
*R0⊢
40:
LTR AR0/3,X-(Y-X
)*.2,331;PLT "TI
ME(SEC)"⊢
41:
FLT 3;LTR -.1*A*
R0,X+(Y-X)*.02,2
11;PLT X⊢
42:
LTR -.1*A*R0,Y;
PLT Y⊢
43:
LTR -.05*A*R0,X+
(Y-X)/3,332;PLT
"FREQ (HZ)"⊢
44:
"M";1→Z;0→C⊢
45:
"LUP";PLT C,RZ⊢
46:
Z+1→Z;C+A→C;IF Z
≤R0;GTO "LUP"⊢
47:
PEN ⊢
48:
DSP "DIFF. NONLI
N.";STP ⊢
49:
1→Z⊢
50:
"ST";PLT 5;Z+2→X
;(RX-RZ)/(2*A)→R
Z⊢
51:
IF Z+1≤R0;Z+1→Z;
GTO "ST"⊢
52:
R1→X→Y;2→Z⊢
53:
"S";IF RZ>Y;RZ→Y
⊢
54:
IF Z-1≤R0;Z+1→Z;
GTO "S"⊢
55:
SCL -.1*A*R0,A*R
0*1.1,-Y/4,Y*1.5
⊢
56:
IF FLG 0;GTO "N"
⊢
57:
AXE A*R0,0,A*R0/
10,Y/2;FLT 3⊢
58:
LTR A*R0*1.002,Y
,211;PLT Y⊢
59:
LTR A*R0*1.002,Y
/2;PLT Y/2⊢
60:
LTR A*R0,0;FXD 2
;PLT 0.⊢
61:
LTR A*R0*1.05,Y/
1.75,222;PLT "DI
FF. NONLIN."⊢
62:
LTR AR0*1.1,Y/1.
75;PLT "(HZ/SEC)
"⊢
63:
"N";1→Z⊢
64:
"L";PLT Z*A,RZ;
IF Z+1≤R0;Z+1→Z;
GTO "L"⊢
65:
END ⊢
R230
```

USING THE 9830A CALCULATOR

The 9830A Calculator may be used in place of the 9820/21A Calculator with system operation remaining virtually unchanged. The following sections list the necessary equipment for operation with the 9830A Calculator, discuss any differences in program operation, and present a complete program listing of the 9830A software.

MEASUREMENT SET-UP

The 9830A measurement system consists of the 5345A Electronic Counter (opt. 011), the 59308A Timing Generator, the 59405A opt. 030 HP-IB Calculator Interface, the 9862A Calculator Plotter, the 9830A Calculator, the 11274B String Variables ROM, the 11271B Plotter Control ROM, and the 9866A Calculator Printer. Place the Extended I/O ROM, the String Variables ROM, and the Plotter Control ROM in any of the Calculator ROM slots. The instruments are configured in precisely the same manner as in the case when the 9820/21A calculator is the controller.

SYSTEM OPERATION

The system with the 9830A Calculator as controller operates basically in the same manner as the system with the 9820A Calculator as controller. The program requests the user to respond to the following:

"DELTA TIME?" — same as for 9820A program.

"NUMBER OF POINTS?" — enter the number of measurements to be taken. This number must be less than 250 and is limited by the maximum allowable size of an array.

"PLUG-IN: YES OR NO?" — enter YES if the plug-in compartment is used.

"LETTERING — YES OR NO?" — enter YES if the plot is to be lettered.

"CHANGE PEN-PUSH CONT, EXECUTE". The user is allowed time to change pen color for the differential nonlinearity plot. After doing so, push the CONTINUE key followed by the EXECUTE key.

"LETTERING — YES OR NO?" — enter YES if the differential nonlinearity plot is to be lettered.

Figure 4 is a flow diagram of the 9830A software.

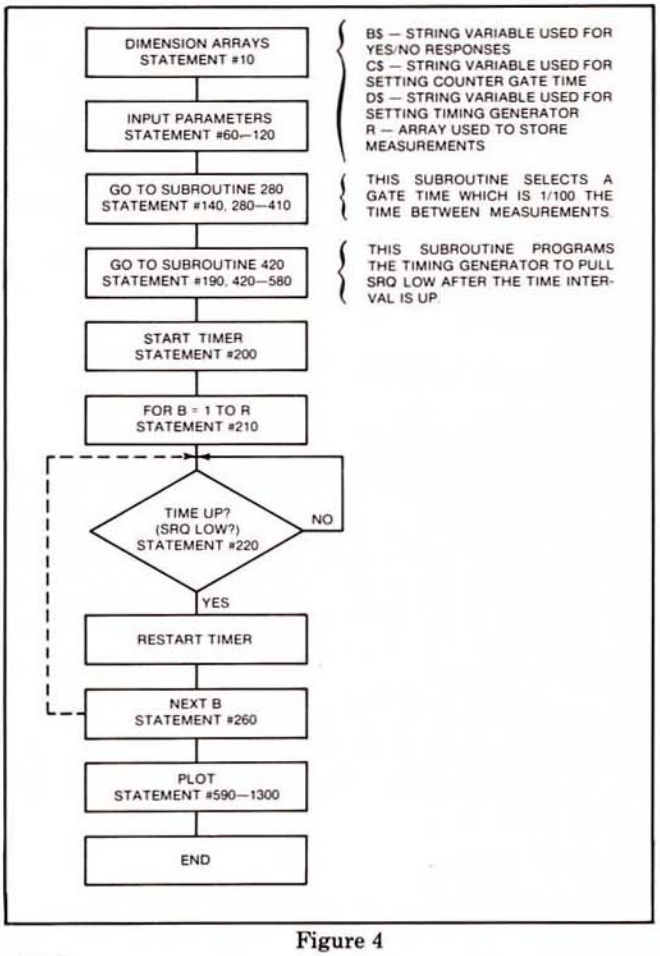

Figure 4

9830A Program Listing

```
10 DIM B$[3],C$[2],D$[7],R[250]
20 C$="G "
30 D$="ST   E "
40 DISP "AN174-12: SWEEP LINEARITY"
50 WAIT 1000
60 DISP "DELTA TIME";
70 INPUT A
80 A=A-0.026
90 DISP "NUMBER OF POINTS";
100 INPUT R
110 DISP "PLUG-IN: YES OR NO";
120 INPUT B$
130 CMD "?U*","I2"
140 GOSUB 280
150 CMD "?U*","E89:I1"
160 IF B$[1,1]#"Y" THEN 180
170 CMD "?U*","F2I1"
180 CMD "?J"
190 GOSUB 420
200 CMD "?U2","R"
210 FOR B=1 TO R
220 IF STAT13>1.9 THEN 220
230 CMD "?U2","R"
240 CMD "?U*","J1","?J5"
250 ENTER (13,*)R[B]
260 NEXT B
270 GOTO 590
280 C=A/100
290 IF C>1E-03 THEN 320
300 C$[2,2]="="
310 GOTO 390
320 IF C>1E-02 THEN 350
330 C$[2,2]=">"
340 GOTO 390
```

9830A Program Listing

```
350 IF C>1E-01 THEN 380
360 C$[2,2]="?"
370 GOTO 390
380 C$[2,2]="0"
390 CMD "?U*"
400 OUTPUT (13,*)C$
410 RETURN
420 Z=-7
430 X=INT(A/(10↑Z))
440 IF X <= 999 THEN 470
450 Z=Z+1
460 GOTO 430
470 C=INT(X/100)
480 Y=INT(X/10)-C*10
490 X=X-100*C-10*Y
500 Z=Z+6
510 OUTPUT (D$[3,3],520)C;
520 FORMAT F1000.0
530 OUTPUT (D$[4,4],520)Y;
540 OUTPUT (D$[5,5],520)X;
550 OUTPUT (D$[7,7],520)Z;
560 CMD "?U2"
570 OUTPUT (13,*)D$
580 RETURN
590 A=A+0.026
600 X=Y=R[1]
610 FOR Z=2 TO R
620 IF R[Z]>X THEN 640
630 X=R[Z]
640 IF R[Z]<Y THEN 660
650 Y=R[Z]
660 NEXT Z
670 FLOAT 5
680 PRINT "YMIN (HZ)=",X
690 PRINT "YMAX (HZ)=",Y
700 SCALE -0.2*A*R,1.2*A*R,
    X-(Y-X)*0.2,Y+(Y-X)*0.2
710 XAXIS X,A*R/10
720 YAXIS 0,(Y-X)/10
730 DISP "LETTERING--YES OR NO";
740 INPUT B$
750 IF B$[1,1]#"Y" THEN 940
760 Z=X-0.1*(Y-X)
770 PLOT 0,Z,1
780 LABEL (790,2,2,0,8/11)0
790 FORMAT F5.1
800 PLOT A*R/2,Z,1
810 LABEL (790)A*R/2
820 PLOT A*R,Z,1
830 LABEL (790)A*R
840 PLOT A*R/3,X-(Y-X)*0.2,1
850 LABEL (*,3,1.7,0)"TIME (SEC)"
860 PLOT -0.2*A*R,X+(Y-X)*0.02,1
870 LABEL (880,1.5,2.5,0)X
880 FORMAT E11.4
890 PLOT -0.2*A*R,Y,1
900 LABEL (880)Y
910 DEG
920 PLOT -0.05*A*R,X+(Y-X)/3
930 LABEL (*,3,1.7,90)"FREQ  (HZ)"
940 FOR Z=1 TO R
950 PLOT (Z-1)*A,R[Z]
960 NEXT Z
970 PEN
980 DISP "DIFFERENTIAL NONLINEARITY"
990 WAIT 1000
1000 DISP "CHANGE PEN-PUSH
     CONT,EXECUTE"
1010 STOP
1020 FOR Z=1 TO R-2
1030 R[Z]=(R[Z+2]-R[Z])/(2*A)
1040 NEXT Z
1050 X=Y=R[1]
1060 FOR Z=2 TO R-2
1070 IF R[Z]<Y THEN 1090
1080 Y=R[Z]
1090 NEXT Z
1100 SCALE -0.2*A*R,A*R*1.2,-Y/4,1.5*Y
1110 XAXIS 0,A*R/10
1120 YAXIS A*R,Y/4
1130 DISP "LETTERING-YES OR NO";
1140 INPUT B$
1150 IF B$[1,1]#"Y" THEN 1270
1160 PLOT A*R*1.002,Y,1
1170 LABEL (1180,1.5,2.5,0)Y
1180 FORMAT E11.4
1190 PLOT 1.002*A*R,Y/4,1
1200 LABEL (1180)Y/4
1210 PLOT A*R,Y/20,1
1220 LABEL (*)0
1230 PLOT A*R*1.05,Y/2.75,1
1240 LABEL (*,3,2,90)"DIFF. NONLIN."
1250 PLOT A*R*1.1,Y/2.35,1
1260 LABEL (*)"(HZ/SEC)"
1270 FOR Z=2 TO R-2
1280 PLOT Z*A,R[Z]
1290 NEXT Z
1300 PEN
1310 GOTO 10
1320 END
```

For more information, call your local HP Sales Office or East (201) 265-5000 • Midwest (312) 677-0400 • South (404) 436-6181 • West (213) 877-1282. Or, write: Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304. In Europe, Post Office Box 85, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan, Yokogawa-Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151.

02-5952-7328 NOVEMBER 1974 Printed in U.S.A.