5345 ELECTRONIC COUNTER

HEWLETT hp PACKARD

MEASURING DIFFERENTIAL NONLINEARITY OF A VOLTAGE CONTROLLED OSCILLATOR

The differential nonlinearity curve is a sensitive measure of the linearity of a device. This application note describes the use of the HP 5345 Electronic Counter in a calculator based HP Interface Bus system to automatically compute and plot the differential nonlinearity curve for a voltage controlled oscillator. In a fraction of the time required to perform the measurements and computations manually, the system measures and plots the differential nonlinearity curve (in less than 10 seconds). Since the system is completely automatic, the repeatability and accuracy of the measurements are improved over 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 solve the problems encountered in the dynamic environment of production, the R & D lab, or quality control.

INTRODUCTION

Differential nonlinearity of a voltage controlled oscillator is a plot of VCO modulation sensitivity ($\Delta f/\Delta V$) as a function of modulating voltage (V). Using this definition, such a plot approximates the derivative of the VCO's transfer characteristic. Since changes in slope of the VCO transfer characteristic are readily apparent in a differential nonlinearity curve, the plot gives useful information concerning VCO linearity. Ideally, the differential nonlinearity curve of a linear VCO is a horizontal straight line.

MEASUREMENT SET-UP

The measurement system consists of the 5345A Electronic Counter (Opt. 011), the 9820 Calculator (Opt. 001 Extended Memory), the ASCII Bus Interface Card and PCII ROM (both included in 10593A), 11221A Math ROM, 11220A PCI ROM, 9862A Calculator Plotter (Opt. 20) and 59303A Digital to Analog Converter (three HP 59304 Numeric Displays are optional). The instruments are connected to the calculator as shown in Figure 1.

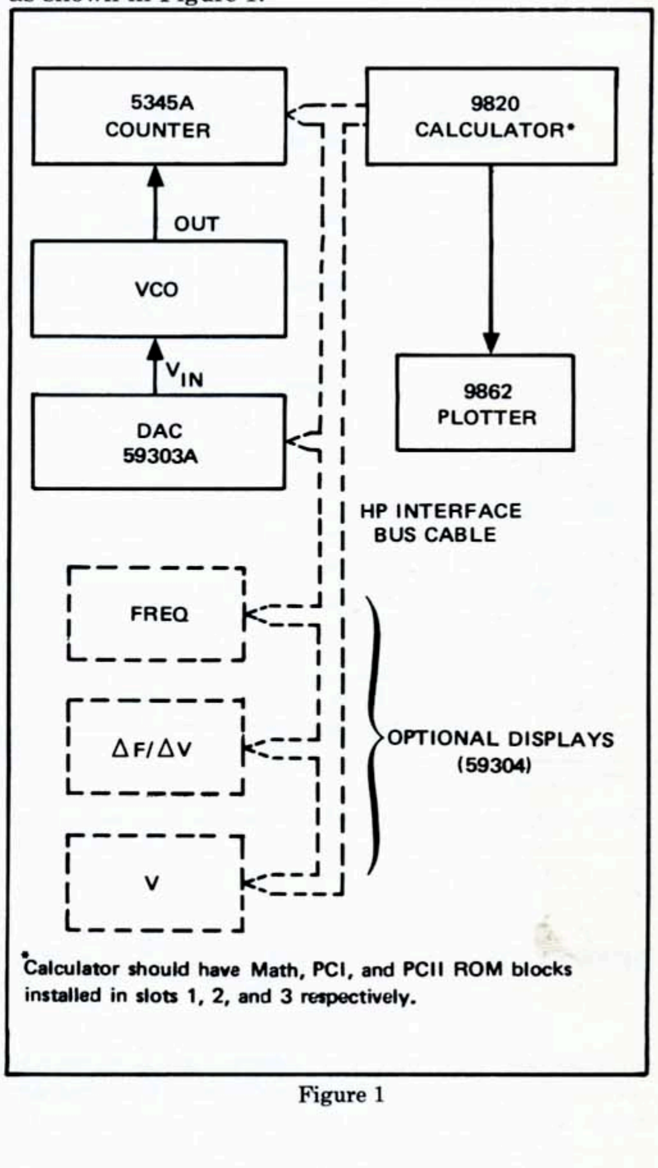


Figure 1

APPLICATION NOTE 174-2

Since the 9820 calculator remotely controls all front panel controls of the D to A converter and frequency counter, there is no need to set these controls to any particular positions. The calculator is electrically interfaced to the 59303 DAC and the 5345A Frequency Counter by connecting ASCII interface cables (10631 A, B, or C) from the rear panel mounted ASCII bus interface card of the calculator to the rear plugs of the DAC and frequency counter. Connect the 9862A plotter I/O card into one of the three remaining rear panel slots of the 9820 Calculator. (The ASCII interface card is plugged into the fourth slot—it does not matter which slots are used.)

Set the Talk/Listen addresses on the DAC and the frequency counter as specified in the following table:

Table 1

	Talk/Listen Addresses	Mode Switch	A5	A4	A3	A2	A1
59303 DAC	/=(program) /<(data)	addressable	1	1	1	0	**
5345 Counter	J/*	addressable	0	1	0	1	**
59304 Display (optional-displays frequency)	/3	addressable	1	0	0	1	1
59304 Display (optional-displays voltage)	/Ø	addressable	1	0	0	0	0
59304 Display (optional-displays Δf/ΔV)	/1	addressable	1	0	0	0	1

** *not used*

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

OPERATION

To compute and plot the differential nonlinearity curve of a VCO, key into the calculator the program listed. The program will request values for the minimum (VMIN) and maximum (VMAX) dc voltages to be applied to the VCO under test (not to exceed the range of the 59303: -9.99 to +9.99 volts dc). The program also requests the voltage step size (in volts) to be used in going between VMIN and VMAX. After entering a requested parameter through the 9820 keyboard, press RUN PROGRAM.

Under control of the calculator, the DAC presents a dc voltage to the VCO. The 5345 Frequency Counter measures the VCO output frequency (f_0) and inputs this value to the calculator. The DAC output is incremented by the requested step size (ΔV) and the resultant frequency (f_1) is measured. The DAC output is again incremented to obtain a third frequency (f_2). The modulation sensitivity at f_1 is computed by the equation:

$$\text{mod. sens.} = \frac{f_2 - f_0}{2\Delta V}\ \text{Hz/Volt}$$

In general, the modulation sensitivity at the point (V, f_n) is determined by calculating the slope between the points ($V - \Delta V$, f_{n-1}) and ($V + \Delta V$, f_{n+1}). The modulation sensitivity and the corresponding voltage are output to the plotter. This process continues until the requested voltage range has been spanned and the differential nonlinearity curve has been generated.

The optional 59304A displays will display frequency, voltage, and modulation sensitivity in Hz/volt. These are useful for data logging since, by pressing the SET FLG key on the calculator, the program halts and the actual parameter values may be copied down. After halting, RUN PROGRAM must be pressed to resume program execution.

The following plot shows the transfer characteristic of an HP 3310A Function Generator and the corresponding differential nonlinearity curve (finite differences have been used to approximate the derivative). The differential nonlinearity plot results from executing the program described in this application sheet. Refer to application sheet 174-1 for a description of the program which plots the VCO transfer characteristic.

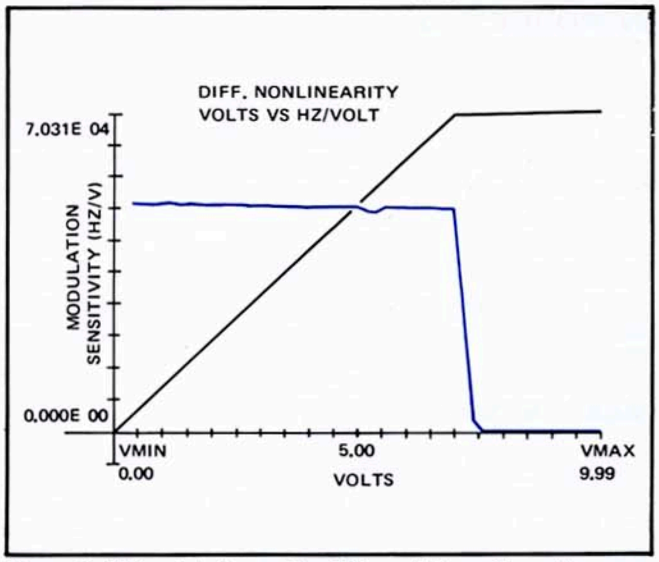


Figure 2. This plot shows the differential nonlinearity curve for an HP 3310A Function Generator. It overlays a plot of the same instrument's transfer characteristic (generated by the program described in Application Sheet 174-1) for comparison. The extremes of the transfer characteristic curve correspond to 251.0 kHz and 602.2 kHz.

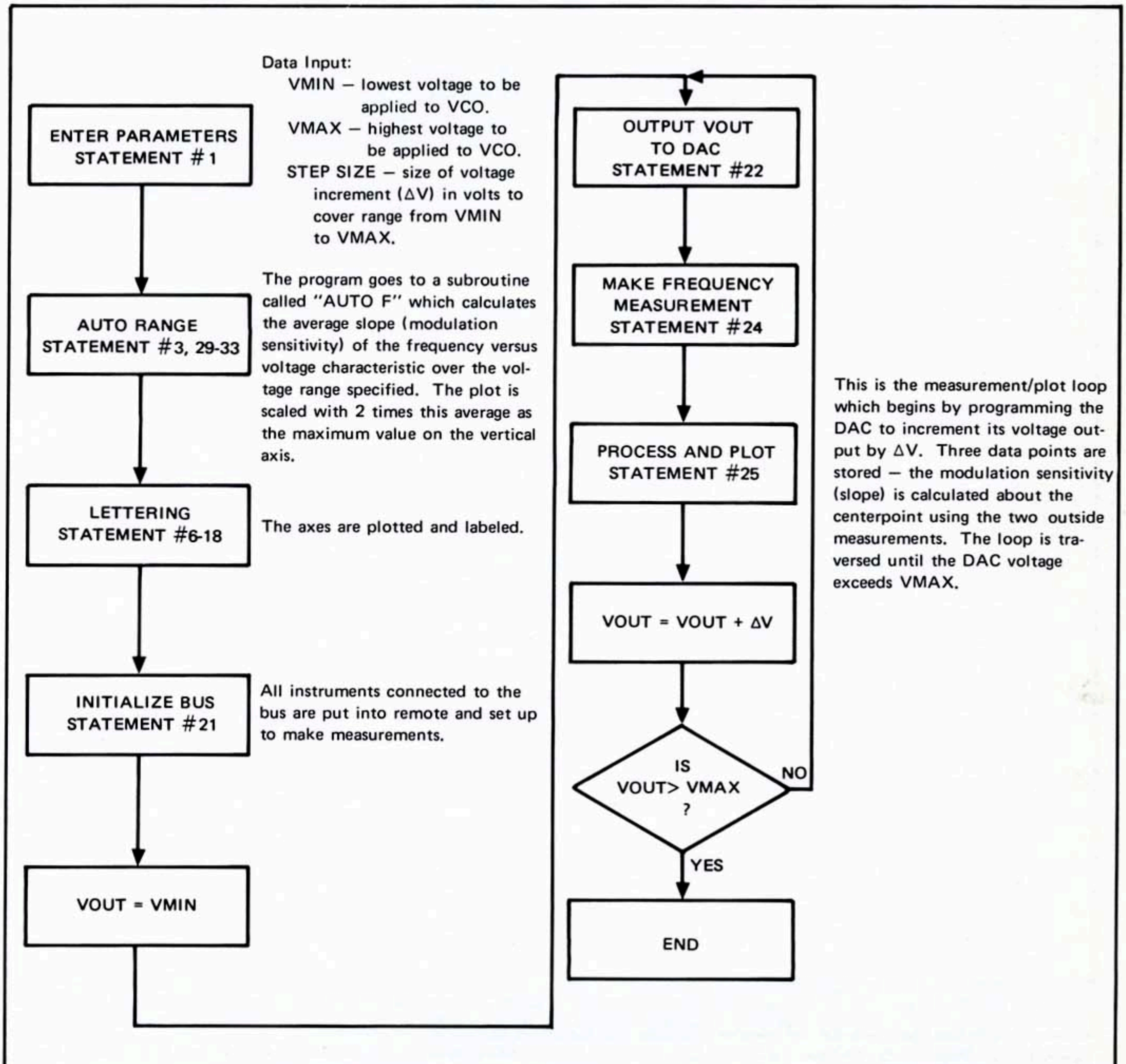
MEASUREMENT CONSIDERATIONS

a) Low modulation sensitivities require high resolution measurements. In the worst case, the counter resolves 1 part in 10^8 per second of gate time. Since the supplied program instructs the 5345 Counter to make measurements with a 100 msec gate time, the gate time should be increased if 1 part in 10^7 is not adequate resolution for the expected frequency change due to the applied voltage change.

b) The accuracy and resolution of measurements made with this set-up is limited by the 59303 DAC. Its accuracy is specified as ±.1% FS over the temperature range of 0° to 55°C. Typically, however, under room temperature conditions, the accuracy is ±.02% FS. For those cases where DAC error becomes significant (e.g., plotting modulation sensitivities using a small voltage step) the error may be essentially eliminated by using the bus compatible HP 3490A Multimeter to measure the DAC output, and input this to the calculator for use in computations. Of course, the program would have to be modified to enable the calculator to control the multimeter.

c) Since the minimum step size possible with the DAC is 10 mV, the STEP SIZE entered into the program should be an integer multiple of 10 mV so as to avoid errors caused by rounding.

Program Flow Diagram



Program Listing

```
0:
DSP "DIFF. NONLI
N.";DSP ;DSP ;
DSP ;DSP ⊢
1:
"LET";ENT "VMIN"
,R0;ENT "VMAX",R
1;ENT "STEP SIZE
",A;R0→B⊢
2:
(R1-R0)/20→C⊢
3:
GSB "AUTO F"⊢
4:
2*(R5-R4)/(R1-R0
)→R5;0→R4⊢
5:
(R5-R4)/10→X⊢
6:
SCL R0-2C,R1,R4-
X,R5⊢
7:
AXE R0,R4,C,(R5-
R4)/10⊢
8:
LTR -.5C+R0,.2(R
5-R4)+R4,322;
PLT "MODULATION
SENSITIVITY (HZ/
V)"⊢
9:
FLT 3;LTR -2C+R0
,.94(R5-R4)+R4,2
11;PLT R5⊢
10:
LTR -2C+R0,.03(R
5-R4)+R4;PLT R4⊢
11:
LTR .45(R1-R0)+R
0,R4-X,321;PLT "
VOLTS"⊢
12:
LTR .95(R1-R0)+R
0,-.3X+R4,211;
PLT "VMAX"⊢
13:
FXD 2;LTR .95(R1
-R0)+R0,-.6X+R4;
PLT R1⊢
14:
LTR .015(R1-R0)+
R0,-.3X+R4,211;
PLT "VMIN "⊢
15:
LTR .015(R1-R0)+
R0,-.6X+R4;PLT R
0⊢
16:
LTR 9.65C+R0,-.3
X+R4;PLT 10C+R0⊢
17:
LTR .25(R1-R0)+R
0,R5-.3X,421;
PLT "DIFF. NONLI
NEARITY"⊢
18:
LTR .25(R1-R0)+R
0,-.7X+R5,211;
PLT "VOLTS VS HZ
/VOLT"⊢
19:
"M";GSB "MEAS"⊢
20:
DSP "END OF PLOT
";GTO 0;STP ⊢
21:
"MEAS";CMD "U?*"
,"I2E9:8I1G?";
DSP ;CMD "J?",""
,"U?=","E0"⊢
22:
"LOOP";CMD "U?≤"
;FMT FXD *.0;
WRT 13,100*B⊢
23:
CMD "U?0";FMT
FXD *.2;WRT 13,B
⊢
24:
CMD "U?*","J1","
J?35";FMT *;RED
13,R6⊢
25:
IF R0+A≤B;PLT B,
(R6-R9)/(2*A);
CMD "U?1";FMT
FLT *.4;WRT 13,(
R6-R9)/2A⊢
26:
R7→R9;R6→R7⊢
27:
B+A→B;R8+1→R8;
IF B>R1;PEN ;
RET ⊢
28:
GTO "LOOP";IF
FLG 0;STP ;CFG 0
⊢
29:
"AUTO F";CMD "U?
*","I2E89:G?I1";
DSP ;CMD "J?",""
,"U?=","E0"⊢
30:
CMD "U?≤";FMT
FXD *.0;WRT 13,1
00*R0⊢
31:
CMD "U?*","J1","
J?5";FMT *;RED 1
3,R4⊢
32:
CMD "U?≤";FMT
FXD *.0;WRT 13,1
00*R1⊢
33:
CMD "U?*","J1","
J?5";FMT *;RED 1
3,R5;RET ⊢
34:
END ⊢
R273
```


025952-0879 **PRINTED IN U.S.A.**