5345 ELECTRONIC COUNTER

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DETERMINING PROBABILITY DENSITIES (HISTOGRAMS) WITH THE 5345 ELECTRONIC COUNTER

This application note describes a calculator based HP Interface Bus System which may be used to make histograms of any quantity capable of being measured by the 5345 Electronic Counter. The system has been successfully used to measure time interval jitter (e.g., frame to frame jitter in a digital communications network) and frequency deviations in signal generators. The 5345 Electronic Counter is particularly well suited to this application due to its high resolution (2 nanoseconds) and compatibility with the HP Interface Bus. Use of this bus permits the interfacing of compatible accessories by simply connecting them together with the bus cable. The program written for this application is flexible in that it allows the counter to be operated by its front panel controls even though the counter outputs data to the calculator under calculator control.

APPLICATION NOTE 174-5

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INTRODUCTION

When the values that a random variable can assume are infinite, it is sometimes convenient to partition the possible outcomes into discrete intervals called bins. After the experiment (e.g., time interval measurement) has been performed a number of times, each bin will have a number in it which represents the number of times that the value of the random variable fell within the boundaries of that particular bin. A histogram is a plot where the set of observed outcomes (bins) lie along the horizontal axis. A vertical bar is erected over each bin position indicating by its height the number of times the value of the random variable fell within the bin's limits. Since the histogram indicates relative frequency of occurrence, it is an approximation to the probability density of the random variable when the number of measurements is large.

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 1.

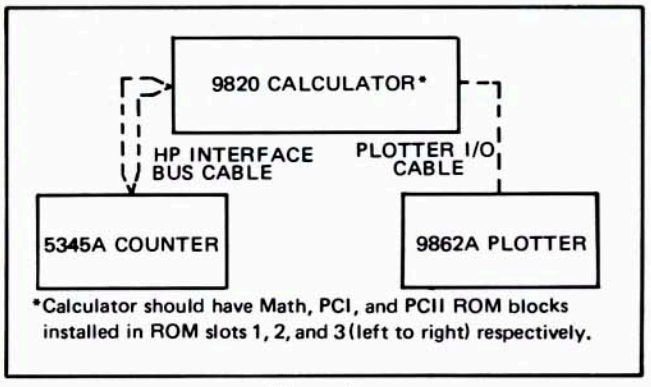


Figure 1

To allow a variety of measurements without modification to the program, the counter is operated in the manual mode (i.e., front panel controls must be set for the particular measurement being made). However, the counter outputs data to the calculator under calculator control. The calculator is interfaced to the 5345A Electronic Counter 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 1

	Talk/Listen Address	Mode Switch	A5	A4	A3	A2
5345 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 plot a histogram for a particular measurement, key into the calculator the provided program and set up the counter to make the desired measurement. During execution the program will request of the user the following parameters (after entering a parameter, press RUN PROGRAM):

1) "NO OF BINS" — enter the desired number of bins available to record events. This is the X coordinate of the histogram.

2) "STEP SIZE" — enter the desired width of each bin. Use the same units which the counter will measure (i.e., seconds, Hz).

3) "NO OF MEAS" — enter the desired number of measurements to be taken.

The program initially takes a set of 10 measurements and computes an "average" for use in scaling the plot. Actual measurements then begin. After the desired number of measurements has been made, the plotting begins. If it is desired that the axes not be plotted, pushing the SET/CLEAR FLAG N key during measurements will bypass that routine. After plotting, the calculator prints out values for "ACTUAL MEAN", "SIGMA" (standard deviation), and "2X SIGMA". The plotter will then plot standard deviation tic marks across the histogram as well as a line representing the mean. The graph will then be lettered with information concerning the mean, the highest number in any bin, and the number of measurements. If it is desired that the lettering not occur, pushing SET/CLEAR FLAG N during plotting will bypass the routine.

The histogram shown in Figure 2 shows the period to period timing variations in a 3310A Function Generator used as a pulse source.

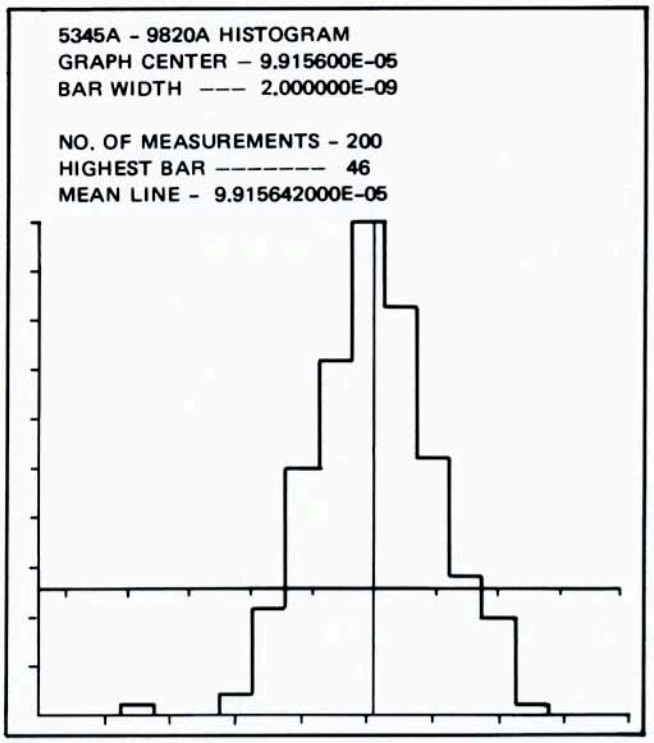


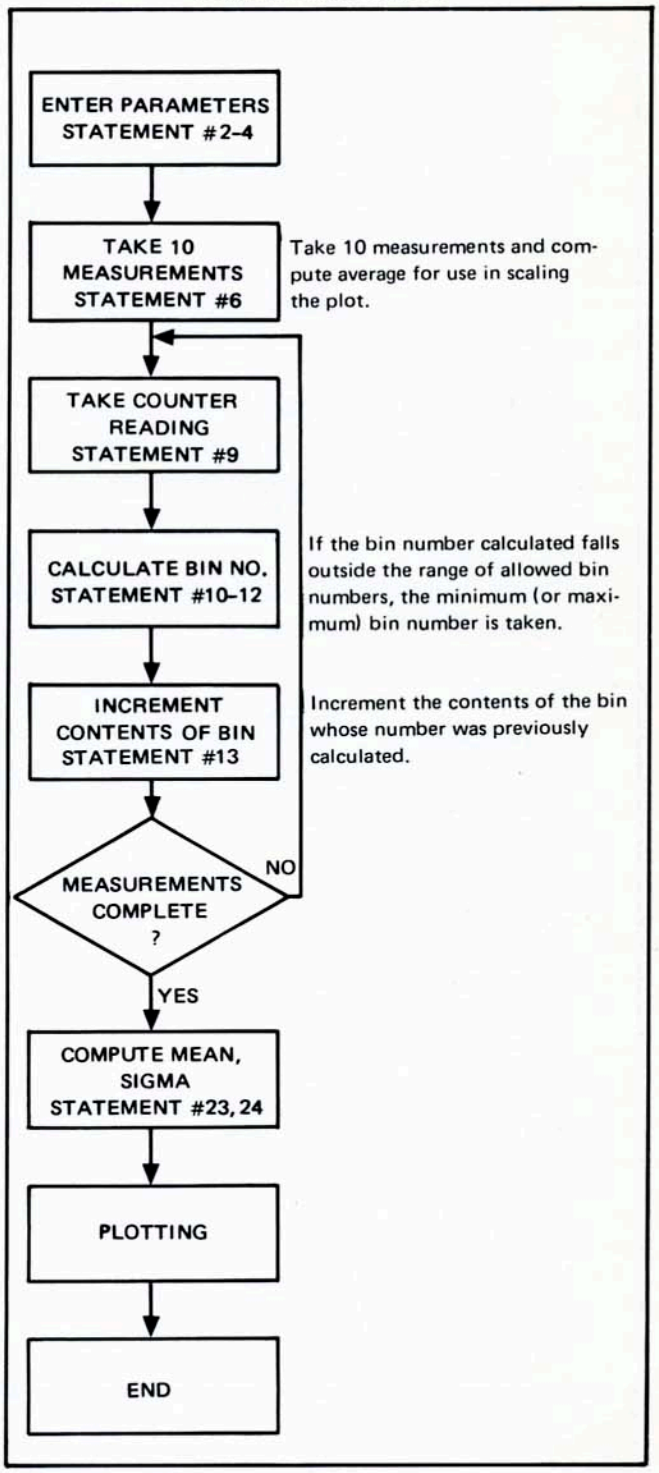
Figure 2. Histogram of 200 period measurements made on the 3310A Function Generator used as a 10 kHz pulse source. The 5345 Counter was set to the period mode and MIN gate time (gate time required to measure one period). The standard deviation tic marks indicate a SIGMA of approximately 4 nsec. The actual SIGMA was computed by the program as 3.75 nsec.

MEASUREMENT CONSIDERATIONS

a) The resolution to which a particular measurement may be made is determined by the counter's gate time (worst case of 1 part in 10^8 per second of gate time). The gate time likewise determines the number of cycles in the input signal over which the measurement will be "averaged". Greater resolution implies greater averaging. Therefore, if the pulse to pulse jitter of a pulse generator is to be measured and no averaging can be tolerated, then the GATE TIME selector switch should be placed in MIN (measures one period). If slowly varying phenomena are to be observed, averaging of the rapid phenomena can be tolerated. The number of measurements should be large enough to insure that the total measurement time allows for a number of cycles of the variation. The gate time must be small enough so as not to average out the variation being measured.

b) The maximum number of bins is 250 and is limited by the storage capacity of the 9820 calculator. There is no limit to the number of measurements which may be made.

Program Flow Diagram



Program Listing

```
0:
DSP "HISTOGRAM";
DSP ;DSP ⊢
1:
TBL 4;FLT 9;SPC
2⊢
2:
ENT "NO OF BINS"
,X⊢
3:
ENT "STEP SIZE",
B⊢
4:
FXD 0;ENT "NO OF
 MEAS",C⊢
5:
0→R285→R284⊢
6:
CMD "J?5";FMT *;
RED 13,R286;R286
+R285→R285;R284+
1→R284⊢
7:
IF R284≤9;JMP -1
⊢
8:
R285/10→A;0→R284
→R285→R286⊢
9:
"M";CMD "J?5";
FMT *;RED 13,R28
6;R281+1→R281;R2
86-A→R286⊢
10:
R286/B+X/2+.5→Y;
R287+R286R286→R2
87⊢
11:
IF Y>X;X→Y⊢
12:
IF Y<0;0→Y⊢
13:
R286+R284→R284;1
+RY→RY;IF RY>R28
5;RY→R285⊢
14:
IF R281+1>C;JMP
2⊢
15:
GTO "M"⊢
16:
SCL 0,X,0,R285+1
;IF FLG 0=1;CFG
0;JMP 2⊢
17:
AXE 0,0,X/10,R28
5/10⊢
18:
0→Y⊢
19:
"P";PLT Y-.5,RY;
PLT Y+.5,RY⊢
20:
Y+1→Y⊢
21:
IF Y>X;JMP 2⊢
22:
GTO "P"⊢
23:
SPC 2;FLT 9;PRT
"ACTUAL MEAN=",R
284/C+A⊢
24:
∫((R287-R284R284
/C)/(C+1))→R287;
PRT "SIGMA",R287
⊢
25:
PRT "2*SIGMA",2R
287⊢
26:
IF X/2<ABS (R284
/CB);JMP 2⊢
27:
AXE R284/CB+X/2,
(R285+1)/4,R287/
B,R285⊢
28:
SPC 2;FXD 0;PRT
"FULLEST BIN HAS
",R285⊢
29:
SCL 0,10,0,10;
LTR 7,9.7,211;
IF FLG 0;CFG 0;
JMP 7⊢
30:
PLT "5345A - 982
0A HISTOGRAM"⊢
31:
LTR 7,9.3;PLT "G
RAPH CENTER - ";
FLT 6;PLT A⊢
32:
LTR 7,9;PLT "BAR
 WIDTH ---- ";
PLT B⊢
33:
LTR 7,8.5;PLT "N
O. OF MEASUREMEN
TS - ";FXD 0;
PLT C⊢
34:
LTR 7,8.2;PLT "H
IGHEST BAR -----
---- ";PLT R285⊢
35:
LTR 7,7.9;PLT "M
EAN LINE - ";
FLT 9;PLT R284/C
+A⊢
36:
R284/C+A→A;SPC 8
;DSP "DONE";CMD
"?";GTO 1;LTR 10
,10;STP ⊢
37:
END ⊢
R292
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