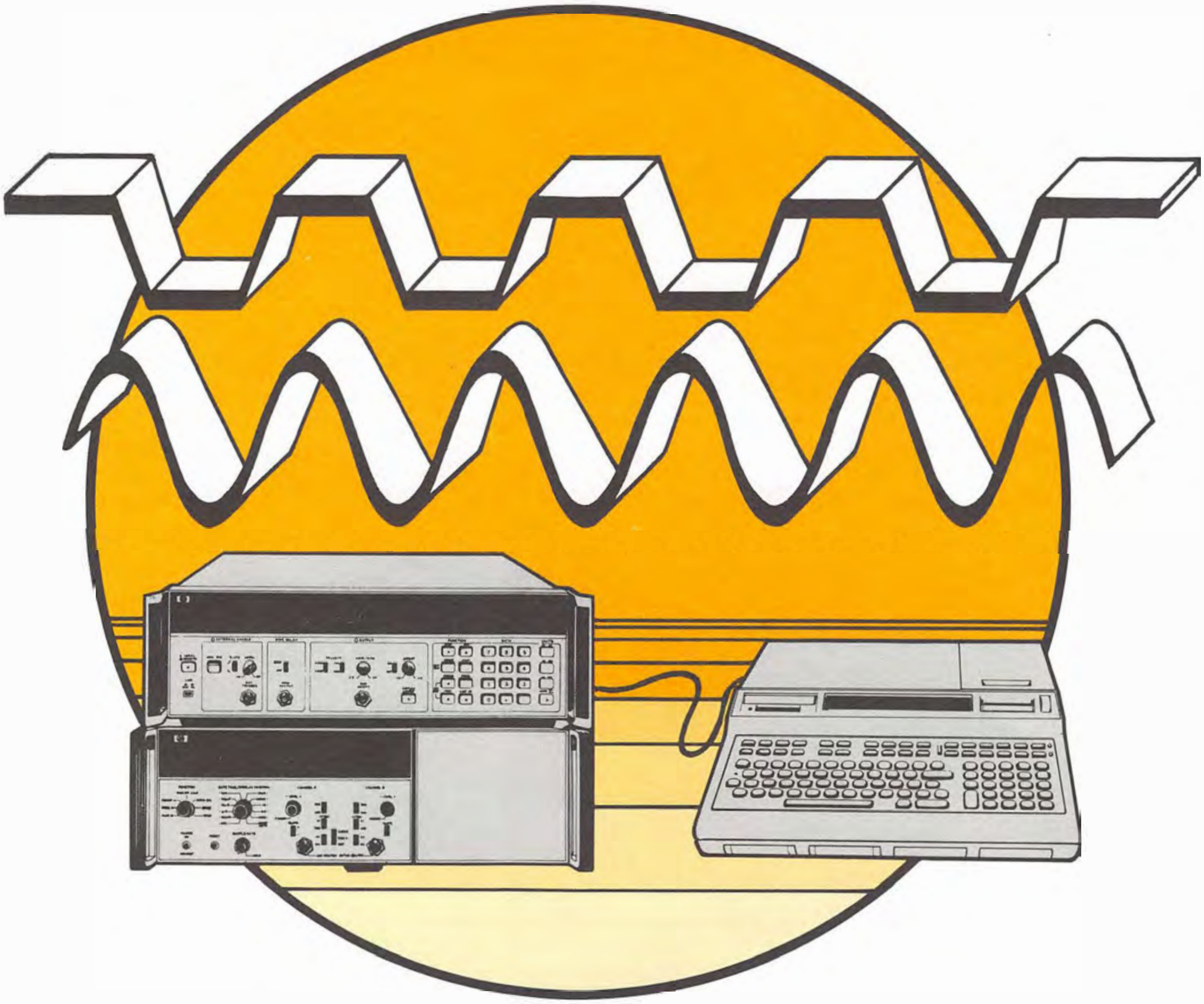
Application Note 287-2

FREQUENCY PROFILE USING AN HP 5345A ELECTRONIC FREQUENCY COUNTER AND AN HP 5359A TIME SYNTHESIZER

HP-IB

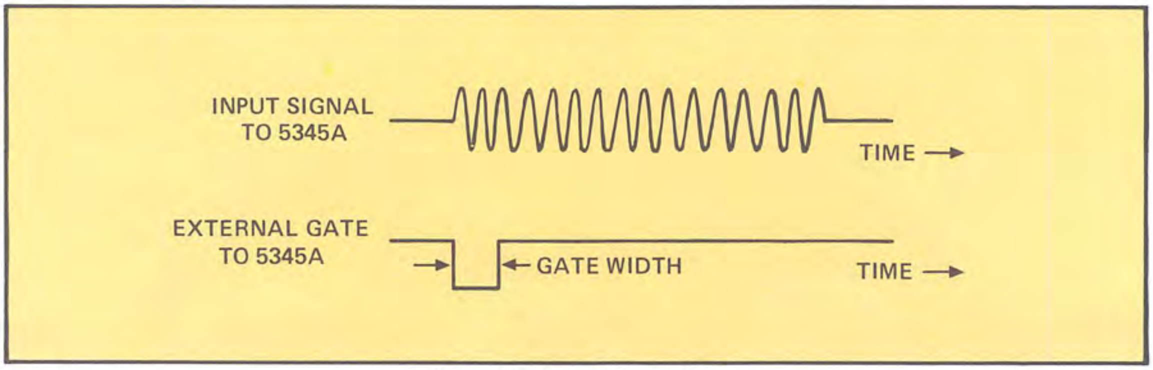


HEWLETT PACKARD

INTRODUCTION

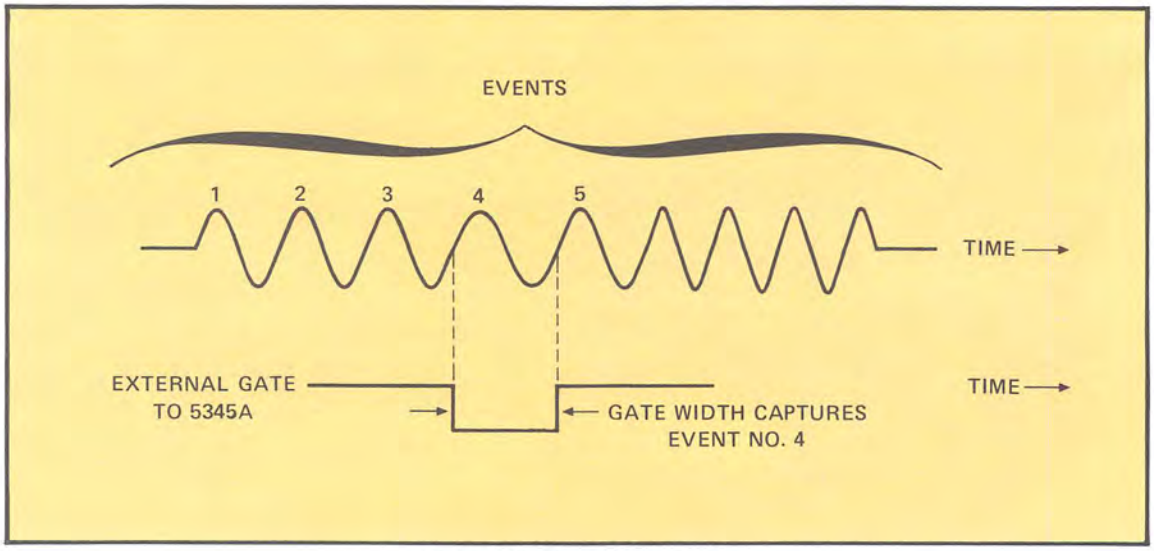
The measurement power of modern day electronic instruments can be further enhanced by operation in the remote mode. Instruments designed to operate on the Hewlett-Packard Interface bus (HP-IB), which is an implementation of IEEE Standard 488-1978, can be very easily interfaced by means of a simple standardized cable interconnection. A computing controller like the Hewlett-Packard 9825A may then be used to control instrument operation. Complex measurements and data collection that would require much interaction by a skilled user under manual operation can now be performed automatically in an HP-IB system.

Frequency Profile is the time variation of frequency within a signal. This Application Note describes the use of an HP 5345A Electronic Counter, an HP 5359A Time Synthesizer together with an HP 9825A Calculator, to obtain the frequency profile of an unknown signal. Two measurement techniques are used, the "time" and "events" modes. In the time mode of operation, the external gate of the counter is controlled by a selectable width and delay signal, generated by the time synthesizer. This gate pulse can move inside a continuous wave stream or burst to obtain its frequency profile. (Figure 1)



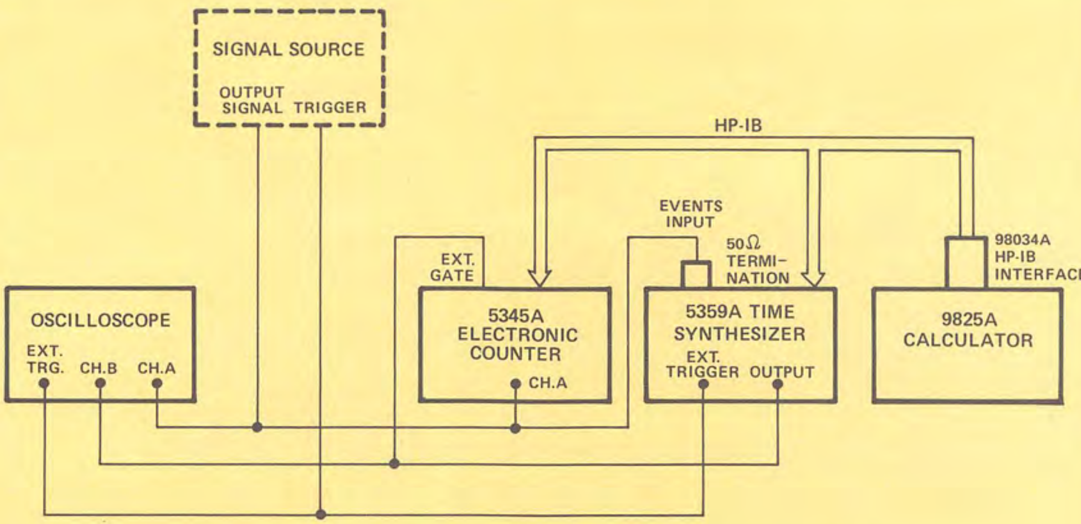
Time Mode of Operation
Figure 1

When in the events mode of operation, the width of the gate signal is the period of one event and can be programmed to move inside a continuous wave or burst to capture any one particular event. The period of each event can be different but the system can still capture its characteristics. (Figure 2)



Events Mode of Operation
Figure 2

CONFIGURATION BLOCK DIAGRAM



HP 5345A Electronic Counter with Option 011 — HP-IB Address 10
HP 5359A Time Synthesizer — HP-IB Address 4
HP 9825A Calculator with:

HP-IB Interface Card/Cable	HP 98034A
String-Advance Programming ROM	HP 98210A
General I/O — Extended I/O ROM	HP 98213A

Figure 3

PROGRAM DESCRIPTION

The overall program is divided in two sections, the Time Operation and Events Operation section. Each one is described as follows:

TIME OPERATION

The equipment set-up is as shown in Figure 3 with the exception of the EVENTS INPUT to the 5359A which is not used in this mode of operation. It is essential that the signal source have a synchronous trigger capable of driving the external trigger input of the 5359A Time Synthesizer. The 5359A can externally trigger on either the positive or negative going slope of the external trigger. Typical timing relationships for this mode of operation are shown in Figure 4.

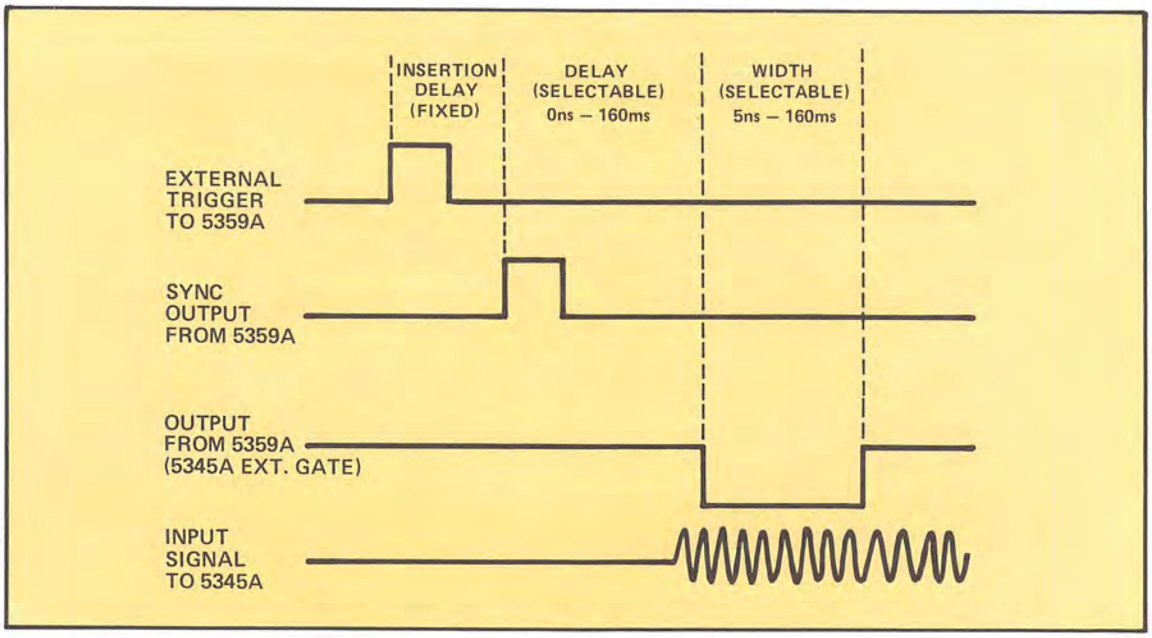


Figure 4

- Width + Delay ≤ 160ms
- SYNC DELAY in PRESET. Insertion Delay ≤ 140 nsec

The calculator will allow the user to select the 5359A's output width, delay and delay step size. It will then ask if either automatic or manual operation is desired. In manual operation, the delay can be incremented one step at a time, thereby allowing the gate pulse to walk through the input signal stream. After each step, the counter will make a frequency measurement and the calculator will print out the step number and frequency measured. Automatic operation is similar, except that the calculator will automatically step through the input signal stream a certain number of steps as specified by the user.

When in Time Operation, the 5345A is programmed for an internal gate of 1 second and an external gate as set by the 5359A. The effective gate time is the sum of individual external gates adding up to the 1 sec internal gate. This technique is called FREQUENCY AVERAGING and its benefit is increased resolution and accuracy.

EVENTS OPERATION

Figure 3 shows the equipment set up for EVENTS OPERATION. As is the case for TIME OPERATION the signal source must have a synchronous trigger capable of driving the external trigger input of the 5359A Time Synthesizer. Typical timing relationships for this mode of operation are shown in Figure 5.

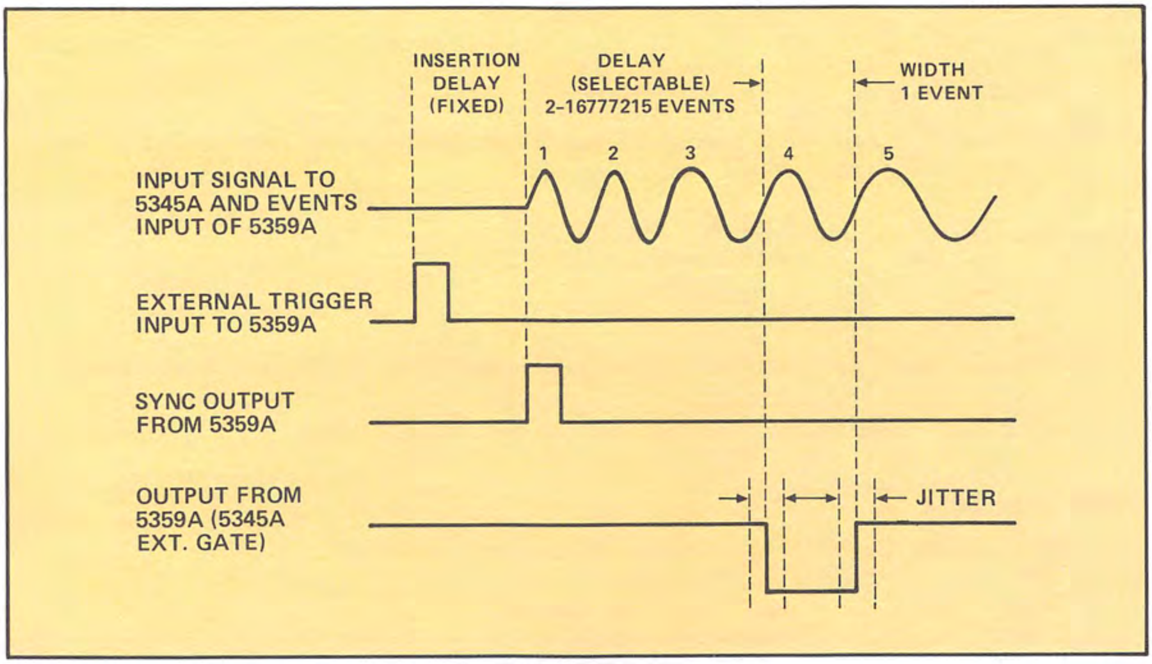


Figure 5

- Width + Delay ≤ 16777215 Events.

The program will first calibrate itself and frame the second event in the input signal stream. The counter will make a frequency and period measurement and the calculator will print out the results. The calculator will then allow a user to select any event/slope of the input signal stream.
Slope selection can vary an event count as shown in Figure 6. As can be seen, event number 3 negative slope is further in the pulse stream than event number 3 positive slope.

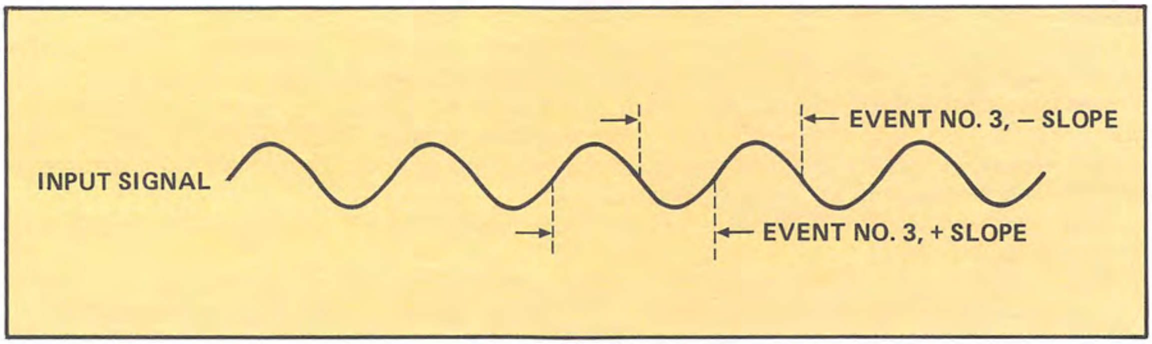


Figure 6

SYSTEM PERFORMANCE CHARACTERISTICS

A. TIME MODE OF OPERATION

For Time Mode of Operation, system resolution and accuracy can be computed as follows:

1. Resolution (Hz) = $\pm \left[\frac{2 \text{ nsec}}{\text{Ext Gate} \times \sqrt{N}} \times \text{freq} \right] \pm \left[\frac{\frac{\text{trigger error}}{\text{Ext Gate}}}{\sqrt{N}} \times \text{freq} \right]$

where:

$$N = \frac{\text{Internal Gate*}}{\text{External Gate}}$$

*Program sets Internal Gate to 1 sec. If another internal gate time is desired, change line 35 of the program to reflect this change.

$$\text{trigger error (rms)} = \frac{1.4 \times \sqrt{X^2 + en^2}}{\text{Input Slew Rate at trigger point}}$$

X = 300 μV for 5345A. Effective rms noise of counter's input channel.
en = rms noise voltage of input signal measured over a bandwidth equal to the counter's bandwidth.

2. Accuracy (Hz) = ± Resolution ± [5345A time base error × freq.] ± Bias

5345A Time Base:

Standard Time Base: High Stability 10544A 10 MHz Oven Oscillator

Aging Rate:	$<5 \times 10^{-10}$ per day
Short Term:	$<1 \times 10^{-11}$ for 1 sec average
Temperature:	$<7 \times 10^{-9}$, 0°C to 55°C
Line Voltage:	$<1 \times 10^{-10}$, +10% from nominal

Option 001 Time Base: Voltage Controlled 10 MHz Room Temperature Crystal

Aging Rate:	$<3 \times 10^{-7}$ per month
Short Term:	$<2 \times 10^{-9}$ rms for 1 sec
Temperature:	$<2 \times 10^{-6}$, 25°C to 35°C
	$<5 \times 10^{-6}$, 0°C to 55°C
Line Voltage:	$<1 \times 10^{-8}$, +10% from nominal

Bias:

While displaying a relatively large amount of very usable resolution, the absolute accuracy of frequency average measurements will be less than the displayed resolution (will read slightly low) due to known circuit delays within the counter. The gate time error is a fixed time error of a few pico seconds; therefore, the frequency error will become more pronounced as the EXT GATE signal becomes narrower. For any given EXT GATE width a good portion of this error can be calibrated out of the measurement when maximum accuracy is required.

When averaging 100 measurements for an improvement of X10 in stable resolution the gate error is usually insignificant.

When taking more samples for greater resolution, greater absolute accuracy can also be obtained by using a calibration factor for the particular EXT GATE width being used. The calibration factor may be determined by counting a stable high frequency signal applied to CHAN A using the FREQ A mode and the same external gating pattern as used for the signal of interest. Average as many readings as necessary to get the resolution desired. When using the 10 MHz STANDARD available on the rear panel of tthe 5345A the counter may display 9.99xx MHz instead of the expected 10.0000 MHz. The calibration factor, cf, for this external gate width will be

$$Cf = \frac{\text{known frequency}}{\text{displayed frequency}} = \frac{10.000\ \text{MHz}}{9.99\text{xx}\ \text{MHz}} = 1.00\text{xx}$$

The unknown pulse carrier = displayed pulse carrier x Cf.

If the 10 MHz STANDARD OUTPUT of the counter is used to determine the calibration factor, the absolute accuracy of a FREQUENCY AVERAGED pulse measurement can be improved by a factor of at least 20 over the single shot case (where accuracy is essentially the same as the resolution).

EXAMPLE:

Video signal applied to mainframe = 345.678910 MHz

External gate pulse width = 1μ sec (or 500 clock pulses)

Single shot video resolution = 345 MHz

Single shot accuracy $= \frac{\pm 1 \text{ clock pulse}}{500 \text{ clock pulses}} = 0.2\%$

TAKING A MEASUREMENT

RMS resolution when averaging = $\sqrt{N}$, so for a visibly stable extra digit take 1000 samples.

Measurement with 1000 samples	$F_{VIDEO} = 345.5$	Measurement is within ±1 count of actual value.
Measurement with 100,000 samples	$F_{VIDEO} = 345.57$	Resolution is stable but actual value is low.

DETERMINING CALIBRATION FACTOR

Cf^1. . . determined by using the 10 MHz out of the counter.

NOTE: At least 10 periods of the calibrating signal should fall within the external gate being used. In this case the period of 10 MHz = 100 nsec so 10 periods will be present in 1μ sec.

$$Cf^1 = \frac{\text{CW value (INT GATE)}}{\text{pulsed value (EXT GATE)}} = \frac{10.0000}{9.9973} = 1.000270$$

$$\text{corrected video} = F_{VIDEO} \text{ X } Cf = 345.57 \text{ X } 1.000270$$

$$= 345.66 \text{ MHz}$$

Therefore, in this example we have an accuracy improvement factor over the single shot case of

$$\frac{0.2\%}{\frac{1}{34566} \text{x } 100\%} = \frac{0.2}{0.00289} = 69$$

As mentioned before, calibrating with the 10 MHz STD OUT signal, as above, will give an expected accuracy improvement factor of at least X20 over the single shot accuracy.

B. EVENTS MODE OF OPERATION

For Events Mode of Operation, system resolution and accuracy can be computed as follows:

1. Resolution $= \pm \left[\frac{2 \text{ nsec}}{T} \text{ x freq} \right] \pm \left[\frac{\text{trigger error}}{T} \text{ x freq} \right]$

Where:

T = single period of event. Program is set for an external gate to the 5345A equal to the period of a particular event. If a larger external gate is desired, change line 11 of program from W1 to whatever width is desired.

$$\text{trigger error (rms)} = \frac{1.4 \times \sqrt{X^2 + en^2}}{\text{Input slew rate at trigger point}}$$

X = 300 μ V for 5345A. Effective rms noise of counter's input channel.

en = rms noise voltage of input signal measured over a bandwidth equal to the counter's bandwidth.

2. Accuracy (Hz) = ± Resolution ± [5345A time base error × freq]* ± Bias*

*5345A time base error and Bias are explained in the Time Mode of Operation.

PROGRAM LISTINGS

A system measurement flow chart is shown in Figure 7. Typical system output listing is shown in Figure 8 and a program listing is shown in Figure 9.

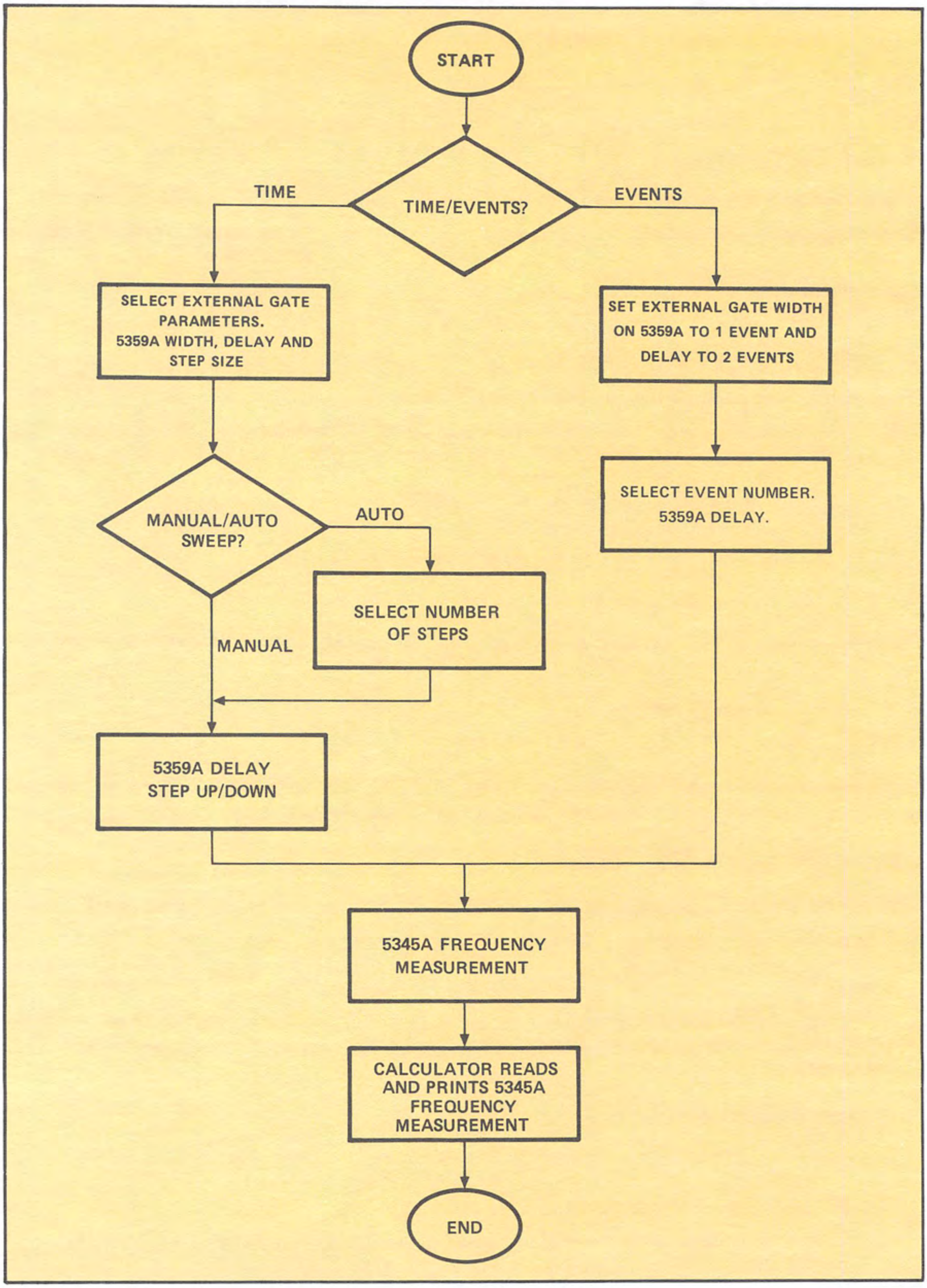


Figure 7

System Measurement Flowchart

```
   FREQUENCY
PROFILES USING A
5345A COUNTER &
5359A TIME SYN-
THESIZER

-----------------
 TIME OPERATION
-----------------
   SUCCESSIVE
WINDOW FREQUENCY
     PROFILE
SET 5345A:
   Level A-Preset
     Input Z-1Mohm
         Atten-X10
       Coupling-DC
Chk/ComA/Sep-Sep

5359A:
Width(sec)
         1.000e-03
Delay(sec)
         0.000e 00
Step Size(sec)
         1.000e-03

MANUAL SWEEP
Step Up 1
Freq 9.76732E 03
Step Up 2
Freq 9.76730E 03
Step Up 3
Freq 9.76741E 03
Step Down 1
Freq 9.76720E 03
Step Down 2
Freq 9.76725E 03
Step Down 3
Freq 9.76754E 03
AUTO SWEEP UP
Step Up 1
Freq 9.76708E 03
Step Up 2
Freq 9.76686E 03
Step Up
Freq 9.76680E 03
AUTO SWEEP DOWN
Step Down 1
Freq 9.76663E 03
Step Down 2
Freq 9.76654E 03
Step Down 3
Freq 9.76701E 03

-----------------
EVENT OPERATION
-----------------

   SUCCESSIVE
PERIOD FREQUENCY
     PROFILE

5359A:
Connect input
signal to rear
panel EVENTS BNC

EventNumber    2
 (+Slope)
Per  1.02384E-04
Freq 9.77190E 03

EventNumber    5
Per  1.02374E-04
Freq 9.76290E 03

EventNumber    7
Per  1.02356E-04
Freq 9.76920E 03

EventNumber   10
Per  1.02384E-04
Freq 9.76980E 03

END
```

Figure 8

Figure 9

```
0: dev "5345",710;dev "5359",704
1: time 30000
2: dim A$[10],B$[10];flt 3;sfg 14
3: fmt 1,"W",e10.3
4: fmt 2,"D",e10.3
5: fmt 3,"SS",e10.3
6: fmt 4,"Step Up",f2.0
7: fmt 5,"Freq",e12.5
8: fmt 6,"Step Down",f2.0
9: fmt 7,"Per ",e12.5
10: fmt 8,"EventNumber",f5.0
11: fmt 9,"D",f2.0,",W1",",",f2
12: prt "   FREQUENCY","PROFILES USING A","5345A COUNTER &"
13: prt "5359A TIME SYN-","THESIZER";spc 2
14: ent "TIME(t)/EVENT(e) OPERATION?",A$;if A$="e";gto 74
15: spc 1;prt "----------------";prt " TIME OPERATION";prt "----------------"
16: prt "   SUCCESSIVE","WINDOW FREQUENCY","    PROFILE"
17: prt "SET 5345A:"," Level A-Preset","  Input Z-1Mohm"
18: prt "       Atten-X10","     Coupling-DC","Chk/ComA/Sep-Sep";spc 1
19: dsp "SELECT 5359 SETTINGS--Press CONT";stp
20: prt "5359A:"
21: ent "WIDTH XXX.XXe+/-X",A
22: prt "Width(sec)",A
23: if A>1.6e-1;beep;gto 21
24: if A<5e-9;beep;gto 21
25: wrt "5359.1",A
26: ent "DELAY XXX.XXe+/-X",B
27: prt "Delay(sec)",B
28: if B>1.6e-1;beep;gto 26
29: if A+B>1.6e-1;beep;gto 26
30: wrt "5359.2",B
31: ent "STEP SIZE XXX.XXe+/-X",C
32: prt "Step Size(sec)",C;spc 1
33: if C<5e-11;beep;gto 31
34: wrt "5359.3",C
35: wrt "5345","I2E;:98"
36: ent "MAN(m)/AUTO(a)SWEEP? PressCONT",A$
37: if A$="a";gto 54
38: prt "MANUAL SWEEP";dsp "MANUAL SWEEP";wait 1000
39: 1→N
40: ent "DELAY STEP UP?(yes=y,no=n)",A$
41: if A$="n";gto 46;1→N
42: wrt "5359","dsu";wait 200;wrt "5345","J1";wait 200
43: on err "CNTR"
44: red "5345",A;wrt 16.4,N;wrt 16.5,A
45: N+1→N;gto 40
46: 1→M
47: ent "DELAY STEP DOWN?(yes=y,no=n)",A$
48: if A$="n";gto 53
49: wrt "5359","dsd";wait 200;wrt "5345","J1";wait 200
50: on err "CNTR"
51: red "5345",A;wrt 16.6,M;wrt 16.5,A
52: M+1→M;gto 47
53: ent "AUTO SWEEP?(yes=y,no=n)",A$;if A$="n";gto 73
54: prt "AUTO SWEEP UP";dsp "AUTO SWEEP UP";wait 1000
55: ent "No of Steps?(X)     PressCONT",J
56: 1→N
57: for I=1 to J
58: wrt "5359","dsu";wait 200;wrt "5345","J1";wait 200
59: on err "CNTR"
60: red "5345",A;wrt 16.4,N;wrt 16.5,A
61: N+1→N
62: next I
63: ent "AUTO SWEEP DOWN?(yes=y,no=n) ",A$;if A$="n";gto 73
64: prt "AUTO SWEEP DOWN"
65: ent "No of Steps?(X)  PressCONT",J
66: 1→N
```

```
67: for I=1 to J
68: wrt "5359","dsd";wait 200;wrt "5345","J1";wait 200
69: on err "CNTR"
70: red "5345",A;wrt 16.6,N;wrt 16.5,A
71: N+1→N
72: next I
73: ent "MANUAL SWEEP?(yes=y,no=n)",A$;if A$="y";gto 38
74: spc 1;prt "----------------";prt "EVENT OPERATION";prt "----------------"
75: spc 1;prt "   SUCCESSIVE","PERIOD FREQUENCY","    PROFILE";spc 1
76: prt "5359A:","Connect input","signal to rear","panel EVENTS BNC";spc 2
77: dsp "WHEN READY PRESS CONTINUE";stp
78: wrt "5345","I2G5F1E;E1E<E8";wait 500
79: wrt "5359","D2,W1,EP"
80: 2→N
81: red "5345",X;red "5345",A
82: wrt "5345","F0";wait 500
83: red "5345",X;red "5345",B
84: wrt 16.8,N;prt " (+Slope)";wrt 16.7,A;wrt 16.5,B;spc 2
85: ent "EVENT NUMBER?",N
86: if N+1>16777215;jmp -1
87: ent "EVENT SLOPE?(+,-)",B$
88: if B$="+";"EP"→B$
89: if B$="-";"EN"→B$
90: wrt "5345","F1";wait 500
91: wrt "5359.9",N,B$
92: red "5345",X;red "5345",A
93: wrt "5345","F0";wait 1000
94: red "5345",X;red "5345",B
95: wrt 16.8,N;wrt 16.7,A;wrt 16.5,B;spc 2
96: ent "ANOTHER MEASUREMENT?(yes=y,no=n)",A$;if A$="y";gto 85
97: prt "END";dsp "END"
98: end
99: "CNTR":beep;dsp "NO 5345 MEASUREMENT";wait 2000;gto 36
*2504
```