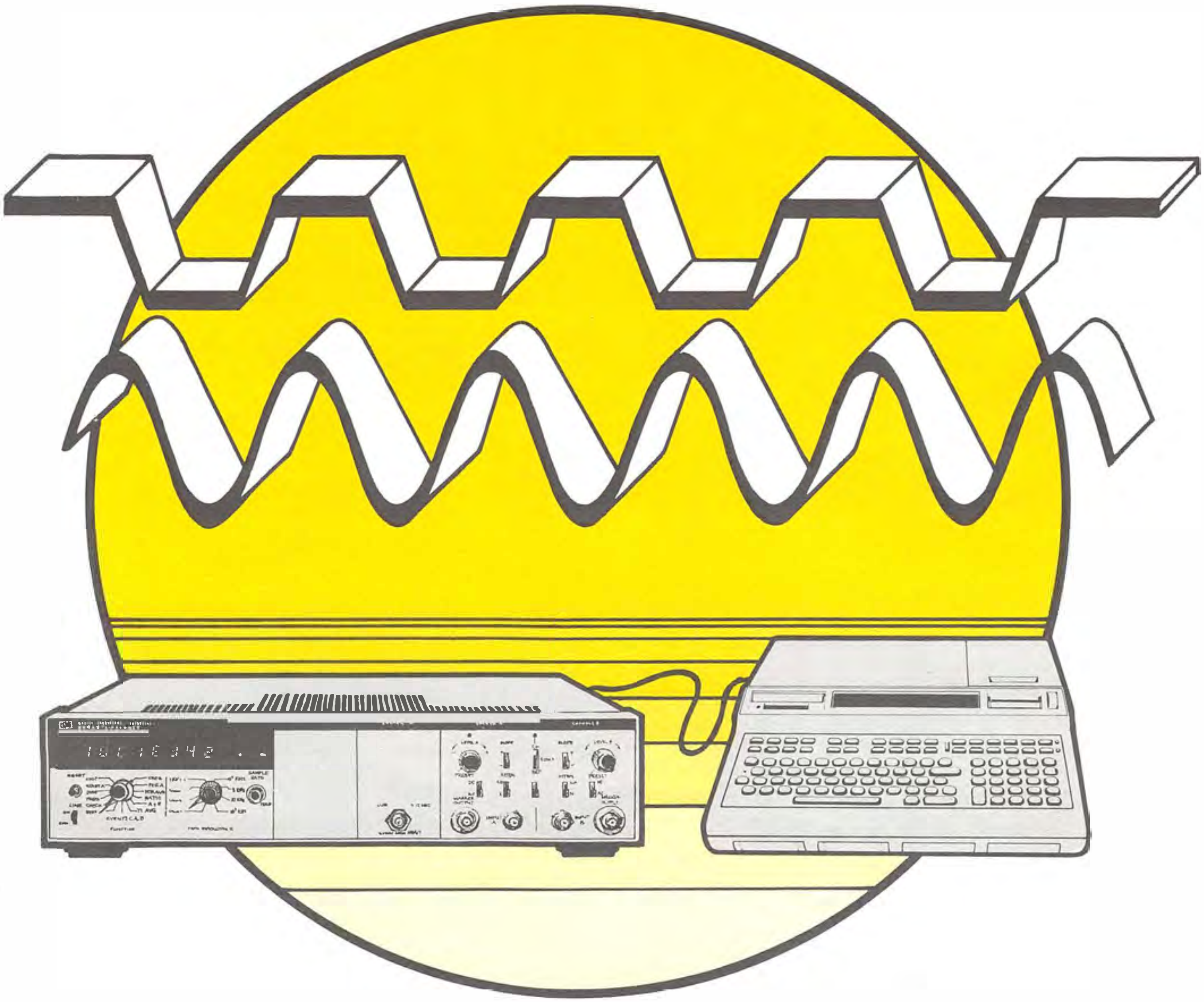
Application Note 287-1

WAVEFORM ANALYSIS USING THE 5328A UNIVERSAL FREQUENCY COUNTER



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-1B), which is an implementation of IEEE Standard 488-1975, 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 may now be executed by means of a single keystroke on the controller. Under manual operation similar measurements would require much interaction by a highly skilled operator.

This application note describes the use of an HP 5328A Universal Frequency Counter and an HP 9825A computing controller for the waveform analysis of unknown input signals. Capabilities of the 5328A Counters are enhanced by this remote operation. The system can be used to automatically perform amplitude, rise time, fall time, pulse width, slew rate, duty cycle, frequency and period measurements of unknown, repetitive input signals.

A system configuration is shown in Figure 1. The 5328A counter must be equipped with Option 011 HP-IB Interface and Option 041 Programmable Input Module.The 9825A calculator must have HP-IB Interface Card/Cable HP 98034A, String-Advance Programming ROM HP 98210A and General I/O - Extended I/O ROM HP 98213A. The input signal to the system is applied to channel A of the frequency counter. A dual channel oscilloscope can be used to monitor the voltage levels at which the counter is triggering by connecting the input signal to one channel and the output marker from the counter to the other channel of the oscilloscope.

CONFIGURATION BLOCK DIAGRAM

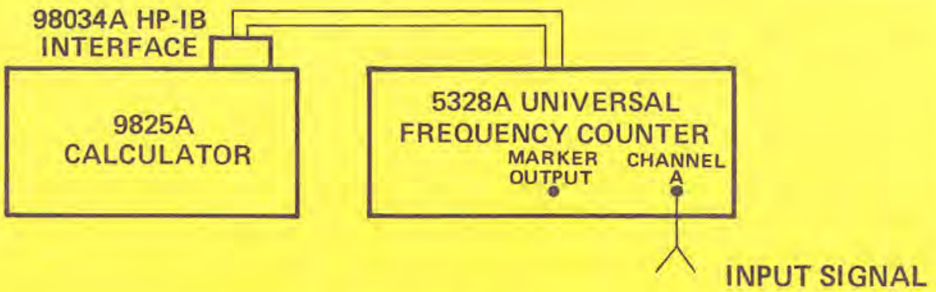


FIGURE 1

PROGRAM DESCRIPTION

The overall program is divided into several subroutines, each subroutine performs a specific task such as amplitude, frequency/period, pulse width, rise time, fall time, slew rate and duty cycle. The system makes use of the special function keys on the 9825A calculator to facilitate operator interface to the waveform analysis system. The calculator has 12 special function keys which provide 12 unshifted functions and 12 shifted functions. The special function keys can be used as typing aids, one line immediate execute keys, or as immediate continue keys. The system makes use of the immediate execute capability of special function keys by loading into each key a command directing the program to a specific subroutine. For example, unshifted key f1 and shifted key f13 have an immediate execute to the amplitude subroutine. Both keys can be labeled "AMPLITUDE" on the special function key overlay as shown in Figure 3. A special function key listing is shown in Figure 6.

An explanation of each subroutine and the special function keys through which it can be accessed is explained below.

RESET (f0, f12): by pressing the RESET key on the 9825A, the counter is programmed to 50 ohm input impedance, DC coupling and X1 attenuation. The program then returns to the initialize state where the operator can select a measurement routine.

AMPLITUDE (f1, f13): the counter will scan the input signal in 100 mV increments until the highest level is detected, the counter will then decrease the trigger level and begin a new scan at 10 mV increments. The program also includes hysterisis compensation for a more accurate determination of the input signal amplitude. The calculator will print out the upper level, lower level, peak to peak voltage, ten percent and ninety percent points of the input signal. By monitoring the input signal with one channel of an oscilloscope and connecting the Marker output from the counter to the other channel, the scanning of the input signal by the counter's DACs can be observed. (Figure 1)

FREQUENCY/PERIOD (f2, f14): by pressing the FREQ/PERIOD key on the 9825A, the counter will go through the Amplitude subroutine and compute the arithmetic mean of the input signal amplitude, the counter will then set the trigger level to the mean and make a frequency and period measurement. The calculator will print out the frequency in Hertz and period in seconds.

PULSE WIDTH (f13, f15): the pulse width measurement routine will first make an amplitude determination of the input signal and then set the counter's trigger levels to the fifty percent point for a time interval measurement. The calculator will print out the pulse width in seconds.

RISE TIME (f4, f16): the counter will first make an amplitude measurement of the input signal and then set the trigger levels to the ten and ninety percent points. It will then make a time interval measurement and print rise time in seconds.

FALL TIME (f5, f17): the fall time measurement routine is very similar to the rise time except that the trigger levels are reversed for a fall time measurement.

SLEW RATE (f6, f18): by pressing the SLEW RATE key on the calculator, the counter will first make an amplitude measurement, the operator must then select either positive or negative slew rate. The counter will then set trigger levels to the midrange area of the input signal (forty and sixty percent points), where the probability of noise is less and linearity the greatest. A time interval measurement is then made and the calculator will compute either positive or negative slew rate in volts per μ second

DUTY CYCLE (f7, f19): the duty cycle measurement routine has the counter make an amplitude measurement, trigger levels are then set to the fifty percent points. Two time interval measurements are made to determine pulse width and pulse repetition interval. The calculator computes the duty cycle and prints it along with the pulse width and pulse repetition interval.

SYSTEM PERFORMANCE CHARACTERISTICS

All counter measurements are done with an input impedance of 50 ohms and X1 attenuation, therefore all results are for a 50 ohm environment. This will allow a signal operating range (trigger levels) variable over ±2.5 volts. If the input signal exceeds these limits, the system will detect the discrepancy and display "INPUT SIGNAL OUT OF RANGE." The counter's dynamic range with a X1 input attenuation is 25 mV to 1 V rms for 0 to 40 MHz and 50 mV to 500 mV rms for 40 to 100 MHz. The dynamic range of the system can be expanded by using a calibrated attenuator at the input to the counter. Rise Time, Fall Time, Pulse Width and Slew Rate measurement routines are done via time interval measurements of the input signal. Resolution and accuracy of the system can be computed as follows:

$$\textbf{RESOLUTION} = \frac{\pm \text{LSD} \pm \text{trigger error}}{\sqrt{N}}$$

where: LSD = 10 nsec for program code of GØ

$$\text{trigger error} = \frac{1.414\sqrt{en^2 + (500\mu\text{V})^2}}{\text{input signal slew rate at trigger point}}$$

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

N = number of time intervals averaged

ACCURACY: = ± RESOLUTION ± trigger level timing error
± differential channel delay error
± (timebase error) × T.I.

where: trigger level timing error = $\dfrac{\text{trigger level error}}{\text{input signal slew rate at trigger point}}$

trigger level error = ± 35mV
differential channel delay = ± 2 nsec for 5328A, Opts. Ø40, Ø41.

PROGRAM LISTINGS

A typical system output listing for a triangular wave input (Figure 2) is shown in Figure 4. The main program listing is shown in Figure 5, and the special function key listing in Figure 6.

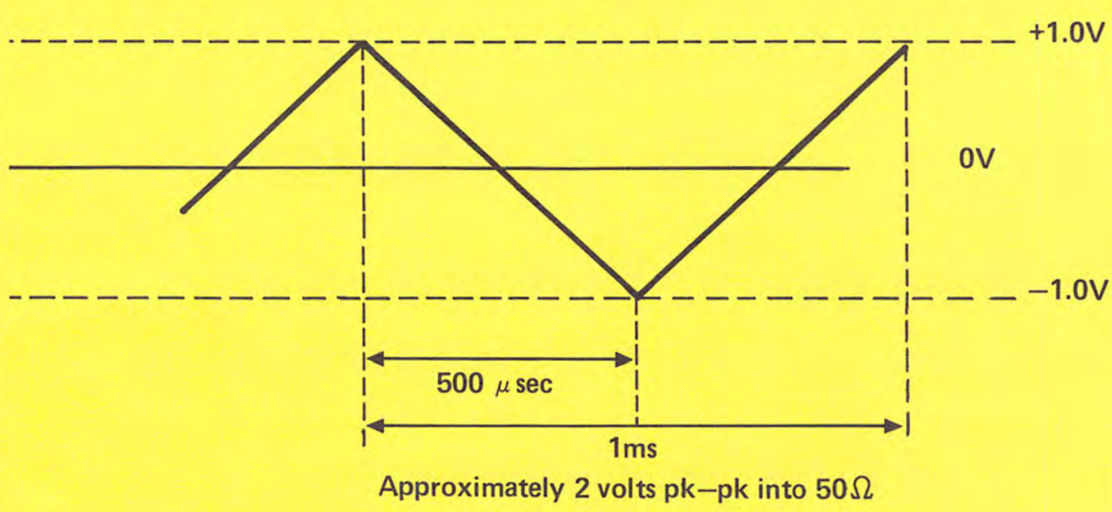


FIGURE 2

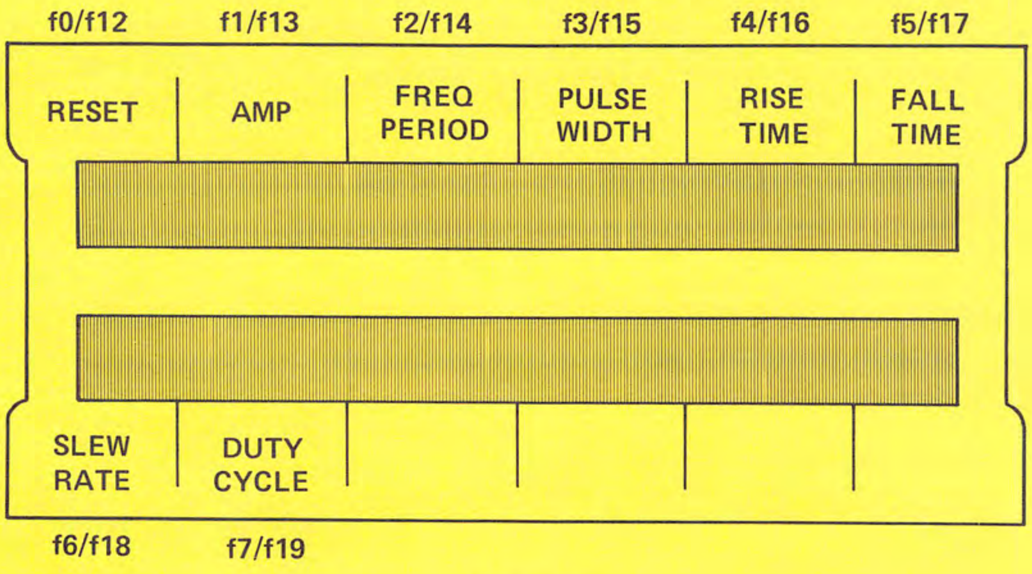


FIGURE 3

Special Function Key Overlay (HP/PN 7120-4802)

Figure 4 Typical System Output Listing

```
WAVEFORM
         ANALYSIS


----------------
AMPLITUDE:


UPPER LEVEL=
(volts)      1.02


LOWER LEVEL=
(volts)     -0.98


PK-PK VOLTAGE=
             2.00


TEN PERCENT=
(volts)     -0.78


NINETY PERCENT=
(volts)      0.82


----------------
FREQ/PERIOD:


FREQUENCY(Hz)=
           997.00


PERIOD(sec)=
 +  1002.330e-6


----------------
PULSE WIDTH:


PULSE WIDTH=
(sec)
 +   499.600e-6


----------------
```

```
RISE TIME:


RISE TIME(sec)=
 +   429.060e-6


----------------
FALL TIME:


FALL TIME(sec)=
 +   399.850e-6


----------------
SLEW RATE:


NEG SLEW RATE=
 (volts/usec)
         4.02e-03


POS SLEW RATE=
 (volts/usec)
         3.81e-03


----------------
DUTY CYCLE:


PULSE REPETITION
  INTERVAL(sec)=
 +  1004.890e-6


PULSE WIDTH=
(sec)
 +    499.30e-6


DUTY CYCLE=
(Percent)   49.69


----------------
END
```

Figure 5 Main Program Listing

```
0: clr 725;rem 725
1: dim A$[20],B$[20];sfg 14
2: time 10000
3: dsp "WAVEFORM ANALYSIS";wait 2000;prt "WAVEFORM","        ANALYSIS";spc 2
4: prt "----------------"
5: dsp "SELECT FUNCTION DESIRED";stp
6: "LEVELS":
7: 43→S;1→r1
8: for K=0 to r1*2.5 by r1*.1
9: abs(K)→V
10: gsb "XYZ"
11: wrt 725,"PF4A137R"
12: wtb 725,65,S,X,Y,Z,42;wait 250;trg 725;wait 25
13: on err "CNTR"
14: rds(725)→R;if R=0;gto "LI"
15: if abs(K)=2.5;gsb "ERROR"
16: next K
17: "LI":
18: if S=45;gto "LL"
19: gsb "IL"
20: J+.03→T;J→r2
21: 45→S;-1→r1;gto 8
22: "LL":
23: gsb "IL"
24: J-.03→B;J→r3
25: T-B→P
26: B+.1P→r4
27: B+.9P→r5
28: ret
29: "IL":
30: abs(K)-.2→W
31: for J=r1W to r1*2.5 by r1*.01
32: abs(J)→V
33: gsb "XYZ"
34: wrt 725,"PF4A137R"
35: wtb 725,65,S,X,Y,Z,42;wait 250;trg 725;wait 25
36: rds(725)→R;if R=0;ret
37: next J
38: "AMPLITUDE":
39: gsb "LEVELS"
40: prt "AMPLITUDE:";spc 2
41: prt "UPPER LEVEL=","(volts)",T;spc 2
42: prt "LOWER LEVEL=","(volts)",B;spc 2
43: prt "PK-PK VOLTAGE=",P;spc 2
44: prt "TEN PERCENT=","(volts)",r4;spc 2
45: prt "NINETY PERCENT=","(volts)",r5;spc 2
46: prt "----------------"
47: gto 5
48: "FREQ/PERIOD":
49: prt "FREQ/PERIOD:";spc 2
50: gsb "LEVELS"
51: B+.5P→r4;B+.5P→r5
52: gsb "R/F TIME"
53: wrt 725,"PF4S13G6R";wait 50
54: wtb 725,65,49,51,43,E,G,H,I,42,82;wait 3000
55: on err "CNTR"
56: red 725,F
57: prt "FREQUENCY(Hz)=",F;spc 2
58: wrt 725,"PF6S13G0R";wait 50
59: wtb 725,65,49,51,43,E,G,H,I,42,82;wait 3000
60: on err "CNTR"
61: red 725,A$
62: prt "PERIOD(sec)=",A$;spc 2
63: prt "----------------"
64: gto 5
65: "R/F TIME":
66: if r4<0;jmp 2
67: 43→C;jmp 2
68: 45→C
```

```
69: abs(r4)→V
70: gsb "XYZ"
71: X→L;Y→M;Z→N
72: if r5<0;jmp 2
73: 43→E;jmp 2
74: 45→E
75: abs(r5)→V
76: gsb "XYZ"
77: X→G;Y→H;Z→I
78: ret
79: "RISE TIME":
80: prt "RISE TIME:";spc 2
81: gsb "LEVELS"
82: gsb "R/F TIME"
83: wrt 725,"PF8S13G0R";wait 50
84: wtb 725,65,49,51,55,57,C,L,M,N,42,66,49,51,55,E,G,H,I,42,82;wait 3000
85: on err "CNTR"
86: red 725,B$;prt "RISE TIME(sec)=",B$;spc 2
87: prt "----------------"
88: gto 5
89: "FALL TIME":
90: prt "FALL TIME:";spc 2
91: gsb "LEVELS"
92: gsb "R/F TIME"
93: wrt 725,"PF8S13G0R";wait 50
94: wtb 725,65,49,51,53,55,57,E,G,H,I,42,66,49,51,53,55,C,L,M,N,42,82
95: wait 3000
96: on err "CNTR"
97: red 725,B$;prt "FALL TIME(sec)=",B$;spc 2
98: prt "----------------"
99: gto 5
100: "PULSE WIDTH":
101: prt "PULSE WIDTH:";spc 2
102: gsb "LEVELS"
103: B+.5P→r4;B+.5P→r5
104: gsb "R/F TIME"
105: wrt 725,"PF8S13G0R";wait 50
106: wtb 725,65,49,51,55,57,E,G,H,I,42,66,49,51,53,55,C,L,M,N,42,82
107: wait 3000
108: on err "CNTR"
109: red 725,B$;prt "PULSE WIDTH=","(sec)",B$;spc 2
110: prt "----------------"
111: gto 5
112: "SLEW RATE":
113: prt "SLEW RATE:";spc 2
114: gsb "LEVELS"
115: B+.4P→r4
116: B+.6P→r5
117: gsb "R/F TIME"
118: ent "POSorNEG SLEW RATE? POS=P,NEG=N",A$;if A$="N";jmp 9
119: wrt 725,"PF8S13G0R";wait 50
120: wtb 725,65,49,51,55,57,C,L,M,N,42,66,49,51,55,E,G,H,I,42,82;wait 3000
121: conv 69,101;red 725,B$
122: abs(r5)+abs(r4)→r6
123: flt 2;prt "POS SLEW RATE="," (volts/usec)",r6/val(B$)*1e-6;fxd ;spc 2
124: ent "NEG SLEW RATE? YES=Y,NO=N",A$;if A$="Y";jmp 3
125: prt "----------------"
126: gto 5
127: wrt 725,"PF:S13G1R";wait 50
128: wtb 725,65,49,51,53,55,57,E,G,H,I,42,66,49,51,53,55,C,L,M,N,42,82
129: wait 3000
130: conv 69,101;red 725,B$
131: abs(r5)+abs(r4)→r6
132: flt 2;prt "NEG SLEW RATE="," (volts/usec)",r6/val(B$)*1e-6;fxd ;spc 2
133: ent "POS SLEW RATE? YES=Y,NO=N",A$;if A$="Y";jmp -14
134: prt "----------------"
135: gto 5
136: "DUTY CYCLE":
137: prt "DUTY CYCLE:";spc 2
```

```
138: gsb "LEVELS"
139: B+.5P→r4;B+.5P→r5
140: gsb "R/F TIME"
141: wrt 725,"PF7S13G0R"
142: conv 69,101;red 725,A$
143: wrt 725,"PF8S13G1R"
144: wtb 725,65,49,51,55,57,C,L,M,N,42,66,49,51,53,55,E,G,H,I,42,82;wait 3000
145: conv 69,101;red 725,B$
146: prt "PULSE REPETITION","  INTERVAL(sec)=",A$;spc 2
147: prt "PULSE WIDTH=","(sec)",B$;spc 2
148: prt "DUTY CYCLE=","(Percent)",val(B$)/val(A$)*100;spc 2
149: prt "----------------"
150: gto 5
151: "XYZ":int(V)+48→X;frc(V)*10→W;int(W)+48→Y;frc(W)*10+48→Z;ret
152: "ERROR":beep;dsp "INPUT SIGNAL OUT OF RANGE";wait 3000;gto 5
153: "CNTR":beep;dsp "COUNTER DOWN";wait 3000;gto 5
154: "RES":wrt 725,"PF6G0A1379B137R";gto 5
155: "END":beep;dsp "END";wait 3000;prt "END";spc 2;end
*27365
```

Figure 6 Special Function Key Listing

```
f0: *dsp"RESET (
 50ohm;DC;atten
 X1)";wait4000;g
 sb"RES"

f1: *dsp"AMPLITU
 DE";gsb"AMPLITU
 DE"

f2: *dsp"FREQ/PE
 RIOD";gsb"FREQ/
 PERIOD"

f3: *dsp"PULSE W
 IDTH";gsb"PULSE
  WIDTH"

f4: *dsp"RISE TI
 ME";gsb"RISE TI
 ME"

f5: *dsp"FALL TI
 ME";gsb"FALL TI
 ME"

f6: *dsp"SLEW RA
 TE";gsb"SLEW RA
 TE"

f7: *dsp"DUTY CY
 CLE";gsb"DUTY C
 YCLE"

f11: *dsp"END";g
 sb"END"
```

```
f12: *dsp"RESET(
 50ohm;DC;attenX
 1)";wait4000;gs
 b"RES"

f13: *dsp"AMPLIT
 UDE";gsb"AMPLIT
 UDE"

f14: *dsp"FREQ/P
 ERIOD";gsb"FREQ
 /PERIOD"

f15: *dsp"PULSE
 WIDTH";gsb"PULS
 E WIDTH"

f16: *dsp"RISE T
 IME";gsb"RISE T
 IME"

f17: *dsp"FALL T
 IME";gsb"FALL T
 IME"

f18: *dsp"SLEW R
 ATE";gsb"SLEW R
 ATE"

f19: *dsp"DUTY C
 YCLE";gsb"DUTY
 CYCLE"

f23: *dsp"END";g
 sb"END"
```