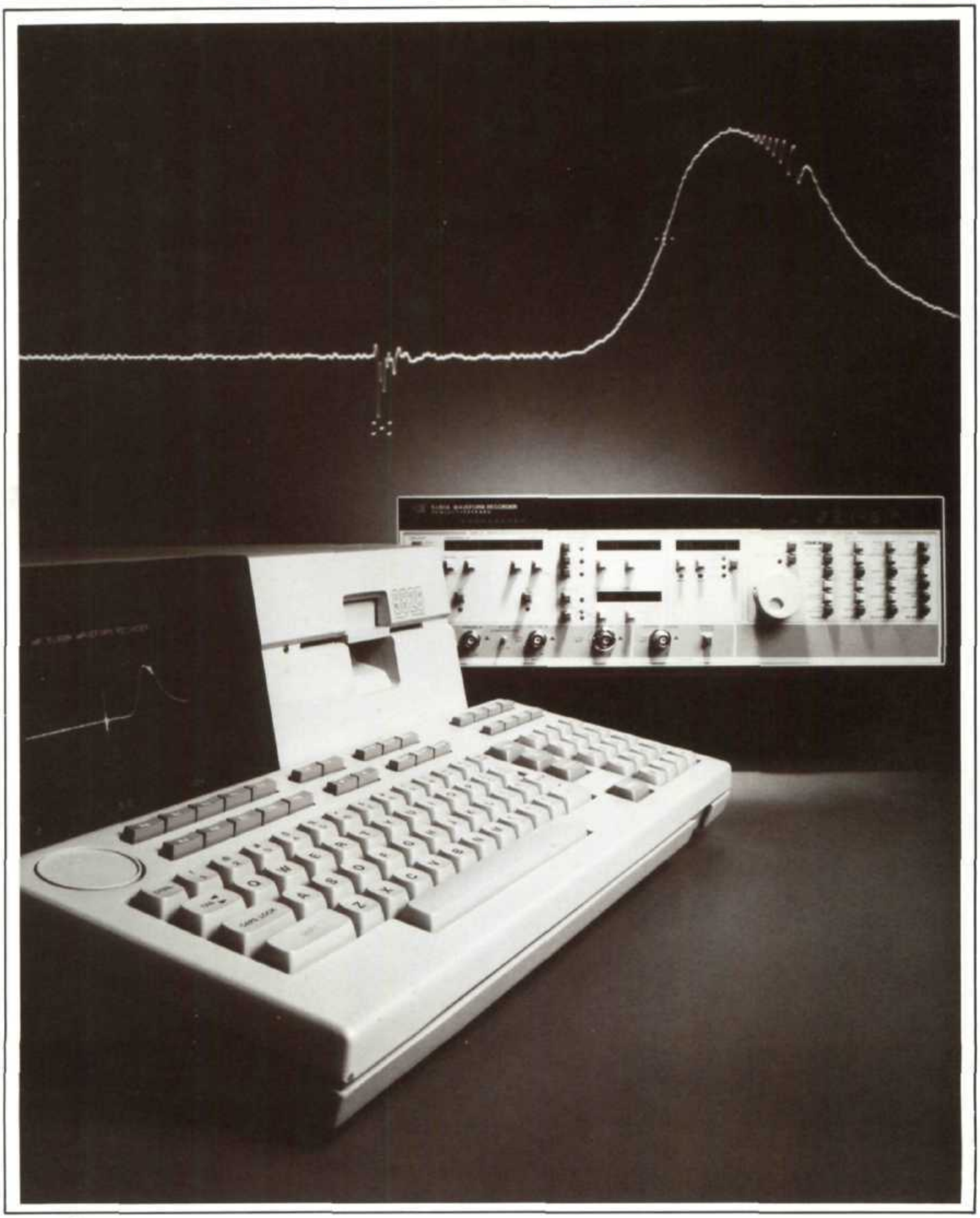
Application Note 313-4

Extending Frequency Range and Increasing Effective Sample Rate on the 5180A Waveform Recorder



HEWLETT PACKARD

Introduction

This note describes a 5180A based system that can be used with **repetitive inputs** to extend the unaliased frequency measurement range beyond 10 MHz (10 MHz is the 5180A's stand-alone unaliased range limit) and provide effective sample rates in excess of 20 MegaSamples/Second (20 MS/S is the maximum sample rate possible on the 5180A). This system enhances 5180A capability *in the same way that a sampling oscilloscope enhances oscilloscope capability. Like the sampling* scope, the "sampling 5180A" is useful for extending the frequency measurement range and for providing more complete sampling of any repetitive input.

A feature of the 5180A Sampling System is that fast effective digitizing rates are acheived without sacrificing amplitude resolution. Traditionally, to adequately sample higher frequency input signals, waveform recorders with faster maximum digitizing rates have provided the only solution. A drawback of these faster waveform recorders is that they sometimes don't provide sufficient amplitude resolution to obtain useful measurement results. The 5180A Sampling System can, when the input is repetitive, make these measurements with very good resolution in both amplitude and time. An example of the enhancement that this system can provide appears in Figure 1.

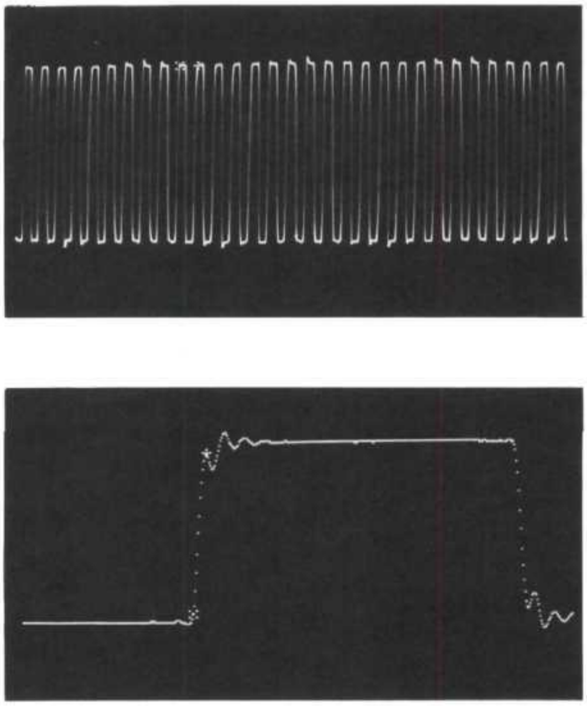


Figure 1. Top display shows pulse train data captured by waveform recorder alone (20 MHz conversion rate). Lower display shows same input captured using system described in this note.

Performance characteristics for the 5180A Sampling System are summarized in the table below:

5180A Input Channel	Maximum Recommended Input Frequency (3 dB Bandwidth)	Maximum Effective Sample Rate
A or B	40 MHz	20 GHz
Auxiliary	70 MHz	

An indication of the quality of the data as a function of the input frequency (dynamic performance) for the system is shown in Figure 9, which summarizes the results of extensive sine wave curvefit testing.*

Highlights of System Operation

In addition to the 5180A Waveform Recorder, the 5180A Sampling System requires a programmable timing generator and an instrument controller. The system implementation described in this note uses a 5359A Time Synthesizer and a 9826 Controller. Figure 2 shows the set-up.

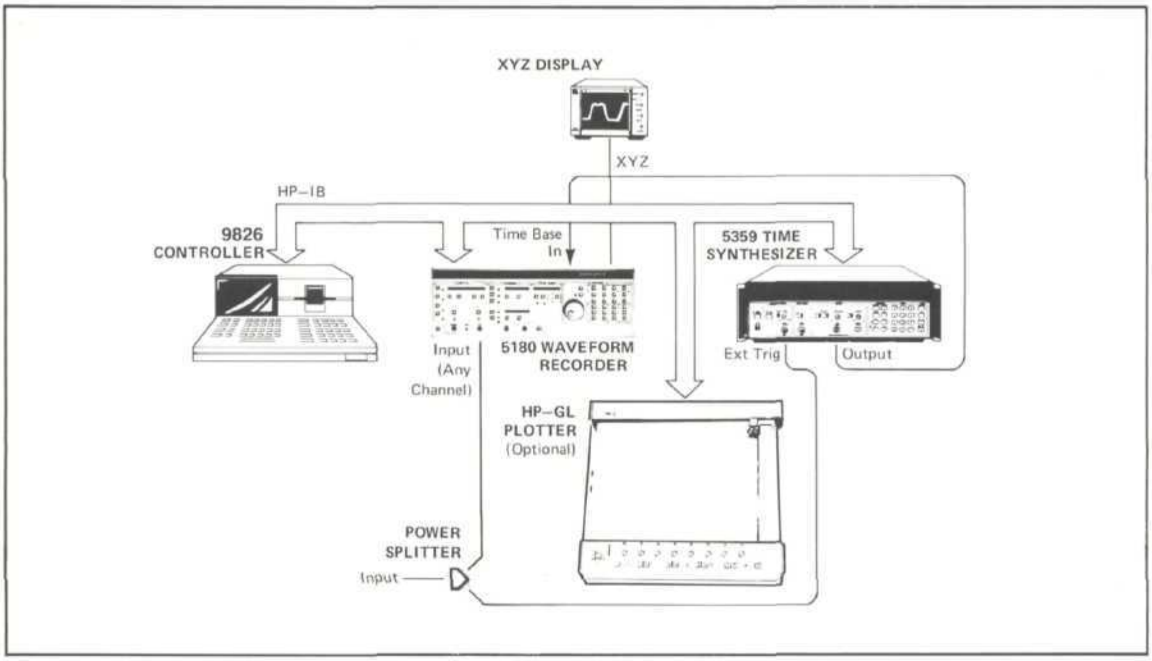


Figure 2. 5180A sampling system.

The measurement technique is similar to that used in a sampling scope – the sample point is walked through the input by successively increasing the delay between the occurrence of an input trigger and the time the input is sampled. As can be seen from Figure 2, the 5359A is externally triggered by the input signal.** The time between occurrence of this trigger and the output of a pulse from the 5359A is precisely controllable (increments as small as 50 picoseconds), so the 5359A provides the variable delay capability. The output pulse from the 5359A is the input that tells the 5180A when to sample the input signal. A detailed description of the system operation appears in the next section.

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*The sine wave curvefit test is an ADC (Analog-to-Digital Converter) performance measure used by Hewlett-Packard and other waveform recorder producers to evaluate the overall quality of the analog-to-digital conversion process. This test is particularly meaningful because it incorporates many of the error factors that can degrade ADC performance.

**For repetitive inputs that don't have a uniquely definable trigger within one period of the input waveform, such as phase coherent pulsed RF (no unique trigger is definable because the signal passes through the same level with the same slope many times within one period), another trigger signal must be generated. For example, with phase coherent pulsed RF, the modulating signal could be used as the trigger.

Here's How it Works

When the 5180A Sampling system is collecting data it iterates through a simple procedure that can be described in chronological steps:

STEP A: The input passes through the exernal trigger level set on the 5359A Time Synthesizer, thus triggering it.

STEP B: The amount of delay time that has been programmed into the 5359A elapses.

STEP C: At the end of the delay time the 5359A generates a pulse.

STEP D: The output pulse, being the timebase for the 5180A, causes the 5180A to sample the input once.

STEP E: After the 5359A output pulse has occurred, the 5359A is automatically re-armed and again becomes ready to accept an external trigger.

Steps A-E are repeated as many times as there are data points in the 5180A record (determined by 5180A RECORD LENGTH value).

STEP F: Once the record has filled, the data is output to the 9826 Controller and the 5359A delay time is increased. Steps A-E are then repeated again.

The process continues until the desired number of measurements have been taken.

STEP G: The measurement data is processed and the results are written to the 5180A, or may be plotted on the 9826 display.

The 9826 Controller oversees the entire measurement process. This sequence of steps is depicted in Figure 3. Figures 4 and 5 show the signal timing relationships.

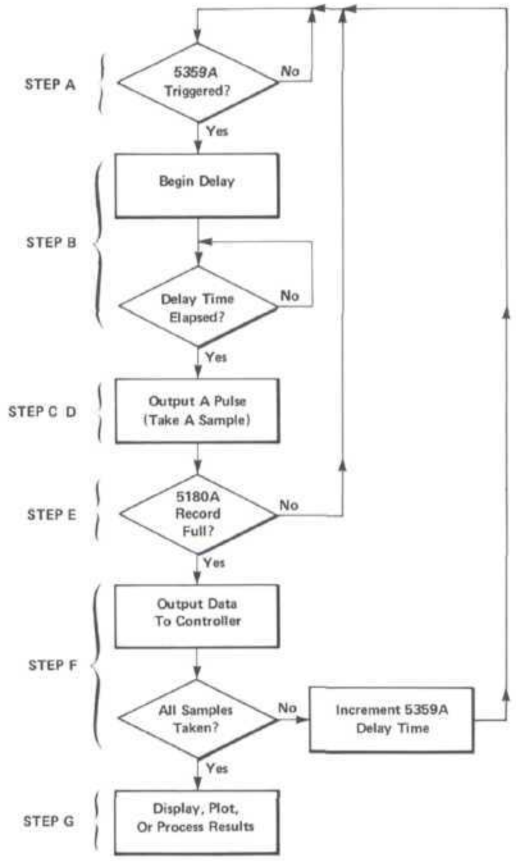


Figure 3. Flow diagram for measurement process.

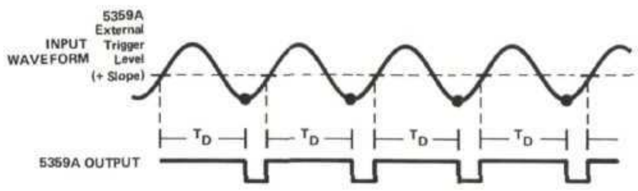


Figure 4. Timing relationships for 5180A sampling system. T_D is 5359A delay time. ● indicates the value of the input when the sample occurs.

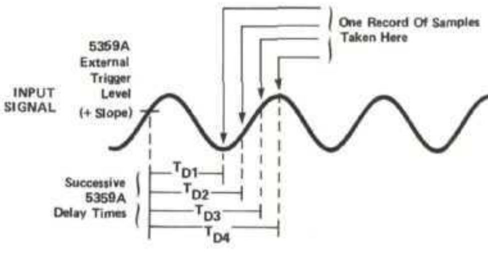
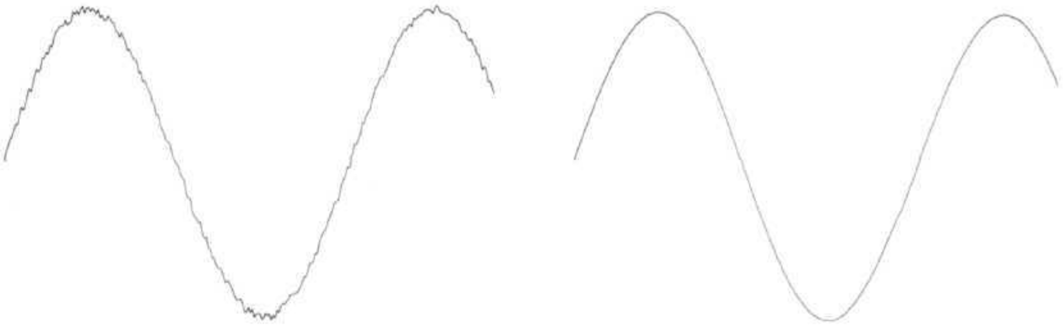


Figure 5. Successive data records are collected at successive time delays for complete sampling of input.

Processing the Data

As each data record is output to the 9826 Controller, the data may be averaged and the average saved or a single data point can be saved. Averaging the data is useful for removing noise (random) components from the input signal. The "smoothing" effect of averaging is illustrated in Figure 6.

Whether the data is averaged or not, the input signal is reconstructed by plotting or displaying the saved data point from each record versus the value of the time delay associated with that record.



6A. No averaging.

6B. Each sample is average of 100 samples.

Figure 6. Averaging reduces the effect of random noise.

Putting the System Together

The equipment set-up and required interconnections are shown in Figure 2. A step-by-step procedure for making the 5180A Sampling System operational is provided below:

1. Complete the system interconnections according to Figure 2. HP-IB device addresses are: 04 for the 5180A, and 10 for the 5359A.
2. A rotary switch near the 5180A's timebase-in input can be set to sample at various input levels: -1, -.3, 0, or 1.8 volts into 50 ohms. Since the 5359A has flexible output level capabillity, any of the 5180A's timebase-in threshold levels could be used. The simplest choice is to set the rotary switch for a zero volt threshold (position 3).
3. Preset the 5180A by pressing the SHIFT key followed by the key marked PRESET. Position the rear-panel INT/EXT timebase switch to EXT, and select the AUTO sweep arming mode.
4. Set the 5359A front panel to:

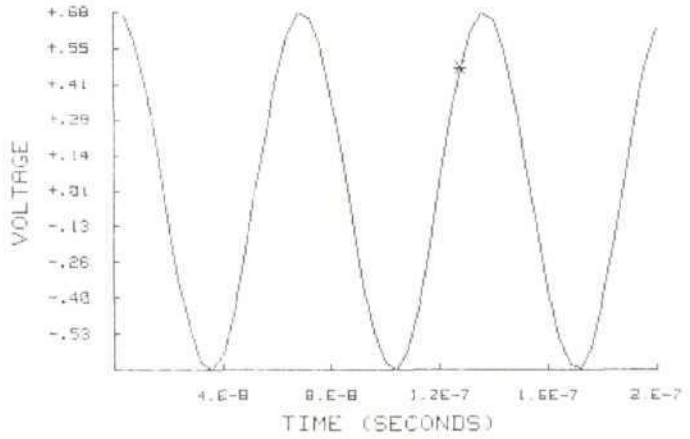
   Sync Delay .... Preset
   Polarity .... Norm and Pos
   Offset .... On
5. On power-up the 5359A outputs a 1 MHz repetitive pulse train. This signal is convenient for establishing that the 5359A output is actually causing the 5180A to sample. Set the output level on the 5359A by pressing DISPLAY LEVELS to bring up the amplitude and offset values on the 5359A display. Adjust the amplitude to about 2 volts with a -1 volt offset. This should cause the output pulse to change from -1 to 1 volt, thus assurring that the 5180A timebase-in threshold level is crossed. If sampling is occurring the input signal will be changing on the XYZ display and the ARM and TRIG annunciators on the 5180A will be flashing. If the 5180A isn't sampling, check and adjust the 5359A output levels.
6. Having verified that the 5359A output is causing the 5180A to sample, the final hardware step is to set the external trigger level on the 5359A. With input signal applied press the DELAY key on the 5359A. The 5359A display will blank, indicating that it's waiting for you to input a delay value. Press 10 (data entry section) followed by ns (units section). This entry specifies that the 5359A will output a pulse 10 nanoseconds after the occurrence of an external trigger (there is some additional fixed delay, but this isn't important). Use the external trigger level adjustment to set an appropriate external trigger level. To verify that an unambiguous trigger level has been chosen, view the captured waveform on the XYZ display. The waveform should be live and essentially a horizontal line. The display represents the data for one sample point of the repetitive input. Since all the data is being taken at the same delay time after the 5359A is externally triggered, you would expect the displayed waveform to be a horizontal line (see Figure 4). If it isn't horizontal, or if the 5180A isn't sampling, adjust the external trigger level on the 5359A.

Once the previous six steps have been successfully completed the system hardware is operational. The system software remains to be loaded into the 9826 Controller. The system software, with documentation and a variable list, is presented in the appendix.

Some of the key features of the 5180A Sampling System software are:

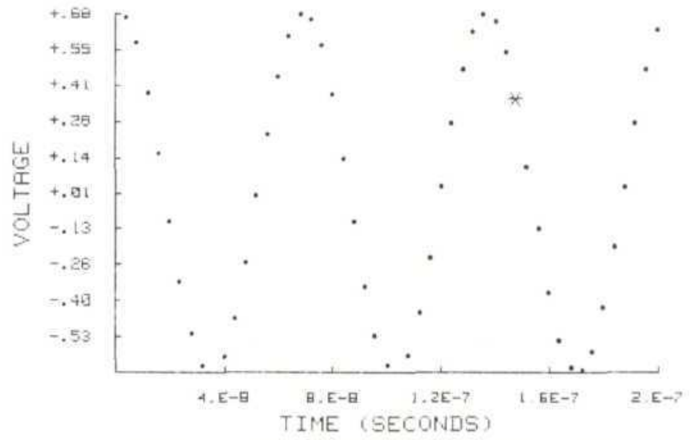
- Softkeys are used to control all system functions.
- Using the softkeys the following parameters can be controlled by the user:
  1) Effective sample rate
  2) Number of samples per measurement
  3) Extent of averaging per sample point
  4) 5180A record location for storing measurement results
  5) High-speed or Normal acquisition mode. The normal acquisition mode uses the measurement procedure of Figure 3. The high-speed mode employs a slightly different procedure, using the 5180A's AUTO ADVANCE feature to sample up to 32 points before any data is output from the 5180A.

- Once the data is collected and processed in the 9826 it is automatically written back into the 5180A. The 5180A display controls can then be used to examine the captured waveform. The amplitude levels are accurate but no time per sample information is available from this display.
- The PLOT softkey displays the measurement result on the 9826 display. An advantage of this display over the data as stored and displayed by the 5180A is that the scaling is optimized on the 9826 display for the actual amplitude and time range of the measurement. A dot/line mode similar to this feature on the 5180A is provided on the 9826 display. Also, a cursor may be enabled for simultaneous time and voltage readout of the data on the 9826 display. These readouts appear in the softkey menu area. Positioning of the cursor is controlled via the 9826 control knob. Illustrations of the 9826 display plot appear below.



EXIT		TIME	VOLTAGE	
PLOT		1.36E-7	.49	

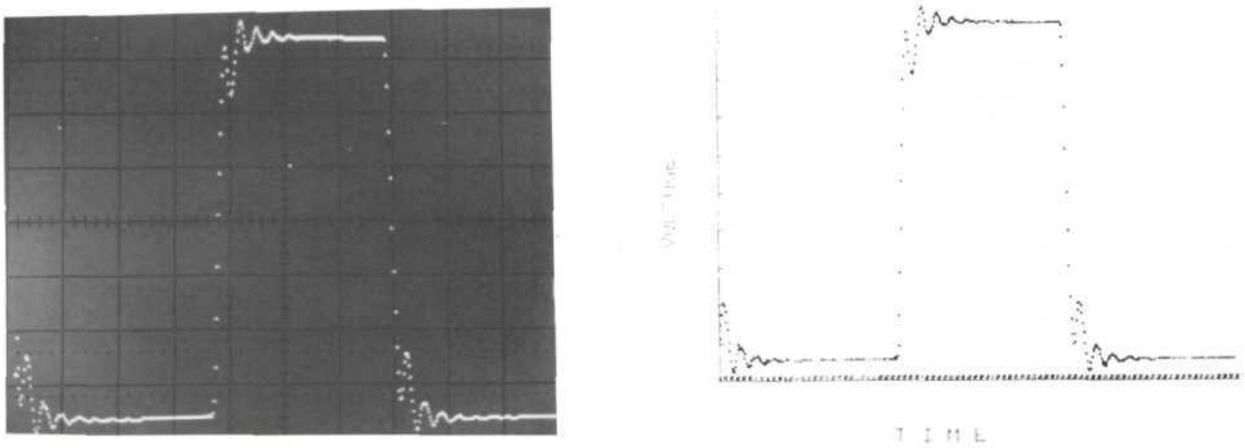
7A. 9826 plot using LINE mode.



EXIT		TIME	VOLTAGE	
PLOT		1.48E-7	.406	

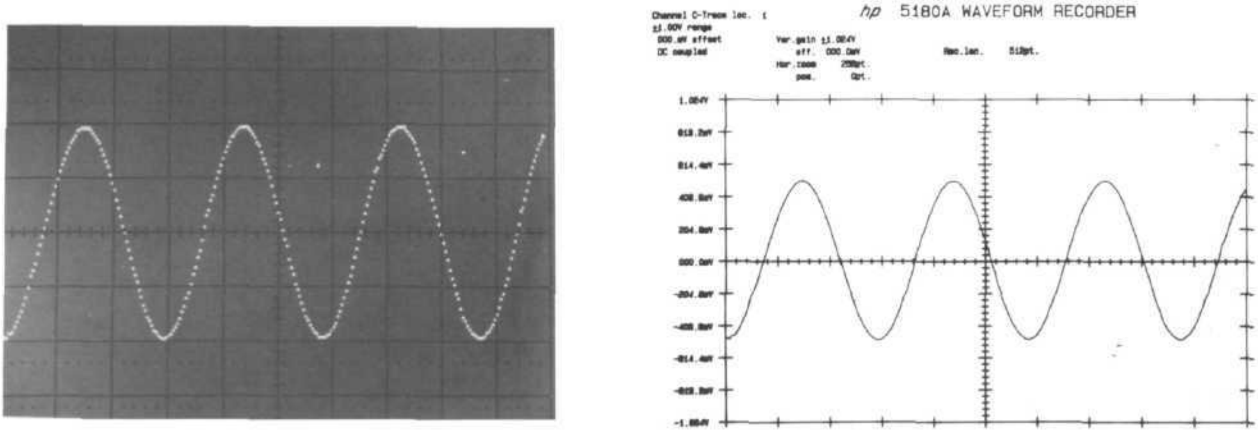
7B. 9826 plot using DOT mode.

Figure 7. The cursor voltage and time values appear in the softkey menu.



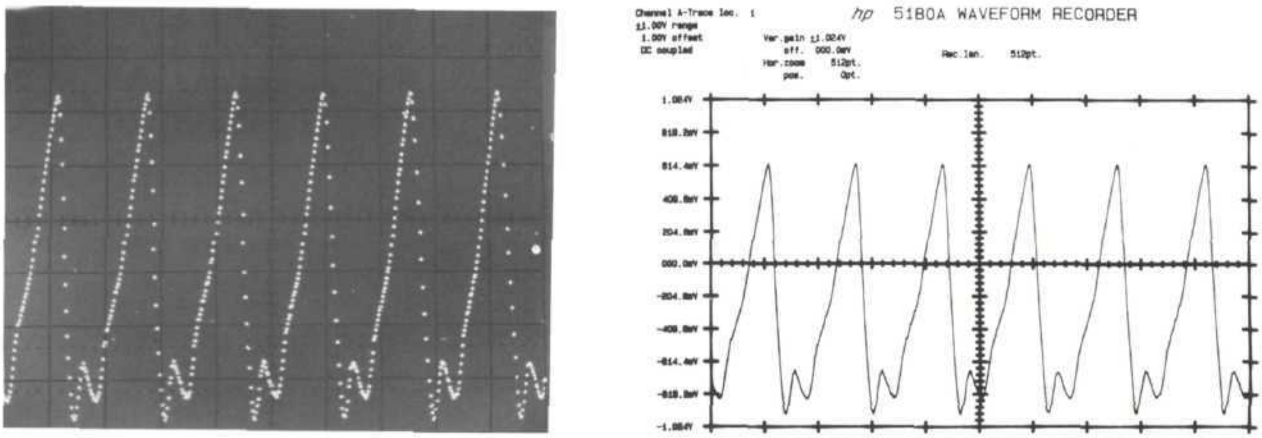
XYZ DISPLAY **PLOT GENERATED BY 9826 CONTROLLER**

8A. Square wave output captured using sampling technique. Effective sample rate is 667 MHz. (1.5 nanoseconds/sample).



XYZ DISPLAY **5180A GENERATED PLOT**

8B. 53.64 MHz sine wave captured using sampling technique. Effective sample rate is 4 GHz. (250 picoseconds/sample).



XYZ DISPLAY **5180A GENERATED PLOT**

8C. Output captured using sampling technique. Effective sample rate is 1 GHz. (1 nanosecond/sample).

Figure 8. Examples of system output.

Measurement Considerations

An indication of typical dynamic performance for the 5180A Sampling System is shown in Figure 9, which plots input frequency versus effective bits (an excellent description of "effective bits" and the test that determines this result appears in 5180A Product Note 5180-2).

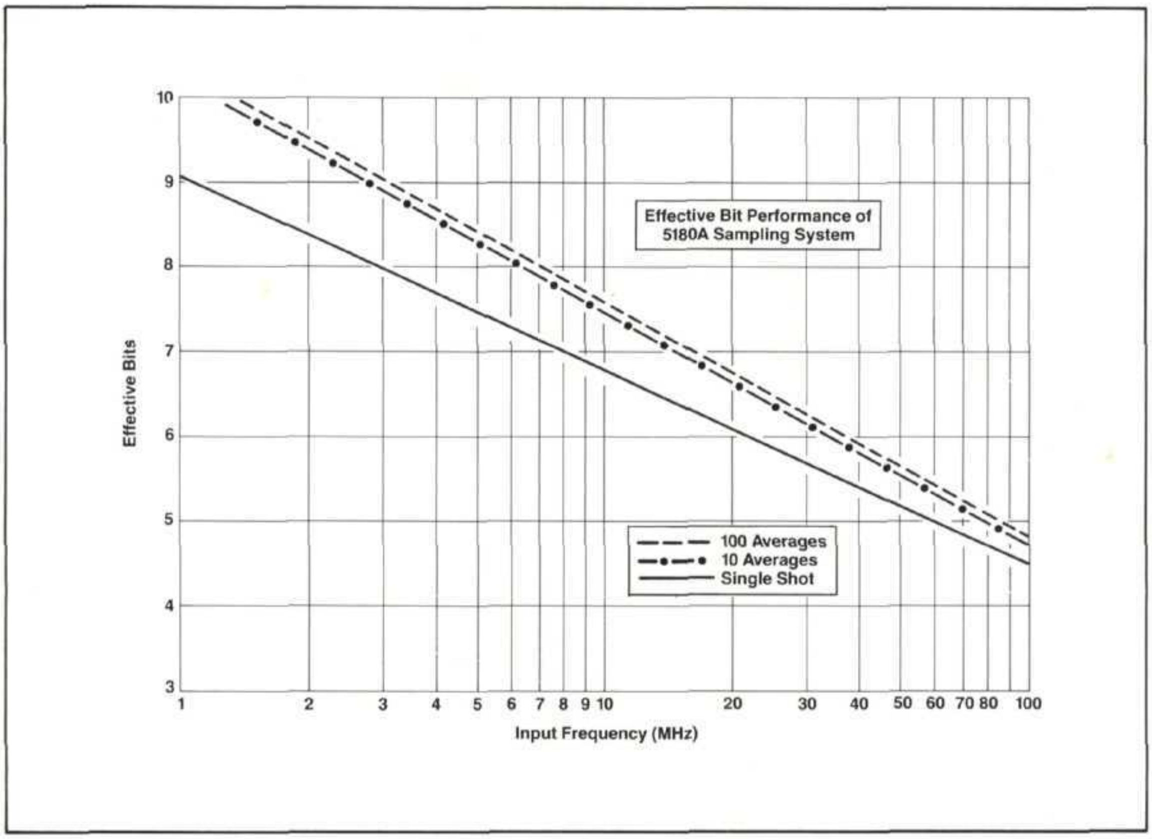


Figure 9. Dynamic Performance data for 5180A Sampling System. Effective sample rate was 500 MHz.

Other important considerations regarding the performance of the 5180A Sampling System are described below.

1. 5180A INPUT BANDWIDTH
The input bandwidths of the 5180A (see table, page 2) impose an upper limit on the frequency extension range of the system. Since the 5180A front-end can be modeled as a single-pole low pass filter (for any of the input channels), data can be collected beyond the 3 dB point, but attenuation and phase-shifting will affect the data according to Figures 10 and 11.

2. 5359A EXTERNAL TRIGGER BANDWIDTH
Since the 5359A Time Synthesizer is externally triggered by the input signal in most implementations of the system (for an exception see the footnote on page 4), the external trigger bandwidth can impose limitations. Measurements taken to evaluate this limitation indicate that the 5359A will trigger reliably for inputs up to 100 MHz.

3. 5359A MINIMUM DELAY STEP SIZE
The 5359A delay step is the effective time per sample of the 5180A Sampling System. Since the minimum delay step size on the 5359A is 50 picoseconds, the maximum effective sample rate is 1/50 picoseconds = 20 GHz. NOTE: This doesn't mean, of course, that inputs in the GHz range can be captured using the 5180A Sampling System (see the previous two points for the reasons). It does mean that lower frequency, repetitive inputs can be sampled at a 20 GHz rate.

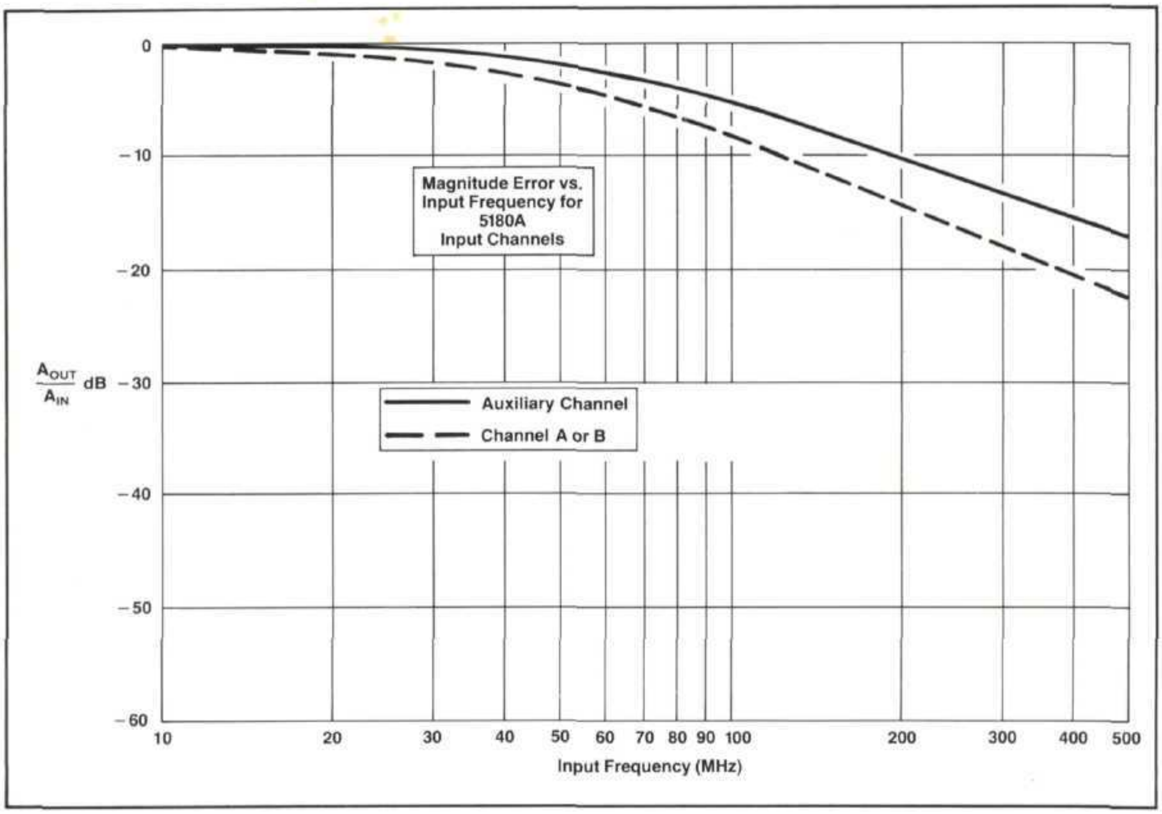


Figure 10. A_{OUT}: Output magnitude (value measured in 5180A) A_{IN}: Input magnitude

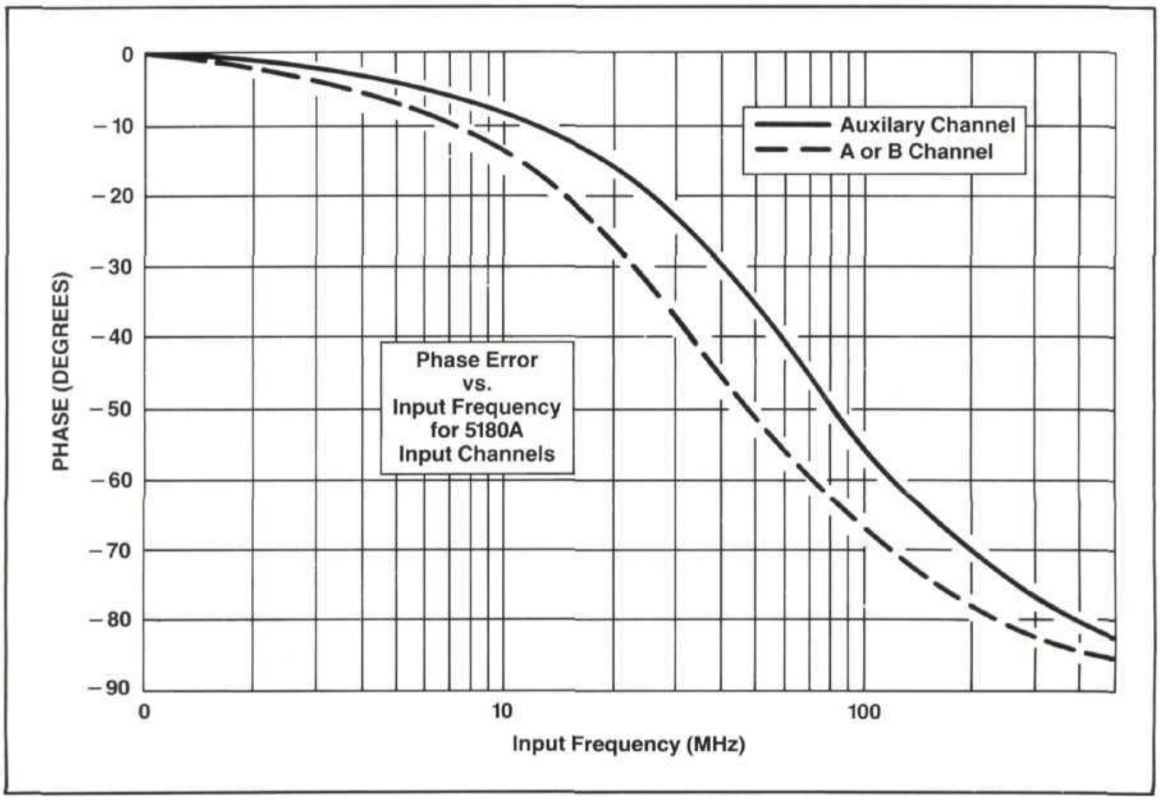


Figure 11.

4. 5359A OUTPUT STABILITY

Since the 5359A controls the sampling of the 5180A Waveform Recorder, the output jitter of the 5359A is actually the aperture uncertainty of the 5180A Sampling System. The effect of aperture uncertainty is a factor in the effective bit measurement. 5359A output jitter (specified at 100 picoseconds TYPICAL) is probably the main cause of performance degradation with increasing input frequency.

5. SYSTEM ACQUISITION TIME

Since the measurement technique requires multiple passes through the input signal before the data can be processed, the time to acquire the signal is an important measurement consideration. The acquisition time is the time between collecting the first data point in the first data record and the last data point in the last record. Acquisition times for the 5180A Sampling System are shown in Figure 12.

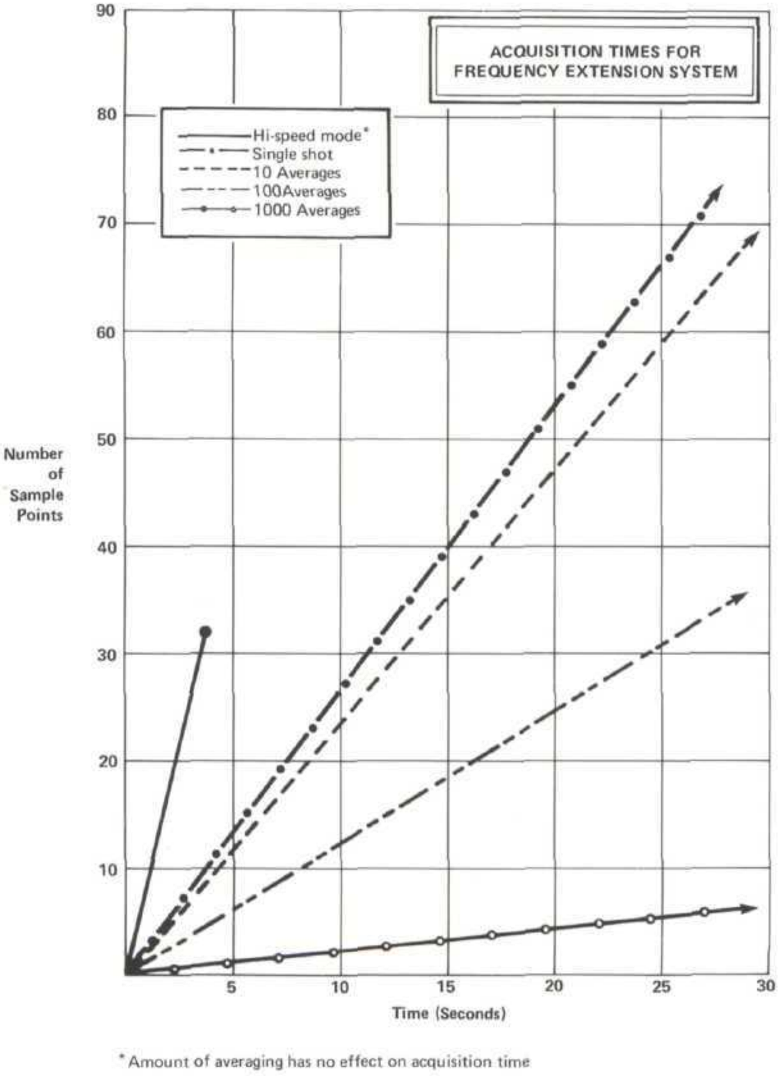


Figure 12.

Appendix : 5180A Sampling System Software

The 5180A Sampling System is controlled by the system software listed in this appendix. The program is written for BASIC as implemented in the 9826A controller. The structure of the software should be evident from the variable list and documentation included alongside the program listing. To operate the system software is simple: after pressing RUN all of the user options appear in the softkey menu. To modify a parameter, press the appropriate softkey, respond to the prompt, and press CONTINUE on the 9826.

The DISPLAY, PLOT, and CURSOR subroutines are useful as general purpose subroutines and could be used with the 5180A in any application to bring the data up on the 9826 display. Although not implemented in this listing, it should be possible to modify the HISPEED subroutine to sample more than 32 points. This could be accomplished using a DMA data transfer from the 5180A to the 9826 following each filling of the 5180A memory. The transferred data could be held in the controller while another series of 32 measurements is taken. This process could be repeated many times (the 9826 has plenty of memory to hold the unprocessed data) and then finally, all the data in the 9826 could be processed to obtain the measurement result.

Variable List and Definitions : in Order of Appearance in the Program

C$[*] : used to store 5180A teach strings

Code(*) : Data array (if memory limitations become important, Code(*) could be ALLOCATED (see 9826 manual) a size of the variable "Length", instead of being dimensioned).

Location : 5180A record location where processed data will be stored

Average : Number of averages per sample point

R : Effective sample rate

Samples : Number of samples per measurement

Length : 5180A record length

Flag : Indicates high-speed or normal measurement mode

C : Temporary data storage

Stay : Flag to allow new display plot on 9826

Channel : 5180A input channel (1=A, 2=B, 4=auxiliary)

Range : 5180A input range

Offset : 5180A offset

Minimum : Minimum Code(*)

Maximum : Maximum Code(*)

V_{max} : Maximum voltage of data

V_{min} : Minimum voltage of data

Connect : Flag identifying dot or line mode for 9826 display plot

Mov : Variable indicating cursor position for 9826 display plot

Old : Previous value of Mov

Left : Indicates Sample range over which data must be re-plotted on 9826 display following a cursor erase

```
10    !
20    !5180A SAMPLING SYSTEM
30    !
40 Main:        !
50    DIM ,C$[300],Code(16384)
60    A$="NORMAL"
70    Length=512                                                Initialize
80    Location=1
90    Average=1
100   GRAPHICS OFF
110   ASSIGN @Hp5180 TO 704                        Assign I/O Path name
120   ASSIGN @Hp5359 TO 710                        for 5180A and 5359A
130   ON KEY 0 LABEL "TIME/PT" GOSUB Sample
140   ON KEY 2 LABEL "SAMP="&VAL$(Samples) GOSUB Number
150   ON KEY 3 LABEL A$ GOSUB Mode
160   ON KEY 4 LABEL "MEASURE" GOSUB Measure
170   ON KEY 5 LABEL VAL$(R) GOSUB Sample                Define Soft Keys
180   ON KEY 7 LABEL "REC= "&VAL$(Location) GOSUB Record
190   ON KEY 8 LABEL "AVE="&VAL$(Average) GOSUB Average
200   ON KEY 9 LABEL "PLOT" GOTO 1110
210   DISP "SELECT DESIRED FUNCTION"
220   OFF KNOB
230   GOTO 130
240   !
250 Sample:  !
260   INPUT "ENTER SAMPLE RATE",R
270   OUTPUT @Hp5359;"DSS",R                    Program Effective
280   RETURN                                          Sample Rate
290   !
300 Number:  !
310   INPUT "ENTER NUMBER OF SAMPLES",Samples    Determine number
320   RETURN                                          of samples
330   !
340 Average:  !
350   INPUT "ENTER AVERAGES PER SAMPLE",Average
360   FOR I=9 TO 14
370      IF Average<2^I THEN GOTO 390             Determine extent of
380   NEXT I                                          averaging and
390   Length=2^I                                compute appropriate
400   RETURN                                    5180A record length
410   !
420 Mode:  !
430   IF Flag=0 THEN
440               A$="HI-SPEED"
450               Flag=1                                  Hi-speed or
460            ELSE                              Normal Measurement
470               A$="NORMAL"                                  Mode
480               Flag=0
490   END IF
500   RETURN
510   !
520 Measure:  !
530   DISP "MEASUREMENT IN PROGRESS"
540   OUTPUT @Hp5359;"D0E-9,W20E-9"                      set-up 5359A
550   OUTPUT @Hp5180;"TE1,SA3,SE1,PP5,LE,",Length        set-up 5180A
560   FOR I=1 TO Samples
570      Code(I)=0
580   NEXT I
```

```
590   IF Flag=1 THEN GOTO Hispeed
600   OUTPUT @Hp5180;"LO,",Location
610   FOR I=1 TO Samples
620      OUTPUT @Hp5180;"MT"                      Trigger 5180A                         Main
630      IF BIT(SPOLL(704),3)=0 THEN GOTO 630     wait for 5180A record to fill         Measurement
640      OUTPUT @Hp5180;"OS,",Location            set-up 5180A for selective            Loop
650      OUTPUT @Hp5180;0,Average                       ASCII output
660         FOR J=1 TO Average
670            ENTER @Hp5180;C                    Averaging
680            Code(I)=Code(I)+C                      Loop
690         NEXT J
700      Code(I)=Code(I)/Average
710      OUTPUT @Hp5359;"DSU"                     increase the delay time
720   NEXT I
730   GOSUB Display
740   LOCAL @Hp5180
750   RETURN
760   !
770 Hispeed:  !
780   OUTPUT @Hp5180;"AD0,LO1,AA1"                           set-up 5180, use
790   OUTPUT @Hp5180;"SA3"                                   Auto-Advance mode
800   Samples=(16384/INT(Length))               determine number of available 5180A records
810   DISP "MEASUREMENT IN PROGRESS"
820   FOR I=1 TO Samples
830      OUTPUT @Hp5180;"MT"                                 High Speed
840      IF BIT(SPOLL(704),3)=0 THEN GOTO 840                Measurement Loop
850      OUTPUT @Hp5359;"DSU"
860   NEXT I
870   FOR I=1 TO Samples
880      DISP "ACQUISITION COMPLETE"
890      OUTPUT @Hp5180;"OS,",I
900      OUTPUT @Hp5180;0,Average
910         FOR J=1 TO Average                               Data Processing Loop
920            ENTER @Hp5180;C
930            Code(I)=Code(I)+C
940         NEXT J
950      Code(I)=Code(I)/Average
960   NEXT I
970   GOTO 730
980   !
990 Display:  !
1000  FOR I=Samples+1 TO Length
1010     IF Samples=Length THEN GOTO 1040                    Fill all extra points in
1020     Code(I)=512                                         5180A record with a baseline
1030  NEXT I
1040  OUTPUT @Hp5180;"JB,",Location             set-up 5180A to accept processed data
1050  FOR I=1 TO Length
1060     OUTPUT @Hp5180;Code(I)                              write data into 5180
1070  NEXT I
1080  OUTPUT @Hp5180;"TL,",Location
1090  RETURN
1100  !
1110 Plot: !
1120  Stay=0
1130  DISP ""
1140  OFF KEY
1150  OFF KNOB
1160  ON KEY 0 LABEL "EXIT" GOTO 100                         Redefine Soft Keys
1170  ON KEY 2 LABEL "CURSOR" GOTO 1890
```

```
1180  ON KEY 4 LABEL "DOT" GOTO 1810    ┐
1190  ON KEY 5 LABEL "PLOT" GOTO 100    ├── Redefine Soft Keys
1200  ON KEY 9 LABEL "LINE" GOTO 1850   ┘
1210  IF Stay=1 THEN GOTO 1210
1220  GCLEAR                            ┐
1230  GRAPHICS ON                       │
1240  VIEWPORT 20,125,20,90             │
1250  WINDOW 0,100,0,100                │
1260  CLIP ON                           │
1270  AXES 20,10,0,0                    │
1280  CLIP OFF                          │
1290  CSIZE 5                           │
1300  MOVE 50,-15                       ├── get axes and
1310  LABEL "TIME (SECONDS)"            │   title on
1320  DEG                               │   9826 display
1330  LDIR 90                           │
1340  MOVE -17,50                       │
1350  LABEL "VOLTAGE"                   │
1360  LDIR 0                            │
1370  CSIZE 3.4                         │
1380  LORG 5                            ┘
1390  OUTPUT @Hp5180;"OI,",Location     ┐── output and read input amplifier
1400  ENTER @Hp5180;C$                  ┘   teach string from 5180A
1410  FOR I=1 TO LEN(C$)
1420     IF C$[I,I]=" " THEN C$[I,I]="+"
1430  NEXT I
1440  Channel=VAL(C$[POS(C$,"ch")+2])   ┐
1450  IF Channel=1 THEN B$="a"          │
1460  IF Channel=2 THEN B$="b"          │
1470  Range=VAL(C$[POS(C$,B$&"r")+2])   ├── Determine 5180A
1480  Offset=VAL(C$[POS(C$,B$&"o")+2])  │   input channel,
1490  IF Channel=4 THEN Range=1         │   range, and offset
1500  IF Channel=4 THEN Offset=0        ┘
1510  Minimum=1023
1520  Maximum=0
1530  FOR I=1 TO Samples                                 ┐   Find data
1540     IF Code(I)>Maximum THEN Maximum=Code(I)         ├── minimum and
1550     IF Code(I)<Minimum THEN Minimum=Code(I)         ┘   maximum
1560  NEXT I
1570  Vmax=Range*(Maximum-512)*.002-Offset  ┐── convert 5180A offset binary code
1580  Vmin=Range*(Minimum-512)*.002-Offset  ┘   to true voltage value
1590  WINDOW 0,R*Samples,Vmin,Vmax
1600  FOR I=1 TO 10                                       ┐
1610     MOVE -.1*R*Samples,Vmin+((Vmax-Vmin)*I/10)       ├── label voltage
1620     LABEL USING "SDD.DD";Vmin+((Vmax-Vmin)*I/10)     ┘   axis values
1630  NEXT I
1640  FOR I=1 TO 5                                        ┐   label time
1650     MOVE R*Samples*I/5,Vmin-.07*(Vmax-Vmin)          ├── axis values
1660     LABEL R*Samples*I/5                              ┘
1670  NEXT I
1680  FOR I=1 TO Samples                                  ┐
1690     IF Connect=1 AND I>1 THEN GOTO 1710              ├── plot the data
1700     MOVE I*R,Range*(Code(I)-512)*.002-Offset         │
1710     DRAW I*R,Range*(Code(I)-512)*.002-Offset         ┘
1720  NEXT I
1730  Stay=1
1740  GOTO 1130
```

```
1750  !
1760 Record: !                                        Determine 5180A record
1770  INPUT "ENTER RECORD LOCATION",Location          location for data storage
1780  RETURN
1790  !
1800 Dot:  !
1810  Connect=0
1820  GOTO 1220                                       Don't connect the data points
1830  !
1840 Connect: !
1850  Connect=1                                       Connect the data points
1860  GOTO 1220
1870  !
1880 Cursor:   !
1890  Mov=INT(Samples/2)
1900  Old=Mov                                         Initialize
1910  CLIP OFF                                        Cursor
1920  CSIZE 6                                         Parameters
1930  GOTO 2040
1940  ON KNOB .04,15 GOTO 1960                        wait for 9826 control
1950  GOTO 1950                                       knob to turn
1960  OFF KNOB
1970  Mov=(KNOBX+Mov)
1980  IF Mov>Samples THEN Mov=Samples                 determine new
1990  IF Mov<1 THEN Mov=1                             cursor position
2000  IF Old=Mov THEN GOTO 1940
2010  PEN -1
2020  MOVE Old*R,Range*(Code(Old)-512)*.002-Offset    erase old cursor
2030  LABEL "*"
2040  PEN 1
2050  Left=INT(Samples/52.5)
2060  IF Left=0 THEN Left=1
2070  FOR I=-Left TO Left
2080     IF Old+I<1 THEN GOTO 2130
2090     IF Old+I>Samples THEN GOTO 2130
2100     IF Connect=1 AND (I>-Left AND Old+I<>1) THEN GOTO 2120   Re-plot data
2110     MOVE (I+Old)*R,Range*(Code(I+Old)-512)*.002-Offset        destroyed
2120     DRAW (I+Old)*R,Range*(Code(I+Old)-512)*.002-Offset        by cursor
2130  NEXT I                                                       erase
2140  MOVE Old*R,Range*(Code(Old)-512)*.002-Offset
2150  DRAW Old*R,Range*(Code(Old)-512)*.002-Offset
2160  MOVE Mov*R,Range*(Code(Mov)-512)*.002-Offset
2170  ON KEY 2 LABEL " TIME" GOTO 2170                Put cursor information
2180  ON KEY 3 LABEL "VOLTAGE" GOTO 2180              in Soft Key label area
2190  ON KEY 7 LABEL VAL$(Mov*R) GOSUB Return
2200  ON KEY 8 LABEL VAL$(Range*(Code(Mov)-512)*.002-Offset) GOSUB Return
2210  LABEL "*"                                       draw the cursor
2220  Old=Mov                                         save cursor position
2230  GOTO 1940
2240 Return:  RETURN
2250  END
```

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