Application Note 313-7

Interconnecting Two or More 5180A Waveform Recorders to Obtain Multiple Input Channels

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INTRODUCTION

Many applications for waveform recorders require simultaneous sampling of two or more waveforms. For example, an electrical stimulus and the response to this stimulus may need to be recorded at the same time. In application areas such as explosive or structural testing, several output signals may occur simultaneously; in these cases, several signals must be sampled synchronously and recorded. To meet the need for recording more than one waveform at the same time, it's possible to interconnect two (or more) 5180A Waveform Recorders to obtain multiple input channels, each of which will sample an incoming waveform at a maximum 20 MHz rate. There are several ways of setting up for synchronous sampling, depending on how close in time samples must be.

These methods use various interconnections to provide timebase and triggering signals to the 5180As. Since both timebases and trigger points affect sample timing, both must be adjusted to obtain "simultaneous" samples with a known amount of time error.

Timebase Considerations

To insure that samples will be taken at the same frequency by two or more 5180As, the 5180A timebases must be locked together. However, there may be a time offset between the sample times of the 5180As, as shown in Figure 1. This note includes several equipment setups for synchronizing timebases, describes a method for reducing the time offset between simultaneous samples, and provides a technique for measuring how closely two 5180As are synchronized.

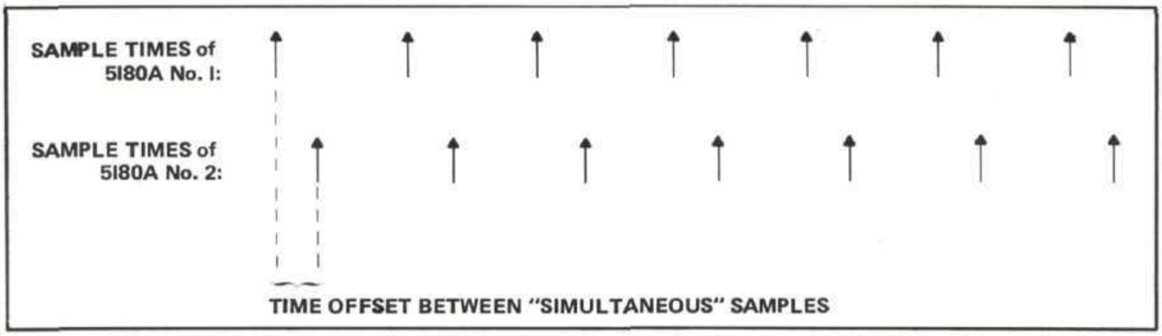

Figure 1. Synchronized 5180As sample at same rate, but there may be a time offset between "simultaneous" samples.

Triggering Considerations

The trigger location in each 5180A also affects how accurate sampling will be. If both 5180As recognize the trigger during the same sample interval (Figure 2A), the samples will be as close together in time as the timebase offset allows. If, on the other hand, the 5180As receive the trigger during different sample intervals (Figure 2B), there are two possibilities: 1) the time difference is known, and may be corrected for by shifting one 5180A's recorded data by a known number of samples; 2) the time difference is unknown or variable, and cannot be corrected for.

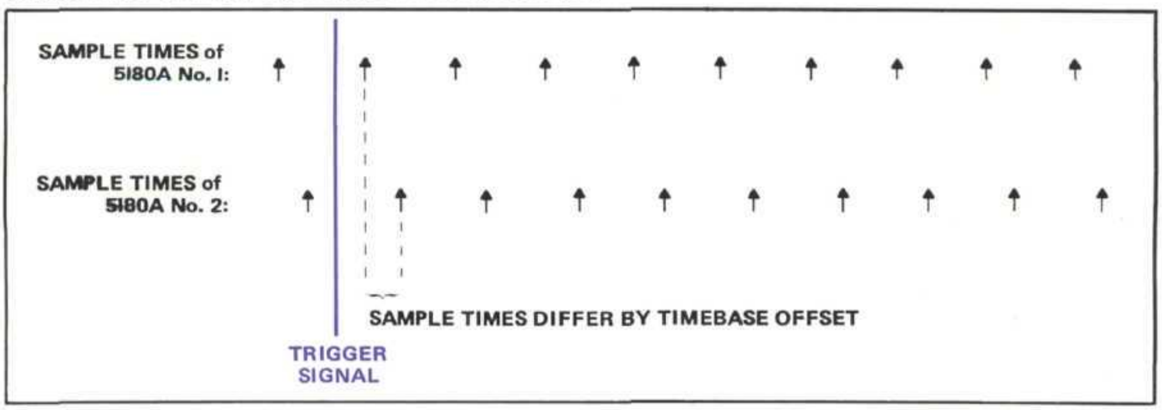

Figure 2A. 5180As recognize trigger during same sample interval; sample times differ by timebase offset.

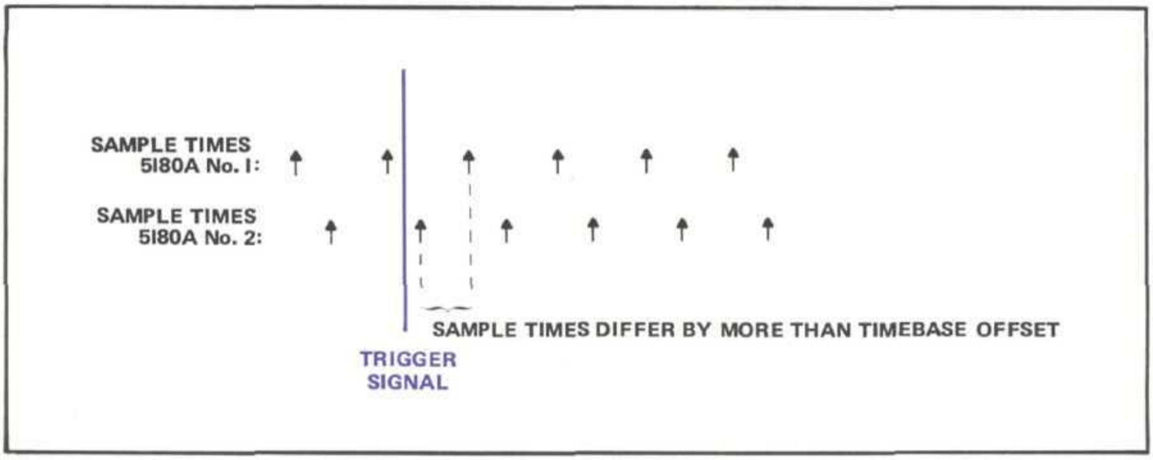

Figure 2B. 5180As recognize trigger during different sample intervals; time difference may be greater than timebase offset.

The likelihood of these possible outcomes depends on the triggering method used. The effectiveness of various triggering methods is described in the section entitled "Triggering Methods", beginning on page 7; a technique for measuring time difference between trigger points in two 5180As is provided in software. (See Program #3, page 17.)

Organization of this Note

This application note will discuss timebase synchronization first, then will describe triggering methods. Also, several programs are provided for system testing using BASIC on the HP 9826 Computer System. These include:

Program #1: Phase Setup for Testing Timebase Synchronization

Program #1 adjusts the phase of a test sinewave (which is synchronized with a 5180A timebase), so that the 5180A will sample the sinewave at the rising edge zero-crossing. Program #1A should be selected when sampling is at the rate of the internal or external timebase. If sampling is at a rate less than that of the timebase, a "sync" signal must be used. An appropriate signal is incorporated into Program #1B, where an HP 8112A Programmable Pulse Generator is added.

Program #2: Time Difference Between Samples

Program #2 compares voltage values of "simultaneous" samples, and calculates the average time difference between these samples. RMS time error is also calculated, to give a measure of consistency of the average time difference.

Program #3: Testing for Consistency of Triggering in two Synchronized 5180As

This routine tests how close in time the trigger occurs in two 5180As; when the timebases are synchronized and the first 5180A provides a trigger signal to the next, trigger delay is normally one sample interval.

TIMEBASE SYNCHRONIZATION

Approximate Timebase Synchronization Requiring Least Equipment

Two 5180As may be synchronized to sample incoming waveforms (and perform A/D conversions) approximately 20 ns apart, by simply interconnecting them with a 6 to 12 inch 50 Ω coax cable. To synchronize the 5180A timebases for this sampling method, the setup shown in Figure 3A should be used. This method may be easily extended to three 5180As, since each 5180A timebase output will drive up to two 5180A timebase inputs. (See Figure 3B).

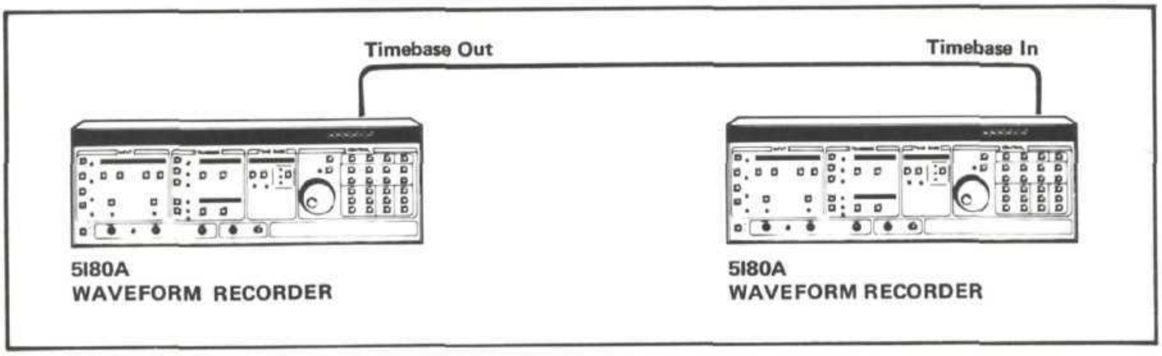

Figure 3A. First 5180A timebase output drives second 5180A timebase input.

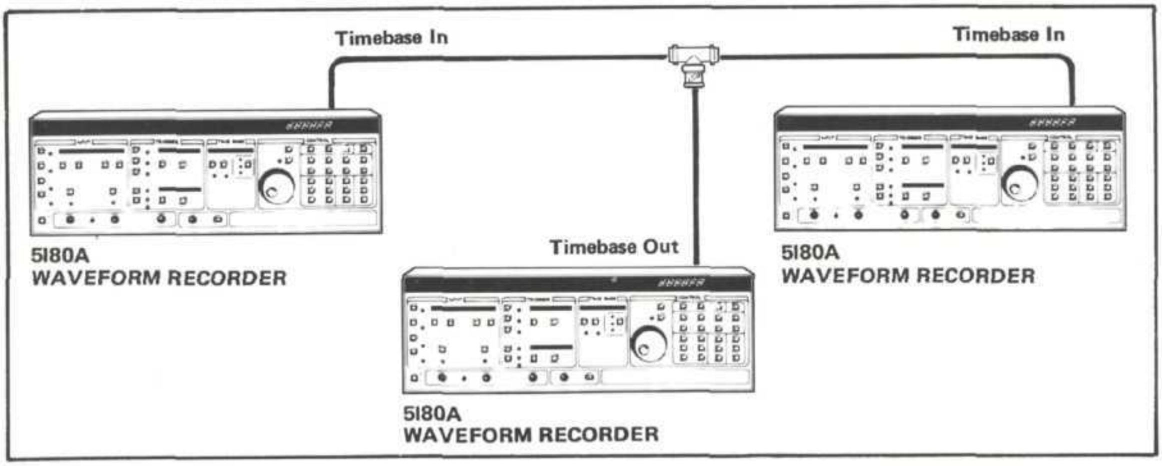

Figure 3B. One 5180A timebase output will drive two 5180A timebase inputs.

An alternative setup may be used for three or more 5180As. (See Figure 4). This method incurs a delay of about 20 ns for each successive 5180A. Consequently, the second 5180A in the series will sample 20 ns later than the first, the third will sample 40 ns later than the first, etc.

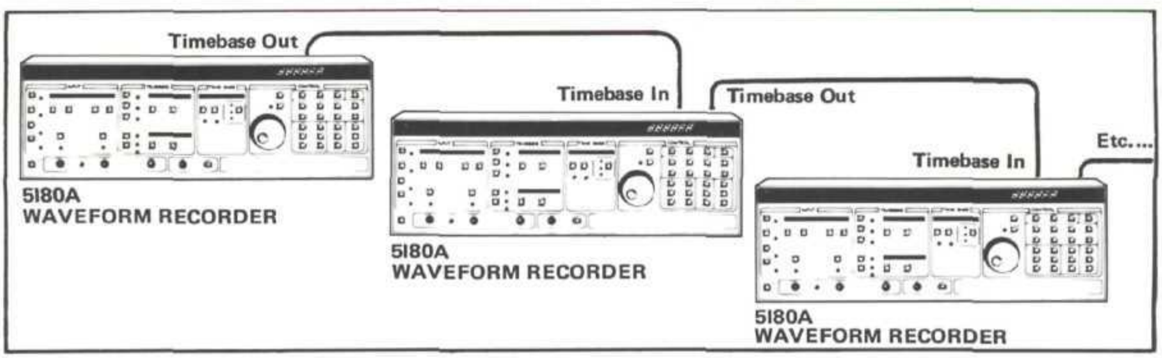

Figure 4. Three or more 5180As may receive timebase inputs in series, with a 20 ns delay for each successive 5180A.

Improving on the Approximate Timebase Synchronization

The method described for approximate synchronization may be noticeably improved by adding 50 Ω coax cable length to the permanent measurement setup. By increasing the length of cable interconnecting the two 5180A timebases, the second 5180A timebase may be delayed until it is again in phase with the first 5180A timebase, reducing the time error considerably. (See Figure 5).

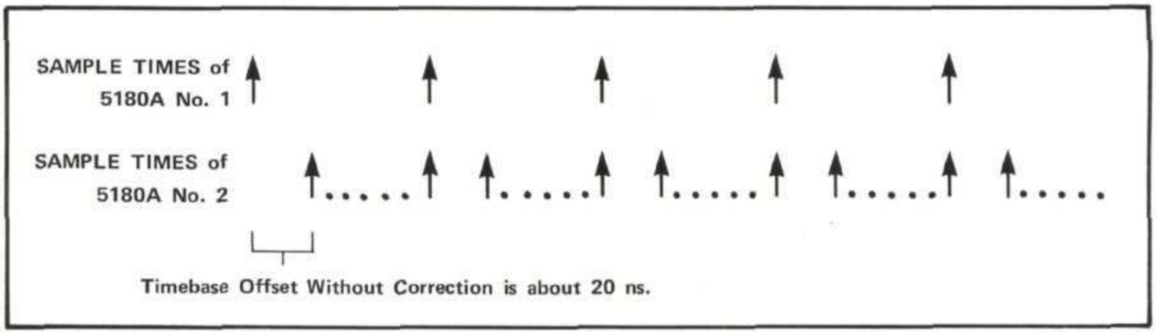

Figure 5. By delaying the second 5180A timebase an additional 30 ns, the timebase offset may be considerably reduced.

The equipment setup and software described later in this note may be used to test timebase synchronization following each cable adjustment. Program #1 aligns the phase of the test sinewave so that the first 5180A samples the sinewave on the rising edge at the 0 volt level. If a minimum-length cable is used to interconnect the 5180A timebases, the second 5180A will sample the input sinewave about 20 ns later, near 0 volts on the falling edge. (See Figure 6). Increasing the cable length in one- or two-foot increments will cause the second 5180A to sample at more negative voltage levels on the falling edge of the test sinewave, then to sample at less negative voltages on the rising edge of the sinewave. When the cable is long enough, samples will occur at 0 volts on the rising edge of the test sinewave. Each foot of cable adds about 1.5 ns delay, so approximately 20 feet of cable are required for this adjustment. After the cable length has been adjusted, the external timebase and test signal synthesizer are no longer needed.

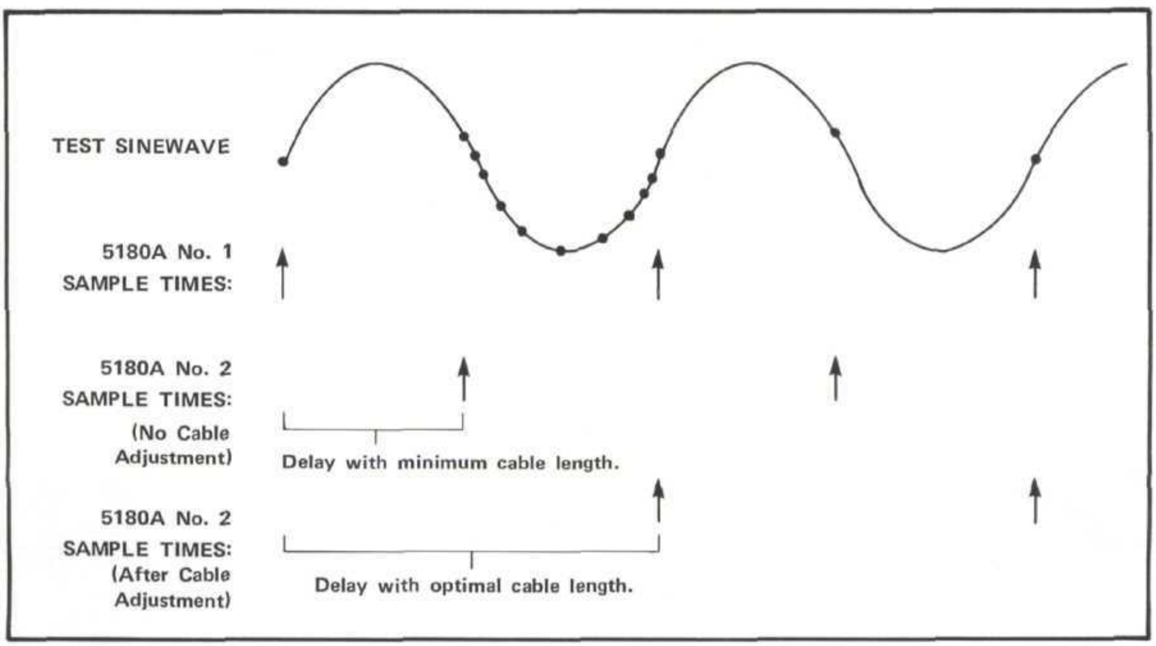

Figure 6. As the second 5180A timebase is delayed by increasing cable length between the first and second 5180A, voltage samples taken by the second 5180A will decrease to about -1.0 volt, then increase to 0 volts again.

Precise Timebase Synchronization Requiring More Equipment

For excellent synchronization of two 5180As with minimal setup effort, an HP 3325A, HP 3335A, or similar frequency synthesizer may be used to provide an external timebase signal. The synthesizer output should be set for maximum voltage output, then divided using a power splitter such as the HP 11667A or HP 11652-60009. The resulting timebase signals should then be sent (using matched 50 Ω coax cables) to the two 5180A timebase inputs. (See Figure 7). This method of synchronizing 5180A timebases may be extended to three or four 5180As, by adding power splitters as shown in Figures 8A and 8B.

Using a frequency synthesizer to provide external timebase signals in this manner allows 5180A sample times to be synchronized within about 300 ps. A technique for measuring how closely the timebases are synchronized is provided in Program #2.

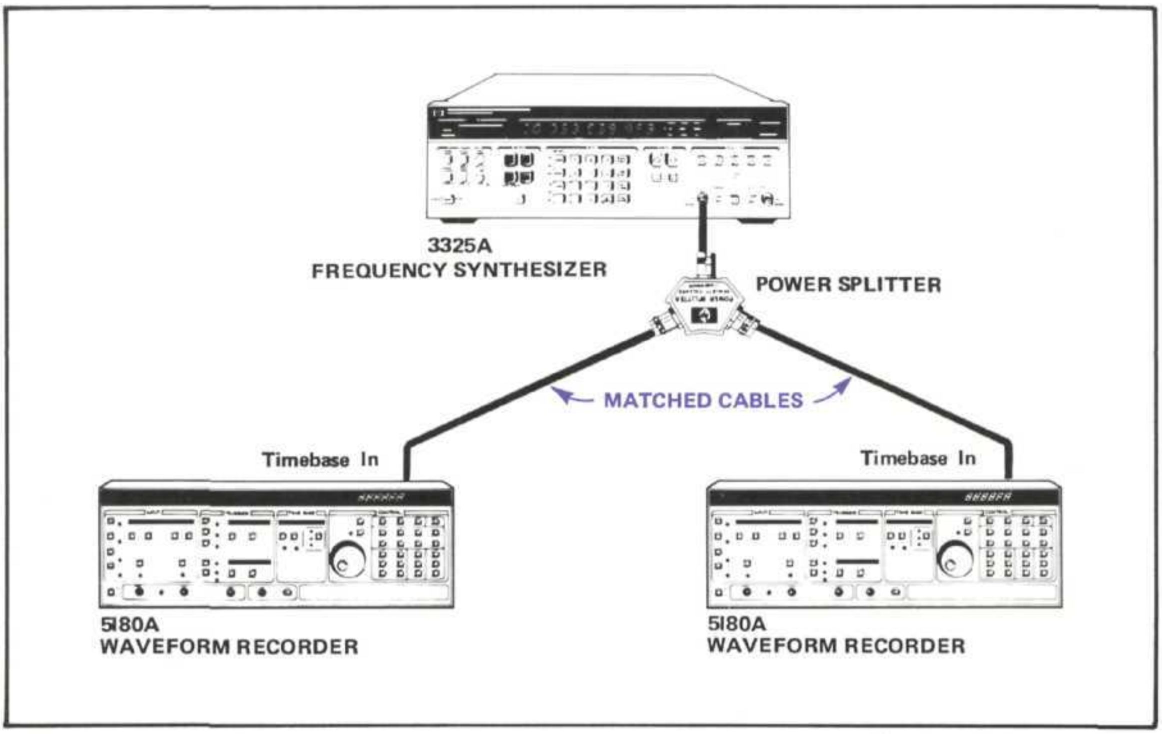

Figure 7. A frequency synthesizer such as the HP 3325A may be used to provide a precise timebase for two 5180As.

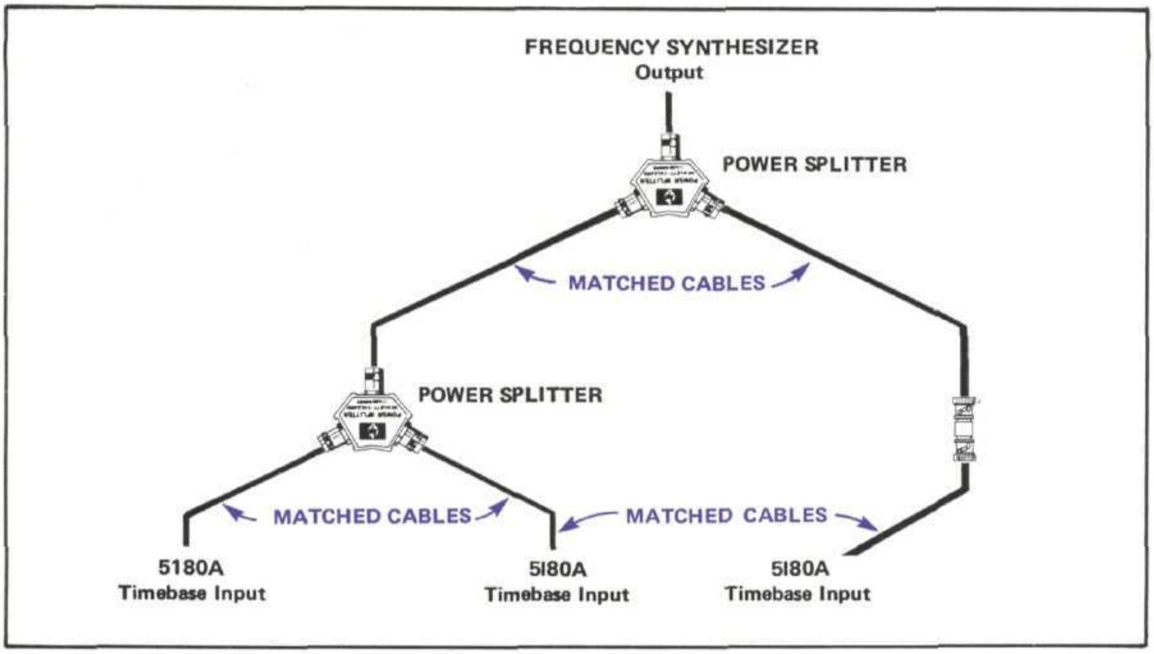

Figure 8A. Use two power splitters when a frequency synthesizer provides timebase for three 5180As.

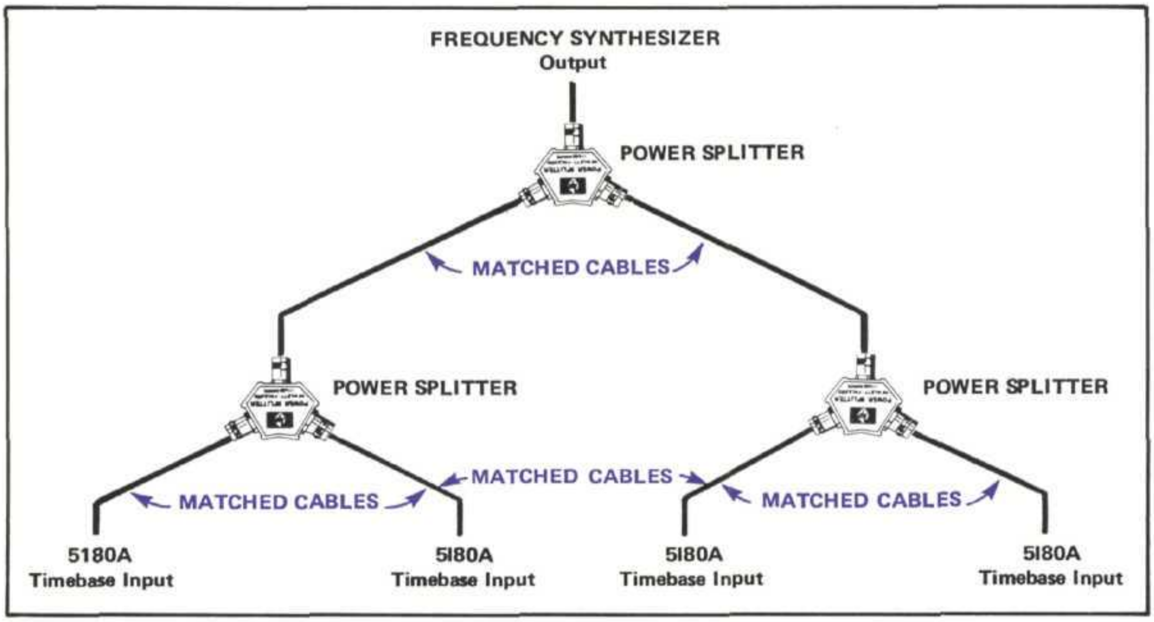

Figure 8B. A frequency synthesizer such as the HP 3325A will drive as many as four 5180As simultaneously by using three power splitters.

TRIGGERING METHODS

First 5180A Provides External Trigger Signal to Subsequent 5180As

The best way of triggering two synchronized 5180As is to trigger the first 5180A internally (based on the input waveform). The trigger output from this 5180A should then be used to trigger the next 5180A. (See Figure 9). Note that a 50 ohm feed-through (HP Part #10100C) must be used on the 5180A external trigger input when a 50 ohm signal (such as the 5180A trigger output) is used to provide a trigger. In addition, triggering conditions should be set for rising slope, and -0.3 volt trigger level. This setup may be extended for more than two 5180As; the trigger output from each 5180A may be used to trigger the next 5180A. When this method is used, there is normally a one sample interval delay between the trigger point in the first 5180A and that in the next 5180A.

A one sample interval delay between two trigger points may be corrected for by shifting the stored data one sample point. This shifting may be performed automatically, in advance, by selecting an absolute location as a trigger position; the 5180A with the earlier trigger should be assigned to trigger at position X, and the 5180A with the later trigger assigned to trigger at position X-1. For example, the 5180A receiving the earlier trigger may be assigned to trigger at location 0 by sending the command "PA0". The other 5180A should then be assigned to trigger at location -1 by sending the command "PA-1". This correction is possible only when a controller is used to remotely program the 5180A.

If the first 5180A is triggered externally, instead of internally, there is normally a one sample interval delay between the trigger point in the first 5180A and that in the second 5180A. However, there may occasionally be a one sample interval ambiguity in the second 5180A's trigger location. The probability of this ambiguity occurring may be determined by running Program #3 many times using the external trigger signal under test, and measuring how often the trigger points differ by more or less than one sample interval.

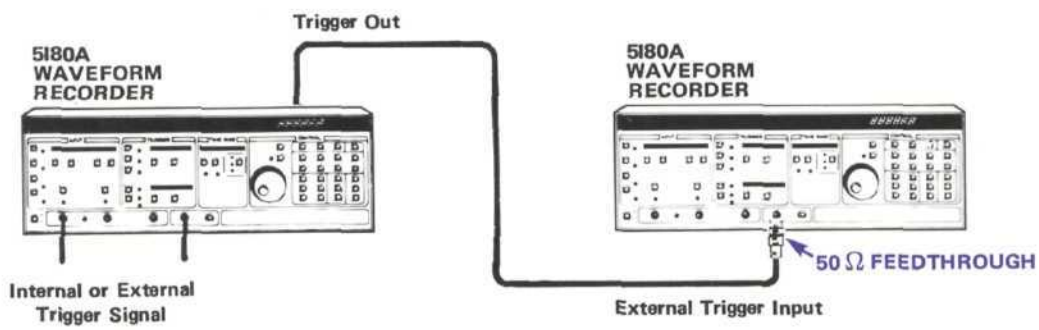

Figure 9. Trigger output from first 5180A provides external trigger signal to second 5180A.

All 5180As Receive Same External Trigger Signal

Another way of triggering synchronized 5180As is to connect the same signal to all external trigger inputs, and select the same triggering conditions. (See Figure 10). This will usually cause the 5180As to trigger during the same sample interval. However, there may occasionally be a one sample interval difference, if the trigger point is near the edge of a sample interval.

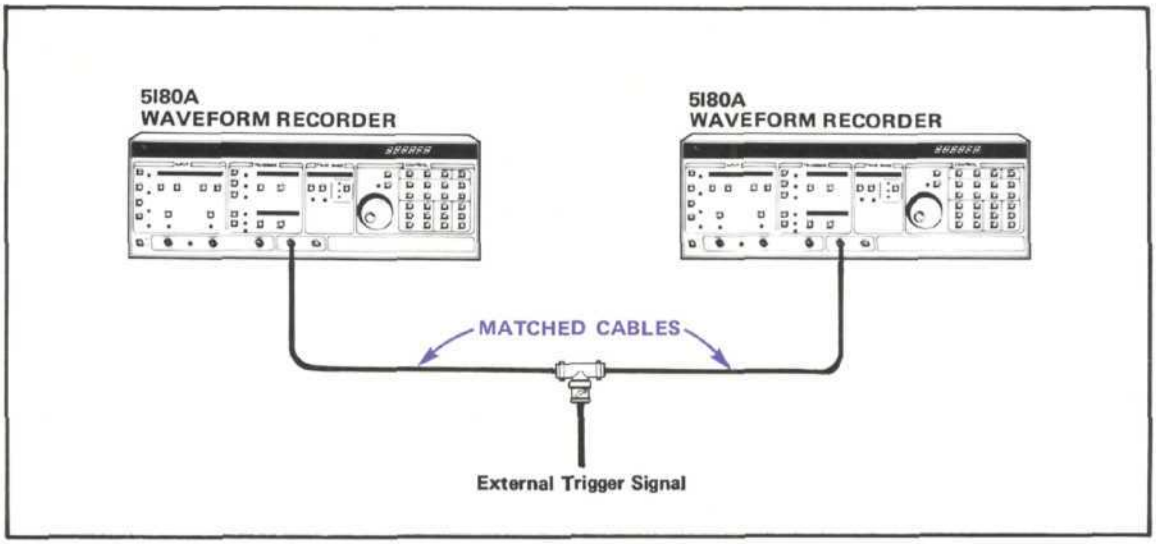

Figure 10. Two synchronized 5180As may be set for the same trigger conditions and triggered based on the same external trigger signal.

Additional Considerations If Sampling Rate is Less Than Timebase Rate

When two or more 5180A timebases are locked together and the time offset is acceptable, the two will sample synchronously if both are set to sample at the internal timebase rate (20 MHz) or at the rate of a shared external timebase (1 to 20 MHz). In this case, the selected sampling rate is the same as the timebase rate and the two 5180As will necessarily store simultaneous samples into memory. However, if a sampling rate less than the timebase rate is selected, the 5180As will continue to digitize the incoming waveform at the timebase rate, but will select 1 of N output samples from the A/D converter to store in memory, where N depends on the selected sampling rate. If, for example, the (internal or external) timebase is 20 MHz, and the selected sampling rate is 10 MHz, then each 5180A must select 1 of 2 samples from the A/D converter to store in memory. Setting both 5180As for the same sampling rate causes them to select the same "division factor", N, but does not ensure that they will record the same 1 of N samples. To ensure that the 5180As will select samples which are simultaneous (see Figure 11), a "sync" pulse must be sent to all 5180As simultaneously before beginning to make measurements. The sync pulse should be a single pulse, with a minimum width of at least 10 times the sample time. In the example above, where the sampling rate is 10 MHz, the sample interval is 100 ns, so the minimum sync pulse width is 1 μs.

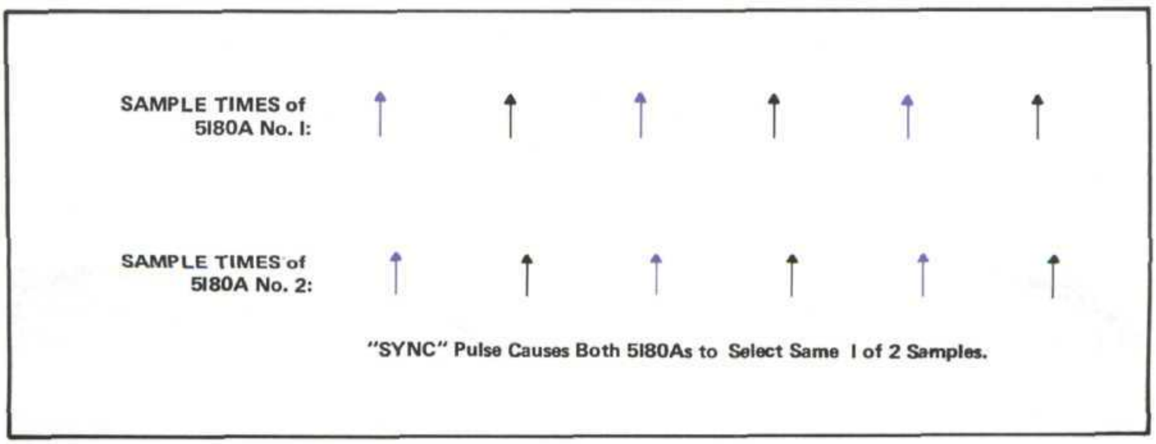

Figure 11. Use "sync" pulse to cause both 5180As to select same 1 of N samples, when sampling rate is less than timebase rate. Samples indicated in color are stored in the 5180A memory.

SYSTEM SETUP FOR TESTING

Begin by setting up the equipment to provide timebases and trigger signals in the selected manner. The software provided will test timebase synchronization and trigger time difference for two 5180As, which should be set for HP-IB addresses 704 and 705. If more than two 5180As are synchronized, the first may be set to address 704 and compared to the others one-at-a-time.

For system testing, a frequency synthesizer such as the HP 3325A or HP 3335A is required. (The software following is written for an HP 3325A with HP-IB address 717.) Set the test signal frequency synthesizer for a 1 volt range and the same frequency as the selected sampling rate. When a sampling rate less than the timebase rate is used, the test frequency should still be the same as the sampling rate. In addition, if a sampling rate lower than the timebase rate is needed, a pulse generator such as the HP 8112A must be used to synchronize the 5180As, as described previously. The pulse generator should be connected into the system as shown in Figure 12. (The software is written for an HP 8112A with address 712.)

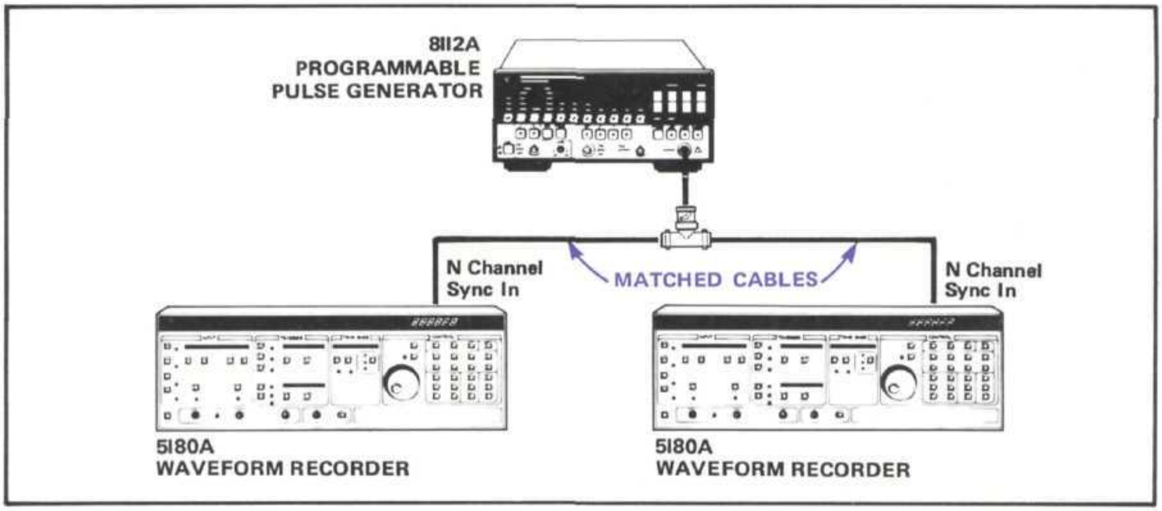

Figure 12. A sync pulse input is needed to synchronize two 5180As when the sampling rate is less than the timebase rate.

Test Setup When One 5180A Provides Timebase to the Next 5180A

The 5180As and test synthesizer must be synchronized for system testing. There are two possible ways of doing this, when one 5180A is providing a timebase for the next 5180A. One method requires no additional equipment beyond the test synthesizer, and allows timebase synchronization for a 10 MHz timebase only. This means that the cable length may be tested and adjusted for optimal timebase synchronization at 10 MHz. The equipment setup for this test is shown in Figure 13.

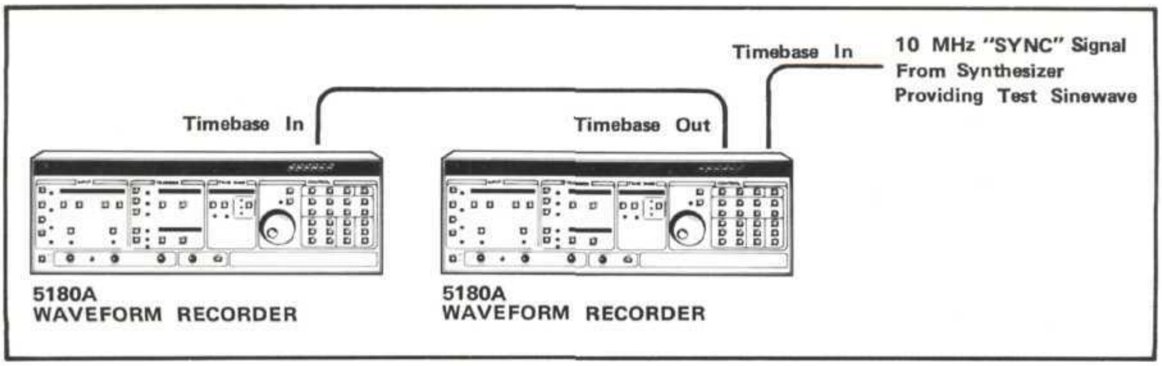

Figure 13. To save equipment, the "sync" output signal from the synthesizer providing the test sinewave may be used as a 10 MHz timebase for the 5180A.

An alternative equipment setup which will allow timebase synchronization testing for all timebase rates from 1 to 20 MHz is shown in Figure 14. This method requires an additional frequency synthesizer to drive the first 5180A timebase, so that the timebase rate is selectable. Synchronizing the test signal and the 5180A timebase is accomplished by connecting the timebase input from the 5180A timebase synthesizer to the timebase input on the test signal synthesizer.

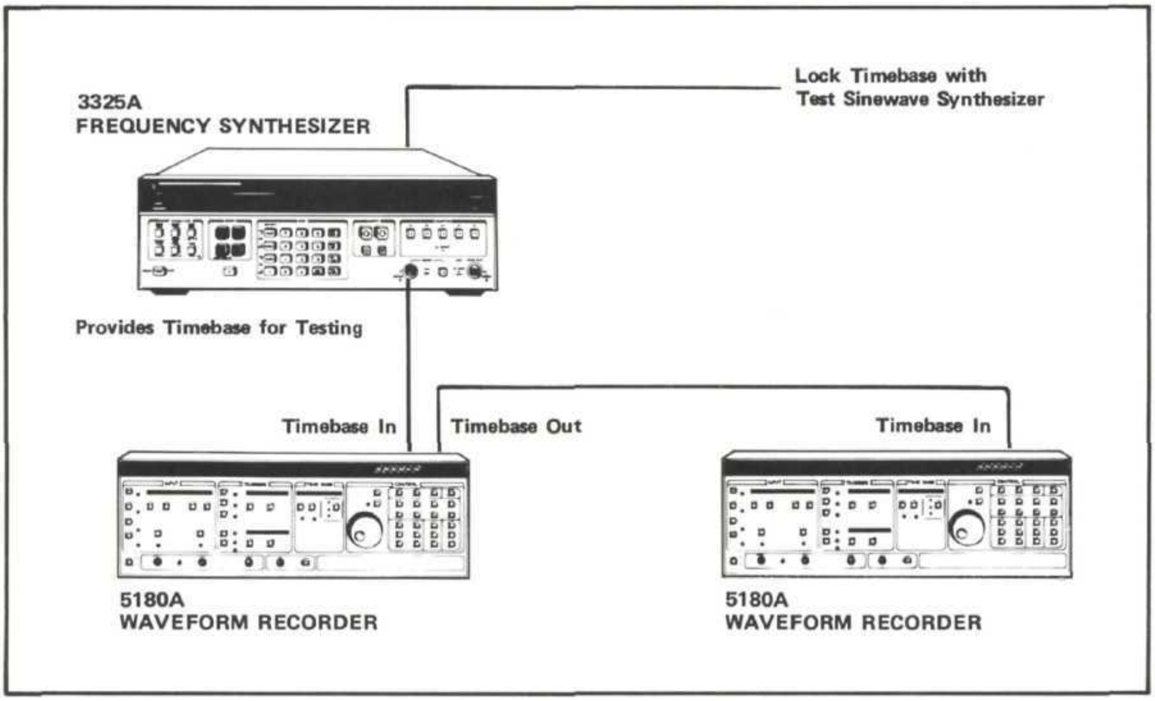

Figure 14. An additional frequency synthesizer may be used to allow testing of synchronization at any frequency between 1 and 20 MHz.

Test Setup When Both 5180As Receive Timebase from Synthesizer

When both 5180A timebases are driven by an external synthesizer, the timebase output from the synthesizer providing the 5180A timebases should be connected to the timebase input on the synthesizer providing the test signal.

If this setup is used, the synthesizer providing the 5180A timebases may be set for any frequency from 1 to 20 MHz; the maximum available voltage range should also be selected. When a 5180A receives a sinewave signal (without DC offset) as a timebase input, external timebase should be selected on the 5180A back panel, and the back panel timebase level switch should be set for position "3".

When one 5180A provides the timebase for a second 5180A, the back panel switch on the second 5180A should be set for external timebase, and the back panel timebase level selector should be in position "2".

SYSTEM TESTING SOFTWARE: DESCRIPTION AND USE

An HP-IB compatible printer may be used with these test programs to record outputs from the 9826. If, for example, a printer with HP-IB address 701 is used, the command "PRINTER IS 701" should be executed before the test programs are run.

Program lines which require user input or which print output values are shown in color for easy reference.

Program #1A: Phase Setup for Testing Timebase Synchronization at the Timebase Sampling Rate

After the test frequency synthesizer is set up as shown in Figure 15, it's necessary to adjust the phase of the test signal until sampling occurs at the rising edge zero-crossing of the signal. This program iteratively adjusts the phase of the test signal until the best possible sampling position is located. If a frequency synthesizer other than the HP 3325A is used, some program codes need to be changed.

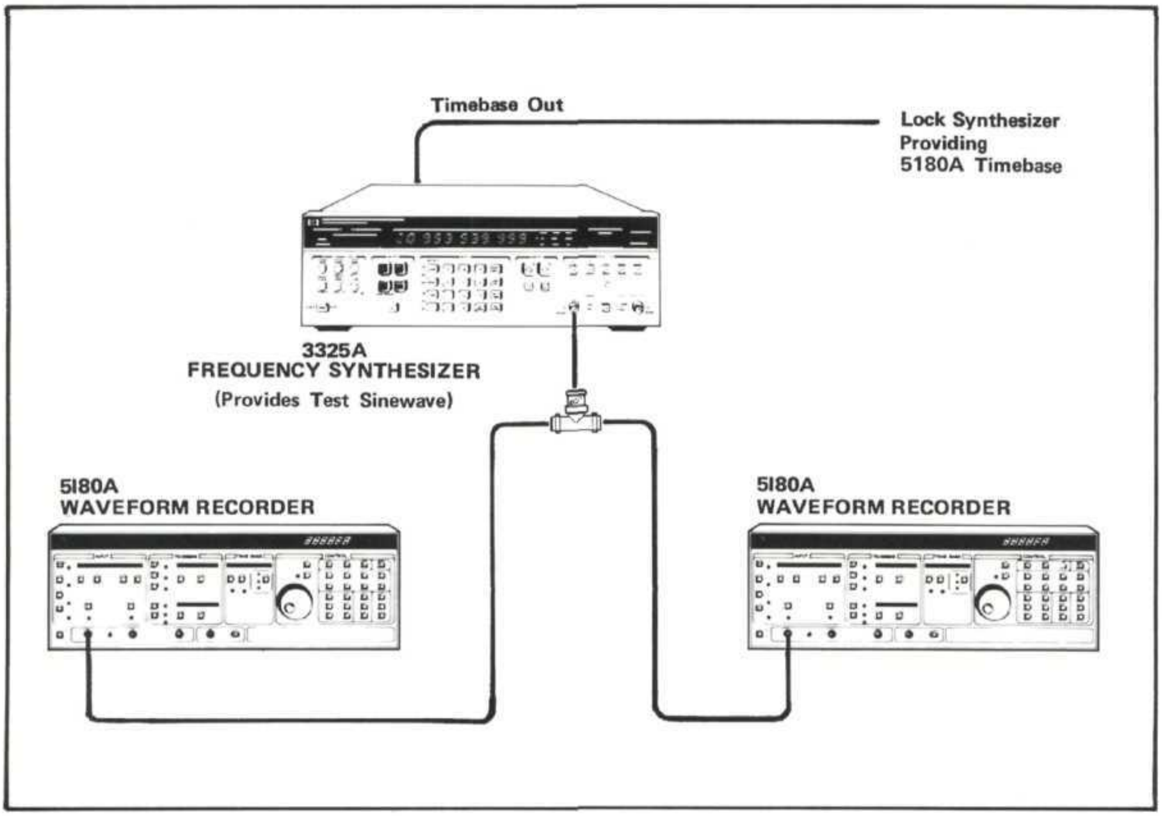

Figure 15. Connect the frequency synthesizer providing the test sinewave as shown. Lock the timebase of test signal synthesizer to the 5180A, either by connecting to the synthesizer providing the 5180A timebase, or to the 5180A directly, if no synthesizer is used.

Program #1A: Phase Setup for Testing Timebase Synchronization at the Timebase Sampling Rate

```
10     !PROGRAM #1A      10.28.82
20     DIM A$[28]
30     !PROGRAM ASSUMES 5180S IN SYNC; ADJUSTS PHASE FOR #704
40     REMOTE 704 !5180 IS #704
50     REMOTE 717 !FREQ SYNTHESIZER IS #717
60     OUTPUT 704;"PR,AR1,SA1,PP0,LP0"
70     OUTPUT 704;"SE1,TE1,CU512,CV1"
80     P1=0
90     OUTPUT 717;"PH0.0DE"
100    GOSUB Calc
110    !IF SAMPLES ARE NEAR 0V, PHASE IS ACCEPTABLE
120    IF ABS(V1)<=.006 THEN GOTO 380
130    !IF SAMPLES ARE NOT NEAR 0V, CHANGE PHASE ACCORDINGLY
140    IF V1>.006 THEN A1=1
150    IF V1<-.006 THEN A1=-1
160    !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN 10 DEG STEPS
170    P1=P1+10*A1
180    OUTPUT 717;"PH",P1,"DE"
190    GOSUB Calc
200    IF ABS(V1)<=.006 THEN GOTO 380
210    A2=V1/ABS(V1)
220    IF A1<>A2 THEN GOTO 240
230    GOTO 170
240    !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN 1 DEG STEPS
250    P1=P1-A1
260    OUTPUT 717;"PH",P1,"DE"
270    GOSUB Calc
280    IF ABS(V1)<=.006 THEN GOTO 380
290    A3=V1/ABS(V1)
300    IF A1=A3 THEN GOTO 320
310    GOTO 250
320    !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN .1 DEG STEPS
330    P1=P1+(.1*A1)
340    OUTPUT 717;"PH",P1,"DE"
350    GOSUB Calc
360    IF ABS(V1)<=.006 THEN GOTO 380
370    GOTO 320
380    DISP "P1=";P1 !P1 IS SELECTED PHASE
390    GOTO 510
400 Calc:!
410    OUTPUT 704;"SA4"
420    WAIT 1
430    OUTPUT 704;"MT"
440    OUTPUT 704;"OG"
450    ENTER 704;A$
460    P=POS(A$,"d2")+2
470    IF A$[P+8;1]=" " THEN A$[P+8;1]="+"
480    V1=VAL(A$[P])
490    DISP "V1=";V1
500    RETURN
510    END
```

Program #1B: Phase Setup for Testing Timebase Synchronization at Sampling Rates below the Timebase Rate

This program (following page) should be used instead of Program #1A to adjust the phase of the input sinewave, when sampling is at a lower rate than the timebase rate. Adjusting the phase of the frequency synthesizer is slightly more complicated when the sampling rate is less than the 5180A timebase rate. This is because the 5180A continues to digitize the incoming waveform at the timebase rate, but then selects 1 of N outputs from the A/D converter to store in memory, as described on page 8.

A sync pulse is sent automatically, if this program is used and the sync pulse is provided by an 8112A Programmable Pulse Generator. Following the sync pulse, the program automatically adjusts the phase of the input signal so that sampling occurs at the rising edge zero-crossing of the signal. Otherwise,this program is similar to Program #1A.

Program #1B: Phase Setup for Testing Timebase Synchronization at Sampling Rates Below the Timebase Rate

```
10    !PROGRAM #1B     10.28.82
20    ASSIGN @Adc TO 704,705 !PROGRAM ASSUMES TEST OF TWO 5180S
30    REMOTE @Adc !ASSIGNS BOTH 5180S TO REMOTE OPERATION
40    REMOTE 712
50    REMOTE 717
60    DIM A$[28]
70    OUTPUT @Adc;"PR,AR1,SA1,PP0,LP0,SE1,TE1,CU512,CV1" !SET UP BOTH 5180S
80    INPUT "FREQUENCY OF TEST SINEWAVE IN MHZ?",S1
90    PRINT "TEST FREQUENCY =";S1;"MHZ"
100   M1=1/(S1*1000000)
110   OUTPUT @Adc;"MM",M1
120   DISP "INPUT SINEWAVE TO 5180S"
130   WAIT 1 !NOW SET UP 712 FOR 10V PULSE
140   OUTPUT 712;"M2,T1,PER1MS,DEL65NS,W1,HIL10.0V,LOL0V,L0,C0,D0"
150   M2=1.E+7*M1
160   OUTPUT 712;"WID",M2,"US" !SELECT PULSE WIDTH= 10X SAMPLE INTERVAL
170   WAIT 1
180   TRIGGER 712 !SEND SYNC PULSE TO 5180S
190   P1=0
200   !BEGIN PHASE ADJUSTMENT ROUTINE
210   OUTPUT 717;"PH0.0DE"
220   GOSUB Calc
230   !IF SAMPLES ARE NEAR 0V,PHASE IS ACCEPTABLE
240   IF ABS(V1)<=.006 THEN GOTO 490
250   !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN 10 DEG STEPS
260   IF V1>.006 THEN C1=1
270   IF V1<-.006 THEN C1=-1
280   P1=P1+10*C1
290   OUTPUT 717;"PH",P1,"DE"
300   GOSUB Calc
310   IF ABS(V1)<=.006 THEN GOTO 490
320   C2=V1/ABS(V1)
330   IF C1<>C2 THEN GOTO 350
340   GOTO 280
350   !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN 1 DEG STEPS
360   P1=P1-C1
370   OUTPUT 717;"PH",P1,"DE"
380   GOSUB Calc
390   IF ABS(V1)<=.006 THEN GOTO 490
400   C3=V1/ABS(V1)
410   IF C1=C3 THEN GOTO 430
420   GOTO 360
430   !IF SAMPLES NOT NEAR 0V, ADJUST PHASE IN .1 DEG STEPS
440   P1=P1+.1*C1
450   OUTPUT 717;"PH";P1;"DE"
460   GOSUB Calc
470   IF ABS(V1)<=.006 THEN GOTO 490
480   GOTO 430
490   DISP "P1=";P1 !P1 IS SELECTED PHASE
500   GOTO 610
510 Calc: !FINDS VOLTAGE LEVEL OF SAMPLES
520   OUTPUT @Adc;"SA4"
530   WAIT 1
540   OUTPUT @Adc;"MT"
550   OUTPUT 704;"OG"
560   ENTER 704;A$
570   P=POS(A$,"d2")+2
580   IF A$[P+8;1]=" " THEN A$[P+8;1]="+"
590   V1=VAL(A$[P])
600   RETURN
610   END
```

Program #2: Time Difference Measurement Between Samples From Two 5180As

After setting up the equipment and running the first two programs, this program (following page) will test how closely two 5180As are synchronized. The 5180As' sampling rates and the frequency of the input sinewave should be the same, as in Program #1. This program takes 1024 voltage samples from each 5180A, and determines the average voltage difference. Since Program #1 adjusts the input sinewave phase so that sampling occurs at the 0 volt level, and the slew rate of the sinewave is known at this point, the average time difference between "simultaneous" samples may be calculated.

The recorded results from two 5180As simultaneously sampling a 20 MHz sinewave at the rising edge zero-crossing are shown superimposed in Figure 16. The two 5180As are synchronized to within 200ps, so the voltage levels of samples from the two 5180As are indistinguishable in the plot.

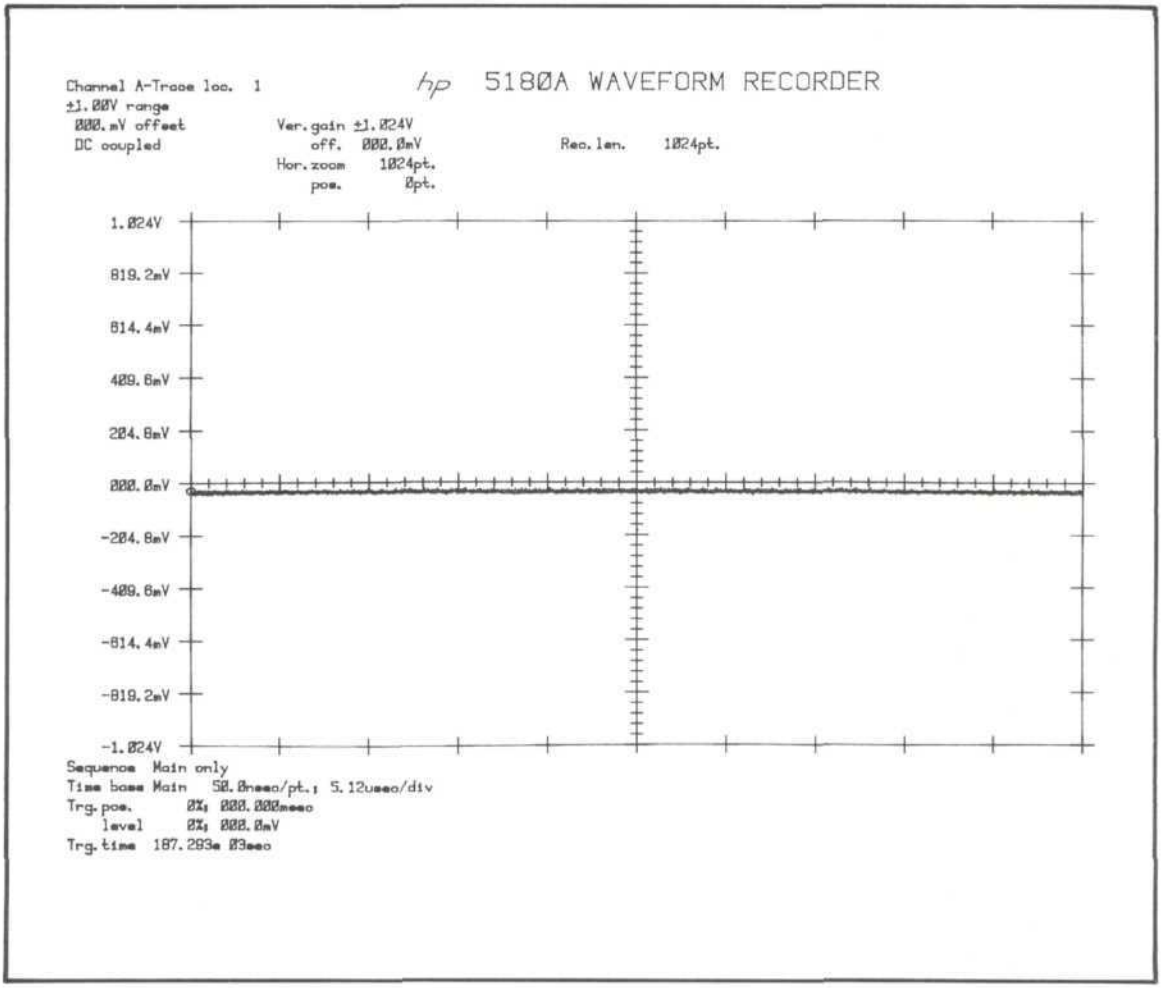

Figure 16. Superimposed plots show samples taken simultaneously by two synchronized 5180As.

Program #2: Time Difference Measurement Between Samples from Two 5180As

```
10    !PROGRAM #2    10.28.82
20    ASSIGN @Adc TO 704,705 !PROGRAM ASSUMES TEST OF TWO 5180S
30    REMOTE @Adc
40    OUTPUT @Adc;"PR,AR1,SA1,PP0,LP0,SE1,TE1"
50    INPUT "FREQUENCY OF TEST SINEWAVE IN MHZ?",S1
60    PRINT "TEST FREQUENCY =";S1;"MHZ"
70    WAIT 1
80    OUTPUT @Adc;"SA4"
90    WAIT 1
100   OUTPUT @Adc;"MT"
110   REAL A(1024),B(1024),C(1024)
120   OUTPUT 704;"BB1"
130   FOR J=0 TO 1023
140   ENTER 704 USING "#,B";A1
150   ENTER 704 USING "#,B";B1
160   A(J)=A1*32+B1/8
170   A(J)=((A(J)-512)*.002)
180   NEXT J
190   !A(J) CONTAINS VOLTAGE SAMPLE VALUES FROM 5180 #704
200   OUTPUT 705;"BB1"
210   FOR J=0 TO 1023
220   ENTER 705 USING "#,B";A1
230   ENTER 705 USING "#,B";B1
240   B(J)=A1*32+B1/8
250   B(J)=((B(J)-512)*.002)
260   NEXT J
270   !B(J) CONTAINS VOLTAGE SAMPLE VALUES FROM 5180 #705
280   !THE FOLLOWING ROUTINE COMPARES SAMPLES FROM 5180 #704 AND 5180 #705
290   A1=0
300   A2=0
310   FOR J=0 TO 1023
320   A1=A1+A(J)/1024
330   A2=A2+B(J)/1024
340   NEXT J
350   A1=DROUND(A1,3)
360   A2=DROUND(A2,3)
370   PRINT "A1=";A1;"VOLTS";" A2=";A2;"VOLTS"
380   D1=A2-A1 !D1=AVERAGE VOLTAGE DIFFERENCE BETWEEN #705 AND #704 DATA
390   E1=0
400   FOR J=0 TO 1023
410   C(J)=B(J)-D1-A(J)
420   E1=E1+C(J)^2
430   NEXT J
440   E1=(E1/1024)^.5
450   E1=DROUND(E1,3) !E1 IS RMS ERROR LEFT AFTER TAKING OUT D1 DIFFERENCE
460   PRINT "DELAY DIFFERENCE =";D1;"VOLTS"
470   PRINT "RMS NOISE ERROR =";E1;"VOLTS"
480   !THE FOLLOWING ROUTINE CALCULATES TIME DIFFERENCE BASED ON D1 VALUE
490   T1=D1/(2*PI*S1*1000000)
500   T1=DROUND(T1,3) !T1 IS AVERAGE TIME DELAY BETWEEN #704 AND #705 SAMPLES
510   T2=E1/(2*PI*S1*1000000)
520   T2=DROUND(T2,3) !T2 IS RMS ERROR TIME BETWEEN #704 AND #705 SAMPLES
530   PRINT "DELAY DIFFERENCE =";T1;"SECONDS"
540   PRINT "RMS NOISE DIFFERENCE =";T2;"SECONDS"
550   INPUT "1 TO CONT., 0 TO STOP",N
560   IF N=0 THEN GOTO 580
570   GOTO 80
580   END
```

Program #3: Testing for Consistency of Triggering in Two Synchronized 5180As

This program measures the time difference between trigger points in two 5180As. To allow a one or two sample interval delay to be visible, the frequency of the input sinewave should be much lower than the sampling rate. For example, if a 20 MHz sampling rate is used, the input sinewave should be 1 MHz. In this program, trigger position 0 is selected, so the first sample stored in memory location 0 in both 5180As will be the trigger point. The voltage values at the trigger points are compared, and the time difference calculated based on the slew rate of the input sinewave.

This program may be run iteratively to determine whether the time between two trigger points is consistent, or if not, how often it varies. If the time difference is inconsistent, the results of running this program many times will give a measure of probability of error.

Normally, when the trigger output from one 5180A externally triggers a second 5180A, the two record the same input signal with a one sample interval offset. Two recorded sinewaves are shown superimposed in Figure 17; the two trigger points are marked by cursors. The trigger point offset could be corrected for by selecting absolute trigger position as described in the Triggering Methods section, on page 7.

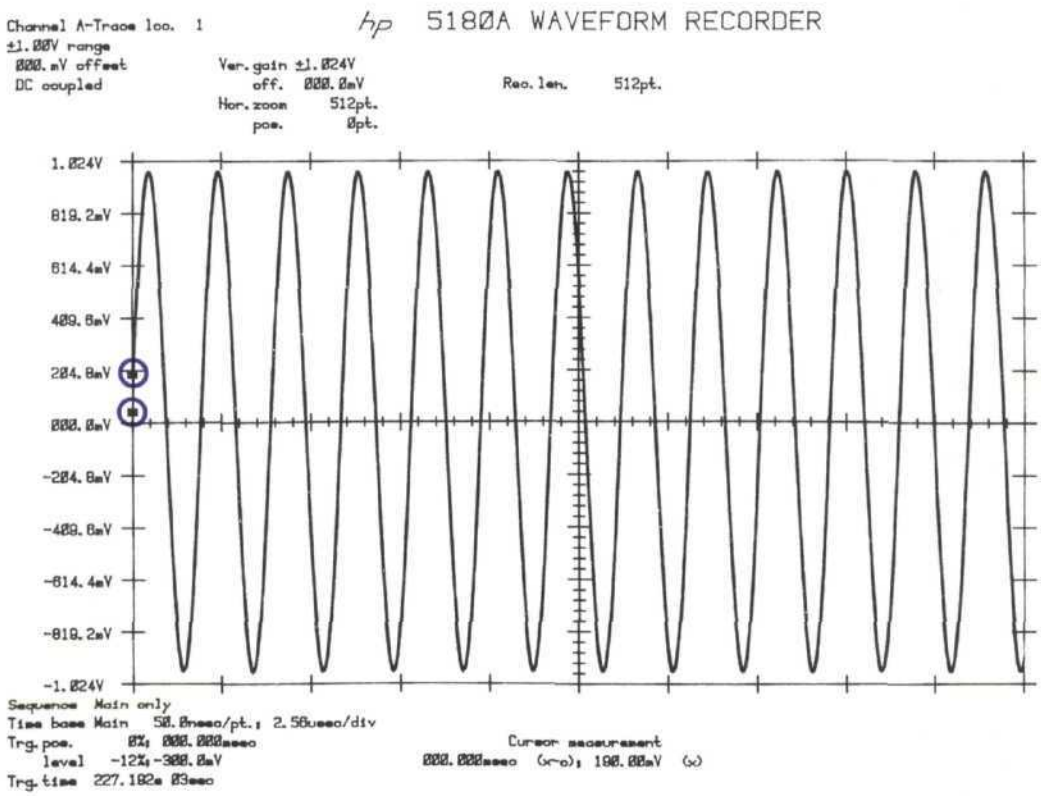

Figure 17. Trigger point time difference for two 5180As may be calculated based on voltage difference between the two trigger points (circled). Superimposed plots show this voltage difference graphically.

Program #3: Testing for Consistency of Triggering in Two Synchronized 5180As

```
10    !PROGRAM #3    10.28.82
20    DIM A$[28],B$[28]
30    ASSIGN @Adc TO 704,705
40    REMOTE @Adc !SETS_BOTH 5180S FOR REMOTE OPERATION
50    !SET UP #704, USE INTERNAL TRIGGER; FOR EXTERNAL TRIGGER, USE "SE1"
60    OUTPUT 704;"PR,AR1,SA1,PP0,SE0,LV-.1,TE1,CU0,CV1"
70    !SET UP #705, USE EXTERNAL TRIGGER (MAY RECEIVE SIGNAL FROM #704)
80    OUTPUT 705;"PR,AR1,SA1,PP0,SE1,LV-.3,TE1,CU0,CV1"
90    INPUT "FREQUENCY OF TEST SINEWAVE IN MHZ?",S1
100   PRINT "TEST FREQUENCY =";S1;"MHZ"
110   OUTPUT 705;"SA4"
120   OUTPUT 704;"SA4"
130   WAIT 1
140   S=SPOLL(705)
150   !WAIT FOR MEASUREMENT COMPLETE
160   IF BIT(S,4)=1 THEN GOTO 140
170   OUTPUT 704;"OG"
180   ENTER 704;A$
190   P=POS(A$,"d2")+2
200   IF A$[P+8;1]=" " THEN A$[P+8;1]="+"
210   !V1 IS VOLTAGE AT FIRST SAMPLE IN #704
220   V1=VAL(A$[P])
230   OUTPUT 705;"OG"
240   ENTER 705;B$
250   P=POS(B$,"d2")+2
260   IF B$[P+8;1]=" " THEN B$[P+8;1]="+"
270   !V2 IS VOLTAGE AT FIRST SAMPLE IN #705
280   V2=VAL(B$[P])
290   V1=DROUND(V1,3)
300   V2=DROUND(V2,3)
310   !SINCE TRIGGER IS ON RISING SLOPE, ASSUME HIGHER VOLTAGE IS LATER SAMPLE
320   V3=V2-V1
330   !CALCULATE TIME DIFFERENCE, BASED ON SLEW RATE OF INPUT SINEWAVE
340   T1=V3/(2*PI*S1)
350   T1=DROUND(T1,3)
360   PRINT "V1=";V1;" V2=";V2;" VOLTAGE DIFFERENCE=";V3;" TIME DELAY=";T1;"US"
370   INPUT "1 TO CONTINUE, 0 TO STOP",N
380   IF N=1 THEN GOTO 90
390   END
```

RESULTS

Program #1 (either A or B) adjusts the phase of the test signal so that the 5180As will sample the input sinewave at the rising edge zero-crossing. When the program ends, the selected phase (P1) is displayed by the 9826.

The results of Program #2 indicate how closely the timebases of two 5180As are synchronized. Figure 18 shows a typical printout obtained from this program. The "delay difference" measures the average voltage or time difference between samples taken by each of the two 5180As. The "rms noise error" is the random error affecting the measurement of time difference between samples.

```
TEST FREQUENCY = 20 MHZ
A1 = .305 VOLTS A2 = .334 VOLTS
DELAY DIFFERENCE = .029 VOLTS
RMS NOISE ERROR = .00394 VOLTS
DELAY DIFFERENCE = 2.31E-10 SECONDS
RMS NOISE DIFFERENCE = 3.14E-11 SECONDS
```

Figure 18. Printout resulting from Program #2.

Program #3 measures the time difference between two 5180As' trigger points, when both are recording the same input sinewave. The results of this test, when it is run using a 20 MHz sampling rate and 500 KHz test sinewave, are shown in Figure 19.

```
TEST FREQUENCY = 1 MHZ
V1= .0948 V2= .389 VOLTAGE DIFFERENCE= .2942 TIME DELAY= .0468 US
```

Figure 19. Printout of Program #3 results.

The results obtained using these tests provide a measure of both timebase and triggering error for two synchronized 5180As. If more than two 5180As are to be synchronized, each of the 5180As should be compared to one "control"; the time relationship of all the 5180As will then be known.

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