DATA ACQUISITION (SIGNAL AVERAGING) UNDER WIRED-PROGRAM CONTROL

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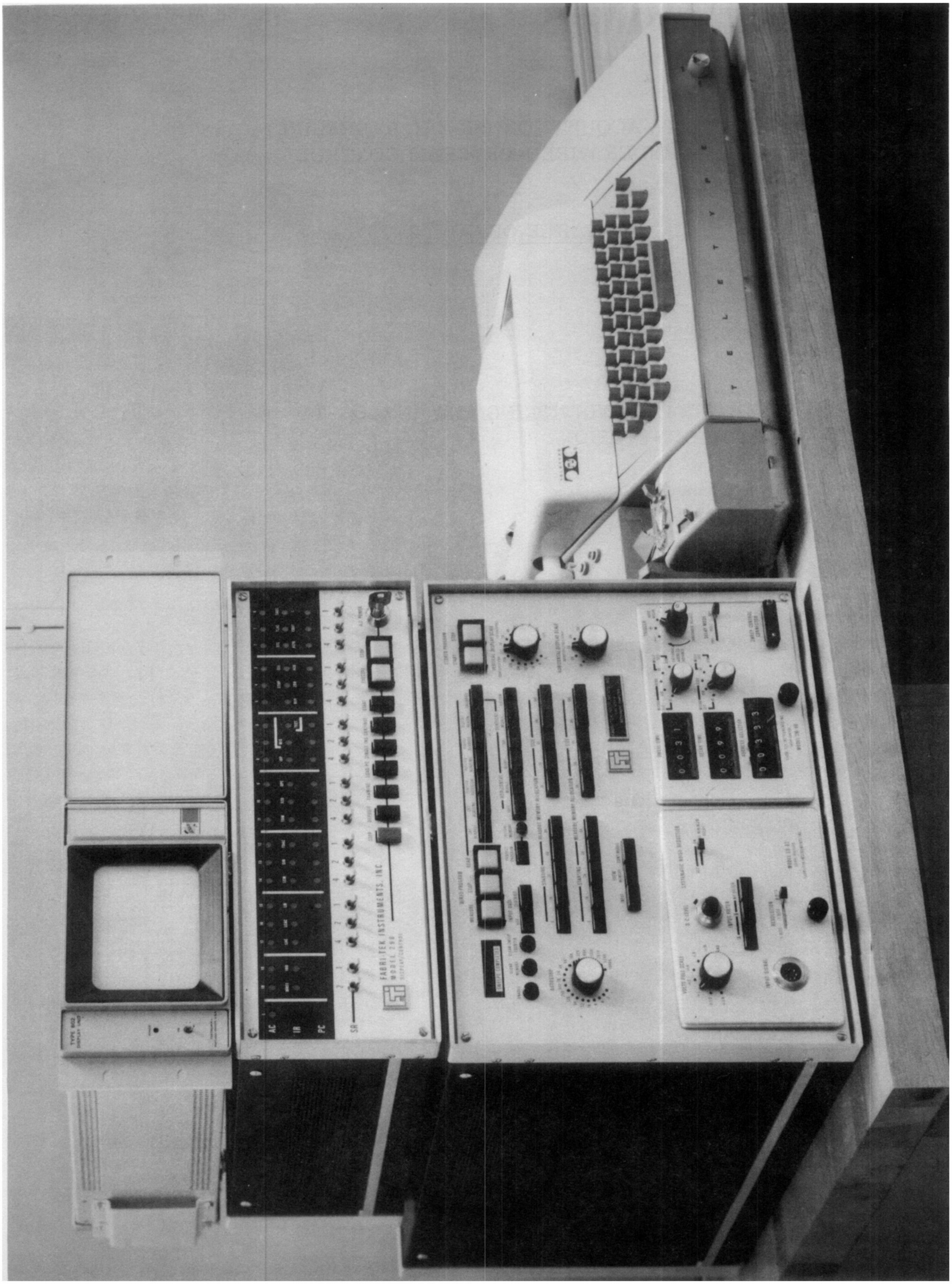
FABRI-TEK INSTRUMENTS, INC.
TELETYPE

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I. INTRODUCTION

Acquiring free induction decay (FID) or continuous wave (CW) data from an nmr spectrometer with the 1080 system can be likened to the operation of an oscilloscope. Figure 1 shows the flow of information to and from the spectrometer to the various components of the 1080 system. The analytical (FID or CW) signal is fed to the input of the analog-to-digital converter (SD-82) for pre-conditioning and conversion to a discrete number of levels, a form that the 1080 wired program processor can readily assimilate into its magnetic core memory. All of the necessary timing controls which establish the start time (trigger) of the sweep, sweep width or sweep rate are found on the sweep control unit (SW-80).

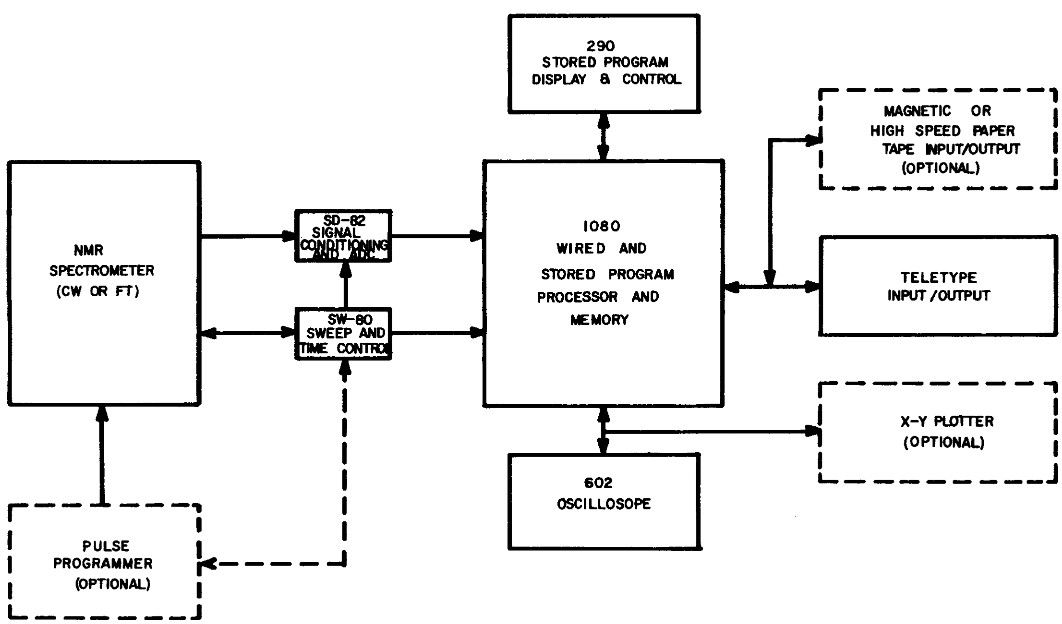


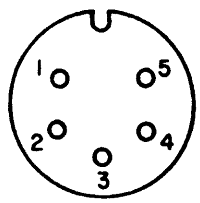
Figure 1. Components of a 1080 NMR Data System.

Parameters relating to acquisition processes such as the number of signals to be averaged, the number and location of storage points as well as factors determining display or readout characteristics are all located on the 1080 main frame.

II. SD-82 SIGNAL CONDITIONING AND ANALOG-TO-DIGITAL CONVERSION

A. Connections

The first step in acquiring data is to connect the spectrometer output signal to the connector marked INPUT CONNECTOR on the front of the SD-82. Although this connector has five terminals, only four of them are used (see Figure 2).



Pin Number	Function
1	Non-Inverting ADC Input
2	Chassis Ground
3	Inverting ADC Input
4	Not Used
5	Circuit Ground

Figure 2. Orientation and Pin Connection List of Front Panel Connector on SD-82 Signal Digitizer

Pins 1 and 3 are the non-inverting and inverting inputs of two operational differential amplifiers whose outputs are fed to a third differential amplifier (see Figure 3). This provides a truly differential input for eliminating common-mode signals (-80 db rejection) that are carried on the analog signal lines. Pin 5 is a "clean" (noise free) common signal ground which should be connected to the signal reference point in the spectrometer. Pin 2 is chassis ground and should be attached to the chassis ground of the spectrometer through the shield of the 3-wire shielded cable to eliminate electrical hazards due to metal housings being at different potentials. Pin 4 is not used. These connections may vary somewhat depending upon spectrometer characteristics.

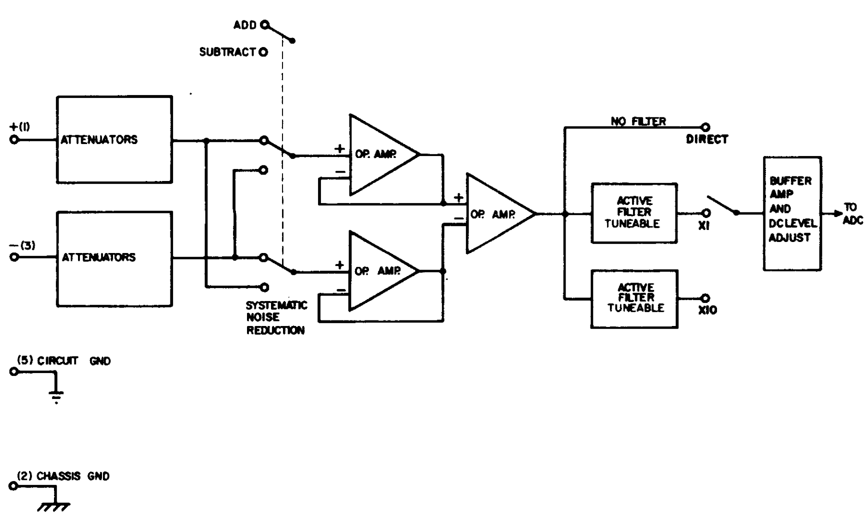


Figure 3. Block Diagram of SD-82 Signal Conditioning Section

The amplitude of the differential input signal can range from ±250 millivolts to ±16 volts for full scale input. The full scale signal voltage should be close to one of the indicated settings of the FULL SCALE VOLTS switch so that the maximum dynamic range of the digitizer is utilized. The differential input will reject common mode voltages which can be up to ±20 times the full scale input with an absolute maximum of ±50 volts. The input impedance is 400K ohms balanced or 200K ohms unbalanced. If the input signal is connected in a single-ended, unbalanced manner, the unused terminal should be connected to the common terminal. (See Figures 4a and 4b.)

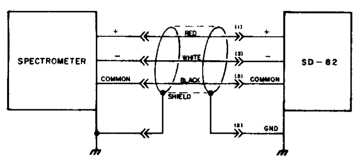


Fig. 4a. Connections for Balanced Input

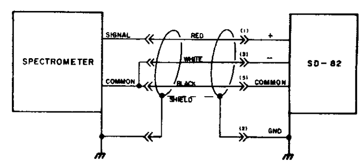


Fig. 4b. Connections for Unbalanced Input (non-inverting)

B. Controls

VOLTS FULL SCALE -- This control, variable from ±1/4 volt to ±16 volts, determines the requirements of the input signal amplitude to produce a full scale number of counts from the analog-to-digital converter. This switch and the RESOLUTION switch determine the relationship between the sampled input voltage and the number of counts representing that voltage and is expressed

$$\frac{\text{Counts}}{\text{Volt}} = \pm \frac{2^{R-1}}{\text{VFS}}$$

where R is the number of bits determined by the setting of the RESOLUTION switch and VFS is the setting of the VOLTS FULL SCALE switch. The plus or minus sign is determined by the polarity of the input signal.

The GND position of this switch disconnects the input signal and connects the inputs of the operational amplifier to the common terminal.

This switch should be positioned during operation such that the maximum excursion of the input signal is close to, but does not exceed, this value. A more definitive procedure is given in a later section.

D. C. LEVEL -- This ten turn control permits a d.c. voltage to be added to or subtracted from the input signal. This allows cancellation of unwanted bias voltages present on the input signal and also provides for offsetting the input signal to permit better utilization of the dynamic range of the analog-to-digital converter. For example, if the input signal is from a CW nmr spectrometer and has a reasonably good signal-to-noise ratio, most of the signal will be positive and subtracting a d. c. voltage from it with this control will improve the resolving capability (resolution) of the analog-to-digital conversion process. In Fourier spectroscopy this control should be adjusted so that the maximum positive and negative excursions of the FID signal come close to but do not exceed the full scale range of the digitizer. Zero d. c. level corresponds to a setting of approximately 5 on the dial with settings of zero and 10 corresponding to minus and plus full scale respectively. This control is <u>not</u> effective when using the Systematic Noise Reduction mode of operation and should be set to position 5 (zero volts) when this mode is being used.

INPUT FILTER -- This is one of the more important controls of the data acquisition system from the standpoint that the selection of the input filtering network can grossly affect the accumulated FID signals, from a signal-to-noise standpoint as well as the effect upon the phase characteristics of the real and imaginary components. A sharp cut-off, low pass filter is essential. For optimum results the cut-off frequency of the filter should be matched to the selected sampling rate (and therefore sweep width) as set on the DWELL TIME control on the SW-80. The cut-off frequency should be set as close as possible to $1/2\Delta t$ where Δt is the dwell time setting. See Technical Data Sheet C050-50-5/70 of Analog Devices Inc., Cambridge, Massachusetts for complete description and specifications of filters.

The SD-82 contains two tunable 4-pole Butterworth plug-in filters which provide a frequency range from 125 to 25,000 Hertz in 24 steps, selected from the front panel by pushing × 1 Hz or × 10 Hz pushbuttons respectively. Contact the factory if different cut-off frequencies are required. If an external filter such as the Kron-Hite 3300 Series is used, the DIRECT pushbutton is depressed. Refer to the section in this instruction manual on Phase Correction for information on changes that can be made to correct for the phase characteristics of different filters.

RESOLUTION -- Digitizer resolution can be defined as the smallest voltage difference that will make a one count difference in the voltage/count relationship of an ADC. It is generally expressed in terms of the full scale number of counts for a full scale input voltage and therefore has a label of bits (binary digits). For example, in the 9 BIT position the SD-82 will resolve an input signal to one part in 2^9 (512). In the 7 BIT position a resolution of 1 part in 128 is achieved and in the 5 BIT position one part in 32.

In actual operation the setting of this control is determined by the signal-to-noise ratio (S/N) of the incoming FID signal and the number of sweeps (repetitions) that are to be made. In general, coherent signals will reinforce with each sweep and will therefore add linearly with the number of sweeps made, whereas non-coherent data will add in proportion to the square root of the number of sweeps made.

The highest coherent amplitudes in FID signals occur early in time and decay exponentially while the non-coherent components are relatively constant throughout. Therefore the S/N ratio of the FID signal decreases with time. Since frequency resolution increases with time, a balance must be struck between digitizer resolution, the number of sweeps, and the dwell time.

The ultimate limiting factors on S/N ratio improvement are the length of each data word and the systematic noise introduced in the analog to digital conversion process. The algorithm used in computing the average, whether it be the normalized method or straight summation method, will not alleviate the restriction imposed by the word length.

By changing the RESOLUTION control from the 9 BIT position to the 5 BIT position, 16 times as many sweeps can be made and therefore, a theoretical improvement of a factor of 4 in the S/N ratio can be achieved. In actual practice, the improvement in S/N ratio will not be quite as great since the digitizing accuracy has to be considered in relation to the actual FID signal amplitude. Correspondingly, changing the RESOLUTION switch from the 9 BIT position to the 7 BIT position, 4 times as many sweeps can be made and therefore a factor of approximately 2 improvement in S/N ratio can be achieved.

SYSTEMATIC NOISE REDUCTION -- In those applications where an extremely large number of sweeps is to be made, a scheme to reduce coherent noise arising from the digitizing process can be introduced. This technique will only reduce noise generated within the SD-82, and not coherent noise which may be coming from the spectrometer. The theory on which it operates is quite simple: data presented to the input terminals have their polarity inverted on alternate sweeps by means of reed-relay switches.

At the same time the add/subtract logic is switched between add and subtract on alternate sweeps at the end of each sweep. This means that data from the spectrometer will always be added to memory totals, but systematic noise arising inside the digitizer, whose polarity does not get inverted, will be cancelled out due to the alternate addition and subtraction operation.

When this technique is used, a minimum delay of 2 milliseconds must occur between successive sweeps. If no external delay is provided this delay must be set on the DELAY TIME switches of the SW-80 Sweep Control plug-in. This permits the reed relays to "settle down" after being switched.

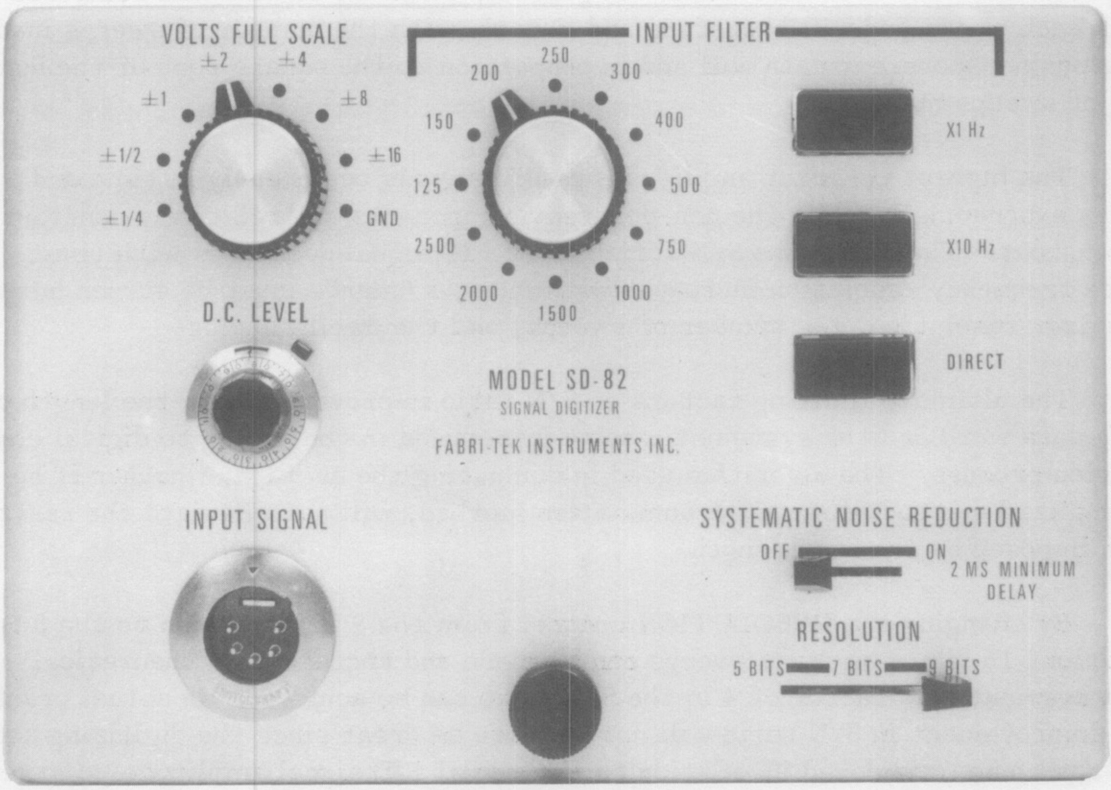


Figure 5. Front Panel of SD-82 Signal Digitizer

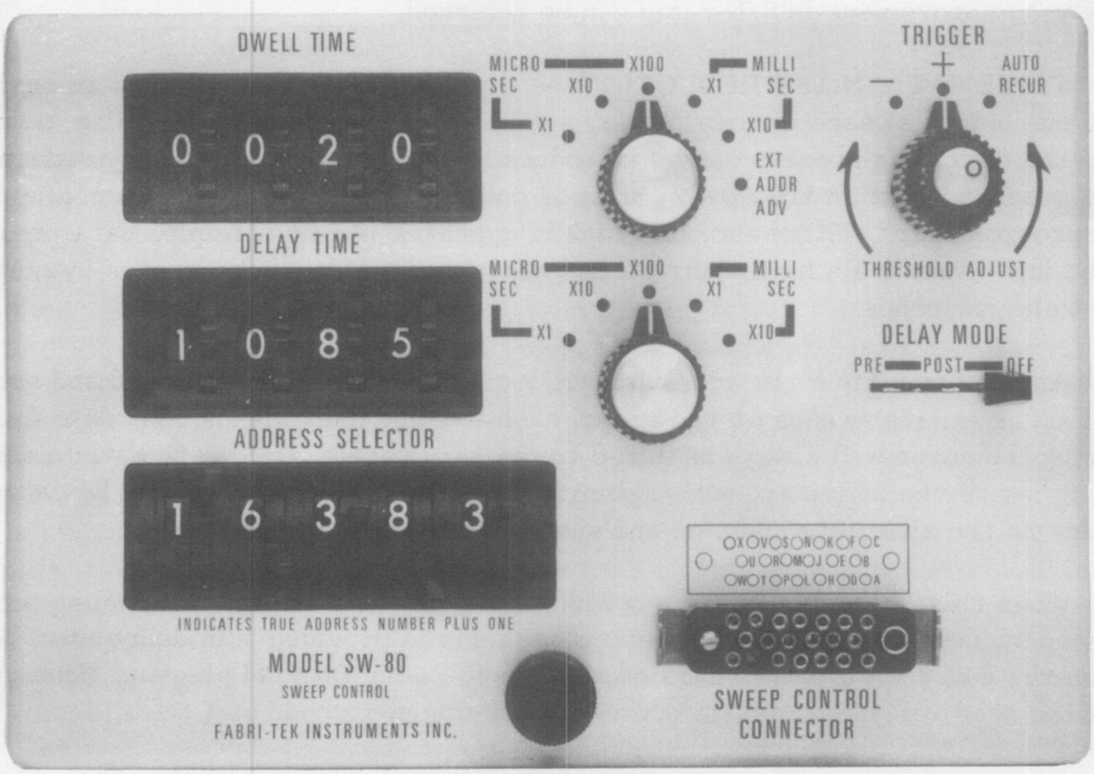
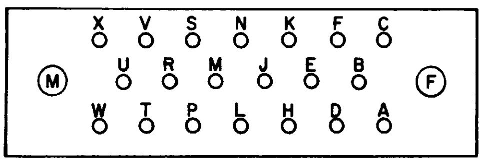


Figure 6. Front Panel of SW-80 Sweep Control

III. SWEEP CONTROL (TIME BASE)

A. Connections

The SWEEP CONTROL CONNECTOR on the front panel of the SW-80 is a female 20 pin AMP Inc. connector, catalog number 201356-1 which mates with a male 20 pin AMP Inc. connector, catalog number 200346-2. Female pins, AMP Inc. catalog number 66104-12P are used in the panel mounted connector and Male pins, AMP Inc. catalog number 66102-12P are used in the mating connector. The following is a list of the signals on this connector.



Front View of Sweep Control Connector

PIN	FUNCTION
A	Delay Flag Output
C	External Address Reset Input
D	External Trigger Input
E	Sweep Ramp Output
F	Cursor Reset Input
H	Cursor Output
K	External Address Advance Input
L	External Clock Input
M	Clock Output
N	Internal Clock Inhibit
P	Measure Address Cursor Inhibit
S	Sweep Flag Output
U	Readout Trigger
V	Extra Delay Enable
W	Chassis Ground
B, J, R, and X	Circuit Ground

Figure 7. Pin Connection List of SW-80 Sweep Control Connector Cable

Pin	Signal Description
A	DELAY FLAG -- A +10 volt level (enabled only in the Measure mode of operation) is present on this pin for the duration of the delay period as selected on the SW-80 DELAY TIME and DELAY MODE switches. With the DELAY MODE switch in the PRE position, the delay is inserted between the time of triggering a sweep and the start of the sweep. With the DELAY MODE switch in the POST position the delay is inserted between the end of one sweep and the start of the next.
C	EXTERNAL ADDRESS RESET -- A +4 volt pulse applied to this pin will cause the termination of a measurement sweep immediately on completion of the next memory cycle.

D EXTERNAL TRIGGER INPUT -- An external trigger signal of from -5 to +5 volts amplitude applied to this pin will initiate a sweep unless a sweep is currently in progress (in which case it is ignored). The start of the sweep occurs as the trigger signal passes through the threshold level selected by the THRESHOLD ADJUSTMENT control on the SW-80 with a slope selected by either the + or - position of the TRIGGER control.

E SWEEP RAMP OUTPUT -- An analog output voltage proportional to the address number during a measurement sweep is provided on this pin. The voltage can start at 0 or +8 volts at the beginning of a sweep and go to +8 volts or 0 at the end of the sweep, as selected by an internal switch. Another internal switch selects the total number of increments (addresses) that the voltage ramp is to include. Two more internal controls allow d. c. offsetting of the voltage ramp by as much as ±10% of full scale and trimming the amplitude of the ramp by ±10% of full scale. If fewer than 32K addresses are used the voltage ramp can be attenuated by setting the internal increment switch to a higher value than the number of addresses actually being used.

F $\overline{\text{CURSOR RESET}}$ -- (See description for pin H) A +5 volt to zero volt pulse applied to this pin causes the CURSOR OUTPUT scaler to reset.

H $\overline{\text{CURSOR OUTPUT}}$ -- A +5 to zero volt pulse with a duration of 2 microseconds is presented on this pin when the sweep enters the address selected by ADDRESS SELECTOR thumbwheel switches. This pulse is present during either the Measure or the Readout modes of operation. During the Measure mode with Continuous Display, the $\overline{\text{CURSOR OUTPUT}}$ signal is present when the CRT display is intensified (i. e. , when the display register passes through the selected address). Connecting pin P of this connector to pin X (gnd) will cause the $\overline{\text{CURSOR OUTPUT}}$ signal to be preserved when the measure address register goes through the selected address number. Instead of a pulse at one address during a sweep it is possible to arrange for this pin to provide a pulse at every n^{th} address where n is the number selected on the ADDRESS SELECTOR switches. To accomplish this, connect the $\overline{\text{CURSOR OUTPUT}}$ signal (pin H) to pin F which is called $\overline{\text{CURSOR RESET}}$. Again, by connecting pin P to pin X this signal will occur every n^{th} measure address.

K EXTERNAL ADDRESS ADVANCE -- A +4 volt pulse applied to this pin will cause the ADC to sample the input signal, convert the sample to a digital value, and add that value into successive addresses of memory. The DWELL TIME decade switch must be in the EXT ADDR ADV position for these pulses to be recognized. The thumbwheel switches will divide the frequency of this signal by the indicated value (range 1 to 9999).

L EXTERNAL CLOCK -- An externally derived clock signal (such as from a frequency synthesizer) can be inserted on this pin. The clock signal will be divided by 10 immediately and can be further divided by the setting of the DWELL TIME thumbwheel switches and decade switch which will then indicate the additional factor by which the frequency of the EXTERNAL CLOCK signal is divided. The actual time between sampling commands will then be equal to 10 times the reciprocal of the divided down external clock frequency. Clock signal should be +5 volts and can have a maximum frequency of 20 MHz. When an EXTERNAL CLOCK signal is used pin N must be connected to ground to inhibit operation of the internal clock.

M CLOCK OUT -- The internal 10 MHz clock or the applied external clock from which all dwell and delay times are derived is available at this pin. This makes possible the exact synchronization of external timing equipment such as pulse programmers.

N $\overline{\text{INTERNAL CLOCK INHIBIT}}$ -- If an external clock signal is to be used on pin L, then the internal clock signal must be inhibited. This is accomplished by connecting pin N to pin X (circuit ground). (See pin L description.)

P $\overline{\text{MEASURE CURSOR}}$ -- When this pin is grounded (by connecting it to pin X) the $\overline{\text{CURSOR OUTPUT}}$ signal (pin H) occurs when the measure address equals the number set on the ADDRESS SELECTOR thumbwheel switches.

However, if the Continuous Display mode is selected on the 1080 main frame and it is desired to intensify the selected address on the CRT display, then pin P should not be connected to pin X (circuit ground). In this case however, there is no time relationship between the $\overline{\text{CURSOR OUTPUT}}$ signal and the actual measure address. (See pin H for further description.)

S SWEEP FLAG -- A +10 volt level is present on this pin for the duration of a wired-program measurement sweep. (Should a negative level be required consult factory for modification information. This modification is required when operating with a Varian XL-100.)

U READOUT TRIGGER -- A transition from +5 volts to ground applied to this pin will cause the start of the Realtime Readout mode (either CRT or PEN) when the TRIGGER switch is in either the + or - position. This allows synchronization of the start of a Pen Readout cycle with external equipment.

V EXTRA DELAY MODE -- Grounding this pin, placing the TRIGGER switch in the + or - position, and placing the DELAY switch in the

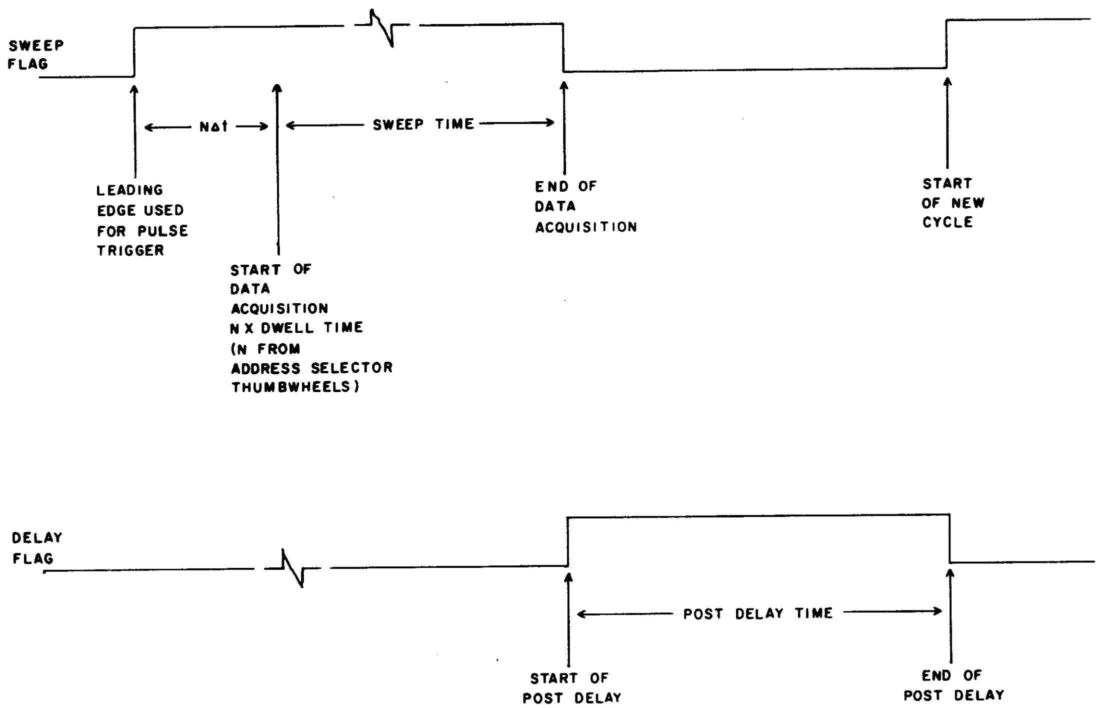


Figure 8. Timing Diagram when Using EXTRA DELAY ENABLE mode.

POST position will allow the ADDRESS SELECTOR thumbwheel switches to insert a second delay, i. e. , a pre-delay before the start of data accumulation. This mode would be used when the 1080 is to control the timing of the experiment. (See Figure 8 for timing diagram.) For example, with the ADDRESS SELECTOR switches set at 00004, a DWELL TIME of 100 microseconds, a DELAY TIME of 1804 × 100 microseconds, and 8192 data points (8K) used, the following will be the sequence of events when the MEASURE (WIRED PROGRAM) pushbutton is depressed:

(1) The SWEEP FLAG signal (pin S) will go high (this can be used to trigger the experiment).

(2) For exactly 400 microseconds (ADDRESS SELECTOR switch setting multiplied by DWELL TIME switch setting, i. e. , 4 × 100) no data will be accumulated.

(3) At the end of this delay period data accumulation will start and continue for 819,200 microseconds (number of data points multiplied by DWELL TIME switch setting, i.e., 8192×100).

(4) At the end of this sweep period, the SWEEP FLAG signal will go to ground and the DELAY FLAG signal (pin A) will go high for 180,400 (1804×100) microseconds.

(5) At the end of this second delay period, the cycle restarts.

When these data are Fourier transformed, the frequency spectra will have an upper frequency value (f_{max}) of 5 KHz (1 / $2 \times$ DWELL TIME), and a frequency resolution (Δf) of 1.2207 Hz (1 / Number of data points $\times$ DWELL TIME) per data point. The total time of one acquisition cycle is 1 second of which 0.0004 seconds are used for pre-acquisition delay to permit feed-through energy to settle down, 0.8192 seconds for acquisition of the FID signal, and 0.1804 seconds are used to allow the nuclear spin system to relax to its equilibrium state. Note that this pre-acquisition delay of 400 microseconds will cause a contribution to the frequency dependent phase shift term "B" of 720 degrees (number of sampling intervals of delay $\times$ 180 degrees).

W CHASSIS GROUND -- This point is connected to the main frame and plug-in metal frame. In general it should not be used as circuit ground for either internally or externally generated signals.

B, J, R, X CIRCUIT GROUND -- All externally applied signals should be referenced to one of these ground connections. All internally generated signals are referenced to these ground connections.

B. Controls

DWELL TIME -- Four thumbwheel switches permit selection of the 4 most significant digits of the sampling period Δt. The rotary switch alongside the thumbwheel switches selects the decade multiplier of the thumbwheel switch settings and therefore determines whether the numbers indicate microseconds, tens of microseconds, etc. With the SD-82 Signal Digitizer the minimum setting for the Measure mode is 20 microseconds. (Any setting less than this will still result in a 20 microsecond dwell time.)

The setting of these switches is the sole determining factor of the sweep width f_{max} in Fourier nmr. The relationship is expressed

$$f_{max} = \frac{1}{2\Delta t}$$

where f_{max} is in Hertz when Δt is in seconds. Therefore to select the Δt setting given the desired sweep width in Hertz the relationship is

$$\Delta t = \frac{1}{2f_{max}}$$

or to select the Δt setting given the desired sweep width in parts per million (δ) the relationship is

$$\Delta t = \frac{1}{2F\delta}$$

where F is the nominal spectrometer frequency in megahertz for the nucleus being observed.

The Δt control along with the selection of the number of data points will affect the resolution of the frequency spectra after the Fourier transform operation. This relationship is

$$\Delta f = \frac{1}{N\Delta t}$$

where Δf is the change in frequency from one value of the frequency spectrum to the next adjacent one, and N is the number of data points selected for storage of the FID signal. Since f_{max} is the maximum frequency in the spectrum and Δf is the increment in frequency, then

$$\frac{f_{max}}{\Delta f} = \frac{1/2\Delta t}{1/N\Delta t} = \frac{N}{2}$$

is the number of frequency values that will be computed in the Fourier transformation.

For a given number of points of data storage (N) of the FID signal, a compromise has to be made between sweep width and resolution. Resolution (Δf) improves with longer observation time ($N\Delta t$) but sweep width (f_{max}) increases with shorter sampling periods (Δt).

Instead of the internally generated time base for sampling the analytical signal it is possible to use an external time base. Two methods are provided for connecting this external time base:

1. The external time base signal can be connected to pin K of the SWEEP CONTROL CONNECTOR and the DWELL TIME decade switch should be put in the EXTERNAL ADDRESS ADVANCE position. The thumbwheel

switches will then select the integer by which the input clock frequency will be divided.

2. If the frequency of the external time base signal has to be divided by any arbitrary integer, it can be connected to pin L of the SWEEP CONTROL CONNECTOR. The divisor is selected with the DWELL TIME thumbwheel switches and decade switch. In this case, pin N must be connected to pin X to inhibit the internal clock. The DELAY TIME thumbwheel and decade switches will now select the number of periods (× 10) of the external clock signal as the delay time.

DELAY TIME -- Four thumbwheel switches permit the selection of the 4 most significant digits of a delay time that can be inserted between the trigger signal and the start of a measurement sweep or between the end of a sweep and the beginning of a new sweep. The rotary switch alongside the thumbwheel switches selects the decade multiplier of the thumbwheel switch settings and therefore determines whether the thumbwheel numbers indicate microseconds, tens of microseconds, etc. up to 99.99 seconds.

DELAY MODE -- A selectable time delay may be inserted before the start of a measure sweep or at the end of a measure sweep if this switch is in the PRE or POST positions. If this switch is in the OFF position any setting of the DELAY TIME switches is ignored and a measure sweep begins immediately upon presentation of a trigger signal if the TRIGGER switch is in the + or - position or immediately upon completion of a sweep if the TRIGGER switch is in the AUTO position. (This continues until the preset number of sweeps as set on the main frame AUTOSTOP switch is reached.) Figures 9, 10, 11 and 12 show the timing relationships between the delay and sweep times when using external or autorecurrent trigger and PRE and POST delay modes.

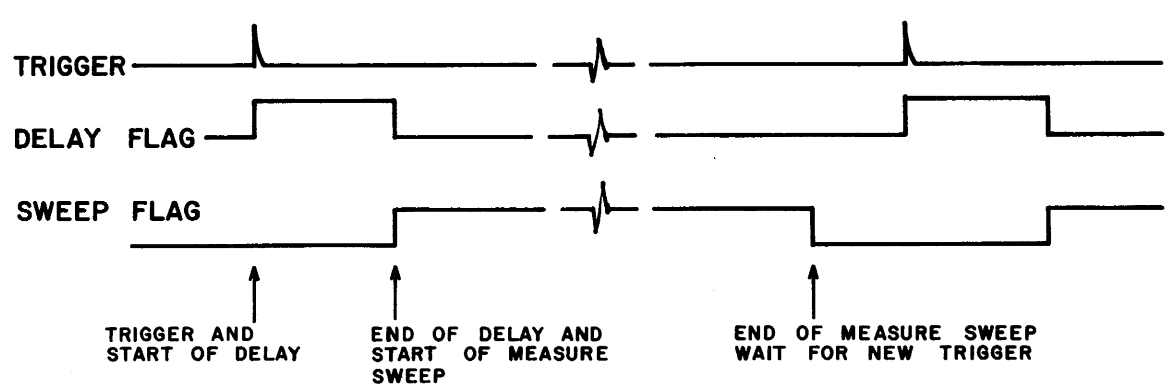


Figure 9. Timing Diagram when Using Delay Time with External Trigger and Predelay Mode

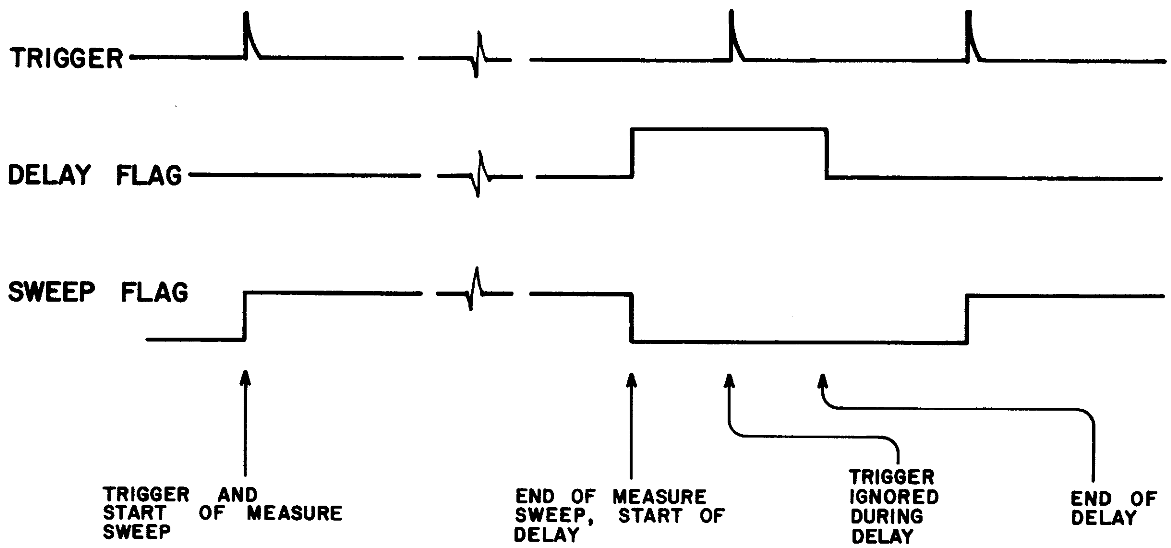


Figure 10. Timing Diagram When Using Delay Time with External Trigger and Postdelay Mode

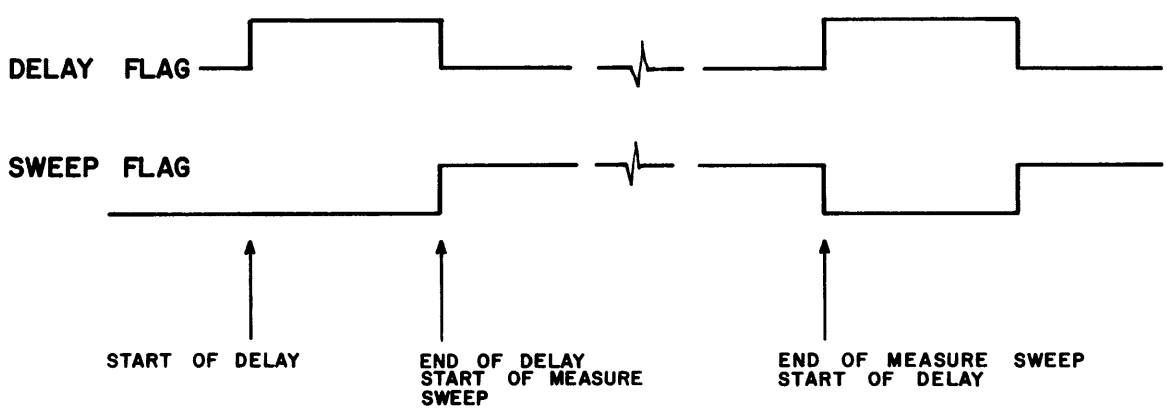


Figure 11. Timing Diagram When Using Delay Time with Autorecurrent Trigger and Predelay Mode

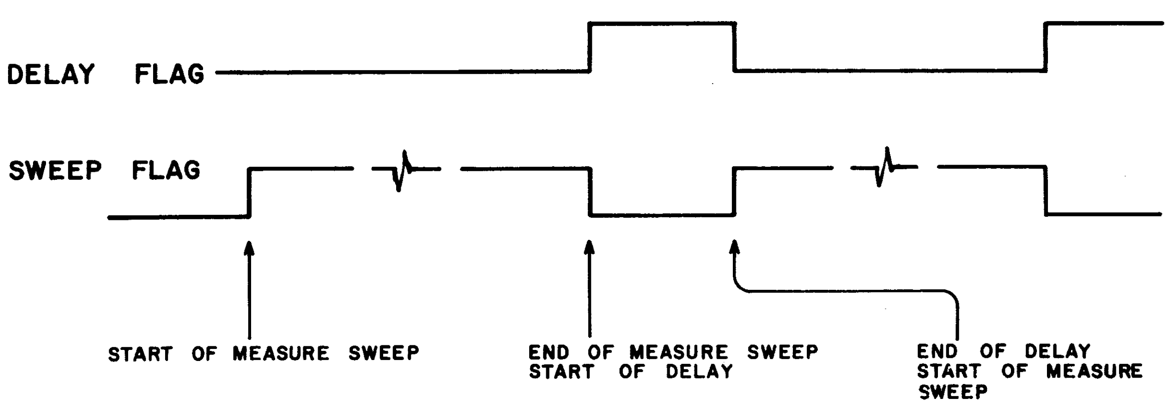


Figure 12. Timing Diagram When Using Delay Time with Autorecurrent Trigger and Postdelay Mode

TRIGGER -- These are two concentric controls with the small outer knob providing adjustment at trigger threshold level and the large inner knob selecting the mode of triggering a measure sweep. The modes of triggering the sweep may be either on the positive or negative slopes of an externally supplied trigger signal (connected to pin D of SWEEP CONTROL CONNECTOR) when the mode control is in the + or - position. When this mode switch is in the AUTO position a measure sweep is automatically started when the main frame WIRED PROGRAM START pushbutton is depressed and also when a sweep is completed. This will continue until a preset number of sweeps as set by the main frame AUTOSTOP has been made or until the main frame WIRED PROGRAM STOP button has been pushed.

The relationship between the + and - slope control and the threshold control is shown in Figure 13.

ADDRESS SELECTOR -- Five thumbwheel switches permit selection of a 5 digit decimal number for either display purposes or for timing purposes when in the Measure mode of operation.

When in the WIRED PROGRAM CRT READOUT mode, these switches will indicate the number of the relative address in memory which is being intensified on the CRT display. To determine the absolute address number, the number of addresses as indicated by the STARTING READOUT MEMORY ALLOCATION switch on the main frame must be added to the indicated number on the thumbwheel switches. There is a one address discrepancy due to the fact that when the switches are all set to zero, this signal is inhibited. That is, a thumbwheel settinf of 00001 will select address 0, a setting of 00002 address 1, etc.

Another use of these switches is for timing signals when in the WIRED PROGRAM MEASURE mode of operation. A +5 volt pulse will appear on pin H of the SWEEP CONTROL CONNECTOR when the sweep reaches the address number indicated by the thumbwheel switches. This pulse can then be used for external timing purposes.

If it is desired to have a pulse output after every n addresses after starting a measurement sweep, this can be accomplished by connecting pin J to pin F of the SWEEP CONTROL CONNECTOR and the output pulse again appears on pin H of this connector. In this case "n" is the number selected by the ADDRESS SELECTOR thumbwheel switches.

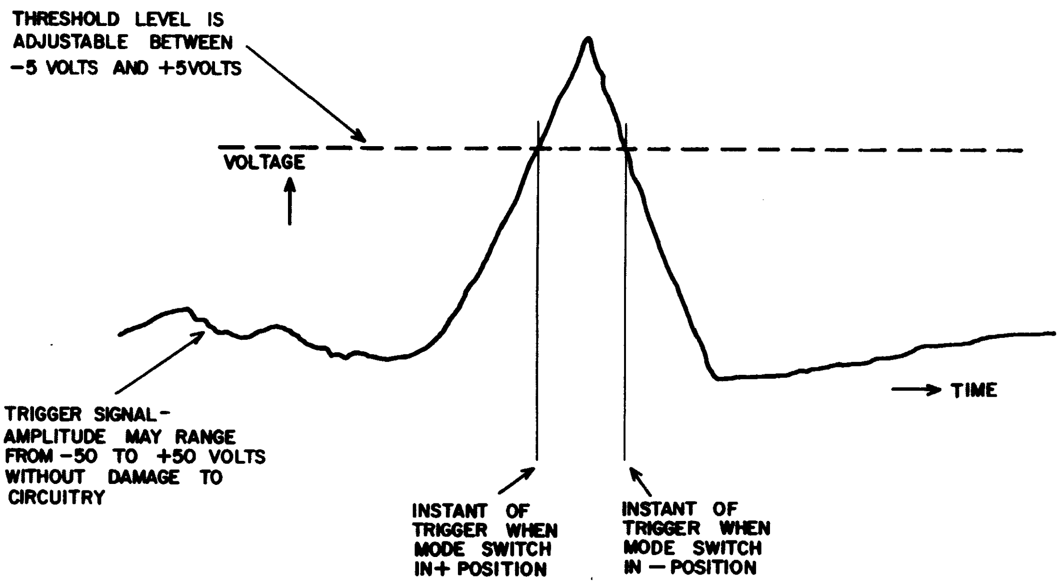


Figure 13. Illustration of Effect of Trigger Mode and Threshold Controls on Instant of Trigger

IV. 1080 MAIN FRAME

A. Connections

The SD-82 Signal Digitizer and SW-80 Sweep Control plug-ins are constructed so that either plug-in can be inserted on either the right or left hand 1080 main frame cavities.

Interconnections between the 1080 main frame rear panel and the Model 290 Display/Control unit are as follows:

1. Connect 80-pin printed circuit type cable connector labeled TO 1080 R3 to connector R3 marked INPUT/OUTPUT TO NIC-290 on the 1080 and the other end marked TO NIC-290 INPUT/OUTPUT to the Model 290 connector labeled INPUT/OUTPUT.

2. Connect 80-pin printed circuit type cable connector labeled TO NIC-1080 R4 to connector R4 marked DISPLAY CONTROL TO NIC-290 on the 1080 and the other end marked TO NIC-290 DISPLAY CONTROL to the Model 290 connector marked DISPLAY CONTROL.

3. Connect 80-pin terminator cord to connector labeled INPUT/OUTPUT on the 290.

4. Connect 24-pin connector cable between connector marked D. C. COMPUTER POWER on the 1080 and connector marked D. C. COMPUTER POWER on the Model 290.

5. Connect cable from Teletype I/O device to 1080 rear panel connector marked INPUT/OUTPUT DEVICE 1.

6. Connect Teletype power cord to Model 290 rear panel A. C. accessory power connector.

7. If extended memory unit Model 1080E is used, connect 80-pin printed circuit type connector cable labeled TO NIC-1080 R1 to R1 marked MEMORY CONTROL TO NIC-1080E on the 1080 and the other end marked TO NIC-1080E to the connector marked MEMORY CONTROL FROM NIC-1080 on the 1080E.

8. Connect 1080E power cord to Model 290 rear panel A. C. accessory power connector.

9. Connect three dual banana (BNC on later models) shielded cables from the rear panel 1080 connectors marked CRT DISPLAY HORIZ, VERT and J2 to the Tektronix 602 oscilloscope rear panel connectors marked X, Y and Z respectively.

10. Connect oscilloscope power cord to Model 290 rear panel A. C. accessory power connector. Operating procedure for the oscilloscope can be found in the Tektronix Model 602 Operating Manual.

11. If an X-Y recorder is to be used with this system, connections are made to the 1080 rear panel connectors marked PEN RECORDER HORIZ and VERT. Normally the Vertical Pen Output signal is a positive voltage. If a negative Vertical Pen Output signal is required, consult factory for modification information. (This modification is required when operating with a Varian XL-100.)

B. Controls

SWEEPS COMPLETED -- An electronic (light emitting diode), seven-digit decimal display indicates the number of measurement sweeps completed. Display is updated at the beginning of each sweep. (Maximum count is 9,999,999.) Once this counter has reached the preset value (see AUTOSTOP control) continued measurement sweeps cannot be accomplished until the counter is reset by means of the CLEAR SWEEP COUNTER control.

WIRED PROGRAM -- MEASURE, STOP and READ pushbuttons select the basic mode of wired program operation. The MEASURE button starts the wired program measurement operation. The STOP button will stop the wired program measurement after completion of the sweep in progress or will stop the wired program readout mode. The READ button initiates one of the following wired program readout operations.

Wired Program READ Modes:

CRT READOUT permits linear CRT display of data stored in memory.

CRT REAL TIME allows the CRT readout rate to be selected by the DWELL TIME controls on the SW-80 Sweep Control plug-in. Minimum DWELL TIME setting is approximately 10 microseconds and depends upon the setting of the VERTICAL DISPLAY SCALE switch. Dwell times of 20 microseconds or slower may be selected at any VERTICAL DISPLAY SCALE switch setting.

PLOTTER REAL TIME provides XY readout of data stored in memory to pen recorder output jacks on rear panel. In this.mode, rate of address advance (X-axis scan) is determined either by DWELL TIME setting of the SW-80 Sweep Control or by external address advance commands applied to the sweep control unit.

PLOTTER AUTOSLEW provides XY readout of data stored in memory to pen recorder output jacks on rear panel. In this mode, rate of address advance is controlled by an internal readout clock. Readout rate is nominally 10 points per second in data regions where there is no change in Y-axis values from point to point, but where large changes occur between adjacent data points, the readout rate slows to approximately one point in two seconds. Readout rate and slew rate are internally adjustable. See section on internal adjustments. Between these extremes, the time between successive address advances is approximately proportional to the change in deflection voltage.

DIGITAL READOUT is available for initiating wired program digital readout.

DIGITAL READ-IN is available for initiating wired program digital read-in.

GENERAL: All of the above wired program read operations will operate only on the section of memory selected by the READOUT MEMORY ALLOCATION STARTING and SIZE pushbuttons.

CALIBRATE facilitates calibration of X and Y inputs to analog readout devices. HORIZONTAL pushbuttons permit selection of zero (LEFT), center (MIDDLE) or full-scale (RIGHT) X-axis outputs. VERTICAL pushbuttons permit selection of plus full-scale (TOP), zero (MIDDLE) or minus full scale (BOTTOM) Y-axis outputs. Any of nine possible combinations of these X and Y outputs may be selected. Selected deflection voltages appear on both PEN and CRT output jacks on rear panel. The 1080 must be in the WIRED PROGRAM STOP mode for calibration voltages to be enabled.

STORED PROGRAM -- START and STOP pushbuttons allow initiation and termination of operation under stored program control. (See Stored Program Operation section.) The stored program mode cannot be initiated unless the wired program mode is stopped.

ENABLE -- This pushbutton when depressed in conjunction with the CLEAR MEMORY and/or CLEAR SWEEP COUNTER pushbuttons will clear the section of memory being displayed and/or the SWEEPS COMPLETED indicator. The purpose of this pushbutton is to prevent accidental erasure of valuable information.

CLEAR MEMORY -- When this pushbutton is depressed simultaneously with the ENABLE pushbutton, the contents of the memory subgroup selected by the READOUT MEMORY ALLOCATION pushbuttons only will be erased. Operable only in CRT READOUT mode.

CLEAR SWEEP COUNTER -- When this pushbutton is depressed simultaneously with the ENABLE pushbutton, the contents of the SWEEPS COMPLETED indicator is set to zero.

INPUT DATA -- ADD/SUBTRACT pushbuttons determine whether digital data acquired under wired program control are to be added to or subtracted from prior contents of memory (if any) in MEASURE mode.

PROGRAM PROTECT -- When this button is depressed the ILLEGAL MEMORY warning lamp is illuminated when operator selects for display or data storage a non-existent section of memory or the portion of memory in which the stored program instructions are located. It is good practice to keep this button depressed except to display the section of memory reserved for program storage.

VERTICAL DISPLAY SCALE -- Selects the 12 most significant bits of memory contents to be presented to the digital-to-analog converter. The converted analog signal is used for both the Y-axis CRT display and the Y-axis PEN output. Vertical display scale ranges of 4, 8, 16, 32, 64, 128, 256, 512, 1K, 2K, 4K, 8K, 16K, 32K, 65K or 131K counts/division (8 divisions) are switch selectable. This in effect is a digital attenuator control on the displayed data. Memory contents are not affected by the position of this control, only the manner in which they are decoded. It may be used in both wired program and stored program display modes, but must be programmed to be used during stored program operations.

READOUT MEMORY ALLOCATION -- Two banks of pushbuttons permit selection of STARTING address (0, 1K, 2K, 4K or 8K) and SIZE (1K, 2K, 4K, 8K or 16K) of memory subgroup to be used for data readout in any of the wired program READ modes of operation. More than one STARTING address pushbutton may be pushed in order to select a starting address additively up to 15K. These switches also select the section of memory that will be operated on during stored program operation.

AUTOSTOP -- Permits preselection, for automatic stop, of a number of measurement sweeps equal to 2^n, n being any integer from 0 to 20. (Autostop range is selectable from 1 to 1,048,576 in powers of two.) An OFF position enables continuous sweeping until manually stopped. The number of sweeps completed is stored in an auxiliary register and is displayed on the SWEEPS COMPLETED numerical display.

MEASURE MEMORY ALLOCATION -- Two banks of pushbuttons permit selection of STARTING address (0, 1K, 2K, 4K or 8K) and SIZE (1K, 2K, 4K, 8K or 16K) of memory subgroup to be used for data storage in wired program MEASURE mode of operation. Two or more STARTING address pushbuttons may be depressed to select any starting address in integral multiples of 1K up to 15K.

HORIZONTAL DISPLAY SCALE -- Selects the portion of memory to be displayed over full scale horizontal deflection of CRT. Horizontal display scale ranges of 1K, 2K, 4K, 8K and 16K are switch selectable, and can affect both wired and stored display operations without programming.

VIEW INPUT/MEMORY/CONTINUOUS -- Three pushbuttons allow selection of digitized input signal (INPUT), live display of accumulation of data in the memory addresses (MEMORY) or continuously updated display of entire contents of all addresses in the selected memory subgroup (CONTINUOUS) for presentation on the CRT during wired program MEASURE mode of operation.

ADJUSTMENT OF STACK SIZE SWITCH -- The small Printed-Circuit switch at the rear of 1080 Board 2 marked "Stack" adjusts the memory protect electronics of the 1080. The purpose of the memory protect is to prevent the 1080 hard-wired programs from destroying the stored-program. The switch is set by the following table:

1081	4K
1082	8K
1083	12K
1084	16K
1085	20K
1086	24K
1087	28K
1088	32K
1089	36K
10810	36K

HARDWARE DESCRIPTION OF THE NIC-80 SERIES

Nicolet Instrument Corporation
5225 Verona Road
Madison, Wisconsin

(608) 271-3333

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HARDWARE DESCRIPTION OF THE NIC-80 SERIES

I. SETTING UP YOUR NIC-80 SYSTEM

The NIC-80 system, a close relative of Nicolet's popular 1080 system, has all the features of the 1080 system, with a small reduction in costly hardware switches. Many of these same switch functions are available under software control, however. The NIC-80 series includes the NMR-80, the BNC-12 and the LAB-80.

The NIC-80 incorporates the same powerful minicomputer instruction set, utilizing the unique 20-bit word for both instruction and data. Further it has the extremely valuable hardwired averaging mode, which enables data to be collected under wired control exactly as in a classical signal averager. This method allows much more accurate timing between data points, allows faster acquisition speeds and prevents the wasting of valuable program space for averaging programs. It also allows the unique continuous display feature, in which the entire data block can be displayed regardless of sampling rate.

The data system itself is extremely easy to set up, allowing the scientist to begin using it immediately. The minimum NIC-80 system should consist of the following items:

(1) A NIC-80 data processor mainframe
(2) An AC line cord and a collection of BNC-banana cables
(3) A Tektronix oscilloscope
(4) An ASR-33 Teletype or equivalent
(5) A NIC-80 software package
(6) A set of manuals

The NIC-80 is set up as follows:

(1) Connect the AC line cord to the rear of the NIC-80 mainframe.

(2) Connect one BNC-banana cable from the CRT display Y output to the left hand amplifier input on the scope. Similarly connect the CRT Display X output to the right hand scope amplifier. Connect the jack marked INTENSIFY at the rear of the NIC-80 to the BNC connector just above the scope ON-OFF switch. Connect the scope AC line cord to one of the plugs at the rear of the NIC-80. The scope can be calibrated as described under the CL command of the Signal Averaging Package.

(3) Unpack the Teletype and mount it on its stand. Connect the small Teletype power supply unit to the plastic plug hanging from the rear of the Teletype. This power supply should then be grounded to the cabinet using the supplied lugs to connect to small pins in the Teletype stand. The power supply can be hooked to the stand by two attached lugs.

(4) Connect the Teletype "microphone" connector to the NIC-80 rear plug marked Input/Output Device 1. Connect the AC power cord to another of the plugs at the rear of the NIC-80. NOTE: If terminals other than a Teletype are used, they will have a small flat plug which is to be connected to the RS-232 input at the rear of the NIC-80.

(5) If a high speed reader is used, it will terminate in a flat 80-pin connector board having round and square plastic key pins. These are to be connected to the INPUT/OUTPUT slot at the rear of the NIC-80. If other I/O devices such as disk drives are connected, they will go in this slot and the high speed reader will connect at the end of the "daisy chain" of I/O cables.

(6) To actually start up the system, turn the NIC-80 power key-switch to ON and turn the Teletype switch to LINE. If no program has been loaded, it can be loaded as described below. Otherwise, you can begin by depressing the Data Processor Start button on the upper right hand corner of the NIC-80.

(7) Briefly, tapes are loaded by the following procedure:

(a) Be sure that the processor is STOPped.

(b) Set the switch register to 7777(00 000 000 111 111 111 111). This is the position in which the right-hand twelve toggle switches are up, the remainder down.

(c) Depress Load PC and press Execute.

(d) Place the program tape in the tape reader. The arrows should be on the top side, pointing toward you. The reader switch should be in the Free position. Latch the reader cover over the tape and turn the reader switch to Start.

If you have a high speed reader, the tape goes in the right hand bin and the arrows point to the left.

(e) Depress Continue and press Execute. The tape should begin reading in. It will stop at the end of the tape, on a Rubout (all eight holes punched) embedded in the trailer section. The program is now loaded and ready for use.

(f) If the tape does not read in, the loader program, called the Binary Loader, is not present and must be bootstrapped in. Consult the Loading Programs section of the manual or the section in the Programming Manual describing how to load the Binary Loader program.

(8) The connection of various equipment to the NIC-80 is extremely easy. It involves two cables carrying the analog signal and the trigger. In the simplest case, the NIC-80 will accept an ADC input of 2.5 volts full scale and a trigger of 3.5 volts. These are connected to the BNC connector marked ADC INPUT and TRIGGER INPUT. The trigger level and a small dc bias bucking voltage on the ADC are adjustable within the NIC-80. The trigger level adjustment is a small screwdriver adjustable potentiometer in the center of board 7, and is so marked on the rear of the board. The DC level pot is located on board 9, and is the fifth pot from the back of the board. The numbers of the boards are given on the front corner, on the left side of the boards. All of the processor boards are located on the left side of the NIC-80. The memory is located on the right.

The sensitivity of the ADC is fixed in the NIC-80, but a variable input attachment, including 4-pole Butterworth filters, is available in the NIC-301. Consult the factory for details.

If you wish to signal average asynchronously, or at a rate determined by an external clock, the clock should be connected to the BNC connector marked Address Advance.

Your NIC-80 should now be ready for use.

II. FRONT PANEL DESCRIPTION OF THE NIC-80 SYSTEM

Pushbuttons

On the bottom of the NIC-80 there are seven rectangular pushbuttons which stay in when pressed and two square buttons, marked Execute and Stop, which do not. When one depresses one of the seven buttons he indicates which function he wishes to perform. Pressing Execute actually causes this function to be performed.

Directly above the pushbuttons are 20 toggle switches, called the Switch Register. Twenty bit binary numbers can be represented in the Switch Register, where the up position represents a one and down a zero. These switches can be used to specify memory addresses and data to be deposited in memory. The use of these switches is discussed in detail below. They are shown in the photograph on page

LOAD PC -- Depressing this button, followed by pressing Execute causes the contents of the Switch Register to be transferred to the Program Counter (or PC). This value is also loaded into the AC at the same time, although this is of little general use.

CONTINUE -- Pressing Execute when this button is depressed causes the Stored Program processor to begin interpreting instructions at the address specified in the Program Counter. Thus, using the combination LOAD PC, Execute, CONTINUE, Execute, the processor can be started at any address.

START -- This button causes the processor to begin executing instructions at location Ø. It is equivalent to loading the PC with 0000000 and then pressing CONTINUE followed by Execute. One can also start programs at location zero using the Stored Program Start pushbutton at the upper right of the NIC-80 console.

SINGLE INS -- If the processor is running, depression of this button will cause it to stop at the end of whatever instruction it is performing. Then, each time Execute is depressed the processor will execute one instruction. One can execute single instructions from any arbitrary address by loading the PC with that address, depressing SINGLE INS, and then pressing Execute once for each instruction to be executed.

EXAMINE -- The contents of the location whose address is in the PC are loaded into the AC for examination. If a number of sequential locations are to be examined, the red button STEP should be depressed. STEP causes the PC to be incremented automatically, so that each time Execute is depressed the next sequential location is displayed in the AC.

DEPOSIT -- The contents of the Switch Register are loaded into the memory address specified in the PC. Thus, to deposit a number in memory, one sets the address into the switch register and depresses LOAD PC followed by Execute and then sets the desired number into the switch register and depresses DEPOSIT followed by Execute. As before, if STEP is depressed, the PC will be incremented automatically allowing the next sequential memory location to be modified by simply setting the next number into the switch register and pressing Execute again.

Function of the Connectors on the NIC-80 Rear Panel:

SENSE1 SENSE2	These connectors are used to accept a TTL compatible signal. If that signal is high the software commands SENSE1 and SENSE2 will cause skips.
PEN LIFT	This connector provides the pen lift signal for the plotter. It is an open switch with a current rating of 250 ma and a voltage rating of 40V. The relay is closed and opened under software control.
INTENSIFY	This connector provides the intensify signal for the oscilloscope, to modulate the Z axis.
PEN RECORDER	These connectors provide the signals for the horizontal and vertical plotter inputs. X = -1.5 to +1.5V, Y = 0 to 1V.
CRT DISPLAY	These connectors provide the signals for the horizontal and vertical oscilloscope inputs. X = 0 to 10V, Y = -5 to +5V.
PULSE1, PULSE2	These connectors provide a 400 nsec pulse under program control.
REMOTE ADD/SUB INPUT	This connector overrides the Control Word if the ADD bit is set. When this connector is grounded, the Subtract Data mode is set.
REMOTE STOP INPUT	When this connector is grounded a return to the Data Processor mode from the Measure mode will occur at the end of the current sweep.
SWEEP FLAG OUTPUT	This connector goes high when a sweep is in progress.
ADC INPUT	This connector accepts a -2.5 to +2.5 input voltage.
ADDRESS ADVANCE	This connector accepts a TTL signal for the external advance of the current address, providing for asynchronous data acquisition.
SWEEP TRIGGER INPUT	This connector accepts a 3.5 volt signal for the start of the sweep. Trigger can be on either the rising or falling edge of the signal depending on the setting of the control word.

NIC-80 HARDWARE COMMANDS

4002	PENLFT	AC0 (0 = pen up, 1 = pen down) AC1 (0 = plotter output clamp, 1 = plotter output enable)
4372	STDG	Start Digitizer
44374	RDG	Read Digitizer into AC
4032	ASCNTR	Increment Sweep Counter LED Display
6362	DWSK	Skip on Dwell
4031	RSCNTR	Reset Sweep Counter to 0
4311	LDWELL	Load Dwell Time Clock from AC
4312	LDELAY	Load Delay Time Clock from AC
6314	OVSK	Skip if any memory word has become more than 15/16 full during last Measure sweep. Cleared when tested. Must be called before first Measure to initialize. Ignore this first result.
4301	SETKNB	Select Knob A if AC0 = 1, Knob B if AC0 = 0
4302	SETM	Set Measure Flag. Starts wired measure program when STOP is given.
4304	LCWORD	Load control word from AC bits 0 - 16
4102	PULSE1	Pulse 1 out to rear panel connector, 400 nsec long
4104	PULSE2	Pulse 2 out to rear panel connector, 400 nsec long
6112	SNS1SK	Skip if Sense 1 input is high
6114	SNS2SK	Skip if Sense 2 input is high

CONTROL WORD BIT ASSIGNMENTS

Bit #	Function Name	Bit = 1	Bit = 0
0	Measure Add	Add data	Subtract data
1	Address Advance	Internal	External
2	Trigger	Positive Slope	Negative Slope
3	Recur	Auto Recur	Triggered Sweep
4	View	View Memory	View Input Signal
5	Continuous (overrides bit 4)	Continuous Display	Bit 4 in control
6	Multichannel Scaling	Enable MCS (w/NIC-301)	Signal Averaging Mode
7	Readout Light	On	Off
8	Compute Light	On	Off
9	Enable Clock for DWSK	On	Off
10	Digitizer Resolution)	00=12 bit 10 = 8 bit	Active only when front
11	Digitizer Resolution)	01 = 10 bit 11 = 6 bit	panel switch is set to Computer Control
12	Dual Input	Dual	Single
13	Inhibit Input A Display	View B	If both bits 13 and 14 are
14	Inhibit Input B	View A	high, both inputs will be shown overlapped
15	Transient Recorder	Transient Recorder bits 3 & 5 must be 0	Normal
16	Homodecoupling Mode	Starts dwell signal running. Trigger only at dwell times (must be in Auto Recur mode)	Normal

III. DESCRIPTION OF THE NIC-80 WIRED PROGRAM FEATURES

The preceeding sections have described the hardware features of the NIC-80 system. Since many of the hardware features require some software control to operate, this section describes simple programs for testing these features.

Parameter Knobs

The following program starts at Ø and reads Knob A or Knob B into the AC. Its value is thus displayed on the accumulator register. Knob A is read until B is struck on the Teletype, Knob A is again read if A is struck.

```
                            *Ø
Ø      110200               MEMA (200      /INITIALIZE CONTROL WORD
1        4304               LCWORD
2     2110012 ST1,          MEMA KNOB      /LOAD KNOB MULTIPLEXER
3        4301               SETKNB
4        4373               STDG           /START DIGITIZER
5        5000               RASH           /WASTE 10 USEC
6        5000               RASH
7        5000               RASH
10      44374               RDG            /READ DIGITIZER
11       6454               TTYRF          /TELETYPE STRUCK?
12          4               JMP # -6       /NO, GO BACK
13      44453               RDTTY          /YES, READ
14     462301               A-MZ ("A       /WAS CHAR AN "A"?
15     160000               ZERZ           /NO, SKIP
16    2024023               ONEM KNOB      /YES - SET KNOB = 1
17     462302               A-MZ ("B       /WAS CHAR A "B"?
20          2               JMP ST1        /NO, GO BACK
21    2164023               ZERM KNOB      /YES - SET KNOB = Ø
22          2               JMP ST1        /AND RELOAD MUX
23          Ø KNOB, Ø
```

Measure Mode

The measure mode of the NIC-80 is a true wired signal averager mode with all of the versatility and stability of such a mode. However, it can only be entered by software command. The following small program is provided for testing the various bits of the status register. It uses three control words located at the end of the program for determining dwell time, delay and triggering features. Suggested control word values for various function tests are given. The program cycles continuously until stopped. It starts at address 100.

Both the DWELL and DELAY registers are 20-bit registers loaded from the accumulator and indicate the number of microseconds per point and the number of microseconds between trigger and the onset of measure.

```
                                /MEASURE MODE TEST
                                *100
100      4031                   RSCNTR         /RESET SWEEP COUNTER TO Ø
101   2110112                   MEMA DELAY     /LOAD DELAY REGISTER
102      4312                   LDELAY
103   2110113                   MEMA DWELL     /LOAD DWELL REGISTER
104      4311                   LDWELL
105   2110114                   MEMA CWORD     /SET CONTROL WORD
106      4306                   LCWORD SETM    /LOAD CONTROL WORD AND SET MEASURE
107      5220                   STOP           /STOP PROCESSOR AND ENTER MEASURE
110      4032                   ASCNTR         /ADVANCE LED SWEEP COUNTER
111       101                   JMP 101
112         Ø    DELAY,         Ø              /ZERO DELAY
113       144    DWELL,         144            /100 USEC DWELL
114        46    CWORD,         46             /IA+PT+CD
```

To vary the dwell time change location 113 as suggested below. To vary the delay analogous changes should be made on location 112.

Setting	USEC Per Point
1	1
12	10
144	100
1732	1000

Varying the Control Word

The NIC-80 control word controls various parameters concerning display and triggering as shown below:

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
HOMO	TRANS	INHIBIT B	INHIBIT A	DUAL	DIGITIZER RESOLUTION		ENABLE CLOCK	YLW	RED	MCS	CD	VM	AR	PT	INT ADV	SUB

To test various functions, load location 114 of the above program with the indicated values.

Trigger and Display Tests

	CWORD
Positive trigger - continuous display - internal advance - add data	46
Positive trigger - view memory - internal advance - add data	66
Positive trigger - view input - internal advance - add data	6
Negative trigger - continuous display - internal advance - add data	42
Positive trigger - continuous display - internal advance - subtract data	47
Auto recur - continuous display - internal advance - add data	56
Auto recur - view input - external advance - add data	10

Digitizer Resolution Tests

All use AR + CD + IA + AD

	CWORD
12 bit	56
10 bit	1056
8 bit	2056
6 bit	3056

Dual Input Tests

If your NIC-80 has both inputs built in(check board 9) you can test the dual input mode as follows. The total data size is twice that selected by the buttons. Points are acquired the same instant using two sample-and-hold circuits and digitized sequentially. All codes below assume 12 bits + AR + CD + IA + AD.

	CWORD
Display input A only	30056
Display input B only	50056
Display both inputs overlapped	10056

Homodecoupling Mode

During homodecoupling mode, the dwell time clock runs continuously during both Measure and program control. The computer must be in the Auto Recur mode.

To test this mode, set the control word to

200056

Test of Pulse 1 Pulse 2

The connectors at the rear of the NIC-80 marked PULSE1 and PULSE2 produce 400 nsec TTL pulses upon command. The following program will produce a 400 nsec pulse every 13.2 + [2(N-1) * 3.3] μsec. If location 3 is changed to 4104 PULSE2 comes out instead.

```
                      *Ø
Ø    2110005          MEMA N      /GET COUNTER VALUE
1     552000          AMOAZ       /DECREMENT UNTIL ZERO
2          1          JMP# -1     /SKIP WHEN AC = Ø
3       4102          PULSE1      /ISSUE PULSE - MAKE 4104 FOR PULSE2
4          Ø          JMP Ø       /THEN GO BACK
5          2   N,     2
```

Test of Sense 1 Sense 2

The connectors SENSE1 and SENSE2 will cause the software instructions SENSE1 and SENSE2 to skip when a high TTL level is connected to these connectors. These connectors have no "memory," and a very short pulse can only be detected in a tight loop. The following program changes the state of the AC from all lights on to all off and vice-versa whenever a high level is detected at the sense connector 1.

```
                *Ø
Ø    0170000    ZERA        /SET AC = Ø
1       6112    SENSE1      /SKIP IF INPUT HIGH
2          1    JMP# -1
3    0210000    ACPA        /COMPLEMENT THE AC
4          1    JMP 1       /AND WAIT FOR NEW LEVEL
```

The SENSE2 connector may be tested by changing location 1 to 6114.

IV. NIC-80/BIOMATION 8100 DATA ACQUISITION

Interconnections

Interconnection between the Biomation 8100 Transient Recorder and the NIC-80 computer system is made by way of two cables. One cable is a multi-conductor cable and connects between the NIC-80 rear panel connector labeled TRANSIENT RECORDER, and the multi-pin connector on the rear of the Biomation 8100. The second cable is a single conductor coax cable with a BNC connector on each end. One end of this cable connects to the NIC-80 rear panel BNC labeled SWEEP FLAG OUTPUT. The other end of this cable connects to the 5 VFS ARM input on the Biomation 8100.

Operation

Biomation 8100 Set-Up

1. Initially, prior to any series of sweeps, momentarily depress the OFF pushbutton in the OUTPUT section. The AUTO pushbutton should next be depressed and left in that position. Any time thereafter, if the system should get into a locked up state and will not commence to measure when commanded, momentarily depress the OFF pushbutton and then back to AUTO. This will recycle the circuitry in the 8100 and leave it in the appropriate state to take data.

2. Switch ARM MODE to INPUT and ARM SOURCE to EXT. Select ARM SLOPE +. Set ARM DELAY to 000 and LEVEL to +3.

3. All other switches will be set according to the particular experiment conditions.

NIC-80 Set-Up

1. Select either 0 or 2K starting memory group and 2K memory size. 2K memory size must be selected in order for proper operation to occur.

2. Assuming the proper program has been loaded into the program memory, a series of sweeps may now be initiated by typing GO on the Teletype. (Refer to LAB-80 program instructions.) The 8100 will be armed from the NIC-80 and begin a measure sweep when the next trigger arrives. At the end of the 8100 sweep, the transient recorder will switch to digital dump and the transfer mode will begin. Data from the 8100 memory will be transferred to the NIC-80 memory at a 3 µsec/address rate. When all 2048 addresses have been transferred, the NIC-80 will re-arm the 8100 and a new sweep may be triggered. Because of the extremely high transfer rate, no x-y output is presented to the CRT during the measure mode.

V. NIC-301 SIGNAL CONDITIONER

General

The NIC-301 Signal Conditioner unit is designed to be used in conjunction with the NIC-80 computer system. The signal conditioner has four basic sections which may be purchased as options as requirements dictate. These four sections are:

(1) The analog signal conditioner(s). This section may involve either one, or two identical sections if two inputs are to be utilized.

(2) The trigger conditioner.

(3) A measure address proportional ramp generator.

(4) Multi-channel scaler circuitry.

All signal communication between the NIC-301 and the NIC-80 are made between rear panels via BNC cables and I/O connector. Power is supplied by the NIC-80 power supply through a power umbilical cable between rear panels.

Analog Signal Conditioner

1. Connections

The analog signal is connected either to the front panel or rear panel BNC connectors marked either input 1 or input 2 if two inputs are being used. The BNC connectors are connected to provide differential input. The center terminal is the non-inverting input and the outside of the BNC is connected to the inverting input amplifier. To connect to a single ended output the inverting input (BNC outside) is normally connected to ground. Any of the NIC-301 BNC connectors other than the analog signal inputs have their outside shield connected to system ground. The differential input can be used to eliminate common mode signals (-80 db rejection) that are carried on the analog signal lines.

The output connection for each input section is located at the rear panel. The signal at this point is single ended. The gain of the system is such that if the input analog voltage equals the VOLTS FULL SCALE switch setting, and is not being attenuated by the filters, the output voltage will be 5 volts, which is the input requirement of the NIC-80 ADC.

A shielded BNC connector cable should be used between the NIC-301 rear panel BNC input 1 or 2 output connector and the NIC-80 rear panel input labeled ADC input 1 or 2.

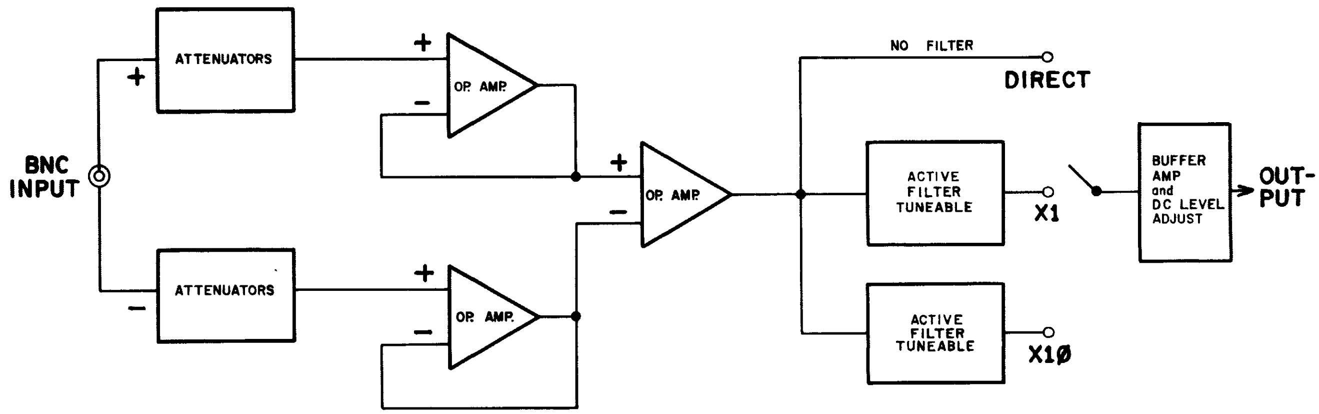

Figure 1.

The amplitude of the differential input signal can range from ±250 millivolts to ±16 volts for full scale input. The full scale signal voltage should be close to one of the indicated settings of the FULL SCALE VOLTS switch so that the maximum dynamic range of the digitizer is utilized. The differential input will reject common mode voltages which can be up to ±20 times the full scale input with an absolute maximum of ±50 volts. The input impedance is 400K ohms balanced, or 200K ohms unbalanced.

2. Controls

VOLTS FULL SCALE -- This control, variable from ±1/4 volt to ±16 volts, determines the maximum input signal amplitude required to produce a full scale number of counts from the analog-to-digital converter in the NIC-80. This switch and the RESOLUTION switch on the NIC-80 determine the relationship between the sampled input voltage and the number of counts representing that voltage and is expressed

$$\frac{\text{Counts}}{\text{Volt}} = \pm \frac{2^{R-1}}{\text{VFS}}$$

where R is the number of bits determined by the setting of the RESOLUTION switch on the NIC-80, and VFS is the setting of the VOLTS FULL SCALE switch. The plus or minus sign is determined by the polarity of the input signal. The GND position of this switch disconnects the input signal and connects the inputs of the operational amplifier to the common terminal.

D.C. LEVEL -- This ten-turn control permits a dc voltage to be added to or subtracted from the input signal. This allows cancellation of unwanted bias voltages present on the input signal and also provides for offsetting the digital converter. For example, if the input signal is all positive and has a reasonably good signal-to-noise ratio, subtracting a dc voltage from it with this control and reducing the attenuator setting will improve the resolving capability(resolution) of the analog-to-digital conversion process. This control along with the VOLTS FULL SCALE switch should be adjusted so that the maximum positive and negative excursions of the time domain signal come close to but do not exceed the full scale range of the digitizer as viewed on the CRT in the View Input mode of operation.

INPUT FILTER -- This is one of the more important controls of the data acquisition system from the standpoint that the selection of the input filtering network can grossly affect the accumulated time domain signals from a signal-to-noise standpoint as well as the effect upon the frequency dependent phase and amplitude characteristics of the transformed data. A sharp cut-off, low pass filter is essential. For optimum results the cut-off frequency of the filter should be set close to or slightly greater than 1/2 the sampling frequency. The sampling frequency is equal to the spectral width entered or 1/2 1/t where t is the dwell time setting entered into the NIC-80.

Each NIC-301 input contains two tunable 4-pole low-pass Butterworth plug-in filters with controls which allow selection of the cut-off frequency from 100 to 50,000 Hertz in 29 steps. (See Technical Data Sheet C050-50-5/70 of Analog Devices, Inc., Cambridge, Massachusetts for complete description and specifications of filters.)

If an external filter, or no filtering is used, the DIRECT mode should be selected.

3. Input Specifications

Inputs: One or two inputs, each balanced, 2-wire BNC connectors. Minimum input impedance 400K ohms balanced, 200K ohms unbalanced. Common mode rejection of 20 times full scale input with an absolute maximum of 50 volts.

Input Signal Range: ±1/4, ±1/2, ±1, ±2, ±4, ±8, ±16 volts full scale, switch selected for each input.

Input Filtering: Four-pole Butterworth low-pass filters having selectable cut-off frequencies of 100, 120, 150, 200, 300, 400, 500, 600, 700, 800, 1000, 1200, 1500, 2000, 3000, 4000, and 5000 Hz with multipliers of 1 and 10 each input.

D.C. Level Adjustment: Permits a dc bias voltage of ±100% of full scale to be added to each input signal. Level selected by means of a ten-turn precision potentiometer. Drift less than ±0.05% of full scale per hour at constant temperature. At the 5.0 setting of the potentiometer there is no added DC level, at 10.0 a full scale positive voltage is added and at 0.0, a full scale negative voltage is added.

Trigger Input

The trigger circuitry of the NIC-301 provides the user with the capability of selecting trigger level and also trigger polarity. The 301 provides a pulse out with the proper requirements to trigger the NIC-80 sweep when the trigger threshold is reached. The NIC-80 must be programmed to accept positive triggers for the system to operate properly. At the moment the input signal passes through the trigger threshold, a +4 volt pulse is presented at the rear panel "trigger out" BNC. This pulse is approximately 10 microseconds wide.

When the front panel toggle switch is on the "+" position, the trigger pulse will occur when the input voltages rises through the threshold setting. When the switch is in the "-" position, the trigger will occur when the input voltage falls below the threshold setting.

The range of the trigger threshold is from -5V to +5V with at least a 10 times safety margin.

Refer to system interconnection block diagram for proper interconnection of trigger signal.

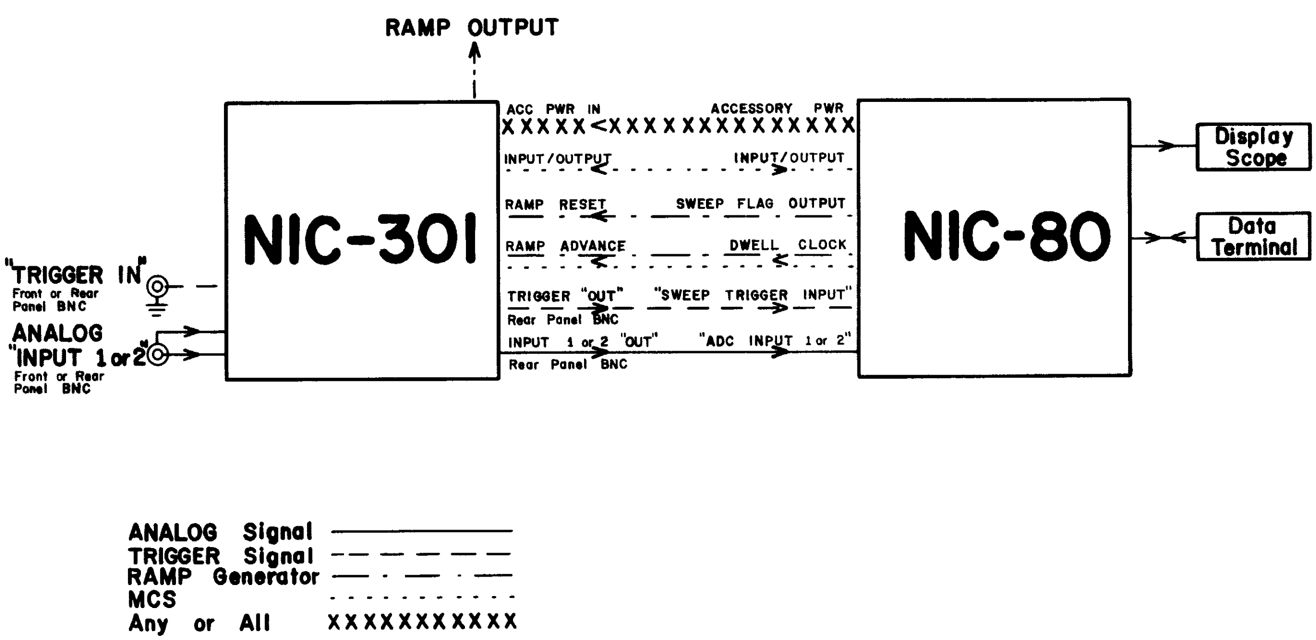

Figure 2

Ramp Generator

The function of the ramp generator is to produce an analog output voltage proportional to the address number during a measurement sweep. The voltage produced can start at 0 or +10 volts at the beginning of a sweep and go to +10 volts or 0 at the end of the sweep, as selected by an internal switch.

A rear panel switch selects the number of steps that are required to get to full scale. This switch should be set to equal the number of memory addresses selected on the NIC-80(i.e., 1K, 2K, 4K, 8K or 16K). If fewer than 16K data addresses are used the voltage ramp can be attenuated by setting the rear panel switch to a higher value than the number of addresses actually being used.

See system interconnection block diagram for proper interconnection when using this mode of operation.

Multi-Channel Scaling

Use of the MCS capability of the NIC-301 enables the NIC-80 to be used as a multi-channel scaler instead of an analog signal processor. In this case, the NIC-301 counts pulses for the dwell time period selected on the NIC-80. At the end of this period, the number of pulses that has been counted in that period of time is stored in the current memory address and the next counting period begins. This sequence continues throughout the preselected number of memory addresses. The number stored in each address is therefore proportional to the pulse frequency at the input during the time the machine resided in each address.

To enable the MCS mode, bit 6 of the control word in the NIC-80 has to be set to a "1". This disables the NIC-80 ADC assuming the NIC-80 has been prepared for MCS operation. The NIC-301 rear panel switch needs to be switched to "Enable MCS" and the proper interconnections made as shown on the system interconnection block diagram. The system should now be ready for MCS operation.

The pulse input should be from 0 to +3 to +10V. A pulse is counted whenever the voltage rises from ground to a positive voltage. Any frequency up to 10 MHz may be counted. Any number up to 2^{20} may be counted before memory overflow occurs.

If analog signals are to be processed be sure to switch the rear panel switch from "Enable MCS" as there can be some conflicts if both modes are selected simultaneously.