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INSTRUCTION MANUAL FOR MODEL DIGITAL OSCILLOSCOPE WITH MODEL [redacted] INPUT UNITS

MARCH, 1974

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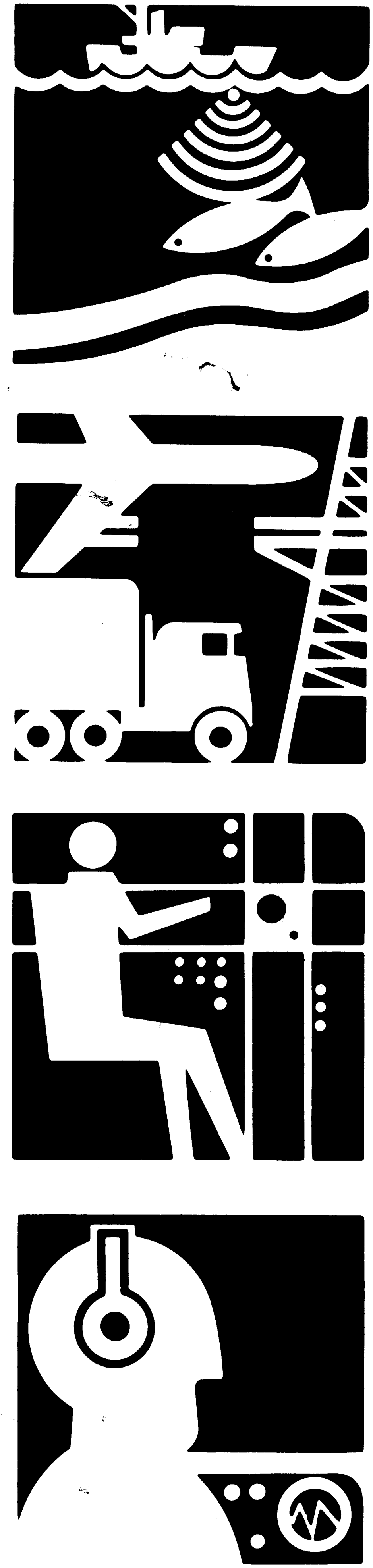

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MODEL 1090 DIGITAL OSCILLOSCOPE

I. INTRODUCTION

The digital oscilloscope is designed for use in applications in which conventional analog oscilloscopes have been used, but where high resolution and accuracy are desired. There are numerous benefits to the use of digital rather than analog circuits beyond the precision available. One of these is easier operation, and it is a purpose of this operator's manual to point out the ways in which the easiest operation can be realized. With little doubt, increasing use will be made of digital methods in oscilloscope design in the future so time spent in understanding this oscilloscope is worthwhile beyond learning the behavior and operation of this particular instrument.

II. GENERAL DESCRIPTION OF OPERATION

A. General

Unlike conventional oscilloscopes, the waveform display shown on the cathode-ray-tube (CRT) screen is not directly produced by the input signal voltage. The beam is controlled digitally from information previously recorded in memory. The information stored in memory was received from an analog-to-digital converter which measured the input signal at typically 4096 times following the start of the sweep.

The recording of digital signal information in memory is a process which is used in many instruments such as signal averagers and control computers. The display of information previously recorded in this way is also familiar. There are certain differences in the way this is handled in this instrument because an important requirement is that the device have the essential characteristics of an oscilloscope, in particular a storage oscilloscope.

One difference in the recording and display processes results from the desirability of showing each signal waveform as it occurs, at times; and at other times to hold a particular waveform for prolonged examination by the operator. This is different than most other signal recorders in which a particular signal is recorded and held until the operator takes specific action to allow it to be replaced. In this instrument every signal is recorded (with certain exceptions to be described), during one mode of operation called the released mode. Each new signal is measured and the voltage information replaces in memory that of the previous signal, in this mode. The stored information is read from memory and displayed continuously, so if signals do not occur frequently the display is nevertheless steady. The released mode therefore provides for the display of waveforms just as for conventional non-storage oscilloscopes except that the waveform can be shown in the intervals between signal occurrences.

The other basic operation mode is the hold mode. Depressing one of the two hold pushbuttons causes the last previous signal, or the next signal, to be held and thereafter displayed steadily until the release pushbutton is depressed.

Aside from this choice of hold or released operation, and the controls used in choosing the display scale and position, the oscilloscope operates conventionally. The sweep triggering, sweep speed selection, voltage sensitivity and d. c. level adjustments are conventional, from an operator's point of view. The display scale and position controls are different than for a non-digital oscilloscope although they have their direct counterparts. In most analog oscilloscopes there are provisions for magnifying the horizontal scale and for selecting which portion of the signal will be magnified. In the digital oscilloscope the effect and the way in which the controls are operated are very similar but they may be used for examining different parts of the waveform after, as well as during the recording processes. Vertical expansion of scale is available, also, but ordinarily is not accomplished by changing the gain of the input amplifier. It is accomplished by digital means, and the scale may be changed during or after the recording processes.

The vertical and horizontal resolution of the information (when using either the model 90 or 92 input unit) is 4096 × 4096 resolution elements. This resolution, combined with the ability to magnify the display scale during or after the signal occurrences, can be used to real advantage compared with the case of an analog storage oscilloscope, because all regions of even very complex singly occurring signals can be captured and examined in detail. The detailed descriptions of the use of the display controls and others is given in a later section.

A numeric display of voltage and time information recorded is provided, with the values normalized to take into account the voltage range switch setting and the sweep speed switch settings. This, of course, makes the instrument accuracy completely independent of the CRT accuracy.

There are provisions for making pen recordings of the stored waveforms, as well as for readout into a digital magnetic tape recorder, and also for reading from digital tape back into memory.

B. Measurement and Recording

The "sweep" of an analog oscilloscope is a descriptive name derived from the fact that the CRT beam sweeps across the screen once each time the triggering signal occurs properly. Once during each sweep, the signal is displayed because the vertical deflection is controlled by the voltages present at the input terminal during that sweep.

The "sweep" of the digital oscilloscope is a term more loosely used. It refers to all of the processes involved during the measurement and recording of a signal, following a valid sweep triggering pulse. A modification of the term is needed; it is more properly called a measurement sweep to distinguish it from the display sweep, during which the CRT beam is actually sweeping across the CRT screen. (The display sweep processes will be described later.) The term "sweep" will be used when referring to a measurement sweep; when a display sweep is being discussed this will be made apparent.

After a trigger pulse initiates a sweep, digital timing circuits produce a series of (typically) 4096 timing pulses, separated by a specific period of time chosen by the sweep speed selector switch settings. Each pulse causes an analog-to-digital converter to sample and measure the input signal voltage, and each measurement result is recorded in the 4096 word (12 bits/word) memory, replacing previously recorded information word-by-word as needed. After 4096 samples the process ends until the next sweep is triggered. The processes involved usually occur concurrently with certain display processes, and many circuits are shared, but measurement processes always have priority. The measurement and recording processes can be considered to be entirely independent of the display processes, despite the time sharing of the memory and other circuits.

The measurement which follows each timing pulse involves first a sample and hold operation, then an analog-to-digital conversion, then a memory storage operation. The sampling, and storage processes, require different amounts of time depending on the plug-in used. Where necessary, these steps may be concurrent with the next measurement process. After the 4096 measurements, the sweep ends, until the next triggering signal.

C. Data Display

The display operations time share some of the circuitry used in data recording. Except for the fact that there must be interruptions for measurement recordings, the display operations are independent of the measurement processes, so they will be discussed independently.

The generation of an unexpanded display of the recorded waveforms is straightforward. The memory is read out address sequentially, and for each coordinate a point is plotted at a vertical position proportional to the recorded voltage value, and at a horizontal position proportional to the address number corresponding.

Following one complete display sweep, a vertical and horizontal marker line is drawn, as will be described, and a numerical display showing the voltage-time coordinates of the waveform point intersected by the vertical marker line is generated. (If the instrument is in the released mode, the markers and numerical display are deleted because these are too time-consuming to generate concurrent with measurements.)

The expanded display is generated by digitally magnifying the voltage and time values about the intersection of the vertical and horizontal marker positions. The process is simple enough from a mathematical point of view; the voltage and time values are multiplied by the selected magnification constants after first subtracting suitable constants from the ordinate and abscissa values. The revised values are presented to the display circuits. The information in memory is not altered by these arithmetic operations. From a hardware point of view this process would be very complicated. However, use is made of a data processing computer which can handle arithmetic problems by use of software (use of a set of simple computer programs which control the processing steps).

The software (program) is contained in a read-only memory, and operation is automatic so that you need not be aware that there is a digital computer involved. The computer is also used in converting the binary voltage and time values to decimal form, and in controlling the CRT beam during the writing of the numerical display and marker lines, as well as for normalizing the voltage and time values according to the settings of the sweep speed and voltage range switches.

The inputs to the processor include:

(1) The data from memory, and the addresses corresponding,
(2) The input range switch setting,
(3) The sweep speed switch settings,
(4) The vertical and horizontal display scale expansion factors,
(5) A constant selected by use of the vertical position switch,
(6) A constant selected by use of the horizontal position switch,
(7) A constant indicating the size of the memory section in use.

The structure of the processor is of course quite special because of the need to make several computations for each point plotted, in as short a time as possible. A detailed discussion of that structure and the programs involved is beyond the scope of this manual.

D. Display Priorities

In the case of the faster sweep speeds, each such single display sweep occurs after the entire signal has been recorded. But for sweep speeds of 100 μsec or greater, the display sweep proceeds during the signal occurrence. The reason for the difference is that during the faster sweep speeds there is insufficient time to complete the computations involved in plotting each data point until the signal has been recorded entirely. To the observer, the display is quite indistinguishable from a true real-time display. The continuous display causes the memory to read out almost continuously, though this readout must be interrupted whenever the memory is needed for data recording.

There is a situation in which readout, rather than measurements, has priority. This is at fast sweep speeds when signals recur one immediately after another. To give complete priority to measurement operations in this case would result in no display at all because the measurement priority could always prevail. For this reason, after every signal involving 50 μsec sweep speeds or less, the readout circuits are given priority for sufficient time to complete one display sweep, after which priority is restored to the measurement processes. The effect of this is that some signals may be blocked; there is a dead time after each signal equal to about 50 μsec plus 11 μsec for each point displayed. The number of points displayed may be as few as 16 and as many as 4096 depending upon the horizontal display expansion in use. It is rare that this effect could be of consequence, but if it is, it should be minimized by using a high magnification in the horizontal direction. Further remarks concerning the effect of this dead time are given in the section concerning remote control.

E. Input/Output Capabilities

1. Pen Recordings

The instrument provides horizontal and vertical drive voltages of nominally 0 - 4.5 volts for operating a pen recorder. The readout rate is constant, but adjustable by means of a control on the rear panel, from about 2 to 15 coordinate values per second. The output impedance is nominally 10,000 ohms, and any pen recorder having high input impedance, adjustable gain and d.c. level offset, and adequate pen slew rate, may be used. Output resolution is approximately 0.1%.

2. Digital Output

This instrument is compatible with the Nicolet Model 283A magnetic tape interface and control unit, which interfaces to a magnetic tape unit. The output format is industry compatible, and includes two three-byte (18 bits total) file markers. One identification number is thumbwheel selected, the second can be the consecutive file number. Either number can be used in automatic searching of the tape for a particular waveform record, when it is desired to read that waveform back into the oscilloscope.

III. OPERATING PROCEDURES

A. Initial Operation

1. Power

The power supply for the 1090 digital oscilloscope is a DC to DC converter type in which a line voltage from 100 VAC to 260 VAC is rectified and filtered, thus producing a DC voltage of 140 to 370 VAC. This DC voltage is then converted to the usable internal voltages by a 20 kHz converter. The duty cycle and frequency of the converter are determined by the oscilloscope power requirements. The immediate output voltages of the converter are semi-regulated; thus, series regulators are used for further regulation and smoothing on all supplies except the +5 volt supply. The overall efficiency of the converter and regulators is about 70%. The use of a converter type supply not only improves efficiency of the instrument but also reduces the weight significantly. Power source restrictions are also much less severe. In the 1090 a power source of 140 VDC to 370 VDC or 100 VAC to 260 VAC 45 to 440 Hz will supply the 1090 converter quite satisfactorily.

2. Temperature

For best long term reliability, this unit should not be operated in temperature environments of over 110° F, for extended periods of time. Shortening of trouble-free life can occur if operated above this rated maximum temperature, although each unit has been tested for proper operation in environments above 130° F. Temperatures above 110° F are not usually encountered in oscilloscope use, except if the instrument is operated on top of other equipment which is hot, so that situation should be avoided.

The d. c. stability of the instrument is an important factor whenever very slow sweep speeds are involved. For best results the temperature should be constant, preferably within a range of ten degrees. The effect of instrument self-heating is such that where stability within 0.1% of full scale is desired, the instrument should be turned on for a few minutes before a measurement involving very long sweep times is started.

3. General

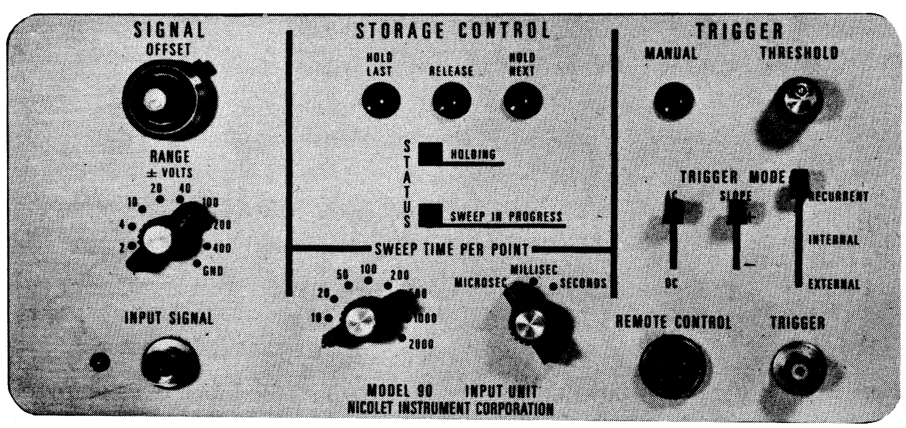
One probe and one trigger pulse cable have been provided. Other oscilloscope signal probes may be used, including those having built-in attenuators, if the probe is designed to operate into a one megohm impedance. The accuracy of attenuation should be checked, and it should be kept in mind that data normalization does not include the effects of external attenuators.

The voltage maximums for the signal and trigger inputs should not be exceeded (see specifications). After this has been assured, the instrument may be turned on, and may be operated according to the instructions below.

4. High Voltages

Voltages dangerous to life are involved in some of the circuits of the oscilloscope. It should not be operated with the covers removed, without suitable precautions.

B. Use of the Controls, Model 90 Input Plug-In Unit



1. <u>General</u>

Most of the controls have obvious functions, and you should be able to operate the oscilloscope without difficulty without further reading. However, for best results it is advisable that this discussion be read so that the instrument be understood in detail. Some of the special techniques described below are not obvious, and may prove time saving to you.

2. <u>Storage Control</u>

The release and hold pushbuttons initiate changes in operating mode. When the instrument is in the hold mode, the display shows the memory contents, marker lines, and (if in use) the numerics. It will not respond to sweep trigger signals. In the released mode the instrument will respond to sweep trigger pulses. During sweeps the display will usually show the signal waveforms corresponding; to insure this, switch to continuous display.

When first learning to use the instrument you should place certain main frame and plug-in unit controls in the following positions, in order to most easily observe the effects produced by using the storage control pushbuttons:

Expansion switches -- Off.
Trigger Mode switch -- External. Remove trigger input cable.
Sweep time -- 10 μsec per point.
Signal offset -- about mid-range.
Display switch -- y/t.
Numerics switch -- Coordinates.
Memory switch -- All.
Input signal -- Clip onto any low frequency voltage source having peak amplitudes of roughly ± 1 volt.
The other switch settings are not important at present.

Now press the Release pushbutton. Both status lights will be off. Press the Manual Trigger pushbutton. The Sweep in Progress lamp will momentarily light, and the voltage waveform will be displayed. Press the Hold Last pushbutton. The same waveform will be shown continuously, and pressing the manual trigger pushbutton will produce no effect. You have caused the signal corresponding to the last sweep to be held and displayed.

Now release the oscilloscope again, and press the Manual Trigger a few times to observe the display. Now press the Hold Next pushbutton. When you again press the Manual Trigger pushbutton another sweep will begin, after which the Hold mode will occur automatically and the stored waveform will be shown. You have caused the next signal, following touching the Hold Next pushbutton, to be held.

A significant point is that the term "hold last" refers to the last signal to have started before touching the button. You may, therefore, elect to hold a signal even if the sweep has already started. Switch to a one millisecond/point sweep speed and try this. Trigger a sweep without pressing a Hold pushbutton. No hold action occurs. Now trigger another sweep and before the sweep ends, press the Hold Last button. When the sweep ends, the hold condition will occur. Release the instrument again, trigger a sweep, and in mid-sweep press the Hold Next pushbutton. At the end of the sweep there will be no hold condition, but if you trigger another sweep, the hold condition will occur at the end of that sweep. You can profitably experiment with the storage control pushbuttons for a while longer. If you have used analog storage oscilloscopes, you will probably appreciate how easily signals may be acquired and discarded, even though you are operating in the somewhat awkward situation of having to manually trigger the instrument, at present.

3. Sweep Triggering

The sweep triggering for this instrument is conventional except for the availability of the manual trigger. Avoid applying trigger voltages in excess of 25 volts; the maximum required trigger signal is five volts, and the minimum is about 0. 25 volts. Damage can result if more than 100 volts is applied.

Internal triggering requires the availability of a signal waveform feature of at least 20% of the full scale signal range in use. The Recurrent Sweep mode is one in which sweeps are automatically initiated, without need for any waveform feature or external trigger. There is no synchronization at all with any signal feature, in this trigger mode. You will find that often you can use this unsynchronized operation, since depressing a Hold pushbutton "freezes" the signal for visual examination. Often the signals are cyclic, and the only reason that a sweep synchronization is needed is to hold the waveform steady so that you can examine it. With this oscilloscope, the memory availability permits this examination without having to take the time to achieve synchronized sweep operation.

4. Single Sweep Operation

Many oscilloscopes have provisions for single sweep operation. This can be achieved in this oscilloscope by depressing the Hold Next pushbutton immediately after depressing the Release pushbutton.

5. Signal Range Switch and Signal Level Offset Controls

The Range switch indicates the maximum signal amplitudes which can be accepted by the instrument without the signal being "off scale." The values indicate the range for the case in which the d.c. offset control is set to provide zero offset volts. A signal having the absolute voltage limits of zero to positive two volts can be measured, if a negative one volt d.c. offset is added. The maximum available d.c. offset is ±90% of the selected signal range, nominally.

> Do not apply more than ± 50 volts to the signal input terminal, when using the ±1 volt range setting. Damage can occur if greater voltages are applied. For other ranges the maximum allowable voltage is ±(100 + 20R) volts where R is the selected range, but in no case may the applied voltage exceed 500 volts.

The numerical display shows voltage and time values normalized according to the plug-in unit switch settings; d. c. offset values are not normalized. You can determine accurately what offset voltage you have selected by removing the signal cable, initiating a single sweep, and reading the voltage. The voltage indicated is equal to the offset voltage. Although the amount of available offset voltage is nominally ±90% of the selected signal range, a little more than this is usually available. If more than ±100% of the selected voltage range is used, measurement of the offset voltage in the manner described above cannot be used.

You will find that it is preferable to set the d.c. offset at zero volts, and to leave the offset control locked thereafter, because then the numerical voltage values shown are absolute (within the accuracy limits of the instrument). If for some reason it is necessary to use an offset voltage other than zero, try to select a convenient value such as -1.000 volts, to make it easy to mentally revise the numerical values shown. When you have selected some offset such as -1.000 volts, changing the voltage range switch to a higher range automatically also multiplies the offset voltage value.

A -1.000 volt offset made when the Range switch is in the ±1 volt setting automatically becomes -2.000 volts when the Range switch is set at ±2 volts, -4.000 volts for a range of ±4 volts, etc. For highest accuracy always re-check the d.c. offset value before or after measurements requiring maximum precision, whether you have chosen zero volts or some other offset value.

The easiest way to adjust the offset voltage to zero is to use the highest vertical scale expansion, in the following manner. It is presumed for the moment that you have become familiar with the use of the expansion controls, after reading later sections of this manual.

Clear the memory manually. Momentarily place the Autocenter control to the "on" position, then "off." This causes the display center to be at zero. Use an automatically recurrent 10 μsec/point sweep, and the released mode of operation. Ground the signal terminal or place the range switch at the ground position. With a vertical expansion of ×64, observe the trace position. Center it vertically by use of the Signal Offset control, switching back and forth between the hold mode and the released mode, to confirm that the voltage trace is directly overlapping the centerline marker trace. Lock the Signal Offset control. Double-check the numerical value of the offset by use of the numerical display.

6. Remote Control

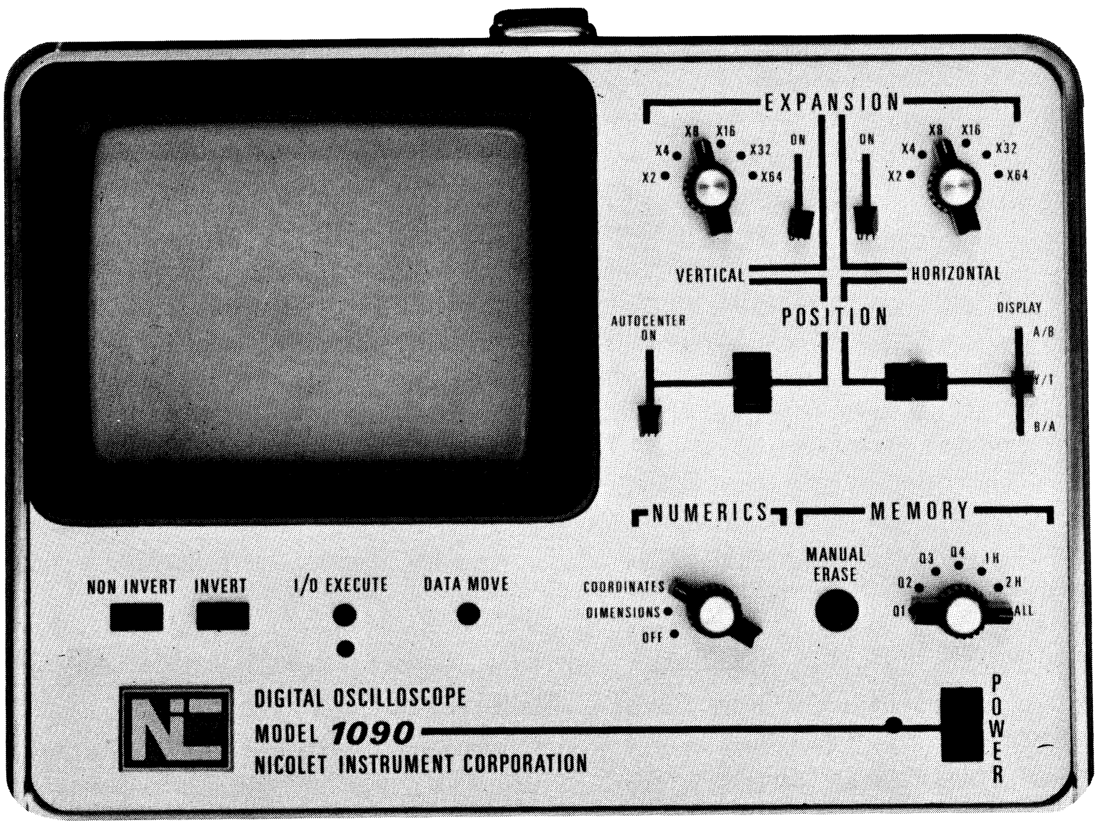
The functions of the two Hold pushbuttons and the Release pushbutton can be achieved by use of signals provided to the front panel Remote Control connector. To actuate, a ground (zero voltage) should be applied to the appropriate pin of the connector, momentarily. The ground may be by a contact closure or by a TTL integrated circuit output signal.

The three top terminals of the connector are used for the three functions, with the left being the Hold Last initiator; the center the Release initiator; and the right the Hold Next. The bottom two terminals are grounded within the plug-in unit.

It should be kept in mind that there are occasions in which the oscilloscope is not receptive to new signals, an effect similar to the re-trace dead time of analog oscilloscopes. If you have initiated a Hold Next command, and the next signal begins during a dead time, it will happen that the next signal to occur will neither be accepted nor held, but the one after that will be. You should avoid misinterpretation.

This effect can occur only if the sweep triggers frequently, for the dead time is for only 11 microseconds per displayed point after each signal (plus 50 usec). If there is a time gap between the end of each measurement sweep and the next trigger pulse, there will be no dead time effects. If holding the wrong signal is a matter of consequence to you, it is mandatory that you logically block all Hold Next commands which could occur during an existing measurement sweep and during the dead time following, using a delay multivibrator.

IV. MAIN FRAME CONTROLS



A. Expansion and Position Switches, Horizontal

The horizontal expansion controls permit you to view, across the full screen width, either all 4096 coordinate points, or as few as 64 points. The position switch, when in either the left or right position, causes an up-down counter in the instrument to be stepped upwards or downwards. The state of that counter always determines which data point you have selected as the center point of the expanded display, so of course it determines which set of coordinates will be displayed when you switch to an expanded display. With the horizontal expansion switch turned off, if the instrument is in the Hold mode, the vertical marker can be seen to move left or right when you move the position switch left or right. That marker intersects the voltage waveform at the point which corresponds to your selection of the center coordinate point. It is that point which is at horizontal screen center when you switch to the expanded display, and also the point whose voltage-time values are shown in the numerical display (if you have switched the Numerics switch to the Coordinates position).

Observe that when an unexpanded display is in use, the marker position can be moved left or right at a rate of about a thousand points/sec. But notice that when a large expansion factor is in use, the waveform moves left or right across the screen at the rate of only a few data points per second when you operate the position switch. The up-down counter is stepped at a rate which is higher for lower expansion amounts. Therefore, to make a large change in position of the selected center point rapidly you must use a low expansion factor. But to make fine (small) changes, it is much easier to use large expansion factors.

The switch for changing position is designed in such a way that you can step the position one coordinate point at a time by moving the switch left or right just momentarily, then releasing it. This is so that you can reliably step through the coordinates one at a time, in the event you wish to observe the numerical values of a series of adjacent coordinates.

The expansion controls work in the same way for either the Hold or Release mode. Displaying a fraction of your total record does not disturb information stored or being acquired into a much larger portion of memory.

B. Vertical Expansion Switches, and the Autocenter Operation

The vertical expansion controls are similar in effect to the horizontal controls. The horizontal marker line shown in either expanded or non-expanded modes (vertical) shows the voltage level about which data will be expanded. The position can be changed slowly or rapidly, depending upon the amount of expansion in use.

The autocenter control is very useful for making a rapid change in selected center-level. When this switch is on, the vertical center level is automatically made to be the same level as the ordinate value of the coordinate intersected by the vertical marker line. This allows you to keep the waveform on the screen more easily. The autocenter switch may be turned on momentarily, then off again. The selected vertical center level then remains fixed until you manually alter it by use of the vertical position control.

You should practice using the autocenter switch, and the other vertical display controls, until you are quite familiar with them. They are quite different in their effects than you have experienced in vertically centering and expanding the displays of conventional oscilloscopes, but once you are familiar with their use you will find it very easy to examine data in fine detail with little effort.

C. Memory Selector Switch

You may use all 4096 memory addresses, or either 2048 or 1024 at a time, during measurements. The 1024 address sections are referred to as Q1, Q2, Q3 and Q4. The 2048 address sections are named H1 and H2. You may store a reference waveform in any of the selected sections while using another section for other purposes. Naturally you must use care not to destroy information that has been stored in one section, accidentally. If you have stored data in section Q1 or Q2, you must not measure waveforms while using the ALL switch position, because the new measurement will replace whatever is in the entire memory and that includes Q1 and Q2. Similarly, you must not measure into H1, if you have a reference stored in Q1 or Q2, for H1 ("half memory section 1") includes Q1 (quarter memory section 1) and Q2. H2 includes Q3 and Q4, so do not use H2 if data are being stored in Q3 or Q4.

These cautions refer only to use of the instrument in the released mode. In the hold mode you can freely switch to any memory section. Waveforms recorded into 1024 address groups will then be shown superimposed, and if you are using an expanded view of the data, corresponding voltage-time regions will be shown for both (or all four) waveforms.

When using a two input plug-in and both inputs are on, each signal is recorded into one half of the memory block chosen by the Memory switch. Input A is always placed in Q1 or H1 and input B in Q2 or H2.

D. Display Switch

The display switch is a unique convenience in that it allows you to observe two signals as related to time, or one as a function of the other. In most cases the information will be recorded simultaneously using a two input plug-in but this need not be the case. For instance, a waveform may be recorded in one-half of memory from a single input and later a second waveform may be recorded in the other half of memory. In either case the information is recorded in the digital oscilloscope in the usual Y-T fashion. The change comes in choosing a display program.

Coordination is necessary with the Memory Selector switch. This switch determines where information is to be placed in memory and/or the part of memory to be displayed. For instance if the Memory switch is in the All position and two inputs are used, each waveform recorded is now in one half of memory. It is also possible to record two inputs into as little as one quadrant of memory. By this control the choice is made as to what is displayed.

The Display switch selects how the information is displayed. In the center position the waveforms appear with time on the X axis; in the other two positions the waveforms appear in time coordination, but one as a function of the other. Either can be chosen for the X or Y axis. To switch from one display mode to another does not disturb information stored in memory, or the data gathering process. Therefore, it is possible to observe a continuing process, "live" while displaying A/B, Y-T, or B/A, or while switching display modes. It should be noted that expansion in the A/B and B/A modes is available only on the vertical axis.

E. Numerics Selector

The three positions of this switch permit you to see the coordinate values of the selected coordinate, or the screen dimensions. The Off position is to allow uncluttered photographs of the screen, although often it is desirable to show the screen dimensions on the same photograph as the waveform.

The time and voltage values shown are normalized according to the voltage range, sweep speed, and magnifier switch settings which exist at the time of viewing. After you have stored a waveform, it is necessary for you to remember, or to keep a record of, the range switch and sweep speed switch settings, or leave those switches unchanged. When viewing that waveform, if numerical values are needed, you must return those switch settings to the positions used during the measurement.

F. Invert/Non-Invert Switches

This pair of switches causes the numerical voltage values to be multiplied by -1 before storage, if in the Invert condition.

G. Data Move Pushbutton

The purpose of this switch is to allow you to alter the voltage values recorded, upwards or downwards. Two waveforms, recorded in different sections of memory, can be compared more accurately if they are adjusted to have the same d. c. baseline voltage. Sometimes one of the waveforms must be adjusted upwards or downwards to allow this. Select one of the waveforms, only, by use of the Memory Selector switch, and turn off the horizontal expansion on/off switch, then hold the Data Move pushbutton in, until the desired level has been reached. The Invert/Non-Invert switch may be used to change the direction of movement of the waveform. If the horizontal expansion on/off switch is on, no data changes can occur. This characteristic was included to prevent accidental alteration of just part of a waveform.

A quick tap of this button results in an incremental change of data; it is often necessary to use that method of making a small change in data level because the rate of data level change can be as high as about 30 units/second if the pushbutton is held depressed.

Data levels can be restored to their original levels if desired, if you make a note of the voltage level at some convenient point on the waveform, before altering the level, so that you can return it to its original level later.

The memory has a range of from +4095 units to -4096 units. If the Data Move switch is used to increase numerical values beyond either limit, an ambiguity results, as you can see if you do this experimentally. But the ambiguity is removed again if you restore the data to its original level by changing the Invert/Non-Invert switch selection and depress the Data Move pushbutton until the original level is again reached.

H. Input/Output Execute Switch

If the instrument is not interfaced with external digital recording apparatus (such as the Nicolet Model 283A with tape deck), depressing this pushbutton when the instrument is in the Hold mode causes a slowing of readout rate suitable for pen recording. The voltage at the rear deck Pen Output connector is ordinarily held at about zero volts, but during pen readout vary from nominally zero to +4.5 volts to drive the recorder. The Pen Speed control may be used to alter the readout rate from nominally 2 - 15 points/sec.

If a pen recording is started, it ordinarily runs its course through 1024, 2048, or 4096 addresses and then the instrument automatically returns to its normal display mode. This is a long process, and often you may wish to interrupt it to end the recording for some reason. To do this, depress the I/O Execute button once more.

I. Pen Recorder Calibration

To adjust the zero level, and the range, of the pen recorder, the following procedures may be used.

The negative full scale deflection should cause the pen trace to be at the bottom margin of the paper, and positive full scale at the top. The oscilloscope provides a voltage half way between plus and minus full scale, for recorded waveforms regions corresponding to zero signal volts, and such voltage should result in a trace along the center of the paper. So in calibrating the recorder, first generate a negative full scale deflection and adjust the d.c. level offset control so the pen is at the bottom margin of the paper. Next generate a positive full scale deflection and adjust the pen recorder gain until the pen is at the top margin.

It is easy to generate positive and negative full scale deflections if no valuable data are in memory when calibrating. Select memory section ALL, using no horizontal expansion, and using maximum vertical display expansion. Clear the memory by depressing the erase pushbutton. Momentarily turn the autocenter switch on and then off. The display trace will be at screen vertical center. Now switch to memory Q1 and depress the Data Move switch until the "waveform" saturates at screen top. Switch to Q2, and do the same except with the Invert/Non-Invert switch in the Invert condition. The trace saturates at screen bottom this time. Now press the I/O Execute button, and if you switch between Q1, Q2, and Q3 you will have pen deflection voltages corresponding to ± full scale, and half way between.

When adjusting the recorder, use the recorder d. c. level offset control when the pen output is least positive, and use the recorder gain control when the pen output is most positive. You may have to repeat the d. c. level offset and gain adjustments because changes in one will affect the setting needed for the other. This is the reason it is worthwhile providing yourself with easily selected ± full scale voltages by use of the different memory sections.

J. Pen Recorder Horizontal Data Position

Before making a pen recording, select the waveform region you wish to record (all or part of the waveform may be selected) by observing the CRT display. What you see is what you get, to use a familiar saying, when you later start a pen recording. Both the vertical and horizontal positions and expansions that provide the CRT display govern the format of the pen recording. If you have selected a 256 point segment of the waveform, starting with the 1870th data point, this region is what the pen recording will show. It is not necessary to record all 4096 points of the waveform.

K. Digital Recordings

If you will be using the Nicolet Model 283 recorder interface unit and tape deck, information concerning the digital recording is given in the instruction manuals accompanying that equipment.

For other digital input/output devices, the following information concerning interfacing should be used. (See connector diagram on page 20.)

1. The external apparatus must provide a d. c. voltage on two wires, indicating whether data are to be read from, or into, the oscilloscope. A zero voltage on the terminal labeled TC TAPE RD means information is to be read from tape (or other device) to the oscilloscope. A zero voltage on the terminal TC TAPE WRT means information is to be read from the oscilloscope to the external device. Only one of these wires should be grounded at once. If neither is grounded, but instead both are at a potential of from +2. 5 to +5 volts, the oscilloscope will assume that the pen recorder mode of operation has been selected and will improperly respond to commands from the external apparatus.

2. The external apparatus should be designed to be in a standby mode until the oscilloscope provides a nominally zero volts potential at the terminal labeled TC TAPE. That control signal will be present shortly after you depress the I/O Execute pushbutton. The delay after depressing the button may be as long as 0. 1 second or as short as a few microseconds.

3. A series of clock pulses must be provided to the oscilloscope, after the signal TC TAPE from the oscilloscope becomes zero (rather than its normal positive level of about 4 volts). For reading out of the oscilloscope these signals should be negative going pulses with a baseline of +2.5 volts to +5 volts, and extending to nominally ground potential, and should be applied to the terminal READ CLOCK. For writing into the oscilloscope, they should be applied to the terminal WRT CLOCK.

4. For reading into the oscilloscope, the first 6 bits of the most significant byte must be present at least one microsecond before the first READ CLOCK pulse occurs, and must remain present at least 100 nanoseconds after the clock pulse. The same is true of the next clock pulse; the second byte of information must be present on the six data line input terminals one microsecond before and held for 0.1 microsecond after the second clock pulse.

A third clock pulse must be provided at the end of that sequence. The data line state at that time does not matter. At this time the 12 bits of data corresponding to the first input word will be written into the oscilloscope memory. Clock pulse spacing should be 20 microseconds or greater.

This three step sequence should be repeated for each of the 1024, 2048 or 4096 memory addresses in use. The oscilloscope will automatically switch from the I/O mode when the number of words recieved "fills" the memory section in use.

5. When reading from the oscilloscope the external apparatus must provide WRITE CLOCK pulses of the same polarity as the READ CLOCK pulses used during reading into the oscilloscope. Three pulses per word, at 20 microsecond intervals or more are required. The first byte of data will be present within 50 μsec of the time the TC TAPE signal goes to zero, and will be held for at least one microsecond after the start of the first clock pulse. The next byte will be present within one microsecond after the end of the first clock pulse. Zeroes will be present at the six output lines after the second clock pulse and during the third clock pulse. The output format is therefore an 18 bit, 3 byte word, with the least significant bits all zeroes.

The three step sequence of clock pulses, spaced at 20 μsec or greater intervals, is needed for each of the 1024, 2048 or 4096 words being read from memory. There must be a sufficient number of clock pulses; the oscilloscope will sense when the proper number have been received, and will cause the signal TC TAPE to again become positive signifying the end of readout.

6. The data input lines, at terminals RDC 1 to RDC 6, should be nominally zero for "1", and from 2.5 to 5 volts positive for zero. Loading in the oscilloscope is one standard TTL load. The output lines DL 1 to DL 6 are

also zero volts for "1", and positive 2.5 to 5 volts for "0". They are capable of driving one TTL load. All control signals into and out of the oscilloscope are capable of driving, or cause, a load of one standard TTL load.

7. If an insufficient number of clock pulses are received, you may depress the I/O button to return the oscilloscope to the display mode.

L. Digital 12-Bit Parallel Output

It should be noted that this is a readout mode only, and that writing into the oscilloscope from an external source must be as described in Section K.

For 12-bit parallel output operation, the following information concerning interfacing should be used:

1. The external apparatus must provide a d.c. voltage on two wires, indicating which mode of readout is to be used. A zero voltage on the terminal labeled TCTAPEWRT restricts the oscilloscope to its digital readout mode. A zero voltage on the terminal labeled PAR12 means that information is to be read out in 12-bit parallel form. Both of these wires must be grounded to be in parallel readout mode. If it is desired to return to the pen recorder mode of operation, TCTAPEWRT and PAR12 must both be allowed to return to a positive potential. (Pen recorder operation is not prevented if PAR12 remains grounded, but its readout rate will be increased by a factor of 3.) All other external apparatus should be in standby mode to avoid improper response to commands from this apparatus.

2. The external apparatus should be designed to be in a standby mode until the oscilloscope provides a nominally zero volts potential at the terminal TCTAPE. That control signal will be present shortly after you depress the I/O Execute pushbutton. The delay after depressing the button may be as long as 0.1 second or as short as a few microseconds.

3. Clock pulses must be provided to the oscilloscope, after the signal TCTAPE from the oscilloscope becomes zero (rather than its normal positive level of about 4 volts). These clock pulses should be negative going pulses with a baseline of +2.5 volts to +5 volts, and extending to nominally ground potential, and should be applied to the terminal WRITE CLOCK. One pulse per word, at 30 microsecond intervals or longer are required. The first word of data will be present within 50 µsec of the time the TCTAPE signal goes to zero, and will be held for at least one microsecond after the start of the first clock pulse. One clock pulse is needed for each of the 1024, 2048, or 4096 words being read from memory. There must be a sufficient number of clock pulses; the oscilloscope will sense when the proper number have been received, and will cause the signal TCTAPE to again become positive signifying the end of readout.

4. A ready flag which is synchronized with the external apparatus clock has been provided at the terminal labeled READY. This need not be used if the 30 μsec minimum clock rate is observed. The negative transition to ground potential of READY may be interpreted as follows:

a. If external clock has been low (gnd) for at least 30 μsec, data is valid at exact instant of READY's negative transition.

b. If external clock has been low (gnd) for less than 30 μsec, data is valid 1 μsec <u>after</u> READY's negative transition.

5. A terminal is provided for remote triggering of the oscilloscope into its readout mode, and is labeled RETR. This terminal responds to a negatively going pulse extending to nominally ground potential, and accomplishes the same thing as depressing the I/O button.

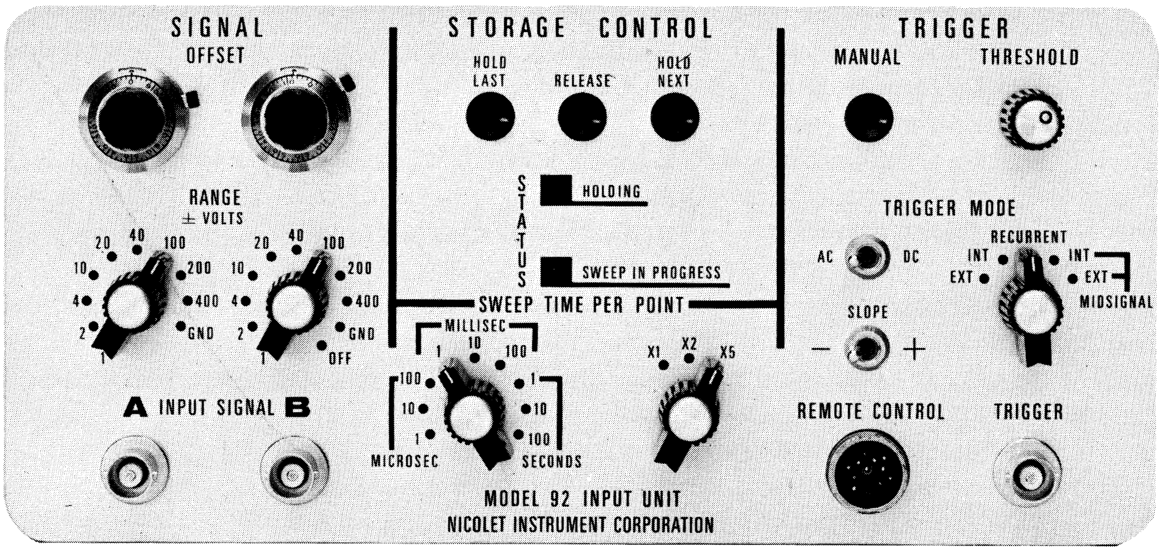
6. The output lines M0 to M11 are from 2.5 to 5 volts positive for "1" and zero volts for "0". They are capable of driving one TTL load. All control signals into and out of the oscilloscope are capable of driving, or cause, a load of one standard TTL load.

7. If an insufficient number of clock pulses are received you may depress the I/O button to return the oscilloscope to the display mode.

DIGITAL I/O CONNECTOR DIAGRAM

M^{0}	2	1	DL^{6}-
M^{6}	4	3	DL^{5}-
M^{1}	6	5	DL^{4}-
M^{7}	8	7	DL^{3}-
M^{2}	10	9	DL^{2}-
M^{8}	12	11	DL^{1}-
M^{3}	14	13	RDC^{4}-
M^{9}	16	15	RDC^{1}-
M^{4}	18	17	RDC^{6}-
M^{10}	20	19	RDC^{2}-
M^{5}	22	21	RDC^{3}-
M^{11}	24	23	RDC^{5}-
	26	25	GND
	28	27	
	30	29	
+5	32	31	
	34	33	
	36	35	
	38	37	RCDEND B
	40	39	ROHOLD-
	42	41	TCTAPE-
PENCLKSTP-	44	43	TCTPRD-
RETR-	46	45	TCTPWRT-
PAR12-	48	47	MFWRTCLK-
READ -	50	49	MFRDCLK-

V. MODEL 92 INPUT UNIT



A. General

The use of the controls of the Model 92 plug-in unit is quite straightforward, differing from analog oscilloscope operation principally in that storage controls are available to cause information to be held or not as desired. Another difference is the additional sweep trigger mode, called the Mid-Signal mode.

Many of the controls are the same as those on the Model 90 plug-in. See that section of the manual for a discussion of Storage Control, Remote Control, Sweep Triggering and Signal Range switch. The differences for the Model 92 plug-in are discussed in this section.

B. Mid-Signal Triggering

When this mode of operation is in use, a 4096 × 12 memory in the plug-in unit is continually receiving signal information, and concurrently the mainframe memory is being used for display of information previously received.

A trigger signal (either externally produced or some prominent feature of the signal itself) causes the process to discontinue after a certain length of time, and causes the plug-in unit memory information to be transferred to the main memory. The plug-in unit memory at that time contains information about the signal waveform for times both preceding and following the trigger time because it was receiving that information both before and after the trigger signal.

The timing is arranged so that information corresponding to equal amounts of time prior to and after the trigger will be stored, and the display therefore will show the trigger time at the screen center if an unexpanded display is in use.

This mode of operation is useful when sweep triggers occur rarely or sporadically. An example is the observation of heartbeat signals which usually are irregular and, therefore, difficult to observe with ordinary oscilloscopes. The Mid-Signal Trigger mode greatly eases observation of these because the prominent mid-beat r-wave feature can be used as a trigger signal, yet the entire heartbeat complex can be examined without horizontal position irregularity.

If trigger spacing is less than half the total sweep time (1/2 time per word × number of words), some old information will be displayed at the left of the screen as if it were part of the new record. The buffer memory receives information as a closed loop and is quite unaware of where in that loop it received the previous trigger. Usually a discontinuity in the information makes such occurrence obvious, but you should be aware and not be mislead if your triggers are frequent. Also it should be kept in mind that if very long sweep speeds are employed, it will be a long time after the sweep trigger signal occurs before the entire waveform has been entered into the mainframe memory for display.

General Operating Considerations

C. Voltage Controls

It is usually best to operate the instrument with the Signal Offset control adjusted for no offset, since the displayed voltage values will then be with respect to ground. To adjust, use a recurrent fast sweep, clear the memory manually and while holding the Erase pushbutton place the Autocenter switch of the mainframe momentarily in the Autocenter position. This assures that zero voltage will correspond to vertical screen center regardless of what vertical display scale is used. Use a ×64 magnification and with zero volts applied to the signal input adjust the Signal Offset control until the trace appears at center. Check the numerical value by placing the unit in the Hold mode. Trim the Signal Offset control setting if necessary, then lock. Repeat for Input B. To utilize Input B, its Range Control must be switched to some setting other than "off". Input A can be disabled by setting the Range switch one position clockwise beyond the "Gnd" position.

1. Normalization

The numerical voltage values displayed are normalized according to the setting of the Input A range switch. Regardless of what settings are used for Input B, the voltage values shown will be incorrect unless the Input A switch setting corresponds to the setting that was used for Input B signals. This does not mean that the two switch settings need to correspond when signal information is being acquired, only that when later examining Input B information for numerical voltage values, Input A switch must be set to the appropriate setting.

D. Calibration

Upon delivery the instrument has been calibrated to within 0.25%. Removal of the left side cover of the mainframe exposes two gain adjustment trimming resistors (see Fig. B1) for use if greater accuracy or recalibration is needed.

Except for vertical gain adjustments it is not recommended that other adjustments be altered. There should be no need for changing other trimming resistors for long periods of time, and if such adjustments are made they should be made by factory or factory-trained personnel.

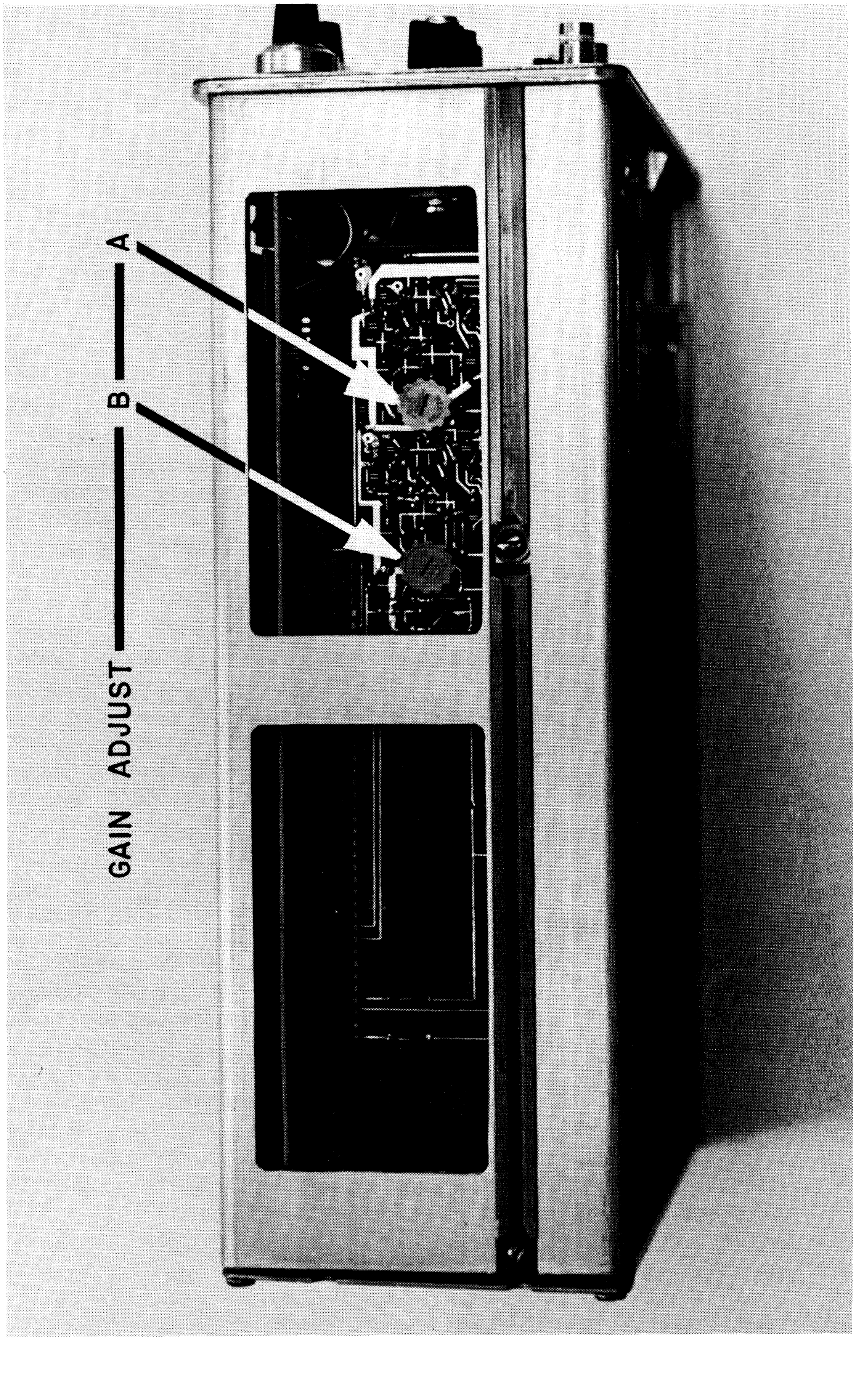
Performance testing should be done by use of a linear sawtooth or triangular waveform to check for discontinuities, and d.c. voltages to test general linearity and amplitude calibration.

To test for discontinuities, use a sweep speed such as to include only about one or two cycles of the linear waveform. First use a full scale signal amplitude, with no display magnification, to detect large discontinuities. Then decrease the amplitude by a factor of 10, use a display magnification of 8, and vary the dc offset control over its range while carefully examining the displayed waveform. The mainframe Autocenter mode should be used to keep the display on scale. Repeat with a signal attenuation of about 100 and a display magnification of 32 or 64. All steps should be quite uniform in size. A completely missing step represents the limit of the instrument specifications, and a more severe discontinuity need not be tolerated; it is evidence of an improper initial adjustment of the analog-to-digital converter or a faulty component. The oscilloscope including mainframe may be returned to the factory for recalibration if such discontinuity is found, without cost except transportation from site to factory during the warranty period, and at reasonable cost after that period.

E. Crosstalk and Noise

Typically the crosstalk between signal channels is 0.1%. This crosstalk tends to be constant and predictable and therefore not excessive. Circuit malfunctions can cause increases in this effect. Since a crosstalk test can be made in a few seconds, this effect should be tested at least every few months.

Noise is typically less than 0.025% rms, and rather random. This means that there will be a few percent of the data points scattered to one level above or below their proper level, with a much smaller percentage scattered by two levels from the proper level. Noise can be tested by use of a very low amplitude sine wave (e.g., 1% of full scale) and high display magnification.


GAIN ADJUST
A
B

F. Extremely Slow Sweep Speeds

When making hours-long measurements of some variable, care must be used to depress the Hold Last pushbutton following the sweep start, to avoid any possibility of a second sweep occurring after the first has ended. Always confirm that a sweep has actually started with reasonable signal scale setting, by examining the early data points measured, using appropriate Vertical and Horizontal Display Expansion. Before starting the sweep, move the Position crosshairs to the region very near the first data points so that the field of view will allow inspection of single data points to aid in inspecting behavior at the first few points. After confirming, inspect the Sweep Time and Input Signal Range switch settings again, and once more depress the Hold Last pushbutton.

These precautions prevent loss of information due to improper control switch settings.

During long sweeps, dc level drifts may be a factor if high accuracy is needed. The oscilloscope has a temperature sensitivity of about 0.01% of full scale per degree F, so where high precision is needed the temperature should be held constant.

G. Sweep Triggering

Do not exceed ±50 volts for long periods at the external trigger input, nor ±100 volts for short periods. The maximum trigger sensitivity is approximately 0.25 volts at a threshold variable over ±3 volts. The trigger signal must return below (or above) the threshold before another sweep can be triggered by the signal. Recurrent sweeps are produced by an internal oscillator which has a limited amplitude; the threshold adjustment control should be approximately centered to permit recurrent sweeps to occur.

H. Dead Time

For fast sweep speeds (50 μsec per point or less) there is a dead time following each accepted signal during which information is transferred to the main memory and is displayed at least once. The dead time depends upon the size of the memory group in use, and the number of points displayed. It is 5 μsec per data point transferred plus 12 μsec per point displayed. To minimize the dead time, use a one quarter portion of the memory and as much horizontal display magnification as practical. There is essentially no dead time for slower sweeps.

VI. DESIGN

A. General Description of the Logic Structure

The instrument has the basic nature of other hard-wired devices such as signal averagers. A substantial difference is in the use of a read-only memory for program control, which is better organized and more versatile than the averager equivalent (a 13 step pulser and many logic gates).

The read-only memory is capable of producing about 63 different command pulses such as RM, read, transfer A to M, etc. It is also capable of conditionally jumping from one routine to another. Its use makes the 1090 a hard-wired processor capable of complex and varied display routines.

The commands and conditional jumps in the programs are described below. The program used for the Model 1090 oscilloscope with the Model 90 input unit (plug-in unit) is Program I. The details of this program are subject to minor variations. Where those variations are made, a listing of the new program will be included with this manual, in addition to Program I.

With few exceptions, no mainframe operation occurs except in response to a program command. The behavior of the mainframe is drastically altered, however, by changes in the jump conditions caused by changes in front panel controls. The exceptions include alterations of the operator's selection of display center, and forcible clearing of certain control flip-flops when the instrument is placed in the "release" mode.

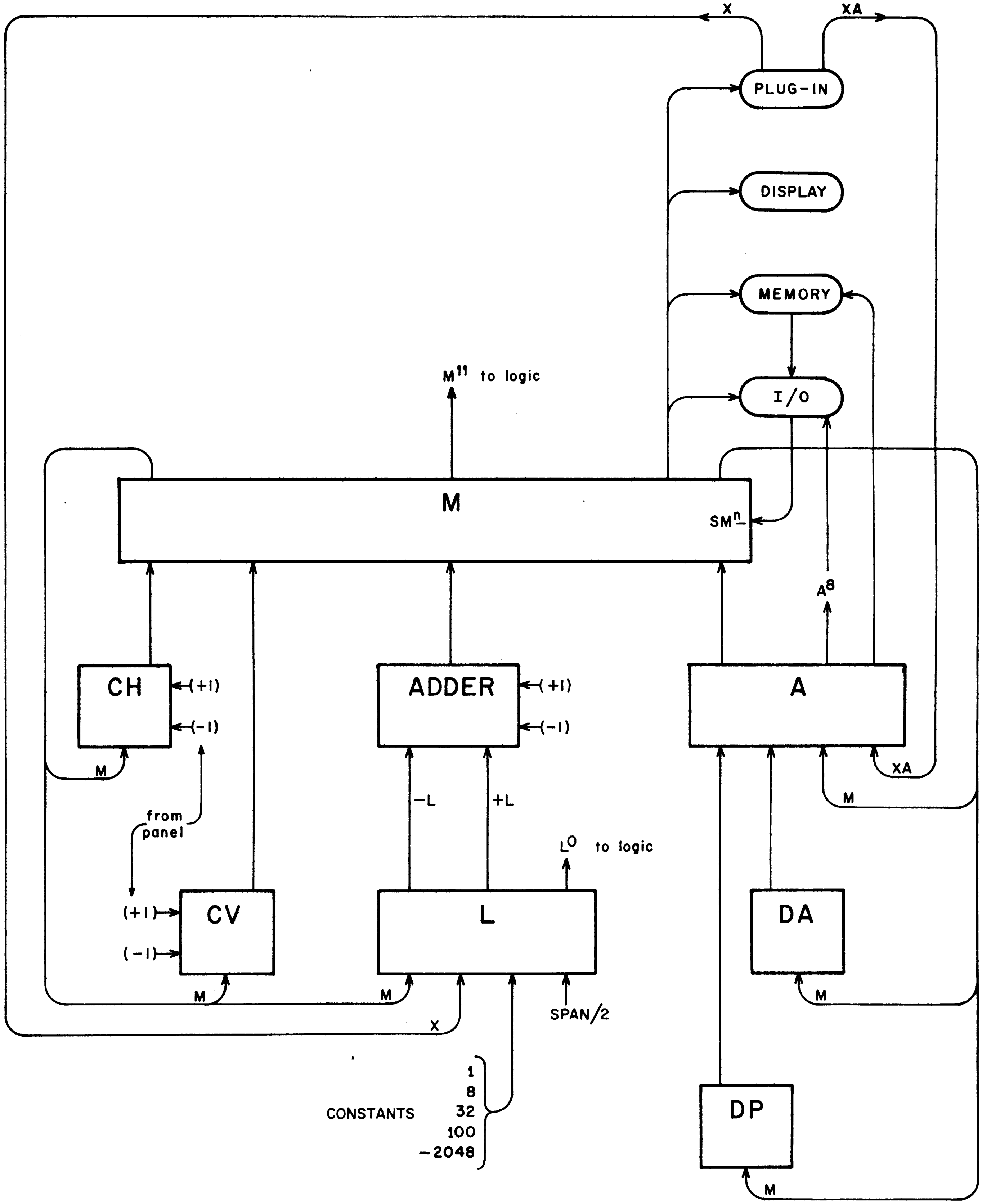
Therefore, understanding the instrument almost entirely depends upon understanding the structure of the mainframe registers, and the programs stored in the read-only memory.

B. The Registers

Figure M1 shows the individual registers in the mainframe, and their inputs and outputs. A particular command such as (M+L) automatically causes the adder inputs to be M and L, and this is followed shortly thereafter by the pulse TOGM which clocks the sum into M. TDAA causes the input to A to be the output of register DA, then automatically the pulse LOADA occurs, causing the transfer.

It is easier to remember the individual register names, if their principal functions are known. All registers are 12 bits.

1. The M register is the main register, serving as an accumulator, the memory data register, and the only register from which all other registers (including the display registers) can receive information directly.



REGISTER STRUCTURE — FIG. MI

2. The A register controls the memory addressing directly, but as a second purpose serves as part of the pathway between DA and DP to M.

3. DA is used principally to remember which memory address is to be read next from memory, for display. Hence the name DA, for display address.

4. DP is used principally to remember the next position on the screen, horizontally, that the next point will be placed. As for DA, DP can be stepped forward one step at a time. These are binary counters.

5. CH is an up-down counter controlled by hardware circuits directly from the front panel horizontal position switch. Its state essentially always corresponds to the selected centerpoint of the display during use of the expanded display. The name CH stands for "cursor, horizontal".

6. CV stands for "cursor, vertical". It is controlled as for CH but by the vertical center position control.

7. The L register is used in part as a step in the link between the plug-in unit data output register and the memory, and in part to hold the addend or subtrahend during addition or subtraction.

8. Registers not shown include display shift registers, display output registers, and input/output registers for reading to and from magnetic tape. Those registers operate independently of the programs, except for transfers from M to the display registers H and V. The plug-in data register X, and address control register XA also are not shown.

C. Addressing System

For simplicity of computations, both the memory addresses and the CRT display positions are defined in 2's complement nomenclature. The first memory address is -2048 (1 000 0000 0000) and the last is +2047 (0111 1111 1111). Similarly the left edge and bottom edge of the screen are at -2048, and the right and top at +2047.

The memory can be used in parts. Instead of assigning the first 1024 addresses to one "quadrant", the next 1024 to the next, as is customary, addresses -2048, -2044, -2040, etc. comprise the first quadrant; -2047, -2043, -2039, etc., comprise the second.

D. Program Control

A 256 word, 20 bit read-only memory and instruction decoders control the program. The machine steps through the instructions sequentially, except if a jump condition is satisfied, in which case the instruction address is jumped to that indicated in the last executed instruction. There are provisions for forcing the instruction address to state zero, under certain circumstances, which force overrides any other instruction address change mechanism.

VII. MAINTENANCE

A. General

The nature of this instrument is such that maintenance by the owner will almost invariably consist of no more than minor adjustments, with troubleshooting and repair accomplished by Nicolet Instrument Corporation personnel. The time and effort required to become familiar with the circuitry and programs is far greater than the value of your possibly being able to make a repair on site, in the event of a failure. The mean time between failures has not yet been established for this instrument, but similar instruments such as the Nicolet signal averagers have mean times between failures of about three years, following the first month of use. In some cases, repairs can be effected by on-site engineers with the telephone assistance of Nicolet engineers, but experience shows that return to the factory for repair has better long term results. Repairs are generally completed the same day as received; we prefer to observe the instrument for at least 24 hours thereafter, and therefore the instrument will ordinarily be returned within two working days following receipt.

Modifications of the circuits, and damage caused by accidents during customer's attempts to repair the instruments, void the warranty. Experience shows that such modifications and accidents can result in later malfunctions, so it is urged that a "look but don't touch" policy be followed.

B. Adjustments

There are few adjustments likely to be necessary during the life of this oscilloscope if it has not been physically or electrically abused. The adjustments of mainframe circuits include only those for the display, most of which are located on circuit board 7A, located adjacent to the CRT base, and pictured in figure A1.

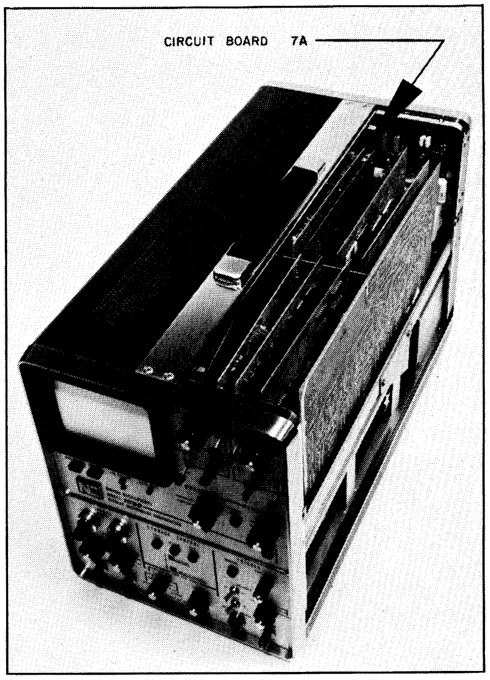


Figure A1

Two display adjustments, which can be classified as semi-available to the operator for ordinary use, are the beam intensity and focus controls, accessible by removing the left hand cabinet cover. Even these have not been made easily available, because they should seldom need to be changed. See Figure A2.

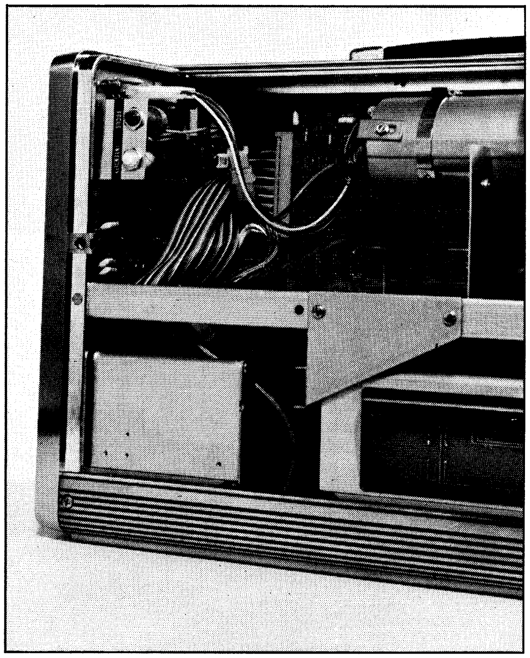


Figure A2

The adjustments on the display board are labeled in Figure A3. They are, from left to right (rear of cabinet to front):

1. Horizontal balance. This is a digital to analog decoder adjustment which determines the relative weighting of the least significant six bits and the other bits. It is a factory adjustment, only. Any need for readjustment is indicative of a circuit component failure or near failure.

2. H Offset. This may be adjusted by you to reposition the display left or right on the screen.

3. H Rotation. This should never need alteration. It causes rotation of the pattern with respect to horizontal screen margins.

4. H Span. This may be used to increase or decrease the width of the display.

5. Astigmatism. It is not likely that you will need to readjust this, but it is conventional in purpose; it has been adjusted to provide best dot definition.

6. V Span. Similar to H Span, but for vertical expansion.

7. V Rotation. Rotates the display with respect to the vertical screen edges.

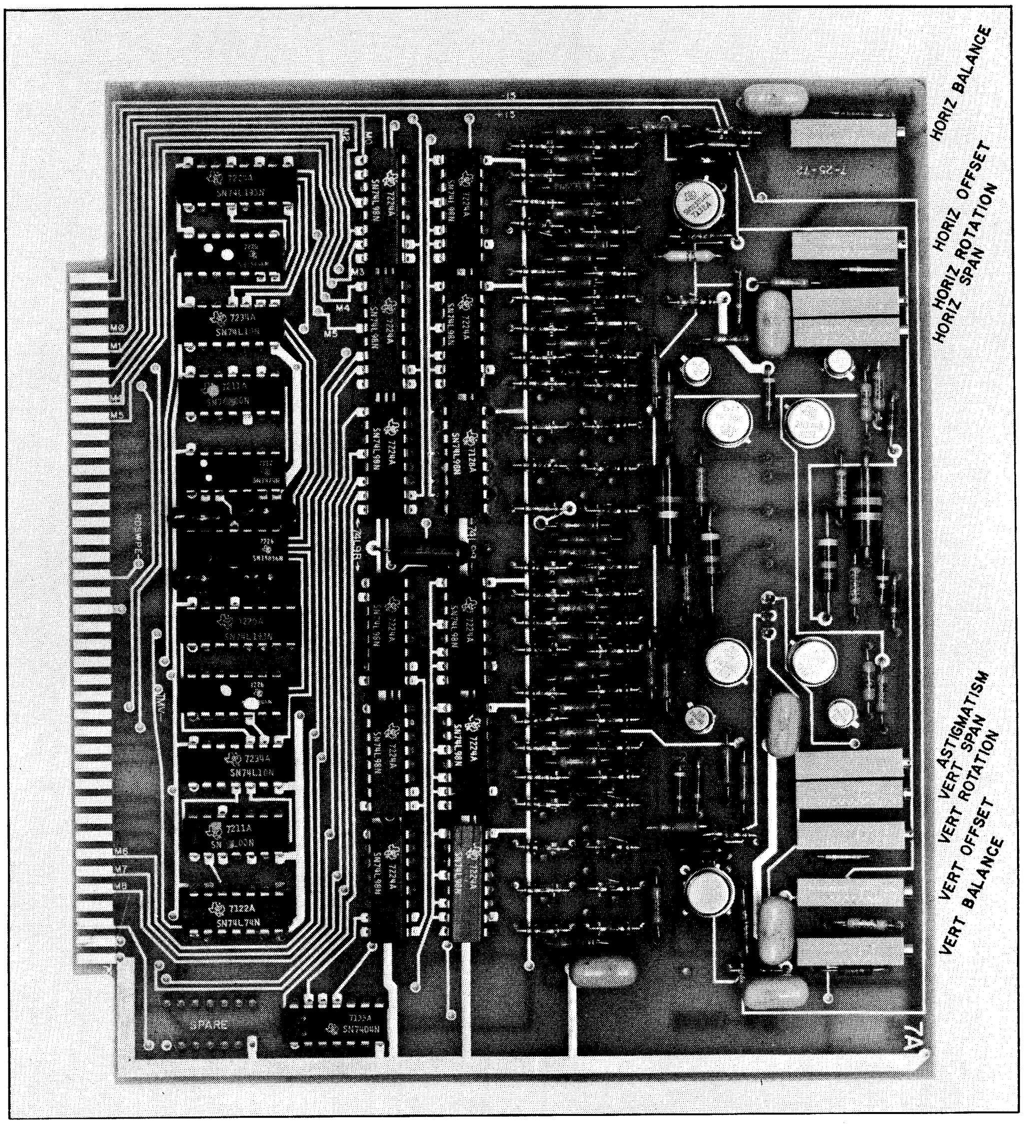


Figure A3

8. V Offset. For vertical display positioning.

9. V Balance. The vertical digital-to-analog decoder adjustment.

These adjustments are included principally in order to match the particular cathode-ray-tube to the associated circuits. They are not subject to drift, but if the CRT is replaced, adjustments may be needed to properly position the displayed information, and to obtain optimum focus and contrast. Do not alter the vertical or horizontal balance controls, the first and last controls on the board, since the CRT characteristics do not affect their optimum settings.

C. Pen Speed Control

This control, located on the rear deck, may be used to alter the rate of readout during pen recordings. See Figure A4.

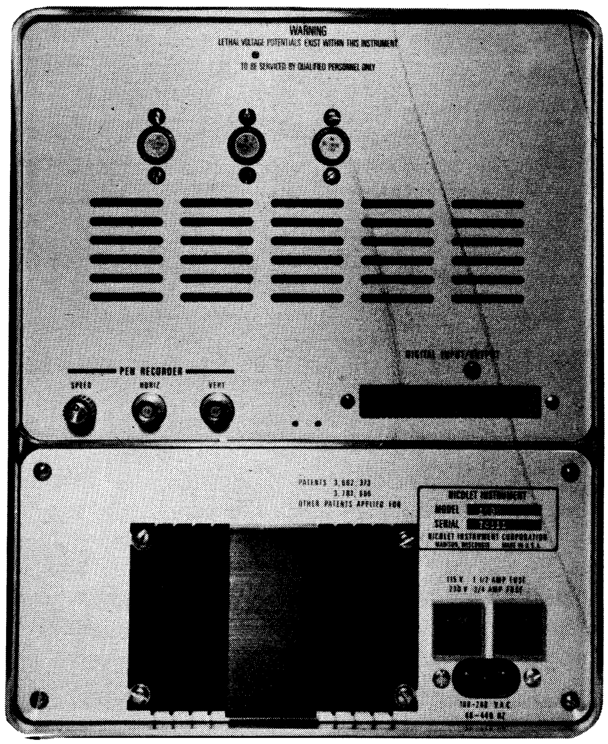


Figure A4

1090 MAIN FRAME SPECIFICATIONS

Memory: 4096 words, 12 bit words.

CRT: 8 cm x 10 cm rectangular tube.

Display Expansion: Separate controls for horizontal and vertical axes. Each switched on or off and expanded around a selected point x2, x4, x8, x16, x32, x64.

Cross Hairs: Positions of vertical and horizontal lines are controlled separately and target the point around which expansion will take place. In the unexpanded display the cross hairs are moved across the data. In the expanded mode the data is moved while the cross hairs remain center screen. (Present in hold mode only.)

Numerical Display: Three switch selections.

Coordinates: Where the vertical cross hair intersects the information determines the value of the decimal display at the bottom of the screen; time from the trigger and volts recorded at that point in time are indicated.

Dimensions: The decimal display indicates time and volts of the screen dimensions as these are changed by expansion controls.

Off: No decimal display.

Memory Store/Display: All 4096 words of memory can be used, or divided into two 2048 word parts, or four 1024 word parts for record, display and readout modes. When different information is recorded in halves or quadrants these records are displayed superimposed by placing the memory switch in All.

Display Real Time/Continuous: In the release mode and a time per point of 50 microseconds or less, "continuous" selection will cause the continuous display of memory (according to expansion switch settings) between infrequent triggers. If the time per point is greater than 50 microseconds "continuous" selection will cause a refreshing of the display between the time each point of new information is put into memory. In the release mode and "real time" selection there is only display following a trigger and then a spot moving across the screen in real time for time per point selections of more than 50 microseconds, or at time per point of 50 microseconds or less there is a display between sweeps.

Erase: Push button for manual erase of memory if desired.

Non-Invert/Invert: In the release mode the polarity of the input can be reversed or not. In the hold mode "data move" will add with the "non-invert", and subtract with the "invert" selection.

Data Move: When held down, will continually add or subtract a constant to Y values selected by the Memory switch. (It will not function with horizontal expansion turned on.)

Auto Center: When turned on and expansion switches off the horizontal cross hair will move to the Y value intercepted by the vertical cross hair; if the vertical expansion is on and expanded x2 or more the stored data will move on the display so that the Y value intersected by the vertical cross hair is moved to the center of the screen.

Size: 20.5" length, 10.25" width, 12.25" height.

Weight: 45 pounds including typical plug-in unit.

Digital I/O: Binary out on rear panel connector, TTL compatible. Interface and magnetic tape for reading in and out are available accessories.

Pen: X axis 0-4.5 volts nominal across all of memory, or across any portion chosen for expanded display.

Y axis 0-4.5 volts nominal; speed variable from 2 to 15 addresses per second standard. Other speeds available on request.

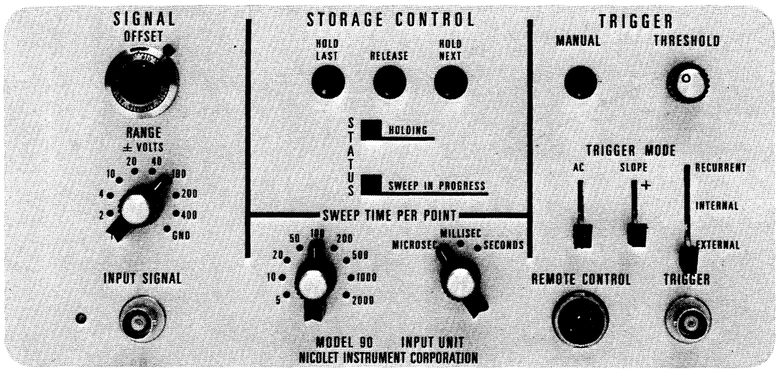
Pen lift signal available on I/O connector; nominal ground during readout, nominal +4 volts otherwise.

Temperature: Ambient temperature 40° to 110° F.
Storage temperature -30° to 150° F.

Power: 100 to 253 volts, 48-440 Hz. Power consumption 85 watts.

SPECIFICATIONS

MODEL 90 PLUG–IN



Input Ranges: ±1, ±2, ±4, ±10, ±20, ±40, ±100, ±200, ±400 volts full scale.
Impedance 1.00 megohms ±1%.

D. C. Offset: Nominally 90% of range setting, ten turn pot control.

Resolution: One part in 4096, voltage and time.

Measurement Accuracy: ±0.03% linearity. Amplitude (scale) ± 0.1%, adjustable
Amplitude and level stability 0.01%/°C. Timing accuracy 0.05%, ±0.001%/°C.

Trigger: Switch selectable Recurrent, Internal, or External. Minimum signal 0.5 volts, P-P, threshold adjustable over ±5 volt range. Slope selection and a. c. or d. c. coupling. External trigger input impedance nominally 1.0 megohm.

Sweep Time Per Point: Crystal oscillator controlled. Ranges in microseconds, milliseconds, or seconds times 5, 10, 20, 50, 100, 200, 500, 1000 or 2000. Sweep jitter ±0.5 microseconds for 1 volt square wave trigger signal.

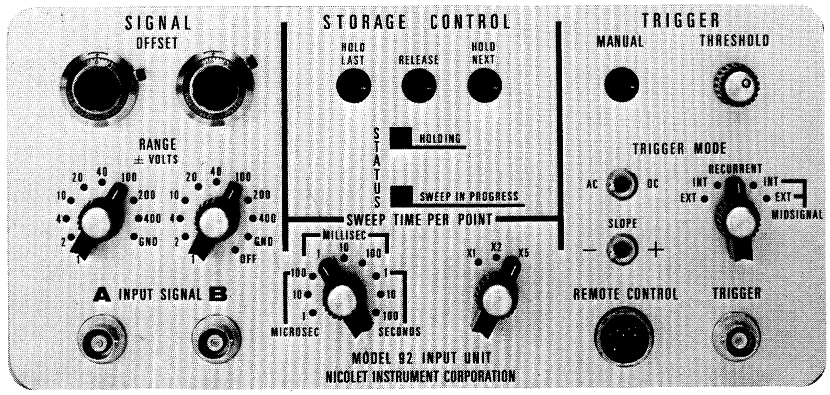
Push Button Controls:

Manual Trigger: Simulates electrical trigger signal.
Hold Last: Stores the information which followed last trigger.
Hold Next: Stores the information which will follow the next trigger.
Release: Accepts the next valid trigger and records new information presented to the input.

Remote Control: Hold and release commands ±5 volts normal level, 0-0.5 volts, or switch closure (one microsecond) duration or more) to initiate action.

SPECIFICATIONS

MODEL 92 PLUG-IN



Input Ranges: ±1, ±2, ±4, ±10, ±20, ±40, ±100, ±200, ±400 volts full scale. Impedance 1.00 megohms ±1%.

D. C. Offset: Nominally 70% of range setting, ten turn pot control.

Maximum Input Signal: ±10 times range, or 400 volts, whichever is least.

Resolution: One part in 4096, voltage and time.

Measurement Accuracy: (At normal room temperature range).

Voltage:
1. Scale calibration: 0.25% of range.
2. Linearity: 0.05% of full scale, monotonic.
3. Drift: ±0.025% per 10°F after warm-up.
4. Noise: 0.025% of full scale, nominally gaussian distribution.
5. Sample and Hold Aperture: Nominally 25 nanoseconds.
6. Signal Channel Crosstalk: 0.1% or less

Time:
1. Calibration: ±0.02%.
2. Drift: ±0.01% per year.

Trigger Signal: Range: ±0.25 to ±5V, a. c. or d. c. coupled.
Maximum allowable: 25V.
Trigger occurs on transition through an adjustable threshold level.
External trigger input impedance is nominally 100 K ohms.

Sweep Trigger Insensitive Times: At slow sweep speeds (100 usec per point or slower) there is essentially no "dead" time between sweeps. At faster sweep speeds, a dead time of from 5.5 milliseconds to 64 milliseconds exists depending upon the number of points used per sweep and the number of points displayed on the CRT. During this time, following acceptance of a signal into memory, the instrument is insensitive to incoming sweep trigger pulses.

Sweep Time Per Point: Ranges of 1, 2, 5, times 1, 10, or 100 microseconds, milliseconds, or seconds.

Push Button Controls:
Manual Trigger: Simulates electrical trigger signal.
Hold Last: Stores the information which followed the last trigger.
Hold Next: Stores the information which will follow the next trigger.
Release: Accepts the next valid trigger and records new information presented to the input.

Remote Control: Hold and release commands +5 volts normal level, 0 to 0.5 volts, or switch closure (one microsecond duration or more) to initiate action.

Note: Specifications subject to change without notice.