Model 4850
DIGITAL MEMORY OSCILLOSCOPE

595-3457

OPERATION/SERVICE

MANUAL

HEATH
ZENITH

HEATH COMPANY PHONE DIRECTORY

The following telephone numbers are direct lines to the departments listed:

Kit orders and delivery information	(616) 982-3411
Credit	(616) 982-3561
Replacement Parts	(616) 982-3571

Technical Assistance Phone Numbers

8:00 A.M. to 12 P.M. and 1:00 P.M. to 4:30 P.M., EST, Weekdays Only

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Aircraft, Marine, Security, Scanners, Automotive, Appliances and General Products	(616) 982-3496
Computers — Hardware	(616) 982-3309
Computers — Software:	
Operating Systems, Languages, Utilities	(616) 982-3860
Application Programs	(616) 982-3884

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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

WARNING

This equipment has been certified to comply with the limits for a Class B computing device, pursuant to Subpart J of Part 15 of FCC Rules. Only computers certified to comply with the Class B limits may be attached to this equipment. Operation with non-certified computers is likely to result in interference to radio and TV reception.

This equipment uses radio frequency energy for its operation; and it not installed and used properly, that is, in strict accordance with the instruction manual, may cause interference to radio and television reception. It has been type tested and found to comply with the RF emission limits for a Class B computing device which is intended to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio and television reception, which you can determine by turning the equipment off and on, try to correct the interference by one or more of the following measures:

- Move the computing device away from the receiver being interfered with.
- Relocate the computing device with respect to the receiver.
- Reorient the receiving antenna.
- Plug the computing device into a different AC outlet so that the computing device and receiver are on different branch circuits.
- Disconnect and remove any I/O cables that are not being used. (Unterminated I/O cables are a potential source of high RF emission levels.)
- Be certain that tne computing devices are plugged into grounded outlet receptacles. (Avoid using AC cheater plugs. Lifting of the power cord ground may increase RF emission levels and may also present a lethal shock hazard to the user.)
- The I/O cable that connects between this Oscilloscope and a computer must be *shielded*.

If you need additional help, consult your dealer or ask for assistance from the manufacturer. Customer service information is on the inside back cover of this Manual or on an insert sheet supplied with this equipment. You may also find the following booklet helpful: "How to Identify and Resolve Radio-TV Interference Problems." This booklet is available from the US Government Printing Office, Washington, D.C. 20402, Stock No. 004-000-00345-4.

Table of Contents

INTRODUCTION

The Heath Digital Memory Oscilloscope (DMO), Model 4850, is a versatile accessory for an oscilloscope or a PC-compatible computer, such as the Heath/Zenith H/Z-100 PC series or IBM-PC. The DMO can upgrade a low-frequency bandwidth oscilloscope to one that has a 50 MHz bandwidth on repetitive signals, and can also add waveform storage capabilities.

When you connect the DMO to a computer via the RS-232 connector, the supplied software provides you with full control of the DMO functions from the computer keyboard, waveforms displayed on the computer's screen. The computer software also provides you with the added capabilities for disk storage; averaging; and cursor measurement of voltage, time, and frequency. User-written software can be used to customize the DMO for specific applications, such as automated testing.

The DMO is a sampling oscilloscope; it periodically samples analog input signals, converts them into digital code, and then stores them in its memory. When these coded signals are later retrieved, they are displayed as waveforms on the oscilloscope or on the computer's CRT. The DMO samples repetitive signals from 0.4 s/sample to 200 ps/sample and nonrepetitive signals from 0.4 s/sample to 10 μs/sample.

The attenuator networks for channels Y1 and Y2 have ten calibrated ranges, from 5 mV/div to 5 V/div, and are switched in a 1-2-5 sequence. The calibrated time base ranges from 20 s/div to 10 ns/div and is also switched in a 1-2-5 sequence. The trigger select and trigger level controls allow the time base to be triggered at any point along the positive or negative slope of either the Y1 or Y2 trigger signal. An auto-baseline function is provided to automatically display a base line on the screen when there is no trigger signal present.

Some of the features when you use the DMO with a normal oscilloscope include:

- Dual trace.
- 2.5 Hz to 100 kHz real-time sampling rates on nonrepetitive signals.
- 50 MHz bandwidth on repetitive signals.
- 7 ns rise time on repetitive signals.
- Single sweep function.
- 5 mV/division vertical sensitivity.
- Waveform storage.
- Comparison of live to stored waveforms.

Some of the outstanding features when you use the DMO with a computer include:

- Control over long distances via RS-232.
- Control via a modem.
- Signal averaging.
- Inversion of either channel.
- Hard copy output of the screen display.
- Cursor measurement of voltage and differential voltage.
- Cursor measurement of frequency, time, and time difference.
- Waveform storage on disk.

This DMO is a laboratory-grade test instrument that is ideal for a wide range of measurements used in electronic development, education, production lines, and scientific research.

SPECIFICATIONS

VERTICAL

Display Modes	Y1, Y2, Dual. (All displays except 500 μs/div are chopped. 500 μs/div uses an alternate display.)
Deflection Factor	
Sensitivity	5 mV/div to 5 V/div. 10 steps in a 1-2-5 sequence.
Accuracy	Within 3% ± 2 bits (20°C to 30°C); 5% ± 2 bits (10°C to 40°C), referenced to 20 mV/div.
Vertical Response	
DC Coupling	5 mV to 5 volts/div, DC to 50 MHz.
AC Coupling	5 mV to 5 volts/div, 10 Hz to 50 MHz.
Rise Time	7 ns or less.
Overshoot	Less than 5%.
Vertical Input	
Impedance	1 MΩ shunted by 40 pF.*
Maximum Input	125 volts peak combined AC and DC.
Connector	BNC.

HORIZONTAL

Time Bases Range	20 s/div to 500 μs/div; Real Time Sampling. 200 μs/div to 10 ns/div; Equivalent Time Sampling.
Maximum Real Time Sampling Rate	100 kHz.
Positions	29 steps in a 1-2-5 sequence.
Accuracy	Within 3% ± 2 bits (20°C to 30°C); 5% ± 2 bits (10°C to 40°C), referenced to 1 ms/div.

* Capacitance depends upon probe used for calibration.

TRIGGER

Source .... Y1, Y2.

Coupling .... Same as vertical input.

Modes .... Automatic baseline, Normal, Single Sweep.

Level .... Variable over at least eight divisions; 256 steps.

Sensitivity/Bandwidth:

MODE	1.0 div	1.5 div
DC	DC to >60 MHz	DC to >90 MHz
AC	6 Hz to >60 MHz	2 Hz to >90 MHz

OSCILLOSCOPE OUTPUT

Vertical .... 4 volts peak-to-peak (oscilloscope setting is 0.5 V/div vertical, 1 ms/div horizontal).

Trigger .... TTL level.

SYSTEM REQUIREMENTS*

Operating Software .... MS-DOS™, GW-BASIC™ (not supplied).

Operating Hardware .... PC-compatible computer with RS-232 card, color graphics card, single 5-1/4" disk drive, 128K RAM (minimum); such as the Heath/Zenith H/Z-100 PC-series computers.

* GW-BASIC is not required to run the compiled version of the "SCOPE" programs. You can use the DMO with any computer that has RS-232 serial communications and graphics capability, if you develop your own required software.

GENERAL

Vertical Resolution	8 bits (1 part in 256).
Record Length	512 samples.
Interface	RS-232C.
Baud Rate	110 to 9600 baud (selected by internal jumper).
Power Supplies	Fully regulated.
Operating Temperature	10°C to 40°C.
Power Requirements	108 to 132 VAC, 60 Hz, 48 watts (at 120 VAC).
Dimensions	
Height	4-1/2" (11.4 cm).
Length	12-1/2" (31.8 cm).
Width	10" (24.4 cm).
Weight	8 lbs. (3.6 kg).

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate features in products previously sold.

OPERATION

OTHER EQUIPMENT NEEDED

You can use your Digital Memory Oscilloscope (DMO) with a display oscilloscope or a computer. If you plan to use your DMO with an oscilloscope, you will need the following equipment:

- An oscilloscope that meets the following requirements:

  Bandwidth — 1 MHz or greater.

  Vertical Sensitivity — .5/div.

  Vertical Channels — One (1) plus the ability to trigger from a second source (either an external trigger input or a second vertical channel).

  Trigger — Must have a triggered sweep and be capable of triggering on the positive slope of a TTL level signal. Operate the trigger in the NORMAL trigger mode (not AUTO trigger).

  Graticule — The DMO output assumes that the display oscilloscope has an 8 × 10 division graticule. Other graticules may be used, but you will have to scale the VOLTS/DIV and TIME/DIV indicators on the front panel of the DMO accordingly before you make any measurements.

- Two cables. One end of each cable must have a BNC connector to mate with the connectors on the front panel of the DMO. The other end must mate with your oscilloscope.

If you plan to use your DMO (and the software package supplied) with a computer, you will need the following:

- A PC-compatible computer (such as the Heath/Zenith H/Z-100 PC series). The computer must contain the following:

  Memory Required — At least 128K bytes.

  Optional Cards — A color graphics card (standard on the H/Z-100 PC series).

  — A serial communications adapter (standard on the H/Z-100 PC series).

  Software — MS-DOS version 2.0 or later operating system.

  — GW-BASIC version 2.0 or later (if you wish to use the noncompiled version of the software).

  Cables — One female-to-female null-modem cable (Model HCA-52 or equivalent).

If you plan to write your own applications software, you will need the following:

- A computer that has serial communications capabilities.
- An RS-232 cable to connect the computer to the DMO.
- Software as required by your application. Refer to Appendix A at the rear of this Manual for the necessary commands and responses.

GETTING STARTED

The following instructions help you get your DMO operating as quickly as possible. If you intend to use the DMO with a display oscilloscope, proceed to "Using Your DMO With an Oscilloscope." If you intend to use your DMO with a computer, however, proceed directly to "Using Your DMO With a Computer."

USING YOUR DMO WITH AN OSCILLOSCOPE

NOTE: The Pictorials referred to in the following steps are located in the Illustration Booklet.

1. Connect a suitable cable from the VERTICAL OUTPUT of the DMO to the vertical input of your oscilloscope.

2. Connect the TRIGGER OUTPUT of the DMO to a second trigger input of the oscilloscope. (This can either be an external trigger input or a second vertical channel. Do not display the second input.)

Steps 3 through 7 match the DMO to your display oscilloscope (refer to Pictorial 2-4):

3. Preset the controls of the oscilloscope (not the DMO) as follows:

Vertical Input Sensitivity	.5 V/div
Vertical Input Coupling	DC
Vertical Position	Center
Trigger Source	Second source (see step 2 above)
Trigger Slope	+
Trigger Mode	Auto
Trigger Level	Center
Sweep Speed	1 ms/div

4. Turn the DMO on. The front panel LEDs will flash in sequence for ten seconds and then stop in preprogrammed positions. You should see a display on the Oscilloscope similar to the one shown in the Pictorial. Change the Trigger Mode on the oscilloscope to Normal (no automatic baseline) and adjust its trigger level for a stable display. The trace should blank out momentarily approximately once each second. If you are using an uncalibrated oscilloscope, or one with less than 8 vertical divisions, the "No Trigger" message may be off the top of the screen. If you cannot see the "No Trigger" message, use the TRIGGER LEVEL ▲ and ▼ pushbuttons on the DMO to change the Trigger Level until it appears.

5. Separately push the Y1 and Y2 ▲ and ▼ Position pushbuttons to separate the traces. Then push the Save pushbutton on the DMO; the LED indicator just to the left of this pushbutton will light. Separately push the Y1 and Y2 ▲Position pushbuttons again. There should now be four traces and a "No Trigger" message. If you do not see four traces, readjust the Trigger Level on the oscilloscope. If you still cannot see four traces, refer to "Internal Jumpers" on Page 13 to adjust the holdoff.

6. Push the Save pushbutton. There should now be two traces and a "No Trigger" message. Use the vertical position control on the oscilloscope to position the reference center line so it is on the center graticule line. If the line preceding the "No Trigger" message does not lay on the top graticule line, change the vertical sensitivity of the oscilloscope until it does. (You may have to change both the variable and volts/div range to obtain the correct setting.) Recheck the centering of the reference line to make sure it did not move when you changed the sensitivity (repeat this step if it has moved).

   NOTE: If you are using an oscilloscope that does not have an 8-division vertical graticule, you will have to use the oscillscope position controls to shift the display the necessary number of divisions for a 4-division adjustment. If your oscilloscope has a 6 × 10 graticule, for example, move the reference center line down one division below the center and place the line preceeding the "No Trigger" message on the top graticule line (four divisions between the reference and the top). Now when you recenter the reference center line, the vertical calibration of the DMO will be correct even though the "No Trigger" message is off the screen.

7. Use the oscilloscope Horizontal Position control to position the beginning of the traces on the left graticule line. Then use the time base (sweep) variable to position the beginning of the center reference line (the end with the traces) on the 10th graticule line on the oscilloscope. (You may have to change the sweep range to obtain the proper setting.) Be sure to recheck the position of the beginning of the traces after you change the time base setting. If they have moved, repeat this step as necessary. NOTE: If your oscilloscope does not have a 10-division horizontal graticule, you can use the "No Trigger" message to set your time base. Use the time base variable to set the beginning of the N in No on the sixth graticule line.

The DMO is now matched to your oscilloscope and the indicators on the DMO's front panel are calibrated. If your oscilloscope drifts, or you change display oscilloscopes, repeat steps 3 through 7 as necessary.

We recommend that you read the remainder of the "Operation" section before you actually use your DMO.

USING YOUR DMO WITH A COMPUTER

NOTE: The Pictorials referred to in the following steps are located in the Illustration Booklet.

The diskette supplied with the DMO contains a compiled program that was written in GW-BASIC. This program enables you to use your PC-compatible computer as a digital oscilloscope. You can control all oscilloscope functions from the keyboard. The diskette also contains a noncompiled version of the program, which allows you to use your computer as an oscilloscope if you have GW-BASIC and do not want to use the compiled version. **Appendix A toward the rear of this Manual contains a listing of the commands, along with a brief discussion of the responses**. You can use this information to customize the supplied program, or you may wish to use some of the subroutines in your own application software.

The program allows you to select either COM1: or COM2: as the communications port to the DMO. If your computer supports both serial communications channels, we recommend that you use COM2: to communicate with the DMO. This way, you will not have to disconnect equipment that is connected to COM1:, such as a printer, when you use the DMO.

When you are directed to configure the communication port you decide to use, be sure to configure it as follows:

Baud Rate	Optional (is set by the program).
Stop Bits	Optional (is set to one by the program).
Parity	Optional (is set to none by the program).
Word Length	Optional (is set to eight bits by the program).
Handshake	DTR Positive (pin 20).
Pad Character	None.

Do not strip parity on input or output. In addition, do not map lowercase to uppercase on input or output.

NOTE: Refer to Appendix B when you perform the next two steps if you need help making a backup copy of the disk supplied with the DMO. Also refer to Appendix B if you need help making a working disk and then configuring it.

1. Make a backup copy of the disk supplied with the DMO. Then store the original disk in a safe place. Use the copy when you perform the following steps.

NOTE: The files you need to copy onto your working disk depend upon whether you wish to use the compiled version of the software or the GW-BASIC version. If you choose to use the compiled version, perform Step 2A. If you would rather use the BASIC version, however, skip Step 2A and perform Step 2B.

2A. To use the compiled version of the osftware, first make a working disk that contains an MS-DOS operating system. From your operating system disk, you may wish to copy the Print Screen driver that matches your printer (optional). You may also wish to include an AUTOEXEC.BAT file (optional). Now copy the following files from the disk supplied with the DMO onto the working disk:

SCOPE.EXE

BANNER.SAV

HELP.SAV

BAUD.SAV

2B. To use the BASIC version of the software, first make a working disk that contains an MS-DOS operating system and BASICA.EXE (GW-BASIC, not supplied). From your operating system disk, you may wish to copy the Print Screen printer driver that matches your printer (optional). You may also wish to include an AUTOEXEC.BAT file (optional). Now copy the following files from the disk supplied with the DMO onto the working disk:

SCOPE.BAS

BANNER.SAV

HELP.SAV

BAUD.SAV

REQ.SAV

PLOT.SAV

UARTINI.BIN

REQFRT.BIN

CKUART.BIN

SEND.BIN

MAP.BIN

AVG.BIN

GRAT.BIN

3. Configure the disk to make sure the handshaking is set for DTR positive. Then store this information on the working disk.

4. Connect a female-to-female null-modem cable from the DMO to your computer's serial port.

5. Boot the system from the working disk that contains the files supplied with your DMO. When the A› prompt appears, type SCOPE < RETURN› to run the compiled version **OR** type BASICA SCOPE <RETURN› to run the GW-BASIC version. NOTE: If you use the GW-BASIC version, be sure to include a single space between BASICA and SCOPE.

You will now see the Banner display, which contains communications information such as COM: 9600 Baud and a short menu. If you press the C key, you will see a list of valid baud rates, Press the number key that corresponds to the baud rate setting of your DMO (this is preset to 9600 baud). Then press the number key that corresponds to the communications channel you are going to use (COM1 or COM2). The Banner will then again return to the screen.

If you now press the ? key, you will see a help menu. You can look at this menu at any time during the operation of the DMO, except when the screen prompts you for an input. To look at the menu during the program, first press the ? key to return to the Banner. Then press the ? key again to see the help messages. Press any key when you wish to return to the program.

While the Banner is present on the screen, press any key (except C or ?) to display the DMO graphics. At this time, the screen will normally display the data applied to the DMO as it receives it.

Note that one of the items listed on the right side of the screen is in reverse video. Press the F10 key several times and notice that the reverse video moves from left to right and down the screen. Now press the F9 key and notice that the reverse video moves from right to left up the screen. When an item is displayed in reverse video, you can use the up and down arrow keys (explained next) to change the item.

Use the F9 or F10 key to move the reverse video to the Y1 sensitivity (which is probably 100 mV/div, if you have not already changed it). Press the up arrow key and note that the sensitivity increases (the displayed number gets smaller). Now press the down arrow key and note that the sensitivity decreases (the displayed number gets larger).

Operate the F9, F10, up arrow, and down arrow keys several times until you bedcome familiar with the way they work (use the arrow keys to change the sensitivity and the time base settings). These are the keys that you will use most when you operate your DMO.

NOTE: We recommend that you read the remainder of the "Operation" section before you actually use your DMO.

CONTROLS AND CONNECTORS

Refer to Pictorial 1-1 for the locations of the front panel controls and connectors referred to in the following paragraphs. The controls and connectors for channels Y1 and Y2 are identical. Wherever channel Y1 is referred to, channel Y2 is shown in parentheses (Y2).

NOTE: All front panel indicators are active all the time; it does not matter if you are using the front panel pushbuttons or a computer to set the various functions.

1. VOLTS/DIV indicators — These indicators show you which sensitivity range has been selected for Y1 (Y2).

2. Y1 (Y2) SENSITIVITY ▲ — Push this pushbutton to increase the sensitivity of the Y1 (Y2) input. The LEDs to the left of this pushbutton (1) indicate the sensitivity that has been selected. The display output is calibrated in VOLTS/DIV for a display oscilloscope that has a graticule which contains eight vertical divisions. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change sensitivity.

3. Y1 (Y2) SENSITIVITY ▼ — Push this pushbutton to decrease the sensitivity of the Y1 (Y2) input. The LEDs to the left of this pushbutton (1) indicate the sensitivity that has been selected. The display output is calibrated in VOLTS/DIV for a display oscilloscope that has a graticule which contains eight vertical divisions. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change sensitivity.

4. Y1 (Y2) POSITION ▲ — Push this pushbutton to move the Y1 trace up on the display oscilloscope. To recenter the trace, simultaneously push both the ▲ and ▼ pushbuttons. NOTE: When you make DC measurements, always be sure to center the base line.

5. Y1 (Y2) POSITION ▼ — Push this pushbutton to move the Y1 (Y2) trace down on the display oscilloscope. To recenter the trace, simultaneously push both the ▲ and ▼ pushbuttons. NOTE: When you make DC measurements, always be sure to center the base line.

6. AC-GND-DC indicators — Show what type of coupling has been selected. When none of the indicators are lit, the Y1 (Y2) input is turned off. This function may be used to remove unwanted traces from the display. When you select OFF, the display remains AC coupled so you can use it as a trigger source. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the input coupling.

7. INPUT COUPLING — Push this switch to select the type of input coupling. The LEDs to the left of this pushbutton (6) indicate what type of coupling has been selected.

8. Y1 (Y2) INPUT – Use this connector to apply a signal to the Y1 (Y2) input of the DMO. This connector is rated at 125 volts maximum (peak +DC).

9. TIME/DIV indicators — These indicators show which time base has been selected.

10. TIME BASE RATE ▲ — Push this pushbutton to increase the time base rate. The LEDs to the left of this pushbutton (9) show the time base that has been selected. The display output is calibrated in TIME/DIV for a display oscilloscope that has a graticule which contains 10 horizontal divisions. When a time base between 500 ms/DIV and 20 s/DIV is selected, the trigger channel is shown on the display oscilloscope as it is being sampled (trigger view). On the 500 ms/div range, the trigger view is only 9-1/2 divisions long. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the time base rate.

11. TIME BASE RATE ▼ — Push this pushbutton to decrease the time base rate. The LEDs to the left of this pushbutton (9) show the time base that has been selected. The display output is calibrated in TIME/DIV for a display oscilloscope that has a graticule which contains 10 horizontal divisions. When a time base between 500 ms/DIV and 20 s/DIV is selected, the trigger channel is shown on the display oscilloscope as it is being sampled (trigger view). NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the time base rate.

12. This indicator (not labeled) lights when you press the SAVE pushbutton to indicate that a waveform has been stored in auxiliary memory.

13. SAVE — If the LED to the left of this pushbutton is off, push this pushbutton to save the waveforms that are currently being displayed in auxiliary memory. The LED lights and the "saved" waveforms are displayed continuously. All functions of the input channels remain active. This feature allows you to compare live waveforms with the "saved" waveforms. If you push this pushbutton while the LED is lit, the auxiliary memory is erased and the LED is turned off.

14. + 0 – indicators — These indicators show you whether the trigger level is above ground (+), at ground (0), or below ground (–).

15. TRIGGER LEVEL ▲ — Push this pushbutton to increase the trigger level. Simultaneously press both the ▲ and ▼ pushbuttons to set the trigger level to ground (0 indicator will light). This allows you to quickly return the trigger level to ground. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the trigger level.

Whenever you push this pushbutton, the channel selected as the trigger source and a line that represents the trigger level are shown on the display oscilloscope. If you have used the position controls to raise or lower the channel you selected as the trigger source, the line that represents the trigger level will be raised or lowered by the same amount. This allows you to easily set the trigger level so that the DMO triggers on a specific portion of the waveform.

16. TRIGGER LEVEL ▼ — Push this pushbutton to decrease the trigger level. Simultaneously press both the ▲ and ▼ pushbuttons to set the trigger level to ground (0 indicator will light). This allows you to quickly return the trigger level to ground. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the trigger level.

Whenever you push this pushbutton, the channel selected as the trigger source and a line that represents the trigger level are shown on the display oscilloscope. If you have used the position controls to raise or lower the channel you selected as the trigger source, the line that represents the trigger level will be raised or lowered by the same amount. This allows you to easily set the trigger level so that the DMO triggers on a specific portion of the waveform.

17. AUTO-NORM-SINGLE indicators. These indicators show you which trigger mode has been selected.

18. TRIGGER MODE — Push this pushbutton to select the trigger mode you desire (auto, normal, or Single Sweep). The LEDs to the left of this pushbutton (17) indicate which trigger mode has been selected. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the trigger mode.

19. TRIGGER RESET-MANUAL — Push this pushbutton to force a manual trigger while the TRIGGER MODE is in either AUTO or NORM. If the TRIGGER MODE is set to SINGLE and the READY LED (20) is lit, this button will also force a manual trigger. If the TRIGGER MODE is set to SINGLE and the READY LED is not lit, this button turns on the READY LED to indicate that the trigger circuits are armed and waiting for a trigger. NOTE: If the NORMAL/CALIBRATE jumper is at NORMAL and the Trigger Mode is AUTO, the DMO automatically rezeros the vertical amplifiers when you push this button. This is convenient for rezeroing the vertical channels because the front panel settings are not changed.

20. READY indicator — This indicator shows you that the trigger circuits are armed and are waiting for a trigger.

21. SOURCE — Push this pushbutton to select Y1 or Y2 as the trigger source. The LEDs to the left of this pushbutton (22) show you which source has been selected. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the source.

22. Y1 & Y2 indicators. These indicators show you whether Y1 or Y2 has been selected as the trigger source.

23. SLOPE — Push this pushbutton to cause the trigger to occur on positive or negative slopes. The LEDs to the left of this pushbutton indicate whether you have selected positive or negative slopes. NOTE: If the NORMAL/CALIBRATE jumper on the main circuit board is at NORMAL, the DMO will automatically rezero the vertical amplifiers when you change the slope.

24. + & – indicators — These indicators show you whether the trigger occurs on positive or negative slopes.

25. VERTICAL OUTPUT — Connect a cable from this connector to the vertical input of your display oscilloscope. Set the sensitivity of the display oscilloscope to .5 V/DIV. NOTE: Also refer to "Calibration with Oscilloscope" beginning on Page 39 for more information.

26. TRIGGER OUTPUT — This connector provides a TTL-level trigger signal for use as a trigger source by your display oscilloscope. Set the display oscilloscope to trigger on the rising edge of this signal. Set the sweep speed of the display oscilloscope to 1 ms/DIV. NOTE: Also refer to "Calibration with Oscilloscope" beginning on Page 39 for more information.

Refer to Pictorial 1-2 for the locations of the rear panel controls and connectors referred to in the following paragraphs.

27. POWER — Use this switch to turn the DMO on and off. NOTE: Your DMO is supplied with a 3-wire line cord. Do not defeat the ground wire for any reason.

28. RS-232 port — Use this connector to connect a female-to-female null-modem cable from the DMO to the serial port of your computer.

INTERNAL JUMPERS

CAUTION: Disconnect the line cord and test leads before you remove the cabinet from your DMO. DO NOT remove the small shield that covers the AC wiring inside the rear of the chassis.

Refer to Pictorial 1-3 for the locations of the jumpers on the main circuit board. NOTE: You will have to remove the cabinet top to gain access to these jumpers. Be sure to reinstall it when you are finished.

Locate jumpers JP400 through JP405 near the center of the main circuit board. These jumpers select the serial communications baud rate, holdoff between scope traces, and the normal or calibrate mode.

Refer to Pictorial 1-5 and set the baud rate jumpers (JP400, JP401, and JP402) to match the baud rate of your computer. We recommend that you use the fastest baud rate that your computer will support.

Always set jumper JP403 to NORMAL unless you are performing the calibration procedure. Refer to the "Calibration" section of this Manual for complete instructions.

JP404 and JP405 set the holdoff between scope traces. You will have to experiment with these jumpers to determine their proper setting. The following steps show you how to determine the correct settings of these jumpers. NOTE: If you intend to use your DMO with more than one display oscilloscope, you may wish to leave the holdoff jumpers set at 10 ms. This will result in less than optimum display flicker, but you will not have to change the holdoff jumpers each time you change display oscilloscopes.

1. Preset jumpers JP404 and JP405 for 10 ms holdoff.

2. Connect a suitable cable from the VERTICAL output of the DMO to the vertical input of an oscilloscope.

3. Connect the TRIGGER output of the DMO to the external trigger input of the oscilloscope.

4. Turn the DMO on.

5. Ground the inputs of the DMO.

6. Preset the controls of the oscilloscope (not the DMO) as follows:

Y1 & Y2 Input Coupling	GND
Vertical Input Sensitivity	.5 V/div
Sweep Speed	1 ms/div
Trigger Source	Ext
Trigger Slope	+
Trigger Mode	Auto
Trigger Level	Center

7. Temporarily switch the trigger mode of the display oscilloscope to Auto. You should now see a display similar to the one shown in Pictorial 1-4. If you cannot see the "No Trigger" message on the screen, move the trigger level up or down until the message appears. Change the Trigger Mode on the oscilloscope to Norm (no automatic baseline) and adjust the Trigger Level for a stable display. The trace should blank out momentarily approximately once each second.

8. Separately push the Y1 and Y2 POSITION pushbuttons to separate the traces. There should now be two traces.

9. Push the SAVE pushbutton on the front of the DMO. The indicator just to the left of this pushbutton should light.

10. Separately push the Y1 and Y2 POSITION pushbuttons to separate the traces. There should now be four traces.

NOTE: In the next step you will adjust the holdoff for the shortest amount that will still display the "no trigger" message and four horizontal traces.

11. Refer back to Pictorial 1-5 and, starting from the 10 ms setting (both JP404 and JP405 at 1), move the jumpers to the 7.5 ms setting, followed by the 5 ms setting, and finally the 2.5 ms setting. Readjust the Trigger Level control on your oscilloscope after you make each change and check for the proper display. Leave the jumpers in the fastest (shortest time) position that will still display the "no trigger" message and four horizontal traces.

12. Reinstall the cover on the DMO.

CONNECTIONS TO OSCILLOSCOPE AND/OR COMPUTER

To connect your DMO to a display oscilloscope, refer to Pictorial 1-6 and perform the following steps:

1. Connect a suitable cable from the VERTICAL OUTPUT of the DMO to the vertical input of the oscilloscope.

2. Connect the TRIGGER OUTPUT of the DMO to the external trigger input of the oscilloscope.

To connect your DMO to a computer, refer to Pictorial 1-7 and connect a female-to-female null-modem cable from the RS-232 port on the rear of the DMO to your computer's serial port. Detail 1-7A shows the pin connections to make a null modem cable. The RS-232 port on the DMO is configured as RS-232 data terminal equipment (DTE) and the control signals are as follows:

Pin 1 — Chassis ground.

Pin 2 — Transmit data.

Pin 3 — Receive data.

Pin 4 — Request to send (RTS). This output is set high whenever the DMO is turned on.

Pin 6 — Data set ready (DSR). This input is checked by the DMO. The DMO will not transmit data unless DSR is high.

Pin 7 — Signal ground.

Pin 20 — Data terminal ready (DTR). This output is set high whenever the DMO is turned on.

USING THE KEYBOARD

Refer to Pictorial 1-8 as you read the following information.

IMPORTANT: The NUM LCK key **must be OFF**; the CAPS LOCK may be ON or OFF.

The F9 and F10 keys allow you to select the functions on the right side of the graticule. Use these keys to highlight the function you wish to change. Then use the arrow keys to change that parameter. The 14 available functions are described below. The numbers correspond to the numbers on Pictorial 1-9.

1. Y1 INPUT COUPLING — When you select this function, the up or down arrow keys cause the Y1 input coupling to cycle through AC-GND-DC-OFF. The OFF channel, although not shown on the display, remains AC coupled so it can be used as a trigger source. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

2. Y1 TRACE INVERT — When you select this function, the up or down arrow keys cause the Y1 input to toggle between normal and invert (the Y1 trace will be upside down). NOTE: Invert affects only the display; the data arrays are not changed. (The information in the cursor display area and the trigger level are not affected by the invert function.)

3. Y1 VERTICAL SENSITIVITY — When you select this function, the up arrow key increases the Y1 vertical sensitivity and the down arrow key decreases the Y1 vertical sensitivity. You can step the input sensitivity from 5 mV to 5 V in a 1-2-5 sequence. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

4. Y1 VERTICAL OFFSET — When you select this function, the up arrow key increases the Y1 trace vertical offset and the down arrow key decreases the Y1 trace vertical offset. The HOME key quickly returns the vertical offset to zero. NOTE: Offsets affect only the display. The data arrays are not changed. (The information in the cursor display area and trigger level are not affected by the offset controls.)

5-8. Y2 INPUT COUPLING through VERTICAL OFFSET — These functions control Y2, and operate just like their Y1 counterparts.

9. HORIZONTAL POSITIONING — When you select this function, the left arrow key moves both the Y1 and Y2 traces toward the left and the right arrow key moves the traces toward the right. If the traces are left of center, the double arrow becomes a single arrow that points toward the left. If the traces are right of center, the double arrow becomes a single arrow that points toward the right. You can press the HOME key to quickly recenter the traces. NOTE: Horizontal offset affects only the display; the data arrays are not changed. (The information in the cursor display area and the trigger level are **not** affected by the horizontal offset function.

10. TIME BASE — When you select this function, the up arrow key increases the time base rate and the down arrow key decreases the time base rate. You can select time base ranges between 10 ns/div and 20 s/div in a 1-2-5 sequence. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

11. TRIGGER SOURCE — When you select this function, either the up arrow or the down arrow key causes the trigger level to toggle between Y1 and Y2. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to re- zero the vertical amplifiers.

12. TRIGGER SLOPE — When you select this function, either the up arrow or down arrow key causes the trigger slope to toggle between "+" and "−". If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

13. TRIGGER LEVEL — When you select this function, the up arrow key causes the trigger level to increase and the down arrow key causes the level to decrease. The HOME key quickly returns the trigger level to zero. While the trigger level changes, a short line appears at the left of the display to indicate where the trigger is set in relation to the trace. The trigger level is not affected by any vertical offsets that may have to be added to the traces. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

14. TRIGGER MODE — When you select this function, either the up arrow or the down arrow key causes the trigger mode to cycle between AUTO-NORM-SINGLE. If the NORMAL/CALIBRATE jumper on the main circuit board is set to NORMAL, this function forces the DMO to rezero the vertical amplifiers.

ADDITIONAL FUNCTIONS AND FEATURES

In addition to the functions you can select with the F9 and F10 keys, the display contains information as to whether or not the DMO was triggered and whether or not a data transfer is in process. Also available are cursors which you can position on the displayed waveforms to allow you to make precise measurements of voltages and times. These features are each described below. As before, the numbers correspond to the numbers on Pictorial 1-9.

15. TRIGGER INDICATOR — This indicator tells you whether or not the DMO was triggered when the data currently being displayed was gathered. In addition, if the DMO is in the Single Sweep Mode, this section of the display will say "armed" while the DMO is waiting for a trigger. If the DMO is in the Single Sweep Mode and the display says "triggered," the current data display remains on screen and no new data will be gathered by the DMO until it is re-armed.

16. DATA TRANSFER INDICATOR — When the computer is receiving data from the DMO, via the RS-232 link, the message "TRANSFER" will appear in this location. When the data transfer is complete, the "TRANSFER" message will disappear and the computer will display the data on the screen. If you press a key while a transfer is in process, the data transfer will abort and the program will respond to the key press.

    On time base ranges between 100 ms/div and 20 s/div, an additional message will appear in this location. As soon as the DMO begins to take samples, it sends a signal to the computer. During this time, a "SAMPLING" message will appear on the screen. This message indicates that the DMO is busy taking samples and should not be interrupted.

17. C1 CURSOR INDICATOR — This represents cursor C1. You can position it anywhere on the Y1 or Y2 trace, or you can turn it off. When it is on, the voltage at the cursor (measured or referenced to ground) is shown at the bottom of the screen. The time difference between the cursor position and the beginning of the trace is also printed at the bottom of the screen. If both cursors are on, an additional line of information is displayed that contains the voltage difference and the time difference between the two cursors. If the time difference is other than zero, it is converted to frequency (inverted) and also displayed.

18. C2 CURSOR INDICATOR — This represents cursor C2. It functions just like cursor C1.

19. C1 CURSOR DISPLAY — This line contains the information for cursor C1.

20. C2 CURSOR DISPLAY — This line contains the information for cursor C2.

21. C1-C2 CURSOR DISPLAY — This line contains the difference information between cursor C1 and cursor C2.

ABOUT THE MENUS

The bottom line of the display shows the current menu. To select other menus, press the F8 key. Each menu shows several function keys and a brief description about their use. The following information describes the menus in detail.

Menu #1

Refer to Pictorial 1-10 Part A as you read the following descriptions.

F1: ZERO CAL — Press F1 to force the DMO to rezero the vertical amplifiers. You should occasionally rezero these amplifiers during the first 15 minutes of use (to correct for warm-up drift) and when you make DC measurements.

F2: RESET/MANUAL — If the DMO is in the Single Sweep Mode and is triggered, press the F2 key to re-arm the trigger circuits. In all other cases, this key causes a manual trigger of the DMO. (The F2 key has the same effect as the RESET/MANUAL key on the front of the DMO.)

F3: CURSOR C1/C2 — The cursor that is shown in reverse video is the cursor that is currently under the control of the left and right arrow keys. If both cursor numbers are shown in reverse video, both cursors will move together when you press the left or right arrow keys. Push the F3 key to toggle the cursor selection between C1-C2- C1/C2.

F4: DEFINE CURSORS — Press the F4 key to turn the cursors on or off and to define the channel (Y1 or Y2) that the cursor is assigned to. When you press F4, the message shown in Pictorial 1-10 Part B is displayed.

The selection shown in reverse video is the current selection. To change it, press 1, 2, or 3 along the top of the computer keyboard. If you do not wish to change it, just press the RETURN key. All other responses are invalid and will cause the bell to sound. If you press 1, cursor C1 is assigned to channel Y1. Similarly, if you press 2, cursor C1 is associated with channel Y2. If you press 3, cursor C1 is not shown. After you respond to the above prompt, a second message like that shown in Pictorial 1-10 Part C is displayed.

Select cursor C2 just like you did for cursor C1. After you make your selection, the software will return to the main program and again start displaying data.

NOTE: As it takes time to calculate and display the cursors, the display will update faster if you turn the cursors off. If you are not using the cursors, therefore, turn them off.

F8: NEXT MENU — Changes the bottom line of the display to show selections that are available in the next menu.

Menu #2

Refer to Pictorial 1-11 as you read the following descriptions.

F5: SCOPE ON/OFF — Press the F5 key to turn the display oscilloscope that is connected to the front panel (if you are using one) on or off. The reverse video block indicates the current state of the display scope outputs. If the scope outputs are off, the data transfer between the DMO and the computer is a little faster. If you are not using a display oscilloscope, therefore, it is best to turn off the scope outputs.

F6: GRAT ON/OFF — Press the F6 key to turn the graticule on or off. The reverse video block indicates the current state of the graticule.

F7: LINE/DOT — The data for each channel consists of 512 points. If you select dot (as indicated by the reverse video block), only the data points are shown on the display. If you select line, a line is drawn between successive data points. This makes the display look more "natural." It takes more time, however, to plot the extra points needed to draw the lines. If display speed is important, the dot mode may be more useful.

Menu #3

Refer to Pictorial 1-12 as you read the following description.

F5: MEMORY — Press the F5 key to save a waveform on disk, recall a waveform from disk, or to control the display of waveforms that have been recalled from disk. After you press the F5 key, the following menu is displayed:

```
SELECTION:   1) SAVE WAVEFORM ON DISK
             2) RECALL WAVEFORM FROM DISK
             3) MEMORY ON/OFF
```

Press F5 again to exit this function.

If at any point during the execution of the memory functions you decide that you do not wish to continue, you can press F5 again to exit without changing anything.

The following paragraphs explain each of the menu selections in detail.

Save Waveform on Disk

Press the 1 key to save one of the waveforms that is currently being displayed. The display will ask you if you wish to see the directory of the default drive. Press the Y key to see the directory, or N to go on to the next message. If you press the Y key, the screen will display the following message:

```
Drive name < Type return for default drive > ?
```

If you wish to see the default drive directory, press the RETURN key. If you wish to look at another drive or subdirectory, enter the proper information. If you desire to look at the directory of drive B, for example, enter B:. Enter B:\SCOPE\ to look at a subdirectory named "Scope" on drive B. Once you look at the directory, press any key to continue.

The following message will now be displayed:

```
Which channel do you want to save?  1) Y1
                                    2) Y2
```

Press the 1 key to save the contents of channel Y1, or press the 2 key to save the contents of channel Y2. When a waveform is saved on disk, the vertical sensitivity, time base, offsets, and whether or not the channel was inverted are also saved in addition to the data points. The additional information is saved so that a recalled waveform looks exactly like it did when you saved it.

After you choose the channel that you wish to save, the display will ask you for a filename. This is the name of the file where the display data will be stored. The form of the name should be d: Pathname\Filename.EXT. The letter d is the drive designation of the destination drive, Pathname is the path name that identifies the directory (if it is not the source directory) where you wish to copy the file, and Filename.EXT is the fule you wish to save. (Refer to your computer manuals for more information about filenames.) At this point, type in the drive name (if it is not the default drive), the pathname (if it is not the default directory), and the filename, followed by a RETURN. After a pause, while the data is being stored on disk, the display will ask you if you wish to save another waveform. Press the Y key to either store the other channel on disk or to store the same channel under a different name. If you do not wish to save any more waveforms, press the N key in response to the question. This causes the program to exit the memory function.

Recall Waveform from Disk

Recalling a waveform from disk is similar to saving the waveform to disk. To recall a waveform from disk, press the 2 key in response to the Selection menu. As before, the display will ask you if you wish to see the directory. It will then display the following message:

```
Which memory do you want to use?  1) MEM1
                                  2) MEM2
```

There are two data arrays you can use to display waveforms that are recalled from disk. Pick the one you wish to use and enter the proper response. The display will then ask you for a filename. After you enter the filenamenecessary response (which may include the drive name, the pathname, and the filename), followed by a RETURN, the program will load the data from the disk and display it. The name of the recalled file along with the vertical sensitivity and time base that were in effect when you stored the data will appear in the lower right corner of the display. The recalled display will appear on top of anything that was being displayed at the time you recalled the saved display.

The recalled display will look exactly like the display that was previously saved. If the display was inverted or offset at the time that it was saved, it will still be inverted or offset when you recall it.

After you display the recalled data, the display will ask you if you wish to recall additional waveforms. At this point, you can recall a waveform to either one of the memories. NOTE: If you recall a waveform to a memory that already contains data, the old data will be lost and will no longer be displayed. Only two recalled waveforms may be displayed at a time.

Memory ON/OFF

Once MEM1 and/or MEM2 are loaded with data, you can turn them on or off by pressing the 3 key in response to the Selection menu. This will result in the following display:

```
MEM1:      1) ON
           2) OFF
```

The highlighted selection is the current selection. To change the current selection, either press the 1 or the 2 key. To keep the current selection, simply press the RETURN key. You cannot turn MEM1 on unless data has previously been recalled from disk and loaded into it. If MEM1 is on, the contents of MEM1 will be displayed. If MEM1 is off, the contents of MEM1 are not displayed, but the data is maintained in memory. This function allows you to quickly turn a recalled display on or off without going through the longer process of naming a file and recalling it from disk.

After you turn MEM1 on or off, the display will ask you to make a similar selection for MEM2. The program will then exit the Memory function.

NOTE: If an error occurs when the program tries to either save or recall a waveform, an error message is printed along with an error number. This number corresponds to the error numbers listed in the GW-BASIC Manual. Typical errors are:

#64....bad file name
#61....disk full
#71....disk not ready
#53....file not found

F6: AVERAGING — Press the F6 key if you wish to turn the averaging function on or off. The first message you will see is:

```
Select channel to be averaged:
      1) Y1        3) Y1 and Y2
      2) Y2        4) AVERAGING OFF
```

The highlighted selection is the current selection. You can retain the current selection by simply pressing the RETURN key, or you can choose a different selection by pressing the 1, 2, 3, or 4 key. If you select a channel for averaging, "avg" will appear on the right side of the display under the channel's name.

If you select at least one of the channels for averaging, the display will ask you to select the number of averages it should perform. The value shown highlighted is the current value, which is retained when you press the RETURN key. To change the number of averages, which must be between 1 and 250, enter the number followed by a RETURN.

The averaging process then begins as follows. Assume the number of averages has been set to 10. The program asks the DMO for data. When the program receives this data, it adds it to a special array that has been set aside to act as a summation array. A counter keeps track of the number of averages that have been completed so far. The display then shows the result of the data in the summation array divided by the value in the counter. It also displays the current average number.

This process repeats until the value of the average counter equals 10, the value selected as the number of averages to complete. At this point, the program stops and waits for further instructions. The averaged waveform can be manipulated exactly like an unaveraged waveform. It may be saved to disk, measured with cursors, and offset. If you have changed any DMO parameters (from the computer) that would make the averaged display invalid, such as time base or vertical sensitivity, the averaging routine restarts. You can also restart the averaging routine by pressing the F1 key. To stop averaging, again use the F6 key to select the averaging function, and then select the AVERAGING OFF position.

NOTE: Be careful not to use the front panel pushbuttons to change any DMO parameters while averaging is in process. The averaging software will most likely not notice the change and the averaged data may be invalid.

The following brief discussion of the need and uses for averaging routines may be helpful. Averaging routines are typically used to remove random noise from a signal so that the signal can be displayed more clearly. A conventional oscilloscope performs this averaging process automatically. The trace you see in the display of a conventional oscilloscope typically has hundreds of individual traces repeated every second. For example, assume that one of these tracks has a burst of noise on it. Due to the nature of the phosphors used in a typical oscilloscope CRT, the points that correspond to the noise burst on the display do not become very bright and disappear quite rapidly. Only the points that are displayed repeatedly (such as the points associated with the main waveform) are bright enough and persist long enough for the eye to see them. The noise, which is assumed to be different on each trace, is not visible. It has been removed by the natural averaging process of the phosphors.

On a digital oscilloscope, there is no averaging process built into the display system. A digital oscilloscope takes a "snapshot" of the input waveform and then displays it. In the case of the hypothetical waveform with a burst of noise, the waveform along with the noise burst would be sampled and displayed. Since the noise is now displayed just as clearly as the main waveform, the signal appears to be noisy. As the noise is real, it is probably fair to say that the digital oscilloscope is more accurate. Depending upon the application, however, seeing the noise may be a disadvantage.

There are two reasons for including averaging routines in the software for the DMO. One reason is that these routines use mathematical algorithms to approximate the averaging that occurs in a normal oscilloscope. If you use averaging on a waveform that contains a small amount of noise, the noise will disappear, and only the signal will be displayed. It is then easier to analyze the signal.

Another reason to include averaging routines is an extension of the first. It is possible to extract signals from noise, even if the noise levels are greater than the signal levels. If a trigger source is available that is locked to the desired signal, signals that would be "buried" in noise on a conventional oscilloscope can be averaged and then displayed clearly on a digital oscilloscope. This process is not possible on a conventional oscilloscope.

MISCELLANEOUS INFORMATION

Display screen — the display is based on an 8-division by 10-division graticule. Each vertical division is 25 bits, which produces a 200-bit display (with 28 bits of overscan on the top and bottom). Due to screen limitations, however, this 200-bit display is scaled down to 160 bits before it is displayed by the computer. This scaling affects the display only and does not affect the information in the cursor printout area or the trigger level. The data arrays are also unaffected by this scaling. The vertical compression of the display means that 2 points that are 1 bit apart may seem to be on the display but have different values in the cursor printout area. In such cases, the cursor printout is always correct.

There is no compression of the horizontal scale, but only 500 of the 512 points stored in the data arrays are actually plotted. The use of 512 points in the data arrays makes the implementation of certain mathematical algorithms that are based on powers of two easier.

Screen blanking — The screen will go blank when either of the following conditions occur:

1. Less than 512 data points per channel are transferred. Such a condition may be caused by an error during the transfer of one or more of the data bytes, or if you touch the front panel of the DMO during data transfer.

2. Many of the computer keyboard functions cause the screen to blank. This eliminates the possibility of displaying "old" data after you change one of the keyboard functions.

Function select blanking — The function that is highlighted on the right side of the graticule blanks whenever the program asks the DMO for information about the front panel settings. If the function that is selected remains blank, the communication channel between the computer and the DMO is not working.

NORMAL OPERATING CHARACTERISTICS

You should keep the following items in mind whenever you use your DMO:

1. Rezero the DMO occasionally during the first 15 minutes of operation. This will null out the DC drift that occurs during the initial warm-up period. Also rezero the DMO occasionally when you make DC measurements to ensure the best possible accuracy. The easiest way to rezero the DMO is to press the RESET/MANUAL pushbutton on the front panel, or have the computer send a rezero command to the RS-232 port. (Many other commands also cause the unit to rezero itself. Refer to "Controls and Connectors."

2. The DMO checks the BAUD RATE jumpers only at turn-on. If you wish to change the baud rate, turn the DMO off, move the jumpers to select the new baud rate, and turn the DMO back on. The new baud rate will now be in effect.

3. The DMO continuously checks the NORMAL/CALIBRATE and holdoff jumpers. You can change these jumpers at any time. This feature is especially useful when you adjust the holdoff jumpers to match your display oscilloscope.

4. If you use the front panel VERTICAL POSITION controls to move the output waveform on the display oscilloscope, the waveform data stored in the internal memory is not affected. If the RS-232 port receives a Data Request command, the data that is sent to the computer is not offset. If the computer needs to determine the vertical offset, it should issue a Status Request command.

5. The output display is designed for eight vertical divisions of 25 bits each. This yields a 200-bit display with 28 bits of overscan at both the top and bottom of the display. The front panel controls can be used to bring the bits that are "off screen," back on screen. The vertical offsets affect only the display and not the data in memory. The total "window" available for display, therefore, remains at 256 bits regardless of the amount of offset. If you overdrive the "window" with a large input signal, the result will be a waveform that appears to be clipped at zero and 256 bits. This happens whenever the range of the A to D converter is exceeded.

6. On all time base settings, except 500 µs/div, the DMO samples both input channels at the same time (often referred to as "chopped" on a conventional oscilloscope). On the 500 µs/div range, however, all 512 samples of channel Y1 are sampled first and then (after it receives a second trigger) 512 samples of channel Y2 are sampled (usually referred to as alternate sweep). After the DMO takes the samples of Y1 (on the 500 µs/div range), the READY LED on the front panel turns on to indicate that the DMO is waiting for another trigger before it continues to take samples of channel Y2.

7. The DMO contains no delay line. This means that the leading edge of the waveform that is being triggered will be lost. On time base ranges between 20 s/div and 500 µs/div, approximately 80 µs of the waveform will be lost. On the 200 µs/div to 5 µs/div time base ranges, approximately 1/2-division of the leading edge is lost. On time base ranges between 2 µs/div and 20 ns/div, approximately 1.5 divisions plus 45 ns of the leading edge will be lost. On the 10 ns/div range, approximately 80 ns of the leading edge is lost.

8. In general, commands received from the front panel or from the RS-232 port will interrupt the current activity of the DMO. If, for example, the DMO was in the process of gathering data on one of the slow time base ranges, any command received from either the front panel or the RS-232 port will stop the data-gathering process. After the DMO responds to the received command, it will return to the data-gathering mode. This point is especially important if you are writing your own program to control the DMO. Always wait for the DMO to send an indication that the data- gathering process is complete before you allow the computer to issue any new commands. If you do not do this, the data received by the computer from the DMO is most likely incorrect.

   Commands received from the RS-232 port will most likely make the waveforms on the display oscilloscope wink. This happens because the DMO does not refresh its output display while it is responding to the received commands. If the computer you have connected to the RS-232 port continuously issues commands to the DMO, the output display will blink more often than normal.

9. If the NORMAL/CALIBRATE jumper is in the NORMAL position, the DMO rezeros the vertical channels every time it receives a command; either from the front panel or the RS-232 port. This causes a slight delay before the relays click into their final positions. The rezeroing delay is slightly longer on time base ranges between 200 µs/div and 10 ns/div. (There are a few commands which do not cause the DMO to re-zero itself. Refer to "Controls and Connectors.")

10. On time base ranges between 200 µs/div and 10 ns/div, the DMO operates in an equivalent time-sampling mode. (Also see "Operating Characteristics of a Digital Oscilloscope – Equivalent Time Sampling".) Since this mode of operation requires 512 triggers in order to reproduce the input waveform, the input waveform must be repetitive on these time base ranges. In addition, if the duty cycle of the repetitive waveform is low (does not repeat very often), it could take a fairly long time for the DMO to completely sample the waveform. If you wish to measure a waveform that generates a trigger every 10 ms, for example, it will take 5.12 seconds to completely sample the waveform. In general, waveforms that are measured on these faster time base ranges have duty cycles that are fast enough so the time required to generate 512 individual triggers is not significant. If, however, the DMO is in the Equivalent Time-Sampling Mode and appears to be triggered, but seems to take a long time to generate a display, there

could be a significant amount of time delay between trigger events. Assuming that you have the trigger level properly adjusted, the input signal probably has a low repetition rate and you will simply have to wait until all 512 samples have been taken.

11. In the Single Sweep and Normal modes, random noise can cause the highly sensitive sweep circuits to trigger. If this happens, slightly readjust the TRIGGER LEVEL control.

12. At slower sweep speeds, it takes a long time to sample 512 data points. If you are using a slow sweep speed, the computer display will not update until all 512 points are sampled. On the 20 s/div range, for example, this process will take 200 seconds.

13. The baud rate used for serial communication is the main limiting factor that determines how fast the screen updates. You can calculate the time required to transfer data using the following equation:

$$\text{Time per channel} = \frac{10}{\text{Baud Rate}} \times 513$$

At 9600 baud, for example, each channel takes 0.53 seconds to transfer data from the Oscilloscope to the compute. At 300 baud, it takes over 17 seconds to transfer this data. You should, therefore, use the fastest rate your computer allows.

USING A 5-MILLIVOLT OSCILLOSCOPE

When you use an Oscilloscope as sensitive as this one, you must use special care to make reliable measurements. Keep the following points in mind when you measure very low-level signals.

— **Where** you place the ground clip may be critical, if the signal source ground carries an appreciable current. Voltage differences of several millivolts are common from one side of a chassis or ground foil to the other. Place the ground clip at the point that gives the least error. This usually means nearest to the signal source. You may have to move the clip when you measure at different points.

— It may be hard to eliminate the pickup of stray 60 Hz signals, especially in high-impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.

— Wideband measurements in the millivolt and microvolt regions are more difficult due to the inherent noise (shot noise and thermal noise) generated by electronic components. Noise on the base line that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of external noises such as those generated by lightning, ignition, appliance noises, etc. Noise of any kind may cause erratic triggering.

— Radio frequency interference may be picked up in strong RF signal areas. This type of interference may come from a commercial broadcasting station or from nearby equipment.

— Thermal drift may also appear if the test clip is connected across a junction of two dissimilar metals or across a semiconductor. This will appear as a baseline drift when the junction changes temperature.

OPERATING CHARACTERISTICS OF A DIGITAL OSCILLOSCOPE

This DMO uses digital sampling techniques to represent analog input signals as a series of digital words that are then stored in memory. Since digital sampling systems have disadvantages as well as advantages, it is important that you understand how they operate so you can make the best use of your DMO. This section briefly describes how a digital oscilloscope works and suggests some measurement techniques that will help you avoid the limitations that are inherent in a digital oscilloscope.

REAL-TIME SAMPLING

The DMO uses real-time sampling techniques on time base ranges between 20 seconds/division and 500 microseconds/division. Real-time sampling is a system that, once triggered, takes a series of **equally spaced** samples of the input signal. One limitation of this type of system is that changes in the signal that occur between samples is lost. This loss of information is referred to as "aliasing."

Aliasing occurs when the input signal is not sampled often enough. This generates false signals that usually appear to be at a lower frequency than the input signal. Unless you know in advance what the input signal looks like, it is usually not obvious that aliasing has occurred. The following simple example shows you how aliasing can occur and suggests a measurement technique to avoid it. If you have a signal generator available, you can perform the following example on your DMO and see the results of aliasing.

Example of aliasing:

Assume a 1000 Hz signal is applied to the input of the DMO. If you set the time base of the DMO to 1 ms/div, 10 cycles of the sine wave will appear on the display. Since the DMO samples the waveform 50 times per division, each cycle of the sine wave is sampled 50 times. The result is a very clear representation of the input signal. See Pictorial 1-13.

Now assume that you change the time base setting to 10 ms/div. The display now looks crowded. See Pictorial 1-14.

As mentioned earlier the DMO samples 50 times per division, which results in sample points that are 200 µs apart. Since the input signal is a 1000 Hz sine wave, it is sampled 5 times per cycle. Although the above display is too crowded to be useful to the eye (it is still useful to a computer), it is not "wrong." Actually, it is much like what you would see on a conventional oscilloscope. NOTE: If you try this example on your DMO, the display you see will vary due to the exact frequency of the input signal. Vary the input frequency slightly and observe the changes in the display pattern.

Now assume that you change the time base setting to 50 ms/div. The resulting display will most likely resemble the one shown in Pictorial 1-15. This is definitely not what you would expect to see on a conventional oscilloscope. To understand what has happened, remember that since 50 samples are taken per division, a sample is being taken every 1 ms. If you draw the original waveform and show the sample points, it would resemble the expanded portion of Pictorial 1-15.

As you can see, the input waveform is sampled at the same point each time (assuming the signal is exactly 1000 Hz). Since only the sample points are shown on the display, the display seems to show that the input signal has no AC component, but only a DC component (of zero volts in this example). If you actually try this example on your DMO, vary the frequency slightly and observe the display. You will see various waveforms on the display, but all of them are incorrect. These are all examples of aliasing. Even though the display looks reasonable, the displayed data is incorrect. If you use the measurement technique described next, however, you can always avoid an aliased display.

MEASUREMENT TECHNIQUE TO AVOID ALIASING

The input circuits of the DMO have a bandwidth of 50 MHz, but input signals up to 100 MHz reach the digital sampling circuits. A mathematical theorem called the "Sampling Theorem" indicates that aliasing does not occur if the input signal is sampled at least twice per cycle (one cycle at 100 MHz is 10 ns). If you wish to sample each cycle at least twice, you must take a sample every 5 ns or faster. If the time base is set to 200 ns/div, a sample is taken every 4 ns and aliasing does not occur for input signals with frequencies less than 100 MHz. This is the key to making alias-free measurements. **If you initially set the time base to 200 ns/div or faster, you can be sure that, even if the display is not useful, at least it will not be aliased. You can now slow down the time base setting until you see a useful display**. Since you have approached the input signal from the non-aliased side, the display is not aliased unless you continue to slow down the time base even further.

As you gain experience using a digital oscilloscope, you will find that it is usually not necessary to go to the above extreme to make sure the display is not aliased. If you are dealing with an unknown input signal, simply adjust the time base for a reasonable-looking display. Count the number of cycles of the waveform on the display. If you increase the time base setting until it is 10 times faster, you should see 1/10 as many cycles. If this is not the case, the slower time base setting was causing the display to alias. Try a faster time base setting and repeat the procedure.

EQUIVALENT TIME SAMPLING

The DMO uses equivalent-time sampling techniques on time base ranges between 200 μs/div and 10 ns/div. The major difference between equivalent-time sampling and real-time sampling is that, while real-time sampling may be used on any type of waveform, equivalent-time sampling is only useful on repetitive signals. This is true because the equivalent-time-sampling technique takes only one sample each time the oscilloscope is triggered. Since the DMO takes 512 samples of the input before it is displayed, it must get 512 triggers if it is in the equivalent-time-sampling mode. This requires the input signal to repeat itself at least 512 times. The following example and Pictorial 1-16 will make this clear.

Pictorial 1-16 Part A shows a sine wave. The DMO is set to trigger at zero volts on positive slopes. The first sample is taken as soon as the DMO is triggered. Sample #1, therefore, is approximately zero volts. This sample is converted to a digital value and then stored in memory.

Part B of the Pictorial shows what occurs when the DMO is ready to take a second sample. The trigger circuits are rearmed and the DMO is retriggered when the sine wave again crosses through zero volts with a positive slope. This time, however, there is a delay before the sample is taken. This delay is equal to the time base setting of the DMO divided by 50. The second sample is converted to a digital value and then stored in memory.

Part C of the Pictorial shows what occurs when the DMO is ready to take a third sample. The trigger circuits are again rearmed and the DMO is retriggered when the sine wave crosses through zero volts. This time the DMO delays even longer before it takes the third sample. This time, the delay is equal to twice the delay that took place for the second sample. This process of triggers followed by samples taken after increasing delays continues until the last sample is taken, as shown in Part D.

After 512 points have been sampled, they are used to generate the display. Note that, not only must the waveform repeat itself 512 times, but it must be the same each time. If there was a "glitch" in waveform #3, for example, it would not show up in the final display unless it happened to coincide with the sample point. This means that equivalent-time sampling is not very useful if you are looking for occasional glitches, even if the main waveform is repetitive.

Except for the requirement that the input signals must be repetitive, equivalent-time sampling is much like real-time sampling. You must take care to make sure the display is not aliasing. You should always use the techniques described earlier to make sure the display is valid.

DIGITIZING ERRORS

The DMO uses an 8-bit analog-to-digital-digital (A/D) converter to convert input waveforms into digital data. This means there are 256 digital levels that may be used to describe the input waveform. A "smooth" input waveform is, therefore, converted into a series of small "steps" when the digitized waveform is shown in the display. The following example and Pictorial 1-17 illustrates this.

The levels on the left represent a one-bit change in the output level of the A/D converter. Since the DMOs A/D converter really has 256 different output levels, only a small portion of its range is shown here. Times T1 through T11 are the points in time where the A/D converter is requested to take a sample of the input waveform and convert it into digital data. At time t = T1, the input waveform's value is zero. The A/D converter changes this value into digital data that represents the value zero. The input waveform changes between times T1 and T2, but the output of the A/D converter does not. The output of the A/D converter does not change again until time T2, when it is again requested to take a sample of the input waveform. This characteristic of the A/D converter yields the staircase effect that is characteristic of a digitized waveform.

Note that at time T3 the A/D converter seems to have a slight problem. The input waveform has a value of about 3.6, but the A/D converter has only output values of 3 and 4 to choose from. Since 3.6 is closer to 4 than it is to 3, an "ideal" A/D converter would output the value 4 as shown in the Pictorial. As you can see, the output of the A/D converter is always within ± 1/2-bit of the input value. This would be called ± 1/2-least-significant bit (LSB) accuracy. As the value of each bit is made smaller, the "steps" in the output of the A/D converter become smaller and the output looks more like the input waveform and less like a staircase. 256 display bits ensure a smooth-looking waveform.

Now consider the case of a non-ideal A/D converter and a non-ideal input signal. The A/D converter in the DMO has only ± 1 LSB accuracy. If you consider power supply variations, temperature variations, temperature-induced gain variations, and input noise, the error may increase to ± 2 bits. The following example and Pictorial 1-18 illustrates this.

Two input signals are shown along with their digitized versions. Since input waveform #2 is nearly centered between 3 and 4, a small noise glitch in one direction on the other can cause the output of the A/D converter to be either 3 or 4. This causes a "noisy" looking output display because the A/D converter cannot seem to decide what the output value should be. Since waveform #1 is centered at +3, it takes a large noise glitch to make the A/D converter change values. The result is a fairly constant output display which makes signal #1 appear less noisy, even though the two input signals have the same amount of noise.

In addition to making the noise appear worse than it really is, digitizing errors can effect your measurements in another way. At first glance, a 2-bit error does not seem to be very important. Two bits out of 256 bits is less than a 1% error. Consider, however, what happens when you try to measure two different DC values. Assume that you have applied a +4-volt signal to the input of the DMO. Also assume that the input sensitivity is set to 1 v/div. Since the display of the DMO uses 25 bits per division, each bit will have a value of:

$$\frac{1V}{25} = 40 \text{ mV}$$

The input value is 4 volts, so it takes one hundred 40 mV steps to represent the input value. As long as the output of the A/D converter remains at 100, there is no error. If, however, for one of the above-mentioned reasons, the A/D converter makes a 2-bit error, you can now see a 2% error. While this is worse than the $<$ 1% error that 2-bits out of 256 bits represents, it is still a reasonable error value.

Now assume that you change the input value to 1 volt. Since each bit still represents 40 mV, the output of the A/D converter should be 25. Again, as long as the output of the A/D converter remains at 25 there is no error. If, as above, you assume that the A/D converter makes a 2-bit error, you suddenly have an error of 8%! As you make the input signal even smaller, the errors get progressively worse.

The only way to avoid this problem is to keep the displayed waveform as large as possible, especially if you need to make accurate measurements. Whenever possible, adjust the input sensitivity of the DMO to produce a full scale, or nearly full scale, output display.

OPERATIONAL EXAMPLES

This section of the Manual provides you with several examples for using the DMO in its various modes of operation. Since you can control the DMO from either the front panel or from a computer that is running the SCOPE program supplied, the following examples do not specifically refer to the computer or the front panel (unless the feature being described is available only from that source). In addition, whenever the display is referred to, it can be either the display oscilloscope or the computer display. If a feature is unique to one of these displays, it is described separately.

If you have not already done so, connect the DMO to your display oscilloscope and/or computer. Turn the DMO off and then on again to reset the DMO's circuits. The LEDs on the front panel will cycle for about 10 seconds and then stop. The DMOs controls are now preset for the examples that follow. Do not change any of the control settings unless you are directed to do so. If you are using a computer, boot the computer and run the program on the diskette supplied (if necessary, refer to "Getting Started" beginning on Page 10).

EXAMPLE 1 — TRIGGER SLOPE AND TRIGGER LEVEL

Connect a 1000 Hz (approximate) sine wave signal to the Y1 input of the DMO. Set the TIMEBASE of the DMO to 500 μs/div, turn channel Y2 OFF, and adjust the Y1 VERTICAL SENSITIVITY (or the generator output level) so that the sine wave fills most of the screen vertically.

Change the TRIGGER SLOPE from + to −. Note that the trigger point now occurs on the negative slope of the sine wave. Now change the slope back to + and note that the trigger point again occurs on the positive slope.

Refer to Pictorial 1-20 and change the TRIGGER LEVEL. Notice how the trigger starting point moves up or down on the graticule as you increase or decrease the trigger level. Also notice that the first point shown on the display is not equal to the trigger starting point. Since there is no delay line in the DMO, the actual trigger point occurs to the left of the graticule as shown in the Pictorial.

If you change the TRIGGER LEVEL from the front panel, a line will appear on the display oscilloscope. This line represents the trigger level that has currently been selected. If the trigger level is above zero, the "+" LED on the front panel will light. Similarly, if the trigger level is below zero, the "−" LED will light. If you are using the front panel, press both LEVEL pushbuttons at the same time to return the trigger level to zero.

If you change the TRIGGER LEVEL from the computer keyboard, a small mark will appear on the left side of the computer graticule whenever you change the LEVEL. This mark provides you with a visual indication of where the present trigger level is set. The numeric value of the trigger level is also printed on the right side of the computer graticule. When TRIGGER LEVEL is highlighted on the computer display, press the HOME key to return the trigger level to zero.

EXAMPLE 2 — NORMAL, AUTOMATIC, SINGLE-MODE TRIGGERING

The Auto mode (automatic triggering) provides a base or reference trace whenever the DMO is not triggered. In this mode, the DMO waits approximately 0.25 second and, if the trigger has not been generated, generates its own trigger. This mode keeps the display from going blank when the trigger is lost.

Set the TRIGGER SOURCE to Y2. Since there is no signal connected to Y2, the trigger should be lost. (If the DMO appears to remain triggered, the Y2 input could be picking up stray noise since the inputs remain AC coupled when they are off. If this occurs, use the LEVEL controls to move the TRIGGER LEVEL far enough away from zero so that trigger is lost.) Notice that the "no trigger" message appears and the starting point of the waveform on the display is no longer consistent. The waveform appears to wander across the display.

Now change the TRIGGER MODE to NORM (normal triggering); notice that the display remains blank. In the normal triggering mode, the DMO waits indefinitely for a trigger. Only after a valid trigger is received will data be gathered and a display generated. Switch the TRIGGER SOURCE back to Y1 and notice that the trigger is restored and a display is generated. (If you moved the trigger level away from zero in the above step, rezero it at this time.) When a trigger is present, there is very little difference between NORM and AUTO. NORM is usually used on signals that are so slow that the AUTO mode would generate an automatic trigger before the signal has a chance to generate a real trigger.

Now change the MODE to SINGLE. The display may not appear to be different at first, but disconnect the input signal from the Y1 input and notice that the display does not change. Once a trigger is received in the Single mode, one sample of data is captured and then held until another command is received.

While the input signal is still disconnected, press RESET/MANUAL. Since there is no input signal present, the display will go blank, because there is no trigger. (As before, a trigger may occur if the Y1 input picks up stray noise. If this occurs, move the TRIGGER LEVEL way from zero until the DMO no longer triggers on noise.) The computer display should say "armed" to indicate that it is waiting for a trigger. The READY LED on the front panel will be lit, which also indicates that the DMO is waiting for a trigger. If you press the RESET/MANUAL pushbutton again, a manual trigger will be generated and the display will show the signal that is present at the Y1 input. (Since the Y1 input is disconnected, this signal should be near ground.) The computer display will indicate "manual trigger" and the oscilloscope will display "No Trigger" to show you that the displayed waveform was not triggered when it was captured.

Reconnect the sine wave signal to channel Y1. Notice that the display does not change. Again press RESET/MANUAL. Since the trigger signal has been reconnected, the trigger will rearm itself and then trigger. The 1000 Hz sine wave will again be displayed.

As shown in this example, the RESET/MANUAL control has two functions. If the DMO is in the Single mode and is already triggered, RESET/MANUAL rearms the trigger circuits and blanks the display until it receives a trigger. If the trigger circuits are already armed, RESET/MANUAL generates a manual trigger and forces the DMO to gather and display one sample of data. In addition, if the DMO is in the Norm mode, RESET/MANUAL may be used to generate a manual trigger. This is useful when the DMO is in the Norm mode and is not triggering. In this case, RESET/MANUAL forces a trigger and allows you to see what is on the inputs.

Example 3 — Loss of Trigger in Equivalent Time Mode

Set the TRIGGER MODE to AUTO and the TRIGGER LEVEL to zero. Be sure the TIMEBASE is still set to 500 μs/div and the 1000 Hz sine wave is still connected to channel Y1. Now change the TIMEBASE to 200 μs/div. On time base ranges of 200 μs/div or faster, the DMO is in the equivalent-time sampling mode. This means that 512 triggers are required for the DMO to completely sample the input signal. This example demonstrates what happens when it looses the trigger.

Change the TRIGGER SOURCE to Y2. The trigger is now lost, but because the TRIGGER MODE is AUTO, an automatic trigger is generated and a reference trace is displayed. Now change the TRIGGER SOURCE back and forth between Y1 and Y2. Notice that the amplitude of the sine wave does not change, but the apparent frequency does. Recall that when the trigger was lost on the 500 μs/div range, the sine wave frequency did not appear to change. This shows that loss of trigger in the equivalent-time mode can cause erroneous displays. For this reason, an "Error....No Trigger" message appears whenever trigger is lost on an equivalent-time range. Although inaccurate, the display may still be useful as a guide to where the TRIGGER LEVEL should be set to reestablish trigger.

EXAMPLE 4A — FRONT PANEL POSITION CONTROLS AND SAVE

Set the TIMEBASE back to 500 μs/div and the TRIGGER SOURCE back to Y1. Be sure the TRIGGER MODE is set to AUTO and the 1000 Hz sine wave is again displayed.

Use the Y1 position pushbuttons, on the front panel, to move the display up one or two divisions on the display oscilloscope. You can use these pushbuttons to position the displayed waveform on the graticule as you desire. Typically, you would use these controls to separate channel Y1 from channel Y2, or to align the displayed waveform with the graticule to make a measurement easier. If you want to move the waveform horizontally, use the horizontal position control on the display oscilloscope.

Now press the SAVE pushbutton on the front panel. The SAVE LED will light and the display that was present when you pressed the button is saved in memory and redisplayed. Whenever the SAVE LED is lit, it indicates that the SAVE memories of the DMO are being displayed. To see this, remove the sine wave from the Y1 input and notice that the saved sine wave is still displayed along with the new input, which is still offset. Simultaneously press both Y1 POSITION pushbuttons on the front panel so the display offset returns to zero. Notice that the "No Trigger" message is also on since the trigger signal has been lost. Now reconnect the sine wave to channel Y1. There are now two sine waves on the display oscilloscope, the "saved" sine wave and the "live" sine wave.

The SAVE function is very useful if you need to compare waveforms, such as before and after a circuit modification has been made. It is much easier to see the effect of such changes if the "before" waveform is available for direct comparison.

Note that you can use the SAVE function to store both channels Y1 and Y2 if they are both on when you press the SAVE pushbutton. Also note that the saved information is lost if you press the SAVE pushbutton again (to turn off the SAVE function), or if you turn the DMO off. The SAVE function has no effect on the computer display.

Now turn the SAVE function off and recenter the Y1 position controls, if necessary.

EXAMPLE 4B — COMPUTER POSITION CONTROLS AND INVERT (Computer Only)

The computer keyboard allows you to position the waveform on the computer display both vertically and horizontally. Use the F9 and/or F10 function keys to select the "Offset" function in channel Y1. Use the "up" arrow key to move the sine wave up one or two divisions. Notice that the amount of vertical offset that has been used is displayed in the highlighted area next to "Offset:". Now press the HOME key on the computer keyboard to recenter the waveform.

Use the F9/F10 keys to select the left/right arrow that is to the right of "TIMEBASE:". When this function is highlighted, the left and right arrow keys move the displayed waveform horizontally. Now use the right arrow key to move the sine wave one or two divisions to the right. Notice that the arrow on the display now points to the right. Press the HOME key to recenter the sine wave, and then use the left arrow key to move the sinewave to the left. The display arrow tells you if the display has been moved to the left or right. When the display arrow points both left and right, the display is centered. Again press the HOME key to recenter the display.

Normally you would use the vertical and horizontal position controls to move waveforms relative to the graticule or relative to each other, in order to make measurements or comparisons more convenient. Note that these position controls affect the waveform display only and do not affect the trigger level or the value of the cursors (if on).

Use the F9/F10 keys to select the "normal" in channel Y1. Press either the "up" or "down" arrow key. Note that the sine wave is now inverted and the highlighted area now says "invert" to indicate that channel Y1 is inverted. As with the position controls, the invert function affects the waveform display only and does not affect the cursor readouts (if on) or the trigger level. Press the arrow key again to return to "normal".

EXAMPLE 5 — VOLTAGE MEASUREMENTS

Peak-to-Peak Voltage Measurements

To measure the peak-to-peak voltage of a signal, count the number of divisions from the top of the waveform to the bottom of the waveform. Then multiply the number of divisions by the VOLTS/DIV setting of the appropriate channel. (It may be easier to count the number of divisions if you first use the vertical position controls to place either the top or the bottom of the waveform on one of the graticule lines.)

The waveform in Pictorial 1-20 should closely resemble the waveform on your display. The waveform in the Pictorial is four divisions from peak to peak. Assuming that the Y1 vertical channel sensitivity is set to 100 mV/div, the peak-to-peak amplitude of the signal is:

$$4 \text{ divisions} \times 100 \text{ mV/div} = 400 \text{ mV}$$

You could also use the cursors to make this measurement. Example 8 shows you how to use the cursors.

Ground-Referenced Voltage Measurements

To make a ground-referenced voltage measurement, first make sure you use the vertical position controls to center the channel you are using. When you have the channel centered, the ground reference is the center of the display. Count the number of divisions from the center of the display to the point you wish to measure. As before, multiply this number by the VOLTS/DIV setting of the channel you are using.

Again look at Pictorial 1-20 and note that the peak of waveform 2 is two divisions above the center of the graticule. The voltage at this point, therefore, is (assuming the vertical sensitivity is still 100 mV/div):

$$2 \text{ divisions} \times 100 \text{ mV/div} = 200 \text{ mV}$$

You could also use the cursors to make this measurement as described in Example 8.

EXAMPLE 6 — TIME DURATION AND FREQUENCY MEASUREMENTS

NOTE: If you are using your DMO with a display oscilloscope, the front panel time base ranges assume that the display oscilloscope has 10 horizontal divisions. If your display oscilloscope has a different number of horizontal divisions, you will have to read your display as if it had 10 divisions to make accurate measurements.

To find the time duration between two points on a waveform, multiply the horizontal distance between the two points (in divisions) by the setting of the TIMEBASE. Frequency is the reciprocal of the time duration of one cycle of a waveform.

Increase the TIMEBASE until two cycles of the sine wave are displayed. (If you are using a 1000 Hz sinewave, the TIMEBASE setting should be 200 μs/div.) Your display should be similar to the one shown in Pictorial 1-21.

In Pictorial 1-22, one cycle of the sine wave is 5 divisions. One cycle, or the period, of the sine wave is therefore:

$$5 \text{ divisions} \times 200\ \mu\text{s/div} = 1000\ \mu\text{s} = 1 \text{ ms}$$

The frequency is the reciprocal of the period or:

$$1 \div 1 \text{ ms} = 1000 \text{ Hz}$$

Return the TIMEBASE to 500 μs/div.

EXAMPLE 7 — RISE TIME MEASUREMENTS

NOTE: Refer to Pictorial 1-22 as you study this example. Do not change any of the DMO's controls yet.

Rise time measurements are a form of the time duration measurement. These measurements are made between the 10% and 90% points on the edge of a square wave transition. Use the following procedure:

1. Adjust the controls of the DMO so that the edge you want to measure fills as much of

the display as possible. To do this, you will have to use the fastest time base that allows you to see the edge of the waveform you wish to measure.

2. Measure the vertical amplitude of the signal (in divisions). If possible, adjust the input signal and/or the input sensitivity so that the vertical amplitude is an exact number of divisions. This will make the calculations easier.

3. Calculate 10% of the waveform's amplitude (in divisions). Add this value to the bottom of the waveform. This is the 10% point. Subtract the value from the top of the waveform. This is the 90% point. The horizontal distance between these two points is the rise time.

Pictorial 1-22 shows the procedure. Ten percent of the 6-division square wave is 0.6 divisions. The bottom of the waveform is at -3 divisions, so the 10% point is:

-3 div $+ 0.6$ div $= -2.4$ div   10% point

The 90% point is:

$+3$ div $- 0.6$ div $= +2.4$ div   90% point

The time duration between these points is four divisions, so the risetime of the waveform is:

$$4 \text{ div} \times 500\ \mu\text{s/div} = 2 \text{ ms}$$

NOTE: When you measure very fast rise times (less than 20 ns), the rise time of the DMO must be subtracted from the measured rise time. In such cases, the rise time is:

$$\text{Actual Rise time} = \sqrt{(\text{Measured Rise Time})^2 - (7 \text{ ns})^2}$$

where 7 ns is the rise time of the DMO.

EXAMPLE 8 — MEASUREMENTS WITH CURSORS (Computer Only)

Press the F8 key until the menu that includes "F4:DEFINE CURSORS" appears. Now press the F4 key and select Y1 for both cursors (press the 1 key twice). Refer to Pictorial 1-23 and use the left/right arrow keys to move cursor 1 to the position shown in the Pictorial. Move the cursor until the voltage readout next to "C1:" is as close to zero as you can get it. The voltage readout next to "C1:" is the voltage of the sine wave with respect to ground at the point where the cursor is centered. The time readout to the right of "C1:" is the time difference between the cursor position and the start of the trace.

Now press the F3 key. Notice that the highlighted area switches from "C1" to "C2". This means that the left/right arrows will now move cursor C2 instead of cursor C1. Move cursor C2 to the approximate position shown in the Pictorial. Position the cursor so that the voltage printed beside "C2:" is as close as possible to the value printed beside "C1:". (NOTE: It will probably not be possible to make the values exactly the same unless the period of the sine wave is an exact multiple of 10 μs. Noise and sampling errors will also probably cause the cursor values to change.) The time readout to the right of "C2:" is the time, relative to the beginning of the trace of cursor C2's position.

The remaining line of information, "C1-C2", contains the indicated differences between cursor C1 and cursor C2. Since the cursors are at the beginning and at the end of a single cycle of the sine wave, the time readout to the right of "C1-C2:" is the period of the sine wave. The information in parentheses is the time difference between the cursors converted to an equivalent frequency. Since the cursors are at the beginning and end of a cycle, this is the frequency of the sine wave.

The cursors are very useful in making voltage and time measurements. They eliminate the "guesswork" when you try to read voltages and times from only a graticule. Remember that if you make voltage measurements with respect to ground, you should occasionally press the F1 key to make sure the DMO is zeroed.

Press the F4 key again and turn both cursors off.

EXAMPLE 9 — MEMORY (Computer Only)

Use the position controls to move the sinewave up and to the right one or two divisions.

Press the F8 key until the menu appears at the bottom of the display that contains "F5:MEMORY". Now press the F5 key to obtain the following menu:

```
SELECTION:      1) SAVE WAVEFORM ON DISK
                2) RECALL WAVEFORM FROM DISK
                3) MEMORY ON/OFF
```

Note that a message also appears which states that pressing the F5 key again exits the Memory routine. This feature is useful if, for example, you find that a waveform you wanted to recall from disk is not on the disk installed in the default drive. The F5 key allows you to exit the routine without encountering the error messages that would appear if you tried to recall a waveform that was not on the disk.

Saving to Disk

Press the 1 key to save the displayed waveform on disk. The display will ask you if you wish to see the current directory. This is helpful if there are several waveforms currently on the disk, and you want to be sure you do not overwrite one of them. For this example, press the N key.

The display will now ask you which channel you want to save. Since only channel Y1 is on, press the 1 key in response to this question. (NOTE: You may store the information that is currently in the Y2 data array at this time, but since channel Y2 is off, you may not be sure what the data looks like. It is better to turn Y2 on and look at it before you save it on disk.)

The display will now ask you for a filename. For this example, enter "TEST.ONE", followed by a RETURN. There will a be a pause while the data is stored on your default disk; then the display will ask you if you want to store another waveform. Press the N key in response to this question. The program will now exit the memory routine and return to normal operation.

Use the HOME key with the offset controls to re-center the displayed sinewave.

Recalling From Disk

Press the F5 key to return to the MEMORY routine. Press the 2 key in response to the Selection menu to recall a waveform from disk. As before, the display will ask you if you wish to see the directory. Assuming that you have forgotten the name of the file that was just saved, press the Y key in response to the question. The directory of the disk in the default drive will appear. Note that the file "TEST.ONE" appears in the directory. Press the SPACE bar to erase the directory and continue.

The display will now ask you which memory you wish to use. Press the 1 key to use MEM1. Next, in response to the filename prompt, enter "TEST.ONE" followed by a return. The waveform that was previously stored on the disk will appear on the display. Note that it is offset to the right and above center just as it was when you stored it. Also note that the name of the file, the associated vertical sensitivity, and the associated time base range are all printed in the lower right hand corner of the display. This information is useful when you compare "live" waveforms with recalled waveforms.

After the program displays the recalled waveform, the display will ask you if you wish to recall another waveform. You can use MEM1 and MEM2 to display up to two recalled waveforms. You can also recall a new waveform and load it into MEM1. The data that is currently stored in MEM1 will be erased and the new data loaded and displayed. Press the N key in response to this question. The recalled waveform remains on the display and the program will return to normal operation.

Memory On/Off

Press the F5 key to return to the MEMORY routine. This time, press the 3 key in response to the Selection prompt, to use the MEMORY ON/OFF routine. The program will respond with:

```
MEM1:      1) ON
           2) OFF
```

ON is highlighted to indicate that MEM1 is currently on. If you wish to leave it on, you could either press the 1 key or simply press the RETURN key. For this example, press the 2 key to turn MEM1 off. The display will respond with:

```
MEM2:     1) ON
          2) OFF
```

Since MEM2 is not currently being displayed, OFF is highlighted. Press the RETURN key to leave MEM2 in the OFF position. The program will return to the normal operating mode. Note that there are no recalled waveforms displayed.

Whenever a memory is turned off the data is retained in memory, but it is not displayed. This makes it possible to redisplay the data that is in memory by simply turning it back on with the MEMORY ON/OFF routine. It is not necessary to reload the data from disk.

EXAMPLE 10 — AVERAGING (Computer Only)

Press the F8 key, if necessary, until the menu that includes "F6: AVERAGE" appears at the bottom of the display. Press the F6 key to set up the averaging routine. The following menu will appear:

```
Select channel to be averaged:
      1) Y1     3) Y1 and Y2
      2) Y2     4) AVERAGING OFF
```

The highlighted selection indicates which is currently in effect. You either press the RETURN key to keep the current selection, or one of the selection numbers to change it. Since these examples use channel Y1, press the 1 key.

The display will ask you to select the number of averages to be performed. The highlighted number shown in brackets is the current number of averages being performed. You can either press the RETURN key to retain it or enter a number between 1 and 100 followed by a RETURN to change it. For this example, enter 10 followed by a RETURN.

The program is now in the averaging mode. Each time data is transferred from the DMO to the computer, it is summed into the arrays set aside for this purpose. Then the current average is calculated and displayed. Note that the current average number is displayed below the graticule. Also note that "avg" appears to the right of the graticule in the channel Y1 data area to indicate that channel Y1 is being averaged.

When the average number displayed below the graticule reaches the number of averages that you selected during the setup routine (10 in this case), the program will stop and wait for further instructions. At this time, you can manipulate the averaged waveform just as if it was a live waveform. You can save it to disk, use the cursors to measure various parameters, or move it around on the graticule with the position controls. If you change anything that would make the displayed waveform invalid, such as the Y1 vertical sensitivity, the averaging process will start over. You can also press the F1 function key to restart the averaging process.

Press the F6 key. Then press the 4 key in response to the prompt to exit the averaging mode.

SERVICE INFORMATION

CALIBRATION

WARNING: These servicing instructions are for use by qualified personnel only. To reduce the risk of electric shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

This section of the Manual is divided into two parts: "Calibration With Oscilloscope" and "Calibration With Computer." Perform **either** one of these calibrations after you have replaced parts. Always allow time (at least 15 minutes) for the DMO time to warm up and stabilize before you perform the calibration procedure. NOTE: In this section of the Manual, the names that are screened on the front panel (controls and their positions) are printed in ALL CAPITAL LETTERS. Names on the circuit boards, and other names not screened on the front panel, are printed with Initial Capital Letters.

You will need the following equipment to calibrate your DMO:

- A volt-ohmmeter (VTVM or DMM).
- An Oscilloscope Calibrator, such as the Heath Model SG-4244, or generators that provide the following signals:

  1000 Hz square wave, adjustable output up to 10 volts.

  1000 Hz square wave with an amplitude of 100 mV ± 1%.

  200 Hz to 10 MHz square wave with up to 1 volt output, a rise time of less than 1 ns, and an overshoot of less than 1%, and a frequency accuracy of 1%.

Controls and adjustments associated with channel Y1 are identified as Y1 or by component numbers in the 100 series, such as R102. Those identified with channel Y2 are identified as Y2 or by the component numbers in the 200 series. Use a plastic alignment tool to reach and make the adjustments.

During the calibration procedure, you may experience hum pickup in the sensitive vertical amplifier circuits since the cabinet top is not yet installed. To minimize this, position your hands, and other equipment or cables (line cords, etc.) as far away from the DMO as possible.

If you do not obtain the proper results in the following steps, turn the DMO off. Then refer to the "In Case of Difficulty" section of this Manual and correct any difficulties before you proceed.

Before you begin the calibration, refer to the "Operation" section of this Manual beginning on Page 9, to familiarize yourself with the operation of the DMO.

Calibration With Oscilloscope

( ) Refer to Pictorial 2-1 and remove the ten indicated screws so you can remove the cover. Then set the cover and the screws aside temporarily. CAUTION: Do not remove the AC shield on the rear of the chassis. To do so will expose areas that contain hazardous voltages.

NOTE: Refer to Pictorial 2-2 for the locations of controls on the display logic circuit board and Pictorial 2-3 for locations on the main circuit board.

( ) Make sure jumpers JP400 through JP405 on the main circuit board are set as shown.

( ) Preset the front panel controls as follows:

Y1 SENSITIVITY	5 mV/div
Y1 POSITION	Center (Simultaneously press the UP and DOWN pushbuttons.)
Y1 INPUT COUPLING	GND
Y2 SENSITIVITY	5 mV/div
Y2 POSITION	Center (Simultaneously press the UP and DOWN pushbuttons.)
Y2 INPUT COUPLING	GND
TIMEBASE	2 ms/div
SAVE	OFF
LEVEL	Zero
SLOPE	+
MODE	AUTO
SOURCE	Y1

( ) Connect the common lead of your voltmeter to the solder lug on the rear of the chassis. Leave this lead connected to the chassis until you are directed to disconnect it.

( ) Set the voltmeter to read DC voltage in the following steps. NOTE: You will have to set the range as necessary to accurately read the voltage indicated in the step.

NOTES:

1. Unless a step directs you otherwise, the following test points and adjustments are on the main circuit board.

2. Make the following adjustments as accurately as possible. The accuracy of your DMO depends upon how carefully you make these adjustments.

( ) Touch the positive volt-ohmmeter probe to the indicated lead of resistor R139 (TP1). Then adjust Y1 Step Balance control R123 for an indication of 0.00 volts.

( ) Touch the positive voltmeter probe to the indicated lead of resistor R239 (TP2). Then adjust Y2 Step Balance control R223 for an indication of 0.00 volts.

TRIGGER ZERO

In the following steps you will adjust a control for equal indications on two pins of an integrated circuit (IC). To do this, continually compare the indications at the pins while you adjust the control. The two pins should indicate approximately − 1.3 volts, but the exact value is not important at this time. NOTE: If you have a floating-input voltmeter, you can connect the meter between the two pins and adjust the control for an indication of 0.00 volts.

( ) Alternately touch the volt-ohmmeter probe to IC U303 pins 4 and 5 and adjust Y1 Amp Zero control R152 until the indications at both pins are the same.

( ) Set the TRIGGER SOURCE switch to Y2. Then alternately touch the volt-ohmmeter probe to IC U303 pins 4 and 5 and adjust Y2 Amp Zero control R252 until the indications at both pins are the same.

( ) Touch the volt-ohmmeter probe to IC U303 pin 4. Then adjust Trigger Level control R315 for an indication of −1.30 volts.

( ) Disconnect the volt-ohmmeter from the DMO.

OSCILLOSCOPE SETUP

( ) Connect a suitable cable from the VERTICAL OUTPUT of the DMO to the vertical input of an oscilloscope.

( ) Connect the TRIGGER OUTPUT of the DMO to the external trigger input of the oscilloscope.

( ) Preset the controls of the oscilloscope (not the DMO) as follows:

Vertical Input Coupling	DC
Vertical Position	Center
Vertical Input Sensitivity	.5 Volts/div
Sweep Speed	1 ms/div
Trigger Source	Ext
Trigger Slope	+
Trigger Mode	Auto
Trigger Level	Center

NOTE: If you obtain the horizontal traces but no message, in the next step, change the TRIGGER LEVEL control on the DMO either direction (+ or −) until you have both the message and the trace. If the message is off the top of the screen, adjust OUTPUT CAL control R506 (on the display logic circuit board) until it is on screen. If you are using a display oscilloscope that does not have eight vertical divisions, adjust its Vertical Position until the message is near the top of the screen.

( ) You should now see a display similar to the one shown in Pictorial 2-4. Change the Trigger Mode on the oscilloscope to Norm (no automatic baseline) and adjust the Trigger Level for a stable display. The trace should blank out momentarily approximately once each second. The exact position vertically of the two horizontal lines and the "no trigger" message is not important at this time.

( ) Adjust RT Zero controls R169 (for Y1) and R269(for Y2) on the DMO main circuit board until the traces are near the center of the screen.

( ) Push the SAVE pushbutton on the front of the DMO. The indicator just to the left of this pushbutton should light.

( ) Separately push the Y1 and Y2 ▲ POSITION pushbuttons to move the traces. There should now be four traces.

NOTE: In the next step you will adjust the holdoff for the shortest amount that will still display the message and four horizontal traces.

( ) Refer to Pictorial 2-5 and, starting from the 10 ms setting (both JP404 and JP405 at 1), move the jumpers to the 7.5 ms setting, followed by the 5 ms setting, and finally the 2.5 ms setting. Readjust the Trigger Level control on your oscilloscope after you make each change and check for the proper display. Leave the jumpers in the fastest (shortest time) position that will still display the "No Trigger" message and four horizontal traces.

( ) Push the SAVE pushbutton. The indicator just to the left of this pushbutton should go out.

NOTE: The DMO produces a very accurate display. Your display oscilloscope may have a nonlinear display (such as raster distortion, etc.), especially near the edges and corners. If necessary, compromise during the following adjustments to produce a "best fit" display.

( ) Use the Vertical Position control on your oscilloscope to center the trace by placing the reference center line (.8 division after the word "Trigger" in the center of the screen) so it is on the center graticule line. If the line preceding the "No Trigger" message does not lay on the top graticule line, adjust Output Cal control R506 on the display logic circuit board of the DMO until it does. NOTE: If you are using an oscilloscope that does not have an 8 × 10 graticule, use its position controls to shift the display the proper number of divisions on the screen. If you have a 6 × 10 division oscilloscope, for example, move the reference line down so it is one division below center. Then position the line preceding the "No Trigger" message on the top graticule line. When you recenter the reference line and perform the remainder of the adjustments, the DMO will be properly calibrated. The message, however, will be off screen.

( ) Use the Horizontal Position control on your oscilloscope to position the setup dot (eight divisions down from the top) of the "no trigger" message and the beginning of the two traces on the zero graticule (left edge). The beginning of the reference center line should line up with the tenth graticule line (right edge). If it does not, increase or decrease the Sweep Speed on the oscilloscope until it does.

LF COMPENSATION

( ) Preset the DMO front panel controls as follows:

Y1 INPUT COUPLING	DC
Y1 SENSITIVITY	20 mV/div
Y1 POSITION	Center
Y2 INPUT COUPLING	DC
Y2 SENSITIVITY	20 mV/div
Y2 POSITION	Center
TIMEBASE	500 μs/div
TRIGGER SOURCE	Y1

( ) Connect a 200 Hz (5 ms) square wave signal to the Y1 INPUT and adjust the level for approximately four divisions. Readjust the TRIGGER LEVEL as necessary to obtain a stable display. Then adjust Y1 LF control R126 on the main circuit board for the squarest corners and flattest top possible (see Pictorial 2-6). Disregard the bottom edge of the waveform.

( ) Connect the square wave generator to the Y2 INPUT and change the TRIGGER SOURCE to Y2. Then adjust Y2 LF control R226 for the squarest corners and flattest top possible (refer again to Pictorial 2-6). Disregard the bottom edge of the waveform.

NOTE: The next step directs you to set the Y2 INPUT COUPLING to OFF. To do this, push the Y2 INPUT COUPLING pushbutton until all three indicators (AC, GND, and DC) are out.

( ) Change the Y1 INPUT COUPLING to GND and the Y2 INPUT COUPLING to OFF. There should be one trace near the center of the screen.

( ) Switch the Y1 SENSITIVITY between the 20 mV and 10 mV ranges. The trace should not move vertically. If there is vertical movement, adjust Y1 Step Balance control R123 in small amounts until there is no movement when you switch between these two Y1 SENSITIVITY ranges.

( ) Change the Y1 INPUT COUPLING to OFF and the Y2 INPUT COUPLING to GND.

( ) Switch the Y2 SENSITIVITY between the 20 mV and 10 mV ranges. The trace should not move vertically. If there is vertical movement, adjust Y2 Step Balance control R223 until there is no movement when you change Y2 SENSITIVITY ranges.

VERTICAL CALIBRATION

( ) Preset the DMO front panel controls as follows:

Y1 SENSITIVITY	20 mV/div
Y1 INPUT COUPLING	AC
Y1 POSITION	Center
Y2 SENSITIVITY	20 mV/div
Y2 INPUT COUPLING	AC
Y2 POSITION	Center
TIMEBASE	200 μs/div
TRIGGER LEVEL	Zero
TRIGGER MODE	AUTO
TRIGGER SOURCE	Y1

( ) Connect a 1000 Hz, 100 mV peak-to-peak ± 1% square wave signal to the Y1 INPUT. If the Y1 trace is partially off- screen, use the Y1 EQ Zero control (R171) to approximately center the trace. Then adjust Y1 Amp Gain control R148, on the main circuit board, for a 5-division display. Use the Y1 POSITION control on the DMO to reposition the trace as necessary on the graticule lines.

( ) Change the TIMEBASE to 500 μs/div. Then adjust Y1 RT Gain control R168 for a 5-division display. Use the Y1 POSITION control to reposition the trace as necessary.

( ) Simultaneously push the Y1 UP and DOWN POSITION pushbuttons. Then change the Y1 INPUT COUPLING to GND. Now adjust the Y1 RT Zero control R169 on the main circuit board until the Y1 trace is centered on the screen (exactly on the center graticule line).

( ) Connect the 1000 Hz, 100 mV peak-to-peak signal to the Y2 INPUT and change the TRIGGER SOURCE to Y2. Then change the TIMEBASE to 200 μs/div.

( ) Simultaneously push the Y1 UP and DOWN POSITION pushbuttons. Then adjust Y1 EQ Zero control R171, on the main circuit board, until the Y1 trace is exactly centered on the screen.

( ) If the Y2 trace is partially off-screen, use the Y2 EQ Zero control (R271) to approximately center the trace. Adjust Y2 Amp Gain control R248 for a 5-division display. Use the Y2 POSITION control to reposition the trace as necessary.

( ) Change the TIMEBASE to 500 μs/div. Then adjust Y2 RT Gain control R268 for a 5-division display.

( ) Simultaneously push the Y2 UP and DOWN POSITION pushbuttons and change the Y2 INPUT COUPLING to GND. Then adjust Y2 RT Zero control R269 until the Y2 trace is exactly centered on the screen.

( ) Reconnect the 1000 Hz signal to the Y1 INPUT. Then change the Y1 INPUT COUPLING to AC and the TRIGGER SOURCE to Y1. Then change the TIMEBASE to 200 μs/div and adjust Y2 EQ Zero control R271 to center the Y2 trace on the screen.

ATTENUATOR COMPENSATION

NOTE: You will perform the following procedure twice; once for each channel. The first time through, you will adjust the Y1 channel. Use the instructions as written and ignore the items in brackets []. The second time through, you will adjust the Y2 channel. This time, use the controls, titles, and names included inside the brackets.

( ) ( ) Preset the front panel controls as follows:

Y1 INPUT COUPLING	AC [OFF]
Y1 SENSITIVITY	20 mV/div
Y1 POSITION	Center
Y2 INPUT COUPLING	OFF [AC]
Y2 SENSITIVITY	20 mV/div
Y2 POSITION	Center
TIMEBASE RATE	200 μs/div
TRIGGER SOURCE	Y1 [Y2]

Refer to Pictorial 2-6 for the following steps.

( ) ( ) Connect a 1000 Hz square wave signal to the Y1 [Y2] INPUT and adjust the generator for a 5-division waveform. Then push the SAVE pushbutton to store this waveform.

( ) ( ) Change the Y1 [Y2] SENSITIVITY to 200 mV/div and readjust the generator for a 5-division display.

( ) ( ) Adjust Y1 [Y2] ÷ 10 trimmer C105 [C205], on the main circuit board, until the corners and the top of the square wave look as close as possible to the saved display. Use the Y1 [Y2] POSITION control as necessary to move the display for comparison.

( ) ( ) Change the Y1 [Y2] SENSITIVITY to 2 V/div and readjust the generator for a 5-division display. Then adjust ÷ 100 trimmer C108 [C208] until the corners and the top of this display look as close as possible to the saved display.

( ) Push the SAVE pushbutton.

( ) Change the TRIGGER SOURCE to Y2 and repeat the above steps, but use the information in brackets.

× 10 PROBE COMPENSATION

NOTE: If you do not have a × 10 probe, or do not intend to use a × 10 probe with your DMO, skip the following steps and proceed directly to "Time base."

( ) Preset the DMO front panel controls as follows:

Y1 INPUT COUPLING	AC
Y1 SENSITIVITY	50 mV/div
Y1 POSITION	Center
Y2 INPUT COUPLING	AC
Y2 SENSITIVITY	50 mV/div
Y2 POSITION	Center
TIMEBASE	500 μs/div
TRIGGER SOURCE	Y1
SAVE	OFF

Refer to Pictorial 2-6 for the following steps.

( ) Adjust Y1 ÷ 10 probe trimmer C104, on the main circuit board, to minimum (solder glob away from the flat side of the trimmer).

( ) Attach a × 10 probe to the Y1 INPUT.

( ) Connect the probe to a 1000 Hz, 2-volt square wave signal to the probe. Then use a nonmetallic screwdriver to adjust the compensation screw on the probe to make the waveform corners as square as possible.

( ) Move the probe to the Y2 INPUT and change the TRIGGER SOURCE to Y2. Then adjust ÷ 10 Probe trimmer C204 to make the waveform corners as square as possible. If it is not possible to make the corners square, set trimmer C204 to minimum capacitance (solder glob away from the flat) and readjust the compensation screw on the probe to make the corners flat.

NOTE: Perform the next step only if you adjusted the probe compensation screw in the previous step.

( ) Reconnect the probe to the Y1 INPUT and change the TRIGGER SOURCE to Y1. Adjust Y1 ÷ 10 Probe trimmer C104 to make the corners as square as possible. Then reconnect the probe to the Y2 INPUT and change the TRIGGER SOURCE to Y2.

( ) Change Y1 and Y2 SENSITIVITY to 20 mV/div and decrease the amplitude of the generator output to produce a 5-division display.

( ) Adjust the ÷ 1 Probe trimmer C203 to make the corners as square as possible.

( ) Reconnect the probe to the Y1 INPUT, change the TRIGGER SOURCE to Y1, and adjust Y1 ÷ 1 Probe trimmer C103 to make the corners square.

( ) Change the Y1 and Y2 SENSITIVITY to 500 mV/div and increase the amplitude of the generator to again produce a 5-division display. Then adjust Y1 ÷ 100 Probe trimmer C107 to make the corners square.

( ) Reconnect the probe to the Y2 INPUT and change the TRIGGER SOURCE to Y2. Then adjust Y2 ÷ 100 Probe trimmer C207 to make the corners square.

TIME BASE

( ) Preset the DMO front panel controls as follows:

Y1 INPUT COUPLING	AC
Y1 SENSITIVITY	100 mV/div
Y1 POSITION	Center
Y2 INPUT COUPLING	OFF
TIMEBASE	200 μs/div
TRIGGER SOURCE	Y1

Refer to Pictorial 2-7 for the following steps.

( ) Connect a 200 μs (5000 Hz) square wave signal to the Y1 INPUT and adjust its amplitude to produce a 5-division display (approximately). Use the position control on your oscilloscope to reposition the trace as necessary while you adjust LF Horiz Cal **control** R349, on the main circuit board, for exactly eight cycles in eight divisions.

( ) Readjust the generator to produce a 2 µs (500 kHz) square wave and change the TIMEBASE to 2 µs/div. Then adjust HF Horiz Cal **trimmer** C317 for exactly eight cycles in eight divisions.

HF COMPENSATION

NOTE: If the highest frequency signal that you have available is 1 MHz, you can perform the following procedure by changing the TIMEBASE to 100 ns/div, but it may be more difficult to adjust for exactly one minor division and the final bandwidth may be lower.

( ) Preset the DMO front panel controls as follows:

Y1 INPUT COUPLING	AC
Y1 SENSITIVITY	20 mV/div
Y1 POSITION	Center
Y2 INPUT COUPLING	AC
Y2 SENSITIVITY	20 mV/div
Y2 POSITION	Center
TIMEBASE	10 ns/div
TRIGGER SOURCE	Y1

( ) Connect a 100 ns (10 MHz) fast-rise square wave signal to the Y1 INPUT and adjust the level for a 5-division display.

( ) Refer to Pictorial 2-8 and alternately adjust Y1 HF-C trimmer C128 and Y1 HF-R control R156 for the fastest (steepest) slope and one minor division (.2 division) of overshoot and 1/2 minor division (.1 division) of undershoot. The optimum adjustment will be close to the preset positions and will occur with trimmer C128 and R156 as far clockwise as possible without exceeding one minor division of overshoot.

( ) Connect the generator to the Y2 INPUT and change the TRIGGER SOURCE to Y2. Then adjust Y2 HF-C trimmer C228 and Y2 HF-R control R256 like you did in the above step.

TOUCHUP CALIBRATION

Since some of the adjustments that you performed may interact with each other, some touchup may be necessary. The sequence you should use to make these touchup adjustments is listed below. Keep in mind that some of them may not require any readjustment.

( ) Repeat "Vertical Calibration", but only adjust the gain controls.

( ) Repeat "HF Compensation."

( ) Repeat "Trigger Zero."

( ) Repeat "Vertical Calibration", but only adjust the zero controls.

( ) Move NORMAL/CALIBRATION jumper JP403 on the main circuit board to NORM.

( ) If you intend to use your DMO with a computer, set jumpers JP400 through JP402 (on the main circuit board) for the desired baud rate.

( ) Reinstall the cover on the chassis. If necessary, refer back to Pictorial 2-1.

This completes the "Calibration."

Calibration With Computer

( ) Refer to Pictorial 2-1 and remove the ten indicated screws so you can remove the cover. Then set the cover and the screws aside temporarily. CAUTION: Do not remove the AC shield on the rear of the chassis. To do so will expose areas that contain hazardous voltages.

SETUP

( ) Refer to Pictorial 2-3 and set baud rate jumpers JP400 through JP402 on the main circuit board to the desired rate. We recommend that you use 9600 baud, if possible, as this allows the fastest update time.

( ) Connect a female-to-female null-modem cable from the RS-232 port on the rear of the DMO to your computer's serial port.

If you have not already done so, make a working disk that includes MS-DOS, GW-BASIC (f you intend to use the noncompiled version of the software), and the necessary files from the disk that was supplied with the DMO. Be sure to configure the computers serial communication port for DTR positive (pin 20) handshaking. You may also wish to include the MS-DOS PSC file that applies to your printer, if you want to make a hard copy of the information that is displayed on the computer's screen. In addition, you may want to create a batch file that will automatically load the MS-DOS PSC file and then execute the Scope Program.

Refer to Appendix B if you need help making a working disk. Also refer to Appendix B for information about making a batch file.

( ) Insert a copy of the working disk in the computer. Then load and run the program "SCOPE".

( ) Refer to the "Operation" section of this Manual and familiarize yourself with the operation of the DMO.

CALIBRATION

NOTE: Refer to Pictorial 2-2 for the locations of controls on the display logic circuit board and Pictorial 2-3 for locations on the main circuit board.

( ) Preset jumper JP403 on the main circuit board to CALIBRATE as shown.

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	GND
Y1 SENSITIVITY	20 mV/div
Y1 OFFSET	+0.0 mV
Y2 COUPLING	GND
Y2 SENSITIVITY	20 mV/div
Y2 OFFSET	+0.0 mV
TIMEBASE	2.0 ms/div
TRIG SOURCE	Y1
TRIG SLOPE	+
TRIG LEVEL	+0.0 mV
TRIG MODE	AUTO

( ) Connect the common lead of your volt-ohmmeter to the indicated solder lug (ground). Leave this lead connected to ground until you are directed to disconnect it.

( ) Set the volt-ohmmeter to read DC voltage in the following steps. NOTE: You will have to set the range as necessary to accurately read the voltage indicated in the step.

NOTES:

1. Unless a step directs you otherwise, the following test points and adjustments are on the main circuit board.
2. Make the following adjustments slowly. Wait for the DMO to display at least two updates before you make any readjustments.
3. Make the following adjustments as accurately as possible. The accuracy of your DMO depends upon how carefully you make these adjustments.

( ) Touch the positive volt-ohmmeter probe to the indicated lead of resistor R139 (TP1). Then adjust Y1 Step Balance control R123 for an indication of 0.00 volts.

( ) Touch the positive volt-ohmmeter probe to the indicated lead of resistor R239 (TP2). Then adjust Y2 Step Balance control R223 for an indication of 0.00 volts.

TRIGGER ZERO

In the following steps you will adjust a control for equal indications on two pins of an integrated circuit (IC). To do this, continually compare the indications at the pins while you adjust the control. The two pins should indicate approximately − 1.3 volts, but the exact value is not important at this time. NOTE: If you have a floating-input voltmeter, you can connect the meter between the two pins and adjust the control for an indication of 0.00 volts.

( ) Alternately touch the volt-ohmmeter probe to IC U303 pins 4 and 5 and adjust Y1 Amp Zero control R152 until the indications at both pins are the same.

( ) Set the TRIG SOURCE to Y2. Then alternately touch the volt- ohmmeter probe to IC U303 pins 4 and 5 and adjust Y2 Amp Zero control R252 until the indications at both pins are the same.

( ) Touch the volt-ohmmeter probe to IC U303 pin 4. Then adjust Trigger Level control R315 for an indication of − 1.30 volts.

( ) Disconnect the volt-ohmmeter from the DMO.

There should be two traces on the screen. If one or both of the traces is not on the screen, there will be an arrow near the top or bottom graticule line. This arrow indicates that the trace is off the screen.

( ) Adjust Y1 RT Zero control R169 until the Y1 trace is near the center of the screen.

( ) Adjust Y2 RT Zero control R269 until the Y2 trace is near the center of the screen.

LF COMPENSATION

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	DC
Y1 SENSITIVITY	20 mV
Y1 OFFSET	0.0 mV
Y2 COUPLING	OFF
Y2 SENSITIVITY	20 mV
Y2 OFFSET	0.0 mV
TIMEBASE	500 μs/div
TRIG SOURCE	Y1
TRIG LEVEL	Approximately − 20.0 mV
CURSOR C1	Y1
CURSOR C2	Y1

Refer to Pictorial 2-9 for the following steps.

( ) Connect a 200 Hz (5 ms) square wave signal to the Y1 INPUT and adjust the generator level to produce a 4-division display. Disregard the bottom of the trace. Be sure to perform this step on the 20 mV range.) Position the cursors as shown in the Pictorial so one is near the beginning of the trace and the other is just before the negative slope.

( ) Adjust Y1 LF control R126 for a flat waveform by setting the (C1-C2) value to 0.0 mV.

( ) Connect the square wave generator to the Y2 INPUT and change the TRIG SOURCE to Y2. Change Y2 COUPLING to DC and Y1 COUPLING to OFF. Also change both cursors to read on Y2. Then adjust Y2 LF control R226 for a flat waveform by setting the (C1-C2) value to 0.0 mV.

( ) Change the Y1 COUPLING to GND and Y2 COUPLING to OFF. There should be one trace near the center of the screen.

( ) Switch the Y1 SENSITIVITY between the 20 mV and 10 mV ranges. The trace should not move vertically. If there is any vertical movement, adjust Y1 Step Balance control R123 in small amounts until there is no movement when you switch between these two Y1 SENSITIVITY ranges.

( ) Change the Y1 COUPLING to OFF and the Y2 COUPLING to GND. As in the previous step, adjust Y2 Step Balance control R223 until there is no movement when you change Y2 SENSITIVITY ranges.

VERTICAL CALIBRATION

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	AC
Y1 SENSITIVITY	20 mV/div
Y1 OFFSET	0.0 mV
Y2 COUPLING	AC
Y2 SENSITIVITY	20 mV/div
Y2 OFFSET	0.0 mV
TIMEBASE	200μs/div
TRIG SOURCE	Y1
TRIG SLOPE	+
TRIG LEVEL	0.00 mV
TRIG MODE	AUTO
CURSOR C1 & C2	Y1

Refer to Pictorial 2-10 for the following steps.

( ) Connect a 1000 Hz, 100 mV peak-to-peak ± 1% square wave signal to the Y1 INPUT. Then position the cursors as shown in Part A of the Pictorial so one is on the top of the waveform and the other is on the bottom of the waveform. If the Y1 trace is partially off-screen, use the Y1 EQ Zero control (R171) to approximately center the trace.

( ) Adjust Y1 Amp Gain control R148 for a 5-division display by setting the (C1-C2) value to 100.0 mV.

( ) Change the TIMEBASE to 500 μs/div. Then refer to Part B of the Pictorial and reposition the cursors as shown, if they are not already in these positions.

( ) Adjust Y1 RT Gain control R168 for a 5-division display by setting the (C1-C2) value to 100.0 mV.

( ) Change the Y1 COUPLING to GND. Then adjust Y1 RT Zero control R169 until the Y1 trace is centered on the screen (exactly on the center graticule line).

( ) Connect the 1000 Hz, 100 mV peak-to-peak signal to the Y2 INPUT and change the TRIG SOURCE to Y2. Then change the TIMEBASE to 200 μs/div.

( ) Adjust Y1 EQ Zero control R171 until the Y1 trace is exactly centered on the screen.

( ) Refer again to Part A of the Pictorial and change both cursors to measure Y2. Reposition their positions as necessary. If the Y2 trace is partially off-screen, use the Y2 EQ Zero control (R271) to approximately center the trace.

( ) Adjust the Y2 Amp Gain control (R248) for a 5-division display by setting the (C1-C2) value to 100.0 mV.

( ) Change the TIMEBASE to 500 μs/div. Then refer back to Part B of the Pictorial and adjust Y2 RT Gain control R268 for a 5- division display by setting the (C1-C2) value to 100.0 mV.

( ) Change the Y2 COUPLING to GND. Then adjust Y2 RT Zero control R269 to exactly center the Y2 trace.

( ) Reconnect the 1000 Hz signal to the Y1 INPUT, change the Y1 COUPLING to AC, the TRIG SOURCE to Y1. Then change the TIMEBASE to 200 s/div and adjust Y2 EQ Zero control R271 to exactly center the Y2 trace.

ATTENUATOR COMPENSATION

NOTE: You will perform the following procedure twice, once for each channel. The first time through you will adjust the Y1 channel. Use the instructions as written and ignore the items in brackets []. The second time through you will adjust the Y2 channel. This time, use the controls, titles, and names included inside the brackets.

( ) ( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	AC [OFF]
Y1 SENSITIVITY	200 mV/div
Y1 OFFSET	0.000 V
Y2 COUPLING	OFF [AC]
Y2 OFFSET	0.0 mV
Y2 SENSITIVITY	200 mV/div
CURSORS C1 & C2	OFF
TIMEBASE	200 μs/div
TRIG SOURCE	Y1 [Y2]

Refer to Pictorial 2-6 for the following steps.

( ) ( ) Connect a 1000 Hz square wave signal (approximate) to the Y1 [Y2] INPUT and adjust the generator for a 5-division waveform.

( ) ( ) Adjust Y1 [Y2] ÷ 10 trimmer C105 [C205] until the corners are square and the top of the waveform is as flat as possible.

( ) ( ) Change the Y1 [Y2] SENSITIVITY to 2 V/div and readjust the generator for a 5-division display (approximate).

( ) ( ) Adjust ÷ 100 trimmer C108 [C208] until the corners are square and the top of the waveform is as flat as possible.

( ) Change the TRIG SOURCE to Y2 and repeat the above steps, but use the information in brackets.

×10 PROBE COMPENSATION

NOTE: If you do not have a ×10 probe, or do not intend to use a ×10 probe with your DMO, skip the following steps and proceed directly to "Time Base."

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	AC
Y1 SENSITIVITY	50 mV/div
Y1 OFFSET	0.0 mV
Y2 COUPLING	AC
Y2 SENSITIVITY	50 mV/div
Y2 OFFSET	0.0 mV
TIMEBASE	200 μs/div
TRIG SOURCE	Y1

Refer to Pictorial 2-6 for the following steps.

( ) Adjust Y1 ÷ 10 probe trimmer C104 to minimum (solder glob away from the flat side of the trimmer).

( ) Attach the ×10 probe to the Y1 INPUT.

( ) Connect a 1000 Hz, 2 V square wave signal to the probe. Then use a nonmetallic screwdriver to adjust the compensation screw on the probe to make the waveform corners as square as possible.

( ) Move the probe to the Y2 INPUT and change the TRIG SOURCE to Y2. Then adjust ÷ 10 Probe trimmer C204 to make the waveform corners as square as possible. If it is not possible to make the corners square, set trimmer C204 to minimum (solder glob away from the flat) and readjust the compensation screw on the probe to make the corners flat.

NOTE: Perform the next step only if you adjusted the probe compensation screw in the previous step.

( ) Reconnect the probe to the Y1 INPUT and change the TRIG SOURCE to Y1. Adjust Y1 ÷ 10 Probe trimmer C104 to make the corners as square as possible. Then reconnect the probe to the Y2 INPUT and change the TRIG SOURCE to Y2.

( ) Change Y1 and Y2 SENSITIVITY to 20 mV/div and decrease the amplitude of the generator output to produce a 5-division display.

( ) Adjust Y2 ÷ 1 Probe trimmer C203 to make the corners as square as possible.

( ) Reconnect the probe to the Y1 INPUT, change the TRIG SOURCE to Y1, and adjust Y1 ÷ 1 Probe trimmer C103 to make the corners square.

( ) Change the Y1 and Y2 SENSITIVITY to 500 mV/div and increase the amplitude of the generator to again produce a 5-division display. Then adjust Y1 ÷ 100 Probe trimmer C107 to make the corners square.

( ) Reconnect the probe to the Y2 INPUT and change the TRIG SOURCE to Y2. Then adjust Y2 ÷ 100 Probe trimmer C207 to make the corners square.

TIME BASE

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	AC
Y1 SENSITIVITY	100 mV/div
Y1 OFFSET	0.0 mV
Y2 COUPLING	OFF
TIMEBASE	200 μs/div
TRIG SOURCE	Y1

Refer to Pictorial 2-7 for the following steps.

( ) Connect a 200 μs (5000 Hz) square wave signal to the Y1 INPUT and adjust its amplitude to produce a 5-division display. Use the TIMEBASE OFFSET controls (right and left arrows) on the display to reposition the trace as necessary while you adjust LF Horiz Cal **control** R349 for exactly eight cycles in eight divisions.

( ) Readjust the generator to produce a 2 μs (500 kHz) square wave and change the TIMEBASE to 2 μs/div. Then adjust HF Horiz Cal **trimmer** C317 for exactly eight cycles in eight divisions. Use the TIMEBASE OFFSET control as necessary to reposition the trace.

( ) Readjust the horizontal position to center ↔.

HF COMPENSATION

NOTE: If the highest frequency fast-rate signal that you have avilable is 1 MHz, you can perform the following procedure by changing the TIMEBASE to 100 μs/div, but it may be more difficult to adjust and the final bandwidth may be lower.

( ) Use the computer to preset the display controls as follows:

Y1 COUPLING	AC
Y1 SENSITIVITY	20 mV/div
Y1 OFFSET	0.0 mV
Y2 COUPLING	AC
Y2 SENSITIVITY	20 mV/div
Y2 OFFSET	0.0 mV
TIMEBASE	10 ns/div
TRIG SOURCE	Y1

( ) Connect a 100 ns (10 MHz) fast-rise square wave signal to the Y1 INPUT and adjust the level for a 5-division display.

( ) Refer to Pictorial 2-8 and alternately adjust Y1 HF-C trimmer C128 and Y1 HF-R control R156 for the fastest (steepest) slope and one minor division (.2 division) of overshoot and 1/2 minor division (.1 division) of undershoot. The optimum adjustment will be close to the preset positions and will occur with adjust trimmer C128 and R156 as far clockwise as possible without exceeding one minor division of overshoot.

( ) Connect the generator to the Y2 INPUT and change the TRIG SOURCE to Y2. Then adjust Y2 HF-C trimmer C228 and Y2 HF-R control R256 like you did in the above step.

TOUCHUP CALIBRATION

Since some of the adjustments that you performed may interact with each other, some touchup may be necessary. The sequence you should use to make these touchup adjustments is listed below. Keep in mind that some of them may not require any readjustment.

( ) Repeat "Vertical Calibration", but only the **gain** controls.

( ) Repeat "HF Compensation."

( ) Repeat "Trigger Zero."

( ) Repeat "Vertical Calibration", but only adjust the **zero** controls.

( ) Move the NORMAL/CALIBRATE jumper JP403 to NORMAL.

( ) Reinstall the cover on the chassis. If necessary, refer back to Pictorial 2-1.

This completes the "Calibration."

IN CASE OF DIFFICULTY

This section of the Manual will help you locate any difficulty that might occur in your DMO. The information is divided into three sections:

A. Precautions to observe while you are testing the DMO on your bench.

B. Initial tests for the power supply circuits on the circuit boards.

C. Test charts.

NOTE: For replacement part information, refer to "Replacement Parts List" (Page 65) and "Semiconductor Identification" (Page 71).

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Service Information" information inside the rear cover of this Manual. Your Warranty is also located inside the rear cover.

BENCH TESTING

WARNING: When the line cord is connected to an AC outlet, AC voltage is present at several places on the chassis. Be careful to avoid personal shock when you work on the DMO.

Be cautious when you test the transistors and integrated circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage and current that other circuit components.

Be careful you do not short any terminals to ground when you make voltage measurements. If the probe slips, for example, and shorts out a bias or voltage supply point, it may damage one or more components.

Do not remove any components or wires while the DMO is turned on.

When you make repairs to the DMO, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what caused the resistor to become damaged. If the cause is not eliminated, the replacement resistor may also become damaged when the DMO is put back into operation.

Refer to the "Circuit Board X-Ray Views" and the Schematic Diagrams to locate the various components.

Use a high impedance voltmeter to make any voltage measurements.

Always check the power supplies for proper levels as shown in "Initial Tests" before you attempt to troubleshoot the remaining circuits.

The accuracy of your measurements depend upon the accuracy of your instruments and the settings of the DMO's calibration controls.

An indication should be within ± 20%.

INITIAL TESTS

Refer to Pictorial 3-1 as you read the following information.

WARNING: When the line cord is plugged into an AC outlet, potentially hazardous voltages are present in the area covered by the AC shield. Do not remove this shield when the line cord is connected to an AC outlet. To do so could cause you to receive a severe electrical shock if you come into contact with the AC voltage.

- Push the POWER switch to OFF, if this has not already been done.
- Plug the DMO's line cord to a proper AC outlet.
- Push the POWER switch to ON.

NOTE: Refer to the voltage charts and use the following procedure to perform the measurements:

1. Set the voltmeter range switch for each step, if possible, to obtain a near full-scale indication.
2. Connect the positive voltmeter probe to the indicated test point (TP) location and the negative (common) voltmeter lead to the indicated solder lug (ground). Leave the negative lead connected to ground until you are directed to disconnect it.
3. When a component or group of components is listed as the possible cause of a problem, examine the adjacent foil patterns and associated components for a possible problem.

Display Logic Circuit Board Voltage Chart

TEST POINT #	VOLTAGE RANGE (DC)	POSSIBLE CAUSE OF PROBLEM
TP13	−11.4 to −12.6	U503, −12V circuits
TP14	+11.4 to +12.6	U504, +12V circuits
TP15	+4.75 to +5.25	U1, +5 circuits

Main Circuit Board Voltage Chart

TEST POINT #	VOLTAGE RANGE (DC)	POSSIBLE CAUSE OF PROBLEM
TP1	−5.85 to −6.55	D108, Y1 front end circuits
TP2	+5.85 to +6.55	D107, Y1 front end circuits
TP3	−5.85 to −6.55	D208, Y2 front end circuits
TP4	+5.85 to +6.55	D207, Y2 front end circuits
TP5	−11.4 to −12.6	U433, −12V circuits
TP6	+11.4 to +12.6	U432, +12V circuits
TP7	+4.75 to +5.25	U429, +5V circuits
TP8	−4.94 to −5.46	U432, U303, U304, U305
TP9	+4.75 to +5.25	U107, C426, Q116, Q216, Q117, Q118, R493, D124
TP10	+6.45 to +7.15	D413, R411
TP11	−5.85 to −6.55	D305, R303, R304, R365
TP12	+5.22 to +6.38	D304, R351, R352, R349, R348

- Push the POWER switch to OFF.
- Disconnect the voltmeter leads from the DMO.

NOTE: The following test checks the basic internal circuitry by flashing all of the front panel display LEDs in a top-to-bottom sequence for each row of LEDs. The check takes ten seconds to run. Afterwards, there should be specific LEDs still lit. The LEDs are indicated in Pictorial 3-2.

- Make sure the DMO POWER switch is OFF. Then plug in the line cord, if this has not already been done.
- Watch the front panel of the DMO and push the POWER switch to ON. The rows of LEDs should flash in sequence from top to bottom for 10 seconds, and then stop with the LEDs shown in Pictorial 3-2 still lit.
- Push the POWER switch to OFF and unplug the line cord.

TEST CHARTS

YES Follow the "YES" arrow in the charts when you obtain the proper measurement or condition.

NO Follow the "NO" arrow in the charts when you do not obtain the proper measurement or condition.

NOTES:

1. You must have the computer program installed and operating to obtain the proper results described in the test charts.
2. In addition to a voltmeter, you will need a signal generator and an oscilloscope or a logic probe to detect pulses.

WHEN YOU BEGIN A TEST CHART, PRESET THE FRONT PANEL CONTROLS AND SWITCHES AS FOLLOWS:

Y1 COUPLING	AC
Y1 SENSITIVITY	100 mV
Y1 OFFSET	0.00
Y2 COUPLING	AC
Y2 SENSITIVITY	100 mV
Y2 OFFSET	0.00
TIME BASE	2 ms
TRIG LEVEL	0
TRIG SLOPE	+
TRIG MODE	AUTO
TRIG SOURCE	Y1

( ) Set jumper J403 on the main circuit board to the CAL (calibrate) position.

The following table guides you to the proper trouble-locating Test Charts in the Illustration Booklet. These charts systematically isolate a difficulty to a component or group of components.

The components identified in the charts use the same component numbers that are used in the Schematic Diagrams, Circuit Board X-Ray Views, and other areas of this Manual. This troubleshooting section is intended to be used only as a guide and does not try to lead you to the faulty part for every possible trouble.

When a component or group of components is listed as the possible cause of a problem, examine the adjacent foil patterns and associated components for a possible problem.

NOTE: The TTL and ECL logic levels referred to in the charts correspond to the following voltages:

TTL high = + 2.7 to + 5 volts
TTL low = 0 to + 0.8 volts
ECL high = 0 to − 0.65 volts
ECL lo = − 1.65 to − 5.2 volts

TEST CHART #	TITLE
1	General
2	LED display
3	Front panel switching
4	Scope interface
5	Computer interface
6	Vertical
7	Trigger
8	Equivalent time

THEORY OF OPERATION

Refer to the Block Diagram (Illustration Booklet, Page 27) while you read the following information.

Your DMO is a two-channel, digital oscilloscope that contains the following five distinct circuits:

Two analog input channels.

Digital sampling circuits.

Trigger circuitry.

Controller circuitry.

Front panel circuitry.

The following sections describe these circuits separately.

ANALOG INPUT CHANNELS

Two identical input channels allow the DMO to capture and display two signals at the same time. Since the two channels are the same, the operation of only one channel is explained.

Input signals are routed through the input coupling circuit where they are either AC or DC coupled to the high impedance attenuators. If the channel is OFF, the channel remains AC coupled so that an OFF channel can still be used as a trigger source. If the channel is grounded (GND), the input coupling remains AC coupled, but the relays that select the desired high-impedance attenuator are all switched to ground.

The high-impedance attenuator is comprised of a divide-by-one section, a divide-by-ten section, and a divide-by-one hundred section. The 5 mV/div, 10 mV/div, and 20 mV/div input sensitivities use the divide-by-one section; the 50 mV/div, 100 mV/div, and 200 mV/div input sensitivities use the divide-by-ten section; and the remaining input sensitivities use the divide-by-one hundred section. If a particular section is not being used, its input is grounded to limit high-frequency crosstalk between the attenuators. The input impedance of each of the high-impedance attenuators is 1 MΩ. The output of the selected high-impedance attenuator is routed to the input of the impedance translator.

The impedance translator is a very high input impedance, high frequency, unity-gain amplifier. Its primary purpose is to take the high-impedance signals from the high-impedance attenuators and convert them into low-impedance signals. These low-impedance signals are easier to work with when dealing with high-frequency signals. The output of the impedance translator is routed to the low-impedance attenuator.

The low-impedance attenuator is used in conjunction with the high-impedance attenuator to scale the input signal to the proper level before it reaches the high-frequency amplifier. Divide-by-one, divide-by-two, divide-by-four, and divide-by-ten sections are provided. The first three sections are used with each of the high-impedance attenuators, but the divide-by-ten section is used only on the 5 V/div range. The output of the low-impedance attenuator is then routed to the high-frequency amplifier.

The high-frequency amplifier is used to amplify the signals coming from the low-impedance divider to levels that are usable by the sampling circuitry, which is the final analog stage in the vertical channel. The rest of the circuitry in the vertical channel is devoted to converting these analog signals into digital signals, which can then be manipulated by the controller circuitry.

SAMPLING CIRCUITS

As mentioned earlier, the remaining circuitry in the vertical channel converts the continuous-time analog signal into eight-bit data words that can be stored in the DMO's digital memories. The first step in this process converts the continuous-time analog signal into a discrete-time analog signal. The main difference between these two types of analog signals is that a continuous-time signal can change its value at any point in time, but a discrete-time signal can only change values at distinct points in time. Depending upon whether you have the DMO set for the real-time or the equivalent-time sampling mode, the conversion to a discrete-time signal is handled in one of two different ways.

If the DMO is in the equivalent-time mode, the conversion from continuous time to discrete time uses both the high-speed track and hold circuitry and the low-speed sample and hold circuitry. During the time that precedes a sample command, the high-speed track and hold is in the "track" mode. This means that signals at the input of the track and hold circuit are passed unaltered to the output. When a sample command is received, the track and hold circuit disconnects the input from the output. A small capacitor on the output of the track and hold circuit "holds" the output voltage that was present when the sample command was received. Thus, the continuous-time signal is converted into a discrete-time signal. This circuit is able to sample extremely fast signals and then hold them long enough for the relatively slow circuits which follow.

Although the high-speed track and hold performs the actual conversion from continuous to discrete time, it cannot hold the signal long enough for the analog-to-digital converter. For this reason, a low-speed sample and hold circuit extends the amount of time that the discrete signal can be held accurately. After the high-speed track and hold circuit has sampled the signal, it's output is buffered and then resampled by the low-speed sample and hold. This circuit uses a relatively large capacitor to hold the voltage long enough to perform an accurate analog-to-digital conversion. The low-speed sample and hold circuit functions very similarly to the high-speed track and hold circuit, except it cannot accurately sample high-frequency signals. By combining these two circuits, a continuous-time to discrete-time converter that can sample high-frequency signals and hold them for reasonable periods of time is made possible.

The discrete-time output of the low-speed sample and hold is routed to the channel switch. This switch selects and routes the output from either the Y1 vertical channel or the Y2 vertical channel to the following gain stage where it is amplified. This signal is then routed to the analog-to-digital converter where it is digitized. The signal is now in a format that the controller circuitry can manipulate and place on the data bus.

If you have the DMO in the real-time sampling mode, the main difference in the vertical channel operation is that the high-speed track and hold circuit is not used. It is locked in the track mode and passes the continuous-time input signal directly to the low-speed sample and hold. In the real-time mode, therefore, the low-speed sample and hold circuit performs the conversion from continuous to discrete time. This method is used only on the slow time base ranges where the high-speed track and hold is not required.

TRIGGER CIRCUITRY

The trigger circuitry has two modes of operation: real-time sampling and equivalent-time sampling. Real-time sampling, which is the simplest mode, is discussed first.

The continuous-time signals from the outputs of the Y1 and Y2 high-frequency amplifiers are routed to the trigger source select circuit. The selected source signal is then routed to the input of the trigger amplifier. A second input to the trigger amplifier comes from the trigger level digital-to-analog converter. These two voltages are amplified and then compared by the trigger comparator. The output of the trigger comparator is a one-bit digital signal that changes state each time the signal from the selected trigger source goes above or below the output of the trigger level D/A. This signal is then routed to the trigger slope selector, which uses either the positive or negative edge to activate the ramp switch. If the trigger voltage is high enough to activate the trigger comparator and the correct slope, the ramp switch turns on the equivalent-time ramp generator. The ramp signal and the output of the equivalent-time staircase A/D are both routed to the sample comparator. Since the equivalent-time staircase is set to zero in the real-time mode, the sample comparator trips as soon as the ramp begins to move. As soon as a valid trigger is received, the sample comparator generates an interrupt $\overline{\text{INT}}$ which is sent to the controller circuitry. In the real-time mode, the sample command line from the sample comparator is not used.

When the sample comparator generates an interrupt, the controller circuitry is notified that a valid trigger has occurred. At this point, the controller takes control of the sampling process. It calculates the sample rate, based upon the current time base setting and generates all of the control signals necessary to activate the low-speed sample and hold circuit and the A/D converter. It samples and stores 512 eight-bit data words for each vertical channel. On all real-time time base settings, except 500 μs/div, the value of the input signals from both channels are sampled and stored by the low-speed sample and hold circuit at the same time. There is enough time for the A/D converter to convert the discrete-time analog signals from both channels into a digital format before it is time to take the next sample. If the time base setting is 500 μs/div, there is not enough time for the controller circuitry to convert and store both channels before it is time to take the next sample. On this time base range, 512 samples are taken for the Y1 channel and then, after receiving another trigger, 512 samples are taken for the Y2 channel. This is similar to the alternate-sweep mode on a conventional oscilloscope, and requires two distinct triggers if both channels are on.

The 200 μs/div to 10 ns/div time base ranges use equivalent-time sampling. Up to the point where the sample comparator generates an interrupt when a valid trigger is received, real-time triggering and equivalent-time triggering are identical. On these higher time base ranges, the controller is no longer fast enough to generate the necessary timing and control signals, so specialized analog circuitry and sampling techniques are required.

One difference between real-time triggering and equivalent-time triggering is that the sample command line from the sample comparator actually initiates the sampling process by switching the high-speed track and hold circuit to the hold mode. Since the controller circuit is not involved in the timing process, it is possible to accurately measure much shorter timing intervals by using the equivalent-time ramp generator and the equivalent-time staircase generator. The length of the timing interval is controlled by the ramp speed circuitry. This technique makes it possible to accurately measure the 200 ps timing intervals needed on the 10 ns/div time base range. Once a sample is taken, however, it still takes a relatively long time for the low-speed sample and hold circuit, the A/D converter, and the controller to finish converting the sample into a digital format and store it in memory. By the time this process is finished, it is too late to take the next sample. At this point, the controller increments the value of the equivalent-time staircase generator and resets the main trigger circuitry. Since the output of the staircase generator is now at a slightly higher value, the next time a valid trigger is received, it will take a little longer from the time the ramp starts until a sample command is generated. In this way, the precise, high-speed timing intervals that are needed to measure high-frequency signals are generated. The main drawback of this system is that a distinct trigger is needed each time the staircase increments. Since the DMO samples 512 points per channel, 512 distinct triggers are needed to completely sample the input channels. This means that the equivalent-time sampling mode is useful only on repetitive signals.

CONTROLLER CIRCUITRY

The controller circuitry consists of a Z80 microprocessor, the RAM and ROM memories, the I/O and memory address decoders, the UART, and the associated logic circuits.

A program stored in ROM directs the activities of the microprocessor as required to implement the functions of the DMO. The controller implements these functions by addressing and loading data into the various latches that control the DMO. Its other major duties include monitoring the front panel to see if any of the pushbuttons have been pressed, outputting data as necessary to generate the scope output signals on the front panel, monitoring the UART to see if any commands have been received from the computer, and handling data transfers when the computer requests data.

FRONT PANEL CIRCUITRY

The front panel receives signals from the controller and loads them into the display latches. These latches then drive the display LEDs to give a visual indication of input sensitivity, time base setting, trigger level, etc. It also receives signals used by the D/A converter to generate the display signal for the scope output on the front panel.

Another function of the front panel is to allow you to change the present settings of the DMO. The controller periodically scans all of the front panel switches to see if any have been pressed. If a switch has been pressed, the controller decodes its position and implements the function that is represented by that switch.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Illustration Booklet, Page 27) and the Schematic Diagram (fold-ins) as you read this "Circuit Description."

The components are numbered in the following groups:

1-99	Parts on the chassis.
101—499	Parts on the main circuit board.
501—599	Parts on the display logic circuit board.
601—699	Parts on the display circuit board.

ANALOG INPUT CHANNELS

The analog input channel circuits consist of two similar circuits, one for Channel Y1 and another for Channel Y2. Components in Channel Y1 are numbered between 101 and 199, and components in Channel Y2 are numbered between 201 and 299. (For example, the AC coupling capacitor in Channel Y1 is numbered C101 and the same capacitor in Channel Y2 is numbered C201.) Some of the components do not belong to a specific channel. These components are numbered in the 100 and 400 series. Since the two analog input channels are similar, only Channel Y1 is described below.

INPUT CIRCUIT

High-impedance attenuators, the AC coupling capacitor, and the relays that select the desired coupling and attenuator form the input circuit. Input signals pass through resistor R102 to relay K101, which selects either AC or DC coupling. If K101 is not energized, it shorts R101 and the signal passes through AC coupling capacitor C101 to the relays that select the high-impedance attenuators. If K101 is energized, it shorts C101 and the input signal is DC coupled to the attenuator relays. Resistor R101 makes sure C101 is discharged when the input is DC coupled. Diode D101 prevents inductive voltage when the relay de-energizes.

There are three high-impedance attenuators, each with a relay at the input that selects the desired attenuator. Relay K102 selects the divide-by-one attenuator and, if it is energized, routes the input signal through R103 to K105. When the divide-by-one function is selected, K105 is also energized and the signal passes directly to the input of the impedance translator at C112. Trimmer capacitor C103, along with the capacitance associated with the impedance translator, sets the input capacitance of the divide-by-one attenuator.

If the divide-by-ten attenuator has been selected, K103 energizes and passes the input signal through R105 to the input of the divide-by-ten circuit at R109. Resistors R107 and R108 form a low-frequency divider and capacitors C105 and C106 form a high-frequency divider. Trimmer capacitor C105 allows you to make the high-frequency divider match the low-frequency resistive divider. Trimmer C104 sets the input capacitance for this attenuator. The attenuated signal passes through R112 to relay K106, which energizes when the divide-by-ten attenuator has been selected. The output of K106 passes through K105 (which is de-energized) to the input of the impedance translator.

The divide-by-one hundred attenuator functions similarly to the divide-by-ten attenuator and is selected when K104 is energized and K105 and K106 are de-energized. Trimmer C108 matches the high and low-frequency gains, and trimmer C107 sets the input capacitance for this divider.

Whenever a particular divider is not being used, the relay on its input side is de-energized and grounds the input of the attenuator. This prevents the unused attenuator from picking up stray signals which could distort the desired input signal. In addition, when the input coupling is in the ground (GND) position, all three relays on the input side of the high-impedance attenuators are grounded.

IMPEDANCE TRANSLATOR

The impedance translator is a high-input impedance, low-output impedance, high-frequency buffer amplifier. The output of the high-impedance attenuators is AC coupled to the gate of FET (field-effect transistor) Q101. Its gate-to-drain junction diode and FET Q102, which is connected as a diode, protect its input against high voltage. If the input voltage goes higher than 6.2 volts, the gate-to-drain diode of Q101 becomes forward biased and clamps the gate voltage to about 0.7 volts above Q101's drain voltage. If the input voltage tries to go too far negative, Q102's gate-to-source diode clamps the input voltage to a level that is about 0.7 volts below the emitter voltage of Q103.

Transistor Q101 is connected as a source follower and Q103 is the current source that biases Q101. A resistive divider formed by R136 and R137 set the base (B) voltage of Q103. The emitter (E) of Q103, therefore, is fixed at about 0.7 volt below this level. Since R133 is connected to the emitter of Q103 and the −6.2 volt supply, the current passing through it and through Q103 remains constant. This provides a stable operating point for Q101. The output at the source of Q101 is connected to the base of emitter-follower Q104. Transistor Q104 further reduces the output impedance of the impedance translator circuit. The output of the impedance translator is connected to the low-impedance divider and to the feedback circuit that controls the DC gain.

Low-frequency signals are not passed through C112 to the gate of Q101. Instead, low-frequency signals are handled by a feedback circuit that consists of operational amplifier U101 and its associated circuitry. These signals are first divided in half by resistive divider R121 and R122. These two resistors also set the input resistance of the DMO to 1 MΩ. The halved input signal is connected to the noninverting input of U101, which compares this input voltage to a feedback voltage that comes from the output of the impedance translator. This voltage has also been divided by a resistive divider formed by R125, R126, and R128. If the input and feedback voltages are not equal, U101 adjusts the voltage on the gate of Q101 (through R127) to make them the same. Integrated circuit U101, therefore, tries to make sure the voltage at the output of the impedance translator is always equal to the voltage at the input of the impedance translator. At higher frequencies, however, the impedance of C112 becomes very small compared to R127, and U101 loses control of the gate of Q101. Integrated circuit U101 is, therefore, only effective at low frequencies. Resistor R126 matches the low-frequency gain of the feedback circuit to the gain of the high-frequency circuit. Resistor R123 provides an offset adjustment so that the output of the impedance translator can be set to zero when the input is at ground.

Zener diodes D107 and D108 generate a +6.2 volt supply and a −6.2 volt supply, respectively. These diodes have a very low temperature coefficient and, therefore, to not drift significantly when the temperature changes. The impedance translator and the high-frequency amplifier use these stable supplies to reduce voltage drifts.

LOW-IMPEDANCE DIVIDER

The output of the impedance translator is connected to R139 and to resistor pack RP101. This resistor pack is a thick film divider network which provides divide-by-two, divide-by-four, and divide-by-ten outputs. Resistor R139 provides a divide-by-one output. The proper divider, as determined by the input sensitivity, is selected by relays K107, K108, and K109. These relays are energized or de-energized as necessary to select the proper divider and the divided signal is connected to the input of the high-frequency amplifier.

HIGH-FREQUENCY AMPLIFIER

Transistor array Q105 is made up of five high-frequency transistors. Sections Q105D and Q105C form a differential amplifier. The base of Q105D is the input to the amplifier and is connected to the output of the low-impedance divider. Section Q105B provides the current source to bias the differential pair and is similar to the current source used in the impedance translator. Section Q105A, which is connected as a diode, is included in the base bias network of Q105B to eliminate changes in the bias current due to temperature-induced changes in the base-to-emitter voltage of Q105B.

The output of the differential pair is taken from the collector of Q105C and is connected to emitter follower Q106. The output from Q106 then passes through D113 and R156 to the output of the high-frequency amplifier. Diode D113 is used to set the base-to-collector voltage of Q105C. Resistor R156 sets the open loop output impedance of the high-frequency amplifier and, along with C128, sets the transient response of the amplifier.

The output of the high-impedance amplifier is also fed back through a divider network made up of R147, R148, and R149 to the base of Q105C. This feedback network sets the gain of the high-frequency amplifier. Resistor R148 is a gain adjustment to calibrate the amplifier. Resistor R152, which adjusts the current that is summed into the base of Q105C through R151, provides an offset adjustment.

Section Q105E and diode D114 form a secondary output which drives the trigger amplifier through R164. Since the bases of Q105E and Q106 are connected in parallel, the signals at their emitters and, therefore, at the cathodes of D114 and D113 are the same. The trigger amplifier's input is, therefore, equal to the output of the high-frequency amplifier. The use of a separate output is necessary to prevent distortion caused by reflections from the trigger amplifier's input impedance.

HIGH-SPEED TRACK AND HOLD

The output of the high-frequency amplifier is connected to the input of the high-speed track and hold at the anode of D115. Diode D115 is part of a high-speed Schottky diode bridge formed by D115, D116, D117, and D118. The output of the bridge is taken from the anode of D116 and is connected to C135. The high-speed track and hold has two modes of operation: real-time sampling and equivalent-time sampling.

In the real-time sampling mode, the voltage at pin 6 of U106 remains high. This forces the output of U106 (pin 4) to remain low. Transistor Q107, which is connected to the output of U106 through R157, is off since its base is held low. Since the emitters of Q107 and Q109 are connected in series, Q109 is also off because it does not have a source of emitter current. Similarly, since the bases of Q108 and Q111 are connected in series with the collectors of Q107 and Q109, respectively, they also remain off because they do not have a source of base current. When Q108 and Q111 are off, R161 pulls the cathode of D115 to −0.4 volts below the output of the high-frequency amplifier. Resistor R163 similarly pulls anode of D117 to +0.4 volts above the output of the high-frequency amplifier. Since D116 and D118 have the same voltage drops as D115 and D117, the voltage at the output of the diode bridge (anode of D116) equals the voltage at the output of the high-frequency amplifier. When the diodes are biased on the diode bridge is in the "track" mode.

In the equivalent-time mode, the voltage on U106 pin 6 is low. The output at U106 pin 4 is determined by the voltage on pin 5, which is the EQSAM (equivalent time sample) line. This line is normally high (track mode) and only goes low when the trigger circuitry determines that it is time to take a sample. When the EQSAM line goes low, the output of U106 goes high. The output of U106 is coupled through R157 and C131 to the base of Q107, which then turns on. As Q107 turns on, it pulls current from the base of Q108 and dumps current to the emitter of Q109 which turns those transistors on. Similarly, as Q109 turns on, it dumps current through D119 and D121 to the base of Q111 which also turns on. When Q108 turns on, it pulls the cathode of D115 up to +1.5 volts to reverse bias D115 and D116. As Q111 turns on, it pulls the anode of D117 to −1.2 volts, which reverse biases D117 and D118. Since D116 and D118 are reverse biased and the input to U102 has a very high impedance, C135 is effectively isolated and "holds" the voltage that was present at the output of the high-frequency amplifier when the sample command was received. Thus, when the diodes are off, the track and hold circuit is in the "hold" mode.

It is very important that the transistors that switch the diode bridge switch very quickly and at exactly the same time. Capacitors C131, C133, and C134 speed up the switching speeds of their respective transistors. Resistors R158 and R162 provide a small amount of bias current which, although it is not enough to turn the transistors on, keeps them from turning completely off and reduces variations due to turn-on delays. Diodes D119 and D121 insure that there is enough bias voltage to keep D117 and D118 off when the Q109 and Q111 are on.

LOW-SPEED SAMPLE AND HOLD AMPLIFIER

The output of the high-speed track and hold is connected to the input of high-input-impedance buffer amplifier U102. Integrated circuit U102 is an operational amplifier that is connected as a noninverting buffer. Its high input impedance keeps the voltage stored on C135 from draining off in the equivalent-time mode. The output of the buffer is connected to the low-speed sample and hold.

The low-speed sample and hold is controlled by the S/H line. In the hold mode, this line is low to turn Q112 off. The collector of Q112 is connected to the bias pin of U103. Since there is no bias current for U103, its output goes to a high-impedance state and any charge on C136 is trapped. The voltage on C136, therefore, remains constant or is "held." MOSFET Q113 buffers this voltage and is the output of the sample and hold circuit.

When the S/H (sample/hold) line goes high, Q112 turns on with a collector current set by the resistor in RP103. This current turns on U103 by supplying bias current to U103 pin 5. When transconductance amplifier U103 turns on, it supplies current at pin 6 until the feedback from the source of Q113 at pin 2 equals the input on pin 3. When the S/H line goes high, therefore, the output of the sample and hold circuit changes to match the input. This is called the "sample" mode. After the output has had time to reach the desired value, the S/H line goes low again and the sampled voltage is held as described above.

CHANNEL SWITCH

The output from the low-speed sample and hold is connected to a second transconductance amplifier, voltage follower U104. Q114 turns U104 off or on, depending upon whether the CH1SEL (channel one select) line is low or high. The output at U104 pin 6 is connected to the output of U204 in channel Y2. When Q114 is on, Q214 and U204 are off and the Y1 channel is selected. When Q214 is on, Q114 and U104 are off and the Y2 channel is selected.

The input to U104 is also connected to three controls which allow you to zero and calibrate the Y1 channel. In the real-time mode, the EQ/$\overline{\text{RT}}$ (equivalent time/real time) line is low and the $\overline{\text{EQ}}$/RT line is high. This means that Q117 is off and Q115 and Q116 are on. When Q116 is on, it connects R169 to the +5 volt reference supply. In the real-time mode, R169 sets the amount of offset current that is summed into the input at U104. When Q115 is on, it connects R168 to ground and matches the real-time gain to the equivalent-time gain. In the equivalent-time mode, the EQ/$\overline{\text{RT}}$line is high and the $\overline{\text{EQ}}$/RT line is low. Transistor Q117 is now on and Q115 and Q116 are off. Transistor Q117 then connects R171 to the +5 volt reference supply and adjusts the offset current in the equivalent-time mode.

LOW-FREQUENCY GAIN AMPLIFIER

The output from the channel switch is connected through R172 to the input of U105 at pin 3. Integrated circuit U105 is a wide bandwidth operational amplifier. It amplifies the signals from either channel Y1 or Y2 to the levels that are required by the A/D converter. It also adds an offset voltage to match the zero reference of the input channel to the zero reference of the A/D converter. In addition, it contains clamp circuits that keep the signal levels from going below ground or above the +5 volt reference supply. These voltage clamps are necessary to prevent damage to the A/D converter's input.

Resistor R181 sums in an offset current that adds approximately 2.5 volts to the output level of the amplifier. This matches the zero reference of the amplifier to the zero reference of the A/D converter. The main feedback network for the amplifier is made up of R173, R174, and D122. Whenever D122 is forward biased, the gain of the amplifier is set by R174 and R173. Diode D122 is forward biased whenever the output of U105 is positive with respect to ground. Whenever the output of U105 goes negative, D122 becomes reverse biased and the output of the circuit, which is taken from the cathode of D122, clamps at ground. If the output of U105 does go negative, D123 becomes forward biased and the gain is then set by R175 instead of R174. Diode D123 and R175 keep U105 from operating open loop for negative voltages. Without this network, U105 would saturate on negative signals.

The output of the zero clamp circuit (cathode of D122) passes through R177 to the input of the A/D converter. Diode D124 clamps the output to the +5 volt reference supply. This prevents the signal from going more than +0.7 volts above the +5 volt reference.

A/D CONVERTER

The output of the low-frequency amplifier is connected to pin 1 of A/D converter U415. The A/D converter starts a conversion when pin 6 goes low, and finishes the conversion when pin 6 returns high. The conversion pulse is generated by one-half of dual monostable U428. Resistor R408 and capacitor C433 are selected for a one-microsecond pulse, which appears on pin 4. This pulse can be initiated either by setting pin 2 low and then returning it high, or by setting pin 1 high and then low again. Pin 2 is connected to the $\overline{\text{STARTAD}}$ (start analog to digital conversion) line, which comes from the memory decoder U413. This means that one way to start the A/D converter is to have the controller access address 4000H. The other way to start the A/D is to fire the second monostable in U428, whose output appears on pin 5. When the EQSAM line, U414 pin 8, goes low, U428 pin 5 goes high for 2.5 µs as controlled by R409 and C434. When pin 5 goes low, pin 1 also goes low and starts the A/D conversion pulse.

On all real-time ranges except the 500 µs/div range, the conversion timing is as follows. The $\overline{\text{ALT}}$ (alternate) line, which is connected to U414 pin 4, is high. The CH2SEL (channel two select) line, which is connected to U414 pin 5, is initially set low. U414 pin 11 is also set high. The sample command line, which is connected to U414 pins 1, 12, and 13, goes high once, when it detects the initial trigger, and then remains low for the remainder of the 512 samples. The sample process is initiated each time the controller accesses RAM U411 to store the proceeding data point. The $\overline{\text{CS}}$ (chip select) line from pin 14 of memory decoder U412 is inverted by U424 pin 8 and is applied to U414 pins 9 and 10. Since pin 11 is also high, this causes a negative pulse to appear at U414 pin 8. Since U414 pin 8 is connected to U428 pin 9, a positive 2.5 µs pulse is initiated on the negative edge of the pulse that was generated by U414. A negative 2.5 µs pulse appears on U428 pin 12 at the same time. This negative pulse is connected to U414 pins 2 and 3 and causes pin 6 to go high for 2.5 µs. U414 pin 6 is the S/H line and causes the low-speed sample and hold circuits to take samples of both channels Y1 and Y2. At the end of 2.5 µs, U428 pin 12 returns high and causes U414 pin 6 to return low and put the low-speed sample and hold circuits back in the hold mode. At the same time, U428 pin 5 returns low and, since it is connected to U428 pin 1, initiates the 1 μs A/D pulse. At this point the CH2SEL line is switched high. This locks U414 pin 6 low so that it cannot start the low-speed sample and hold again. The controller now reads the data from the A/D converter, which is selected by pin 9 of I/O decoder U413. The data is then stored in RAM, which again toggles the $\overline{\text{CS}}$ line and reinitializes the sampling process. This time, however, the sample and hold circuit does not take a new sample, so the A/D conversion is performed on the sample that is still being held by the Y2 low-speed sample and hold. In this way, samples taken at the same point in time can be converted to digital data by a single A/D converter. At this point, the CH2SEL line returns to low and the process of reading the A/D converter and storing the Y2 data in RAM starts the conversion of the next sample. The controller determines and implements the necessary timing between samples.

The primary difference between the 500 μs/div range and the other real-time ranges is that the $\overline{\text{ALT}}$ line to U414 pin 4 is low. This means that the low-speed sample and holds are not inhibited when the CH2SEL line is high. The sampling process is very similar except the CH2SEL line remains low for the first 512 samples (while channel Y1 is sampled), and then is held high for 512 samples (while channel Y2 is sampled). If only one channel is on, the CH2SEL line is set for the appropriate channel and only one set of 512 points is taken.

The sampling sequence in equivalent time is also very similar to real-time sampling except U414 pin 11 is held low. The sampling process is now initiated each time the sample command line goes high. This line is the complement of the line that switches the high-speed track and hold to the hold mode. The rest of the sampling process is just like the real-time mode, except the $\overline{\text{STARTAD}}$ line initiates the conversion of channel Y2 instead of the CS line.

TRIGGER CIRCUITS

TRIGGER AMPLIFIER

Relay K301 selects either the signal coming from the Y1 or the Y2 high-frequency amplifier and passes it through R308 to the base of Q301. Transistors Q301, Q302, Q304, and Q305 form a cascode differential amplifier. Q303 is a current source to bias differential input pair Q301 and Q302. Resistor R315 adjusts the DC output of the trigger amp to match the ECL levels at the input of U303. Resistors R309 and R311 set the gain of the amplifier. The output of the amplifier is developed across R322 and R323. Diodes D302 and D303 minimize operating point changes due to temperature-induced variations in the base-to-emitter voltages of Q303, Q304, and Q305.

TRIGGER COMPARATOR

Integrated circuit U303 is an ECL line driver which contains three separate differential amplifiers. It provides the gain necessary to convert the output of the trigger amplifier to an ECL-compatible signal. The differential output of the trigger amplifier is applied to the inputs of the first stage, U303 pins 4 and 5. The signal is amplified and the output from pin 3 drives the input of the second stage at pin 10. The second stage provides additional gain and also uses R327 and R328 to provide hysteresis. This hysteresis prevents the trigger from chattering on slower signals. The differential output of the second stage is connected to the input of the third stage at pins 12 and 13. This stage provides additional gain to assure adequate signal levels to drive slope detector U304.

SLOPE SWITCH

Integrated circuit U304 consists of four ECL NOR gates. The non-inverted output of trigger comparator U303 pin 15 is connected to one input of NOR gate G1. The inverted output at U303 pin 14 drives one input of NOR gate G2. The other input to NOR gate G2 is controlled by the SLOPE (trigger slope) line through the TTL-to-ECL level translator formed by R356 and two resistors in RP302. If the SLOPE line is high, NOR gate G2 is locked low. If the SLOPE line is low, the output of G2 is an inverted version of its input. The translated SLOPE line is also connected to the input of G3, which inverts it and connects it to the remaining input of G1. This ensures that G1 and G2 are never on at the same time. The outputs of G1 and G2 are wire ORed together to drive the ramp switch circuits. Whether the ramp switch triggers on the positive or negative signal slopes depends upon whether G1 or G2 is on, respectively.

RAMP SWITCH

Integrated circuit U305 contains two ECL flip flops, with flip flop #2 used as the ramp switch. The ECL output of slope switch U304 (pins 2 and 3) is connected to U305 pin 11. If flip flop #2 is waiting for a trigger, reset pin 13 is low. The inverting output of flip flop #2 ($\overline{2Q}$) is high and the noninverting output (2Q) is low. Since these outputs are connected to the emitter and base of Q306, respectively, Q306 is off. When Q306 is off, Q309 is on and shorts the collector of Q307 to ground. This prevents the ramp circuit from running.

When a trigger signal causes a positive transition at U305 pin 12, the outputs of flip flop #2 change states. This causes Q306 to turn on, which in turn, turns Q309 off. The equivalent time-ramp circuit then begins to run.

The trigger flip flop is reset by setting the CLRTRG line high and the $\overline{\text{CLRTRG}}$ (clear trigger) line low. The CLRTRG line is connected to the reset pin of flip flop #1 in U305 through a level translator formed by R329, R330, and R331. When flip flop #1 is reset, the $\overline{1Q}$ output is high, which resets flip flop #2 and the ramp switch is off. Flip flop #2 will not recognize a trigger while it is reset.

To arm the trigger flip flop, the CLRTRG line must be returned low by the controller. The $\overline{1Q}$ output of flip flop #1 is now free to change if it receives a clock signal on pin 6. At the same time that the CLRTRG line goes low, the $\overline{\text{CLRTRG}}$ line goes high. This signal is coupled through C321 to U424 pin 5. Since the ramp has been reset, the other input to U424 pin 4 is high, so the output of U424 at pin 6 goes low. This pin is connected to the bus request line of the microprocessor. This causes the microprocessor to stop running and places the data and address busses in a high-impedance state. This results in a considerable reduction in digital noise, which would otherwise degrade the performance of the trigger circuits.

When the microprocessor stops running, it sets the bus acknowledge line low. U306 (pins 12 and 13) inverts this signal and R357 and two resistors in RP302 shift the signal to ECL levels before it is used to clock pin 6 of flip flop #1. The $\overline{1Q}$ output of flip flop #1 then goes low and allows the trigger flip flop to toggle if a valid trigger signal is present. If a trigger occurs, the ramp circuit runs and comparator U311 will toggle. This causes U311 pin 9 to go low, which causes the output of U424 pin 6 to return to high. Capacitor C328 delays the output of U311 long enough to allow completion of the sampling process. At this point the microprocessor again begins to run and decides what action to take, based upon whether the DMO is in the real-time or the equivalent-time mode. Diode D307 prevents negative voltages from being applied to the input of U424 when the $\overline{\text{CLRTRG}}$ line is set low.

If a trigger signal is not present, U424 pin 5 slowly returns to low with a time constant determined by C321 and R368. When this signal returns low, U424 pin 6 returns to high regardless of whether or not there has been a trigger. This also starts the microprocessor and prevents the trigger circuit from locking up if a trigger signal is not present.

RAMP CIRCUIT

The ramp circuit consists of U307, U308, U309, Q307, and their associated components. Pin 3 of operational amplifier U309 is set to a stable reference voltage by D304 and R349. Control R349 allows you to calibrate the ramp speed on the slower equivalent-time ranges. Integrated circuits U307 and U308 select one of the timing resistors and connect it between the +12 volt supply and U309 pin 2. The selected resistor is also connected to the cathode of D305. Since the operational amplifier maintains a constant voltage drop across the selected timing resistor, a constant current flows through it and through D305. This current also flows out the collector of Q307, which serves as the output of a constant-current source.

On the slower ramp speeds, Q308 turns on and C318 dominates the ramp circuit. Capacitor C318 converts the current coming from the collector of Q307 to a linear voltage ramp. On the eight fastest time base ranges, Q308 is off and the ramp speed is set by C316 and C317. Capacitor C317 allows you to calibrate the faster ramp speeds. Diode D306 prevents the collector of Q308 from going negative when Q309 turns off the ramp. This prevents nonlinearities at the beginning of the ramp on the faster ramp speeds.

Source follower FET1 in Q311 buffers the ramp. FET2 is a current source for FET1 and biases the source follower at IDSS. This circuit prevents comparator U311 from loading the ramp and causing nonlinearities.

STAIRCASE CIRCUIT

The outputs of the ramp circuit and the staircase circuit are connected to comparator U311 pins 3 and 4, respectively. The output level of the staircase circuit, therefore, sets the point on the ramp where the comparator trips. 10-bit D/A converter U312 together with U313 generate the 512 distinct voltage levels needed to take the 512 equivalent-time samples. Resistors R366 and R367 divide down the output voltage to a level that matches the output of the ramp circuit. When the ramp reaches the level of the staircase output, the outputs of U311 change state to signal the microprocessor via the interrupt line connected to U311 pin 9. Pin 11 is connected to the sample command line and initiates a sample in the equivalent-time mode, as described above.

CONTROLLER CIRCUITS

OSCILLATOR

Transistor Q401, crystal Y401, and their associated circuitry form an 8 MHz sine-wave oscillator. Two flip flops inside U402 divide down the output of the oscillator to 4 MHz and 2 MHz. The resulting 4 MHz clock is used by the Z80 microprocessor and the 2 MHz clock is used by the UART.

MICROPROCESSOR

Integrated circuit U406 is a Z80 microprocessor which executes the code that is stored in ROM U408. The data bus of U406 is connected directly to ROM U408, RAM U411, UART U407, A/D converter U415, and buffer U409, which reads the on-board jumpers. The data bus also connects to bidirectional transceiver U416. U416 pin 19 is connected to the $\overline{\text{I/O REQUEST}}$ $\overline{\text{(IORQ)}}$ line of the microprocessor, which means U416 is enabled only during I/O operations. Direction pin 1 is normally held high by R406 so the data transfer is from left to right across U416. If a front panel is attached to P401 and the processor is reading the front panel switches, the line attached to P401 pin 16 goes low and reverses the direction of U416. This allows the microprocessor to access the front panel switches.

The RAM, ROM, and the buffer that reads the jumpers are all decoded as memory locations by memory decoder U412. Also included on U412 is an address that starts the A/D conversion process as described earlier. When the microprocessor accesses one of these devices, it puts the proper address on A13, A14, and A15 and then pulls the $\overline{\text{MREQ}}$ (memory request) line low. This line is attached to pin 4 of the memory decoder and enables the memory decoder output. The outputs of the memory decoder then enable the desired device. The $\overline{\text{RFSH}}$ (refresh) line from the microprocessor is attached to U412 pin 6 and disables the memory decoder during refresh cycles.

Integrated circuit U413 decodes the I/O addresses. As described earlier, whenever an I/O operation takes place, U416 is enabled. Address lines A7 through A4 select the various I/O devices. The $\overline{\text{IORQ}}$ line from the microprocessor enables the I/O decoder after the desired I/O address is placed on the address bus. U403 pins 11, 12, and 13 disables the I/O decoder whenever the $\overline{\text{M1}}$ line is low. This prevents accidental enabling of one of the I/O devices during the processing of an interrupt. Integrated circuit U413 selects latches U417, U418, U419, U421, U422, U423, and the UART, and reads the data from A/D converter U415. The latches are loaded by the microprocessor with the necessary data to permit the functioning of the DMO. The UART is periodically checked to see if a command has been received from the computer and is also used to send data to the computer, if necessary. Data that is read from the A/D converter is stored in RAM along with information about the current state of the DMO.

UART

Integrated circuit U407 is a Universal Asynchronous Receiver/Transmitter through which the controller communicates with a computer or some other serial device attached to the RS-232 port. The outputs of the UART are connected to the inverting gates in U405. These gates translate the TTL-level signals coming from the UART to the $\pm$ 12 volt signal levels that are required to meet RS-232 standards. Similarly, U404 is a receiver circuit that converts the signals received from the RS-232 connector to the TTL-level signals that can be used by the inputs of the UART.

The UART handles all data transfers. It is capable of handling both input and output functions without supervision by the microprocessor. This frees the microprocessor for other tasks during data transfers. The microprocessor occasionally polls the UART to see if new data has been received, or to see if it is ready to send a new piece of data.

The UART is accessed by the microprocessor as an I/O device. I/O decoder U413 enables the UART and address lines A0, A1, and A2, select various registers within the UART. These registers give the microprocessor access to information which defines the current state of the UART and provide the microprocessor with input and output information. These registers can be written to by pulling the $\overline{\text{DOSTR}}$ (data output strobe) line (pin 18) low, or read by pulling the $\overline{\text{DISTR}}$ (data input strobe) line (pin 21) low.

The $\overline{\text{RD}}$ (read) and $\overline{\text{WR}}$ (write) lines coming from the microprocessor read from or write to the UART, but they are first conditioned by the delay flip flops in U401 to prevent timing conflicts. Both of the delay flip flops in U401 are clocked by the 4 MHz clock signal. The $\overline{\text{RD}}$ line is connected to the D input of one-half of U401 (pin 12). When $\overline{\text{RD}}$ goes low, the noninverted output of U401 (pin 9) does not go low until the next cycle of the 4 MHz clock. This delays the negative edge of the $\overline{\text{RD}}$ line by one clock cycle before it is applied to the $\overline{\text{DOSTR}}$ pin of the UART. When the RD line returns high, it is inverted by U403, whose output (pin 8) immediately sets the flip flop and causes the $\overline{\text{DOSTR}}$ pin to return to high.

A similar circuit formed by the other delay flip-flop in U401 delays the negative edge of the $\overline{\text{WR}}$ pulse by one clock cycle. The inverting output (pin 6) is connected to the D input (pin 2). When the $\overline{\text{WR}}$ line goes low, pin 6 will go high. On the next clock cycle, pin 6 goes low since the D input is being held high. Since pin 6 is connected to the $\overline{\text{DISTR}}$ pin of the UART, it also goes low at this time. When the $\overline{\text{WR}}$ line returns high, it is inverted by U403 pin and clears the flip flop. Pin 6 then returns to high which also pulls the $\overline{\text{DISTR}}$ pin of the UART high.

POWER SUPPLY

AC power enters the DMO through the line cord and fuse F1 before it is applied to the primary winding of transformer T1. Transformer T1 has two secondary windings to provide 9.5 volts AC and 16.5 volts AC. These secondary voltages are connected to the main circuit board at P403. The 9.5 VAC winding is connected to diodes D404, D405, D406, and D407, which form two full-wave rectifier circuits. The positive output of D405 and D407 is filtered by C412 before U429 regulates it at +5 volts DC. Similarly, the negative output of D404 and D406 is filtered by C414 before U431 regulates it at −5 volts DC.

The 16.5-volt secondary voltage is rectified by D408, D409, D411, and D412. The positive and negative outputs of the rectifiers are filtered by C421 and C423, respectively, and then regulated by U432 and U433 to produce positive and negative 12-volt supplies.

FRONT PANEL

The buffered data bus, address lines A0, A1, A2, A3, A8, A9, and A10, the $\overline{IORQ}$ line, the $\overline{M1}$ line, and several supply lines are connected to the front panel via P501. Address lines A3, A2, A1, and A0 are decoded by front panel I/O decoder U501. This decoder selects either one of the latches that drive the display LEDs (U508, U509, U511, U512, U513, and U514), the latch that controls the output D/A level (U505), or the buffers that drive the front panel switches (U502). (The line that activates the buffer is also returned to the main circuit board to reverse the direction of U416 as described earlier.) The LED latches are loaded with data as necessary to light the proper LEDs on the front panel. Latch U505 is loaded with data which is then connected to D/A converter U506. Integrated circuit U506 along with operational amplifier U507 converts the digital data to an analog voltage, which is then routed through R506 and R507 to the scope output connector on the front panel. Resistor R506 allows you to calibrate this output to the particular oscilloscope that you are using. Transistor Q501 buffers and inverts one of the outputs from latch U514. The output at the collector of Q501 is coupled through R518 to the trigger output connector on the front panel.

Integrated circuits U503, U504, and U502 regulate the supply voltages coming from the main circuit board to provide +12, −12, and +5 volt supplies, respectively. These supplies provide power for all front panel circuits.

The LEDs that are used to indicate Y1 sensitivity, Y2 sensitivity, and the time base range are arranged in matrices to reduce the number of lines necessary to control these LEDs. To explain how these matrices work, the Y1 sensitivity LEDs are used as an example.

LEDs V601 through V611 indicate the channel Y1 input sensitivity. The anodes of V601 through V605 are connected together and through P601 to R511. The other side of R511 is connected to latch U508 pin 16. The anodes of the remaining LEDs are also connected together and to R509, which then connects to U508 pin 15. The cathodes of the LEDs are connected together in pairs with one LED from each group as a pair. For example, the cathode of V601 is connected to the cathode of V606. In order to turn a particular LED on, either U508 pin 15 or 16 is set high (to select the top or bottom group of LEDs) and then the line that is connected to the desired LED is set low. This forward biases the selected LED and turns it on. Resistors R509 and R511 serve as current-limiting resistors for the lower and upper groups of LEDs, respectively. The lines connected to the cathodes of the remaining LEDs are set high to keep them turned off. As you can see, this technique requires only seven lines to control ten LEDs.

The remainder of the indicator LEDs are not connected in matrices. The anodes of these LEDs are connected through a current-limiting resistor to the

+5 volt supply. The cathodes of these LEDs are connected directly to the outputs of the display latches. A particular LED is turned on simply by setting the latch output that it is attached to low.

The front panel switches are read as follows: The resistors in resistor pack RP501 are pull-up resistors to make sure the data lines are high if none of the front panel pushbuttons are being depressed. If the microprocessor is checking the front panel switches, it puts address 0FH on the address bus and performs an I/O request. This causes U501 pin 7 to go low, which enables the buffers in U502. These buffers connect address lines A8, A9, and A10 to the front panel switches. Depending upon which row of switches the microprocessor is checking, one of these address lines is low. If one of the pushbuttons in that row is being held down, the microprocessor reads a low on the data line that is connected to that switch. Otherwise, the microprocessor reads highs on all of the data lines. By setting each of the three address lines low in turn, the microprocessor can determine which pushbutton, if any, is being held down.

REPLACEMENT PARTS LIST

To order a replacement part, use the Parts Order Form supplied. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual.

MAIN CIRCUIT BOARD

RESISTORS

NOTE: The following resistors are rated at 1/4-watt and have a tolerance of 5% unless otherwise listed.

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R101	6-105-12	1 MΩ
R102	6-510-12	51 Ω
R103	6-680-12	68 Ω
R104	6-109-12	1 Ω
R105	6-109-12	1 Ω
R106	6-109-12	1 Ω
R107	2-771-12	900 kΩ, .25% precision
R108	2-773-12	111 kΩ, .25% precision
R109	6-2670-12	267 Ω, 1%
R111	6-4759-12	47.5 Ω, 1%
R112	6-1500-12	150 Ω, 1%
R113	6-109-12	1 Ω
R114	6-109-12	1 Ω
R115	2-772-12	990 kΩ, .25% precision
R116	6-774-12	10.1 kΩ, 1%
R117	6-1431-12	1430 Ω, 1%
R118	6-1829-12	18.2 Ω, 1%
R119	6-1780-12	178 Ω, 1%
R121	6-4993-12	499 kΩ, 1%

RESISTORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R122	6-4993-12	499 kΩ, 1%
R124	6-106-12	10 MΩ
R125	6-4993-12	499 kΩ, 1%
R127	1-158-12	100 MΩ, 10%
R128	6-3833-12	383 kΩ, 1%
R129	6-331-12	330 Ω
R131	6-331-12	330 Ω
R132	6-221-12	220 Ω
R133	6-2490-12	249 Ω, 1%
R134	6-271-12	270 Ω
R135	6-271-12	270 Ω
R136	6-4990-12	499 Ω, 1%
R137	6-4990-12	499 Ω, 1%
R138	6-122-12	1200 Ω
R139	6-1000-12	100 Ω, 1%
R141	6-109-12	1 Ω
R142	6-1301-12	1300 Ω, 1%
R143	6-1500-12	150 Ω, 1%
R144	6-109-12	1 Ω
R145	6-8060-12	806 Ω, 1%
R146	6-3920-12	392 Ω, 1%
R147	6-1100-12	110 Ω, 1%
R149	6-3920-12	392 Ω, 1%

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

RESISTORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R151	6-5111-12	5110 Ω, 1%
R153	6-4990-12	499 Ω, 1%
R154	6-182-12	1800 Ω
R155	6-102-12	1000 Ω
R157	6-511-12	510 Ω
R158	6-103-12	10 kΩ
R159	6-6810-12	681 Ω, 1%
R161	6-1001-12	1000 Ω, 1%
R162	6-225-12	2.2 MΩ
R163	6-1001-12	1000 Ω, 1%
R164	6-470-12	47 Ω
R165	6-6810-12	681 Ω, 1%
R166	6-101-12	100 Ω
R167	6-432-12	4300 Ω
R172	6-1001-12	1000 Ω, 1%
R173	6-1001-12	1000 Ω, 1%
R174	6-2212-12	22.1 kΩ, 1%
R175	6-562-12	5600 Ω
R176	6-102-12	1000 Ω
R177	6-102-12	1000 Ω
R178	6-109-12	1 Ω
R179	6-101-12	100 Ω
R181	6-124-12	120 kΩ
R201	6-105-12	1 MΩ
R202	6-510-12	51 Ω
R203	6-680-12	68 Ω
R204	6-109-12	1 Ω
R205	6-109-12	1 Ω
R206	6-109-12	1 Ω
R207	2-771-12	900 kΩ, .25% precision
R208	2-773-12	111 kΩ, .25% precision
R209	6-2150-12	215 Ω, 1%
R211	6-4759-12	47.5 Ω, 1%
R212	6-2000-12	200 Ω, 1%
R213	6-109-12	1 Ω
R214	6-109-12	1 Ω
R215	2-772-12	990 kΩ, .25% precision
R216	2-774-12	10.1 kΩ, .25% precision
R217	6-1431-12	1430 Ω, 1%
R218	6-1829-12	18.2 Ω, 1%
R219	6-1500-12	150 Ω, 1%
R221	6-4993-12	499 kΩ, 1%
R222	6-4993-12	499 kΩ, 1%
R224	6-106-12	10 MΩ
R225	6-4993-12	499 kΩ, 1%
R227	1-158-12	100 MΩ, 10%
R228	6-3833-12	383 kΩ, 1%
R229	6-331-12	330 Ω
R231	6-331-12	330 Ω
R232	6-221-12	220 Ω
R233	6-2490-12	249 Ω, 1%
R234	6-271-12	270 Ω
R235	6-271-12	270 Ω
R236	6-4990-12	499 Ω, 1%
R237	6-4990-12	499 Ω, 1%
R238	6-122-12	1200 Ω

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

RESISTORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R239	6-1000-12	100 Ω, 1%
R241	6-109-12	1 Ω
R242	6-1301-12	1300 Ω, 1%
R243	6-1500-12	150 Ω, 1%
R244	6-109-12	1 Ω
R245	6-8060-12	806 Ω, 1%
R246	6-3920-12	392 Ω, 1%
R247	6-1100-12	110 Ω, 1%
R249	6-3920-12	392 Ω, 1%
R251	6-5111-12	5110 Ω, 1%
R253	6-4990-12	499 Ω, 1%
R254	6-182-12	1800 Ω
R255	6-102-12	1000 Ω
R257	6-511-12	510 Ω
R258	6-103-12	10 kΩ
R259	6-6810-12	681 Ω, 1%
R261	6-1001-12	1000 Ω, 1%
R262	6-225-12	2.2 MΩ
R263	6-1001-12	1000 Ω, 1%
R264	6-470-12	47 Ω
R265	6-6810-12	681 Ω, 1%
R266	6-101-12	100 Ω
R267	6-432-12	4300 Ω
R268	6-104-12	100 kΩ
R301	6-3161-12	3160 Ω, 1%
R302	6-3161-12	3160 Ω, 1%
R303	6-3161-12	3160 Ω, 1%
R304	6-3161-12	3160 Ω, 1%
R305	6-3161-12	3160 Ω, 1%
R306	6-1131-12	1130 Ω, 1%
R307	6-4759-12	47.5 Ω, 1%
R308	6-470-12	47 Ω
R309	6-3019-12	30.1 Ω, 1%
R311	6-3019-12	30.1 Ω, 1%
R312	6-6040-12	604 Ω, 1%
R313	6-3481-12	3480 Ω, 1%
R314	6-9530-12	953 Ω, 1%
R316	6-6040-12	604 Ω, 1%
R317	6-6040-12	604 Ω, 1%
R318	6-101-12	100 Ω
R319	6-1211-12	1210 Ω, 1%
R321	6-3481-12	3480 Ω, 1%
R322	6-3010-12	310 Ω, 1%
R323	6-3010-12	310 Ω, 1%
R324	6-2370-12	237 Ω, 1%
R325	6-109-12	1 Ω
R326	6-109-12	1 Ω
R327	6-101-12	100 Ω
R328	6-101-12	100 Ω
R329	6-272-12	2700 Ω
R330	6-271-12	270 Ω
R331	6-272-12	2700 Ω
R332	6-102-12	1000 Ω
R333	6-511-12	510 Ω
R334	6-271-12	270 Ω
R335	6-472-12	4700 Ω

RESISTORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R336	6-472-12	4700 Ω
R337	6-472-12	4700 Ω
R338	6-109-12	1 Ω
R339	2-781-12	287 Ω, .25% precision
R340	6-105-12	1 MΩ
R341	2-780-12	143 kΩ, .25% precision
R342	2-779-12	71.5 kΩ, .25% precision
R343	2-778-12	28.7 kΩ, .25% precision
R344	2-777-12	14.3 kΩ, .25% precision
R345	2-776-12	7150 Ω, .25% precision
R346	2-783-12	2870 Ω, .25% precision
R347	2-782-12	1430 Ω, .25% precision
R348	6-1001-12	1000 Ω, 1%
R351	6-1001-12	1000 Ω, 1%
R352	6-6040-12	604 Ω, 1%
R353	6-109-12	1 Ω
R354	6-221-12	220 Ω
R355	6-221-12	220 Ω
R356	6-271-12	270 Ω
R357	6-271-12	270 Ω
R358	6-472-12	4700 Ω
R359	6-332-12	3300 Ω
R361	6-152-12	1500 Ω
R362	6-152-12	1500 Ω
R364	6-472-12	4700 Ω
R365	6-391-12	390 Ω
R366	6-7500-12	750 Ω, 1%
R367	6-1371-12	1370 Ω, 1%
R369	6-271-12	270 Ω
R401	6-222-12	2200 Ω
R402	6-333-12	33 kΩ
R403	6-102-12	1000 Ω
R404	6-103-12	10 kΩ
R405	6-102-12	1000 Ω
R406	6-472-12	4700 Ω
R407	6-102-12	1000 Ω
R408	6-362-12	3600 Ω
R409	6-822-12	8200 Ω
R411	6-181-12	180 Ω

CAPACITORS

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
C101	27-192	.027 μF Mylar®
C102	21-786	.1 μF ceramic
C106	21-788	110 pF ceramic
C109	21-163	.001 μF ceramic
C111	21-786	.1 μF ceramic
C112	21-75	75 pF ceramic
C113	21-739	2.2 pF ceramic
C114	21-769	.01 μF ceramic
C115	25-931	10 μF electrolytic
C116	21-788	110 pF ceramic
C117	21-751	.047 μF ceramic
C118	21-786	.1 μF ceramic
C119	21-751	.047 μF ceramic
C121	21-786	.1 μF ceramic

CAPACITORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
C122	21-751	.047 μF ceramic
C123	21-786	.1 μF ceramic
C124	21-751	.047 μF ceramic
C125	21-786	.1 μF ceramic
C126	21-786	.1 μF ceramic
C127	21-786	.1 μF ceramic
C129	21-786	.1 μF ceramic
C131	21-738	68 pF ceramic
C132	21-786	.1 μF ceramic
C133	21-716	27 pF ceramic
C134	21-716	27 pF ceramic
C135	21-738	68 pF ceramic
C136	21-801	680 pF ceramic
C137	21-715	150 pF ceramic
C138	21-715	150 pF ceramic
C139	21-163	.001 μF ceramic
C141	21-751	.047 μF ceramic
C142	21-751	.047 μF ceramic
C201	27-192	.027 μF Mylar
C202	21-786	.1 μF ceramic
C206	21-788	110 pF ceramic
C209	21-163	.001 μF ceramic
C211	21-786	.1 μF ceramic
C212	21-75	100 pF ceramic
C213	21-739	2.2 pF ceramic
C214	21-769	.01 μF ceramic
C215	25-931	10 μF electrolytic
C216	21-788	110 pF ceramic
C217	21-751	.047 μF ceramic
C219	21-751	.047 μF ceramic
C222	21-751	.047 μF ceramic
C225	21-786	.1 μF ceramic
C226	21-786	.1 μF ceramic
C227	21-786	.1 μF ceramic
C229	21-786	.1 μF ceramic
C231	21-738	68 pF ceramic
C232	21-786	.1 μF ceramic
C233	21-716	27 pF ceramic
C234	21-716	27 pF ceramic
C235	21-738	68 pF ceramic
C236	21-801	680 pF ceramic
C237	21-715	150 pF ceramic
C238	21-715	150 pF ceramic
C242	21-751	.047 μF ceramic
C301	21-148	75 pF ceramic
C302	21-786	.1 μF ceramic
C303	21-786	.1 μF ceramic
C304	21-786	.1 μF ceramic
C305	21-804	56 pF ceramic
C306	21-786	.1 μF ceramic
C307	21-786	.1 μF ceramic
C308	21-786	.1 μF ceramic
C311	21-786	.1 μF ceramic
C312	21-786	.1 μF ceramic
C313	21-786	.1 μF ceramic
C314	21-786	.1 μF ceramic

CAPACITORS (Cont'd)

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
C315	21-786	.1 µF ceramic
C316	20-109	62 pF mica
C318	29-67	.01 µF polystyrene
C319	21-786	.1 µF ceramic
C321	21-786	.1 µF ceramic
C323	21-786	.1 µF ceramic
C324	21-786	.1 µF ceramic*
C325	21-786	.1 µF ceramic
C326	21-786	.1 µF ceramic
C327	21-785	22 pF ceramic
C328	21-784	1000 pF ceramic
C329	21-751	.047 µF ceramic
C331	21-786	.1 µF ceramic
C401	20-102	100 pF mica
C402	21-785	22 pF ceramic
C403	21-786	.1 µF ceramic
C404	25-915	47 µF electrolytic
C405	21-786	.1 µF ceramic
C406	21-786	.1 µF ceramic
C407	21-16	.01 µF ceramic
C408	21-16	.01 µF ceramic
C409	21-16	.01 µF ceramic
C411	21-16	.01 µF ceramic
C412	25-947	6800 µF electrolytic
C413	25-911	22 µF electrolytic
C414	25-895	2200 µF electrolytic
C415	25-911	22 µF electrolytic
C416	21-16	.01 µF ceramic
C417	21-16	.01 µF ceramic
C418	21-16	.01 µF ceramic
C419	21-16	.01 µF ceramic
C421	25-946	4700 µF electrolytic
C422	25-911	22 µF electrolytic
C423	25-893	1000 µF electrolytic
C424	25-911	22 µF electrolytic
C425	21-786	.1 µF ceramic
C426	21-786	.1 µF ceramic
C427	21-786	.1 µF ceramic
C428	21-786	.1 µF ceramic
C429	21-786	.1 µF ceramic
C431	21-786	.1 µF ceramic
C432	21-786	.1 µF ceramic
C433	21-801	680 pF ceramic
C434	21-801	680 pF ceramic
C435	21-786	.1 µF ceramic
C436	21-786	.1 µF ceramic
C437	21-786	.1 µF ceramic
C438	21-786	.1 µF ceramic
C439	21-786	.1 µF ceramic
C441	21-786	.1 µF ceramic
C442	21-786	.1 µF ceramic
C443	21-786	.1 µF ceramic
C444	21-786	.1 µF ceramic
C445	21-786	.1 µF ceramic
C446	21-786	.1 µF ceramic
C447	21-786	.1 µF ceramic

TRIMMERS — TRIMMERS

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
C103	31-71	3.2—18 pF trimmer
C104	31-83	2—6 pF trimmer
C105	31-71	3.2—18 pF trimmer
C107	31-83	2—6 pF trimmer
C108	31-71	3.2—18 pF trimmer
C128	31-85	5—25 pF trimmer
C203	31-71	3.2—18 pF trimmer
C204	31-83	2—6 pF trimmer
C205	31-71	3.2—18 pF trimmer
C207	31-83	2—6 pF trimmer
C208	31-71	3.2—18 pF trimmer
C228	31-85	5—25 pF trimmer
C317	31-85	5—25 pF trimmer
R123	10-1142	100 kΩ control
R126	10-1142	100 kΩ control
R148	10-1155	200Ωcontrol
R152	10-1142	100 kΩ control
R156	10-1173	50Ωcontrol
R168	10-1142	100 kΩ control
R171	10-1142	100 kΩ control
R223	10-1142	100 kΩ control
R226	10-1142	100 kΩ control
R248	10-1155	200Ωcontrol
R252	10-1142	100 kΩ control
R256	10-1173	50Ωcontrol
R258	10-1142	100 kΩ control
R268	10-1142	100 kΩ control
R269	10-1142	100 kΩ control
R271	10-1142	100 kΩ control
R315	10-1140	500Ωcontrol
R349	10-1141	1000Ωcontrol

RESISTOR PACKS

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
RP101	9-127	400 Ω
RP102	9-141	1000 Ω, 8-pin
RP103	9-163	4700 Ω
RP201	9-127	400 Ω
RP202	9-141	1000 Ω, 8-pin
RP203	9-141	1000 Ω, 8-pin
RP301	9-138	1000 Ω, 10-pin
RP302	9-162	2700 Ω
RP303	9-141	1000 Ω, 8-pin
RP401	9-128	10 kΩ

RELAYS — CHOKE — CRYSTAL

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
K101–K109	69-110	Relay
K201–K209	69-110	Relay
K301	69-110	Relay
L401	235-229	35 µH choke
Y401	404-646	8 MHz crystal oscillator

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

DIODES — TRANSISTORS — INTEGRATED CIRCUITS

See "Semiconductor Identification" (Page 75).

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

MISCELLANEOUS

	215-688	Heat sink
	432-1171	2-pin plug
	432-1365	3-pin plug
	432-876	8-pin plug
	432-903	10-pin plug
	432-946	25-pin plug
	432-1041	Jumper socket
	434-230	8-pin IC socket
	434-298	14-pin IC socket
	434-299	16-pin IC socket
	434-311	20-pin IC socket
	434-307	24-pin IC socket
	434-312	28-pin IC socket
	434-253	40-pin IC socket

DISPLAY LOGIC CIRCUIT BOARD

RESISTORS

NOTE: The following resistors are rated at 1/4-watt and have a tolerance of 5% unless otherwise listed.

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
R501	6-3161-12	3160 Ω, 1%
R502	6-3161-12	3160 Ω, 1%
R503	6-3161-12	3160 Ω, 1%
R504	6-3161-12	3160 Ω, 1%
R505	6-3161-12	3160 Ω, 1%
R507	6-472-12	4700 Ω
R508	6-1621-12	1620 Ω, 1%
R509	6-331-12	330 Ω
R511	6-331-12	330 Ω
R512	6-331-12	330 Ω
R513	6-331-12	330 Ω
R514	6-331-12	330 Ω
R515	6-331-12	330 Ω
R516	6-472-12	4700 Ω
R517	6-103-12	10 kΩ
R518	6-102-12	1000 Ω

CAPACITORS

C507	21-786	.1 μF ceramic
C508	21-786	.1 μF ceramic
C509	21-786	.1 μF ceramic
C511	21-786	.1 μF ceramic
C512–C519	21-786	.1 μF ceramic
C521	21-786	.1 μF ceramic

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

TRANSISTOR — INTEGRATED CIRCUITS

See "Semiconductor Identification" (Page 75).

CONNECTORS — SOCKETS — PLUGS

	432-121	Wire connector
	432-866	Spring connector
	432-1080	3-hole socket
	432-1110	5-hole socket
	432-1008	14-hole socket
	432-948	25-hole socket
	434-230	8-pin IC socket
	434-298	14-pin IC socket
	434-299	16-pin IC socket
	434-311	20-pin IC socket
	438-55	Polarizing plug

MISCELLANEOUS

C501–C506	25-911	22 μF electrolytic capacitor
R501	10-1137	2000 Ωcontrol
RP501	9-128	10 kΩ resistor pack

DISPLAY CIRCUIT BOARD

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

NOTE: Refer to "Semiconductor Identification" (Page 75) for the LEDs.

R601-R609	6-331-12	330 Ω, 1/4-watt, 5% resistor

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION
SW601-SW609	64-946	Pushbutton switch
SW611-SW619	64-946	Pushbutton switch
SW621	64-946	Pushbutton switch
	432-1227	20-pin plug
	462-1196	Pushbutton knob

CHASSIS

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

PINS — CONNECTORS

	432-120	Female pin
	432-1033	Gold male pin
	432-1142	Small gold-plated spring connector
	432-866	Small spring connector
	432-753	Large spring connector
	432-59	BNC connector

SOCKET

	432-1030	2-hole socket
	432-1022	8-hole socket
	432-958	10-hole socket
	432-103	25-hole D-connecor socket

CIRCUIT Comp. No.	HEATH Part No.	DESCRIPTION

MISCELLANEOUS

NOTE: Refer to "Semiconductor Identification" (Page 75) for integrated circuit U1.

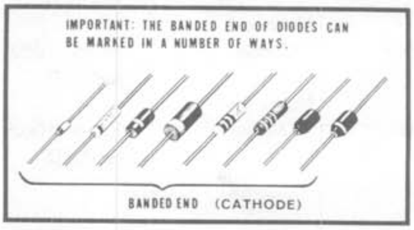
C1	21-72	.005 μF ceramic capacitor
C2	21-72	.005 μF ceramic capacitor
F1	421-42	.375-ampere slow-blow fuse
T1	54-1039	Power transformer
SW1	61-48	Rocker switch
	134-237	Cable with BNC connectors

SEMICONDUCTOR IDENTIFICATION

DIODES

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
D101—D106	56-56	1N4149	A1
D107	56-91	1N823A	A1
D108	56-91	1N823A	A1
D109	56-56	1N4149	A1
D110	Not used		
D111	56-56	1N4149	A1
D112	56-56	1N4149	A1
D113	56-84	1N4148	A1
D114	56-84	1N4148	A1
D115—D118	56-676	MBD201	A2
D119	56-655	1N6263	A1
D120	Not used		
D121	56-655	1N6263	A1
D122—D124	56-56	1N4149	A1
D201—D206	56-56	1N4149	A1
D207	56-91	1N823A	A1
D208	56-91	1N823A	A1
D209	56-56	1N4149	A1
D210	Not used		
D211	56-56	1N4149	A1
D212	56-56	1N4149	A1
D213	56-84	1N4148	A1
D214	56-84	1N4148	A1
D215—D218	56-676	MBD201	A2
D219	56-655	1N6263	A1
D220	Not used		
D221	56-655	1N6263	A1
D301—D303	56-56	1N4149	A1
D304	56-91	1N823A	A1
D305	56-85	5V, 1% zener	A1
D306	56-655	1N6263	A1
D307	56-56	1N4149	A1
D308	56-91	1N823A	A1

A1

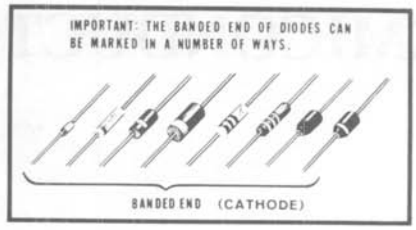


A2

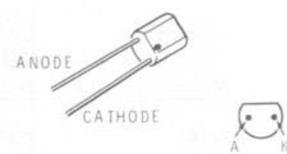
Diodes (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
D401—D403	56-56	1N4149	A1
D404—D407	57-609	1N5393	A1
D408	57-27	1N2071	A1
D409	57-27	1N2071	A1
D410	Not used		
D411	57-27	1N2071	A1
D412	57-27	1N2071	A1
D413	56-637	6.8V zener	A1
D414	56-56	1N4149	A1
V601—V609	412-654	HLMP-1002 red LED	A3
V610	Not used		
V611—V619	412-654	HLMP-1002 red LED	A3
V620	Not used		
V621—V629	412-654	HLMP-1002 red LED	A3
V630	Not used		
V631—V639	412-654	HLMP-1002 red LED	A3
V640	Not used		
V641—V649	412-654	HLMP-1002 red LED	A3
V650	Not used		
V651-V656	412-654	HLMP-1002 red LED	A3
			A3

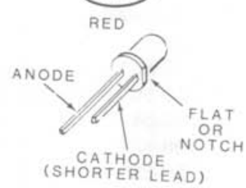
A1



A2

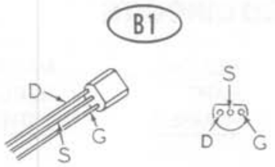


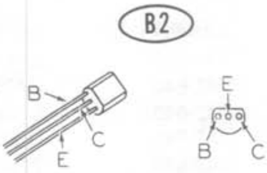
A3

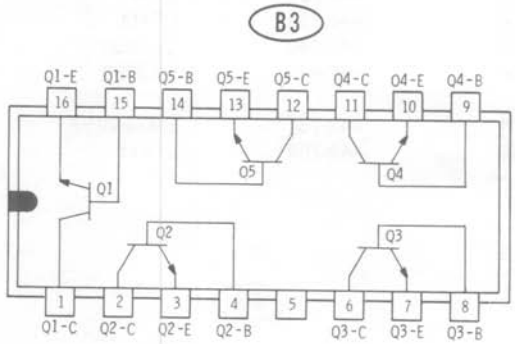


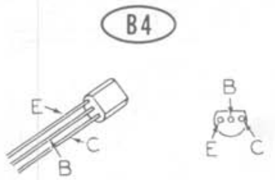
TRANSISTORS

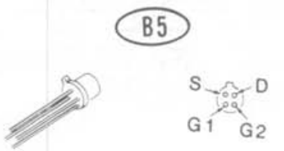
HEATH COMPONENT NUMBER	MAY BE PART NUMBER	REPLACED WITH	KEY NUMBER
Q101	417-828	304	B1
Q102	417-854	E304	B1
Q103	417-887	MPSH10	B2
Q104	417-887	MPSH10	B2
Q105	417-975	CA3127	B3
Q106	417-937	MPS2369	B4
Q107	417-875	2N3904	B4
Q108	417-874	2N3906	B4
Q109	417-874	2N3906	B4
Q110	Not used		
Q111	417-875	2N3904	B4
Q112	417-874	2N3906	B4
Q113	417-863	MFE131	B5
Q114	417-874	2N3906	B4
Q115	417-858	1078E	B6
Q116	417-874	2N3906	B4
Q117	417-874	2N3906	B4
Q201	417-828	304	B1
Q202	417-854	E304	B1
Q203	417-887	MPSH10	B2
Q204	417-887	MPSH10	B2
Q205	417-975	CA3127	B3
Q206	417-937	MPS2369	B4
Q207	417-874	2N3906	B4
Q208	417-875	2N3904	B4
Q209	417-874	2N3906	B4
Q210	Not used		
Q211	417-875	2N3904	B4
Q212	417-874	2N3906	B4
Q213	417-863	MFE131	B5
Q214	417-874	2N3906	B4
Q215	417-858	1078E	B6
Q216	417-874	2N3906	B4
Q217	417-874	2N3906	B4
Q301—Q303	417-887	MPSH10	B2
Q304	417-874	2N3906	B4
Q305	417-874	2N3906	B4
Q306	417-937	MPS2369	B4
Q307	417-917	MPSH81	B2
Q308	417-937	MPS2369	B4
Q309	417-937	MPS2369	B4
Q310	Not used		
Q311	417-902	NPD5566	B7
Q401	417-875	2N3904	B4
Q501	417-937	MPS2369	B4

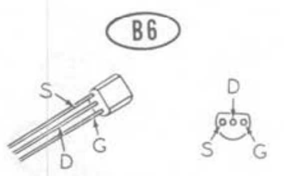


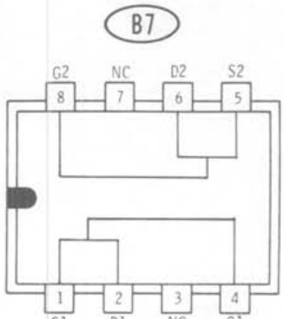








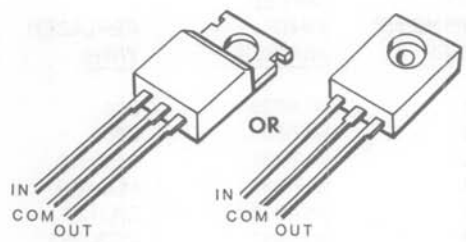




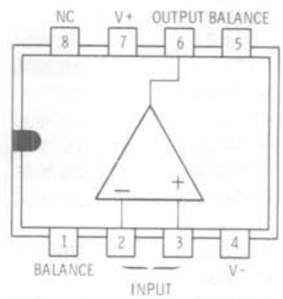
INTEGRATED CIRCUITS

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U1	442-54	UA7805	C1
U101	442-759	LF411	C2
U102	442-759	LF411	C2
U103	442-640	CA3080	C3
U104	442-640	CA3080	C3
U105	442-782	LF357	C2
U106	443-896	74S02	C4
U107	442-627	78L05	C5
U201	442-759	LF411	C2
U202	442-759	LF411	C2
U203	442-640	CA3080	C3
U204	442-640	CA3080	C3
U301	442-751	LM1408N-8	C6
U302	442-759	LF411	C2

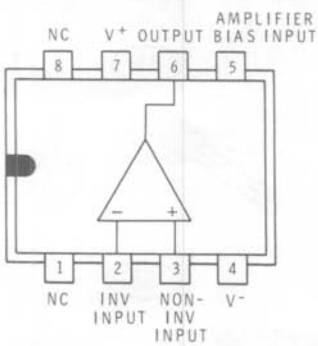
C1



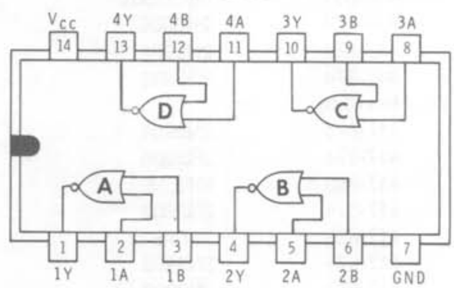
C2



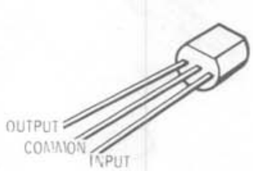
C3



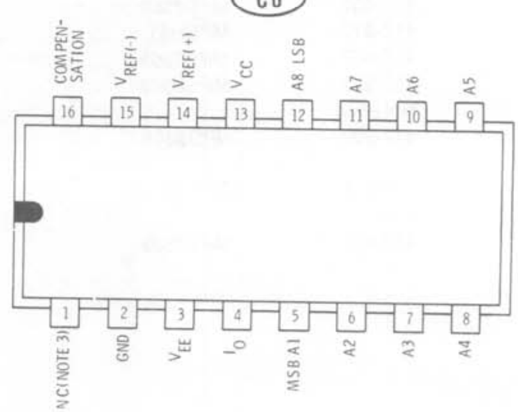
C4



C5



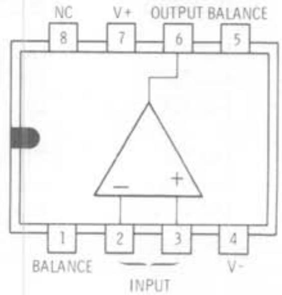
C6



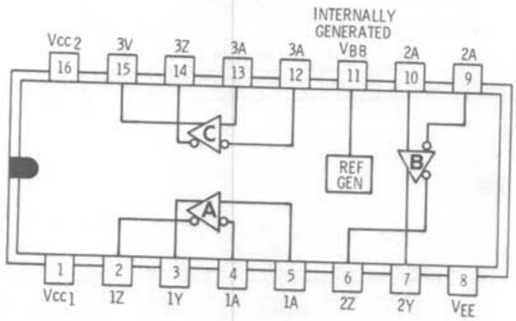
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U303	443-636	MC10116	C7
U304	443-683	MC10102	C8
U305	443-679	MC10131	C9
U306	443-967	7406	C10
U307	443-992	4051	C11
U308	443-992	4051	C11
U309	442-759	LF411	C2
U310	Not used		

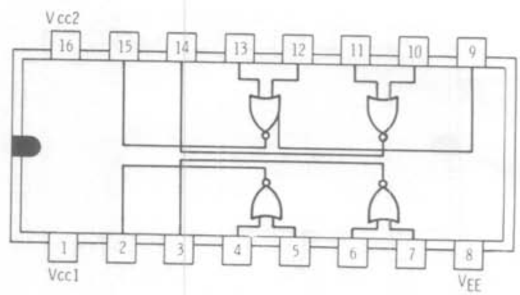
C2



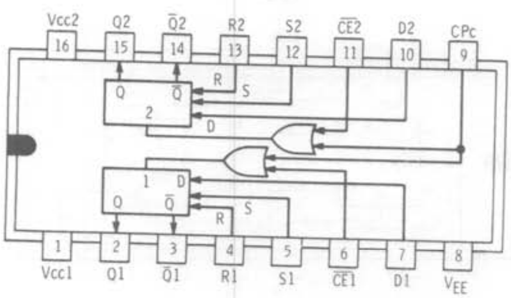
C7



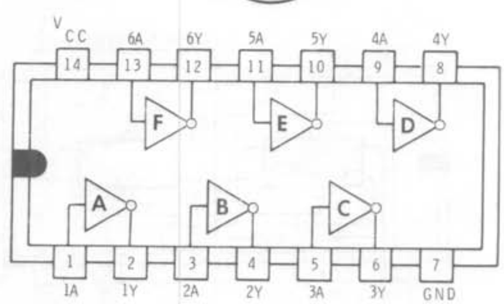
C8



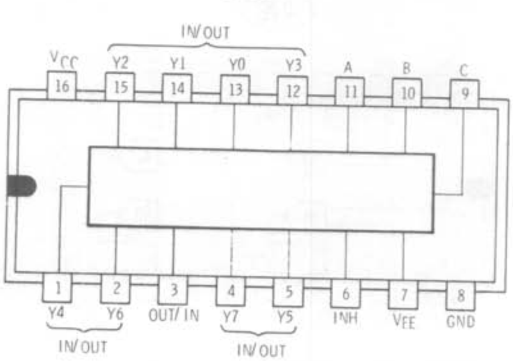
C9



C10



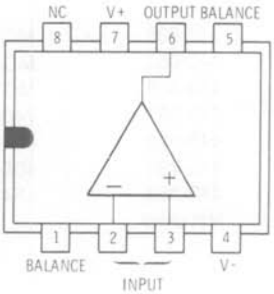
C11



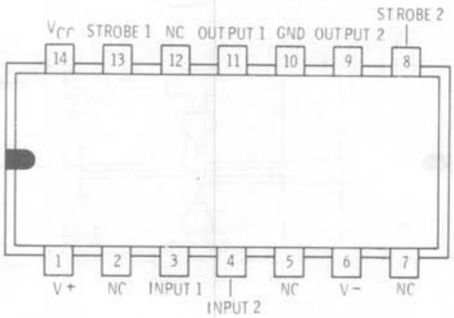
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U311	442-771	LM361	C12
U312	442-768	DAC1021	C13
U313	442-759	LF411	C2
U401	443-730	74LS74	C14
U402	443-948	74LS112	C15
U403	443-1080	74ALS00	C16

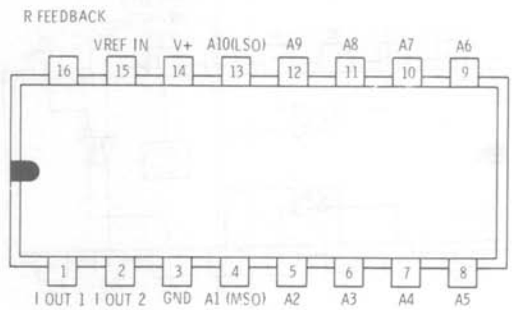
C2



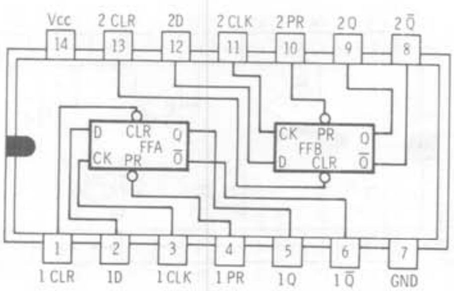
C12



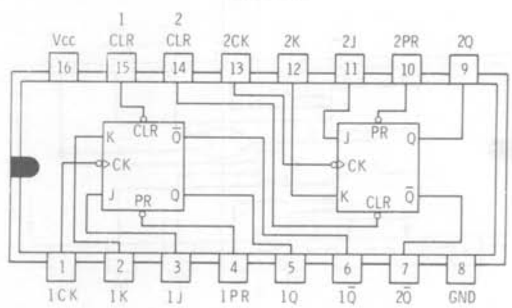
C13



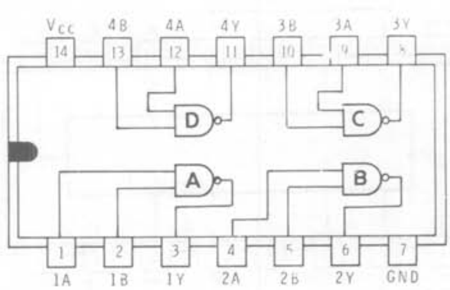
C14



C15



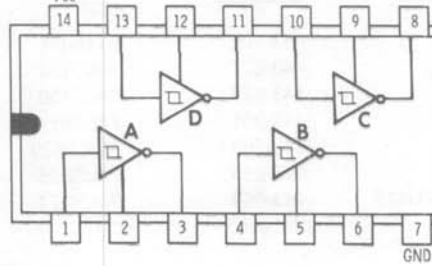
C16



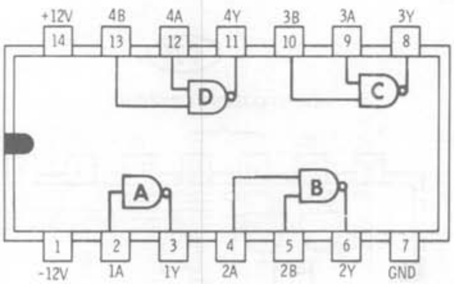
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U404	443-795	75189 or 1489	C17
U405	443-794	75188 or 1488	C18
U406	443-953	3880 or Z80A	C19
U407	443-952	8250	C20
U408	444-344	Special*	C21
U409	443-1039	74LS365A	C22
U410	Not used		

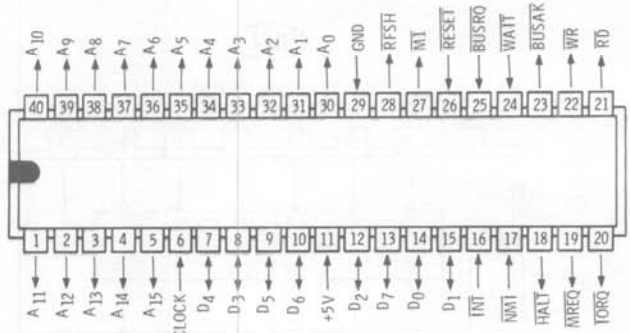
C17



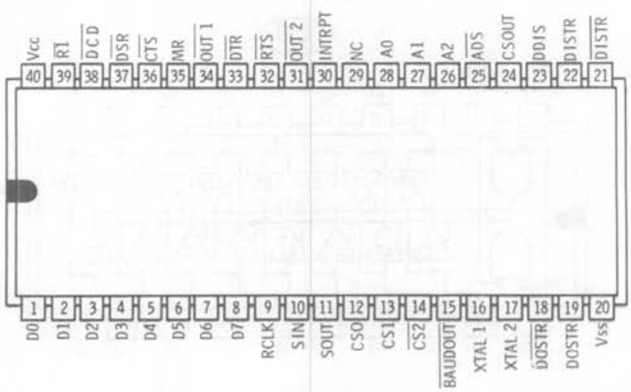
C18



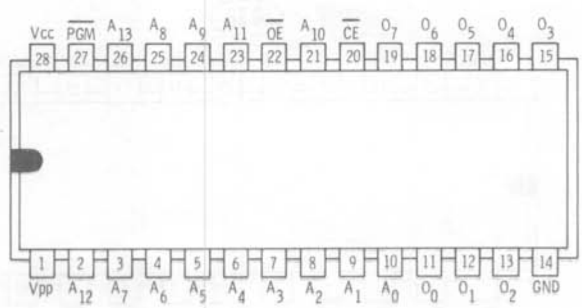
C19



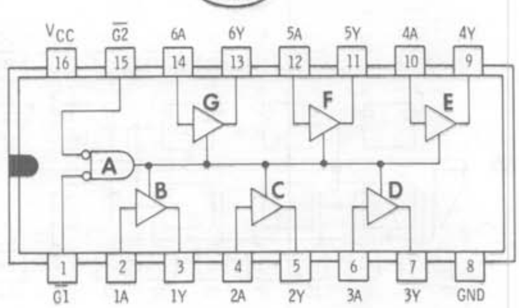
C20



C21



C22

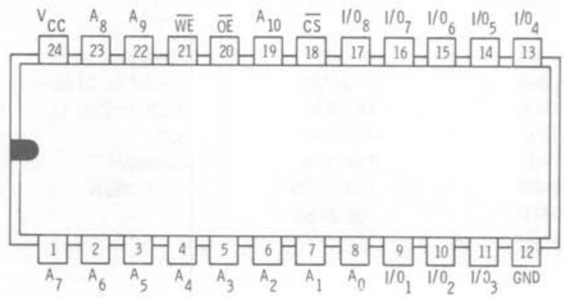


* Available only from the Heath Company.

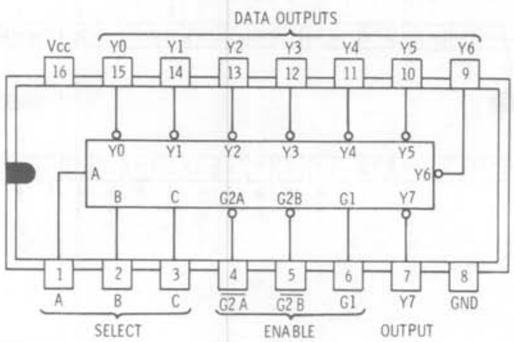
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U411	443-1027	6116-P4	C23
U412	443-877	74LS138	C24
U413	443-877	74LS138	C24
U414	443-951	74LS51	C25
U415	442-769	ADC0820	C26
U416	443-885	74LS245	C27
U417—U419	443-863	74LS374	C28
U420	Not used		

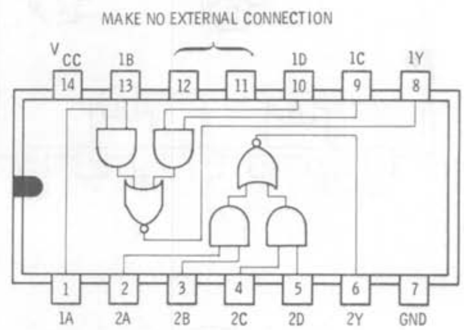
C23



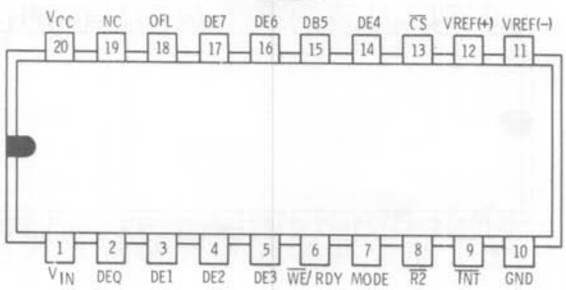
C24



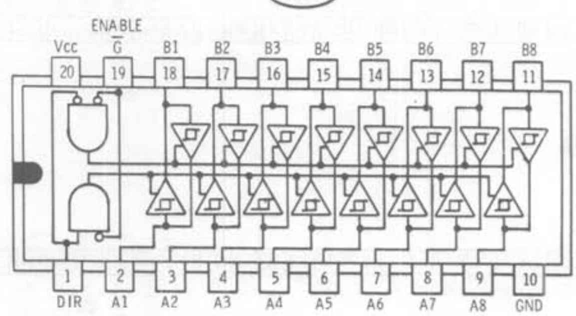
C25



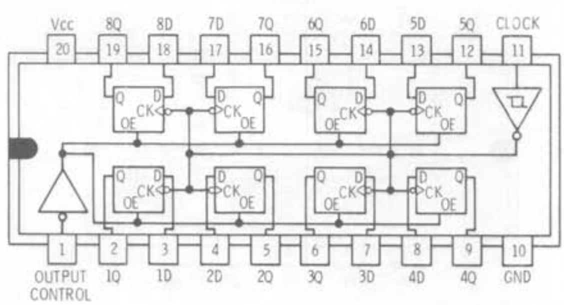
C26



C27



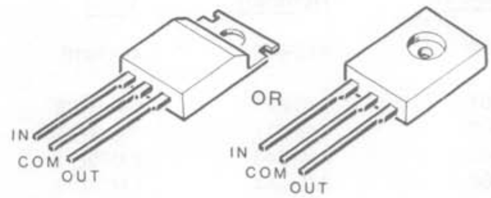
C28



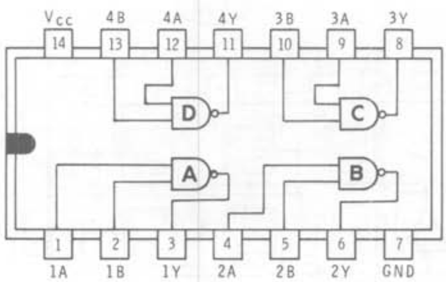
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U421—U423	443-863	74LS374	C28
U424	443-1367	74HCT00	C16
U425—U427	443-1020	7407	C29
U428	443-942	74LS123	C30
U429	442-54	UA7805	C1
U430	Not used		
U431	442-630	MC7905	C31
U432	442-674	UA7812	C1

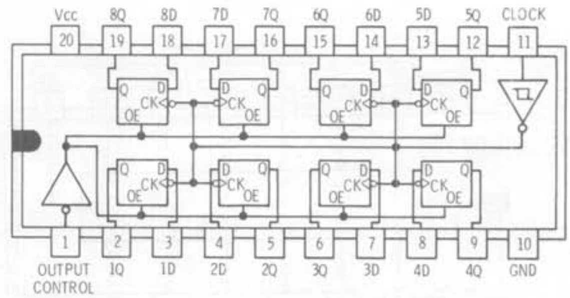
C1



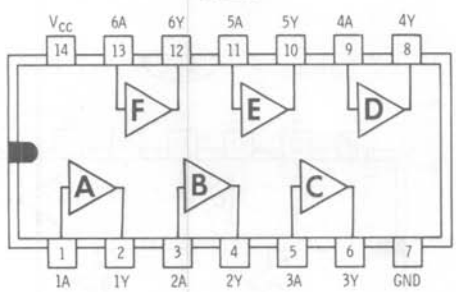
C16



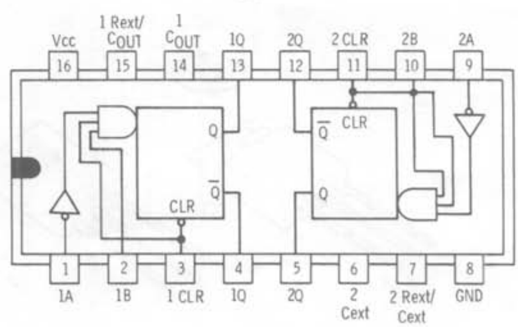
C28



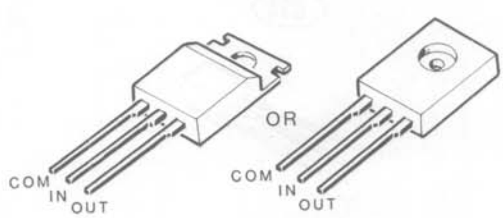
C29



C30



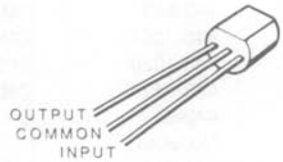
C31



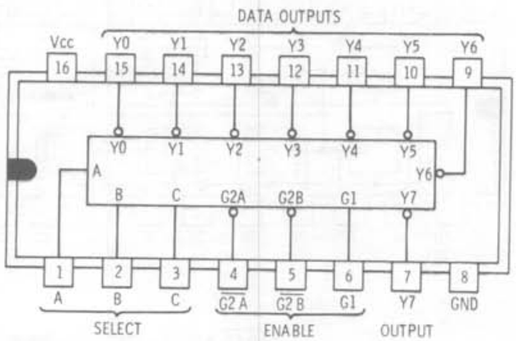
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U433	442-675	UA7912	C31
U501	443-877	74LS138	C24
U502	443-811	74LS125	C32
U503	442-646	LM79L12	C33
U504	442-644	LM78L12	C5
U505	443-863	74LS374	C28

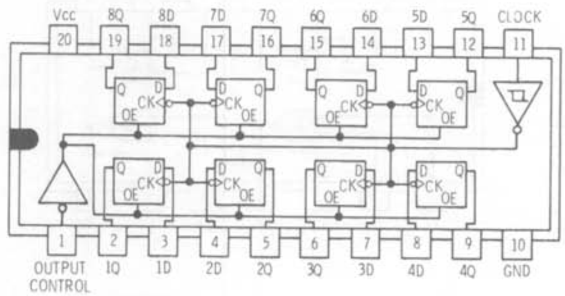
C5



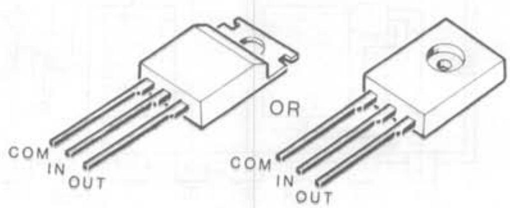
C24



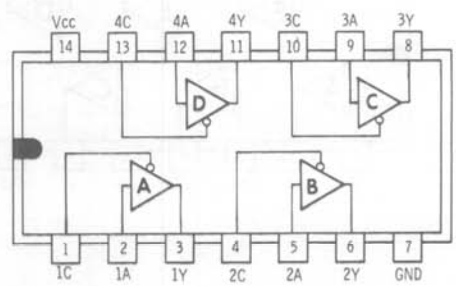
C28



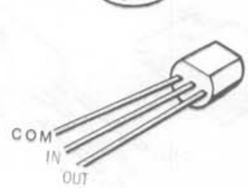
C31



C32



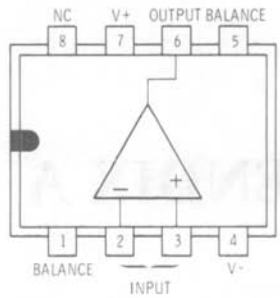
C33



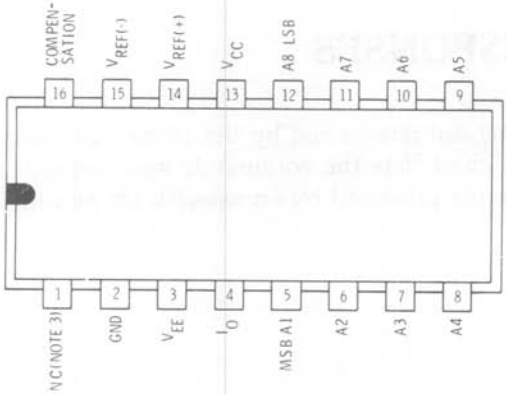
Integrated Circuits (Cont'd)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U506	442-751	LM1408N-8	C6
U507	442-759	LF411	C2
U508	443-863	74LS374	C28
U509	443-863	74LS374	C28
U510	Not used		
U511—U514	443-863	74LS374	C28

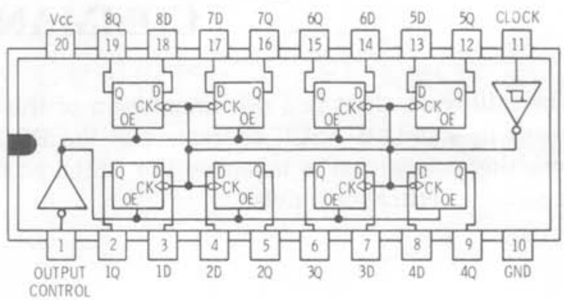
C2



C6



C28



APPENDIX A

COMMANDS & RESPONSES

The following chart is a documentation of the commands that are recognized by the DMO. All commands result in standard ASCII characters at the RS-232 port. The chart lists the commands and documents the resulting action that is taken by the DMO. NOTE: Those actions preceded by an asterisk (*) automatically rezero the vertical channels.

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
65	41	101	A	Y1 sensitivity increase.	*Causes the sensitivity of channel Y1 to increase one range.
66	42	102	B	Y1 sensitivity decrease.	*Causes the sensitivity of channel Y1 to decrease one range.
67	43	103	C	Y2 sensitivity increase.	*Causes the sensitivity of channel Y2 to increase one range.
68	44	104	D	Y2 sensitivity decrease.	*Causes the sensitivity of channel Y2 to decrease one range.
69	45	105	E	Y1 input coupling.	*Causes the Y1 input coupling to change one step in an AC-GND-DC-OFF sequence.
70	46	106	F	Y2 input coupling.	*Causes the Y2 input coupling to change one step in an AC-GND-DC- OFF sequence.
71	47	107	G	Time base rate decrease.	*Causes the time base rate to decrease one range.
72	48	110	H	Time base rate increase.	*Causes the time base rate to increase one range.
73	49	111	I	Trigger slope change.	*Causes the trigger slope to toggle between + and −.
74	4A	112	J	Trigger mode change.	*Causes the trigger mode to change one step in an AUTO-NORM-SINGLE sequence.

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
75	4B	113	K	RESET/MANUAL	*If the DMO is in the single trace mode and the READY LED is off, this command arms the trigger circuit and turns on the READY LED to indicate that the unit is waiting for a trigger. In any other mode, this command forces a trigger (manual trigger).
76	4C	114	L	Trigger source change	*Causes the trigger source to toggle between Y1 and Y2.
77	4D	115	M	SAVE	If there are waveforms currently stored in the auxiliary memory, the waveforms are erased and are no longer displayed by the DMO outputs. If there are no waveforms currently in the auxiliary memory, the present waveforms of channel Y1 and/or Y2 are saved in auxiliary memory and then continuously displayed by the DMO.
78	4E	116	N	Y1 position up.	Moves the position of the Y1 trace up one bit on the output display of the DMO.
79	4F	117	O	Y1 position down.	Moves the position of the Y1 trace down one bit on the output display of the DMO.
80	50	120	P	Y2 position up.	Moves the position of the Y2 trace up one bit on the output display of the DMO.
81	51	121	Q	Y2 position down.	Moves the position of the Y2 trace down one bit on the output display of the DMO.
82	52	122	R	Trigger level increase.	*Increases the trigger level by one bit.
83	53	123	S	Trigger level decrease.	*Decreases the trigger level by one bit.
84	54	124	T	Center Y1 position.	Returns the Y1 vertical position offset to zero.
85	55	125	U	Center Y2 position.	Returns the Y2 vertical position offset to zero.
86	56	126	V	Zero trigger level.	*Returns the trigger level to zero.

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
87	57	127	W	Request date[1]	The DMO samples 512 data points, as necessary, from each input. When the data is ready for transfer, a signal (hex code 72) is sent out through the RS-232 port. The signal tells the computer that the DMO is ready to transmit data. At this point, the DMO waits two seconds for the computer to send a signal back (hex code 72) to indicate that it is ready to accept data. If no signal is received, the DMO assumes the computer no longer wishes to receive data and continues with whatever it was previously doing. If hex code 72 is received, and both channels are on, the DMO sends 1025 bytes of information out through the RS-232 port. The first 512 bytes are the data points for channel Y1. The second 512 bytes are the data points for channel Y2. The last byte indicates whether or not the DMO was triggered when data was sampled. If the last byte is one, the DMO was triggered. If the last byte is zero, the unit was not triggered. If only one channel is on, only 513 bytes of information are sent. The first 512 bytes are the data points for the channel that is on and the 513th byte is the trigger bytes. The following formula converts the 8-bit data value into an equivalent voltage: $\text{Voltage} = \frac{(\text{Data} - 128) \times (\text{Channel sensitivity})}{25}$
93	5D	135	]	Reset/Data request!	Similar to "request memory," except that the trigger circuits are rearmed first. This faces the Oscilloscope to gather new data before signaling the computer that data is ready for transfer.
89	59	131	Y	Status request.	Causes the DMO to send 13 bytes of information out through the RS-232 port as follows: 1st byte = Y1 Sensitivity. 2nd byte = Y2 Sensitivity. 3rd byte = Y1 input coupling. 4th byte = Y2 input coupling. 5th byte = Trigger Slope. 6th byte = Trigger Mode. 7th byte = Trigger Source. 8th byte = Trigger Level. 9th byte = Time Base. 10th byte = Save. 11th byte = Scope.

[1] Any command, except Manual Trigger, that is received before data has been transferred cancels the data request commands.

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION

12th byte = Y1 Vertical Position.

13th byte = Y2 Vertical Position.

The data in each byte is coded as follows:

Y1 and Y2 sensitivity:

DATA	SETTING
00H	5 mV
01H	10 mV
02H	20 mV
03H	50 mV
04H	100 mV
05H	200 mV
06H	500 mV
07H	1.0 V
08H	2.0 V
09H	5.0 V

Y1 and Y2 input coupling:

DATA	SETTING
00H	OFF
01H	AC
02H	GND
03H	—
04H	DC

Trigger Slope:

DATA	SETTING
00H	−
01H	+

Trigger Mode:

DATA	SETTING
00H	—
01H	AUTO
02H	NORM
03H	—
04H	Single-triggered
0CH	Single-armed

Trigger Source:

DATA	SETTING
00H	Y2
01H	Y1

Trigger Level:

8-bit value. You can use the following formula to convert this number into an equivalent voltage:

$$\text{Voltage} = \frac{(\text{Data} - 128) \times (\text{Channel sensitivity})}{25}$$

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
					Time Base:

DATA	RANGE
00H	10 ns
01H	20 ns
02H	50 ns
03H	100 ns
04H	200 ns
05H	500 ns
06H	1 μs
07H	2 μs
08H	5 μs
09H	10 μs
0AH	20 μs
0BH	50 μs
0CH	100 μs
0DH	200 μs
0EH	500 μs
0FH	1 ms
10H	2 ms
11H	5 ms
12H	10 ms
13H	20 ms
14H	50 ms
15H	100 ms
16H	200 ms
17H	500 ms
18H	1 s
19H	2 s
1AH	5 s
1BH	10 s
1CH	20 s

Y1 and Y2 Position:

Signed, two's complement, 8-bit value. This value multiplied by the channel's sensitivity and divided by 25 yields the offset voltage.

DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
91	5B	133	[	Scope Off.	Turns the Vertical Output on the front of the DMO off.
92	5C	134	/	Scope On.	Turns the Vertical Output on the front of the DMO on.
93	5E	135	▲	Reset.	Forces the DMO to jump to 000H and start the program over. This has the same effect as turning the Power Off and then back On.
94	5F	136	_	Rezero.	Forces the DMO to rezero the vertical channels.
114	72	162	r	Ready Signal	Sent by the DMO to the computer to indicate that the DMO is ready to transmit data. As an input from the computer, this command initiates the data transfer. Also refer to the memory request commands.

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
17	11	021	CTRL-Q	Resume Data Transmission (XON).	If a CTRL-S has previously been received, data transmission resumes.
19	13	023	CTRL-S	Suspend Data Transmission (XOFF).	Stops data transmission until a CTRL-Q is received.
115	73	163	s	Sampling.	On the time base ranges between 100 ms/div and 20 s/div, this character is sent to the computer at the beginning of the sampling process (if the computer has requested data). This response indicates that the Oscilloscope is currently gathering data. After the data has been gathered, an "r" is sent to the computer to indicate that data is ready.
97	61	141	a	Set trigger level.	After the Oscilloscope receives this command, it waits approximately 2.5 seconds to receive an 8-bit value at its RS-232 port. If it does not receive a value, nothing happens. If it does receive a value, however, the value becomes the new trigger level. The 8-bit trigger level is encoded in the same manner as the data (see the Request Data commands).
98	62	142	b	Set Y2 position.	After the Oscilloscope receives this command, it waits approximately 2.5 seconds to receive an 8-bit value at its RS-232 port. If it does not receive a value, nothing happens. If it does receive a value, however, the Oscilloscope interprets it as a two's-complement number, and this number becomes the new Y1 position offset.

APPENDIX B

HOW TO MAKE A BACKUP AND/OR A WORKING COPY OF THE SOFTWARE

The following example assumes that your system has two disk drives and you will be using MS-DOS. If your system has only one drive or you will be using a different operating system, you can use the example as a guide to generate a disk that is configured for your system.

1. Insert an MS-DOS system disk that contains the programs FORMAT and CONFIGUR into drive A (the default drive).

2. Insert a blank disk into drive B.

3. Boot the system. When you obtain the A> prompt, type "FORMAT/S/V" followed by the RETURN key.

4. When the program asks you which drive to format, type "B". Make sure a blank disk is in drive B. Then press the RETURN key.

5. When the program asks for a volume label, type "SCOPE" followed by the RETURN key.

6. When the program asks if you have more disks to format, type "N".

7. When the A> prompt reappears, type "CONFIGUR", followed by the RETURN key.

NOTES:

A. During the remainder of this example, **boldface** type indicates a response that you should input from the computer keyboard. If a response has an asterisk (*) beside it, you may use any of the listed responses. You may wish to select a response that allows another serial device to share the communication channel. If the Oscilloscope is the only device that will use the communication channel, use the response shown in the example.

B. The remainder of this example assumes you are using CONFIGUR Version 2.00. If you are using a different Version, refer to your Operating System Manual to use your Version. However, you can use the following information as a guide to CONFIGUR your disk.

```
                    CONFIGUR Version 2.00
          Copyright(C) 1984, Zenith Data Systems, Inc.

Use one of the following options to configure a device

A. Configure LPT device
B. Configure COM device

C. Exit with no changes

Enter selection (A-C): A


Select the serial port to be configured

A. COM1
B. COM2

C. Exit

Enter selection (A-C): A or B (Use the channel that you will use for the Oscilloscope.)


Use one of the following options to select the appropriate configuration

A. Compatibility mode (2400 baud, DTR, and RTS pos.)
B. MX-80 (4800 baud, DTR pos. (pin 20))
C. H/Z-25 (4800 baud, RTS Neg. (pin 4))
D. H-14/WH-24 (4800 baud, RTS Neg. (pin 4))
E. Diablo 630/1640 (1200 baud, ETX/ACK)
F. WH-23/WH-33/WH-43 modem (300 baud, No handshake)
G. WH-12 Votrax Type-N-Talk (4800 baud, RTS Pos. (pin 4))
H. User Defined
I. Exit with no changes

Enter selection (A-I): H


Answer the following questions with a Y for Yes and N for No

Strip parity in input? (Y/N) <N> N
Strip parity on output? (Y/N) <N> N
Map lower case to upper on input? (Y/N) <N> N
Map lower case to upper on output? (Y/N) <N> N
```

```
Select one of the following baud rates

A. 110
B. 150
C. 300
D. 600
E. 1200
F. 2400
G. 4800
H. 9600

Enter one of the baud rate values: H*


Use one of the following stop bit values

A. 1 Stop bit
B. 2 Stop bits

Enter one of the stop bit values: A*


Use one of the following parity selections

A. No parity
B. Odd parity
C. Even parity

Enter one of the parity values: A*


Use one of the following to select the word length
NOTE: Word length is exclusive of stop bits and parity

A. 7 bit words
B. 8 bit words

Enter one of the word length values: B*


Use the following to select a handshaking protocol

A. No Handshaking
B. ETX/ACK
C. DC1/DC3
D. Compatibility mode, DTR and RTS Positive
E. RTS Positive (pin 4)
F. RTS Negative (pin 4)
G. DTR Positive (pin 20)
H. DTR Negative (pin 20)

Enter one of the handshake values: G
```

```
If you do not wish a pad character, simply
strike the RETURN key, and then enter a zero
as the number of pad characters, otherwise type
the actual key character you wish to pad.

For example, to pad after all carriage returns, type
the RETURN key.

Type the key corresponding to your desired pad character: RETURN
Enter the number of pad characters to send (0-255): 0

The time out value is used to give slow devices time to respond
to Input/Output requests. A small value is usually sufficient,
but a number 0 to 255 can be entered.

Enter time out value for COM1: 25


                    CONFIGUR Version 2.00
        Copyright(C) 1984, Zenith Data Systems, Inc.

Use one of the following options to configure a device

A. Configure LPT device
B. Configure COM device

  Use one of the following to modify as existing system

C. Exit program
D. Make changes to disk
E. Make changes to memory
F. Make changes to both disk and memory.

Enter selection (A-F): F

Enter drive name with system to modify (A-F): B


                    CONFIGUR Version 2.00
        Copyright(C) 1984, Zenith Data Systems, Inc.

Use one of the following options to configure a device

A. Configure LPT device
B. Configure COM device

  Use one of the following to modify an existing system

C. Exit program
D. Make changes to disk
E. Make changes to memory
F. Makes changes to both disk and memory

Enter selection (A-F): C
```

8. When the A> prompt returns, remove the system disk from drive A and insert the Scope disk (currently in drive B) into drive A.

9. Insert the disk that was supplied with the Oscilloscope into drive B.

10. If you are making a **backup copy** of the disk supplied with the Oscilloscope, copy all of the files from the supplied disk to the new disk. To do this, type "COPY B:*.* = A:" followed by the RETURN key. Then proceed to Step 11.

    If you are making a **working disk** and intend to use only the **compiled** version of the program, you can copy only the files necessary to run the compiled program. This will help save disk space. To do this, type the following:

        COPY B:SCOPE.EXE = A: followed by a RETURN

        COPY B:*.SAV = A: followed by a RETURN

    Proceed to Step 11.

    If you are making a **working disk** and intend to use only the **GW-BASIC** version of the program, you can copy only the files necessary to run the GW-BASIC program. This will help save disk space. To do this, type the following:

        COPY B:SCOPE.BAS = A: followed by a RETURN

        COPY B:*.SAV = A: followed by a RETURN

        COPY B:*.BIN = A: followed by a RETURN

    Remove the disk supplied with the Oscilloscope from drive B. Then insert a disk that contains GW-BASIC version 2.0 or higher into drive B. Now type the following to copy the GW- BASIC file onto the working disk:

        COPY B:BASICA.EXE = A: followed by a RETURN.

    Proceed to Step 11.

11. Store the disk supplied with the Oscilloscope in a safe place. Use the backup disk or the working disk for the normal operation of your Oscilloscope.

12. If your printer has graphics capability, you may wish to include the appropriate PSC file from your MS-DOS distribution disk. To do this, insert the MS-DOS distribution disk that contains the PSC file for your particular printer into drive B. Then type:

        COPY B:PSCMX80.COM = A: followed by a RETURN

    This example assumes you are using an Epson MX-80 printer that has the graphics option. If you have a different printer, replace MX80 in the above copy command with the letters that correspond to your printer. Refer to your MS-DOS manual for a list of the supported printers.

You must run the PSC program **before** you run the SCOPE program if you want to use your printer. To do this, using the MX-80 printer as example, type PSCMX80 at the A> prompt, followed by a RETURN. Make sure your working disk is properly configured for your printer. (Refer to your MS-DOS and printer manuals to properly configure your disk.) If the disk is not configured properly, the printer may lock up when you try to use it. In addition, you **cannot** use the same serial port for both the printer and the Oscilloscope.

Once you run the PSC program, you can simply press the SHIFT and PRT SC keys (at the same time) to obtain a hard copy output of any of the Oscilloscope displays.

13. You may wish to include an AUTOEXEC.BAT file on your working disk. This file can automatically run the PSC program and the Scope program whenever you boot from your working disk. The following examples show you how to create an AUTOEXEC.BAT file and suggests some things you may wish to include. (As in the other examples, the MX-80 printer is used as an example.)

To create an AUTOEXEC.BAT file for a working disk with the **compiled** version of the program, type the following after the A> prompt:

> COPY CON = AUTO EXEC.BAT followed by a RETURN
>
> DATE followed by a RETURN
>
> TIME followed by a RETURN
>
> PSCMX80 followed by a RETURN
>
> SCOPE followed by a RETURN
>
> Press the F6 key followed by a RETURN to close the file.

Whenever you boot from this working disk, the program will request the date and time (these are useful if you are saving waveforms on this disk), run the PSC program (so you can use the SHIFT/PRT SC function with your printer), and then run the Scope program. This file provides an easy and convenient way to run the Scope program.

If you wish to use an AUTOEXEC.BAT file with the GW-BASIC version of the program, simply replace SCOPE in the above example with BASICA SCOPE.

Refer to your MS-DOS manual for more information about the AUTOEXEC.BAT file as well as other BATCH files.

APPENDIX C

SOFTWARE DESCRIPTION

The two versions of the SCOPE program on the disk supplied with the Oscilloscope are labeled SCOPE.EXE and SCOPE.BAS. The following discussion briefly describes these programs and the files that they use while they are running.

SCOPE.EXE

This is the compiled version of SCOPE.BAS. To run this program, you only need the MS-DOS operating system and the three .SAV files from the disk supplied with the Oscilloscope. The three .SAV files are described below.

BANNER.SAV — Contains the display information that appears when you first start the program. This file was created with the BLOAD command in GW-BASIC.

HELP.SAV — Contains the display information that appears when you type "?" while the Banner display is present. This file was also created with the BLOAD command.

BAUD.SAV — Contains the baud rate and COM channel that are used by the SCOPE program. It also contains a variable that tells whether or not the display oscilloscope output is on or off. This file is created as a sequential file by GW-BASIC and is updated whenever you change baud rates or COM channels. It is also updated when you exit the SCOPE program. The purpose of this file is to remember these three values so that you do not have to re-enter them each time you use the SCOPE program.

SCOPE.BAS

This is the GW-BASIC version of the program. You should use GW-BASIC version 2.0 or higher to run this program. In addition to the .SAV files described above, you need the .BIN files from the disk supplied with the Oscilloscope.

The .BIN files are assembly language subroutines that GW-BASIC loads into memory and then CALLs as subroutines. In general, these subroutines are used to perform functions that would be too slow if they where performed by GW-BASICs interpreter. For each .BIN file, there is a corresponding .ASM file on the disk supplied with the Oscilloscope. The .ASM files are not necessary to run SCOPE.BAS, but are included so that you have the source code for each .BIN file. At the beginning of each .ASM file is a brief description of its operation and how it is CALLed from BASIC.

SCOPE.BAS and the .ASM files were included on the disk so you can customize the SCOPE program. We recommend that you do not modify the .BIN subroutine unless you are familiar with assembly-language programming. You can, however, use these subroutines in your own BASIC programs or in modified versions of SCOPE.BAS. You can use

PLOT.BIN, for example, to plot any data that is contained in a 512 point, integer data array. By modifying the .ASM files and the SCOPE.BAS file, you should be able to write many interesting variations of SCOPE.BAS.

WAVEFORM STORAGE

Both versions of the SCOPE program use the PRINT#1 BASIC command to store waveforms on disk as sequential GW-BASIC files. This means that the data stored is in ASCII format. The first five pieces of information contain sensitivity, time base, and display information. The remaining 512 pieces of data are the waveform data points, beginning with the first data point sampled. The stored data is defined as follows:

DATA	POSSIBLE VALUES	DESCRIPTION
Sensitivity	0	5 mV/div
	1	10 mV/div
	2	20 mV/div
	3	50 mV/div
	4	100 mV/div
	5	200 mV/div
	6	500 mV/div
	7	1.0 V/div
	8	2.0 V/div
	9	5.0 V/div
Time base	0	10 ns/div
	1	20 ns/div
	2	50 ns/div
	3	100 ns/div
	4	200 ns/div
	5	500 ns/div
	6	1 µs/div
	7	2 µs/div
	8	5 µs/div
	9	10 µs/div
	10	20 ns/div
	11	50 ns/div
	12	100 ns/div
	13	200 ns/div
	14	500 µs/div
	15	1 ms/div
	16	2 ms/div
	17	5 ms/div
	18	10 ms/div
	19	20 ms/div
	20	50 ms/div
	21	100 ms/div
	22	200 ms/div
	23	500 ms/div
	24	1 s/div
	25	2 s/div
	26	5 s/div
	27	10 s/div
	28	20 s/div

Invert	0	False
	1	True
Vertical offset	(−128 to +127)	Number of bits that the display is offset vertically.
Horizontal offset	(−128 to +127)	Number of bits that the display is offset horizontally.
512 data points	(0 to 255)	Value of actual data points sent by the Oscilloscope. You can use the following formula to convert the value to an equivalent voltage:

$$\text{Voltage} = \frac{(\text{data} - 128) \times \text{sensitivity}}{25}$$

COMMAND					
DEC	HEX	OCT	CHAR	DESCRIPTION	ACTION
99	63	143	c	Set Y2 position.	After the Oscilloscope receives this command, it waits approximately 2.5 seconds to receive an 8-bit value at its RS-232 port. If it does not receive a value, nothing happens. If it does receive a value, however, the Oscilloscope interprets it as a two's-complement number and this number becomes the new Y2 position offset.

SERVICE INFORMATION

The following Heath Company services are available if you need them: Replacement Parts, Technical Consultation, and Factory Service. Address all correspondence to:

HEATH COMPANY
Benton Harbor, Michigan 49022

For prompt service, use a separate letter for each department you write to.

Replacement parts and carry in repair service are also available at your nearest Heath/Zenith Computer and Electronics center. These are listed in your Heath Catalogs.

REPLACEMENT PARTS

If a replacement part is needed, use the warranty parts order form or a letter including the following information.

1. Part number and description.
2. Model Number of the equipment.

If your equipment is in the Warranty period, add:

3. Date, location and invoice number of purchase.
4. Nature of defect.

Heath Company will fill your order promptly. Save but DO NOT RETURN PARTS unless they are requested. Parts that are damaged through carelessness or misuse by the customer are not replaced without cost.

TECHNICAL CONSULTATION

You can write or call our Technical Consultants for help with any Heath equipment, or for answers to any questions about the use of this equipment.

The completeness and accuracy of the advice mailed back to you depends entirely on the information in your letter. Be sure to include:

1. The Model Number and Series Number of the equipment (on identification label).
2. Date of purchase.
3. An exact description of the difficulty. Include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.
4. List everything you have done in attempting to correct the difficulty.

FACTORY SERVICE

If you do not have qualified repair services at your disposal, you can return your equipment to the Heath Company Service Department to have it repaired for a minimum service fee. (Equipment that has been modified will not be accepted for repair.) Refer to Shipping Instructions for details on how to package and ship the equipment.

To be eligible for replacement parts under the terms of the Warranty, equipment returned for factory service must be accompanied by the invoice or the sales slip, or a copy of either. (If you send the original invoice or sales slip, it will be returned to you.)

SHIPPING INSTRUCTIONS

Check the equipment to see that all parts are in place. Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least three inches of resilient packing material (shredded paper, excelsior, etc.) on all sides between the equipment and the carton.

Seal the carton with gummed paper tape. Ship it by prepaid UPS or insured Parcel Post to:

HEATH COMPANY
SERVICE DEPARTMENT
Benton Harbor, Michigan 49022

Include a letter, containing the following information:

1. Your name and return address.
2. Date of purchase.
3. Complete description of the difficulty.
4. Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the Warranty.

YOUR HEATH FACTORY ASSEMBLED PRODUCT ONE–YEAR LIMITED WARRANTY

Welcome to the Heath family. We believe you will be pleased with the performance of your new Heath assembled product. Please read this consumer protection plan carefully. It is a "LIMITED WARRANTY" as defined in the U.S. Consumer Product Warranty and Federal Trade Commission Improvement Act. This warranty gives you specific legal rights, and you may also have other rights which vary fom state to state.

HEATH'S RESPONSIBILITY

PARTS — Replacement for factory defective parts will be supplied free for one year from date of purchase. Replacement parts are warranted for the remaining portion of the original warranty period. You can obtain warranty parts direct from Heath Company by writing or telephoning us at (616) 982-3571. And we will pay the shipping charges to get those parts to you ... anywhere in the world.

SERVICE LABOR — For a period of one year from the date of purchase, any malfunction caused by factory defective parts or workmanship will be corrected at no charge to you. You must deliver the unit at your expense to the Heath factory, any Heath/Zenith Computer and Electronics center (units of Veritechnology Electronics Corporation) or any of our authorized overseas distributors.

TECHNICAL CONSULTATION — You will receive free consultation on any problem you might encounter in the use of your Heath product. Just drop us a line or give us a call. Sorry, we cannot accept collect calls.

NOT COVERED — Repair service, adjustments and calibration due to misuse, abuse or negligence are not covered by this warranty. Unauthorized modification of the product or of any furnished component will void this warranty in its entirety. This warranty does not include reimbursement for inconvenience, installation, set-up time, loss of use, or unauthorized service.

This warranty covers only Heath factory assembled products and is not extended to other equipment and components that a customer uses in conjunction with our products.

SUCH REPAIR AND/OR PARTS REPLACEMENT SHALL BE THE SOLE REMEDY OF THE CUSTOMER AND THERE SHALL BE NO LIABILITY ON THE PART OF HEATH FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING BUT NOT LIMITED TO ANY LOSS OF BUSINESS OR PROFITS, WHETHER OR NOT FORESEEABLE.

Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

OWNER'S RESPONSIBILITY

EFFECTIVE WARRANTY DATE — Warranty begins on the date of first consumer purchase. You must supply a copy of your proof of purchase when you request warranty service or parts.

OPERATING MANUAL — Read your operating instructions carefully so that you will fully understand the proper operation and function of your unit.

ACCESSORY EQUIPMENT — Performance malfunctions involving connections to (or interfacing with) other non-Heath equipment are not covered by this warranty and are the owner's responsibility.

SHIPPING UNITS — Follow the packing instructions published in your manual. Damage due to inadequate packing cannot be repaired under warranty.

If you are not satisfied with our service (warranty or otherwise) or our products, write directly to our Director of Customer Service, Heath Company, Benton Harbor MI 49022. He will make certain your problems receive immediate, personal attention.

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.