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LAST MONTH WE INTRODUCED THE 16-channel, 50-MHz logic analyzer. We discussed all the capabilities of this digital-test instrument, and the theory behind its operation. This month we'll show you how to build it.

### Construction

The logic analyzer consists of two PC-boards, a case, and an overlay. Due to the extremely high-speed logic used in this design, it is critical that PCB's be used. Wire-wrap and point-to-point construction techniques will not work!

A photo of the inside of an assembled unit is shown in Fig. 7. The main logic board has four circuit layers: two signal layers, one power, and one ground plane. The PC board can only be fabricated by a fairly sophisticated board vendor. Because of that, foil patterns have not been provided in this article. A finished board and all the required parts, however, are available from the source mentioned in the Parts List. Figure 8 shows an internal photo of the unit with the LCD panel removed.

Figure 9 shows the parts-placement diagram. Make sure you observe the correct component orientation and capacitor polarities when soldering the components. Assemble the keyboard first, because it is the simplest circuit. Note how the keys are placed on the component side of the circuit board, as shown in Fig. 9. The keyboard connector, P1, must be placed on the solder side, in the position that is shown.

When soldering the keys, S1-S12, pay particular attention

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# LOGIC

# ANALYZER

**Troubleshooting digital circuits is a cinch with this 16-channel, 50-MHz logic analyzer.**



to their alignment. They must be straight with respect to the edge of the board and to each other, otherwise the cutouts in the case will not fit over them.

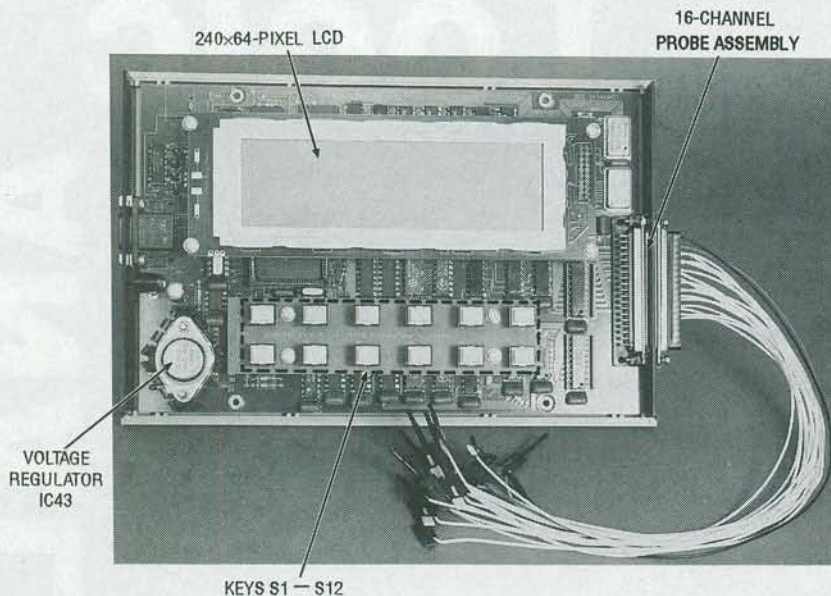
When you've finished soldering in the components, all flux *must* be removed from the circuit boards. We recommend that solder with a water-soluble flux be used, rather than the standard rosin core. Rosin-core flux must be removed with a freon based solvent, which is quite expensive. Water-soluble flux, however, can be cleaned off with warm tap water and a small brush (a toothbrush is remarkably effective). Kester solder with type 331 flux is a good one to use.

Assembling the main circuit board is also straightforward. In-

stall all mechanical components as shown in Fig. 10. Most of the components on the main board are CMOS, therefore they're quite sensitive to static electricity. Make sure you follow adequate precautions when handling those IC's. When assembling the main board, it is critical that you use a properly grounded three-wire soldering iron, and that your workbench is covered with an anti-static mat to avoid damage to the CMOS IC's.

Solder in all of the IC's and sockets first. Notice that IC1, IC2, IC30, IC32, IC40, IC44, IC45, and IC46 are socketed. The socket for IC30 has pin 1 facing to the left. The socket for IC40 is a Dallas Semiconductor Smart Socket. It does not use all of the





**FIG. 7—INTERNAL PHOTO OF the logic analyzer.** The main PC board has four layers: two signal layers, one power, and one ground plane. Wire wrap and point-to-point soldering techniques cannot be used because of extremely high-speed logic.

holes provided for IC40. Align that part in the lower part of the socket.

The capacitors and resistors should then be added, followed by connectors J1–J4, P1, and the header blocks P2–P4. Attach the heatsink to the voltage regulator, IC43, using a thin layer of conductive heat-sink cream. Secure that assembly to the board using 1/2-inch 4-40 screws, washers, and nuts.

The circuit board must be jumpered to work properly with the size of SRAM and ROM being used. To accomplish that place shorting blocks between P2 (pins 1-2), P3 (pins 2-3), and P4 (pins 2-3).

That completes the assembly of the main logic board. After cleaning the board of flux, carefully inspect it for good solder connections and make sure there are no solder bridges present. Touch up any cold or questionable solder joints.

Carefully inspect the alignment of all of the components. Insert the V25 microprocessor (IC30) into its socket. Make sure that pin 1 is aligned correctly. It's very difficult to remove a PLCC device from the socket once it's been inserted. Insert components IC1, IC11, IC44, IC45, and IC46. IC44 and IC45 are programmable logic devices (PLD's).

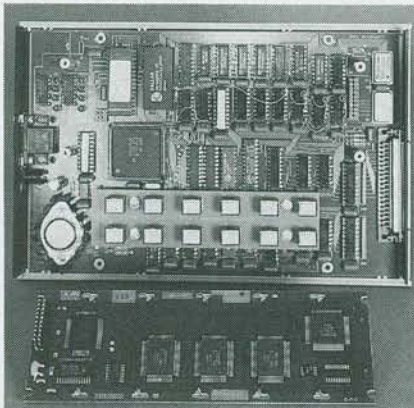
#### Acquisition connector

The acquisition clip assembly

consists of a DB-37 connector shell containing eighteen wires terminating in small micro-clips. It is supplied in a pre-assembled format.

There are three separate parts to each micro-clip assembly; the wire, the body, and the plunger. Each part can have a different color. The color coding is used to separate the function of the input lines; all data input channels have a white wire, the clock wire is green, the ground wire is black.

The plunger and body are used to distinguish the input channel numbers. Channel 0 has a black plunger and a black body, channel 1 has a brown plunger and a black body, channel 2 has a red plunger and a black body, and so on. Table 1 lists the cap, plunger, and wire color coding of the probe assembly.



**FIG. 8—INTERNAL PHOTO OF the logic analyzer with the LCD panel removed.**

#### Final assembly

We're now ready for final assembly. To connect the LCD panel to the main logic board, connector P4 must be soldered onto the display. Connect P4 to the bottom side of the LCD panel (away from the LCD panel itself).

To complete the mechanical assembly, attach four 5/8-inch and four 3/8-inch standoffs to the circuit board as shown in Fig. 10. The shorter standoffs are used for the keyboard. Align the keyboard connector and attach it to the main circuit board. Do the same for the LCD panel.

#### Checkout

At this point we're ready to test the logic analyzer. Measure the resistance between pin 20 and pin 10 of IC1 (the power pins). The resistance should be above 20 ohms. If it's below that value, there's a short somewhere on the board. Do not power the unit up until you find it!

Plug the AC adapter into the wall outlet then plug it into J2. The LCD panel should display a brief title-page before running the software. (You can become familiar with the software running on the logic analyzer by reviewing the introductory sections in the manual provided with the kit or with the ROM). If you don't see the title page, then there's a problem with the microprocessor section (IC30, IC40, IC42, IC44, and IC46). The LCD contrast voltage at R10 should be around -10 volts. The voltage at IC1 pin 20 (+5-volt power supply) should be between 4.75 and 5.1 volts.

We will now test the internal clock generator circuits. For that test, you'll need a 100-MHz counter. Connect the counter to pin 5 of IC38. Go to the SYSTEM screen and select an internal clock. Then select each clock speed in turn. For each clock speed, make sure the counter shows the same speed on the display (for example, if a 10-MHz clock has been selected, the counter should show 10 MHz).

You can check the external clock signal input by selecting the external clock function. Using a function generator, place a TTL-level signal of a known frequency into the CLK pod. The counter should show the function generator's frequency.



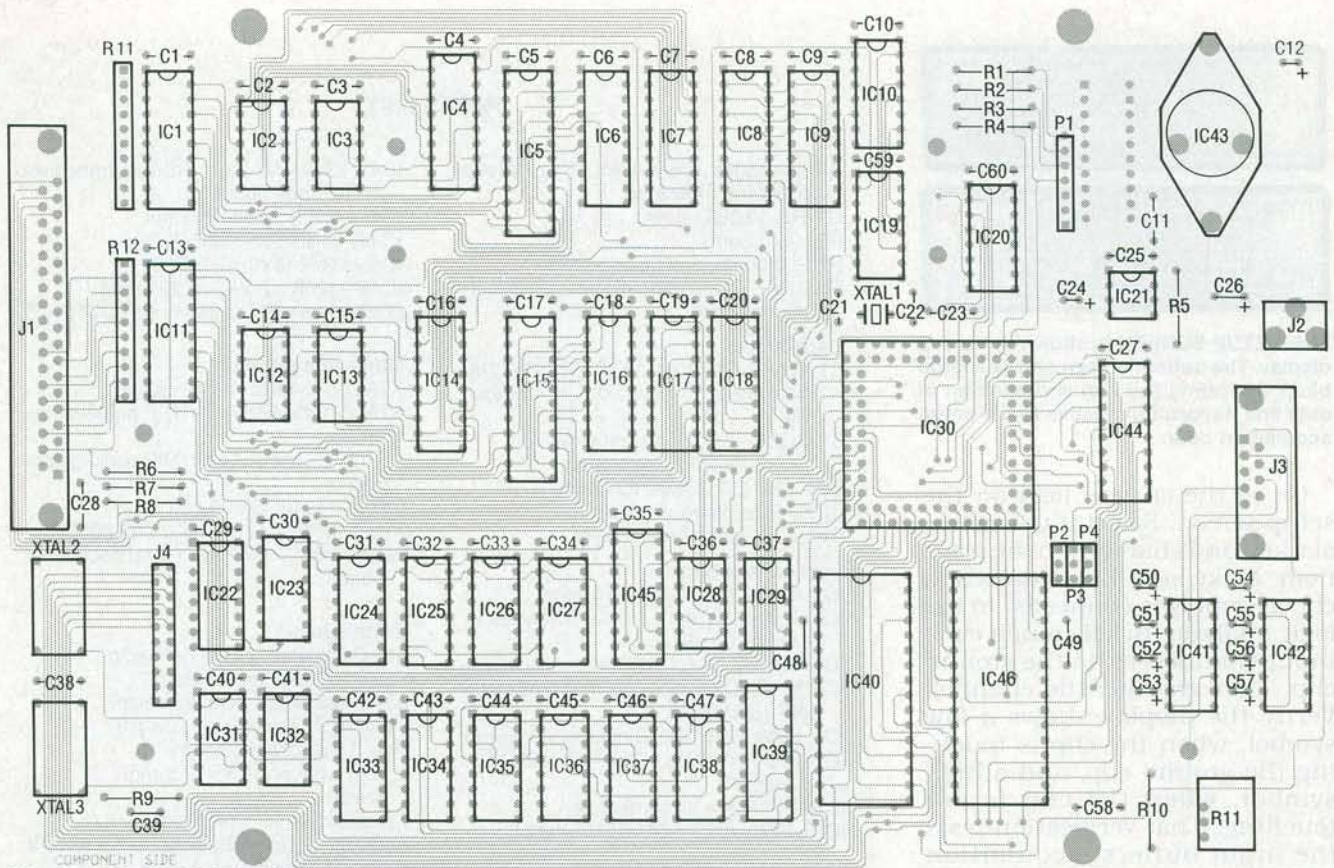


FIG. 9—PARTS-PLACEMENT DIAGRAM.

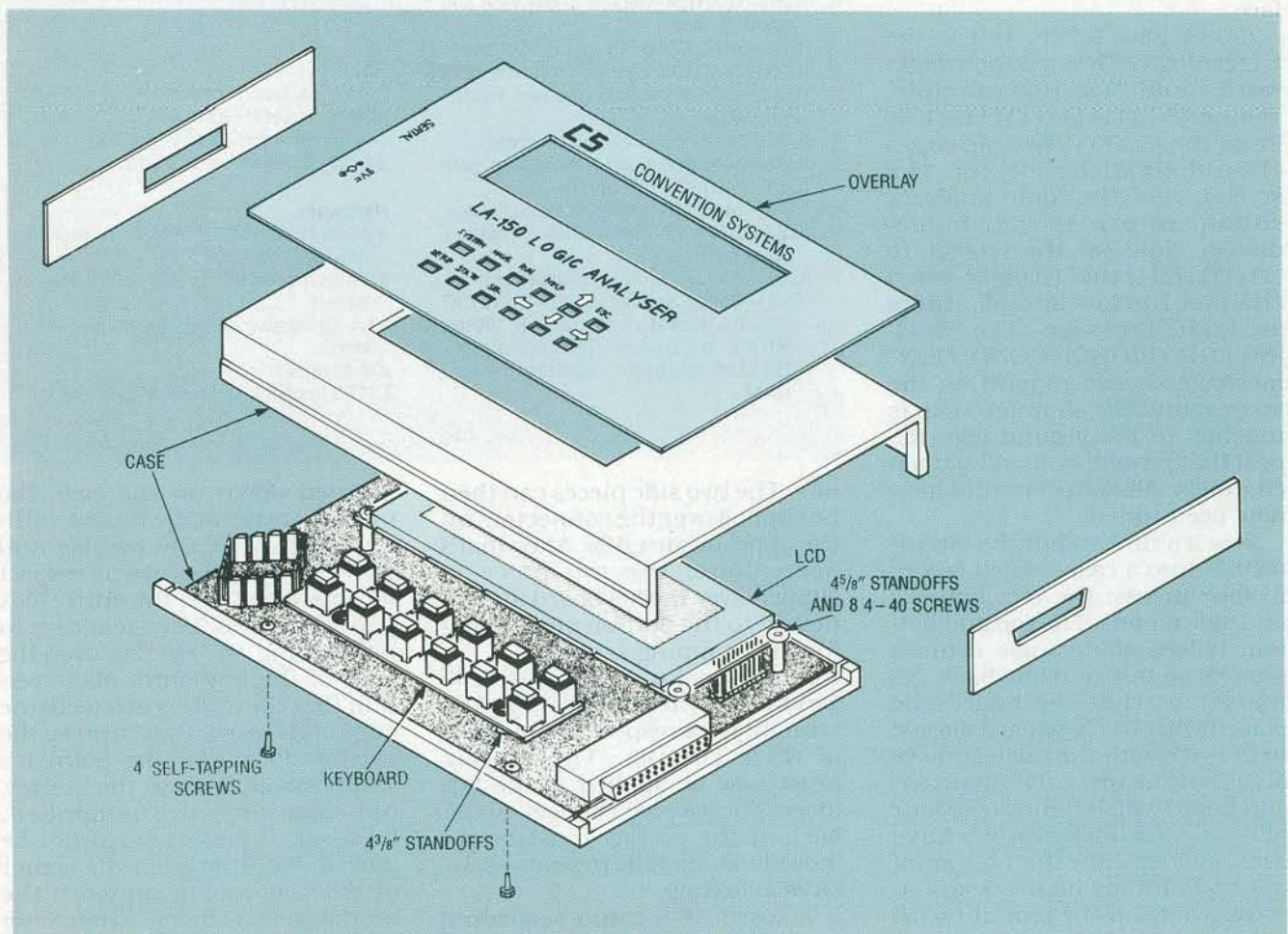
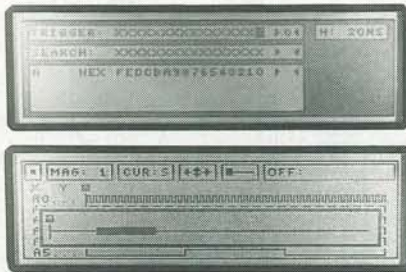


FIG. 10—THE ASSEMBLY DRAWING SHOWS how the case is secured together.





THE SETUP SCREEN is shown in the top display. The bottom screen shows a large block indicating the size and position of data and its location relative to the entire acquisition data.

Go to the SEARCH field on the setup screen. Select it using the SEL key, and change it to the INPUT item. Make sure the acquisition clip assembly is connected to the logic analyzer. Briefly touch each input channel clip to the ground clip. That grounds the channel. Verify the display shows a low symbol, when the clip is touching the ground clip, and a high symbol, when the clip is not touching. That verification tests the input buffers, acquisition RAM, and microprocessor interface.

All we have left to test is the trigger logic. First set the trigger word to all "1's" (for example, TRIGGER = "1111111111111111"). Press the RUN key. Two messages should flash briefly on the screen, and the logic analyzer should return to you immediately. Now set the trigger to "1111111111110" (trigger when channel 1 is low and all others are high). Press RUN. The "WAITING FOR TRIGGER CONDITION" message should remain on the screen until the channel 0 clip is touched to the ground clip. Repeat that procedure for all sixteen channels. All of the circuits have now been tested.

Now it's time to put the circuit boards into a case, which comes in four pieces: the top, bottom, and side panels. The top and bottom halves of the case contain grooves on the front and back. It's important that the boards be placed with the keyboard closest to the side with the raised groove of the bottom piece. The main circuit board will fit tightly over four plastic standoffs which have been molded into the bottom of the case. It may be necessary to press firmly on the circuit board to force the holes over the stand-

All resistors are 1/4-watt, 5%, unless otherwise indicated.

R1-R8—10,000 ohms  
R9—470 ohms  
R10—0 ohms, or jumper wire  
RA1, RA2—1 megohm, 10-pin bussed SIP resistor array

#### Capacitors

C1-C11, C13-C20, C23, C25, C27-C38, C40-C49, C58-C60—0.1  $\mu$ F, ceramic axial  
C12, C24—3.3  $\mu$ F, 10-volt tantalum  
C21, C22—10 pF, ceramic disc  
C26—100  $\mu$ F, 25-volt tantalum  
C39—50 pF, ceramic disc  
C50-C57—22  $\mu$ F, electrolytic

#### Semiconductors

IC1, IC11—74ACT574 8-bit latch  
IC2, IC3, IC12, IC13—74ACT00 quad 2-input NAND gate  
IC4, IC14—74ACT521 8-bit comparator  
IC5, IC15—CY7C128A 2K  $\times$  8 15-ns static RAM (SRAM)  
IC6, IC16—74HCT245 octal transceivers  
IC7-IC9, IC17, IC18, IC39—74HCT574 8-bit latch  
IC10—74F85 4-bit comparator  
IC19, IC22-IC27—74ACT163 4-bit counter  
IC20—74HCT138 3-to-8 demultiplexer  
IC21—TL7705A voltage supervisor and reset control  
IC28—74ACT74 dual D-type flip-flop  
IC29—74ACT02 quad 2-input NOR gate  
IC30—V25 high-integration microprocessor  
IC31—74F32 quad 2-input OR gate  
IC32—74ACT86 quad 2-input XOR gate  
IC33—74F160 4-bit counter  
IC34—74ACT153 dual 4-to-1 multiplexer  
IC35-IC37—74LS390 dual bi-quinary counter  
IC38—74ACT151 8-to-1 multiplexer  
IC40—Dallas Semiconductor DS1213C "Smart Socket" and 32K  $\times$  8 100-ns SRAM or Dallas Semiconductor DS1235 integrated battery backed RAM

offs. The two side pieces can then be slipped over the connectors on the appropriate ends. After that's been done, the top piece is slipped over the keyboard and attached to the bottom piece using four self-tapping screws.

At this point, make sure the keyboard and display are straight with respect to the edges of their cutouts. The overlay must now be applied to the top piece. The wax paper sheet on the back of the overlay must be removed to reveal the pressure-sensitive backing.

A word of caution regarding the glue used: once it's been

IC41, IC42—MAX232 RS-232 transceiver and charge pump  
IC43—7805 5-volt regulator  
IC44—GAL16V8-15LP PLD  
IC45—GAL16V8-10LP PLD  
IC46—128K  $\times$  8 250-ns EPROM  
LCD panel—Sharp part no. LM24014W

#### Other components

XTAL1—16-MHz HC-49 crystal  
XTAL2—20-MHz 14-pin DIP package oscillator  
XTAL3—50-MHz 14-pin DIP package oscillator  
Case—Pactec CM69-120  
Key switches (12)—75120-002/0000  
AC adapter—9 VDC at 1 amp secondary output

#### Connectors

J1—Right-angle DB37 connector  
P2-P4—3-pin socket strip  
J3—Right-angle DB9 connector  
J4—20-pin socket strip (2  $\times$  10)  
P1—7-pin socket strip (1  $\times$  7)  
J2—Power connector (2.3-mm barrel)  
Keyboard—7  $\times$  1 row-header  
Acquisition clip—DB37 connector with 18 wires and micro-clips.  
P1—2  $\times$  10 row-header connector for LCD panel

#### Sockets

20-pin machined sockets for IC1 and IC11  
32-pin socket for IC46  
14-pin machined socket for IC32  
84-pin PLCC socket for IC30

#### Hardware

4 3/8-inch standoffs with 4-40 internal thread  
4 5/8-inch standoffs with 4-40 internal thread  
18 4-40 screws with pan head, 1/4-inch length  
2 4-40 nuts  
1 TO-3 heatsink and heatsink grease

pressed down on the case the overlay, it cannot be moved without destroying the overlay and the case. This glue has no respect for mistakes! Peel the entire wax paper sheet off. Use great care in positioning the overlay over the keys of the keyboard. Make certain that the overlay is true to the edge of the case. Gently press the overlay down. At this point it's still possible to move the overlay, but once pressure is applied, however, the overlay cannot be moved. Working from the center of the overlay out, smooth the overlay down, being careful not to catch air bubbles.



TABLE 1—PROBE ASSEMBLY

Connector Pin No.	Cap Color	Plunger Color	Wire Color
1 (GND)	Black	Black	Black
4 (AQ14)	Brown	Yellow	White
5 (AQ13)	Brown	Orange	White
7 (AQ10)	Brown	Black	White
8 (AQ09)	Black	White	White
10 (AQ06)	Black	Blue	White
11 (AQ05)	Black	Green	White
13 (AQ02)	Black	Red	White
14 (AQ01)	Black	Brown	White
21 (CLK)	Green	Green	Green
22 (AQ15)	Brown	Green	White
24 (AQ12)	Brown	Red	White
25 (AQ11)	Brown	Brown	White
27 (AQ08)	Black	Grey	White
28 (AQ07)	Black	Purple	White
30 (AQ04)	Black	Yellow	White
31 (AQ03)	Black	Orange	White
33 (AQ0)	Black	Black	White

\*Pins not listed are unused.

### Software

The software which controls the logic analyzer is quite sophisticated and very complex. Since a thorough examination of it is beyond the scope of this article we'll only present the highlights of the software interface. The software listing is, however, available on the RE-BBS (516-293-2283, modem settings: 1200/2400, 8N1, file name: LA150.ARC). More information on the operation of the analyzer can be found in the user's guide. That document is provided with every kit or assembled unit, as well as with the separate ROMs, from the source in the Parts List.

Here are some of the special features that the software offers:

- **User Interface**—The logic analyzer has a friendly, consistent user interface. Pull-down and pop-up menus, form menus, and selection boxes enable you to easily configure the analyzer. Four distinct screens allow you to interact with the logic analyzer. Each portion of the screen is associated with one of the SYSTEM, SETUP, WAVE and STATE keys.
- **System Screen**—Most system-wide parameters are set up using this screen. The configuration name, clock type, clock speed, trigger position, and threshold

level are always displayed. A pull-down menu is provided which allows you to change communication and printer parameters.

- **Setup Screen**—The trigger word, search word, and acquisition line groups are defined in this screen. An input-line monitor allows you to view the current state of the input lines without having to start the acquisition cycle again.
- **Waveform Screen**—Displays the contents of the acquisition data buffer in graphical format. Two cursors are provided which let you determine the time relationships between signals. A pull-down menu is provided which allows you to jump to a particular location within the data, search for a pattern, or print out a continuous range of data.
- **State Screen**—Displays the contents of the acquisition data buffer in tabular format. Two cursors are provided which let you quickly determine the time relationships between signals. A pull-down menu, identical to that of the waveform screen, is also provided.
- **On-Line Help**—The logic analyzer contains a true context-sensitive on-line help system. Help is always available at the touch of

### ORDERING INFORMATION

**Note:** The following items are available from Convention Systems, 1214-315 Southampton Dr. SW, Calgary AB, Canada T2W 2T6, (403) 253-4427. Send check or money order. Shipping is by ground delivery. Contact Convention Systems for additional charges if overnight delivery is desired. All items are postpaid, except as noted.

- Etched, drilled and plated main and keyboard PC boards—\$99.00.
- Preprogrammed EPROM, GAL16V8-15LP, and GAL16V8-10LP (IC44-IC46)—\$99.00
- Milled-out case with plastic overlay—\$79.00.
- Probe assembly—\$99.00
- AC adapter—\$15.00
- LCD panel—\$150.00
- IC30 V25 microprocessor—\$29.00
- Manual—\$32.00
- Complete kit, including probe assembly and AC adapter—\$695.00 plus \$20.00 S & H.
- A complete assembled unit, including probe assembly and AC adapter—\$695.00 plus \$20.00 shipping and handling.

the HELP key. Help is always given about the item that is currently highlighted.

- **RS-232 Interface**—The logic analyzer contains a serial RS-232 interface for connecting with external devices. The baud rate, data bits, stop bits, parity, and protocol can all be configured using this interface.
- **Printer Support**—A serial printer can be connected directly to the analyzer. All or part of the acquisition data may be printed out in waveform or state format. All formatting of the output is handled by the logic analyzer.
- **Slave-Mode Operation**—The logic analyzer can be controlled by a host or remote computer, therefore, it can be used in an automated test environment. Acquisition data and configuration settings can be downloaded to the host computer for storage and further manipulation. A library of IBM-PC based interface routines is provided with the logic analyzer.

The next time you find a problem with one of your digital designs, use the logic analyzer to quickly and effectively find the problem. You'll wonder how you ever did without it!

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