Introduction to

The

Tektronix®

7D01

Logic Analyzer

Introduction

The purpose of this package is to introduce you to the operation and use of a Logic Analyzer. It begins with a brief discussion of what a Logic Analyzer is, what it can do, and when it is used. It then covers the setup and operation of the Tektronix® 7D01 as a typical example. There are several exercises using the Logic Analyzer Mini-Lab.

For the exercises, you will need the following equipment:

- KS 14510 or equivalent voltmeter
- Tektronix® 7000 series oscilloscope with 7D01 Logic Analyzer plug-in
- Small screwdriver
- Logic Analyzer Mini-Lab

What is a Logic Analyzer?

A Logic Analyzer is a piece of test equipment that can record and display a sequence of events which occurs at a particular time during the operation of a complex device, such as a microprocessor.

“So what?” you say. “A dual-trace oscilloscope can do that.” True, but the oscilloscope can display, at most, the state of four points in the device under test. The oscilloscope is also limited to having its trace triggered from only one point in the device being tested.

A Logic Analyzer can monitor and display many points in the device being tested. For example, the Tektronix® 7D01 can handle sixteen points. The trigger capabilities of the Logic Analyzer are much broader than the oscilloscope, as it can be triggered by the combined states of a number of points in the device being tested. The Logic Analyzer has memory to store the changes of state of the points being monitored, so that a sequence of events can be displayed as they occurred. The number of memory bits available for each point being monitored (defined as a “data channel” on the 7D01) depends on the number of data channels being used. If four channels are being recorded, there are 1016 bits available for each channel. If all sixteen channels are being used, there are 254 bits available for each channel. The particular sequence of events that will be stored in memory depends on whether the Logic Analyzer is set up to save events occurring after the trigger event (POST TRIG), events occurring before the trigger (PRE TRIG) or events occurring both before and after the trigger (CENTER).

“Wait a minute!” you say. “How can it save what happened before the trigger?”

Now that I have your attention, let’s talk briefly about the memory in a Logic Analyzer. The memory is used as a first-in / first-out storage system, like boxes on a conveyor belt. At any given time, there can be only a limited number of boxes on the conveyor belt (bits in memory). Those boxes will be either empty or full (bit equal to 0 or 1). When the first box (bit) gets to the end of the belt (memory) it drops off and another box is placed at the beginning of the belt. When we stop putting boxes on the belt and look at it (display memory), the boxes (bits) we see will depend on when we started and stopped the process. For after-the-event data, we use POST TRIG, which causes loading to start on the trigger and stop when memory is full. For before-the-event data, we use PRE TRIG, which loads continuously and stops when the trigger occurs. For data on both sides of the trigger event, we use CENTER, which loads data continuously. When the trigger occurs, it marks the bit at which the trigger occurred and continues to load until that bit is centered in memory.

How do you decide which type of trigger and what data position to use? And how do you know when to use a Logic Analyzer in troubleshooting, anyway? Do the trouble analysis procedures tell you to use it?

Let’s answer those questions in order.

1. You determine the type of trigger and the data position to use, based on your knowledge of the device being tested and your troubleshooting skills.

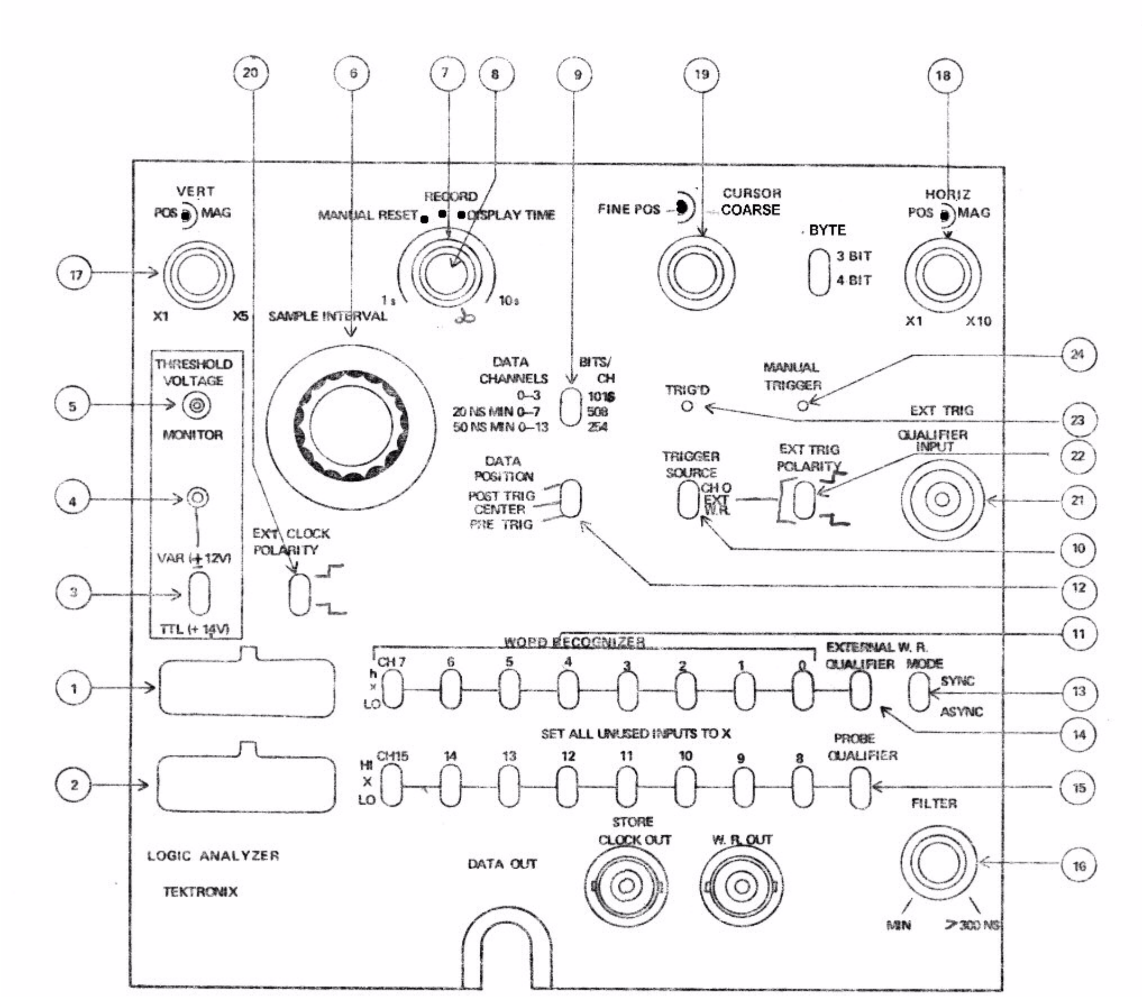
2. You use the Logic Analyzer when it is the most appropriate piece of test equipment. Just as an oscilloscope is used to check waveforms and a voltmeter is used to measure voltage, the Logic Analyzer is used when no other test instrument can provide the information you need.

3. Many trouble analysis procedures specify the use of a Logic Analyzer. However, as with many pieces of test equipment, the setup of the Logic Analyzer involves more than the trouble analysis documents indicate.

Controls and Connectors

Let's look at what is involved in setting up the Tektronix® 7D01 Logic Analyzer. Figure 1 shows the front panel of the 7D01 and its forty-two controls and connectors. We'll identify them by number, starting at the lower left corner.

Figure 1. Front Panel of the 7D01 Logic Analyzer



1, 2	Connectors for the data probes, eight channels each
3, 4, 5	Select the proper threshold voltage (halfway between logic high and logic low) for the device being tested. Use TTL for logic using a +5 volt supply, VAR for others.
6	Selects how often the analyzer looks at the data leads and stores the state of those leads.

7	Selects how long a given sequence will be displayed before being being updated with new data.
8	Resets the display (and memory) to ready it for the next trigger.
9	Selects how many of the sixteen available data channels (probes) will be used
10	Selects the trigger source that causes data to be saved. (data channel 0, an external probe [21], or the Word Recognizer)
11	Selects a particular pattern of highs and lows on the data channels to be used as a trigger - unused inputs are set to X (don't care).
12	Selects the events to be saved - before, after, or centered on the trigger.
13	Selects operation of the Word Recognizer based on an external clock (SYNC) or just the settings of the W.R. switches (ASYNC).
14, 15	Used with the EXTERNAL QUALIFIER input jack [21] and the QUALIFIER lead on the channel 8-15 probe, respectively.
16	Glitch filter used with the WORD RECOGNIZER (W.R.) to keep transients from triggering the analyzer.
17, 18	Position and magnification controls used to place the display properly on the screen.
19	Used to find particular points in time on the display.
22	Selects the polarity of the external trigger applied at [21].
23	Indicates the trigger event has occurred.
24	Allows manual triggering.

OK, now that you are thoroughly confused, let's use the Logic Analyzer and the Mini-Lab to look at some data leads that change on a time-related basis and see if we can record and display a sequence of events.

You need the Tektronix® 7000 series oscilloscope, the 7D01 Logic Analyzer plug-in, the P6451 probes, the manuals, and the voltmeter. Be sure the oscilloscope power is OFF. The 7D01 plugs into the two center plug-in slots. If the 7D01 has an associated DF2 Display Formatter unit, the assembly plugs into the two center slots and the leftmost slot.

The procedure that follows performs a basic check of the 7D01 and the oscilloscope. It is provided for familiarization with the equipment and for checking the basic functions of the Logic Analyzer plug-in.

Refer to the Controls and Connectors discussion as needed while performing this procedure. If a malfunction or possible improper adjustment is revealed while performing this procedure, first check the operation of the oscilloscope mainframe, then refer to the 7D01 Instruction Manual for troubleshooting and adjustment procedures.

The functions of interest to us are checked without removing covers or making internal connections. Performance requirements, functions which require removal of side panels, and detailed checks are provided in the Performance Check and Adjustment section of the 7D01 Instruction Manual.

Setup Procedure

1. Ensure power to the oscilloscope is turned OFF. Install the 7D01 (and DF2, if attached) into the oscilloscope mainframe. Refer to Installation, in the General Information section of the Instruction Manual, if needed. Set the oscilloscope mainframe to display the right vertical and A horizontal compartments. Turn the oscilloscope ON. If equipped with a DF2, its TIMING DIAGRAM switch should be illuminated.

2. Connect one P6451 probe to the CH 0-7 input connector on the 7D01.

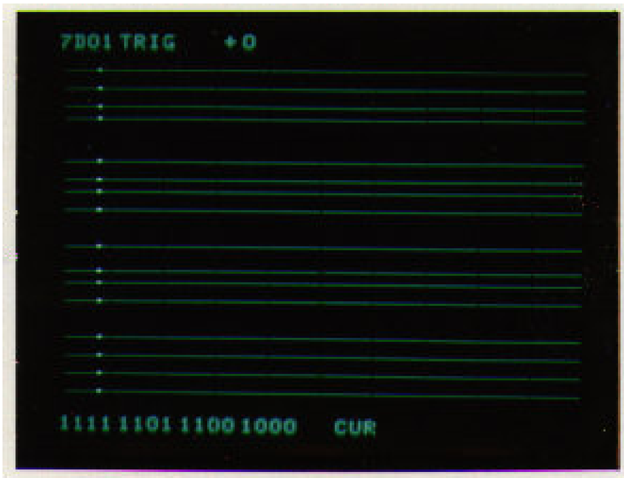
3. Set the 7D01 Logic Analyzer controls as follows:

SAMPLE INTERVAL	1 ms
RECORD DISPLAY TIME	∞
DATA POSITION	POST TRIG
DATA CHANNELS	0-15
TRIGGER SOURCE	W.R.
WORD RECOGNIZER	CH 0 through CH 6: LO
	CH 7: HI
	CH 8 through CH 15: X
	EXTERNAL QUALIFIER: X
	PROBE QUALIFIER: X
W.R. MODE	SYNC
THRESHOLD VOLTAGE	TTL (+1.4V)

4. Press the MANUAL TRIGGER button.

5. Check CRT display for a sixteen channel trace similar to Figure 2.

Figure 2. Sample 16 channel display



It may be necessary to adjust the mainframe intensity, A INTEN, and the 7D01 vertical and horizontal position and magnification controls.

6. Check that the trigger-to-cursor readout is zero (+0 at top center of display) and that the intensified cursor point is superimposed on the intensified trigger point (left side of the display).

7. Set the 7D01 DATA POSITION switch to CENTER and press the MANUAL RESET, then the TRIGGER, push buttons. Check that the trigger point (intensified dots) is near the center of the CRT display and that trigger-to-cursor readout (top center) is approximately -112. Rotate the CURSOR FINE POSITION control (inner knob) and note that cursor point (intensified dots on left side of display) moves in 1-bit increments, as shown by the trigger-to-cursor readout. Rotate the CURSOR COARSE POSITION control and note that the cursor point moves in 16-bit increments. Notice that the logic state for each channel of displayed data (16 characters of 1's and 0's at bottom of display) changes corresponding to the cursor position. Set the CURSOR POSITION

controls for a trigger-to-cursor readout of zero. Check that the intensified cursor point is superimposed on the intensified trigger point (center of CRT).

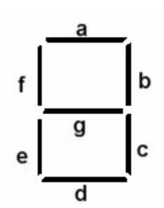
9. Set the DATA POSITION switch to PRE TRIG and press the MANUAL RESET, then MANUAL TRIGGER, push buttons. Check that the trigger point (intensified dots) is at the right side of the display and that the trigger-to-cursor readout is approximately -112. Set the CURSOR POSITION controls for a trigger-to-cursor readout of zero. Check that the intensified cursor point is superimposed on the intensified trigger point (right side of display).

These checks verify that the 7D01 Logic Analyzer operates correctly.

Mini-Lab Exercises

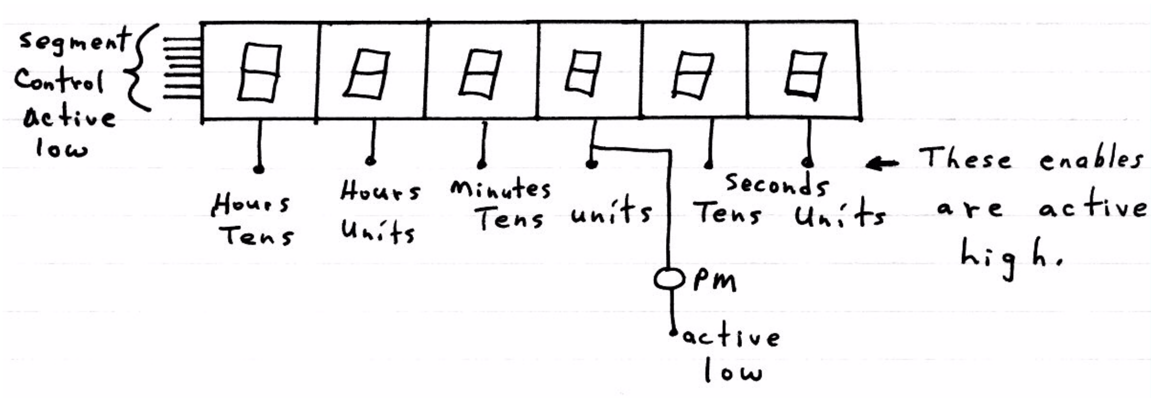
The Mini-Lab that is used with this package is based on a digital clock which has several features that make it useful as a signal source when learning to use a Logic Analyzer. The numeric readouts for the clock are seven segment light-emitting-diode (LED) displays. The segments are identified by the letters “a” through “g”, as shown in Figure 3.

Figure 3. Display segment identification



By lighting the proper segments, any number from 0 to 9 can be displayed. This means that we can look at the segment control leads and determine what number is being displayed. The digits in the display are NOT all on at the same time, they just look that way. By using multiplexing, all of the digits can share the same segment control leads. As the number for a particular digit position (hours tens, hours units, etc.) is presented on the segment control leads, that digit’s enable lead also goes active, causing it to display the number. Each digit is driven, in turn, with its segment information and the digits are accessed frequently enough that they appear to be on continuously. Figure 4 is a sketch of the display wiring.

Figure 4. LED display wiring

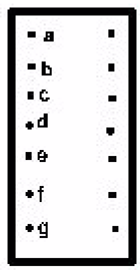


If, for example, we connect the Logic Analyzer's data channel leads to segment control leads of the clock, and sample those leads when the seconds digit is enabled, we could store the transitions of the segments as the seconds counted up: 1, 2, 3, etc. These transitions could then be displayed.

Now let's connect the Logic Analyzer to the Mini-Lab and see if we really can record this series of events.

Connect the data acquisition probe to the upper connector of the 7D01. Set the TTL/VAR switch to VAR. Since the Mini-Lab uses +10 volt logic, the threshold should be set to +5 volts. Connect the DC voltmeter to the MONITOR jack on the 7D01 and to the oscilloscope ground connector. Adjust the recessed control below the MONITOR jack for a reading of +5 volts. Connect leads 0 through 6 of the data probe to the terminals for segments "g" through "a" respectively on the Mini-Lab. The terminal layout is in Figure 5.

Figure 5. Mini-Lab connector terminal identification.



The segment control terminals are on the left. The enable terminals are on the right, in the following order (top to bottom):

seconds units

seconds tens

minutes units

minutes tens

hours units

hours tens

PM indicator

Connect the “C” (clock) lead of the probe to the seconds units enable terminal of the Mini-Lab. Connect the GND lead to the ground screw on the Mini-Lab.
On the 7D01, set the SAMPLE INTERVAL to EXT and set EXT CLOCK POLARITY to ¯|_. Set DATA CHANNELS to 0-7 and set DATA POSITION to POST TRIG. Set TRIGGER SOURCE to CH 0 and set RECORD DISPLAY TIME to ∞. Operate the RUN/STOP switch on the Mini-Lab to STOP, then plug it in. It should display 120000. Press the Minutes, Minutes Tens, and Hours switches to set the clock to 11100. Press the MANUAL RESET button on the 7D01, then operate the Mini-Lab RUN/STOP switch to RUN. The TRIG’D lamp on the 7D01 should light and , in a few seconds, the oscilloscope should display eight traces. There will be a row of bright dots near the left side of the display to mark the trigger point. Using the CURSOR POSITION controls, you can position a second set of dots anywhere on the display. There will be a readout at the top of the display such as TRIG +5. This identifies the location of the cursor in relation to the trigger. For example, +5 is five samples after the trigger. The

bottom of the screen will have a binary display, such as 10001111, which is the high/low state of each trace at that point in time. Using the table below, you should be able to identify the state of each segment and the number displayed. The leftmost digit of the binary corresponds to the bottom trace on the display. Remember that the segments are active low, so a 0 indicates the segment is lit.

Table 1. Segment state versus number displayed.

Segment State								Number Displayed on LED
EN	A	B	C	D	E	F	G	
1	0	0	0	0	0	0	1	0
1	1	0	0	1	1	1	1	1
1	0	0	1	0	0	1	0	2
1	0	0	0	0	1	1	0	3
1	1	0	0	1	1	0	0	4
1	0	1	0	0	1	0	0	5
1	0	1	0	0	0	0	0	6
1	0	0	0	1	1	1	1	7
1	0	0	0	0	0	0	0	8
1	0	0	0	0	1	0	0	9

The leftmost digit is the digit enable line, which is active high and must be active for the digit to be lighted. If the pattern at the bottom of the CRT display is 10000000, then the number displayed on the LED is 8, as all the segments are active.

Use the information in Table 1 to decode the segment control leads in the pictures below. What digit is being displayed in Figures 6 and 7?

Figure 6

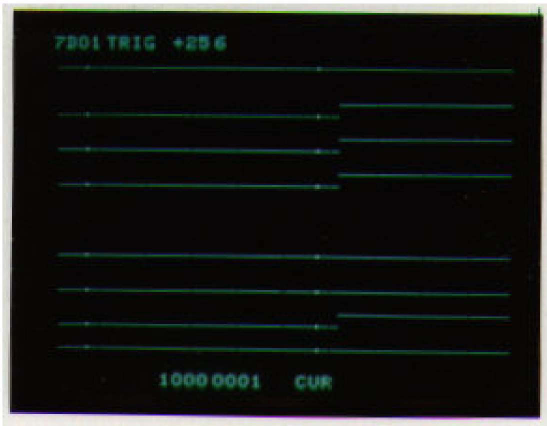
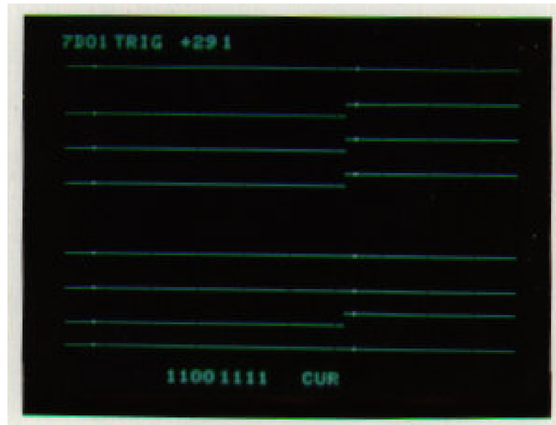


Figure 7



See! It really does work! If you want the CRT display updated periodically, set the RECORD DISPLAY TIME to mid range and press the MANUAL RESET button. The CRT display will then be updated about every 5 seconds, as new data is collected by the Logic Analyzer.

Let's try another example. Could you trigger the Logic Analyzer to begin recording data when the clock showed 120100PM?

If you knew the conditions that identified 120100PM as a unique time, you could select the conditions that would make a good trigger. The conditions would be:

PM indicator ON
hours tens digit is 1
hours units digit is 2
minutes tens digit is 0
minutes units digit changes from 0 to 1

The conditions which would be useful are the PM indicator, since the desired time is 120100PM, and the minutes units digit, which changes at the desired time. We cannot use the state of more than one digit, since only one digit is on at any given time. The PM indicator is enabled at the same time as the minutes units digit so it can also be used (see sketch on page 11).

But how do you recognize the digit 1? Do you have to monitor all seven segments? You only need the status of three segments to identify the digit 1. Refer to Figure 3 on page 10 and see if you can determine which segments these are. For the exercise, we will use the state of all seven segments. Use Charts 1 and 2 to set up the Logic Analyzer and the Mini-Lab and let's see if this works.

Chart 1. Setup for detecting 120100PM.

RECORD DISPLAY TIME		∞
SAMPLE INTERVAL		EXT
DATA CHANNELS		0-7
DATA POSITION		POST TRIG
TRIGGER SOURCE		W.R.
TTL/VAR		VAR
WORD RECOGNIZER	0→3	HI
	4→5	LO
	6	HI
	7	LO
W.R. MODE		SYNC
FILTER		Fully Clockwise

Operate the RUN/STOP switch on the Mini-Lab to STOP. Set the clock to 1159AM. Connect the data probe to the Mini-Lab according to Chart 2.

Chart 2. Probe connections for 120100PM test.

Probe Lead	Terminal
0	g
1	f
2	e
3	d
4	c
5	b
6	a
7	PM indicator
C	minutes units enable

Press the MANUAL RESET button on the 7D01, and operate the RUN/STOP switch on the Mini-Lab to RUN. Watch the clock and the TRIG'D lamp on the 7D01. When the clock goes to 120100PM, the TRIG'D lamp on the 7D01 should light and, in a few seconds, you should have a display on the oscilloscope.

Now see if you can set up the Logic Analyzer to trigger at 1000AM. (What conditions indicate that the clock is displaying 10000AM?) Use the discussion and setups on pages 13 and following for reference. When you think you have a workable setup, set the clock to 959AM, press the MANUAL RESET button on the 7D01, and see if the Logic Analyzer triggers at 1000AM. If not, try at least once more before going to the answer on the next page.

The setup is similar to page 16, but with WORD RECOGNIZER 7 set to HI and the probe Clock lead on the hours tens enable. We are looking for a “1” in a different digit position and with the PM indicator off.

Now see if you can trigger the Logic Analyzer at 50000AM. (Hint: you can recognize the number 5 by the states of only three leads; use as many as you feel you need.) When you think you have a workable setup, set the clock to 45900AM, press MANUAL RESET on the 7D01, and the Logic Analyzer should trigger at 50000AM. Try several settings before going to the answer on the next page.

Chart 3. Setup for detecting 50000AM.

WORD RECOGNIZER	0→1	HI
	2	LO
	3→4	LO
	5	HI
	6	LO
	7	HI
Probe Lead 7	hours units enable	

Now see if you can trigger the Logic Analyzer when a new day occurs.

You need only the state of the PM indicator to identify a new day. Set up as follows:

Probe Lead	0	PM indicator	
	1	minutes units enable	
TRIGGER SOURCE		W.R.	
WORD RECOGNIZER		0	HI
		1	LO
		all others X	

What have you accomplished with all this?

In the first exercise, you used the EXTERNAL CLOCK input of the Logic Analyzer to trigger off the state of a single point and record data which was valid when that point was active. This is similar to using the Logic Analyzer in firmware diagnostic troubleshooting.

In the other exercises, you used the Logic Analyzer to trigger on a particular combination of highs and lows on a group of points. This is similar to triggering on an opcode or address when troubleshooting microprocessor hardware.