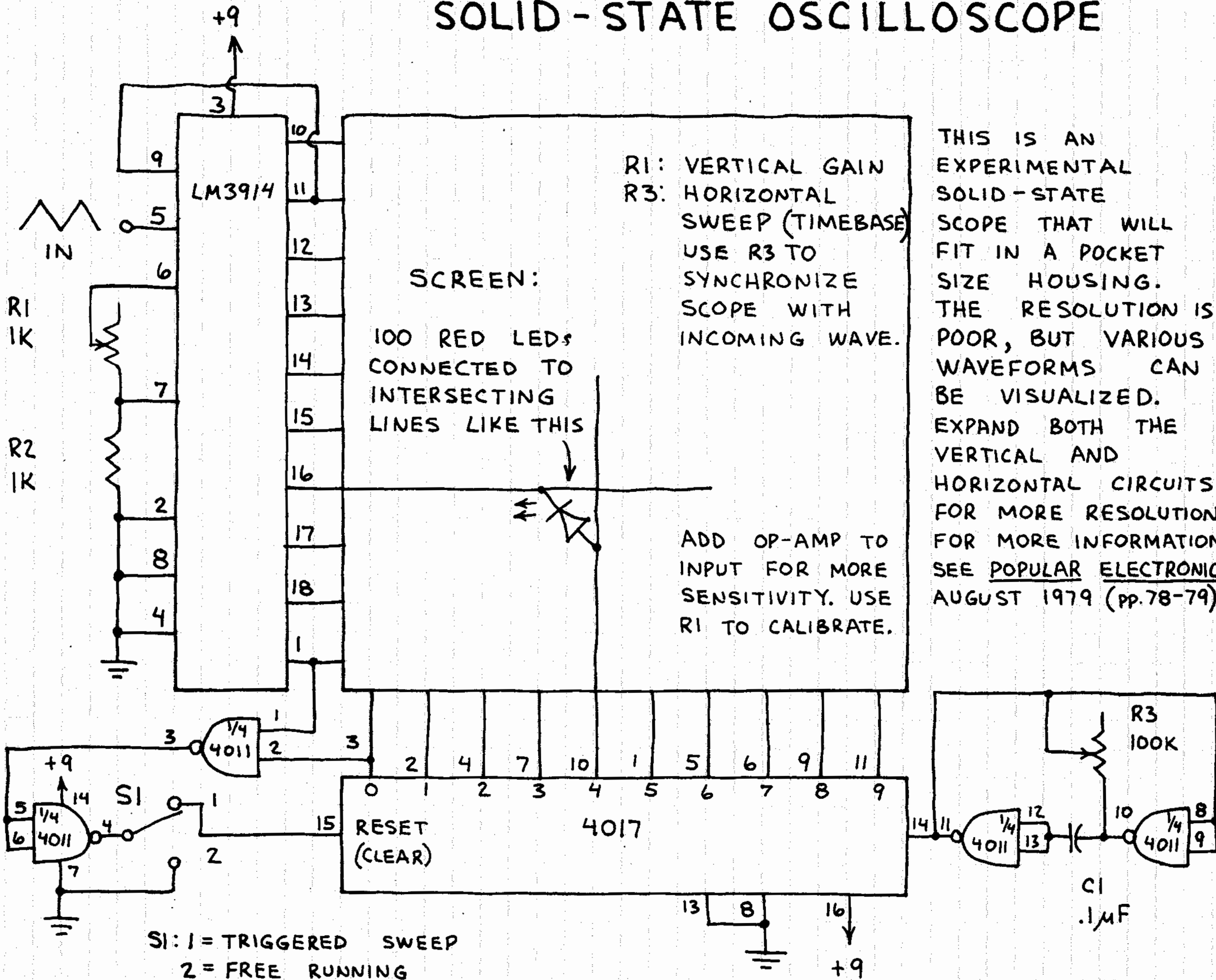
DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

SOLID-STATE OSCILLOSCOPE

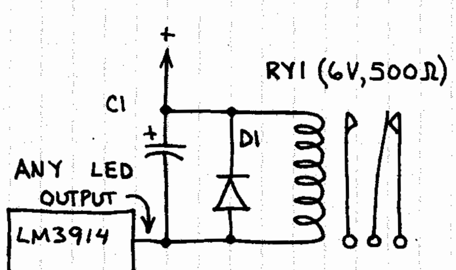


THIS IS AN EXPERIMENTAL SOLID-STATE SCOPE THAT WILL FIT IN A POCKET SIZE HOUSING. THE RESOLUTION IS POOR, BUT VARIOUS WAVEFORMS CAN BE VISUALIZED. EXPAND BOTH THE VERTICAL AND HORIZONTAL CIRCUITS FOR MORE RESOLUTION. FOR MORE INFORMATION SEE <u>POPULAR</u> <u>ELECTRONICS</u>, AUGUST 1979 (pp. 78-79).

S1: 1 = TRIGGERED SWEEP
2 = FREE RUNNING

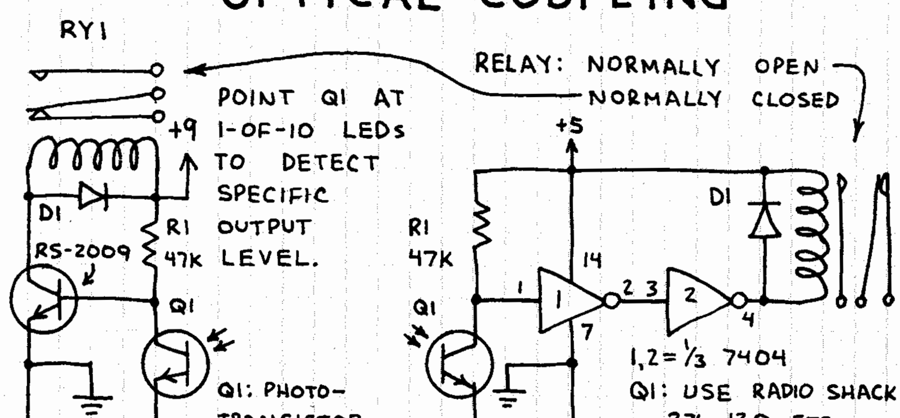
USING THE LM3914 AS A CONTROLLER:

RELAY



C1 — 47μF (PREVENTS CHATTER)
D1 — 1N914
RY1 — RADIO SHACK 275-004

OPTICAL COUPLING



Q1: PHOTO-TRANSISTOR

1,2 = 1/3 7404
Q1: USE RADIO SHACK 276-130, ETC.

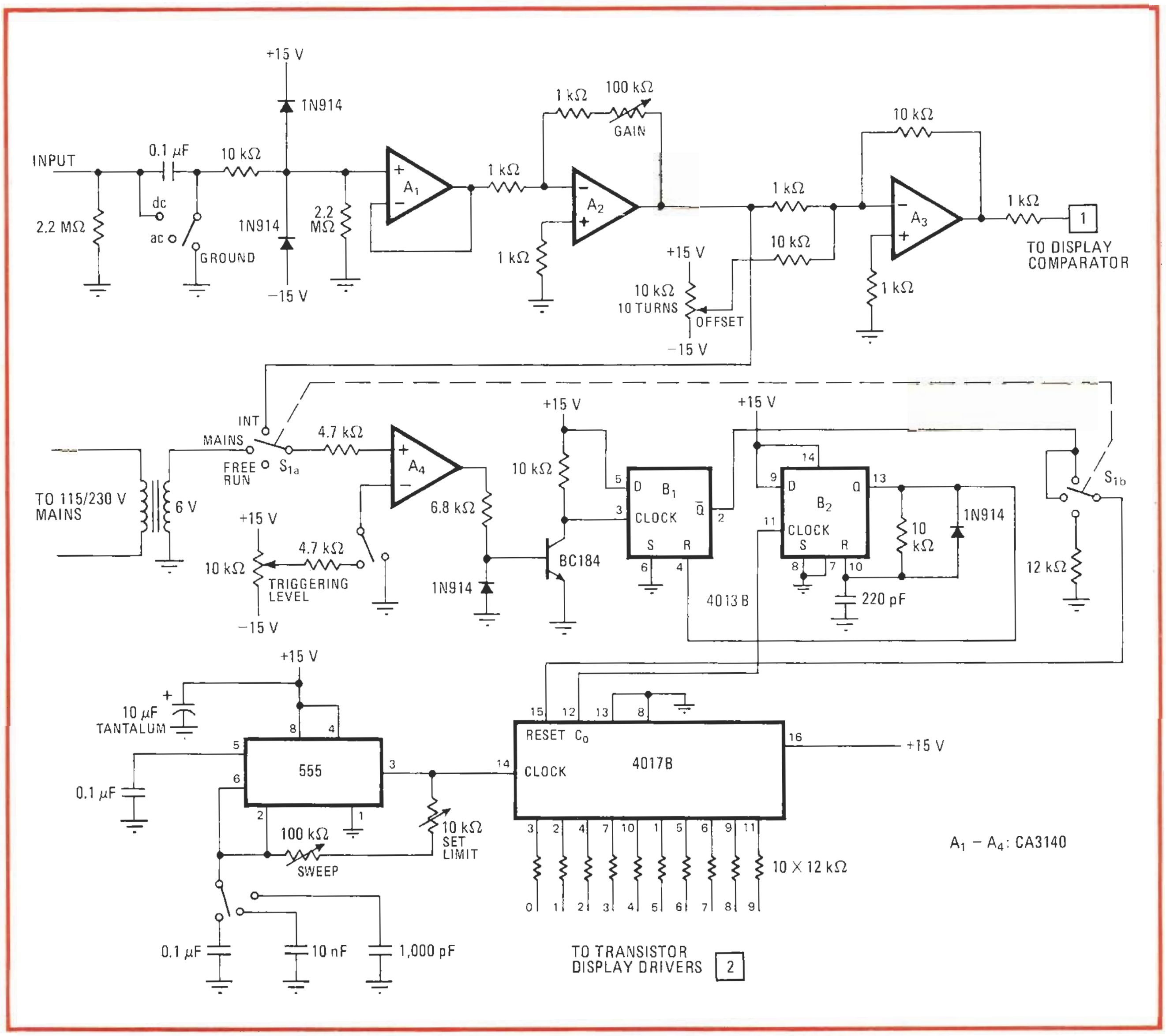
LED bar-segment array forms low-cost scope display

by Vernon Boyd
The Welding Institute, Abington, Cambridge, England

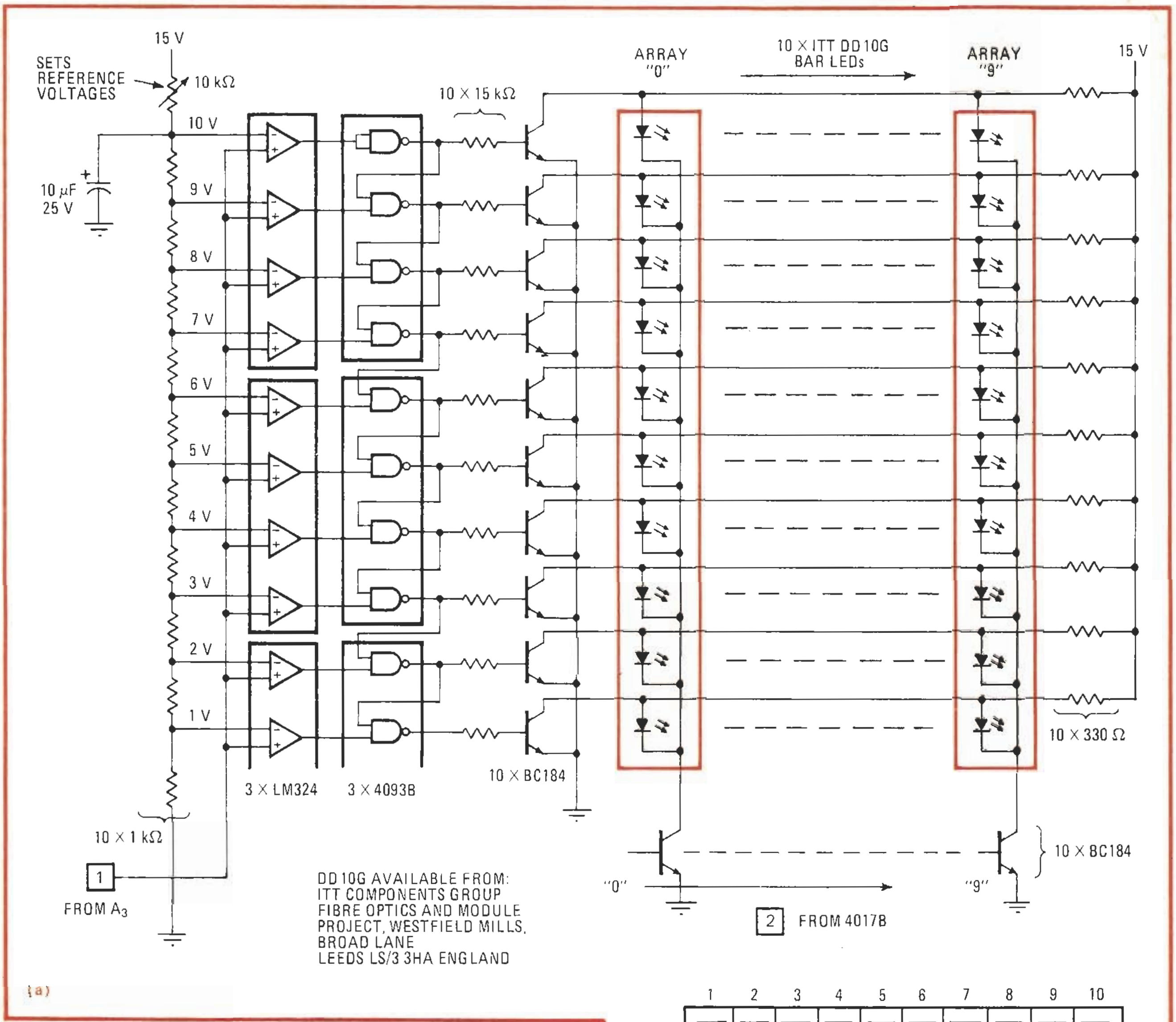
Building a small, low-powered, and low-cost oscilloscope for simple monitoring applications is easy, especially if light-emitting diodes are used in place of the cathode-ray tube. This circuit uses 10 bar displays, each containing 10 LEDs, to form a 100-dot viewing matrix. With this configuration, of course, resolution is only 10% in both the X and Y axes, but it can be improved by adding additional displays and expanding the driving circuitry.

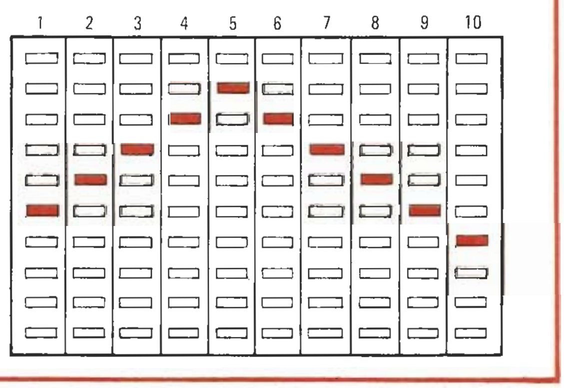
As shown in Fig. 1, the signal-processing and logic circuits for the scope are straightforward. The signal-path circuit is extremely simple and has all of the options usually expected—ac and dc input coupling, variable Y-axis gain, and offset control. The signals to be observed pass through amplifier A_1, are amplified up to 100 times by A_2 and are inverted by A_3, and then pass through to the display comparator.

The trigger and timing circuits are not complicated,



1. Signal, timing, and logic. Driver circuits for scope's LED bar displays are straightforward. Input circuit can process ac or dc signals and has variable Y-axis gain control. $A_1 - A_3$ is input-signal path. A_4, B_1, and B_2 provide sync for 555 clock generator and 4017 counter, which strobes bar displays. Circuit has internal, free-run, or power-line triggering option. Maximum sweep rate with 555 is 10 kHz.





2. Display. Comparators, NAND gates, and transistors drive bar displays as each is strobed in succession (a). Amplitude of Y-axis signal determines which of 10 LEDs in each display is illuminated during sweep. Typical sine wave is displayed on 100-dot matrix (b).

either. During any sweep, the 4017 Johnson counter steps at a rate controlled by the 555 timer and strobes each bar display in turn. A_4, B_1, and B_2 synchronize the counter's location to the sweep rate.

A_4 is triggered either by the signal (internal mode) or by the 60-cycle power-line input. In the free-run mode, A_4 is not required. These three modes are selected through S_{1a}, which is ganged to S_{1b}. The trigger level can be set by the 10-turn potentiometer at A_4's input.

A_4 drives the 4013 D-type flip-flop circuit, composed of B_1 and B_2, through a transistor buffer. The 4013 ensures that triggering on repetitive waveforms will be reliable, for it is reset at the end of any display sweep by the final stage (C_0) of the 4017. This event causes B_2 to reset B_1, which in turn resets the 4017.

As shown in Fig. 2, the bar displays are driven by ten LM324 comparators and a ten-gate NAND decoder. The chain of reference voltages, each separated by 1 volt, are generated by a string of 10 resistors and a 10-kilohm calibration potentiometer. These resistance values must be changed to accommodate the Y-axis resolution required. For example, if there are 20 elements in the Y axis (two 10-bar displays vertically mounted one above the other), the resistances must be selected to provide 0.5-v increments. Also, the Y-axis expansion must be implemented with additional comparators and gates. The NAND gates ensure that only one LED can be activated at any given time.

Expansion of the X axis is a bit more elaborate, but not overly difficult. Simply cascading additional 4017s will not do, however, as two output states will occur, one for each driver. Consequently, these states must be decoded using NAND gates.

The 555 clock generator will sweep at a maximum rate of 10 kilohertz. For faster sweeps, a different clock circuit is needed. The comparators' frequency limits must also be well above the sweep rate. □

LED dot/bar driver simplifies solid-state scope

by Forrest M. Mims III
San Marcos, Texas

The design of this solid-state scope is simplified by use of a one-chip driver to address the rows of the light-emitting-diode matrix comprising the scope's display. The circuit is a viable alternative to a scope that has previously been described.[1]

The unit will handle input signals in the audio-frequency range. Signals to be displayed are applied to pin 5 of the National LM3914 dot/bar driver and resolved to one of ten active-low output levels. Note that R_3 provides a programmable current control for all LEDs in the display. Thus, current-limiting resistors are not required at each output port of the driver. Pin 7 is connected to an internal 1.2-V reference so, as a result, current through R_3 is approximately equal to one tenth the LED current; thus, with R_3 = 1.2 kilohms, the LED current becomes equal to 10 milliamperes.

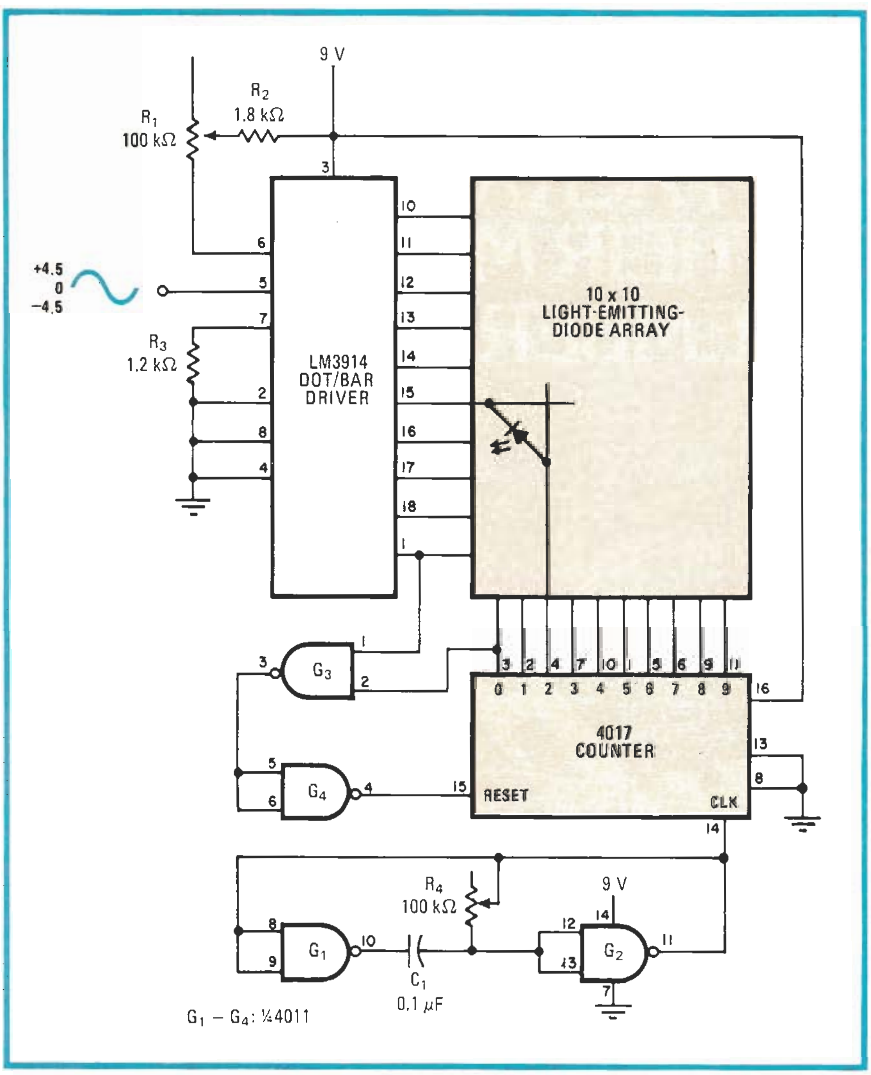
The 4017 Johnson counter and accompanying gates comprise the scope's horizontal-sweep circuit. The sweep oscillator driving the counter is made from half a 4011 quad-NAND gate, G_1 and G_2, its frequency controlled by resistor-capacitor combination C_1–R_4. In this way, the instantaneous input voltage is resolved to 1 LED in 100. G_3 and G_4 provide automatic triggering of the sweep.

As for the LED display itself, bar arrays that contain 10 diodes each are easier to use and provide a more uniform display than discrete diodes, and are therefore recommended. Another option is to employ miniature matrix arrays of five by seven dots. At least one firm, IEE Inc. (7740 Lemona Ave., Van Nuys, Calif. 91405), offers such displays that can be mounted adjacent to each other without a gap in the LED columns.

Both the vertical and horizontal driving sections of the basic scope can be readily expanded. For instance, five cascaded counters and five cascaded dot/bar chips can drive a 50-by-50-diode matrix, forming a scope with a display resolution of 1 LED in 2,500. □

References

1. Vernon Boyd, "LED bar-segment array forms low-cost scope display," *Electronics*, Nov. 24, 1977, p. 128.



Drive center. One-chip dot/bar driver reduces complexity of vertical scanning portion of scope having light-emitting diode display. Horizontal scanning portion uses G_1 and G_2 for clock, wired as astable multivibrator, and 4017 counter. Display resolution is 1 LED in 100.

PROJECT OF THE MONTH

BY FORREST M. MIMS

EXPERIMENTAL SOLID-STATE OSCILLOSCOPE

In the October 1978 Experimenter's Corner I made a brief reference to an experimental solid-state oscilloscope that employs, as a display screen, the 160-element LED array that appeared as the last Project of the Month. Many readers have written requesting additional information, so here it is!

Figure A is the schematic diagram of the experimental scope. In operation, a signal applied to the noninverting input of the 741 op amp is amplified and routed to a flash A/D converter made up of LM339 quad comparators and a 74147 priority encoder. A detailed description of this A/D converter was given in the September and October 1978 Experimenter's Corner columns.

The digital output of the 74147 is a 4-bit BCD nibble. This nibble, after being decoded by a 74145 1-of-10 decoder, activates one of the ten horizontal rows of LEDs. One of the sixteen vertical columns of LEDs is activated simultaneously by a horizontal scanning circuit consisting of a 555 timer, 74193 4-bit counter and 74154 1-of-16 decoder. The 555 serves as a time base whose sweep frequency is controlled by a 1-megohm potentiometer. The 74193 and 74154 form a 0-to-15 sequence generator that sweeps the sixteen columns of LEDs one at a time.

Because only one row and one column of LEDs are activated at any time, only one LED in the array glows at any single instant. When the sweep rate is faster than 20 or 30 complete scans per second, the individual LEDs merge into a broken line that provides a rough pictorial representation of the positive half of the waveform appearing at the input of the 741 op amp.

Three of the gates in a 7400 quad NAND gate add a simple but very useful trigger feature. When pin 14 of the 74193 is grounded by placing the MODE switch in its FREE RUNNING position, the sweep circuit scans the LED columns continuously. A careful adjustment of the time base potentiometer will freeze the waveform being displayed. Any drift, however slight, in the incoming waveform will require a readjustment of the time base. Otherwise, the waveform being displayed will move across the screen from left to right or right to left, as it did before the potentiometer was adjusted.

When the MODE switch is placed in its TRIGGERED position, pin 14 of the 74193 is reset (or cleared) to 0000 when an input signal is *not* present. An input signal with enough amplitude to activate the lowest-order LM339 comparator causes pin 6 of the 7400 to go from high to low. This allows the 74193 to make a complete scan of the display columns.

If the input signal is still present when the scan is completed, another scan is immediately begun. Otherwise, the scope waits for the signal to recur before initiating a new scan. The result is that in the triggered mode the scope automatically locks onto a recurrent waveform, and displays it with its rising portion originating in the first column of LEDs. A LED connected to the trigger gate network indicates when trig-

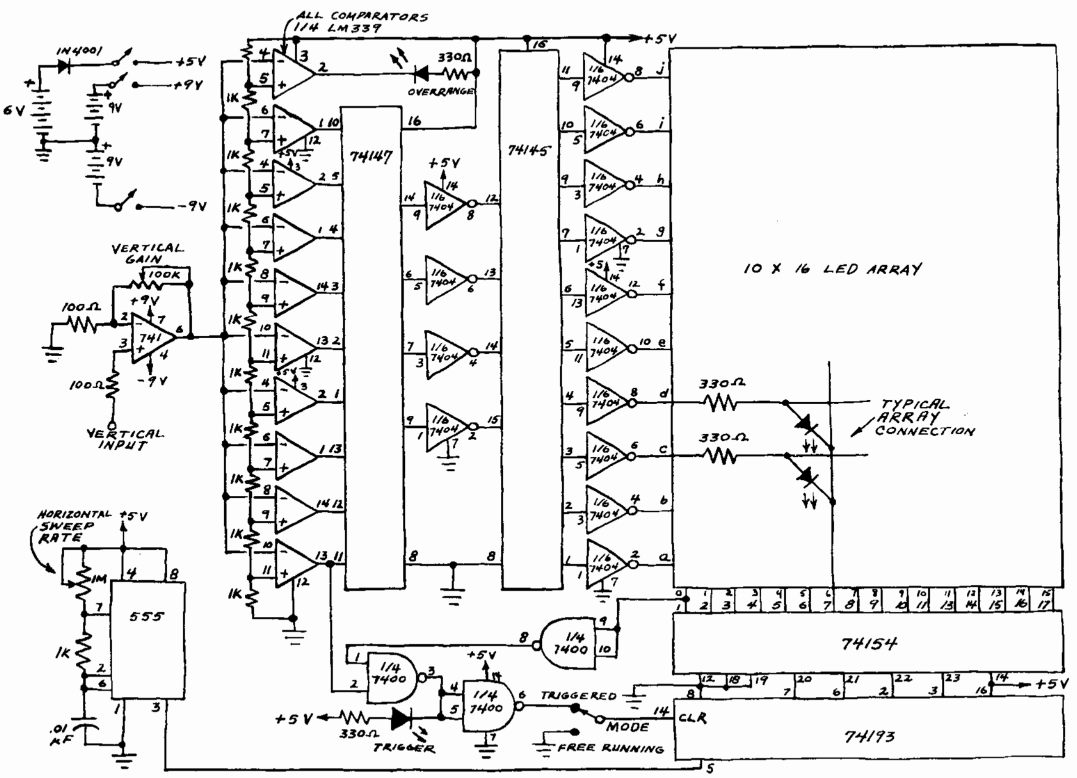


Fig. A. Schematic of a solid-state 10-by-16 LED array oscilloscope.

gering is occurring, which might not be known if the gain is set so high as to prevent observation of the waveform.

When the scope is in the triggered mode, the waveform being displayed can be expanded or compressed by changing the horizontal sweep rate. Similarly, the height of the waveform can be increased or decreased by adjusting the VERTICAL GAIN potentiometer. An overrange LED connected to the output of the highest-order LM339 comparator indicates when the gain is too high and the top of the waveform is therefore off the screen.

Although it is considerably easier to assemble the drive circuit than the LED display board described last month, care must be exercised when building it because wiring errors can be very difficult to find. I assembled the prototype driver circuit on the same kind of board used for the display (Radio Shack 276-152 or similar) using wrapped-wire, point-to-point construction. Figure B shows how the major components were arranged on the top side of the board. Note the miniature phone jack that serves as the vertical input for the scope. This jack should be installed from the front side of the board.

After the components on the board are connected together, connections to the display board, the time base potentiometer, the vertical gain potentiometer and the power supply are provided by soldering wrapping wire to the appropriate copper fingers on the board.

Last month, the bus locations I used on the display board were given. The bus locations used for the remainder of the scope circuit are as follows:

Oscilloscope Circuit	***S-44 Socket***
+5 volts	1
Ground	2
Overrange LED Cathode	3
Vertical Gain Control	M
Vertical Gain Control	N
Horizontal Sweep Control	S
Horizontal Sweep Control	T
Mode Switch:	
Pin 6 7400	U
Ground	V
Pin 14 74193	W
Trigger LED Cathode	X
−9 volts	Y
+9 volts	Z

Don't feel compelled to use these bus locations. All of them can be changed so long as they don't interfere with the display bus. It's a good idea to reserve the 1, 2, Y and Z locations for the power supply since these are closest to the two copper strips that traverse the perimeter of the circuit boards. You can use a small file to separate these into four separate strips.

After the scope circuit has been completed, saw off the upper portion of a second circuit board and install a power switch (3PST), trigger mode switch (SPDT), trigger LED and vertical gain and horizontal sweep rate potentiometer. Figure C shows the layout I used to make the prototype. This board becomes the control panel for the scope. Its components should be connected to the appropriate copper fingers in accordance with the bus given above or the one you select.

You'll need to make a card rack or mother board to hold the three boards that comprise the oscilloscope. If you can afford a commercial mother board, great. If not, do what I did and attach three 44-connector sockets with wire-wrap terminals to a couple of wood or plastic rails. Mount the sockets an inch apart from each other. Next,

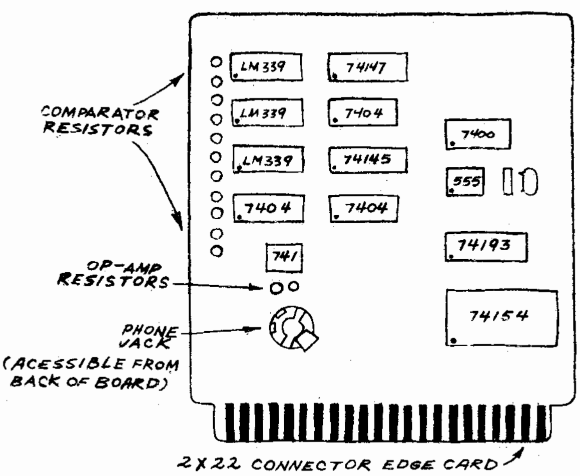


Fig. B. Layout of the major components of the experimental oscilloscope on a 2 x 22 connector edge board.

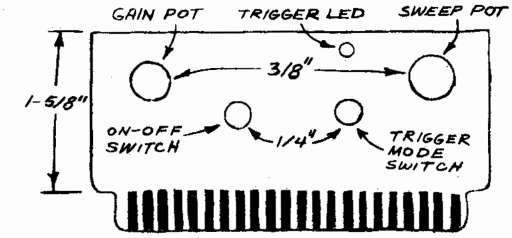


Fig. C. Prototype layout for the control board for the LED oscilloscope.

connect all the common connectors with wrapping wire. Then insert the scope card in the rearmost socket (ICs facing forward), display card in the center socket and control card in the foremost socket.

The prototype scope is powered by two 9-volt batteries and a 6-volt battery made from four AA alkaline cells in a plastic holder. The batteries are connected to the scope with three battery connector clips.

Before applying power to the circuit, be sure to take the time necessary to retrace all the wiring to make sure you've made no errors. The most common problem in a project using wrapped wiring is overlooked connections, particularly those to the power supply pins of the ICs.

Make a probe for the scope from a length of flexible shielded cable, a miniature phone plug, a test clip and an alligator clip. For initial tests, use a ramp or triangle wave having an amplitude of up to a few volts and a frequency of a few hundred hertz. Be sure to perform the tests in a darkened room, at least initially, since the LED array will not be as brightly illuminated as a conventional CRT screen.

If the scope fails to respond, make sure that power is being applied properly. Then try changing the gain and time base settings as well as the trigger mode. If the scope still does not work, you will have to troubleshoot the circuit. Hint: Proceed one step at a time. For example, troubleshoot the sweep circuit by beginning at the 555 (is it pulsing?). Then move to the 74193 (is it counting?), etc.

Once you have the scope working, you'll be able to display a variety of waveforms after a little practice. Spikes, triangles and ramps are the waveforms best reproduced. Sine waves are slightly distorted by the low resolution of the screen, and the rising and falling portions of square waves are usually very faint. Often several LEDs in a vertical column will appear to be on as shown in Figure D, but it's usually possible to resolve the general waveform being displayed.

Although the resolution of this experimental scope is poor and the design of the vertical section leaves much to be desired, it does demonstrate that a flat-screen, compact oscilloscope can be built. If you build the scope you'll want to spend some time calibrating the vertical and horizontal sections with the help of a voltmeter and frequency generator or a conventional oscilloscope. You might also want to modify or try to improve the design if you're experimentally inclined. The A/D converter of the vertical section, for example, can be greatly simplified by using a single-chip A/D converter. The sensitivity of the vertical comparator string can be varied by replacing the 1-megohm resistor at the top of the voltage divider with either a fixed resistor having a different value or, better yet, a 1-megohm potentiometer. Similarly, a wide range of sweep rates can be obtained by replacing the single timing capacitor with a group of fixed capacitors of various values, one of which would be selected by a rotary switch. ◇

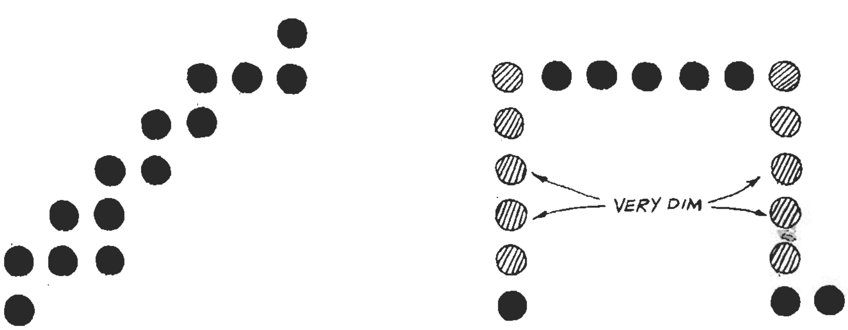


Fig. D. Portions of two waveforms as displayed on 160-element LED display.