Experimenter's Corner

By Forrest M. Mims

LED BARGRAPH DISPLAY CHIPS

THE HEART of many LED bargraph circuits is the quad comparator, a chip that contains four independent comparators. Connecting two or three such chips to a voltage divider comprising a string of series-connected resistors (Fig. 1) results in a straightforward but complex bargraph readout.

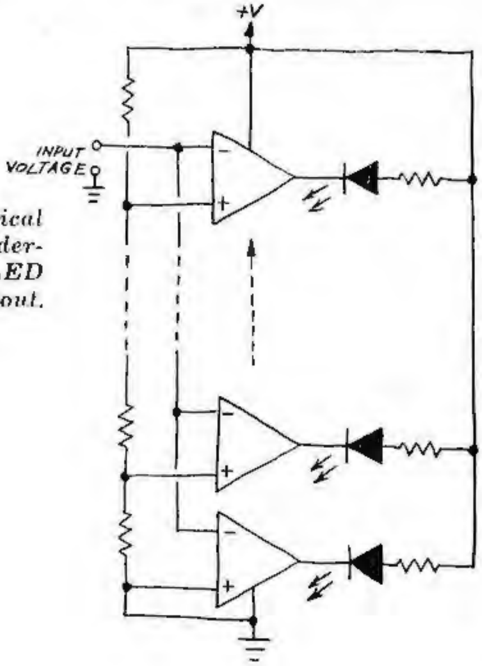

Fig. 1 Typical voltage divider-comparator LED bargraph readout.

Recently, however, semiconductor manufacturers in the United States, England, and Japan have announced new ICs that combine on a single chip the voltage divider and comparators required for a multiple-level bargraph LED display. The new chips have many fascinating applications and are very easy to use. This month, we'll take a close look at three of these chips: Texas Instruments' TL490C/TL491C and National Semiconductor's LM3914.

TL490C/TL491C Bargraph ICs. With the exception of their outputs, these two 10-step analog level detectors are functionally identical. Each contains a resistor voltage divider and ten comparators. They will light a 10-element row of LEDs in adjustable increments of 50 to 200 millivolts per LED.

Both chips incorporate output transistors that allow direct drive of the LEDs. The TL490C has open-collector outputs capable of sinking as much as 40 mA at 32 volts max. The TL491C, on the other hand, has open-emitter outputs capable of sourcing a maximum of 25 mA at up to 55 volts. Figure 2 shows how LEDs are connected to both a current source and a current sink.

These new devices are very easy to use. Figure 3, for example, is a simple 10-element readout. I assembled it on a solderless breadboard using a Texas Instruments data sheet as a guide. Potentiometer *R1* provides a variable voltage to the circuit for demonstration purposes. Varying the setting of *R1* lengthens or shortens the bar of glowing LEDs as the input voltage increases or decreases.

Note that the circuit requires a supply of 10 to 18 volts for proper operation. The chip *can* be powered by a 9-volt bat-

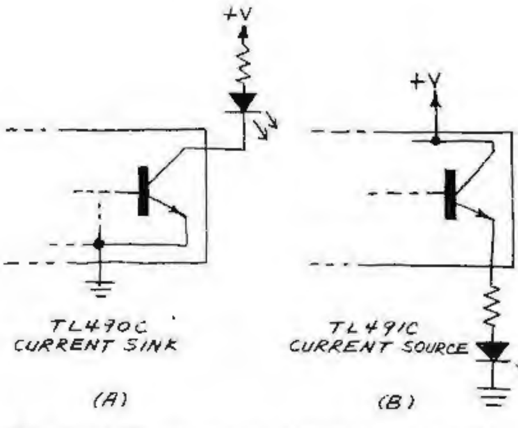

Fig. 2. LEDs connected to current sink (A) and current source (B).

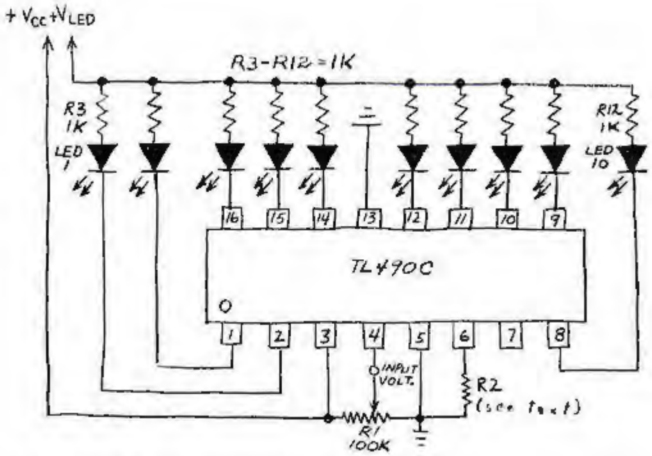

Fig. 3. Basic 10-element bargraph readout using TL490C.

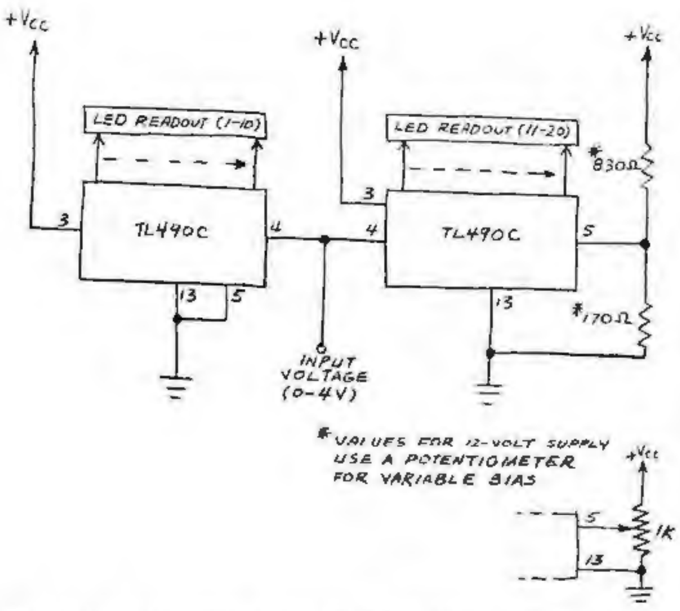

Fig. 4. How to cascade two TL490C chips. A voltage divider provides bias for cascade input of second chip.

tery; but, if that is done, the highest-order LED will fail to glow. A pair of 9-volt batteries connected in series makes an excellent power supply for portable operation. Be sure to use alkaline batteries for best results.

Both the TL490C and TL491C incorporate a THRESHOLD input that allows the sensitivity of the bargraph readout to be varied from 200 millivolts per LED to 50 mV/LED. This is accomplished by connecting pin 6 to ground via a series resistor. TI provides an elaborate formula for calculating the input voltage required to activate the first LED: $0.84/V_{IN} = 1 + (R2 + 700)\,(2240)/(700R2)$ where V_{IN} is the threshold voltage and $R2$ is the resistance between pin 6 and ground.

If this formula seems a little cumbersome, connect a 1000-ohm potentiometer between pin 6 and ground and adjust *R1* so that the first LED just begins to glow. The input threshold voltage can then be measured by placing the probes of a multimeter between the wiper of *R1* and ground. Of course, if you prefer to work with figures, you can algebraically manipulate and simplify the given equation, solving it for V_{IN}.

Considering the number of comparators within each IC package, the total current drain of one of these chips is moderate when no LEDs are on. However, with even a fairly high-value current-limiting resistor connected in series with each LED, current consumption is substantial when all the LEDs are glowing. (Each output pin can sink up to 60 mA of current.) Here are representative values I measured when a TL490C was connected as shown in Fig. 3.

Total Current Demand

V_{CC}	+10 V	+12 V
No LEDs on	11 mA	11 mA
5 LEDs on	54 mA	64 mA
10 LEDs on	93 mA	114 mA

The basic circuit in Fig. 3 has many interesting applications. With *R1* removed and a CdS photocell connected from the positive supply to the input of the IC (pin 4), the circuit functions as a light meter. As the light level at the sensitive surface of the photocell is increased, more LEDs will glow. The photocell may respond to light from the LEDs so be sure to point its sensitive surface away from the rest of the circuit.

You can even measure resistance with the circuit by connecting a resistor between V_{CC} and pin 4. Moisten your index fingers and touch these two points if you want to see the LEDs respond to your body resistance.

For practical, "ballpark" resistance measurements, you'll need to calibrate the circuit with some resistors of known values. If my preliminary results are valid, the circuit will not necessarily respond in a linear fashion to resistance changes.

Connecting a capacitor between pin 4 and ground provides an interesting demonstration of the effects of capacitance. Assuming the capacitor is discharged initially, all the LEDs will glow when the capacitor is first connected to the circuit. They will then wink off in sequence as the capacitor charges. For best results, use a component with a large amount of capacitance (at least 1000 microfarads). Smaller capacitors charge too quickly to allow you to follow the flashing LEDs.

Both the TL490C and TL491C include a CASCADE input that permits the user to cascade up to ten chips to form a 100-element bargraph. Figure 4 shows two TL490C chips connected in cascade. Note how a two-resistor voltage divider provides a 2-volt bias for the CASCADE input of the second of two TL490Cs. The second chip subtracts this reference voltage from the input voltage at pin 4 to automatically arrive at the correct threshold.

LM3914 Dot/Bar Display Driver. This new National IC does everything the TI chips do and more! Like them, it has a self-contained voltage divider and ten comparators, the nucleus of a 10-element bargraph readout. Of more importance, however, is its self-contained decoding network that converts the chip from a straightforward bargraph driver into a more sophisticated moving-dot driver. A single MODE CONTROL input (pin 9) allows easy selection of either mode.

The National Semiconductor data sheet doesn't explain how the LM3914 achieves moving-dot operation. The moving-dot circuits I've described in previous columns required a fair amount of logic to convert a bargraph output into a moving-dot readout. It would be interesting to discover which approach National has selected.

Why is the moving-dot mode so important? One application that comes immediately to mind is a simplified solid-state oscilloscope with a LED screen. More about this later. Another advantage of the moving-dot readout is that one of ten outputs can be selected by a variable voltage. Think of the possibilities! You can connect one or more outputs to relays, drive transistors, optoisolators, or SCRs. In this way, you can make motors, alarms, and many other devices responsive to such variables as changing temperature, humidity, wind speed, weight, pressure, light, or any other analog function that can be converted into a continuously variable voltage by a suitable low-cost transducer.

Figure 5 shows how to use the LM3914 as a basic bargraph driver. Compare this circuit with the TL490C version in Fig. 3. You'll note the circuits are very similar. One major difference, however, is the use of a fixed resistor (*R1*) to control the brightness of the LEDs. This single resistor effectively programs the current available to each LED, thereby eliminating the need for individual current-limiting resistors.

The operation of *R1* as the LED-brightness control is dependent upon an internal reference voltage available at pin 7.

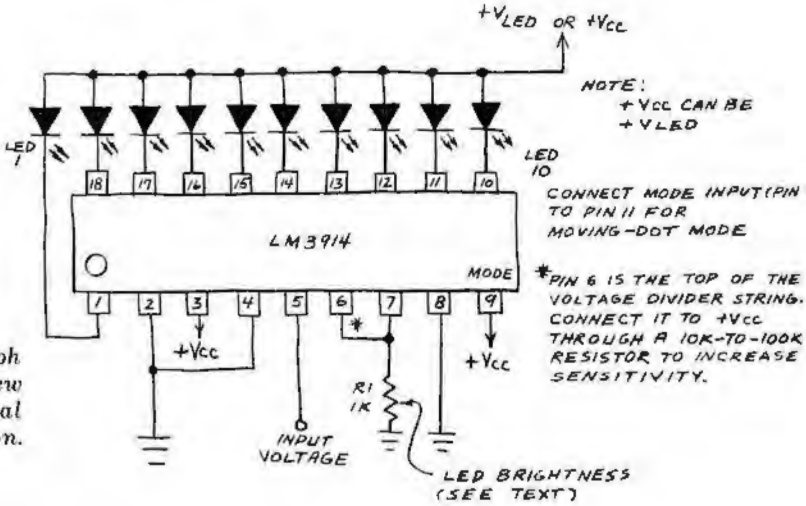

Fig. 5. A 10-LED bargraph readout employing the new LM3914 IC from the National Semiconductor Corporation.

The current passing from pin 7 through *R1* to ground is approximately one-tenth of the current passing through each illuminated LED. Since the voltage reference output is typically 1.3 volts, the LEDs will receive 13 mA of current when the resistance of *R1* is 1000 ohms. (Why? Ohm's law says that the current flowing through a resistor equals the voltage across it divided by its resistance. In this case, the current is 1.3/1000 or 0.0013 A. The LED current is ten times greater or 13 mA.)

To use the LM3914 in the moving-dot mode, mode control pin 9 should be disconnected from the positive supply voltage and connected to pin 11. This modification is easily made to the circuit in Fig. 5.

The LM3914 can be cascaded to form a moving-dot readout having 200 or more elements by connecting pin 9 of the first chip in the series to pin 1 of the next higher chip. This connection pattern is continued for each chip except the last. Pins 9 and 11 of the last IC are tied together. The only other requirement is a 20,000-ohm resistor in parallel with *LED9* of each chip (between $+V_{CC}$ or $+V_{LED}$ and pin 11) except for the first one. For details, see the National data sheet.

Figure 6 shows an interesting circuit from the National data sheet that causes the bargraph readout to flash. This circuit can be programmed to flash when the input voltage reaches a specified level by connecting the junction of *R1* and *C1* to any of the ten LED outputs. (The LEDs flash when the input voltage is sufficient to activate the selected LED output.) This flashing mode is very noticeable and makes for an eye-catching warning indicator.

A Unique Moving-Dot Application. Several readers have found interesting applications for the moving-dot readout described in the Experimenter's Corner of October 1978. Perhaps the most intriguing was developed by Leonard J. Lynch of Dekalb, IL. He had previously constructed a wind-powered generator capable of charging up to 48 2-volt storage cells. Unfortunately, the output of the wind charger is rarely constant. This means the number of cells being charged must be automatically altered to maintain a constant charge rate.

Leonard solved this problem by replacing the LEDs in the moving-dot indicator circuit with optoisolators connected to pass transistors that automatically switch additional banks of storage cells on line as the voltage from the wind charger increases. When the highest voltage level is exceeded, an overrange circuit composed of an optoisolator and a relay changes the pitch of the generator's propeller.

The LM3914 can be used in Leonard's circuit with few modifications and a lot less soldering. It can also be used in an ultra-simple solid-state oscilloscope that, less the 9-volt battery required for power, fits in an empty match box! I'll describe this pocket scope and another, larger LED scope in a forthcoming Project of the Month. ◇

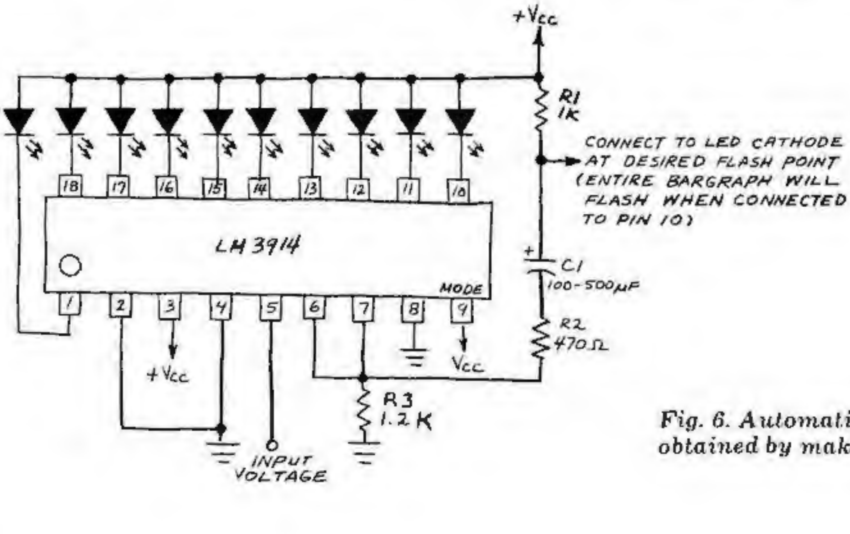

Fig. 6. Automatic bargraph flashing can be obtained by making connection suggested.