DRAWING BOARD

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Let's think about our display

ONE OF THE WORST, AND MOST COMmon traps you can fall into as a designer is not knowing when a job is finished. There's always that last minute brainstorm, the "one more terrific idea," that has to be worked into the final design. I can't tell you how many times that's happened to me. And even though I'm aware of the problem, it's really easy to get caught up in it.

The best way to avoid that is to know what you want to accomplish when you first sit down at the bench. A list of design goals and a set of criteria may seem silly at the onset of a design but, take it from me, you'll read them over and over as you get deeper into the project. No design is static—ideas mature and goals change. What you wind up with at the end is probably going to bear only a vague resemblance to what you originally set out to do.

The reason I'm mentioning that is because it's my way of apologizing again for changing my mind in last month's column. I had originally felt that a lot more could be learned by setting up a buffer-and-latch type arrangement for external access to the memory. When I began putting the design together, the number of chips started to pile up and before I realized it I was looking at designations like IC26! Clearly, the project was past what some people euphemistically like to refer to as "manageable size." Direct Memory Access (DMA) is a perfect way of getting in and out of our Z-80 system. It can be a little tricky, however, so let me know if you have any problems and I'll do my best to give you a hand.

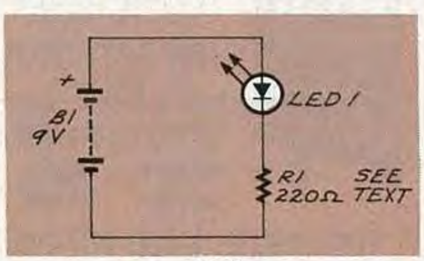

FIG. 1

But now for something completely different.

There are some things in electronics that show up no matter what kind of circuit you're designing. Just about everything from an electric toothbrush to Star Wars has to deal with the problem of how best to display data. Now, if all your circuit needs is a few LED's there's not much of a problem; but if you've got a lot of data that has to be displayed, you're going to have to give it some thought.

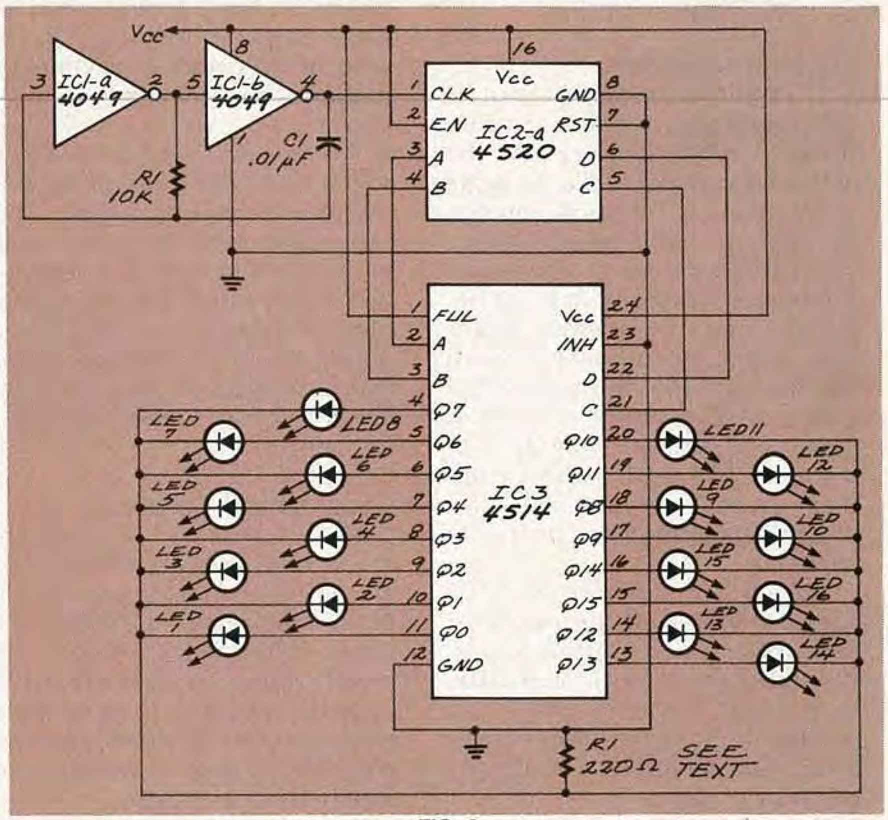

FIG. 2

LED's are notoriously power hungry. Batteries can go dead really fast when you have more than a couple of LED's lit up at the same time. The standard way around that problem is to "multiplex" the display. That's a twelve

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dollar word to indicate that you can take advantage of retinal persistence. If the LED's are turning on and off very quickly, it will seem like they are on continuously.

When you're dealing with LED-based displays, there are several ways to go about multiplexing them. LCD displays can be multiplexed as well, but they're much slower and don't respond well to rapid strobing. And since they basically run on flea power, there's not much of a point in multiplexing them.

To get started, let's suppose that you have sixteen LED's in your display; all of them will be on some of the time, and you're running the circuit off a 9-volt battery. If we do a bit of arithmetic, we can see what's going to happen to the battery. A fresh 9-volt battery is usually somewhere around 8 volts and a value of 220 ohms is a good ballpark figure for a current-limiting resistor. The simplest kind of circuit configuration is shown in Fig. 1. Assuming the voltage drop across each LED to be 1.7 volts, we can apply Ohm's law as follows:

$$I_{LED} = V/R$$
$$= (V_{BAT} - V_{LED})/R$$
$$= (8-1.7)/220$$
$$I_{LED} = 28.6 \text{ mA}$$

So if you were driving 16 LED's, you would have to supply almost half an amp—and that's a significant amount of power!

The circuit in Fig. 2 is one way of multiplexing the same 16 LED's. All we have is a simple clock driving a 4514. The outputs of the decoder are normally low and the selected output goes high. A similar chip, the 4515, has normally high outputs so you can use the circuit for LED's with a common leg tied to either ground or power, whichever you prefer.

The clock is a standard one made up of a pair of inverters driving a 4520 binary counter, which is being used to make the decoder scan across its outputs. You might consider that to be an unnecessarily complex way of doing a simple job, but the circuit is good for demonstrating the basic idea. There are lots of ways to do the same job with fewer IC's and we'll be looking at several of them later on.

The components shown for the clock cause it to oscillate at about 10 kHz. Assuming that it takes no time at all to switch between the outputs, and that the CMOS chips are using no power, you're going to be able to light all 16 LED's with even less current than the circuit in Fig. 1 uses. Even if you allow 10 mA for each of the IC's, you're still looking at only 60 mA for the entire circuit—and, for the record, there's no way those CMOS IC's are going to want 10 mA each.

The price you pay for multiplexing a display is that each of the LED's will appear to be dimmer—how much dimmer depends on a number of things. The efficiency, size, and color of the LED's are all going to have an effect on the apparent brightness; and don't forget that each LED is only on less than one sixteenth of the time.

The easiest way to boost the brightness of a multiplexed display is to drop the value of the current-limiting resistor. Unfortunately, there's no way to tell how much of an increase in brightness you're going to get as you increase the current. Each LED reacts differently. You can, however, choose a value for the current-limiting resistor that will give you the maximum allowable current through the LED—usually about 70 mA or so for the standard T-1 ¾-size LED's.

If the multiplexing frequency is high enough, you can push really huge amounts of current through the LED. Standard jumbo LED's can handle 1 amp if it's

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restricted to a 1 microsecond pulse and a .3% duty cycle! For the purposes of our test circuit (Fig. 2), don't drop R2 much below 47 ohms, because you won't get much more brightness below that—but there's a very good chance you'll send the LED up in smoke. Also, make a few calculations to be sure that you don't exceed the current-limiting resistor's power rating.

We have our clock running at about 10 kHz to make sure that there's no flickering in the display, but that's really overkill for a 16-LED display. Standard movie projectors run at 24 frames per second and provide a good illusion of continuous motion. Since they also use a 180 degree shutter, they have an effective duty cycle of 50 percent. Since our demonstration circuit keeps each LED illuminated for one complete clock cycle, the duty cycle isn't important yet; but keep it in mind.

In order to light our display at film speed, we have to use a clock with a frequency of 16×24 or 384 Hz. You can drop the clock to that frequency by replacing C1 with a 0.2 μF capacitor. The LED's should appear brighter and you shouldn't see them flickering. I say "shouldn't" because biology isn't as precise as electronics. Experiment with different clock frequencies on your own and see "how low you can go" while still maintaining the illusion of constant illumination. **R-E**