DRAWING BOARD

Let's build an oscilloscope!

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There's no such thing as too much test equipment. If you spend enough time at the bench, sooner or later you're going to wind up using not only everything you own, but other stuff as well. If you design for a living, you want the best test gear you can get—clients don't want to hear that you couldn't try something because you had no way to do it at the bench.

You can divide up all test equipment into stuff you absolutely have to have and stuff that's just nice to have. The most important piece of gear—an essential "must have"—is an oscilloscope. These used to be real bank breakers but, as things stand now, you can get a good 30-MHz scope for well under four hundred dollars. There's nothing stopping you from building one, but to come up with a serious, as well as reliable, design you need an oscilloscope. A kind of chicken and egg problem, depending on how you look at it.

We're going to look into building a scope, but before we get started it's important to understand what we can do and what we can't do. The controls on a modern scope—even an inexpensive one—give you a wide range of operating parameters and there's just no way we can duplicate all of them in a home-built oscilloscope given the limited amount of space there is in this column and the available time.

What we *can* do is go through the fundamentals of scope design, examine the basic circuitry, and come up with a working demonstration circuit. This isn't as limited as it sounds since, by the time we finish, you'll have a good idea of how the unit works and what you have to do to refine it. That means adding some of the features found on commercial units, upping the bandwidth, and so on.

Enough talk.

The basic layout of a typical oscilloscope is shown in Fig. 1. You can see that, if you don't get into the bells and whistles found on commercial units, a scope is a pretty simple and straightforward unit—in principle anyway. An oscilloscope is like a vectorscope that has to deal with an input signal that varies over a period of time.

A lot of what the scope circuits have to do depends on what kind of display is being used. For our purposes, let's assume that the display we're going to use is a matrix of LED's, LCD's, or anything made up of a series of discreet points that can be addressed by specifying a pair of x and y coordinates. Since the scope we're building is going to use a row-and-column display system, it's easier to understand what each of the elements in the block diagram has to do.

The horizontal circuit is going to control the enabling of the row drivers. That means we're going to be scanning across the rows in the matrix and enabling one row at a time. That also means we need a clock capable of driving the horizontal circuit at a bunch of accurate frequencies. How fast those frequencies have to be depends on how fast a signal we're going to want the scope to handle. This isn't a trivial decision since the maximum signal frequency will also determine how we have to go about designing the circuitry that's going to be used in the rest of the scope as well.

There's no point in having a horizontal circuit that can scan or, to use the officially correct phrase, sweep at a rate of 10 MHz if the rest of the circuitry takes a nose dive when the incoming signal gets above 1 MHz. Scope design, just like any other project, has to be planned carefully from the beginning. All of the details have to be worked out before you get to the bench or a lot of time will be wasted at the bench.

The other major section of a stan-

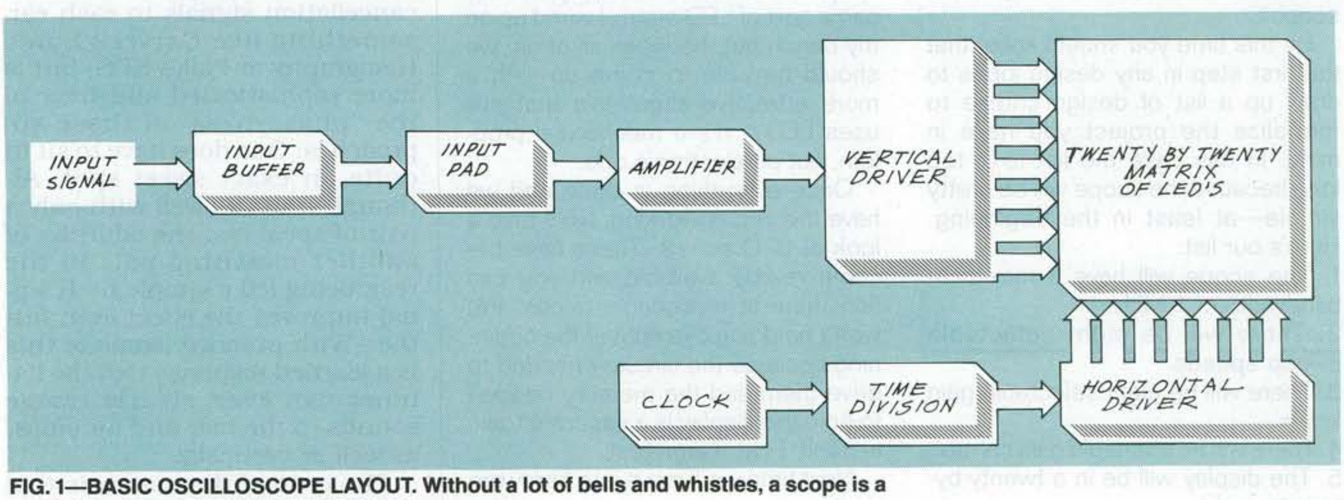

FIG. 1—BASIC OSCILLOSCOPE LAYOUT. Without a lot of bells and whistles, a scope is a pretty simple and straightforward device.

dard oscilloscope is the vertical circuitry. Although there are special considerations, this is really nothing more than an amplifier designed to have a response that's as flat as possible over the rated bandwidth of the scope. Remember that we're using the output of the amp to display changes in the input signal, and we don't want the amplifier to add its own two cents to either the shape or level of the input signal. The point of using a scope, after all, is to display unknowns in a signal, not add to them.

Just as the horizontal section should have several accurate sweep speeds, the vertical section should have several accurate settings for the gain. When you look at the display matrix, going one element to the right should represent a definite amount of time and going up one element should represent a definite amount of voltage increase. Even if you've never used a scope, you've probably heard people talking about the number of volts per division when they're referring to scope measurements. In the scope we're going to build, the equivalent would be to refer to volts per display element.

These three sections—horizontal, vertical, and display—together form the basis of every oscilloscope there is. Before we can even think about including some of the features found on commercial scopes—or even clearly understand what they do—we have to get the basics out of the way. The best way to handle this is to design a basic scope and then, once we have that stuff under control, we'll be in able to think about things like triggered sweep and other bells and whistles found on commercial scopes.

By this time you should know that the first step in any design job is to draw up a list of design criteria to formalize the project you have in mind. In this case the list isn't too long because the scope will be pretty simple—at least in the beginning. Here's our list:

1. The scope will have a maximum bandwidth of 1 MHz.
2. There will be eight selectable sweep speeds.
3. There will be eight selectable gain levels.
4. There will be a variable gain control.
5. The display will be in a twenty-by-twenty matrix.

You can change any of the criteria you want but, for the moment, it's a good idea to leave them all as they are. Once we get into the specifics of the design, you'll find it relatively easy to modify some of the features to adapt to any particular requirements you might have.

Before we start the actual design, we have to talk a bit about the display. Elementary arithmetic tells you that a twenty-by-twenty matrix calls for four hundred LED's and, even though you can get LED's in bulk quantities from mail-order houses at extremely low prices, you still have to do a lot of wiring to get them set together in the kind of matrix we need. Let's face it, it's a real pain in the neck to wire four hundred LED's.

When we get the scope designed, we'll investigate some alternatives to using LED's for the display elements—LCD screens are a perfect choice. I've seen pre-made LED matrix displays that come in various sizes and I'm currently going through my parts books and mail-order house catalogs to see what's available and who has them for sale at reasonable prices. If any of you know where these can be gotten, drop me a line and I'll put it, along with appropriate thanks, in the magazine.

I have a working version of the scope on my bench at the moment and I used four hundred LED's wired into a twenty-by-twenty matrix. It took a bit of time to get it wired but, from personal experience, I can tell you that it's not too bad and certainly not the worst thing I've ever had to do. It was, however, pretty high on my list of unpleasant experiences.

As we develop the circuitry for the scope, I'll base the display on the same sort of LED matrix I wired up on my bench but, between all of us, we should be able to come up with a more attractive alternative that still uses LED's. It's a mechanical problem, not an electronic one.

Once everything is done and we have the circuit working, we'll take a look at LCD panels. These have become readily available and you can find them at reasonable prices. We won't be doing this right at the beginning because the circuitry needed to drive them and the memory needed to hold the display is a separate topic in itself. First things first.

Next time we'll move into hardware design. **R-E**