THE DRAWING BOARD

Generating sinewaves with the 4018

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BY THIS TIME WE SHOULD ALL BE FAMILiar with the unbreakable first rule of electronic design: *Brainwork before board work*. If you can't get it down clearly on paper, you can't design it, much less build it. (I believe that there's some sort of natural law that governs the relationship between the weight of the finished product and the paperwork it generates. If anyone knows what it is, please let us know!) Paperwork always chops mind-boggling design problems down to a manageable size and also lets you concentrate all your energy on specific design problems.

Last month we spent a little time breaking down the problem of using the 4018 to generate sinewaves. Although that's certainly not the most complex problem you'll ever see, it is important to remember that the design approach that you take is as important as the design itself. As a matter of fact, the initial approach will more often than not shape the final product.

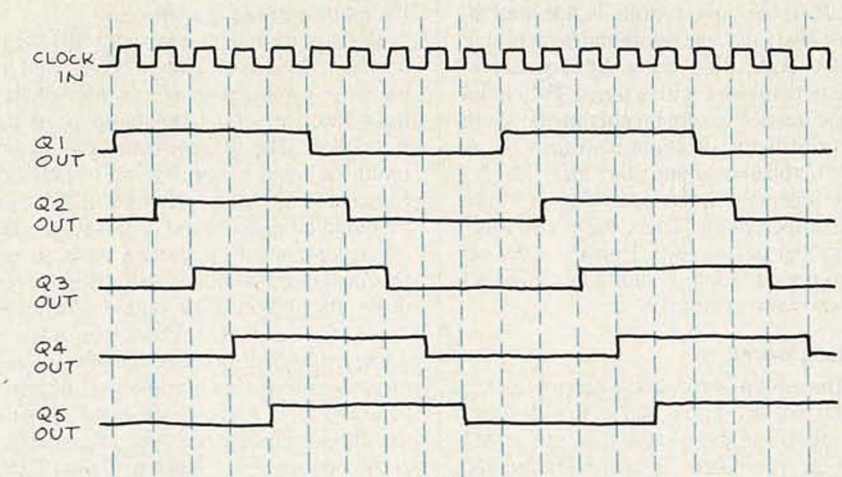

FIG. 1

Generating sinewaves

Take a look at the output waveforms of the 4018 shown in Fig. 1. It puts the procedure to follow (and the problem it causes) in black and white for us to look at. And it should give you some idea as to how to go about using that IC. As you can see, the 4018 provides phase-shifted outputs that are delayed by exactly one incoming clock pulse. Not only that, but we've already seen that the output duty cycle is nice and square. If we sum the outputs together properly, we can produce a digital waveform that can be filtered to any degree of smoothness desired by the circuitry that's tied to it's output.

If the outputs (Q_1 through Q_5) of the 4018 are added together using equal value resistors, we're going to wind up with the very familiar and entirely predictable waveform shown in Fig. 2-a. If you squint your eyes and imagine the waveform to be all smoothed out you'll see that the best that we can hope to get from the circuit in Fig. 2-b is a triangular wave. Obviously, our approach is on the right track but the problem is a little more complex than it first appeared. While, it is evident that we have to add the IC's outputs together, it should also be evident that we have to give more thought to how we do it. The shape of the wave that's generated by the 4018 depends on the values chosen for the summing resistors. Determining the values of those resistors, however, is something else. There's no way to avoid doing some math; but let's see if there's some way to at least cut the required calculations down to a slightly less formidable size. Once again we have some paperwork to do.

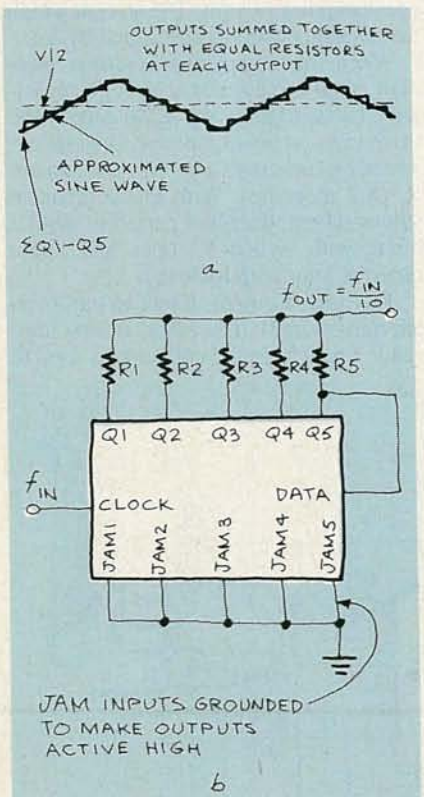

FIG. 2

Now, as everybody knows, there are lots of different ways to go about solving a problem. Which one you pick depends on the problem, but remember that the idea behind all of them is to cut down the amount of work you have to do. Let's attack our problem with the most basic approach—common sense!

In Fig. 2-a we see a composite output waveform from Fig. 1 and we have also overlaid it with an approximation of the sinewave that we're trying to generate. Certain things should become clear almost immediately.

As the sinewave approaches its maximum positive and negative values it flattens out. The staircase shape that was generated using equal value resistors has sharp peaks at those points and therefore, doesn't really fit the curve. That simple observation leads us to a sledgehammer-type fix. All we have to do now is to lose the output of the 4018 that's causing those peaks. In practical terms that means getting rid of the Q_5 output. As you can see from Fig. 2-b, we're using that output for two purposes: It's one of the data outputs

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and since it's the last output in the chain, we're connecting it back to the data input of the IC. Remember that we have to make sure that the incoming data at the clock input is constantly recirculated around and around the daisy-chained flip-flops in the 4018. Any change in the input data to the IC has to be fed into it at the clock input and not the data input. All that we're using the data input for is to make sure that whatever we feed into the 4018 stays there.

Losing the Q_5 output means that we

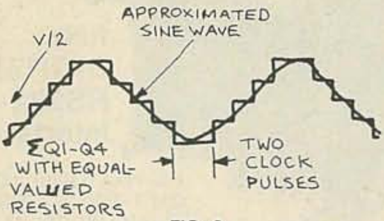

FIG. 3

don't use it to generate the sinewave but we still need it to recirculate the data. The result of eliminating that output is shown in Fig. 3: There have been two changes, the one we expected and one that's just one of those lucky breaks. The most obvious change is the flattening at the top of the waveform. That's what we expected and isn't really any great surprise. We've overlaid the output waveform with a sinewave again and you can see that it is a better fit than we got earlier in Fig. 2-b. Even though the drawing of the sinewave is crude, you can see that it's going to be a much better fit.

The second change isn't quite as obvious because the drawings aren't exactly to scale. Since we've lost one of the outputs (the one that produced the top of the output waveform) the top only remains for two incoming clock periods instead of three, as it did in Fig. 2-b. That not only helps us fit the crest of the sinewave but gives the rise and fall on either side a better shape making the fit even better. Of course, as we've seen over and over again, you can't get something for nothing and we're paying a price here as well. Let's not forget that while we may have an easier time fitting the curve, we've lost one of the outputs and consequently our resolution has suffered. But, as with so many other things, trade-offs are the name of the game in electronics as well.

Picking the ideal resistor values to give us the best approximation of a sinewave involves a lot of math. The principle behind the whole thing, however, isn't really that hard to visualize. Figure 4 gives us a graphic representation of the problem. What we're looking at there is the first 180 degrees of the sinewave. The generating of the sinewave means that all of the outputs are going to come into play during each half of the full-cycle. Take another look at Fig. 1, you'll see that the sequential rise and fall of the flip-flop outputs determine the shape of the summed waveform. Because each of the outputs is out of phase (or delayed) by exactly one incoming clock pulse, each of the outputs controls the amplitude of the output waveform at 45 degree (or 180/4) intervals. (We're dividing by four instead of five because the Q_5 output is not being used. Even though we're allowing for the time it takes to change state, it adds nothing to the amplitude of the output waveform.)

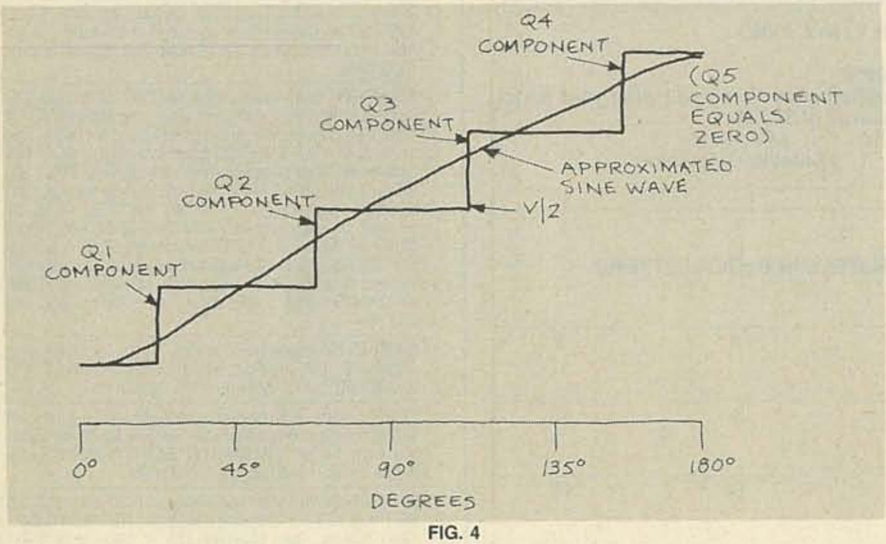

FIG. 4

Finding the correct resistor values, therefore, means a bit of trigonometry and some more analysis. Don't be put off by the math; it's not all that difficult and understanding it only involves common sense and curiosity—two very important tools for anyone who wants to be involved in electronics. **R-E**