THE DRAWING BOARD

Finishing up about regulators

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AS YOU'RE PROBABLY AWARE BY NOW, there's a lot more to consider when you're building a power supply than how to get a battery out of a blister pack. Over the last few months we've gone through the design considerations necessary to build a voltage regulator complete with all sorts of bells and whistles. Before we wrap up this project, be aware that we've just barely scratched the surface. There are lots of different sorts of power supplies and we've been looking at only one particular kind. There are design engineers who do nothing else in their professional lives but design power supplies. (That may strike you as being a bit boring but it certainly gives you an idea of the size of the subject.)

Where's the surprise?

Figure 1 is the full schematic of the regulator circuit we've designed. The values for all the components are shown, and if you look closely you'll see that we've added something to the short-circuit protection we discussed last month. We've put in a switch, S1, and broken R_s into two parts. The reason that was done is the surprise I promised.

I told you that there was a way around trying to locate a 0.13 ohm resistor. You probably realized that we would parallel a few resistors to get the value we wanted and that's exactly what I did. When we close S1 we put the two resistors in parallel and arrive at a value of 0.135 ohms—nothing really surprising about that. Opening S1 puts only one of the resistors in the line and lets us change the trip point of Q2 to two amps. We can now switch-select the short circuit trip-point to be either 2.4 amps or 4.8 amps. The real treat comes when we do the arithmetic necessary to calculate the wattage we need for the resistors.

Let's assume that we have the full value for R_s. We saw that it takes a 0.65 volt drop across the emitter-base junction of Q2 to make it conduct. The short circuit trip-point would be: $I = E/R = .65/.135 = 4.82$ amps.

That's pretty close to our original target of 5 amps. Now let's calculate the wattage we need for R_s: $P = I^2R = (4.82)^2(.135) = 3.14$ watts.

In the interest of safety, and with proper respect for Murphy's law, let's call it 4 watts. This makes R_s a pretty hefty resistor, and probably not too easy to find. It is easy however, to find a 0.27-ohm, 2-watt resistor, so we'll put two of those in parallel. Since the wattage adds when resistors are in parallel (do you know why?) we have 0.135 ohms at 4 watts when S1 is closed and 0.27 ohms at 2 watts when S1 is open. If you want to verify the calculations for the circuit with S1 open, follow the format I've just used. It's satisfying to see the numbers work out so neatly.

TABLE 1

R_S	$R_S + R_B$	I_{R_B} at Q1 turn-on	P_{R_B}
0.135Ω	2.135Ω	305 mA	0.185 watts
.27Ω	2.270Ω	286 mA	0.163 watts

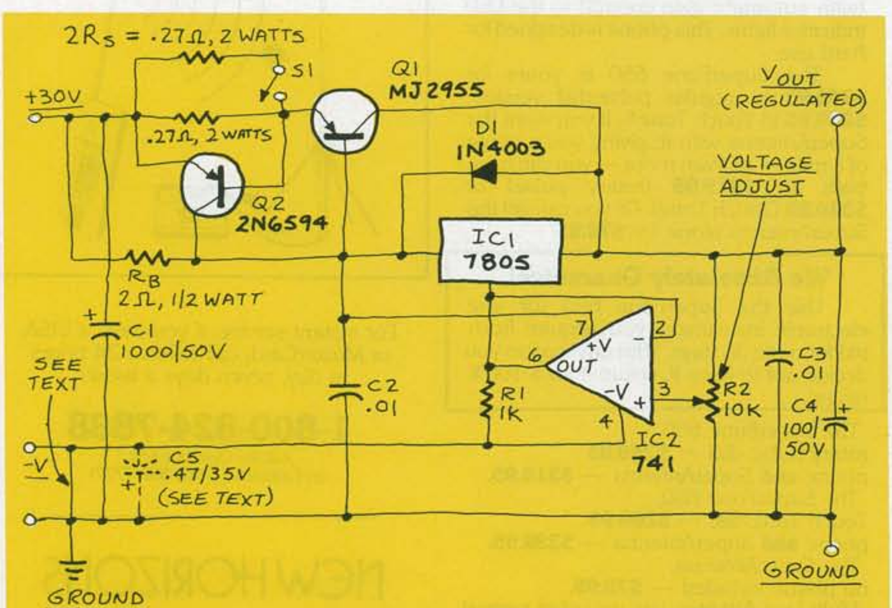

FIG. 1

More about component values

If you remember last month's discussion of R_B, you'll recall that we had to do some math to arrive at a value of 2.47 ohms. A look at Fig. 1 will show you that R_B is now specified to be 2 ohms at half a watt. Changing the value to 2 ohms from 2.47 ohms was done in the interests in reality. The only place you'll be likely to find a 2.47-ohm resistor is the same place you'll find a 0.13-ohm resistor—nowhere. You may be considering the idea of using a trimmer potentiometer in place of a fixed resistor. Don't do it—it's a bad idea.

There are two no-no's as far as R_s and R_B are concerned—trimmers are a bad idea, and so are wire-wound resistors. The reasons for avoiding those things have already been discussed and you should realize what they are. Go back through our discussion of regulators so far and figure out the answer. When you get the answer, let me know. The first person to get it right will have the dubious honor of being credited in this column and will receive a prize of four million dollars. The first person to get it wrong will have to come up with the prize money. Only joking, folks—but I will give credit to the first person with the right answer.

The calculation of the wattage I'm going to leave as an exercise for you. To be fair, though, I'll give you the answers. They are shown in Table 1. Make the same assumptions we did last month about the transistor "resistance" and see if you can work out those values.

As you can see, calling for a half watt

for R_B is a bit of overkill, since the calculated value never even reaches one-quarter watt. When we started this exercise in design I told you that one of the cardinal rules of design was always to aim for worst-case operation. By specifying a half-watt resistor we're adding a safety factor of more than two. If you can get your hands on a one-watt resistor of the right value it wouldn't hurt to use that either—you can never have too many watts.

The transistors listed for Q1 and Q2 have the collector-current maximums the circuit calls for. Since they're being used as switches we don't have to worry about any of the parameters we'd have to consider in an analog circuit (frequency compensation, gain, and so on). It's really just a matter of finding some silicon transistors of the right polarity that can handle the calculated current. The MJ2955 can handle 15 amps at its collector, and our circuit only calls for 5 amps—the safety factor again.

As we saw last month, Q2 has to be able to stand the combined short-circuit currents of both the regulator and Q1—that means a collector current of 0.035 + 4.82 = 5.13 amps. A 2N6594 can handle 12 amps. I called for those transistors because they're easy to find. If you want to substitute other transistors, that's okay—just watch the collector ratings, and make sure you use silicon transistors. If you want to use germanium ones, all the calculations we've done will have to be redone. You tell me why.

Other components

I've called for a 741 as the op-amp to be used for IC2. Actually you can use just about any op-amp there. The 741 seemed to me to be a good choice because it's cheap (always an important design consideration), available, and has internal current-limiting and frequency compensation. If you have some other op-amp lying around, use it. The higher the input impedance the better. Since it's only a buffer, the requirements aren't at all critical.

The last thing to look at is C5. It handles the transients from the negative supply, if you use one, to lower the range of the circuit following the guidelines we developed last month. It goes without saying that if you go this route the connection shown in Fig. 1 between the −V input and ground should be ignored—so I won't say it.

There's nothing sacred about the choice of IC1. If your voltage requirements are going to be consistently higher than five volts use one of the other regulators in the series—the 7812 or 7815 for example. Try giving the the op-amp a bit of gain by putting some resistance on the feedback line from pin 6 to pin 2. The point of these columns is for you to learn—and there are only two ways to do

continued on page 101

DRAWING BOARD

continued from page 99

that. Read everything you can get your hands on, and get your hands in everything you read. Components are cheap enough so that blowing a few up is still less expensive than going to school...and more instructive as well.

You should have learned enough to design your own negative supply. Try it and let me see what you come up with. Just be careful. You're playing around with circuitry that can deliver a lot of power. If you heat-sink everything—and you should—you're looking at circuitry that can melt the tip of a screwdriver!

We'll end this discussion of voltage regulators with a problem. I told you that there were other ways to create a negative supply besides using a center-tapped transformer. There are some MSI chips developed specially for this, but that's not what I'm talking about. Anyone who has ever needed a few measly milliamps from a negative supply knows how real the problem is.

If you can dream up a way to create a negative supply—a true negative supply—using only a two-terminal transformer, write and tell me about it. I know what I would do—let's see what you would. **R-E**